FAIRCHILD

A Schlumberger Company

Power Products Data Book

1986/87

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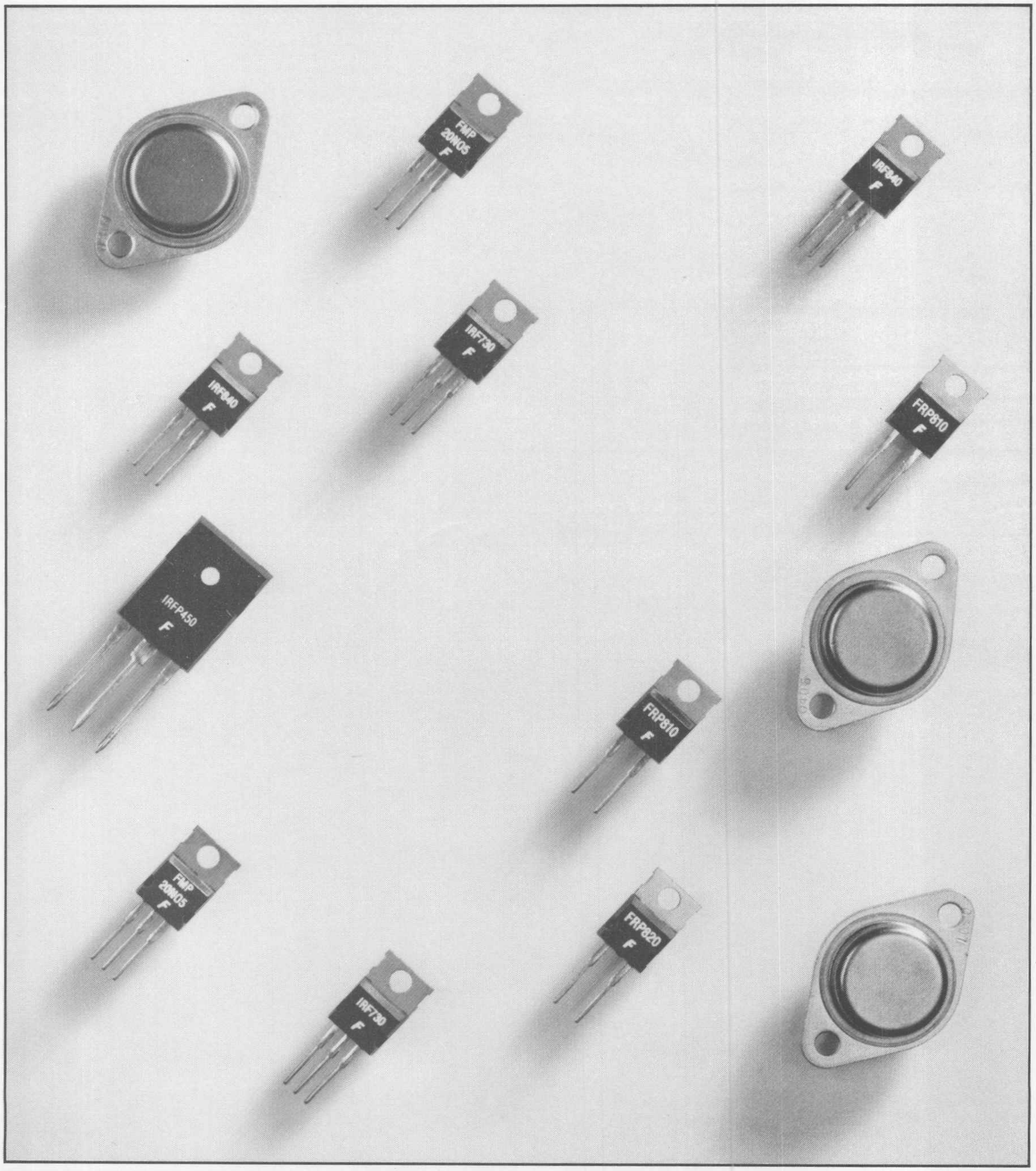
Power Data Book

1986/87

Power and Discrete Division



Power and Discrete Division
4300 Redwood Highway, San Rafael, CA 94903
(415) 479-8000 TWX 910-384-4258

Introduction

The Fairchild Power Semiconductors described in this databook have been designed primarily for use in switching power conversion applications.

The Selection Guides provide easy access to the many types of power devices currently offered by Fairchild. In addition to the products contained herein, special selections can be made to meet specific requirements. For more information on these selections, please contact the nearest Fairchild Field Sales Office.

The continuing advances being made in power semiconductor technology mean that this book can only contain full data on those products available from Fairchild at the time of publication. Section 4 of the book has been devoted to products in advanced stages of development, which are due to be released to production within a few weeks of the publication date. Preliminary data have been included for these products.

Furthermore, following Fairchild's commitment to providing the market with leading-edge products, other devices are also being developed to satisfy an ever-present industry need for more advanced technology in power conversion systems. These products include higher cell density Power MOSFETs, insulated gate devices, better control circuits, high power integrated circuits and lower cost packages displaying improved thermal characteristics.

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Alpha-Numeric Index Power MOSFETs and Ultra-Fast Recovery Rectifiers

Select the appropriate electronic component for your power supply design from the list of power components below. The selection guides briefly describe Fairchild Power MOSFET and Ultra-Fast Recovery Rectifiers. The Industry Cross Reference versus Fairchild part numbers is found after the selection guides.

Power MOSFETs

Fairchild Part Number	Page Number	Fairchild Part Number	Page Number	Fairchild Part Number	Page Number	Fairchild Part Number	Page Number
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FMC20N05	3-6	FRP3215	4-7	IRF342	2-118	IRF622	2-87
FMP18N05	2-43	FRP3220	4-7	IRF343	2-118	IRF623	2-87
FMP20N05	2-43	IRF120	2-67	IRF350	2-123	IRF630	2-92
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FMP35N05	4-5	IRF122	2-67	IRF352	2-123	IRF632	2-92
FMP55N05	4-8	IRF123	2-67	IRF353	2-123	IRF633	2-92
FMP60N05	4-8	IRF130	2-72	IRF420	2-127	IRF640	2-98
FRC805	3-3	IRF131	2-72	IRF421	2-127	IRF641	2-98
FRC810	3-3	IRF132	2-72	IRF422	2-127	IRF642	2-98
FRC815	3-3	IRF133	2-72	IRF423	2-127	IRF643	2-98
FRC820	3-3	IRF140	2-78	IRF430	2-132	IRF710	2-157
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FRM3210CC	2-63	IRF152	2-83	IRF442	2-138	IRF722	2-107
FRM3215CC	2-63	IRF153	2-83	IRF443	2-138	IRF723	2-107
FRM3220CC	2-63	IRF220	2-87	IRF450	2-143	IRF730	2-112
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FRP810	2-47	IRF222	2-87	IRF452	2-143	IRF732	2-112
FRP815	2-47	IRF223	2-87	IRF453	2-143	IRF733	2-112
FRP820	2-47	IRF230	2-92	IRF510	2-147	IRF740	2-118
FRP840	4-6	IRF231	2-92	IRF511	2-147	IRF741	2-118
FRP850	4-6	IRF232	2-92	IRF512	2-147	IRF742	2-118
FRP860	4-6	IRF233	2-92	IRF513	2-147	IRF743	2-118
FRP1005	2-51	IRF240	2-98	IRF520	2-67	IRF820	2-127
FRP1010	2-51	IRF241	2-98	IRF521	2-67	IRF821	2-127
FRP1015	2-51	IRF242	2-98	IFR522	2-67	IFR822	2-127
FRP1020	2-51	IRF243	2-98	IRF523	2-67	IRF823	2-127
FRP1605	2-55	IRF250	2-103	IRF530	2-72	IRF830	2-132
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FRP1610	2-55	IRF252	2-103	IRF532	2-72	IRF832	2-132
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FRP1620CC	2-59	IRF323	2-107	IRF543	2-78	IRF843	2-138
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FRP2010CC	2-51	IRF331	2-112	IRF611	2-152	IRFC120	3-6
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Alpha-Numeric Index Power MOSFETs and Ultra-Fast Recovery Rectifiers

Power MOSFETs (Cont.)

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Selector Guide Power MOSFETs

Metal TO-204AA/TO-204AE

V_{DSS} (V)	R_{DS} (on) (Ohms)	I_{DR} (A)	Part Number	Page Number
500	0.400	13.0	IRF450	2-143
	0.400	12.0	2N6770	2-38
	0.500	12.0	IRF452	2-143
	0.800	7.0	MTM7N50	2-138
	0.850	8.0	IRF440	2-138
	1.100	7.0	IRF442	2-138
	1.500	4.5	IRF430	2-132
	1.500	4.0	MTM4N50	2-132
	1.500	4.5	2N6762	2-18
	2.000	4.0	IRF432	2-132
	3.000	2.5	IRF420	2-127
	4.000	2.0	IRF422	2-127
450	0.400	13.0	IRF451	2-143
	0.500	12.0	IRF453	2-143
	0.500	11.0	2N6769	2-38
	0.800	7.0	MTM7N45	2-138
	0.850	8.0	IRF441	2-138
	1.100	7.0	IRF443	2-138
	1.500	4.5	IRF431	2-132
	1.500	4.0	MTM4N45	2-132
	2.000	4.0	IRF433	2-132
	2.000	4.0	2N6761	2-18
	3.000	2.5	IRF421	2-127
	4.000	2.0	IRF423	2-127
400	0.300	15.0	IRF350	2-123
	0.400	13.0	IRF352	2-123
	0.300	14.0	2N6768	2-33
	0.550	8.0	MTM8N40	2-118
	0.550	10.0	IRF340	2-118
	0.800	8.0	IRF342	2-118
	1.000	5.5	IRF330	2-112
	1.000	5.5	2N6760	2-13
	1.000	5.0	MTM5N40	2-112
	1.500	4.5	IRF332	2-112
	1.800	3.0	IRF320	2-107
	2.500	2.5	IRF322	2-107
350	0.300	15.0	IRF351	2-123
	0.400	13.0	IRF353	2-123
	0.400	12.0	2N6767	2-33
	0.550	10.0	IRF341	2-118
	0.550	8.0	MTM8N35	2-118
	0.800	8.0	IRF343	2-118
	1.000	5.5	IRF331	2-112
	1.000	5.0	MTM5N35	2-112
	1.500	4.5	IRF333	2-112

V_{DSS} (V)	R_{DS} (on) (Ohms)	I_{DR} (A)	Part Number	Page Number
350	1.500	7.0	2N6759	2-13
	1.800	3.0	IRF321	2-107
	2.500	2.5	IRF323	2-107
200	0.085	30.0	2N6766	2-28
	0.085	30.0	IRF250	2-103
	0.120	25.0	IRF252	2-103
	0.180	18.0	IRF240	2-98
	0.220	16.0	IRF242	2-98
	0.400	9.0	2N6758	2-8
	0.400	8.0	IRF230	2-92
	0.500	8.0	IRF232	2-92
	0.800	5.0	IRF220	2-87
	1.200	4.0	IRF222	2-87
150	0.085	30.0	IRF251	2-103
	0.120	25.0	2N6765	2-28
	0.120	25.0	IRF253	2-103
	0.180	18.0	IRF241	2-98
	0.220	16.0	IRF243	2-98
	0.400	9.0	IRF231	2-92
	0.500	8.0	IRF233	2-92
	0.600	8.0	2N6757	2-8
	0.800	5.0	IRF221	2-87
	1.200	4.0	IRF223	2-87
100	0.055	40.0	IRF150	2-83
	0.055	38.0	2N6764	2-23
	0.080	33.0	IRF152	2-83
	0.085	27.0	IRF140	2-78
	0.110	24.0	IRF142	2-78
	0.180	14.0	2N6756	2-3
	0.180	14.0	IRF130	2-72
	0.250	12.0	IRF132	2-72
	0.300	8.0	IRF120	2-67
	0.400	7.0	IRF122	2-67
60	0.055	40.0	IRF151	2-83
	0.080	31.0	2N6763	2-23
	0.080	33.0	IRF153	2-83
	0.085	27.0	IRF141	2-78
	0.110	24.0	IRF143	2-78
	0.180	14.0	IRF131	2-72
	0.250	12.0	2N6755	2-3
	0.250	12.0	IRF133	2-72
	0.300	8.0	IRF121	2-67
	0.400	7.0	IRF123	2-67

Plastic Encapsulated TO-220AB

V_{DSS} (V)	R_{DS} (on) (Ohms)	I_{DR} (A)	Part Number	Page Number
500	0.850	8.0	IRF840	2-138
	1.100	7.0	IRF842	2-138
	1.500	4.5	IRF830	2-132
	1.500	4.0	MTP4N50	2-132
	2.000	4.0	IRF832	2-132
	3.000	2.5	IRF820	2-127
	4.000	2.0	IRF822	2-127
	4.000	2.5	MTP2N50	2-127
450	0.850	8.0	IRF841	2-138
	1.100	7.0	IRF843	2-138
	1.500	4.0	MTP4N45	2-132
	1.500	4.5	IRF831	2-132
	2.000	4.0	IRF833	2-132
	3.000	2.5	IRF821	2-127
	4.000	2.0	IRF823	2-127
	4.000	2.5	MTP2N45	2-127
400	0.550	10.0	IRF740	2-118
	0.800	8.0	IRF742	2-118
	1.000	5.5	IRF730	2-112
	1.000	5.0	MTP5N40	2-112
	1.500	4.5	IRF732	2-112
	1.800	3.0	IRF720	2-107
	2.500	2.5	IRF722	2-107
	3.300	3.0	MTP3N40	2-107
	3.600	1.5	IRF710	2-157
	5.000	1.3	IRF712	2-157
	5.000	2.0	MTP2N40	2-157
350	0.550	10.0	IRF741	2-118
	0.800	8.0	IRF743	2-118
	1.000	5.5	IRF731	2-112
	1.000	5.0	MTP5N35	2-112
	1.500	4.5	IRF733	2-112
	1.800	3.0	IRF721	2-107
	2.500	2.5	IRF723	2-107
	3.300	3.0	MTP3N35	2-107
	3.600	1.5	IRF711	2-157
	5.000	1.3	IRF713	2-157
	5.000	2.0	MTP2N35	2-157
200	0.180	18.0	IRF640	2-98
	0.220	16.0	IRF642	2-98
	0.350	12.0	MTP12N20	2-92
	0.400	9.0	IRF630	2-92
	0.500	8.0	IRF632	2-92

V_{DSS} (V)	R_{DS} (on) (Ohms)	I_{DR} (A)	Part Number	Page Number
200	0.700	7.0	MTP7N20	2-87
	0.800	5.0	IRF620	2-87
	1.200	4.0	IRF622	2-87
	1.500	2.5	IRF610	2-152
	1.800	3.5	MTP2N20	2-152
	2.400	2.0	IRF612	2-152
180	0.350	12.0	MTP12N18	2-92
	0.700	7.0	MTP7N18	2-87
	1.800	3.25	MTP2N18	2-152
150	0.180	18.0	IRF641	2-98
	0.220	16.0	IRF643	2-98
	0.400	9.0	IRF631	2-92
	0.500	8.0	IRF633	2-92
	0.800	5.0	IRF621	2-87
	1.200	4.0	IRF623	2-87
	1.500	2.5	IRF611	2-152
	2.400	2.0	IRF613	2-152
100	0.085	27.0	IRF540	2-78
	0.110	24.0	IRF542	2-78
	0.150	20.0	MTP20N10	2-72
	0.180	14.0	IRF530	2-72
	0.250	12.0	IRF532	2-72
	0.300	8.0	IRF520	2-67
	0.330	10.0	MTP10N10	2-67
	0.400	7.0	IRF522	2-67
	0.600	4.0	IRF510	2-147
	0.800	3.5	IRF512	2-147
	0.800	5.0	MTP4N10	2-147
80	0.150	20.0	MTP20N08	2-72
	0.330	10.0	MTP10N08	2-67
	0.800	5.0	MTP4N08	2-147
60	0.085	27.0	IRF541	2-78
	0.110	24.0	IRF543	2-78
	0.180	14.0	IRF531	2-72
	0.250	12.0	IRF533	2-72
	0.300	8.0	IRF521	2-67
	0.400	7.0	IRF523	2-67
	0.600	4.0	IRF511	2-147
	0.800	3.5	IRF513	2-147
50	0.085	20	FMP20N05	2-43
	0.100	18	FMP18N05	2-43

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Selector Guide
Ultra-Fast Recovery Rectifiers

Single Rectifier Per Package

Part Number	V_{RSM} (V)	I_F(AVG) (A)	t_{rr} (ns)[2]	V_F (V)[1]	Case Style	Page Number
FRP805	50	8	35	0.95	TO-220AC	2-47
FRP810	100	8	35	0.95	TO-220AC	2-47
FRP815	150	8	35	0.95	TO-220AC	2-47
FRP820	200	8	35	0.95	TO-220AC	2-47
FRP1005	50	10	35	0.95	TO-220AC	2-51
FRP1010	100	10	35	0.95	TO-220AC	2-51
FRP1015	150	10	35	0.95	TO-220AC	2-51
FRP1020	200	10	35	0.95	TO-220AC	2-51
FRP1605	50	16	35	0.95	TO-220AC	2-55
FRP1610	100	16	35	0.95	TO-220AC	2-55
FRP1615	150	16	35	0.95	TO-220AC	2-55
FRP1620	200	16	35	0.95	TO-220AC	2-55

Dual Rectifiers, Common Cathode

Part Number	V_{RSM} (V)	I_F(AVG) (A)	t_{rr} (ns)[2]	V_F (V)[1]	Case Style	Page Number
FRP1605CC	50	16	35	0.95	TO-220AB	2-59
FRP1610CC	100	16	35	0.95	TO-220AB	2-59
FRP1615CC	150	16	35	0.95	TO-220AB	2-59
FRP1620CC	200	16	35	0.95	TO-220AB	2-59
FRP2005CC	50	20	35	0.95	TO-220AB	2-51
FRP2010CC	100	20	35	0.95	TO-220AB	2-51
FRP2015CC	150	20	35	0.95	TO-220AB	2-51
FRP2020CC	200	20	35	0.95	TO-220AB	2-51
FRM3205CC	50	32	35	0.95	TO-204AA	2-63
FRM3210CC	100	32	35	0.95	TO-204AA	2-63
FRM3215CC	150	32	35	0.95	TO-204AA	2-63
FRM3220CC	200	32	35	0.95	TO-204AA	2-63

Notes
1. V_f measured at I_f (avg).
2. t_{rr} measured at $I_f = 1$ A; $dI/dt = 50$ A/μs; $T_j = 25°C$

All Ultra-Fast Recovery Rectifiers listed are available in chip form.
See Section 3 for details.

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Industry Cross Reference

Power MOSFETs

Industry Type	Fairchild Part No.	Page No.
2N6755	2N6755	2-3
2N6756	2N6756	2-3
2N6757	2N6757	2-8
2N6758	2N6758	2-8
2N6759	2N6759	2-13
2N6760	2N6760	2-13
2N6761	2N6761	2-18
2N6762	2N6762	2-18
2N6763	2N6763	2-23
2N6764	2N6764	2-23
2N6765	2N6765	2-28
2N6766	2N6766	2-28
2N6767	2N6767	2-33
2N6768	2N6768	2-33
2N6769	2N6769	2-38
2N6770	2N6770	2-38
2SK133	IRF223	2-87
2SK134	IRF223	2-87
2SK135	IRF222	2-87
2SK175	IRF222	2-87
2SK176	IRF222	2-87
2SK176H	IRF222	2-87
2SK220H	IRF222	2-87
2SK221H	IRF222	2-87
2SK259	IRF323	2-107
2SK260	IRF322	2-107
2SK277	IRF333	2-112
2SK278	IRF332	2-112
2SK294	IRF522	2-67
2SK295	IRF522	2-67
2SK296	MTP3N35	2-107
2SK298	IRF332	2-112
2SK299	IRF431	2-132
2SK308	IRF243	2-98
2SK310	IRF710	2-157
2SK311	IRF823	2-127
2SK312	IRF342	2-118
2SK313	IRF441	2-138
2SK319	IRF720	2-107
2SK320	IRF723	2-107
2SK324	IRF352	2-123
2SK325	IRF453	2-143
2SK338	IRF730	2-112
2SK346	IRF523	2-67

Industry Type	Fairchild Part No.	Page No.
2SK355	IRF241	2-98
2SK357	IRF623	2-87
2SK382	IRF822	2-127
2SK383	IRF530	2-72
2SK428	IRF543	2-78
2SK440	IRF630	2-92
2SK512	IRF452	2-143
2SK552	IRF831	2-132
2SK553	IRF830	2-132
2SK554	IRF841	2-138
2SK555	IRF840	2-138
BUZ10	FMP18N05	2-43
BUZ10A	FMP18N05	2-43
BUZ20	IRF530	2-72
BUZ21	IRF540	2-78
BUZ21A	IRF540	2-78
BUZ23	IRF130	2-72
BUZ24	IRF150	2-83
BUZ25	IRF140	2-78
BUZ30	IRF632	2-92
BUZ31	IRF640	2-98
BUZ32	IRF630	2-92
BUZ32A	MTP12N20	2-92
BUZ33	IRF232	2-92
BUZ34	IRF240	2-98
BUZ35	IRF230	2-92
BUZ35A	IRF230	2-92
BUZ36	IRF252	2-103
BUZ40	IRF822	2-127
BUZ41	IRF842	2-138
BUZ41A	IRF830	2-132
BUZ42	IRF832	2-132
BUZ42A	IRF832	2-132
BUZ43	IRF422	2-127
BUZ44	IRF442	2-138
BUZ44A	IRF430	2-132
BUZ44B	IRF430	2-132
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BUZ45A	MTM7N50	2-138
BUZ45B	IRF452	2-143
BUZ45C	IRF453	2-143
BUZ46	IRF432	2-132
BUZ46A	IRF430	2-132
BUZ60	IRF730	2-112

Industry Type	Fairchild Part No.	Page No.
BUZ60A	IRF730	2-112
BUZ60B	IRF732	2-112
BUZ63	IRF330	2-112
BUZ63A	IRF330	2-112
BUZ63B	IRF332	2-112
BUZ64	IRF352	2-123
BUZ64A	IRF352	2-123
BUZ71	FMP18N05	2-43
BUZ71A	FMP18N05	2-43
BUZ72	IRF530	2-72
BUZ72A	IRF532	2-72
BUZ73A	IRF632	2-92
BUZ74	IRF820	2-127
BUZ74A	IRF822	2-127
BUZ76	IRF720	2-107
BUZ76A	IRF722	2-107
D84BK2	IRF511	2-147
D84BL2	IRF510	2-147
D84BM2	IRF611	2-152
D84BQ1	IRF711	2-157
D84BQ2	IRF710	2-157
D84CK1	IRF521	2-67
D84CK2	IRF521	2-67
D84CL1	IRF520	2-67
D84CL2	IRF520	2-67
D84CM1	IRF621	2-87
D84CM2	IRF621	2-87
D84CN1	MTP7N18	2-87
D84CN2	IRF620	2-87
D84CQ1	IRF721	2-107
D84CQ2	IRF720	2-107
D84CR1	IRF821	2-127
D84CR2	IRF820	2-127
D84DK1	IRF531	2-72
D84DK2	IRF531	2-72
D84DL1	IRF530	2-72
D84DL2	IRF530	2-72
D84DM1	IRF631	2-92
D84DM2	IRF631	2-92
D84DN1	MTP12N18	2-92
D84DN2	IRF630	2-92
D84DQ1	IRF731	2-112
D84DQ2	IRF730	2-112
D84DR1	IRF831	2-132

Power MOSFETs

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D84EK1	IRF541	2-78
D84EK2	IRF541	2-78
D84EL1	MTP4N08	2-147
D84EL2	IRF540	2-78
D84EM1	IRF641	2-98
D84EM2	IRF641	2-98
D84EN1	IRF640	2-98
D84EN2	IRF640	2-98
D84EQ1	IRF741	2-118
D84EQ2	IRF740	2-118
D84ER1	IRF841	2-138
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D84MN2	IRF610	2-152
D86CK1	IRF121	2-67
D86CL1	IRF120	2-67
D86CM1	IRF221	2-67
D86CN1	IRF220	2-67
D86DK1	IRF131	2-72
D86DK2	IRF131	2-72
D86DL1	IRF130	2-72
D86DL2	IRF130	2-72
D86DM1	IRF231	2-92
D86DM2	IRF231	2-92
D86DN1	IRF230	2-92
D86DN2	IRF230	2-92
D86DQ1	IRF331	2-112
D86DQ2	IRF330	2-112
D86DR1	IRF431	2-132
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D86EK1	IRF141	2-78
D86EL1	IRF140	2-78
D86EM1	IRF241	2-98
D86EN1	IRF240	2-98
D86EQ1	IRF341	2-118
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D86ER1	IRF441	2-138
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PM1503P	IRF611	2-152
PM1504P	IRF623	2-87
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PM510P	IRF521	2-67
PM512M	IRF131	2-72
PM512P	IRF531	2-72
PM518M	IRF143	2-78
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RFM18N10	IRF142	2-78
RFM25N05	IRF141	2-78
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RFP2N18	IRF612	2-152
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RFP7N35	IRF741	2-118
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RRF121	IRF121	2-67
RRF122	IRF122	2-67
RRF123	IRF123	2-67
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RRF221	IRF221	2-87
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RRF223	IRF223	2-87
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RRF323	IRF323	2-107
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RRF331	IRF331	2-112
RRF332	IRF332	2-112
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RRF612	IRF612	2-152
RRF613	IRF613	2-152
RRF620	IRF620	2-87
RRF621	IRF621	2-87
RRF622	IRF622	2-87
RRF623	IRF623	2-87
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RRF711	IRF711	2-157
RRF712	IRF712	2-157
RRF713	IRF713	2-157
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RRF722	IRF722	2-107
RRF723	IRF723	2-107
RRF730	IRF730	2-112
RRF731	IRF731	2-112
RRF732	IRF732	2-112
RRF733	IRF733	2-112
RRF820	IRF820	2-127
RRF821	IRF821	2-127
RRF822	IRF822	2-127
RRF823	IRF823	2-127
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RRF833	IRF833	2-132
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SD1005CD	IRF631	2-92
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SD500KD	IRF433	2-132
SD900KD	IRF442	2-138
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SFN106B3	IRF121	2-67
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SFN204B3	IRF221	2-87
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STM361	IRF330	2-112
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UFN121	IRF121	2-67
UFN122	IRF122	2-67
UFN123	IRF123	2-67
UFN130	IRF130	2-72
UFN132	IRF132	2-72
UFN133	IRF133	2-72
UFN140	IRF140	2-78
UFN141	IRF141	2-78
UFN142	IRF142	2-78
UFN143	IRF143	2-78
UFN150	IRF150	2-83
UFN151	IRF151	2-83
UFN152	IRF152	2-83
UFN153	IRF153	2-83
UFN220	IRF220	2-87
UFN221	IRF221	2-87
UFN222	IRF222	2-87
UFN223	IRF223	2-87
UFN230	IRF230	2-92
UFN231	IRF231	2-92
UFN232	IRF232	2-92
UFN233	IRF233	2-92
UFN240	IRF240	2-98
UFN241	IRF241	2-98
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UFN320	IRF320	2-107
UFN321	IRF321	2-107
UFN322	IRF322	2-107
UFN323	IRF323	2-107
UFN330	IRF330	2-112
UFN331	IRF331	2-112
UFN332	IRF332	2-112
UFN333	IRF333	2-112
UFN340	IRF340	2-118
UFN341	IRF341	2-118
UFN342	IRF342	2-118
UFN343	IRF343	2-118
UFN350	IRF350	2-123
UFN351	IRF351	2-123
UFN352	IRF352	2-123
UFN353	IRF353	2-123
UFN420	IRF420	2-127
UFN421	IRF421	2-127
UFN422	IRF422	2-127
UFN423	IRF423	2-127
UFN430	IRF430	2-132
UFN431	IRF431	2-132
UFN432	IRF432	2-132
UFN433	IRF433	2-132
UFN440	IRF440	2-138
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UFN453	IRF453	2-143
UFN510	IRF510	2-147
UFN511	IRF511	2-147
UFN512	IRF512	2-147
UFN513	IRF513	2-147
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UFN521	IRF521	2-67
UFN522	IRF522	2-67
UFN523	IRF523	2-67
UFN530	IRF530	2-72
UFN531	IRF531	2-72

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UFN541	IRF541	2-78
UFN542	IRF542	2-78
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UFN610	IRF610	2-152
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UFN612	IRF612	2-152
UFN613	IRF613	2-152
UFN620	IRF620	2-87
UFN621	IRF621	2-87
UFN622	IRF622	2-87
UFN623	IRF623	2-87
UFN630	IRF630	2-92
UFN631	IRF631	2-92
UFN632	IRF632	2-92
UFN633	IRF633	2-92
UFN640	IRF640	2-98
UFN641	IRF641	2-98
UFN642	IRF642	2-98
UFN643	IRF643	2-98
UFN710	IRF710	2-157
UFN711	IRF711	2-157
UFN712	IRF712	2-157
UFN713	IRF713	2-157
UFN720	IRF720	2-107
UFN721	IRF721	2-107
UFN722	IRF722	2-107
UFN723	IRF723	2-107
UFN730	IRF730	2-112
UFN731	IRF731	2-112
UFN732	IRF732	2-112
UFN733	IRF733	2-112
UFN740	IRF740	2-118
UFN741	IRF741	2-118
UFN742	IRF742	2-118
UFN743	IRF743	2-118
UFN820	IRF820	2-127
UFN821	IRF821	2-127
UFN822	IRF822	2-127
UFN823	IRF823	2-127
UFN830	IRF830	2-132
UFN831	IRF831	2-132

Industry Type	Fairchild Part No.	Page No.
UFN832	IRF832	2-132
UFN833	IRF833	2-132
UFN840	IRF840	2-138
UFN841	IRF841	2-138
UFN842	IRF842	2-138
UFN843	IRF843	2-138
VN0600A	IRF543	2-78
VN0601A	IRF543	2-78
VN0800A	IRF130	2-72
VN0800D	IRF530	2-72
VN0801A	IRF132	2-72
VN0801D	IRF532	2-72
VN1000A	IRF130	2-72
VN1000D	IRF530	2-72
VN1001A	IRF132	2-72
VN1001D	IRF532	2-72
VN1106N5	IRF511	2-147
VN1110N5	IRF510	2-147
VN1116N5	IRF612	2-152
VN1120N5	IRF612	2-152
VN1200A	IRF641	2-98
VN1201A	IRF643	2-98
VN1210N1	IRF120	2-67
VN1210N5	IRF520	2-67
VN1216N1	IRF220	2-87
VN1216N5	IRF620	2-87
VN1220N5	IRF620	2-87
VN2306N1	IRF143	2-78
VN2310N1	IRF142	2-78
VN2310N5	IRF542	2-78
VN2316N1	IRF242	2-98
VN2316N5	IRF642	2-98
VN2320N1	IRF242	2-98
VN2320N5	IRF642	2-98
VN2335N1	IRF341	2-118
VN2335N5	IRF741	2-118
VN2340N1	IRF340	2-118
VN2340N5	IRF740	2-118
VN2345N1	IRF443	2-138
VN2345N5	IRF843	2-138
VN2350N1	IRF442	2-138
VN2350N5	IRF842	2-138
VN3500A	IRF331	2-112
VN3500D	IRF731	2-112

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VN3501D	IRF733	2-112
VN3502A	IRF430	2-132
VN4000A	IRF330	2-112
VN4000D	IRF730	2-112
VN4001A	IRF332	2-112
VN4001D	IRF732	2-112
VN4501A	IRF431	2-132
VN4501D	IRF831	2-132
VN4502A	IRF433	2-132
VN4502D	IRF833	2-132
VN5001A	IRF430	2-132
VN5001D	IRF830	2-132
VN5002A	IRF432	2-132
VN5002D	IRF832	2-132
VNL001A	IRF331	2-112
VNM001A	IRF330	2-112
VNN002A	IRF443	2-138
VNP002A	IRF430	2-132

Ultra-Fast Reverse Recovery Rectifiers

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BYV32-50	FRP2005CC	2-51
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BYV79-150	FRP1615	2-55
BYV79-200	FRP1620	2-55
BYV79-50	FRP1605	2-55
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BYW29-150	FRP815	2-47
BYW29-200	FRP820	2-47
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BYW51-100	FRP1610CC	2-59
BYW51-150	FRP1615CC	2-59
BYW51-50	FRP1605CC	2-59
BYW80-100	FRP810	2-47
BYW80-150	FRP815	2-47
BYW80-200	FRP820	2-47
BYW80-50	FRP805	2-47
BYW99-100	FRM3210CC	2-63
BYW99-150	FRM3220CC	2-63
BYW99-50	FRM3205CC	2-63
FE16A	FRP1605	2-55
FE16B	FRP1610	2-55
FE16C	FRP1615	2-55
FE16D	FRP1620	2-55
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MUR1510	FRP1610	2-55
MUR1515	FRP1615	2-55
MUR1520	FRP1620	2-55
MUR1605CT	FRP1605CC	2-59
MUR1610CT	FRP1610CC	2-59
MUR1615CT	FRP1615CC	2-59
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MUR805	FRP805	2-47
MUR810	FRP810	2-47
MUR815	FRP815	2-47
MUR820	FRP820	2-47
RUR810	FPR810	2-47
RUR815	FRP815	2-47
RUR820	FRP820	2-47
RURD1610	FRM3210CC	2-63
RURD1615	FRM3210CC	2-63
RURD1620	FRM3220CC	2-63
RURD810	FRP1610CC	2-59
RURD815	FRP1615CC	2-59
RURD820	FRP1620CC	2-59
UES1401	FRP805	2-47
UES1402	FRP810	2-47
UES1403	FRP815	2-47
UES1404	FRP820	2-47
UES1501	FRP1605	2-55
UES1502	FRP1610	2-55
UES1503	FRP1615	2-55
UES1504	FRP1620	2-55
UES2401	FRP1605CC	2-59
UES2402	FRP1610CC	2-59
UES2403	FRP1615CC	2-59
UES2404	FRP1620CC	2-59
UES2601	FRM3205CC	2-63
UES2602	FRM3210CC	2-63
UES2603	FRM3215CC	2-63
UES2604	FRM3220CC	2-63
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VHE1402	FRP1010	2-51
VHE1403	FRP1015	2-51
VHE1404	FRP1020	2-51
VHE2401	FRP2005CC	2-51
VHE2402	FRP2010CC	2-51
VHE2403	FRP2015CC	2-51
VHE2404	FRP2020CC	2-51
VHE2601	FRM3205CC	2-63
VHE2602	FRM3210CC	2-63
VHE2603	FRM3215CC	2-63
VHE2604	FRM3220CC	2-63

FAIRCHILD

A Schlumberger Company

2N6755/2N6756 N-Channel Power MOSFETs, 14 A, 60 V/100 V

Power And Discrete Division

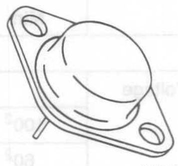
2

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $R_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AA



IS00020F

2N6755
2N6756

Maximum Ratings

Symbol	Characteristic	Rating 2N6756	Rating 2N6755	Unit
V_{DSS}	Drain to Source Voltage	100	60	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1\ M\Omega$	100	60	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.18	0.25	Ω
I_D	Drain Current			A
	Continuous at $T_C = 25°C$	14	12	
	Continuous at $T_C = 100°C$	9	8	
I_{DM}	Pulsed	30^2	25^2	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	75	75	W
	Linear Derating Factor	0.6	0.6	W/°C

Notes

All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage			V	V_{GS} = 0 V, I_D = 1 mA
	2N6756	100[2]			
	2N6755	60[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			4		V_{DS} = Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 1 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[1]			Ω	V_{GS} = 10 V
	2N6756		0.18		I_D = 9 A
	2N6755		0.25		I_D = 8 A
				Ω	V_{GS} = 10 V, T_C = 125°C
	2N6756		0.33		I_D = 9 mA
	2N6755		0.45		I_D = 8 A
$V_{DS(on)}$	Drain-Source On-Voltage[1]				
	2N6756		2.52	V	V_{GS} = 10 V; I_D = 14 A
	2N6755		3.0		V_{GS} = 10 V; I_D = 12 A
g_{fs}	Forward Transconductance[1]	4.0	12	S (℧)	V_{DS} = 10 V, I_D = 9 A
Dynamic Characteristics					
C_{iss}	Input Capacitance	350	800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance	150	500	pF	
C_{rss}	Reverse Transfer Capacitance	50	150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 36 V, I_D = 9 A V_{GS} = 10 V, R_{GEN} = 15 Ω R_{GS} = 15 Ω
t_r	Rise Time		75	ns	
$t_{d(off)}$	Turn-Off Delay Time		40	ns	
t_f	Fall Time		45	ns	
Q_g	Total Gate Charge		30[2]	nC	V_{GS} = 10 V, I_D = 18 A V_{DD} = 55 V

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current				A	
	2N6756			14		
	2N6755			12		
I_{SM}	Pulsed Source Current				A	
	2N6756			30[2]		
	2N6755			25[2]		
V_{SD}	Diode Forward Voltage					
	2N6756	0.90		1.8	V	$I_S = 14$ A; $V_{GS} = 0$ V
	2N6755	0.85		1.7	V	$I_S = 12$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time		300[2]		ns	$V_{GS} = 0$ V, $T_J = 150°C$; $I_F = I_{SM}$, $dI_F/dt = 100$ A/μS
Q_{RR}	Reverse Recovery Charge		4.0[2]		μC	$V_{GS} = 0$ V, $T_J = 150°C$; $I_F = I_{SM}$, $dI_F/dt = 100$ A

Notes
1. Pulse test: Pulse width ≤ 300 μs, Duty cycle ≤ 1%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

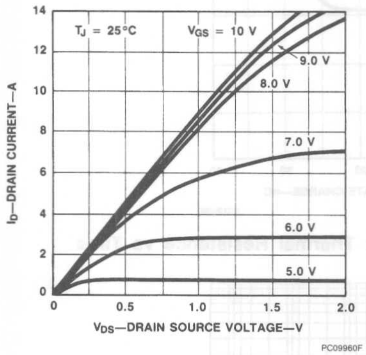
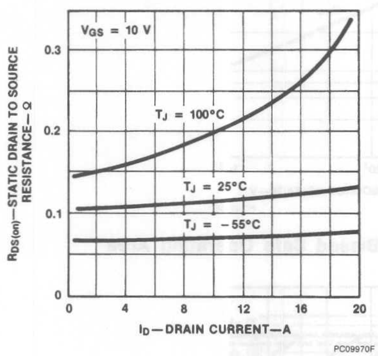


Figure 2 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

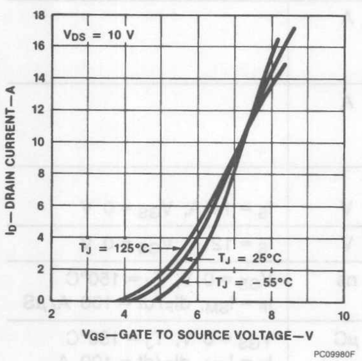


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

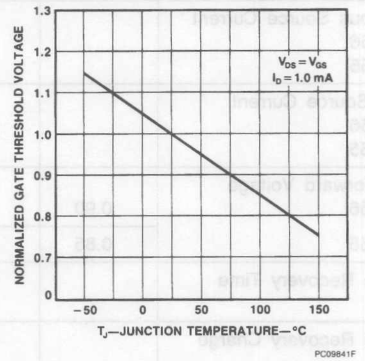


Figure 5 Capacitance vs Drain to Source Voltage

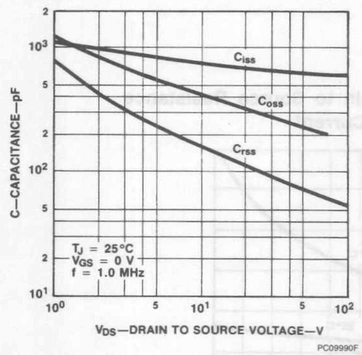


Figure 6 Gate to Source Voltage vs Total Gate Charge

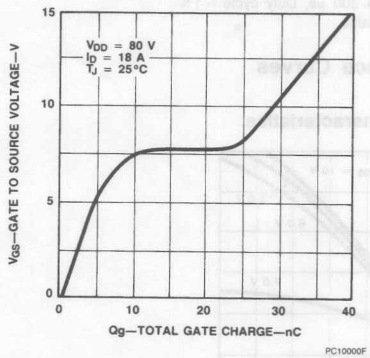


Figure 7 Forward Biased Safe Operating Area

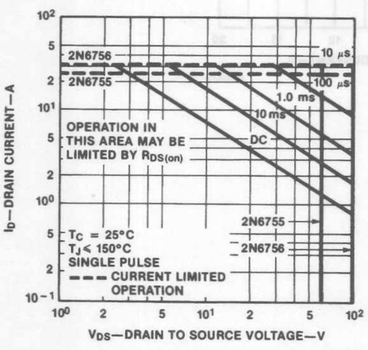
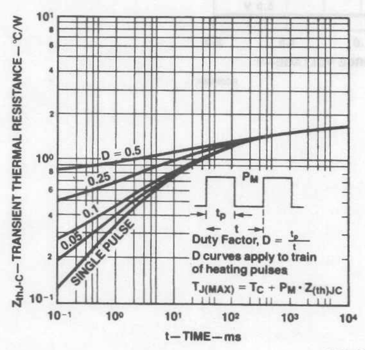


Figure 8 Transient Thermal Resistance vs Time



2

Typical Electrical Characteristics

Figure 9 Switching Test Circuit

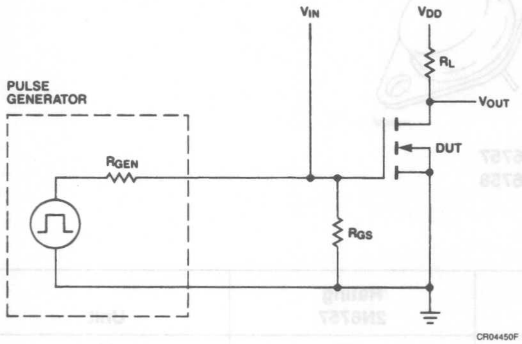
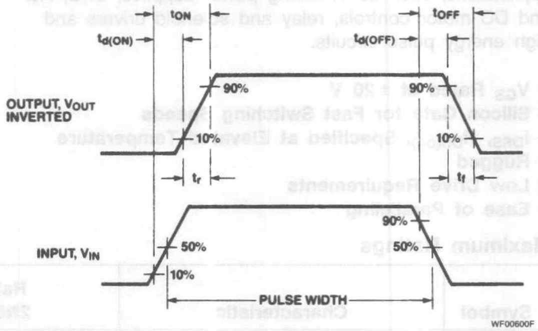


Figure 10 Switching Waveforms



Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $R_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

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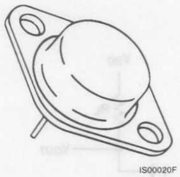


2N6757
2N6758

Maximum Ratings

Symbol	Characteristic	Rating 2N6758	Rating 2N6757	Unit
V_{DSS}	Drain to Source Voltage	200	150	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1\ M\Omega$	200	200	V
V_{GS}	Gate to Source Voltage	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.4	0.6	Ω
I_D	Drain Current			A
	Continuous at $T_C = 25°C$	9.0	8.0	
	Continuous at $T_C = 100°C$	6.0^2	5.0^2	
I_{DM}	Pulsed	15^2	12^2	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	75	75	W
	Linear Derating Factor	0.6	0.6	W/°C

Notes

All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage			V	V_{GS} = 0 V, I_D = 1 mA
	2N6758	200[2]			
	2N6757	150[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			4		V_{DS} = Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 1 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance			Ω	V_{GS} = 10 V
	2N6758		0.4		I_D = 6 A
	2N6757		0.6		I_D = 5 A
	2N6758		0.75		I_D = 6 A, T_C = 125°C
	2N6757		1.13		I_D = 5 A, T_C = 125°C
$V_{DS(on)}$	Drain-Source On-Voltage[1]			V	
	2N6758		3.6		V_{GS} = 10 V; I_D = 9 A
	2N6757		4.8		V_{GS} = 10 V; I_D = 8 A
g_{fs}	Forward Transconductance[1]	3.0	9.0	S (℧)	V_{DS} = 15 V, I_D = 6 A
Dynamic Characteristics					
C_{iss}	Input Capacitance	350	800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance	100	450	pF	
C_{rss}	Reverse Transfer Capacitance	40	150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 90 V, I_D = 6 A V_{GS} = 10 V, R_{GEN} = 15 Ω R_{GS} = 15 Ω
t_r	Rise Time		50	ns	
$t_{d(off)}$	Turn-Off Delay Time		50	ns	
t_f	Fall Time		40	ns	
Q_g	Total Gate Charge		30[2]	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 120 V

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current 2N6758 2N6757			 9.0 8.0	A	
I_{SM}	Pulsed Source Current 2N6758 2N6757			 15[2] 12[2]	A	
V_{SD}	Diode Forward Voltage 2N6758	0.80		1.60	V	$VI_{GS} = 0$ V $I_S = 9$ A
	2N6757	0.75		1.50	V	$I_S = 8$ A
t_{rr}	Reverse Recovery Time		650[2]		ns	$V_{GS} = 0$ V, $T_J = 150°C$ $I_F = I_{SM}$, $dI_F/dt = 100$ A/μS
Q_{RR}	Reverse Recovery Charge		10[2]		μC	$V_{GS} = 0$ V, $T_J = 150°C$ $I_F = I_{SM}$, $dI_F/dt = 100$ A

Notes

1. Pulse test: Pulse width ≤ 300 μs, Duty cycle ≤ 2%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

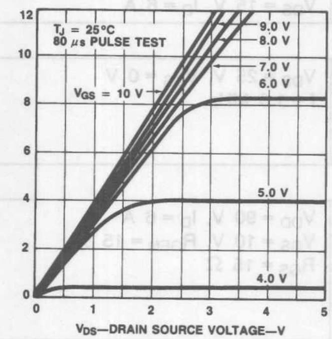
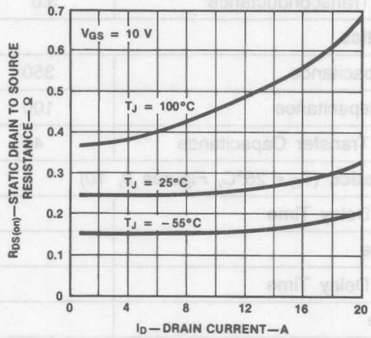


Figure 2 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

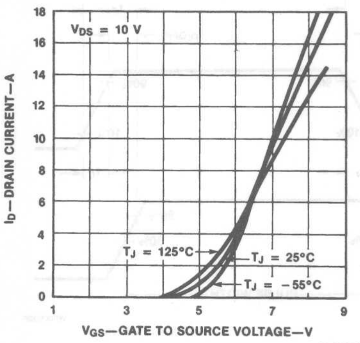


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

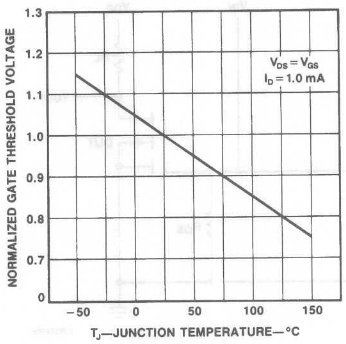


Figure 5 Capacitance vs Drain to Source Voltage

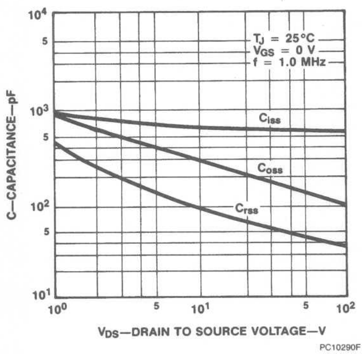


Figure 6 Gate to Source Voltage vs Total Gate Charge

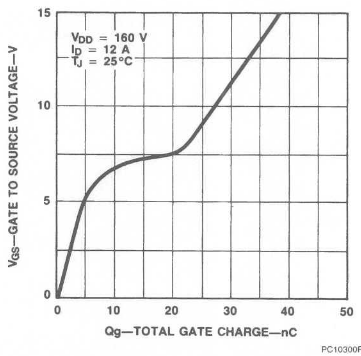


Figure 7 Forward Biased Safe Operating Area

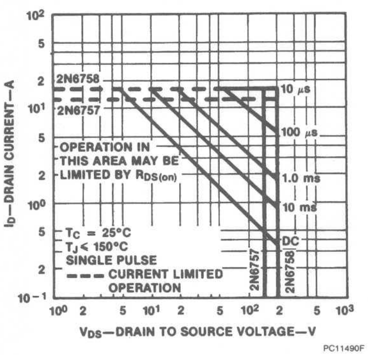
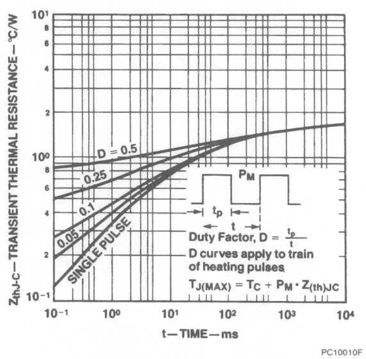


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

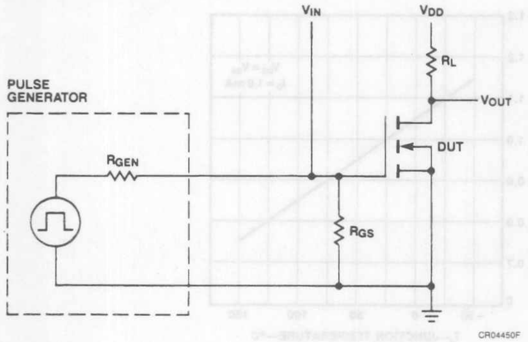
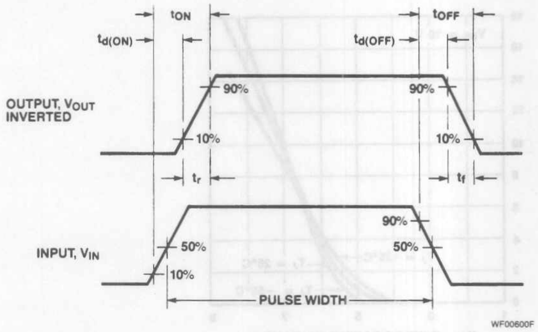


Figure 10 Switching Waveforms



2N6759/2N6760 N-Channel Power MOSFETs, 5.5 A, 350 V/400 V

Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- V_{GS} Rated at ±20 V
- Silicon Gate for Fast Switching Speeds
- I_{DSS}, $R_{DS(on)}$, Specified at Elevated Temperature
- Rugged
- Low Drive Requirements
- Ease of Paralleling

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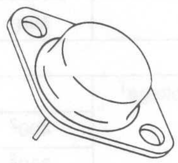


2N6759
2N6760

Maximum Ratings

Symbol	Characteristic	Rating 2N6760	Rating 2N6759	Unit
V_{DSS}	Drain to Source Voltage	400	350	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1.0$ MΩ	400	350	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	1.0	1.5	Ω
I_D	Drain Current			A
	Continuous at $T_C = 25°C$	5.5	4.5	
	Continuous at $T_C = 100°C$	3.5	3.0	
I_{DM}	Pulsed	8.0[2]	7.0[2]	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	°C/W
P_D	Total Power Dissipation			W
	at $T_C = 25°C$	75	75	
	at $T_C = 100°C$	30	30	
	Linear Derating Factor	0.6	0.6	W/°C

Notes
All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 1.0 mA
	2N6760	400[2]			
	2N6759	350[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			4		V_{DS} = Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 1.0 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[1]			Ω	V_{GS} = 10 V
	2N6760		1.0		I_D = 3.0 A
	2N6759		1.5		I_D = 3.5 A
	2N6760		2.2		I_D = 3.5 A, T_C = 125°C
	2N6759		3.3		I_D = 3.0 A, T_C = 125°C
$V_{DS(on)}$	Drain-Source On-Voltage[1]			V	
	2N6760		6.7		V_{GS} = 10 V; I_D = 5.5 A
	2N6759		7.0		V_{GS} = 10 V; I_D = 4.5 A;
g_{fs}	Forward Transconductance[1]	3.0	9.0	S (℧)	V_{DS} = 15 V, I_D = 3.5 A
Dynamic Characteristics					
C_{iss}	Input Capacitance	350	800	pF	V_{DS} = 25 V, V_{GS} = 0 V, f = 1.0 MHz
C_{oss}	Output Capacitance	50	300	pF	
C_{rss}	Reverse Transfer Capacitance	20	80	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 175 V, I_D = 3.5 A, V_{GS} = 10 V, R_{GEN} = 15 Ω, R_{GS} = 15 Ω
t_r	Rise Time		35	ns	
$t_{d(off)}$	Turn-Off Delay Time		55	ns	
t_f	Fall Time		55	ns	
Q_g	Total Gate Charge		30[2]	nC	V_{GS} = 10 V, I_D = 7.0 A, V_{DD} = 180 V

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current 2N6760 2N6759			 5.5 4.5	A	
I_{SM}	Pulsed Source Current 2N6760 2N6759			 8.0 7.0	A	
V_{SD}	Diode Forward Voltage 2N6760	0.75		1.5	V	$I_S = 5.5$ A; $V_{GS} = 0$ V
	2N6759	0.70		1.4		$I_S = 4.5$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time		550[2]		ns	$V_{GS} = 0$ V, $T_J = 150°C$ $I_F = I_{SM}$, $dI_F/dt = 100$ A/μS
Q_{RR}	Reverse Recovery Charge		8.0[2]		μC	$V_{GS} = 0$ V, $T_J = 150°C$ $I_F = I_{SM}$, $dI_F/dt = 100$ A/μS

Notes
1. Pulse test: Pulse width ⩽ 300 μs, Duty cycle ⩽ 2%
3. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

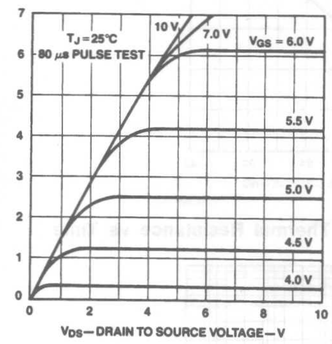
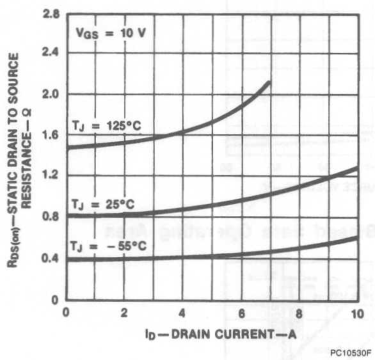


Figure 2 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

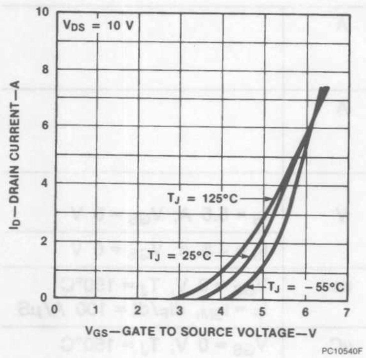


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

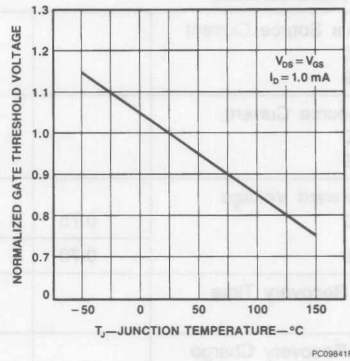


Figure 5 Capacitance vs Drain to Source Voltage

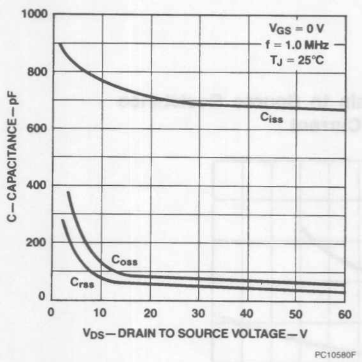


Figure 6 Gate to Source Voltage vs Total Gate Charge

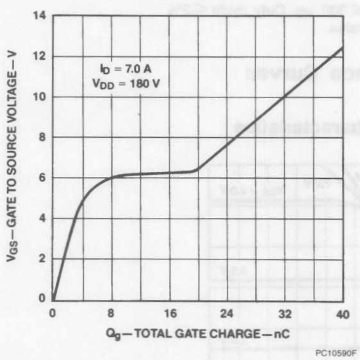


Figure 7 Forward Biased Safe Operating Area

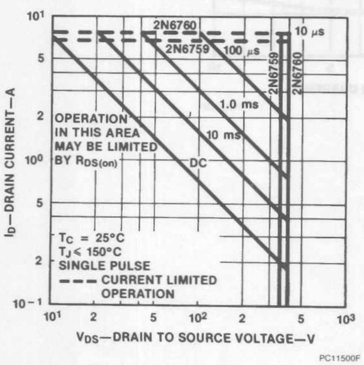
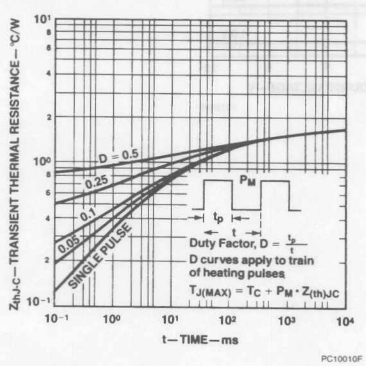


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

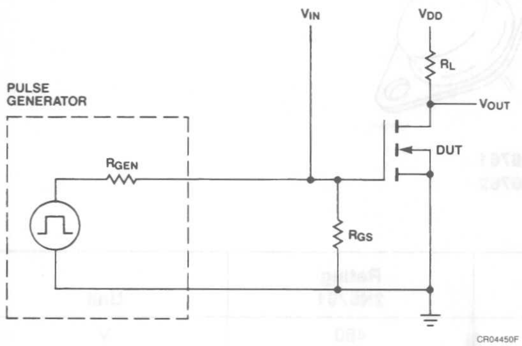
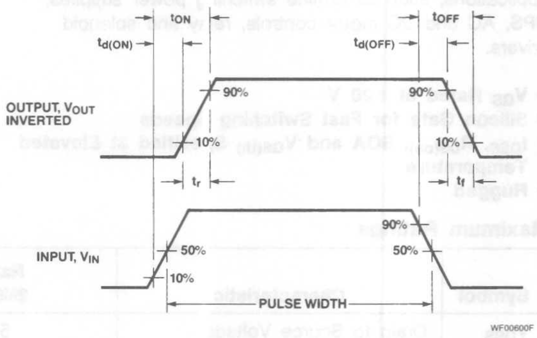


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

2N6761/2N6762 N-Channel Power MOSFETs, 4.5 A, 450 V/500 V

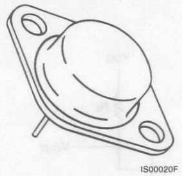
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $R_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

TO-204AA



2N6761
2N6762

Maximum Ratings

Symbol	Characteristic	Rating 2N6762	Rating 2N6761	Unit
V_{DSS}	Drain to Source Voltage	500	450	V
V_{DGR}	Drain to Gate Voltage R_{GS} = 1.0 MΩ	500	450	V
V_{GS}	Gate to Source Voltage	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	1.5	2.0	Ω
I_D	Drain Current			A
	Continuous at T_C = 25°C	4.5	4.0	
	Continuous at T_C = 100°C	3.0	2.5	
I_{DM}	Pulsed	7.0[2]	6.0[2]	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	°C/W
P_D	Total Power Dissipation			W
	at T_C = 25°C	75	75	
	at T_C = 100°C	30	30	
	Linear Derating Factor	0.6	0.6	W/°C

Notes

All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 4 mA
	2N6762	500[2]			
	2N6761	450[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			4		V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		±100	nA	V_{GS} = ±20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 1.0 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[1]			Ω	V_{GS} = 10 V
	2N6762		1.5		I_D = 3.0 A
	2N6761		2.0		I_D = 2.5 A
	2N6762		3.3		I_D = 3.0 A, T_C = 125°C
	2N6761		4.4		I_D = 2.5 A, T_C = 125°C
$V_{DS(on)}$	Drain-Source On-Voltage[1]			V	V_{GS} = 10 V
	2N6762		7.7		I_D = 4.5 A
	2N6761		8.0		I_D = 4.0 A
g_{fs}	Forward Transconductance[1]	2.5	7.5	S (℧)	V_{DS} = 15 V, I_D = 3.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance	350	800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{dss}	Output Capacitance	25	200	pF	
C_{res}	Reverse Transfer Capacitance	15	60	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 225 V, I_D = 3.0 A V_{GS} = 10 V, R_{GEN} = Ω R_{GS} = 15 Ω
t_r	Rise Time		30	ns	
$t_{d(off)}$	Turn-Off Delay Time		55	ns	
t_f	Fall Time		30	ns	
Q_g	Total Gate Charge		30[2]	nC	V_{GS} = 10 V, I_D = 7.0 A V_{DD} = 180 V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current 2N6762 2N6761			 4.5 4.0	A	
I_{SM}	Pulsed Source Current 2N6762 2N6761			 7.0 6.0	A	
V_{SD}	Diode Forward Voltage 2N6762 2N6761	 0.7 0.65		 1.4 1.3	V	V_{GS} = 0 V I_S = 4.5 A I_S = 4.0 A
t_{rr}	Reverse Recovery Time		520[2]		ns	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/μS
Q_{RR}	Reverse Recovery Charge		7.0[2]		μC	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/μS

Notes
1. Pulse test: Pulse width ⩽ 300 μs, Duty cycle ⩽ 1%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

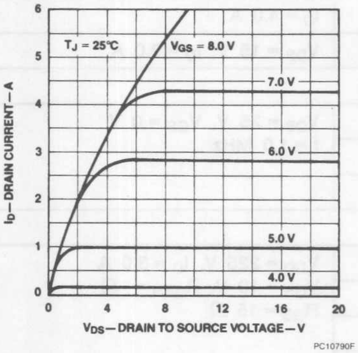
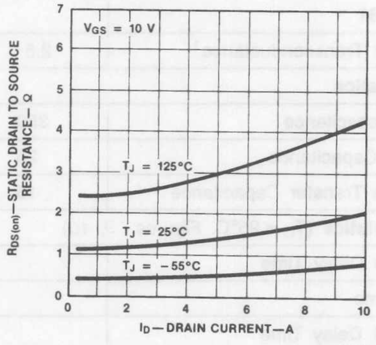


Figure 2 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

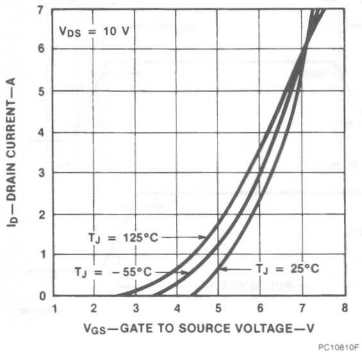


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

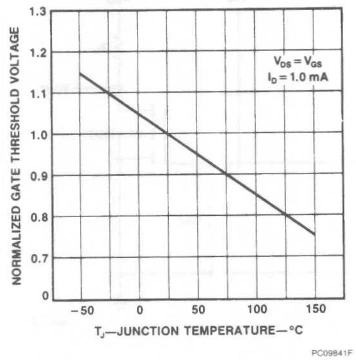


Figure 5 Capacitance vs Drain to Source Voltage

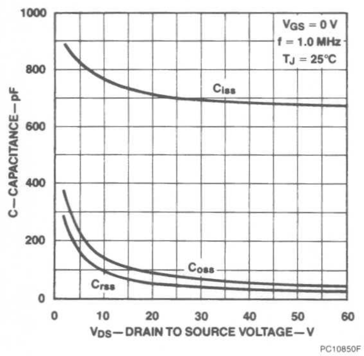


Figure 6 Gate to Source Voltage vs Total Gate Charge

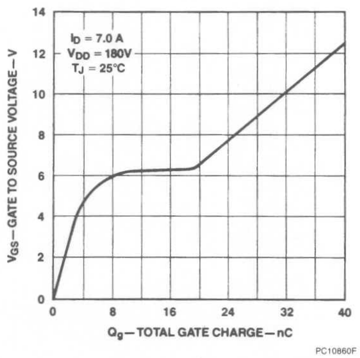


Figure 7 Forward Biased Safe Operating Area

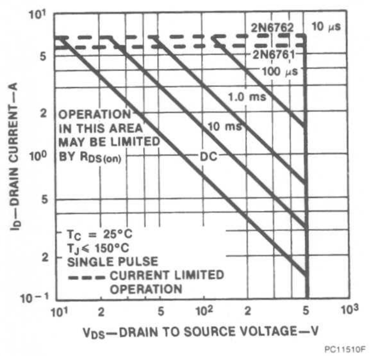
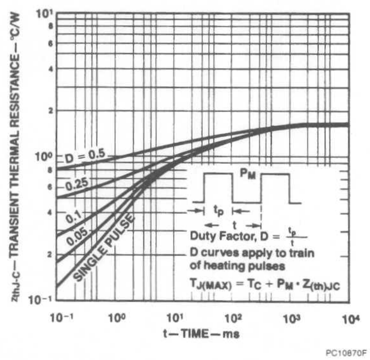


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

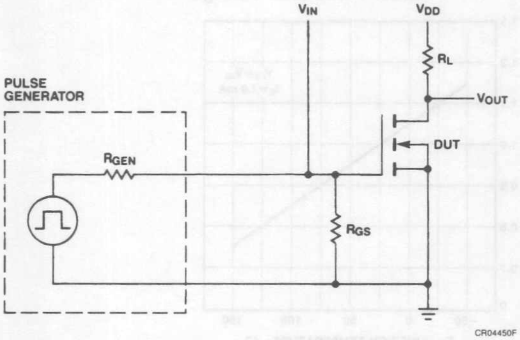
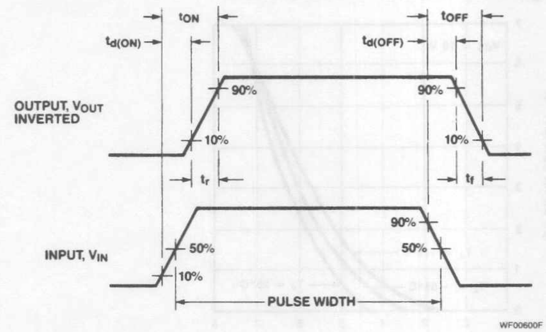


Figure 10 Switching Waveforms



FAIRCHILD
A Schlumberger Company

2N6763/2N6764 N-Channel Power MOSFETs, 38 A, 60 V/100 V

Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid driver and high energy pulse circuits.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $R_{DS(on)}$ Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

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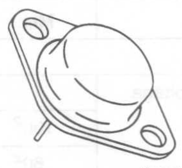


2N6763
2N6764

Maximum Ratings

Symbol	Characteristic	Rating 2N6764	Rating 2N6763	Unit
V_{DSS}	Drain to Source Voltage	100	60	V
V_{DGR}	Drain to Gate Voltage R_{GS} = 1.0 MΩ	100	60	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.055	0.08	Ω
I_D	Drain Current			A
	Continuous at T_C = 25°C	38	31	
	Continuous at T_C = 100°C	24	20	
I_{DM}	Pulsed	70^2	60^2	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation			W
	at T_C = 25°C	150	150	
	at T_C = 100°C	60	60	
	Linear Derating Factor	1.2	1.2	W/°C

Notes
All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage			V	$V_{GS} = 0$ V, $I_D = 1$ m
	2N6764	100[2]			
	2N6763	60[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			4		V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		±100	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[1]			Ω	$V_{GS} = 10$ V
	2N6764		0.055		$I_D = 24$ A
	2N6763		0.080		$I_D = 20$ A
	2N6764		0.094		$I_D = 24$ A; $T_C = 125°C$
	2N6763		0.136		$I_D = 20$ A; $T_C = 125°C$
$V_{DS(on)}$	Drain-Source On-Voltage[1]			V	$V_{GS} = 10$ V
	2N6764		2.09		$I_D = 38$ A
	2N6763		2.48		$I_D = 31$ A
g_{fs}	Forward Transconductance[1]	9.0	27	S (℧)	$V_{DS} = 15$ V, $I_D = 24$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance	1000	3000	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V
C_{oss}	Output Capacitance	500	1500	pF	f = 1.0 MHz
C_{rss}	Reverse Transfer Capacitance	150	500	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	$V_{DD} = 24$ V, $I_D = 24$ A
t_r	Rise Time		100	ns	$V_{GS} = 10$ V, $R_{GEN} = 4.7\ \Omega$
$t_{d(off)}$	Turn-Off Delay Time		125	ns	$R_{GS} = 4.7\ \Omega$
t_f	Fall Time		100	ns	
Q_g	Total Gate Charge		120[2]	nC	$V_{GS} = 10$ V, $I_D = 50$ A, $V_{DD} = 55$ V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current 2N6764 2N6763			 38 31	A	
I_{SM}	Pulsed Source Current 2N6764 2N6763			 70 60	A	
V_{SD}	Diode Forward Voltage 2N6764	 0.95		 1.9	V	V_{GS} = 0 V I_S = 38 A
	2N6763	0.90		1.8		I_S = 31 A
t_{rr}	Reverse Recovery Time		500[2]		ns	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/μS
Q_{RR}	Reverse Recovery Charge		10[2]		μC	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/μS

Notes
1. Pulse test: Pulse width ≤ 20 μs, Duty cycle ≤ 2%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

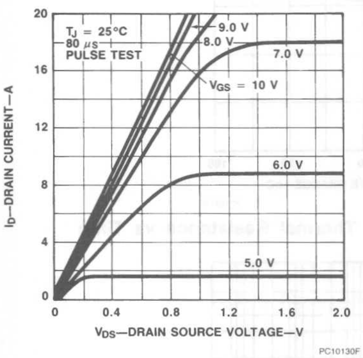
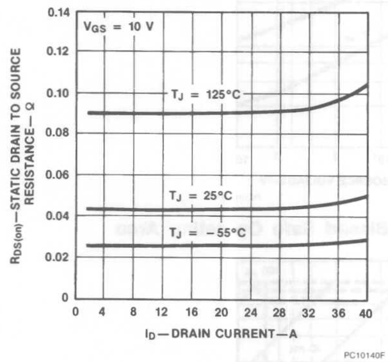


Figure 2 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

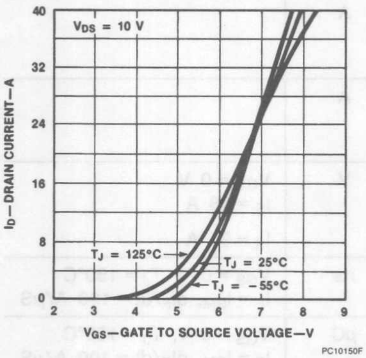


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

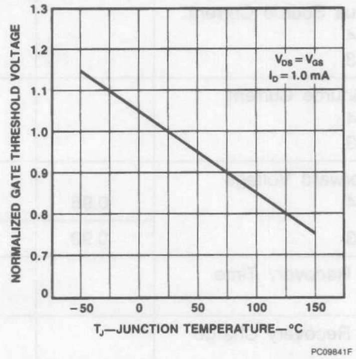


Figure 5 Capacitance vs Drain to Source Voltage

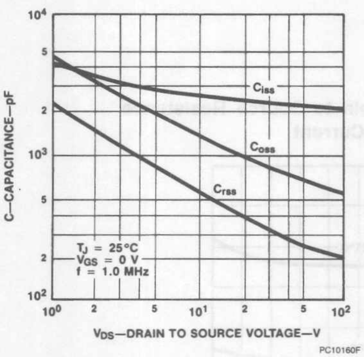


Figure 6 Gate to Source Voltage vs Total Gate Charge

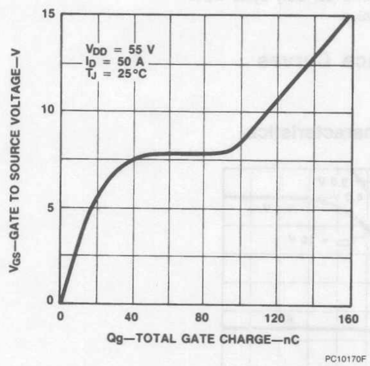


Figure 7 Forward Biased Safe Operating Area

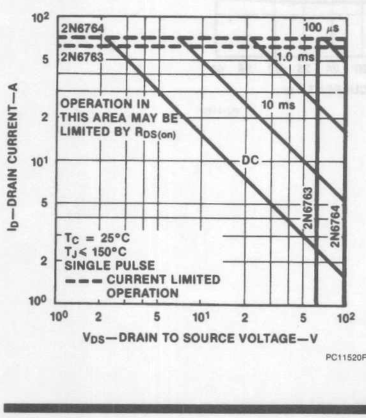
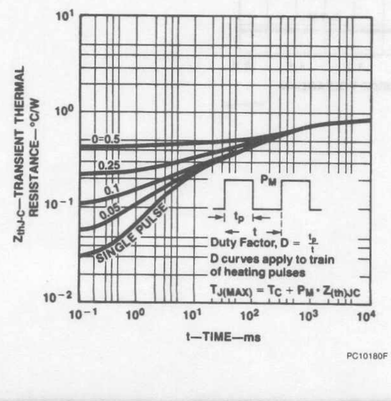


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

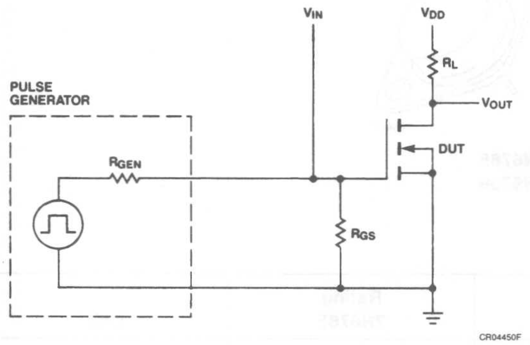
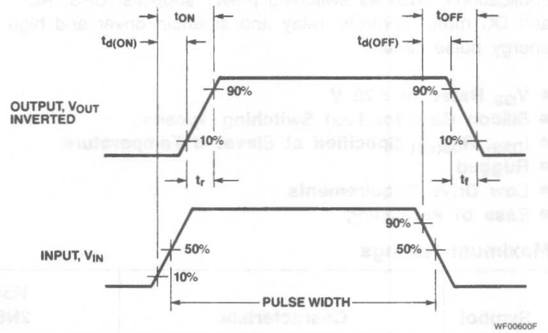


Figure 10 Switching Waveforms

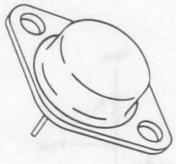


Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid driver and high energy pulse circuits.

- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $R_{DS(on)}$ Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AE



2N6765
2N6766

Maximum Ratings

Symbol	Characteristic	Rating 2N6766	Rating 2N6765	Unit
V_{DSS}	Drain to Source Voltage	200	150	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1\ M\Omega$	200	150	V
V_{GS}	Gate to Source Voltage	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C

Maximum On-State Characteristics

Symbol	Characteristic	Rating 2N6766	Rating 2N6765	Unit
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.085	0.12	Ω
I_D	Drain Current			A
	Continuous at $T_C = 25°C$	30	25	
	Continuous at $T_C = 100°C$	19	16	
I_{DM}	Pulsed	60^2	50^2	

Maximum Thermal Characteristics

Symbol	Characteristic	Rating 2N6766	Rating 2N6765	Unit
$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation			W
	at $T_C = 25°C$	150	150	
	at $T_C = 100°C$	60	60	
	Linear Derating Factor	1.2	1.2	W/°C

Notes
All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage			V	$V_{GS} = 0$ V, $I_D = 1.0$ mA
	2N6766	200[2]			
	2N6765	150[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			4		V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		± 100	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 1.0$ mA, $V_{DS}, = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[1]			Ω	$V_{GS} = 10$ V,
	2N6766		0.085		$I_D = 19$ A
	2N6765		0.12		$I_D = 16$ A
	2N6766		0.153		$I_D = 19$ A, $T_C = 125°C$
	2N6765		0.216		$I_D = 16$ A, $T_C = 125°C$
$V_{DS(on)}$	Drain-Source On-Voltage[1]			V	$V_{GS} = 10$ V
	2N6766		2.7		$I_D = 30$ A
	2N6765		3.0		$I_D = 25$ A
g_{fs}	Forward Transconductance[1]	9.0	27	S (℧)	$V_{DS} = 15$ V, $I_D = 19$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance	1000	3000	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{dss}	Output Capacitance	450	1200	pF	
C_{rss}	Reverse Transfer Capacitance	150	500	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	$V_{DD} = 95$ V, $I_D = 19$ A $V_{GS} = 10$ V, $R_{GEN} = 4.7\ \Omega$ $R_{GS} = 4.7\ \Omega$
t_r	Rise Time		100	ns	
$t_{d(off)}$	Turn-Off Delay Time		125	ns	
t_f	Fall Time		100	ns	
Q_g	Total Gate Charge		120[2]	nC	$V_{GS} = 10$ V, $I_D = 38$ A $V_{DD} = 100$ V

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current 2N6766 2N6765			 30 25	A	
I_{SM}	Pulsed Source Current 2N6766 2N6765			 60^2 50^2	A	
V_{SD}	Diode Forward Voltage 2N6766 2N6765	 0.9 0.85		 1.8 1.7	V	$V_{GS} = 0$ V $I_S = 30$ A $I_S = 25$ A
t_{rr}	Reverse Recovery Time		500^2		ns	$V_{GS} = 0$ V, $T_J = 150°C$ $I_F = I_{SM}$, $dI_F/dt = 100$ A/μs
Q_{RR}	Reverse Recovery Charge		10^2		μC	$V_{GS} = 0$ V, $T_J = 150°C$ $I_F = I_{SM}$, $dI_F/dt = 100$ A/μs

Notes
1. Pulse test: Pulse width ⩽ 300 μs, Duty cycle ⩽ 2%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

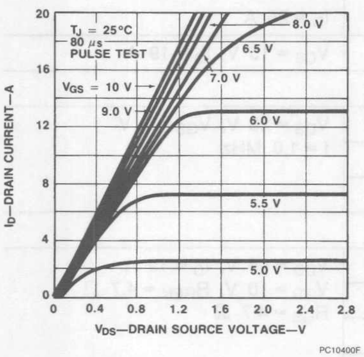
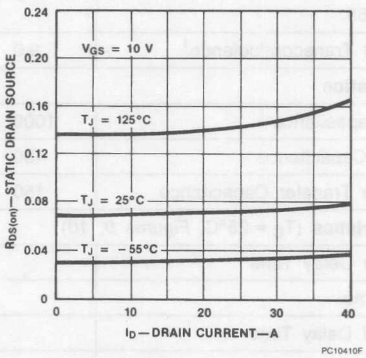


Figure 2 Static Drain to Source On-Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

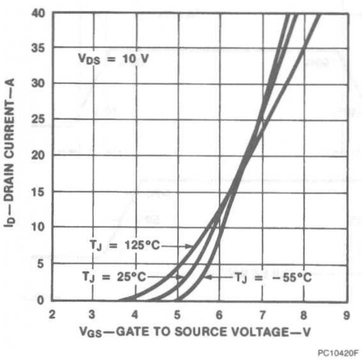


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

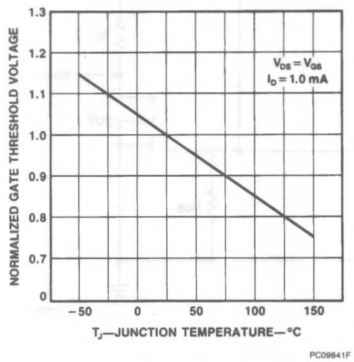


Figure 5 Capacitance vs Drain to Source Voltage

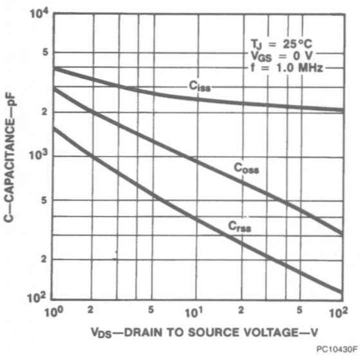


Figure 6 Gate to Source Voltage vs Total Gate Charge

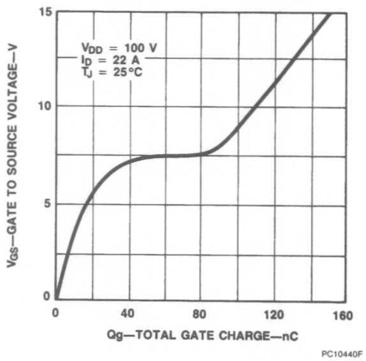


Figure 7 Forward Biased Safe Operating Area

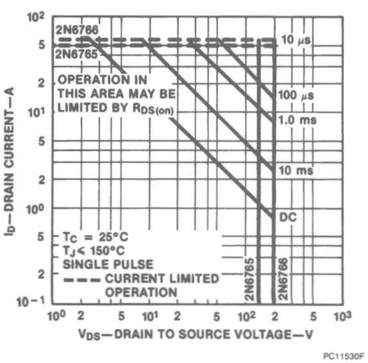
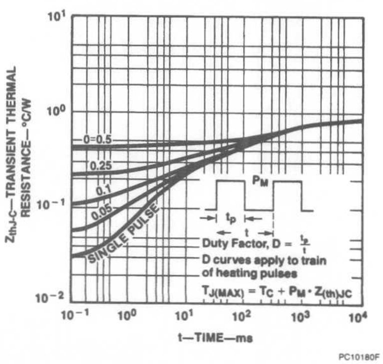


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

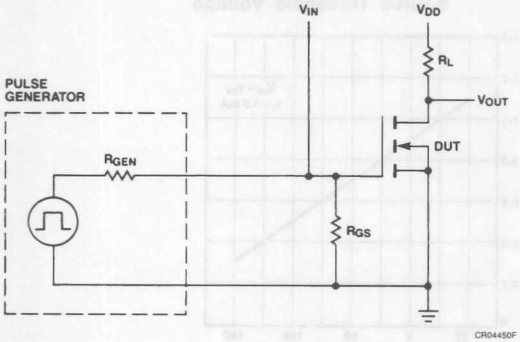
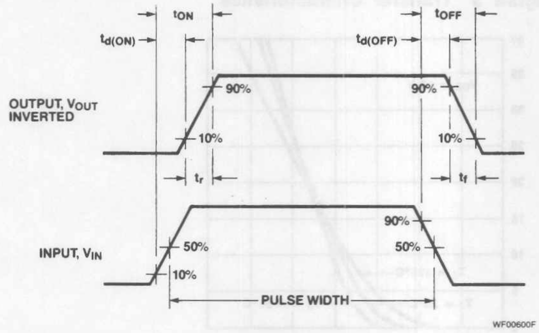


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

2N6767/2N6768 N-Channel Power MOSFETs, 15 A, 350 V/400 V

Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $R_{DS(on)}$ Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AA

2N6767
2N6768

Maximum Ratings

Symbol	Characteristic	Rating 2N6768	Rating 2N6767	Unit
V_{DSS}	Drain to Source Voltage	400	350	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1.0\ M\Omega$	400	350	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.3	0.4	Ω
I_D	Drain Current			A
	Continuous at $T_C = 25°C$	14	12	
	Continuous at $T_C = 100°C$	9.0	7.75	
I_{DM}	Pulsed	25^2	20^2	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation			W
	at $T_C = 25°C$	150	1.50	
	at $T_C = 100°C$	60	60	
	Linear Derating Factor	1.2	1.2	W/°C

Notes

All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 1.0 mA
	2N6768	400[2]			
	2N6767	350[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			4		V_{DS} = Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 1 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance			Ω	V_{GS} = 10 V
	2N6768		0.3		I_D = 9.0 A
	2N6767		0.4		I_D = 7.75 A
	2N6768		0.66		I_D = 9.0 A
	2N6767		0.88		I_D = 7.75 A
$V_{DS(on)}$	Drain-Source On-Voltage			V	V_{GS} = 10 V
	2N6768 2N6767		5.6 5.4		I_D = 14 A I_D = 12 A
g_{fs}	Forward Transconductance	8.0	24	S (℧)	V_{DS} = 15 V, I_D = 9.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance	1000	3000	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{dss}	Output Capacitance	200	600	pF	
C_{rss}	Reverse Transfer Capacitance	50	200	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	V_{DD} = 180 V, I_D = 9.0 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		65	ns	
$t_{d(off)}$	Turn-Off Delay Time		150	ns	
t_f	Fall Time		75	ns	
Q_g	Total Gate Charge		120[2]	nC	V_{GS} = 10 V, I_D = 16 A V_{DD} = 400 V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current 2N6768 2N6767			 14 12	A	
I_{SM}	Pulsed Source Current 2N6768 2N6767			 25[2] 20[2]	A	
V_{SD}	Diode Forward Voltage 2N6768	0.85		1.7	V	V_{GS} = 0 V I_S = 14 A
	2N6767	0.8		1.6		I_S = 12 A
t_{rr}	Reverse Recovery Time		1000[2]		ns	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/µs
Q_{RR}	Reverse Recovery Charge		25[2]		µC	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/µs

Notes
1. Pulse test: Pulse width ≤ 300 µs, Duty cycle ≤ 2%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

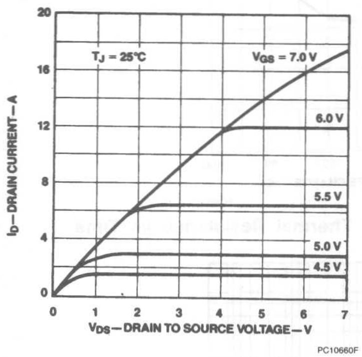
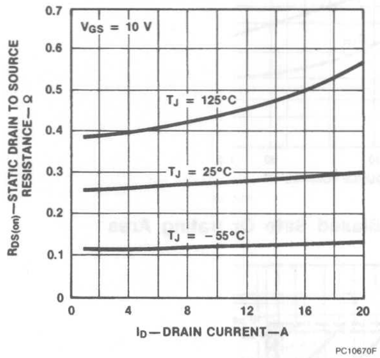


Figure 2 Static Drain to Source On Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

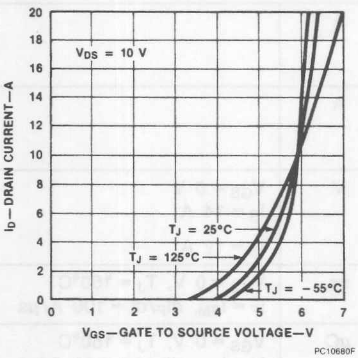


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

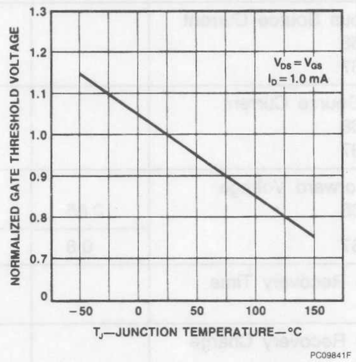


Figure 5 Capacitance vs Drain to Source Voltage

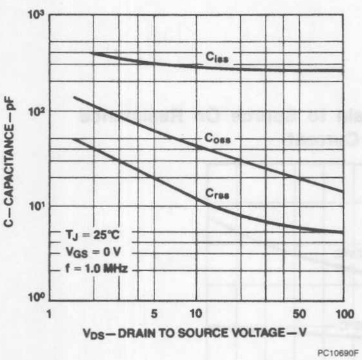


Figure 6 Gate to Source Voltage vs Total Gate Charge

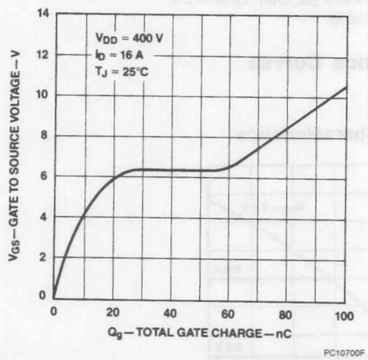


Figure 7 Forward Biased Safe Operating Area

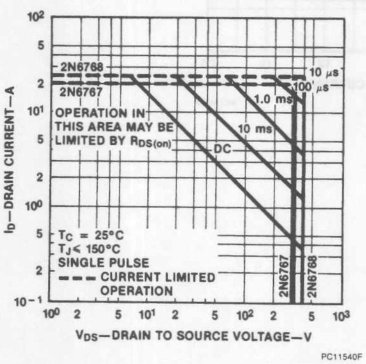
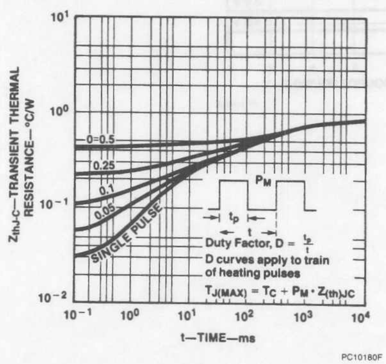


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

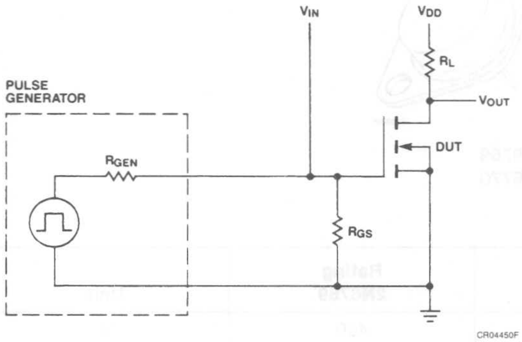
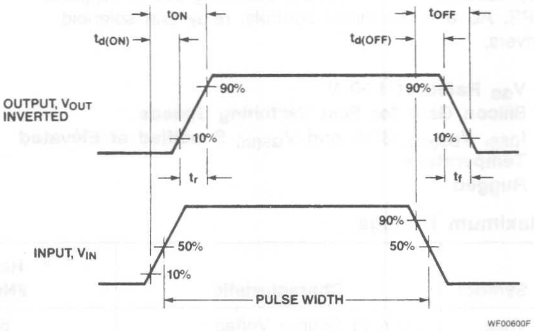


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

2N6769/2N6770 N-Channel Power MOSFETs, 12 A, 450 V/500 V

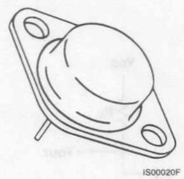
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

TO-204AA



2N6769
2N6770

Maximum Ratings

Symbol	Characteristic	Rating 2N6770	Rating 2N6769	Unit
V_{DSS}	Drain to Source Voltage	500	450	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1.0$ MΩ	500	450	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16″ From Case for 10 s	300	300	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.4	0.5	Ω
I_D	Drain Current			A
	Continuous at $T_C = 25°C$	12	11	
	Continuous at $T_C = 100°C$	4.75	7.0	
I_{DM}	Pulsed	25[2]	20[2]	
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation			W
	at $T_C = 25°C$	150	150	
	at $T_C = 100°C$	60	60	
	Linear Derating Factor	1.2	1.2	W/°C

Notes

All values are JEDEC registered except as noted. For information concerning connection diagram and package outline, refer to Section 7.

2

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0$ V, $I_D = 4$ mA
	2N6770	500[2]			
	2N6769	450[2]			
I_{DSS}	Zero Gate Voltage Drain Current		1	mA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			4		V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		± 100	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[1]			Ω	$V_{GS} = 10$ V
	2N6770		0.4		$I_D = 7.75$ A
	2N6769		0.5		$I_D = 7.0$ A
	2N6770		0.88		$I_D = 7.75$ A, $T_C = 125°C$
	2N6769		1.10		$I_D = 7.0$ A, $T_C = 125°C$
$V_{DS(on)}$	Drain-Source On-Voltage[1]			V	$V_{GS} = 10$ V
	2N6770		6.0		$I_D = 12$ A
	2N6769		6.0		$I_D = 11$ A
g_{fs}	Forward Transconductance	8.0	24	S (℧)	$V_{DS} = 15$ V, $I_D = 7.75$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance	1000	3000	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V, f = 1.0 MHz
C_{dss}	Output Capacitance	200	600	pF	
C_{rss}	Reverse Transfer Capacitance	50	200	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	$V_{DD} = 210$ V, $I_D = 7.75$ A, $V_{GS} = 10$ V, $R_{GEN} = 4.7$ Ω, $R_{GS} = 4.7$ Ω
t_r	Rise Time		50	ns	
$t_{d(off)}$	Turn-Off Delay Time		150	ns	
t_f	Fall Time		70	ns	
Q_g	Total Gate Charge		120[2]	nC	$V_{GS} = 10$ V, $I_D = 16$ A, $V_{DD} = 400$ V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics						
I_S	Continuous Source Current				A	
	2N6770			12[2]		
	2N6769			11[2]		
I_{SM}	Pulsed Source Current				A	
	2N6770			25[2]		
	2N6769			20[2]		
V_{SD}	Diode Forward Voltage				V	V_{GS} = 0 V
	2N6770	0.80		1.6		I_S = 12 A
	2N6769	0.75		1.5		I_S = 11 A
t_{rr}	Reverse Recovery Time		1300[2]		ns	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/µs
Q_{RR}	Reverse Recovery Charge		7.4[2]		µC	V_{GS} = 0 V, T_J = 150°C $I_F = I_{SM}$, dI_F/dt = 100 A/µs

Notes

1. Pulse test: Pulse width ⩽ 300 µs, Duty cycle ⩽ 1%
2. Non-JEDEC registered value.

Typical Performance Curves

Figure 1 Output Characteristics

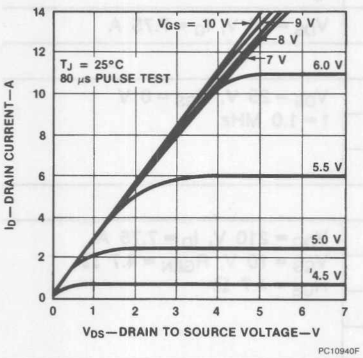
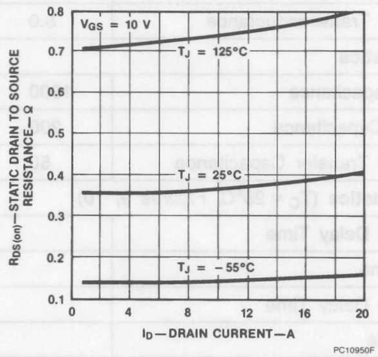


Figure 2 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 3 Transfer Characteristics

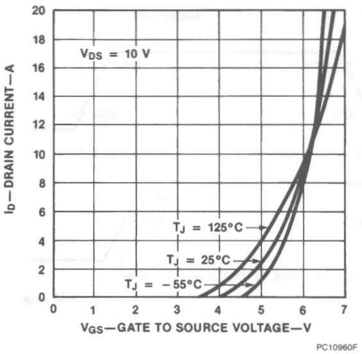


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

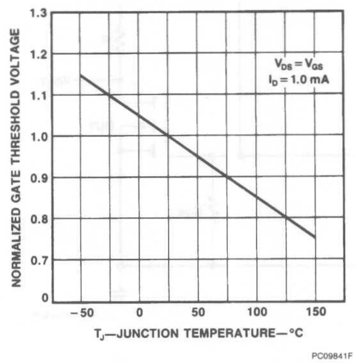


Figure 5 Capacitance vs Drain to Source Voltage

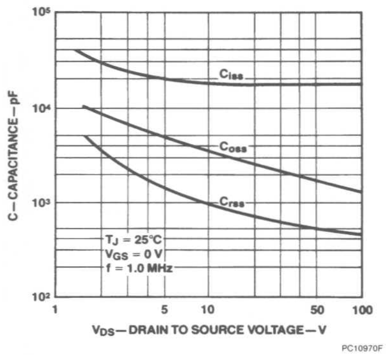


Figure 6 Gate to Source Voltage vs Total Gate Charge

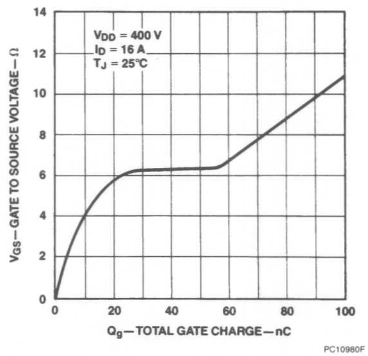


Figure 7 Forward Biased Safe Operating Area

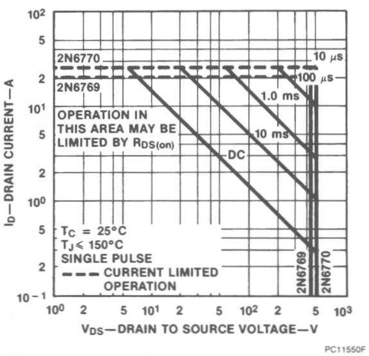
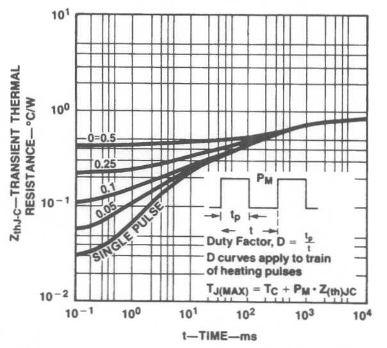


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

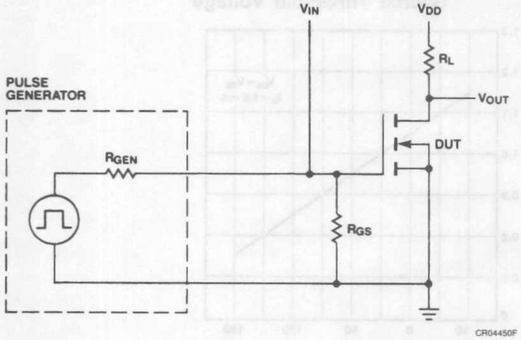
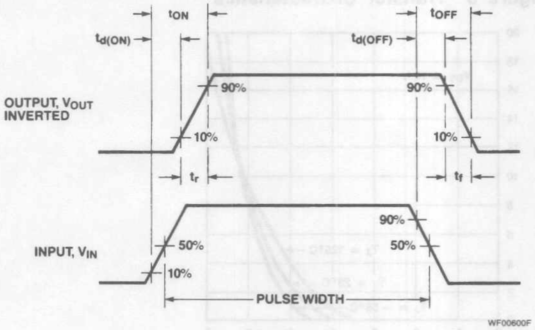


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

FMP20N05/FMP18N05 N-Channel Power MOSFETs, 18-20 A, 50 V

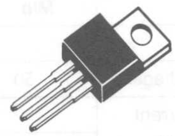
Power And Discrete Division

Description

These devices are very low $R_{DS(on)}$, 50 V, n-channel, enhancement mode, power MOSFETs especially designed to serve the low voltage, high speed, switching markets. Typical applications are SMPS for telecommunication and instrumentation, DC motor controls, emitter switching, synchronous rectification, and systems that are operated from low voltage batteries, such as automotive and portable equipment, etc.

- **Extremely low $R_{DS(on)}$**
- **V_{GS} Rated at ±30 V**
- **Silicon Gate for Fast Switching Speeds**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-220AB



IS00060F

FMP18N05
FMP20N05

Maximum Ratings

Symbol	Characteristic	Rating FMP20N05	Rating FMP18N05	Unit
V_{DSS}	Drain to Source Voltage[1]	50	50	V
V_{DGR}	Drain to Gate Voltage[1] R_{GS} = 20 kΩ	50	50	V
V_{GS}	Gate to Source Voltage	±30	±30	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	300	300	°C

Maximum On-State Characteristics

		FMP20N05	FMP18N05	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.085	0.10	Ω
I_D	Drain Current			A
	Continuous at T_C = 25°C	20	18	
	Continuous at T_C = 100°C	14	13	
	Pulsed	60	50	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	80	80	°C/W
P_D	Total Power Dissipation at T_C = 25°C	75	75	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]	50		V	V_{GS} = 0 V, I_D = 250 μA
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 500	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 10 A
	FMP20N05		0.085		
	FMP18N05		0.10		
$V_{DS(on)}$	Drain-Source On-Voltage[2] FMP20N05		2.0	V	V_{GS} = 10 V; I_D = 20 A;
	FMP18N05		2.25		
	FMP20N05 FMP18N05		1.40	V	V_{GS} = 10 V; I_D = 10 A; T_C = 100°C
g_{fs}	Forward Transconductance	5		S (℧)	V_{DS} = 10 V, I_D = 10 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		850	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		400	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		50	ns	V_{DD} = 40 V, I_D = 10 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		90	ns	
$t_{d(off)}$	Turn-Off Delay Time		60	ns	
t_f	Fall Time		75	ns	
Q_g	Total Gate Charge		20	nC	V_{GS} = 10 V, I_D = 25 A V_{DD} = 40 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage		1.5	V	I_S = 20 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	60		ns	I_S = 20 A; dI_S/dt = 50 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%

Typical Performance Curves

Figure 1 Output Characteristics

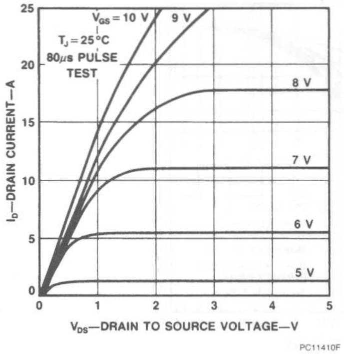


Figure 2 Static Drain to Source Resistance vs Drain Current

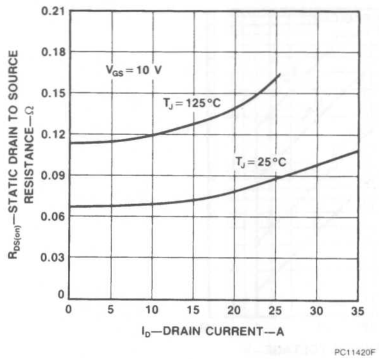


Figure 3 Transfer Characteristics

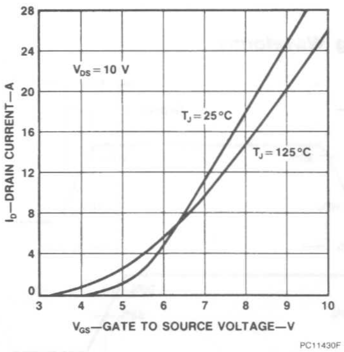


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

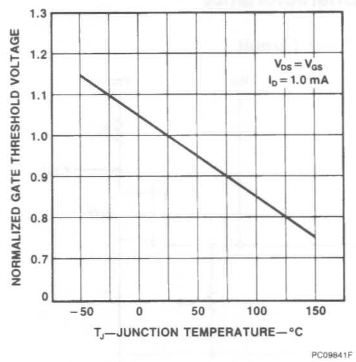


Figure 5 Capacitance vs Drain to Source Voltage

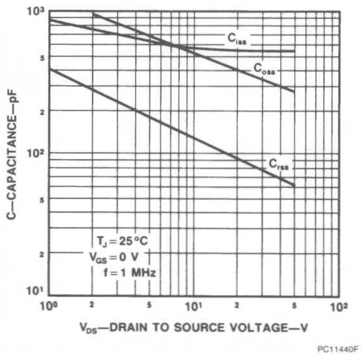
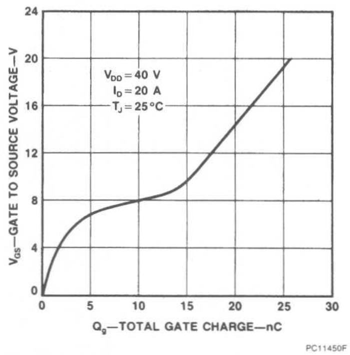


Figure 6 Gate to Source Voltage vs Total Gate Charge



Typical Performance Curves (Cont.)

Figure 7 Forward Biased Safe Operating Area

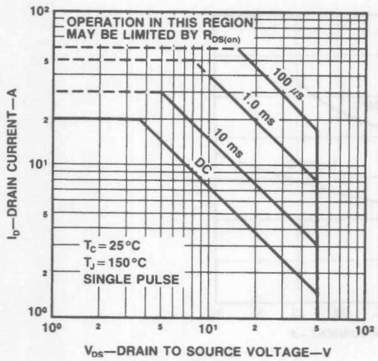
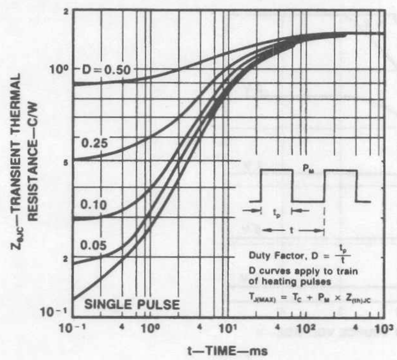


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

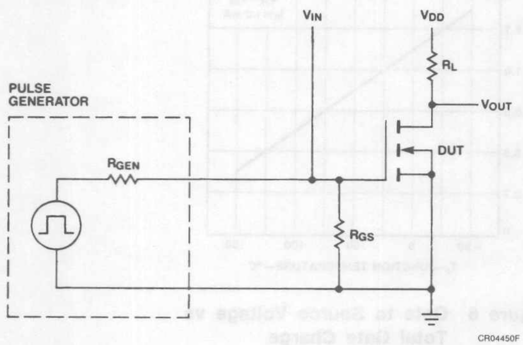
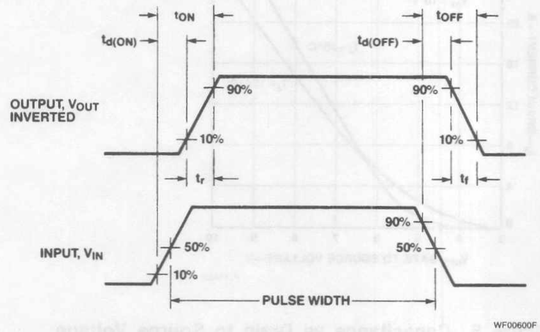


Figure 10 Switching Waveforms



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FRP800 Series Ultra-fast POWERplanar™ Rectifiers 8 A, 50-200 V

Power And Discrete Division

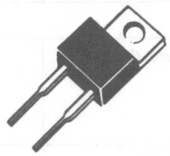
2

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Ultrafast 35 ns Recovery Time**
- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **150°C Operating Junction Temperature**
- **Popular TO-220AC Package**
- **Low V_{FM}**

TO-220AC



IS00030F

FRP805
FRP810
FRP815
FRP820

Maximum Ratings

Symbol	Rating	FRP805	FRP810	FRP815	FRP820	Unit
V_{RRM} V_{RSM} V_R	Peak Repetitive Reverse Voltage Non-repetitive Peak Reverse Voltage DC Blocking Voltage	50 50 50	100 100 100	150 150 150	180 200 180	V
$I_{F(AV)}$	Average Rectified Forward Current, $T_C = 130°C$, Rated V_R	8	8	8	8	A
I_{FRM}	Peak Repetitive Forward Current Rated V_R, 50% Duty Cycle, Square Wave, 20 kHz, $T_C = 130°C$	16	16	16	16	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Surge Applied at Rate Load Conditions Halfwave, Single Phase, 60 Hz	100	100	100	100	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	−55 to +150	°C
Maximum Thermal Characteristics						
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case	2.5	2.5	2.5	2.5	°C/W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	60	60	60	60	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Symbol	Rating	FRP805	FRP810	FRP815	FRP820	Unit
Electrical Characteristics						
V_{FM}[1]	Maximum Instantaneous Forward Voltage $I_F = 8.0$ A, $T_C = 150°C$ $I_F = 8.0$ A, $T_C = 25°C$	0.80 0.95	0.80 0.95	0.80 0.95	0.80 0.95	V
I_{RRM}[1]	Maximum Instantaneous Repetitive Reverse Current Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	5.0 10	5.0 10	5.0 10	5.0 10	mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 1.0$ A, $dI_F/dt = 50$ A/μs $I_F = 8$ A, $dI_F/dt = 100$ A/μs	35 50	35 50	35 50	35 50	ns
$I_{R(REC)}$[2]	Maximum Reverse Recovery Current $I_F = 8$ A, $dI_F/dt = 100$ A/μs, $V_R = V_{RRM}$	2.5	2.5	2.5	2.5	A

Notes
1. Pulse Test: Pulse Width = 300 μs. Duty Cycle ≤ 2.0%
2. See Figure 10 for test conditions.

Performance Curves

Figure 1 Maximum Forward Voltage Drop

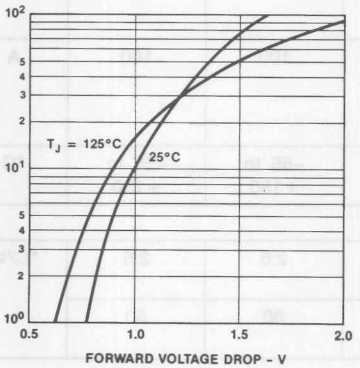
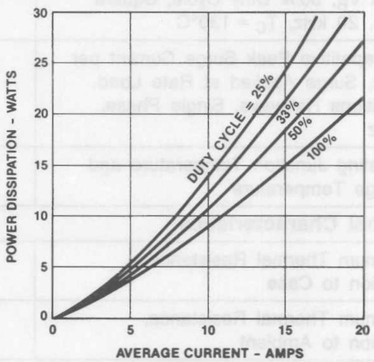


Figure 2 Maximum Power Dissipation



Performance Curves (Cont.)

Figure 3 Transient Thermal Resistance

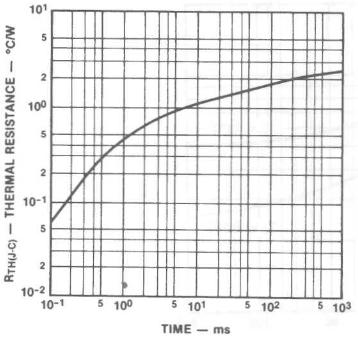


Figure 4 Typical Reverse Leakage Current

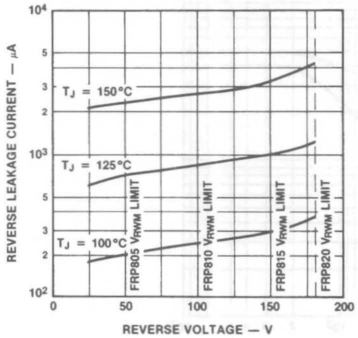


Figure 5 Power Derating

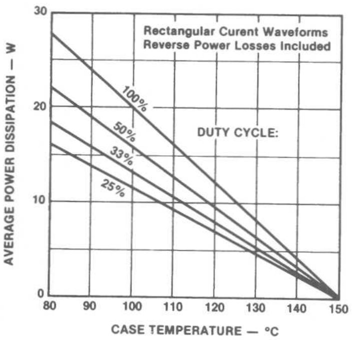


Figure 6 Reverse Recovery Charge

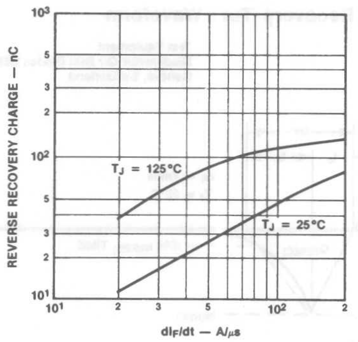
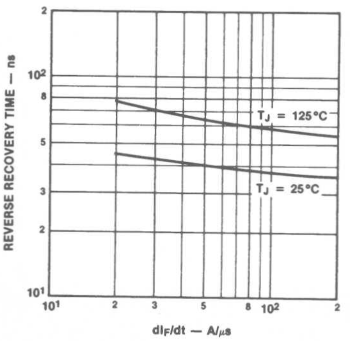


Figure 7 Reverse Recovery Time



Performance Curves (Cont.)

Figure 8 Reverse Recovery Current

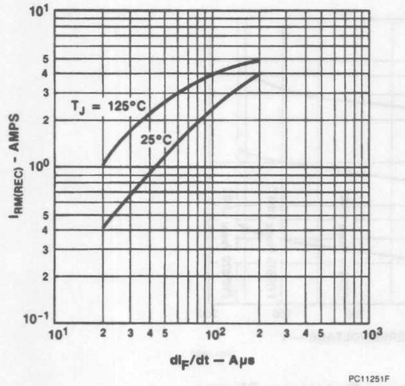


Figure 9 Reverse Recovery Softness

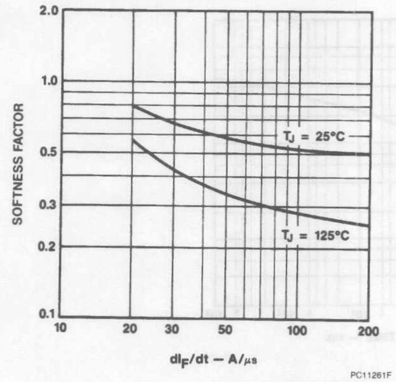
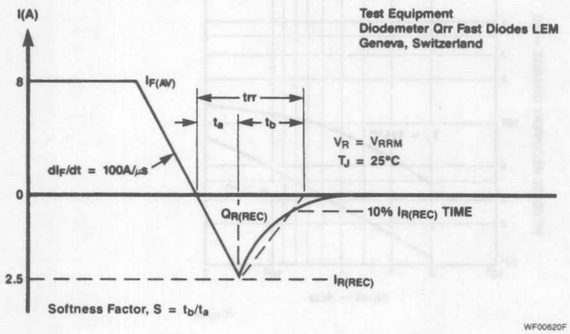


Figure 10 Reverse Recovery Test Waveform



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FRP1000/FRP2000CC Series Ultra-fast POWERplanar™ Rectifiers 10-20 A, 50-200 V

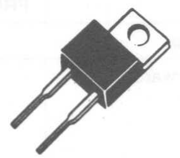
Power And Discrete Division

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Ultrafast 35 ns Reverse Recovery Time**
- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **Dual Rectifiers Matched to ±50 mV**
- **150°C Operating Junction Temperature**
- **Popular TO-220AC and TO-220AB Packages**
- **Low V_{FM}**

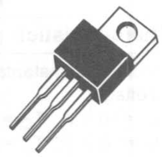
TO-220AC



IS00030F

FRP1005
FRP1010
FRP1015
FRP1020

TO-220AB



IS00010F

FRP2005CC
FRP2010CC
FRP2015CC
FRP2020CC

Maximum Ratings

Symbol	Rating	FRP1005 FRP2005CC	FRP1010 FRP2010CC	FRP1015 FRP2015CC	FRP1020 FRP2020CC	Unit
V_{RRM} V_{RSM} V_R	Peak Repetitive Reverse Voltage Non-repetitive Peak Reverse Voltage DC Blocking Voltage	50 50 50	100 100 100	150 150 150	180 200 180	V
$I_{F(AV)}$	Average Rectified Forward Current, $T_C = 117°C$, Rated V_R; FRP1000 Series FRP2000CC Series	 10 20	 10 20	 10 20	 10 20	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Halfwave, 60 Hz	150	150	150	150	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	−55 to +150	°C
Maximum Thermal Characteristics						
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case FRP1000 Series FRP2000CC Series	 2.5 1.5	 2.5 1.5	 2.5 1.5	 2.5 1.5	°C/W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	60	60	60	60	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Symbol	Rating	FRP1005 FRP2005CC	FRP1010 FRP2010CC	FRP1015 FRP2015CC	FRP1020 FRP2020CC	Unit
Electrical Characteristics per Diode						
V_{FM}[1]	Maximum Instantaneous Forward Voltage $I_F = 10.0$ A, $T_C = 150°C$ $I_F = 10.0$ A, $T_C = 25°C$	0.91 1.0	0.91 1.0	0.91 1.0	0.91 1.0	V
I_{RRM}[1]	Maximum Instantaneous Repetitive Reverse Current Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	5.0 5	5.0 5	5.0 5	5.0 5	mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 1.0$ A, $dI_F/dt = 50$ A/μs $I_F = 10$ A, $dI_F/dt = 100$ A/μs	35 50	35 50	35 50	35 50	ns
$I_{R(REC)}$[2]	Maximum Reverse Recovery Current $I_F = 10$ A, $dI_F/dt = 100$ A/μs, V_{RRM}	2.5	2.5	2.5	2.5	A

Notes
1. Pulse Test: Pulse Width = 300 μs. Duty Cycle ⩽ 2.0%
2. See Figure 11 for test conditions.

Performance Curves per Diode

Figure 1 Maximum Forward Voltage Drop

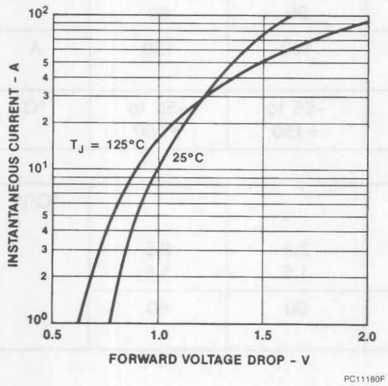
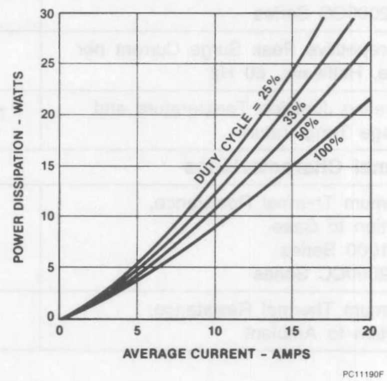


Figure 2 Maximum Power Dissipation



Performance Curves per Diode (Cont.)

Figure 3 Transient Thermal Resistance

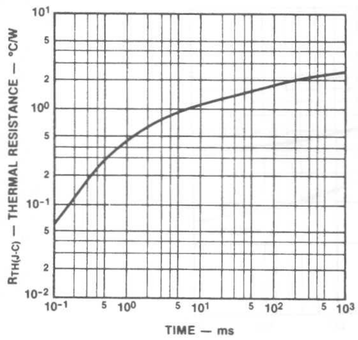


Figure 4 Typical Reverse Leakage Current

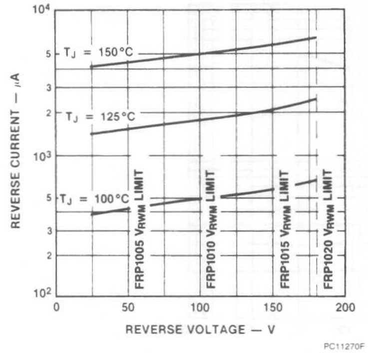


Figure 5 Typical Reverse Leakage Current

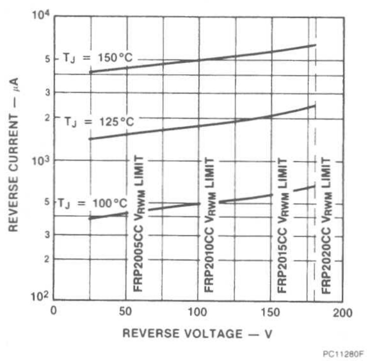


Figure 6 Power Derating

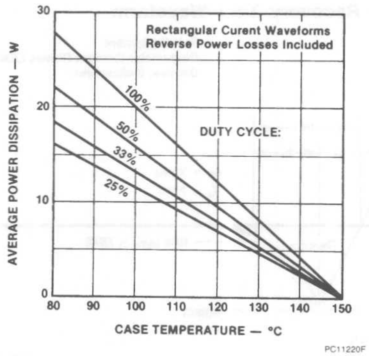


Figure 7 Reverse Recovery Charge

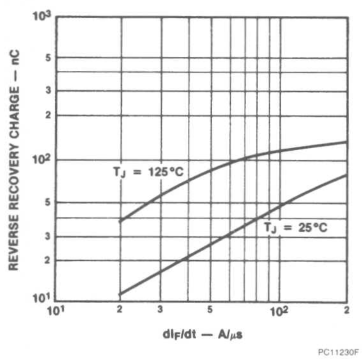
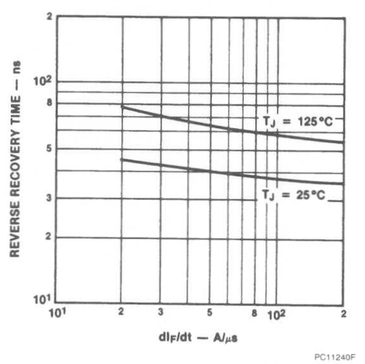


Figure 8 Reverse Recovery Time



Performance Curves per Diode (Cont.)

Figure 9 Reverse Recovery Current

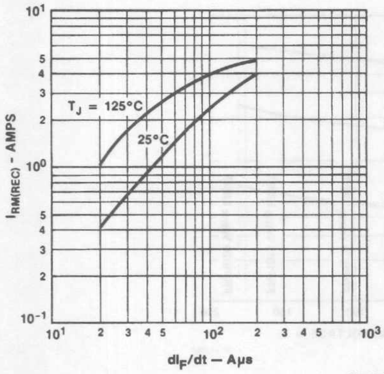


Figure 10 Reverse Recovery Softness

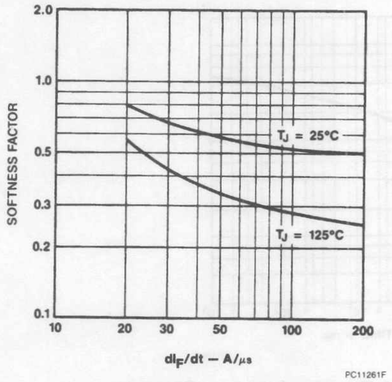
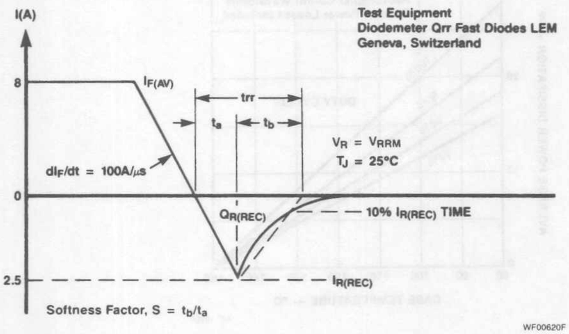


Figure 11 Reverse Recovery Test Waveform



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FRP1600 Series Ultra-fast POWERplanar™ Rectifiers 16 A, 50-200 V

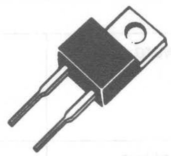
Power And Discrete Division

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Ultrafast 35 ns Reverse Recovery Time**
- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **150°C Operating Junction Temperature**
- **Popular TO-220AC Package**
- **Low V_{FM}**

TO-220AC



FRP1605
FRP1610
FRP1615
FRP1620

Maximum Ratings

Symbol	Rating	FRP1605	FRP1610	FRP1615	FRP1620	Unit
V_{RRM} V_{RSM} V_R	Peak Repetitive Reverse Voltage Non-repetitive Peak Reverse Voltage DC Blocking Voltage	50 50 50	100 100 100	150 150 150	180 200 180	V
$I_{F(AV)}$	Average Rectified Forward Current, Rated V_R, Square Wave, 20 kHz FRP1605/FRP1620: $T_C = 118°C$	16	16	16	16	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Surge Applied at Rate Load Conditions Halfwave, Single Phase, 60 Hz	200	200	200	200	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	−55 to +150	°C

Maximum Thermal Characteristics

Symbol	Rating	FRP1605	FRP1610	FRP1615	FRP1620	Unit
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case FRP1605/FRP1620	1.5	1.5	1.5	1.5	°C/W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	60	60	60	60	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Symbol	Rating	FRP1605	FRP1610	FRP1615	FRP1620	Unit
Electrical Characteristics						
V_{FM}[1]	Maximum Instantaneous Forward Voltage $I_F = 16$ A, $T_C = 150°C$ $I_F = 16$ A, $T_C = 25°C$	 0.80 0.95	 0.80 0.95	 0.80 0.95	 0.80 0.95	 V
I_{RRM}[1]	Maximum Instantaneous Repetitive Reverse Current Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	 10 25	 10 25	 10 25	 10 25	 mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 1.0$ A, $dI_F/dt = 50$ A/μs $I_F = 16$ A, $dI_F/dt = 100$ A/μs	 35 50	 35 50	 35 50	 35 50	 ns
$I_{R(REC)}$[2]	Maximum Reverse Recovery Current $I_F = 8$ A, $dI_F/dt = 100$ A/μs, $V_R = V_{RRM}$	2.5	2.5	2.5	2.5	A

Notes
1. Pulse Test: Pulse Width = 300 μs. Duty Cycle ≤ 2.0%
2. See Figure 10 for test conditions.

Performance Curves

Figure 1 Maximum Forward Voltage Drop

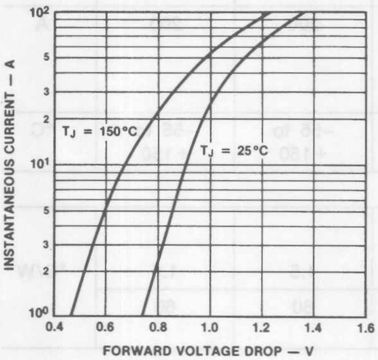
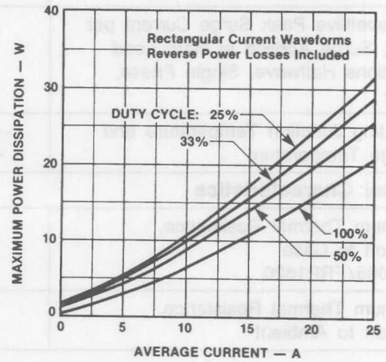


Figure 2 Maximum Power Dissipation



Performance Curves (Cont.)

Figure 3 Transient Thermal Resistance

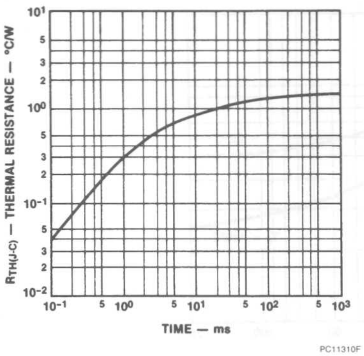


Figure 4 Typical Reverse Leakage Current

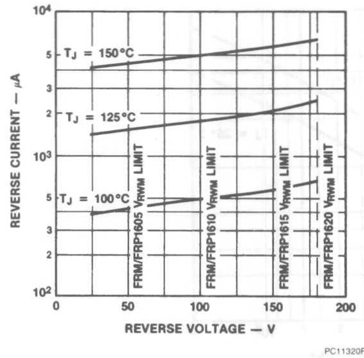


Figure 5 Power Derating

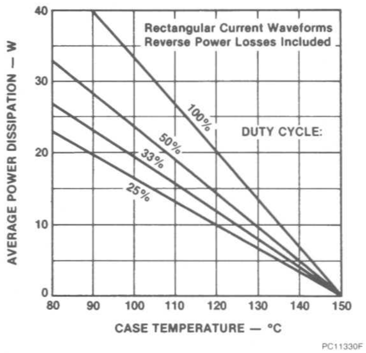


Figure 6 Reverse Recovery Charge

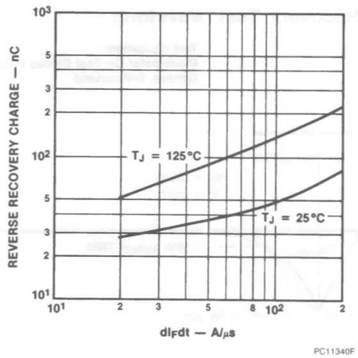
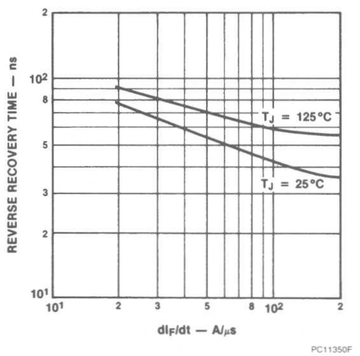


Figure 7 Reverse Recovery Time



Performance Curves (Cont.)

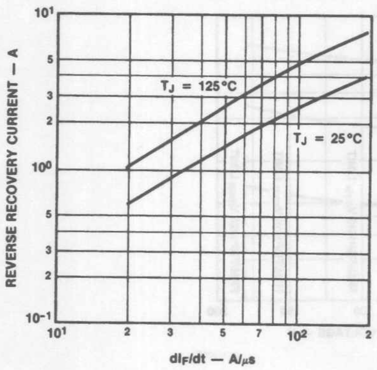


Figure 8 Reverse Recovery Current

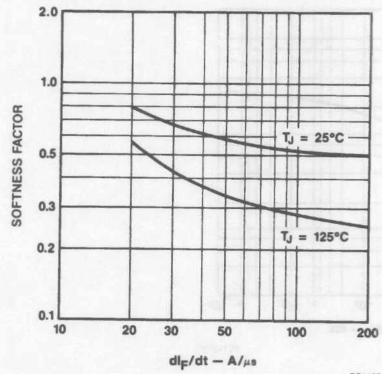


Figure 9 Reverse Recovery Softness

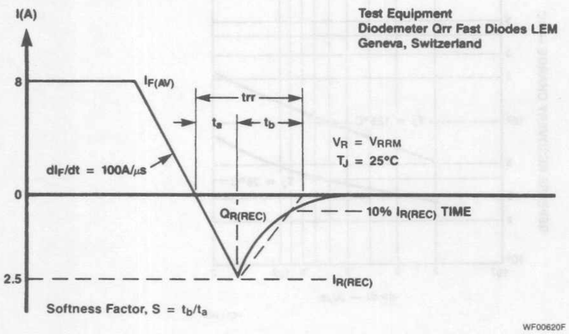


Figure 10 Reverse Recovery Test Waveform

FAIRCHILD

A Schlumberger Company

FRP1600CC Series Ultra-fast POWERplanar™ Rectifiers 16 A, 50-200 V

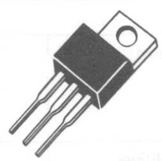
Power And Discrete Division

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Ultrafast 35 ns Reverse Recovery Time**
- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **150°C Operating Junction Temperature**
- **Popular TO-220 Package**
- **Low V_{FM}**

TO-220AB



FRP1605CC
FRP1610CC
FRP1615CC
FRP1620CC

2

Maximum Ratings

Symbol	Rating	FRP1605CC	FRP1610CC	FRP1615CC	FRP1620CC	Unit
V_{RRM} V_{RSM} V_R	Peak Repetitive Reverse Voltage Non-repetitive Peak Reverse Voltage DC Blocking Voltage	50 50 50	100 100 100	150 150 150	180 200 180	V
$I_{F(AV)}$	Average Rectified Forward Current, $T_C = 130°C$, Rated V_R	16	16	16	16	A
I_{FRM}	Peak Repetitive Forward Current Rated V_R, 50% Duty Cycle, Square Wave, 20 kHz, $T_C = 130°C$	32	32	32	32	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Surge Applied at Rate Load Conditions Halfwave, Single Phase, 60 Hz	100	100	100	100	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	−55 to +150	°C
Maximum Thermal Characteristics						
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case	2.5	2.5	2.5	2.5	°C/W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	60	60	60	60	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Symbol	Rating	FRP1605CC	FRP1610CC	FRP1615CC	FRP1620CC	Unit
Electrical Characteristics per Diode						
V_{FM}[1]	Maximum Instantaneous Forward Voltage $I_F = 8.0$ A, $T_C = 150°C$ $I_F = 8.0$ A, $T_C = 25°C$	 0.80 0.95	 0.80 0.95	 0.80 0.95	 0.80 0.95	 V
I_{RRM}[1]	Maximum Instantaneous Repetitive Reverse Current Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	 5.0 10	 5.0 10	 5.0 10	 5.0 10	 mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 1.0$ A, $dI_F/dt = 50$ A/μs $I_F = 8$ A, $dI_F/dt = 100$ A/μs	 35 50	 35 50	 35 50	 35 50	 ns
$I_{R(REC)}$[2]	Maximum Reverse Recovery Current $I_F = 8$ A, $dI_F/dt = 100$ A/μs, $V_R = V_{RRM}$	2.5	2.5	2.5	2.5	A

Notes
1. Pulse Test: Pulse Width = 300 μs. Duty Cycle ⩽ 2.0%
2. See Figure 10 for test conditions.

Performance Curves per Diode

Figure 1 Maximum Forward Voltage Drop

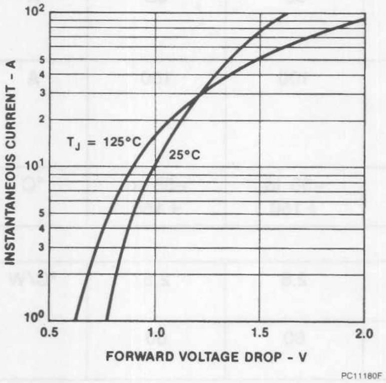
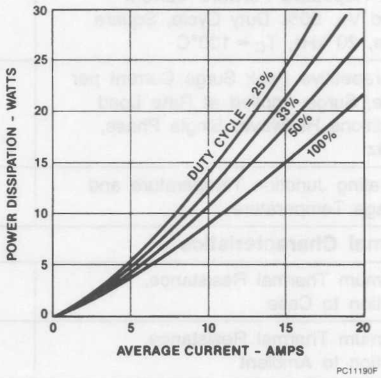


Figure 2 Maximum Power Dissipation



Performance Curves per Diode (Cont.)

Figure 3 Transient Thermal Resistance

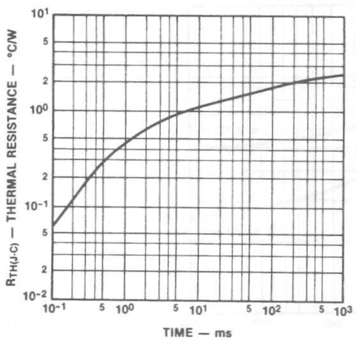


Figure 4 Typical Reverse Leakage Current

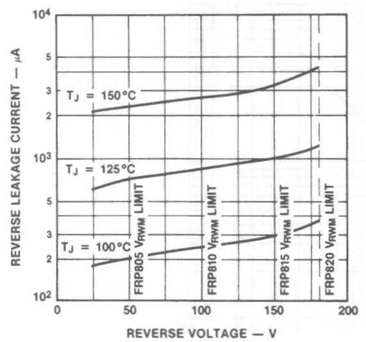


Figure 5 Power Derating

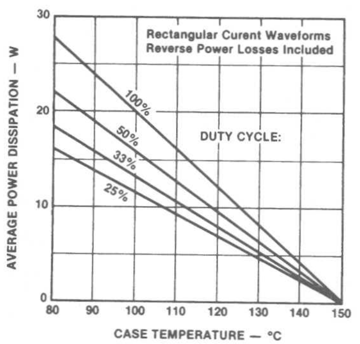


Figure 6 Reverse Recovery Charge

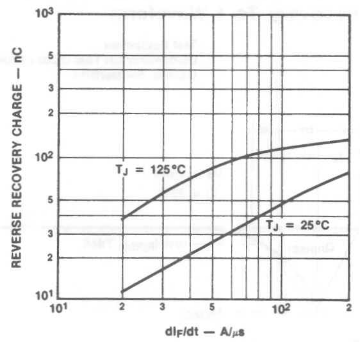
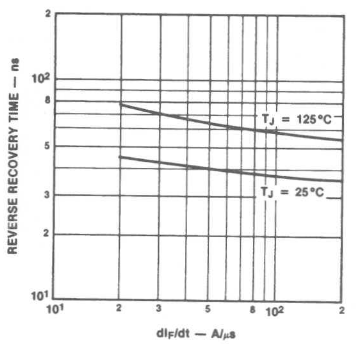


Figure 7 Reverse Recovery Time



Performance Curves per Diode (Cont.)

Figure 8 Reverse Recovery Current

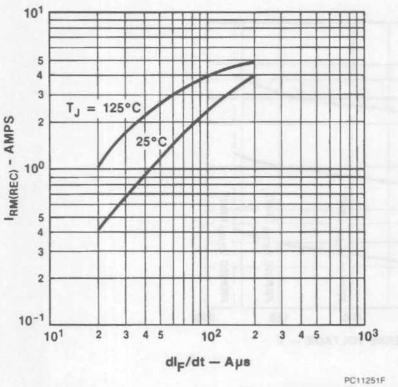


Figure 9 Reverse Recovery Softness

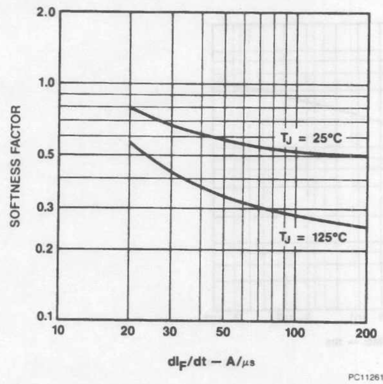
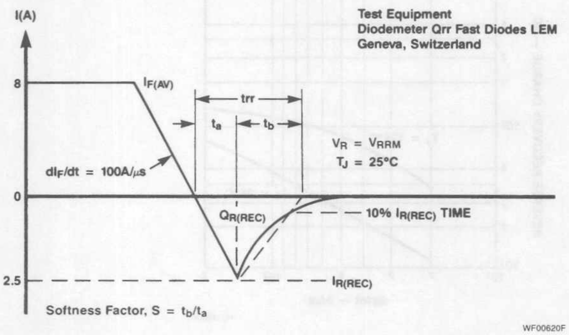


Figure 10 Reverse Recovery Test Waveform



FAIRCHILD

A Schlumberger Company

FRM3200CC Series Ultra-fast POWERplanar™ Rectifiers 32 A, 50-200 V

Power And Discrete Division

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Ultrafast 35 ns Reverse Recovery Time**
- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **150°C Operating Junction Temperature**
- **Popular TO-204AA Package (Formerly TO-3)**
- **Low V_{FM}**

TO-204AA

IS00020F

FRM3205CC
FRM3210CC
FRM3215CC
FRM3220CC

Maximum Ratings

Symbol	Rating	FRM3205CC	FRM3210CC	FRM3215CC	FRM3220CC	Unit
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	150	180	V
V_{RSM}	Non-repetitive Peak Reverse Voltage	50	100	150	200	
V_R	DC Blocking Voltage	50	100	150	180	
$I_{F(AV)}$	Average Rectified Forward Current, T_C = 107°C, Rated V_R	32	32	32	32	A
I_{FRM}	Peak Repetitive Forward Current Rated V_R, Square Wave, 50 kHz, T_C = 107°C	64	64	64	64	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Surge Applied at Rate Load Conditions Halfwave, Single Phase, 60 Hz	200	200	200	200	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	−55 to +150	°C

Maximum Thermal Characteristics

Symbol	Rating	FRM3205CC	FRM3210CC	FRM3215CC	FRM3220CC	Unit
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case	1.0	1.0	1.0	1.0	°C/W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	60	60	60	60	

Notes

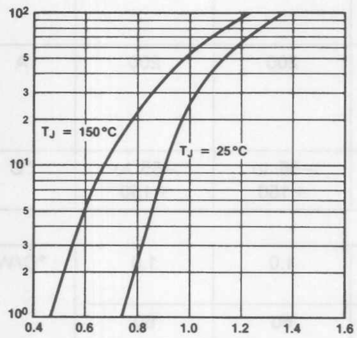
For information concerning connection diagram and package outline, refer to Section 7.

Symbol	Rating	FRM3205CC	FRM3210CC	FRM3215CC	FRM3220CC	Unit
Electrical Characteristics per Diode						
V_{FM}[1]	Maximum Instantaneous Forward Voltage per Diode $I_F = 16$ A, $T_C = 150°C$ $I_F = 16$ A, $T_C = 25°C$	0.80 0.95	0.80 0.95	0.80 0.95	0.80 0.95	V
I_{RRM}[1]	Maximum Instantaneous Reverse Current per Diode Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	10 25	10 25	10 25	10 25	mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 1.0$ A, $dI_F/dt = 50$ A/μs $I_F = 16$ A, $dI_F/dt = 100$ A/μs	35 50	35 50	35 50	35 50	ns
$I_{R(REC)}$[2]	Maximum Reverse Recovery Current $I_F = 16$ A, $dI_F/dt = 100$ A/μs, $V_R = V_{RRM}$	2.5	2.5	2.5	2.5	A

Notes
1. Pulse Test: Pulse Width = 300 μs. Duty Cycle ≤ 2.0%
2. See Figure 10 for test conditions.

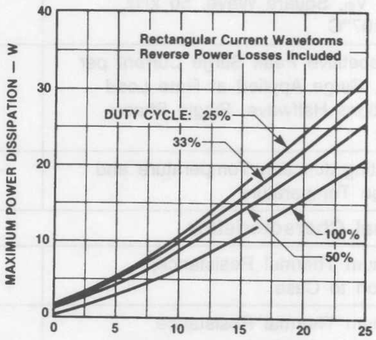
Performance Curves per Diode

Figure 1 Maximum Forward Voltage Drop



PC11290F

Figure 2 Maximum Power Dissipation



PC11300F

Performance Curves per Diode (Cont.)

Figure 3 Transient Thermal Resistance

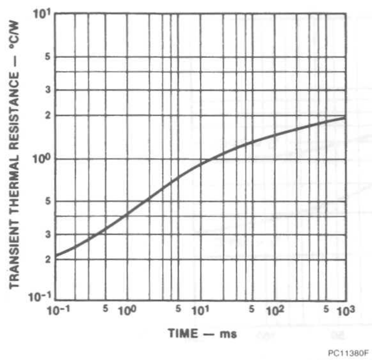


Figure 4 Typical Reverse Leakage Current

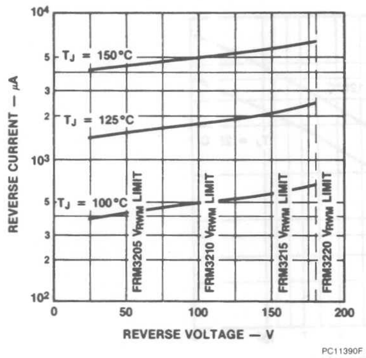


Figure 5 Average Power Derating

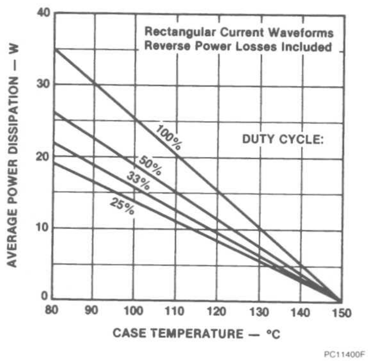


Figure 6 Reverse Recovery Charge

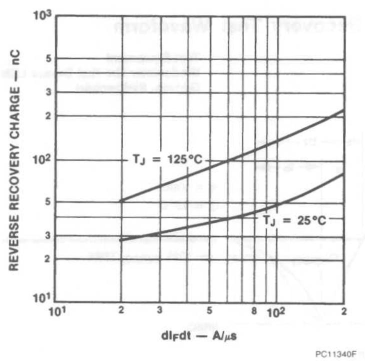
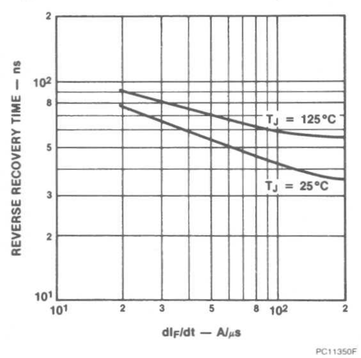


Figure 7 Reverse Recovery Time



Performance Curves per Diode (Cont.)

Figure 8 Reverse Recovery Current

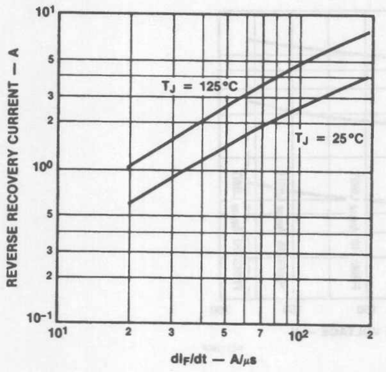


Figure 9 Reverse Recovery Softness

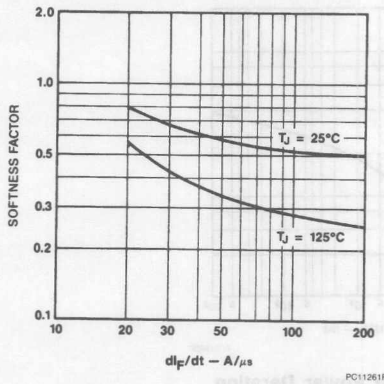
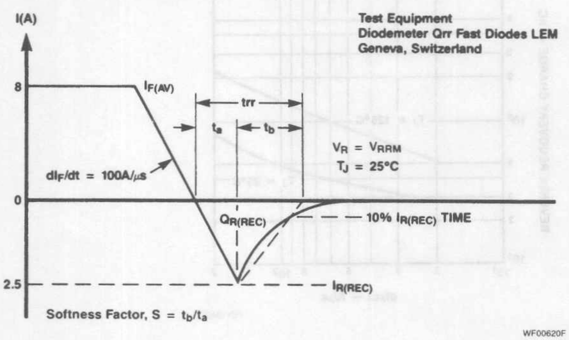


Figure 10 Reverse Recovery Test Waveform



FAIRCHILD

A Schlumberger Company

IRF120-123/IRF520-523 MTP10N08/10N10 N-Channel Power MOSFETs, 11 A, 60-100 V

Power And Discrete Division

Description

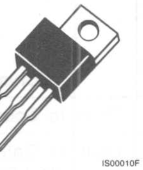
These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AA

IRF120
IRF121
IRF122
IRF123

TO-220AB



IRF520
IRF521
IRF522
IRF523
MTP10N08
MTP10N10

Product Summary

Part Number	V_{DSS}	$R_{DS(on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF120	100 V	0.30 Ω	8.0 A	5.0 A	TO-204AA
IRF121	60 V	0.30 Ω	8.0 A	5.0 A	
IRF122	100 V	0.40 Ω	7.0 A	4.0 A	
IRF123	60 V	0.40 Ω	7.0 A	4.0 A	
IRF520	100 V	0.30 Ω	8.0 A	5.0 A	TO-220AB
IRF521	60 V	0.30 Ω	8.0 A	5.0 A	
IRF522	100 V	0.40 Ω	7.0 A	4.0 A	
IRF523	60 V	0.40 Ω	7.0 A	4.0 A	
MTP10N08	80 V	0.33 Ω	10 A	6.4 A	
MTP10N10	100 V	0.33 Ω	10 A	6.4 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Maximum Ratings

Symbol	Characteristic	Rating IRF120/122 IRF520/522 MTP10N10	Rating MTP10N08	Rating IRF122/123 IRF522/523	Unit
V_{DSS}	Drain to Source Voltage[1]	100	80	60	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	100	80	60	V
V_{GS}	Gate to Source Voltage	± 20	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	275	°C

Maximum Thermal Characteristics

		IRF120-123/IRF520-523	MTP10N08/10	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	3.12	1.67	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	30/80	80	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	40	75	W
I_{DM}	Pulsed Drain Current[2]	20	32	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF120/122/520/522/ MTP10N10	100			
	MTP10N08	80			
	IRF121/123/521/523	60			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current			nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF120-123		± 100		
	IRF520-523/MTP10N08/10		± 500		

2

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF120-123/IRF520-523	2.0	4.0		$I_D = 250\ \mu A$, $V_{DS} = V_{GS}$
	MTP10N08/10N10	2.0	4.5		$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V
	IRF120/121/520/521		0.30		$I_D = 4.0$ A
	MTP10N08/10N10		0.33		$I_D = 5.0$ A
	IRF122/123/522/523		0.40		$I_D = 4.0$ A
$V_{DS(on)}$	Drain-Source On-Voltage[2] MTP 10N08/10N10		4.0	V	$V_{GS} = 10$ V; $I_D = 10.0$ A
			3.3	V	$V_{GS} = 10$ V, $I_D = 5.0$ A $T_C = 100°C$
g_{fs}	Forward Transconductance	1.5		S (℧)	$V_{DS} = 10$ V, $I_D = 4.0$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		600	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{oss}	Output Capacitance		400	pF	
C_{rss}	Reverse Transfer Capacitance		100	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 1, 2*)[3]					
$t_{d(on)}$	Turn-On Delay Time		40	ns	$V_{DD} = 50$ V, $I_D = 4.0$ A $V_{GS} = 10$ V, $R_{GEN} = 50\ \Omega$ $R_{GS} = 50\ \Omega$
t_r	Rise Time		70	ns	
$t_{d(off)}$	Turn-Off Delay Time		100	ns	
t_f	Fall Time		70	ns	
Q_g	Total Gate Charge		15	nC	$V_{GS} = 10$ V, $I_D = 10$ A $V_{DD} = 50$ V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF120/121/520/521		2.5	V	$I_S = 8.0$ A; $V_{GS} = 0$ V
	IRF122/123/522/523		2.3	V	$I_S = 7.0$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time	280		ns	$I_S = 4.0$ A; $dI_S/dt = 25\ A/\mu S$

Notes
1. $T_J = +25°C$ to $+150°C$
2. Pulse width limited by T_J
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

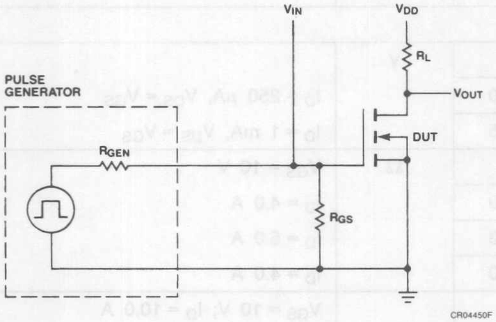
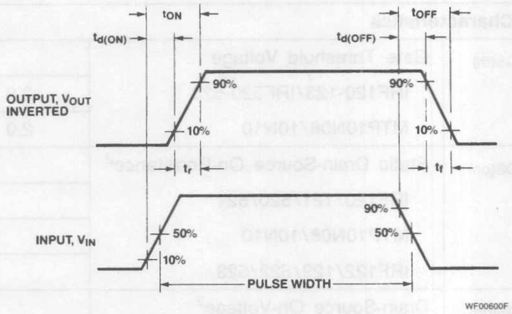


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

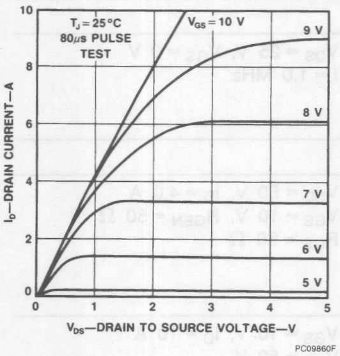


Figure 4 Static Drain to Source Resistance vs Drain Current

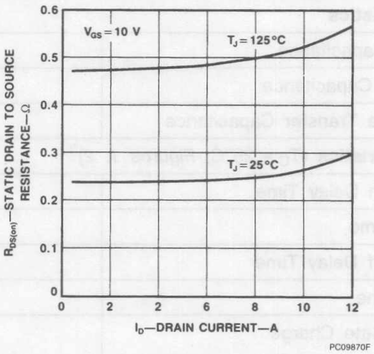


Figure 5 Transfer Characteristics

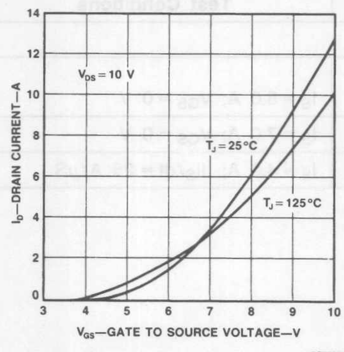
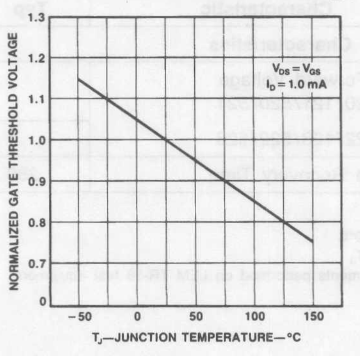
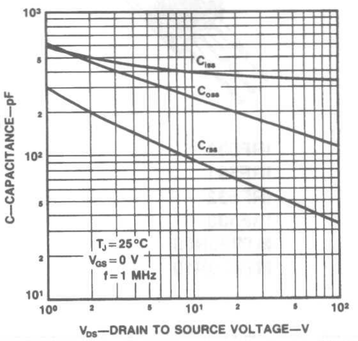


Figure 6 Temperature Variation of Gate to Source Threshold Voltage



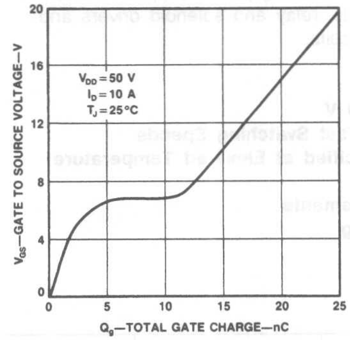
Typical Performance Curves (Cont.)

Figure 7 Capacitance vs Drain to Source Voltage



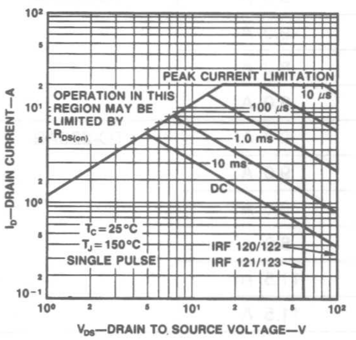
PC09900F

Figure 8 Gate to Source Voltage vs Total Gate Charge



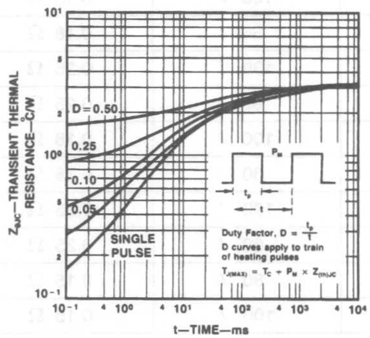
PC09910F

Figure 9 Forward Biased Safe Operating Area for IRF120-123 And IRF520-523



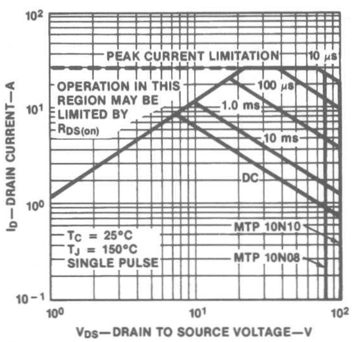
PC09920F

Figure 10 Transient Thermal Resistance vs Time for IRF120-123 And IRF520-523



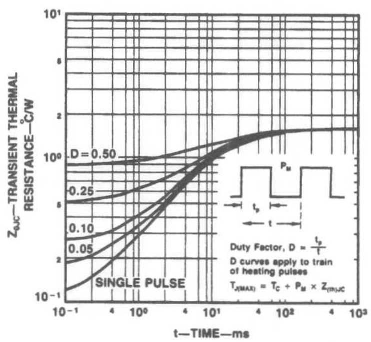
PC09931F

Figure 11 Forward Biased Safe Operating Area for MTP10N08/10N10



PC09941F

Figure 12 Transient Thermal Resistance vs Time for MTP10N08/10N10



PC09951F

FAIRCHILD

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IRF130-133/IRF530-533 MTP20N08/20N10 N-Channel Power MOSFETs, 20 A, 60-100 V

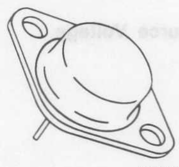
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

- Low $R_{DS(on)}$
- V_{GS} Rated at ±20 V
- Silicon Gate for Fast Switching Speeds
- I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature
- Rugged
- Low Drive Requirements
- Ease of Paralleling

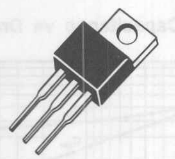
TO-204AA



IS00020F

IRF130
IRF131
IRF132
IRF133

TO-220AB



IS00010F

IRF530
IRF531
IRF532
IRF533
MTP20N08
MTP20N10

Product Summary

Part Number	V_{DSS}	$R_{DS(on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF130	100 V	0.18 Ω	14 A	9.0 A	TO-204AA
IRF131	60 V	0.18 Ω	14 A	9.0 A	
IRF132	100 V	0.25 Ω	12 A	8.0 A	
IRF133	60 V	0.25 Ω	12 A	8.0 A	
IRF530	100 V	0.18 Ω	14 A	9.0 A	TO-220AB
IRF531	60 V	0.18 Ω	14 A	9.0 A	
IRF532	100 V	0.25 Ω	12 A	8.0 A	
IRF533	60 V	0.25 Ω	12 A	8.0 A	
MTP20N08	80 V	0.15 Ω	20 A	11.5 A	
MTP20N10	100 V	0.15 Ω	20 A	11.5 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

2

Maximum Ratings

Symbol	Characteristic	Rating IRF130/132 IRF530/532 MTP20N10	Rating MTP20N08	Rating IRF131/133 IRF531/533	Unit
V_{DSS}	Drain to Source Voltage[1]	100	80	60	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	100	80	60	V
V_{GS}	Gate to Source Voltage	±20	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	275	°C

Maximum Thermal Characteristics

		IRF130-133 IRF530-533	MTP20N08/10	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.25	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	75	100	W
I_{DM}	Pulsed Drain Current[2]	60	60	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF130/132/530/532/ MTP20N10	100			
	MTP20N08	80			
	IRF131/133/531/533	60			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current			nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF130-133		±100		
	IRF530-533/ MTP20N08/MTP20N10		±500		

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF130/133/530/533	2.0	4.0		$I_D = 250\ \mu A$, $V_{DS} = V_{GS}$
	MTP20N08/20N10	2.0	4.5		$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 8.0$ A
	IRF130/131/530/531		0.18		
	IRF132/133/532/533		0.25		
	MTP20N08/20N10		0.15		$I_D = 10$ A
$V_{DS(on)}$	Drain-Source On-Voltage[2]		1.5	V	$V_{GS} = 10$ V; $I_D = 10$ A
	MTP 20N08/20N10		3.6	V	$V_{GS} = 10$ V; $I_D = 20$ A
			3.0	V	$V_{GS} = 10$ V, $I_D = 10$ A $T_C = 100°C$
g_{fs}	Forward Transconductance	4.0		S (℧)	$V_{DS} = 10$ V, $I_D = 8.0$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		800	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{oss}	Output Capacitance		500	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 1, 2*)[3]					
$t_{d(on)}$	Turn-On Delay Time		30	ns	$V_{DD} = 36$ V, $I_D = 8.0$ A $V_{GS} = 10$ V, $R_{GEN} = 15\ \Omega$ $R_{GS} = 15\ \Omega$
t_r	Rise Time		75	ns	
$t_{d(off)}$	Turn-Off Delay Time		40	ns	
t_f	Fall Time		45	ns	
$t_{d(on)}$	Turn-On Delay Time		50	ns	$V_{DD} = 25$ V, $I_D = 10$ A $V_{GS} = 10$ V, $R_{GEN} = 50\ \Omega$ $R_{GS} = 50\ \Omega$
t_r	Rise Time		450	ns	
$t_{d(off)}$	Turn-Off Delay Time		100	ns	
t_f	Fall Time		200	ns	
Q_g	Total Gate Charge		30	nC	$V_{GS} = 10$ V, $I_D = 18$ A $V_{DD} = 80$ V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF130/131/530/531	1.5	2.5	V	I_S = 14 A; V_{GS} = 0 V
	IRF132/133/532/533	1.5	2.3	V	I_S = 12 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	300		ns	I_S = 4 A; dI_S/dt = 25 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse width limited by T_J.
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

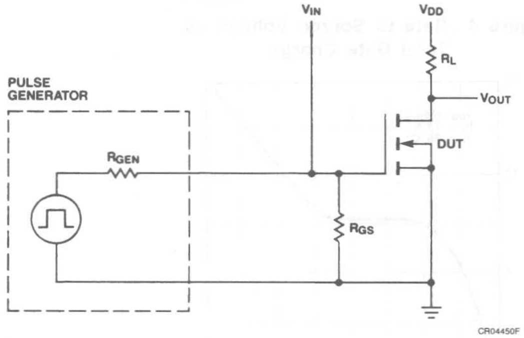
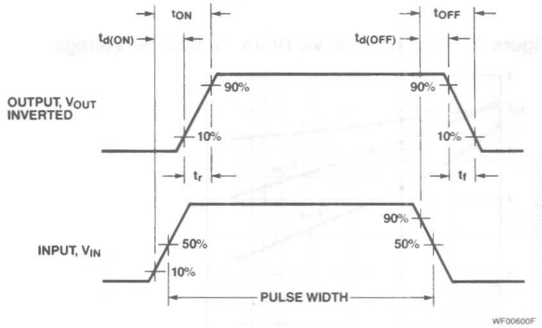


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

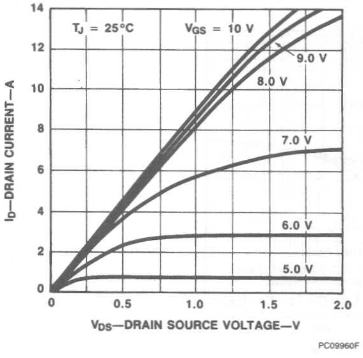
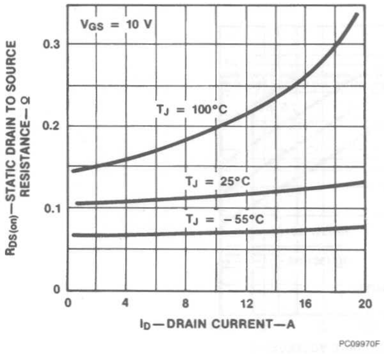


Figure 4 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 5 Transfer Characteristics

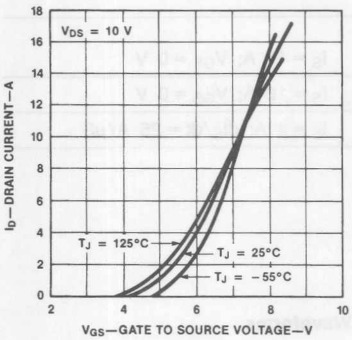


Figure 6 Temperature Variation of Gate to Source Threshold Voltage

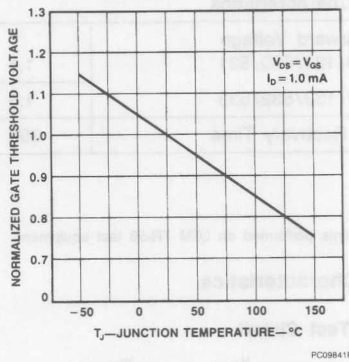


Figure 7 Capacitance vs Drain to Source Voltage

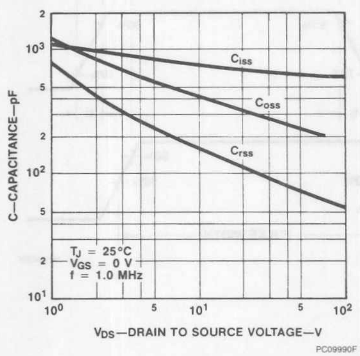


Figure 8 Gate to Source Voltage vs Total Gate Charge

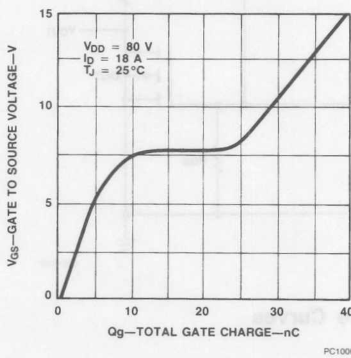


Figure 9 Forward Biased Safe Operating Area for IRF130-133 and IRF530-533

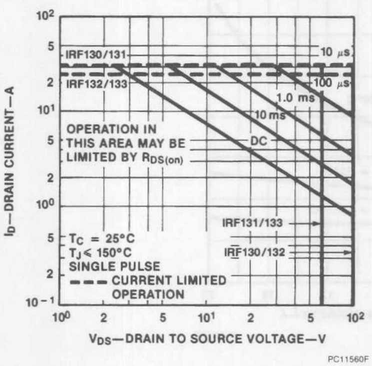
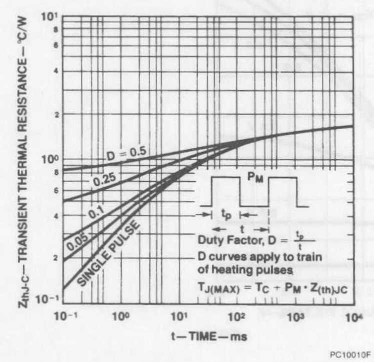


Figure 10 Transient Thermal Resistance vs Time for IRF130-133 and IRF530-533



Typical Performance Curves (Cont.)

Figure 11 Forward Biased Safe Operating Area for MTP20N08/20N10

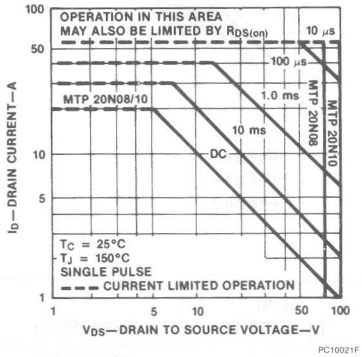
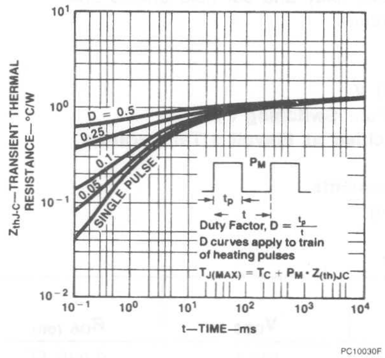


Figure 12 Transient Thermal Resistance vs Time for MTP20N08/20N10



FAIRCHILD

A Schlumberger Company

IRF140-143/IRF540-543 N-Channel Power MOSFETs, 27 A, 60-100 V

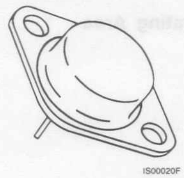
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

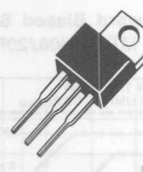
- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AE



IRF140
IRF141
IRF142
IRF143

TO-220AB



IRF540
IRF541
IRF542
IRF543

Product Summary

Part Number	V_{DSS}	$R_{DS\ (on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF140	100 V	0.085 Ω	27 A	17 A	TO-204AE
IRF141	60 V	0.085 Ω	27 A	17 A	
IRF142	100 V	0.11 Ω	24 A	15 A	
IRF143	60 V	0.11 Ω	24 A	15 A	
IRF540	100 V	0.085 Ω	27 A	17 A	TO-220AB
IRF541	60 V	0.085 Ω	27 A	17 A	
IRF542	100 V	0.11 Ω	24 A	15 A	
IRF543	60 V	0.11 Ω	24 A	15 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Maximum Ratings

Symbol	Characteristic	Rating IRF140/142 IRF540/542	Rating IRF141/143 IRF541/543	Unit
V_{DSS}	Drain to Source Voltage[1]	100	60	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	100	60	V
V_{GS}	Gate to Source Voltage	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum Thermal Characteristics

		IRF140-143	IRF540-543	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.0	1.0	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	125	125	W
I_{DM}	Pulsed Drain Current[2]	108	108	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF140/142/540/542	100			
	IRF141/143/541/543	60			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current IRF140-143		± 100	nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF540-543		± 500		
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 250\ \mu A$, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10\ V$, $I_D = 15\ A$
	IRF140/141/540/541		0.085		
	IRF142/143/542/543		0.11		
g_{fs}	Forward Transconductance	6.0		S (℧)	$V_{DS} = 10\ V$, $I_D = 15\ A$

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Dynamic Characteristics					
C_{iss}	Input Capacitance		1600	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		800	pF	
C_{rss}	Reverse Transfer Capacitance		300	pF	
Switching Characteristics (T_C = 25°C, *Figures 1, 2,*)[3]					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 45 V, I_D = 15 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		60	ns	
$t_{d(off)}$	Turn-Off Delay Time		80	ns	
t_f	Fall Time		30	ns	
$t_{d(on)}$	Turn-On Delay Time		60	ns	V_{DD} = 25 V, I_D = 15 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		450	ns	
$t_{d(off)}$	Turn-Off Delay Time		150	ns	
t_f	Fall Time		200	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 34 A V_{DD} = 35 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF140/141/540/541	2.0	2.5	V	I_S = 27 A; V_{GS} = 0 V
	IRF142/143/542/543	2.0	2.3	V	I_S = 24 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	300		ns	I_S = 4.0 A; dI_S/dt = 25 A/µS

Notes

1. T_J = + 25°C to + 150°C
2. Pulse width limited by T_J
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

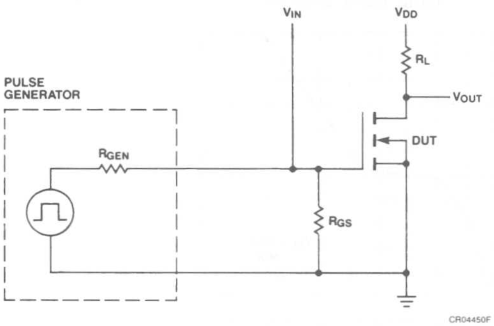
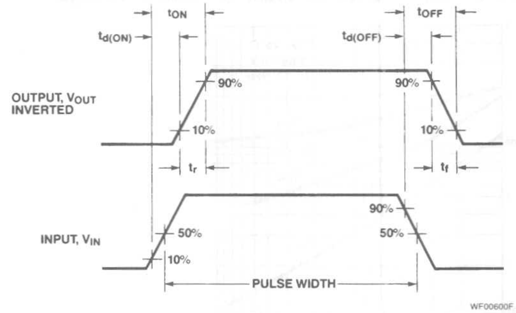


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

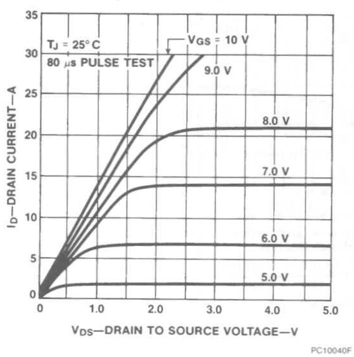


Figure 4 Static Drain to Source Resistance vs Drain Current

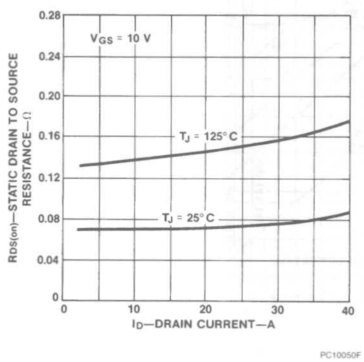


Figure 5 Transfer Characteristics

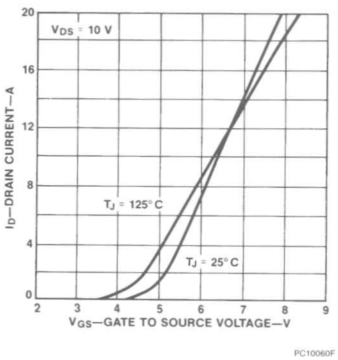
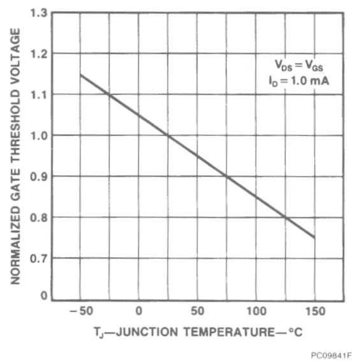
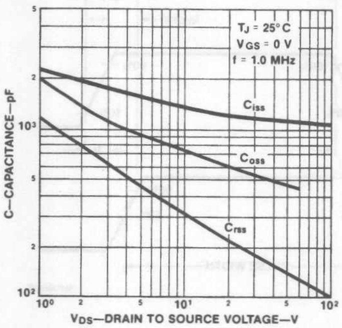


Figure 6 Temperature Variation of Gate to Source Threshold Voltage



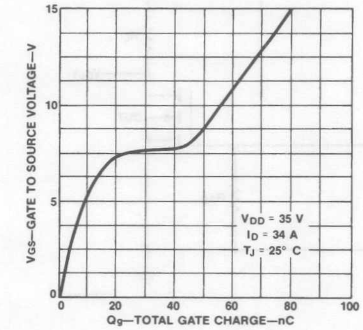
Typical Performance Curves (Cont.)

Figure 7 Capacitance vs Drain to Source Voltage



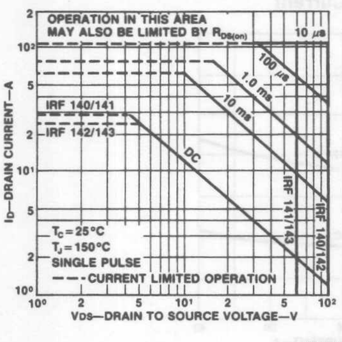
PC10070F

Figure 8 Gate to Source Voltage vs Total Gate Charge



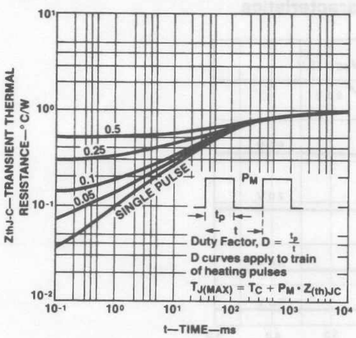
PC10080F

Figure 9 Forward Biased Safe Operating Area



PC10090F

Figure 10 Transient Thermal Resistance vs Time



PC10100F

FAIRCHILD

A Schlumberger Company

IRF150-153
N-Channel Power MOSFETs, 40 A, 60 V/100 V

Power And Discrete Division

Description
These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, SOA Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AE

IS00020F

IRF150
IRF151
IRF152
IRF153

Maximum Ratings

Symbol	Characteristic	Rating IRF150/152	Rating IRF151/153	Unit
V_{DSS}	Drain to Source Voltage[1]	100	60	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20$ kΩ	100	60	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF150/151	IRF152/153	
$R_{DS\ (on)}$	Static Drain-to-Source On Resistance[2]	0.055	0.08	Ω
I_D	Drain Current Continuous Pulsed	 40 60	 33 132	A

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	150	150	W

Notes
For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF150/152	100			
	IRF151/153	60			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 20 A
	IRF150/151		0.055		
	IRF152/153		0.08		
g_{fs}	Forward Transconductance	9.0		S (℧)	V_{DS} = 10 V, I_D = 20 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		3000	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		1500	pF	
C_{rss}	Reverse Transfer Capacitance		500	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)[3]					
$t_{d(on)}$	Turn-On Delay Time		35	ns	V_{DD} = 24 V, I_D = 20 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		100	ns	
$t_{d(off)}$	Turn-Off Delay Time		125	ns	
t_f	Fall Time		100	ns	
$t_{d(on)}$	Turn-On Delay Time		75	ns	V_{DD} = 75 V, I_D = 20 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		450	ns	
$t_{d(off)}$	Turn-Off Delay Time		300	ns	
t_f	Fall Time		200	ns	
Q_g	Total Gate Charge		120	nC	V_{GS} = 10 V, I_D = 50 A V_{DD} = 55 V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF150/151	2.0	2.5	V	I_S = 40 A; V_{GS} = 0 V
	IRF152/153	2.0	2.3	V	I_S = 33 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	300		ns	I_S = 4 A; dI_S/dt = 25 A/μS

2

Notes

1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

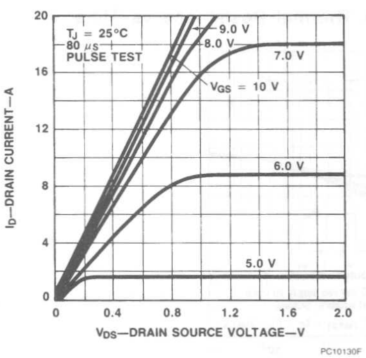


Figure 2 Static Drain to Source Resistance vs Drain Current

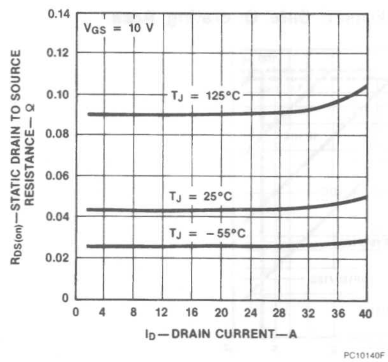


Figure 3 Transfer Characteristics

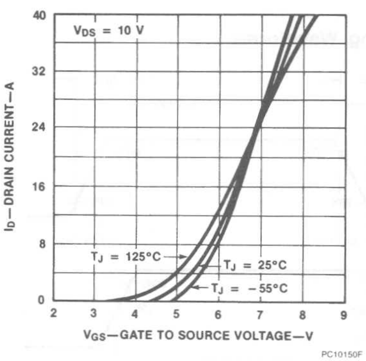
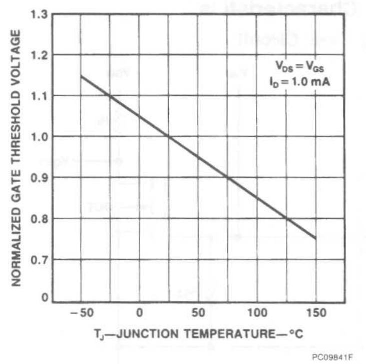


Figure 4 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 5 Capacitance vs Drain to Source Voltage

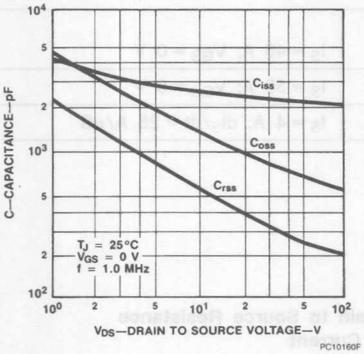


Figure 6 Gate to Source Voltage vs Total Gate Charge

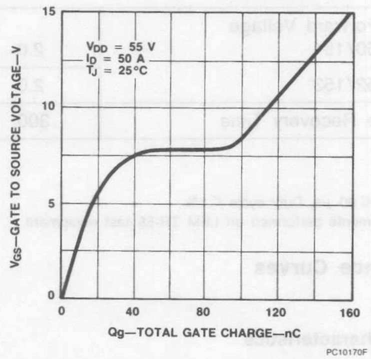


Figure 7 Forward Biased Safe Operating Area

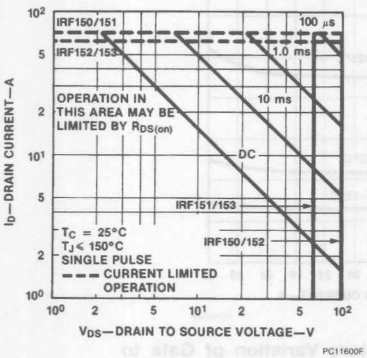
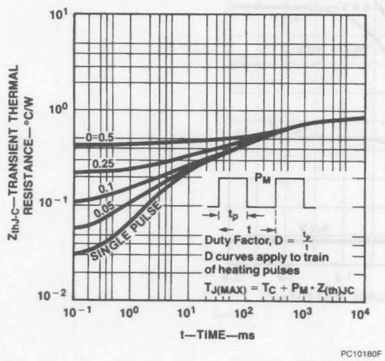


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

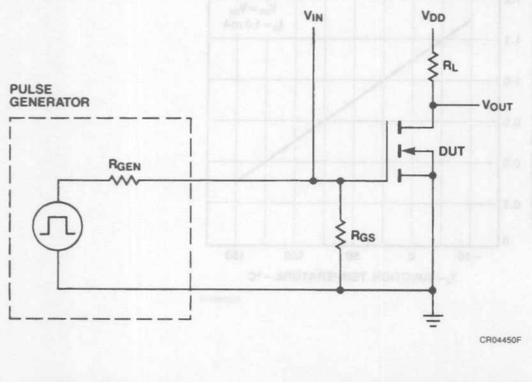
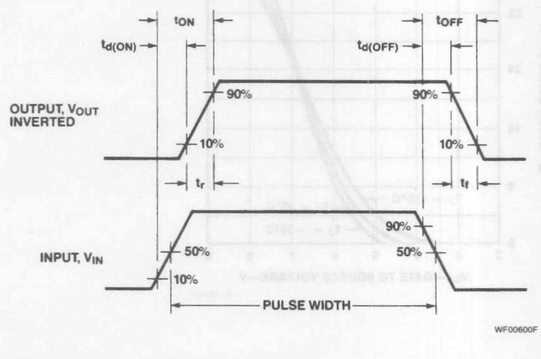


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF220-223/IRF620-623 MTP7N18/7N20 N-Channel Power MOSFETs, 7 A, 150-200 V

Power And Discrete Division

2

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

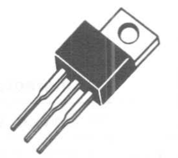
- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AA

IS00020F

IRF220
IRF221
IRF222
IRF223

TO-220AB



IS00010F

IRF620
IRF621
IRF622
IRF623
MTP7N18
MTP7N20

Product Summary

Part Number	V_{DSS}	$R_{DS\ (on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF220	200 V	0.8 Ω	5.0 A	3.0 A	TO-204AA
IRF221	150 V	0.8 Ω	5.0 A	3.0 A	
IRF222	200 V	1.2 Ω	4.0 A	2.5 A	
IRF223	150 V	1.2 Ω	4.0 A	2.5 A	
IRF620	200 V	0.8 Ω	5.0 A	3.0 A	TO-220AB
IRF621	150 V	0.8 Ω	5.0 A	3.0 A	
IRF622	200 V	1.2 Ω	4.0 A	2.5 A	
IRF623	150 V	1.2 Ω	4.0 A	2.5 A	
MTP7N18	180 V	0.7 Ω	7.0 A	4.5 A	
MTP7N20	200 V	0.7 Ω	7.0 A	4.5 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Maximum Ratings

Symbol	Characteristic	Rating IRF220/222 IRF620/622 MTP7N20	Rating MTP7N18	Rating IRF222/223 IRF622/623	Unit
V_{DSS}	Drain to Source Voltage[1]	200	180	150	V
V_{DGR}	Drain to Gate Voltage[1] R_{GS} = 20 kΩ	200	180	150	V
V_{GS}	Gate to Source Voltage	± 20	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	275	°C

Maximum Thermal Characteristics

		IRF220 - 223/IRF620 - 623	MTP7N18/20	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	3.12	1.67	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	30/80	80	°C/W
P_D	Total Power Dissipation at T_C = 25°C	40	75	W
I_{DM}	Pulsed Drain Current[2]	20	20	A

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF220/222/620/622/ MTP7N20	200			
	MTP7N18	180			
	IRF221/223/621/623	150			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current			nA	V_{GS} = ± 20 V, V_{DS} = 0 V
	IRF220-223		± 100		
	IRF620-623/MTP7N18/20		± 500		

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF220-223/IRF620-623	2.0	4.0		$I_D = 250\ \mu A$, $V_{DS} = V_{GS}$
	MTP7N18/20	2.0	4.5		$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 2.5$ A
	IRF220/221/620/621		0.8		
	IRF222/223/622/623		1.2		
	MTP7N18/7N20		0.7		$I_D = 3.5$ A
$V_{DS(on)}$	Drain-Source On-Voltage[2] MTP7N18/7N20		2.45 5.9	V V	$V_{GS} = 10$ V; $I_D = 3.5$ A $V_{GS} = 10$ V; $I_D = 7.0$ A
			5.0	V	$V_{GS} = 10$ V, $I_D = 3.5$ A $T_C = 100°C$
g_{fs}	Forward Transconductance	1.3		S (℧)	$V_{DS} = 10$ V, $I_D = 2.5$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		600	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{oss}	Output Capacitance		300	pF	
C_{rss}	Reverse Transfer Capacitance		80	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 1, 2*)[3]					
$t_{d(on)}$	Turn-On Delay Time		40	ns	$V_{DD} = 100$ V, $I_D = 2.5$ A $V_{GS} = 10$ V, $R_{GEN} = 50\ \Omega$ $R_{GS} = 50\ \Omega$
t_r	Rise Time		60	ns	
$t_{d(off)}$	Turn-Off Delay Time		100	ns	
t_f	Fall Time		60	ns	
Q_g	Total Gate Charge		15	nC	$V_{GS} = 10$ V, $I_D = 6.0$ A $V_{DD} = 45$ V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage		1.8	V	$I_S = 5.0$ A; $V_{GS} = 0$ V
			1.4	V	$I_S = 4.0$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time	350		ns	$I_S = 5.0$ A; $dI_S/dt = 25$ A/μS

Notes
1. $T_J = +25°C$ to $+150°C$
2. Pulse width limited by T_J
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

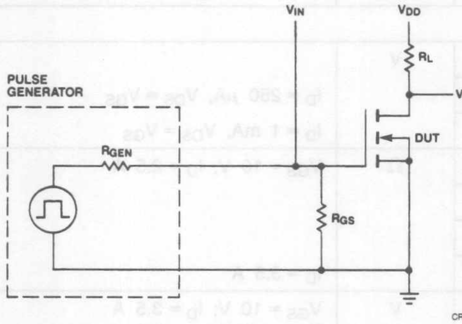
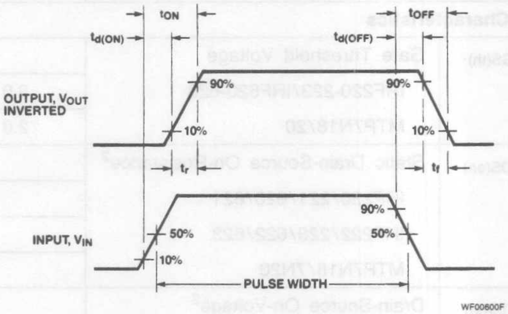


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

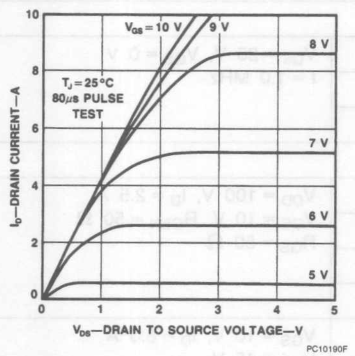


Figure 4 Static Drain to Source Resistance vs Drain Current

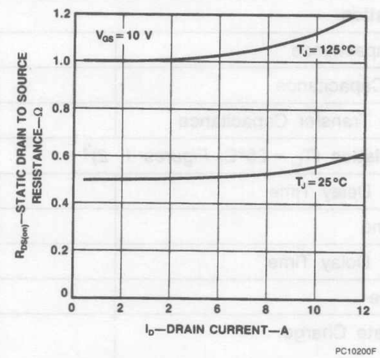


Figure 5 Transfer Characteristics

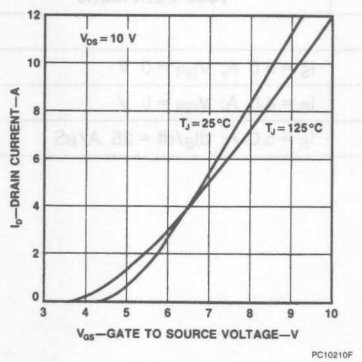
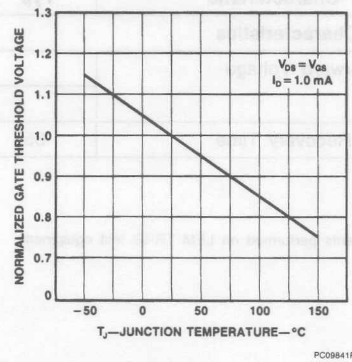


Figure 6 Temperature Variation of Gate to Source Threshold Voltage



2

Typical Performance Curves (Cont)

Figure 7 Capacitance vs Drain to Source Voltage

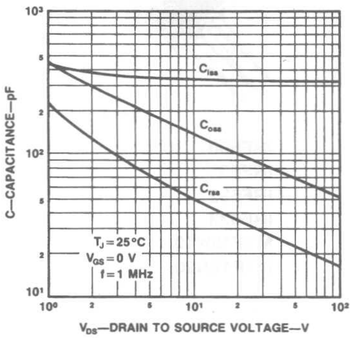


Figure 8 Gate to Source Voltage vs Total Gate Charge

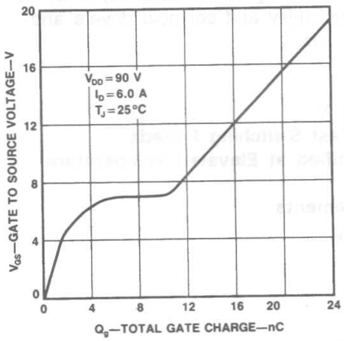


Figure 9 Forward Biased Safe Operating Area for IRF220-223 and IRF620-623

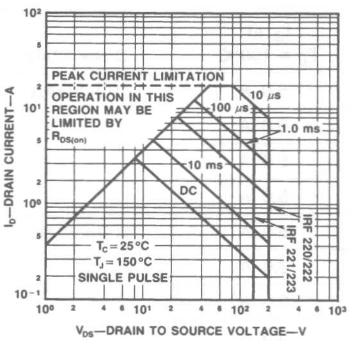


Figure 10 Transient Thermal Resistance vs Time for IRF220-223 and IRF620-623

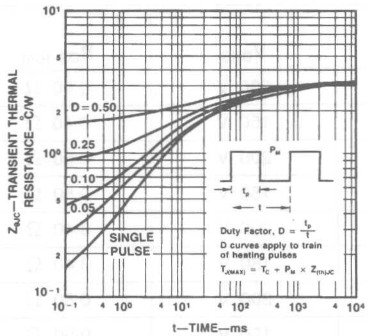


Figure 11 Forward Biased Safe Operating Area for MTP7N18/7N20

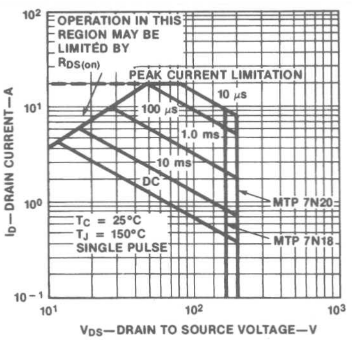
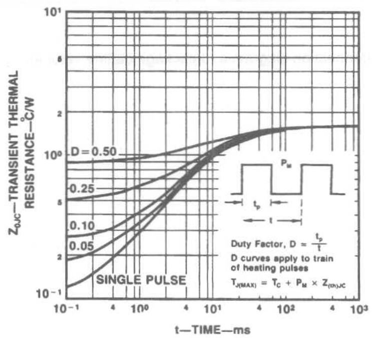


Figure 12 Transient Thermal Resistance vs Time for MTP7N18/7N20



12 A, 150-200 V

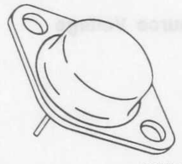
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

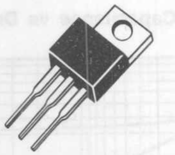
- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AA



IRF230
IRF231
IRF232
IRF233

TO-220AB



IRF630
IRF631
IRF632
IRF633
MTP12N18
MTP12N20

Product Summary

Part Number	V_{DSS}	$R_{DS\ (on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF230	200 V	0.40 Ω	9.0 A	6.0 A	TO-204AA
IRF231	150 V	0.40 Ω	9.0 A	6.0 A	
IRF232	200 V	0.50 Ω	8.0 A	5.0 A	
IRF233	150 V	0.50 Ω	8.0 A	5.0 A	
IRF630	200 V	0.40 Ω	9.0 A	6.0 A	TO-220AB
IRF631	150 V	0.40 Ω	9.0 A	6.0 A	
IRF632	200 V	0.50 Ω	8.0 A	5.0 A	
IRF633	150 V	0.50 Ω	8.0 A	5.0 A	
MTP12N18	180 V	0.35 Ω	12 A	8.5 A	
MTP12N20	200 V	0.35 Ω	12 A	8.5 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

2

Maximum Ratings

Symbol	Characteristic	Rating IRF220/222 IRF620/622 MTP7N20	Rating MTP7N18	Rating IRF222/223 IRF622/623	Unit
V_{DSS}	Drain to Source Voltage[1]	200	180	150	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	200	180	150	V
V_{GS}	Gate to Source Voltage	± 20	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	275	°C

Maximum Thermal Characteristics

		IRF220 – 233 IRF630 – 633	MTP12N18/20	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.25	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	75	100	W
I_{DM}	Pulsed Drain Current[2]	40	40	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF230/232/630/632/ MTP12N20	200			
	MTP12N18	180			
	IRF231/233/631/633	150			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current			nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF230-233		±100		
	IRF630-633/ MTP12N18/12N20		±500		

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF230/233/630/633	2.0	4.0		I_D = 250 μA, V_{DS} = V_{GS}
	MTP12N18/12N20	2.0	4.5		I_D = 1 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 5.0 A
	IRF230/231/630/631		0.40		
	IRF232/233/632/633		0.50		
	MTP12N18/12N20		0.35		I_D = 6.0 A
$V_{DS(on)}$	Drain-Source On-Voltage[2]		2.1	V	V_{GS} = 10 V; I_D = 6.0 A
	MTP12N18/12N20		5.0	V	V_{GS} = 10 V; I_D = 12.0 A;
			4.2	V	V_{GS} = 10 V; I_D = 6.0 A T_C = 100°C
g_{fs}	Forward Transconductance	3.0		S (℧)	V_{DS} = 10 V, I_D = 5.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		450	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 1, 2*)[1]					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 90 V, I_D = 5.0 A V_{GS} = 10 V, R_{GEN} = 15 Ω R_{GS} = 15 Ω
t_r	Rise Time		50	ns	
$t_{d(off)}$	Turn-Off Delay Time		50	ns	
t_f	Fall Time		40	ns	
$t_{d(on)}$	Turn-On Delay Time		50	ns	V_{DD} = 25 V, I_D = 6.0 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		250	ns	
$t_{d(off)}$	Turn-Off Delay Time		100	ns	
t_f	Fall Time		120	ns	
Q_g	Total Gate Charge		30	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 120 V

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF230/231/630/631	1.25	2.0	V	$I_S = 9.0$ A; $V_{GS} = 0$ V
	IRF232/233/632/633	1.25	1.8	V	$I_S = 8.0$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time	450		ns	$I_S = 4.0$ A; $I_S/dt = 25$ A/μS

Notes
1. $T_J = +25°C$ to $+150°C$
2. Pulse width limited by T_J.
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

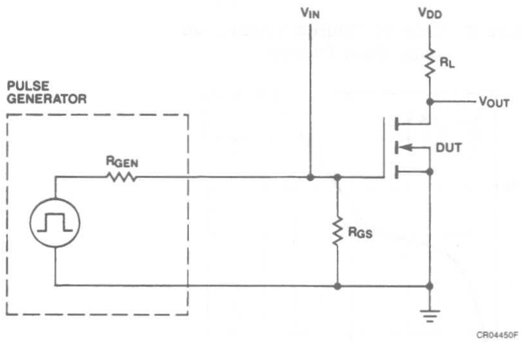
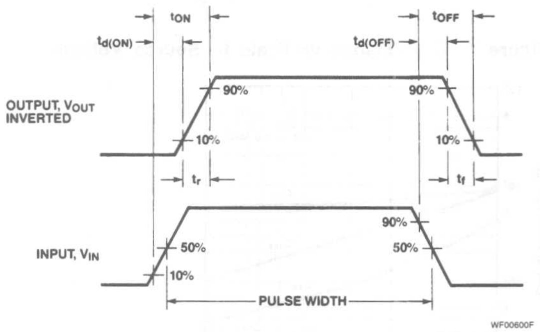


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

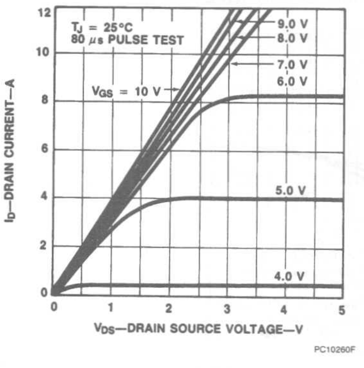
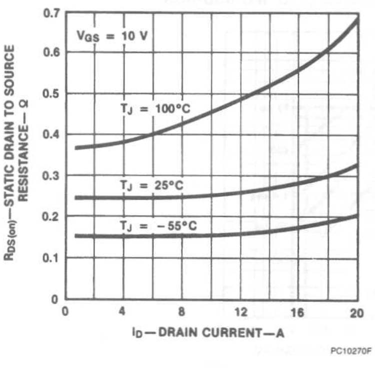


Figure 4 Static Drain to Source Resistance vs Drain Current



Typical Performance Curves (Cont.)

Figure 5 Transfer Characteristics

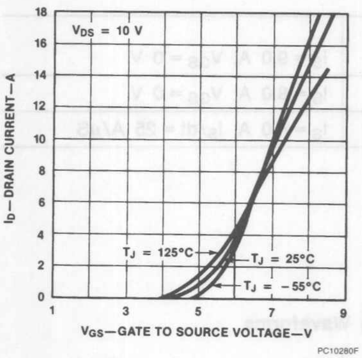


Figure 6 Temperature Variation of Gate to Source Threshold Voltage

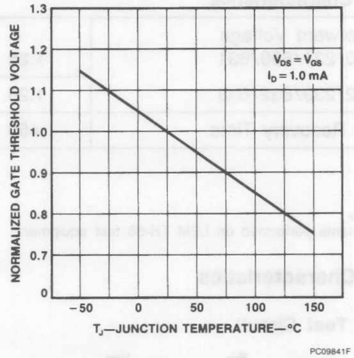


Figure 7 Capacitance vs Drain to Source Voltage

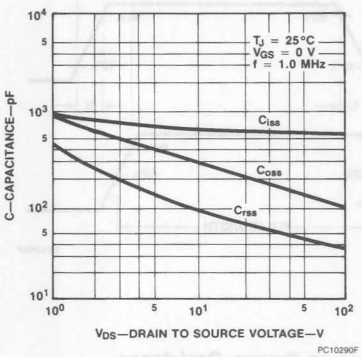


Figure 8 Gate to Source Voltage vs Total Gate Charge

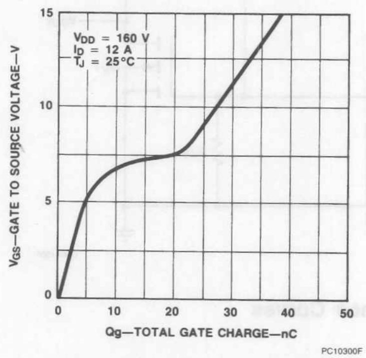


Figure 9 Forward Biased Safe Operating Area for IRF230-233 and IRF630-633

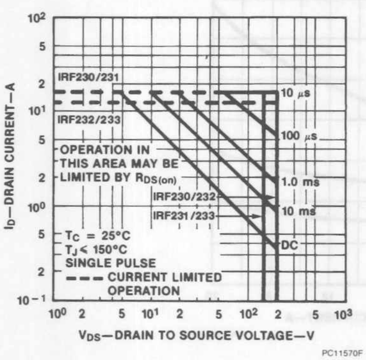
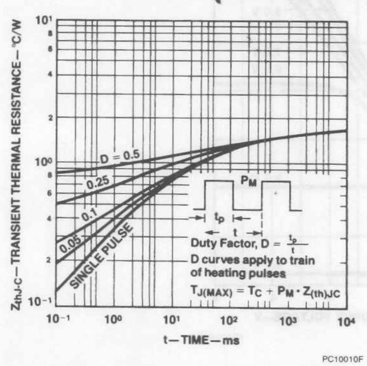
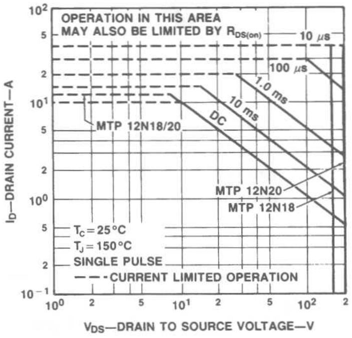


Figure 10 Transient Thermal Resistance vs Time for IRF230-233 and IRF630-633



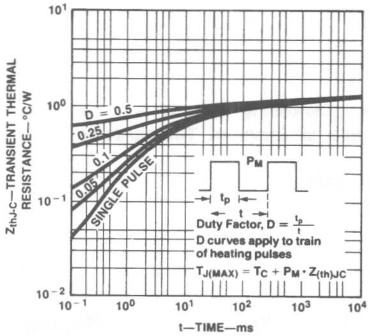
Typical Performance Curves (Cont.)

Figure 11 Forward Biased Safe Operating Area for MTP12N18/12N20



PC10311F

Figure 12 Transient Thermal Resistance vs Time for MTP12N18/12N20



PC10030F

FAIRCHILD

A Schlumberger Company

IRF240-243/IRF640-643 N-Channel Power MOSFETs, 18 A, 150-200 V

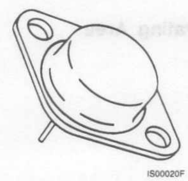
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

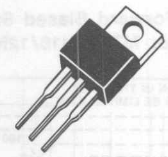
- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AE



IRF240
IRF241
IRF242
IRF243

TO-220AB



IRF640
IRF641
IRF642
IRF643

Product Summary

Part Number	V_{DSS}	$R_{DS\ (on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF240	200 V	0.18 Ω	18 A	11 A	TO-204AE
IRF241	150 V	0.18 Ω	18 A	11 A	
IRF242	200 V	0.22 Ω	16 A	10 A	
IRF243	150 V	0.22 Ω	16 A	10 A	
IRF640	200 V	0.18 Ω	18 A	11 A	TO-220AB
IRF641	150 V	0.18 Ω	18 A	11 A	
IRF642	200 V	0.22 Ω	16 A	10 A	
IRF643	150 V	0.22 Ω	16 A	10 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Maximum Ratings

Symbol	Characteristic	Rating IRF240/242 IRF640/642	Rating IRF241/243 IRF641/643	Unit
V_{DSS}	Drain to Source Voltage[1]	200	150	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	200	150	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum Thermal Characteristics

		IRF240-243	IRF640-643	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.0	1.0	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	125	125	W
I_{DM}	Pulsed Drain Current[2]	72	72	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF240/242/640/642	200			
	IRF241/243/641/643	150			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current			nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF240-243		±100		
	IRF640-643		±500		
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 250\ \mu A$, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10\ V$, $I_D = 10\ A$
	IRF240/241/640/641		0.18		
	IRF242/243/642/643		0.22		
g_{fs}	Forward Transconductance	6.0		S (℧)	$V_{DS} = 10\ V$, $I_D = 10\ A$

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Dynamic Characteristics					
C_{iss}	Input Capacitance		1600	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		750	pF	
C_{rss}	Reverse Transfer Capacitance		300	pF	
Switching Characteristics (T_C = 25°C, *Figures 1, 2*)[3]					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 75 V, I_D = 10 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		60	ns	
$t_{d(off)}$	Turn-Off Delay Time		80	ns	
t_f	Fall Time		60	ns	
$t_{d(on)}$	Turn-On Delay Time		60	ns	V_{DD} = 25 V, I_D = 10 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		300	ns	
$t_{d(off)}$	Turn-Off Delay Time		200	ns	
t_f	Fall Time		150	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 22 A V_{DD} = 120 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF240/241/640/641	1.7	2.0	V	I_S = 18 A; V_{GS} = 0 V
	IRF242/243/642/643	1.7	1.9	V	I_S = 16 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	400		ns	I_S = 4 A; dI_S/dt = 25 A/μS

Notes

1. T_J = +25°C to +150°C
2. Pulse width limited by maximum T_J.
3. Switching time measurements performed on LEM TR-58 test equipment.

2

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

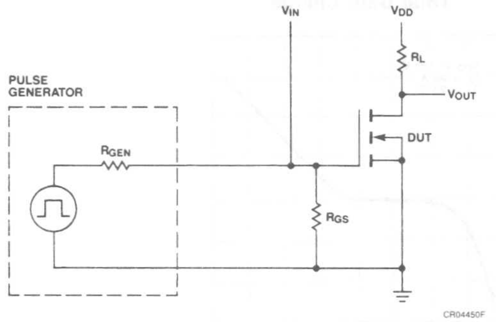
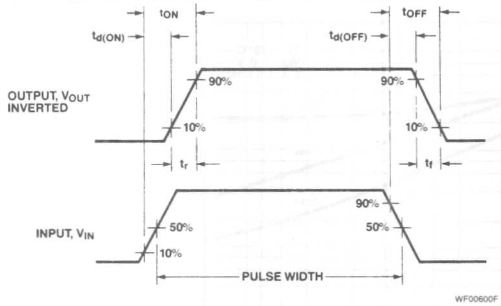


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

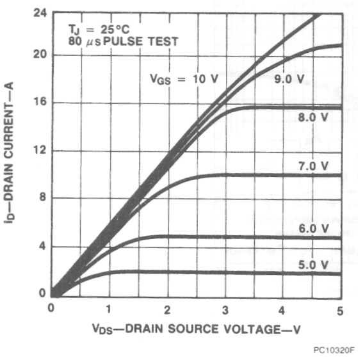


Figure 4 Static Drain to Source Resistance vs Drain Current

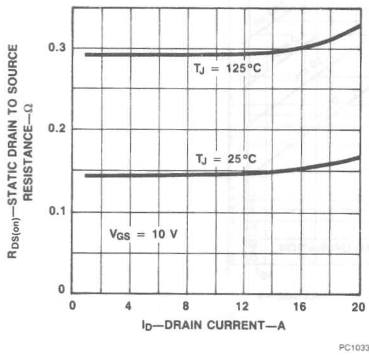


Figure 5 Transfer Characteristics

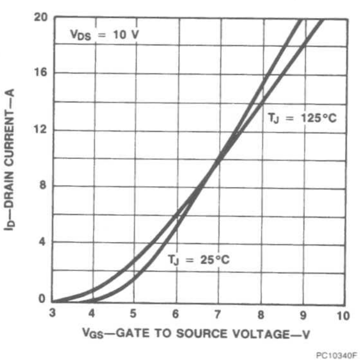
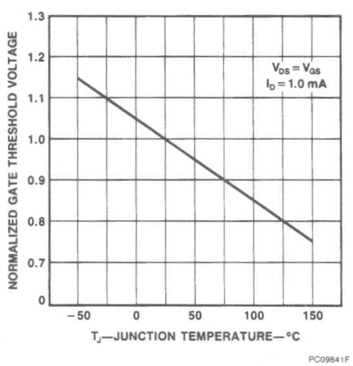


Figure 6 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 7 Capacitance vs Drain to Source Voltage

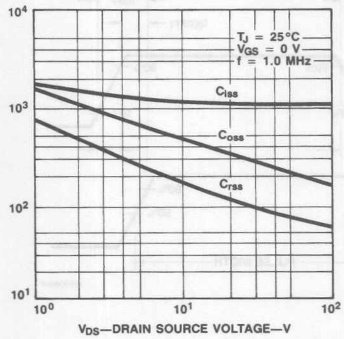


Figure 8 Gate to Source Voltage vs Total Gate Charge

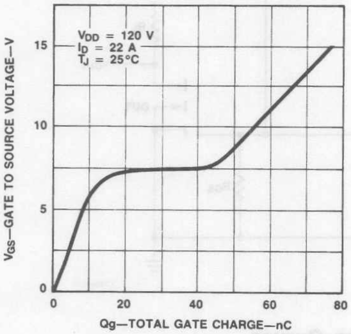


Figure 9 Forward Biased Safe Operating Area

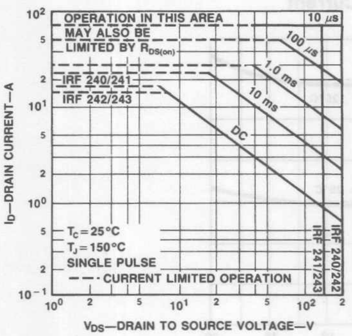
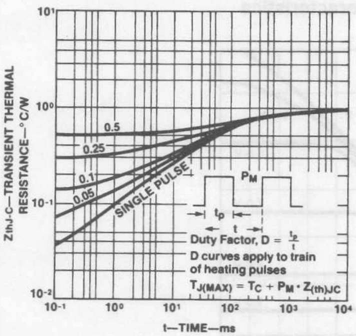


Figure 10 Transient Thermal Resistance vs Time



FAIRCHILD

A Schlumberger Company

IRF250-253 N-Channel Power MOSFETs, 30 A, 150 V/200 V

Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high power, high speed applications, such as switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers and high energy pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, SOA Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AE

IRF250
IRF251
IRF252
IRF253

Maximum Ratings

Symbol	Characteristic	Rating IRF250/252	Rating IRF251/253	Unit
V_{DSS}	Drain to Source Voltage[1]	200	150	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	200	150	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF250/251	IRF252/253	
$R_{DS\ (on)}$	Static Drain-to-Source On Resistance	0.085	0.12	Ω
I_D	Drain Current Continuous Pulsed	 30 120	 25 100	A

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	150	150	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

2

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF250/252	200			
	IRF251/253	150			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 16 A
	IRF250/251		0.085		
	IRF252/253		0.12		
g_{fs}	Forward Transconductance	8.0		S (℧)	V_{DS} = 10 V, I_D = 16 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		3000	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		1200	pF	
C_{rss}	Reverse Transfer Capacitance		500	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)[1]					
$t_{d(on)}$	Turn-On Delay Time		35	ns	V_{DD} = 95 V, I_D = 16 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		100	ns	
$t_{d(off)}$	Turn-Off Delay Time		125	ns	
t_f	Fall Time		100	ns	
$t_{d(on)}$	Turn-On Delay Time		75	ns	V_{DD} = 125 V, I_D = 16 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		300	ns	
$t_{d(off)}$	Turn-Off Delay Time		275	ns	
t_f	Fall Time		150	ns	
Q_g	Total Gate Charge		120	nC	V_{GS} = 10 V, I_D = 38 A V_{DD} = 100 V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF250/251	1.5	2.0	V	I_S = 30 A; V_{GS} = 0 V
	IRF252/253	1.5	1.8	V	I_S = 25 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	400		ns	I_S = 4 A; dI_S/dt = 25 A/μS

Notes

1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

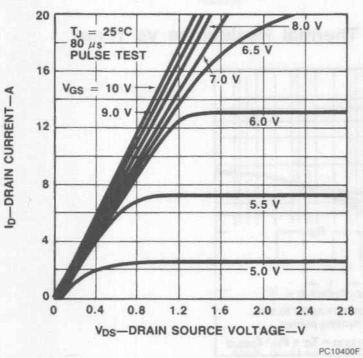


Figure 2 Static Drain to Source Resistance vs Drain Current

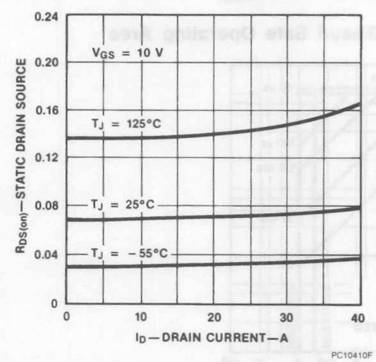


Figure 3 Transfer Characteristics

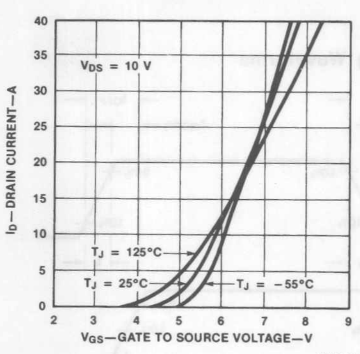
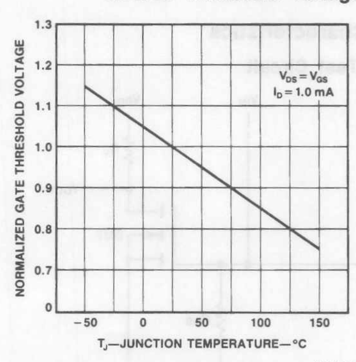


Figure 4 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 5 Capacitance vs Drain to Source Voltage

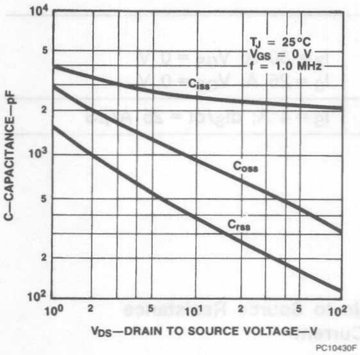


Figure 6 Gate to Source Voltage vs Total Gate Charge

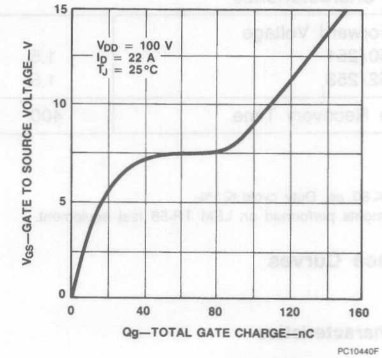


Figure 7 Forward Biased Safe Operating Area

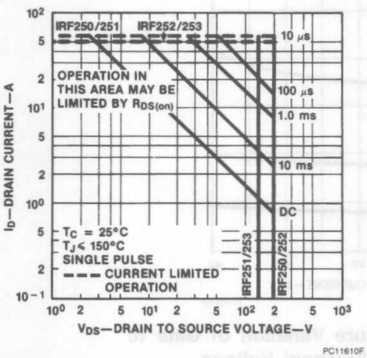
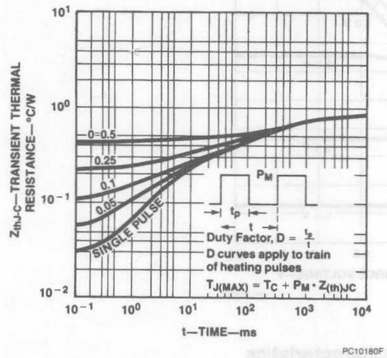


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

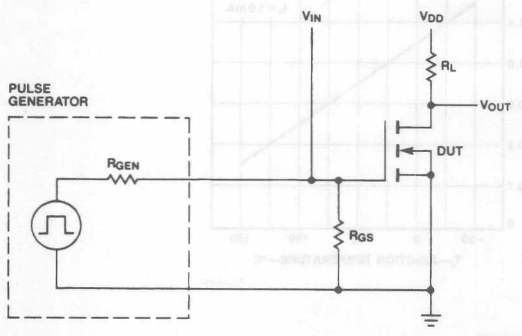
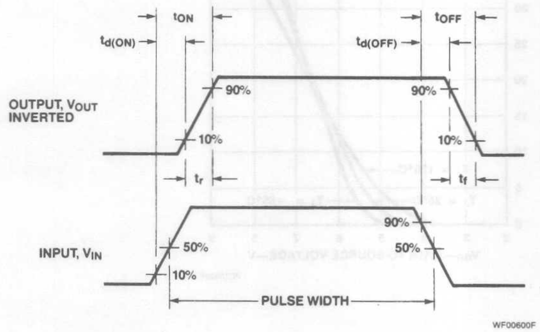


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF320-323/IRF720-723 MTP3N35/3N40 N-Channel Power MOSFETs, 3.0 A, 350-400 V

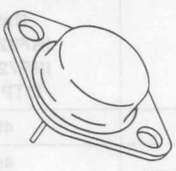
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

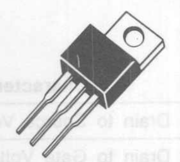
- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-204AA



IRF320
IRF321
IRF322
IRF323

TO-220AB



IRF720
IRF721
IRF722
IRF723
MTP3N35
MTP3N40

Product Summary

Part Number	V_{DSS}	$R_{DS\ (on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF320	400 V	1.8 Ω	3.0 A	2.0 A	TO-204AA
IRF321	350 V	1.8 Ω	3.0 A	2.0 A	
IRF322	400 V	2.5 Ω	2.5 A	1.5 A	
IRF323	350 V	2.5 Ω	2.5 A	1.5 A	
IRF720	400 V	1.8 Ω	3.0 A	2.0 A	TO-220AB
IRF721	350 V	1.8 Ω	3.0 A	2.0 A	
IRF722	400 V	2.5 Ω	2.5 A	1.5 A	
IRF723	350 V	2.5 Ω	2.5 A	1.5 A	
MTP3N35	350 V	3.3 Ω	3.0 A	2.0 A	
MTP3N40	400 V	3.3 Ω	3.0 A	2.0 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Maximum Ratings

Symbol	Characteristic	Rating IRF320/322 IRF720/722 MTP3N40	Rating IRF321/323 IRF721/723 MTP3N35	Unit
V_{DSS}	Drain to Source Voltage[2]	400	350	V
V_{DGR}	Drain to Gate Voltage[2] $R_{GS} = 20\ k\Omega$	400	350	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum Thermal Characteristics

		IRF320-323/ IRF720-723	MTP3N35/3N40	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	3.12	1.67	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	30/80	80	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	40	75	W
I_{DM}	Pulsed Drain Current[2]	12	12	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF320/322/720/722/ MTP3N40	400			
	IRF321/323/721/723/ MTP3N35	350			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current			nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF320-323		±100		
	IRF720-723/MTP3N35/3N40		±500		

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF320-323/IRF720-723	2.0	4.0		I_D = 250 μA, V_{DS} = V_{GS}
	MTP3N35/40	2.0	4.5		I_D = 1 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 1.5 A
	IRF320/321/720/721		1.8		
	IRF322/323/722/723		2.5		
	MTP3N35/40		3.3		
$V_{DS(on)}$	Drain-Source On-Voltage[2] MTP3N35/40		12	V	V_{GS} = 10 V; I_D = 3.0 A;
			10	V	V_{GS} = 10 V; I_D = 1.5 A; T_C = 100°C
g_{fs}	Forward Transconductance	1.0		S (℧)	V_{DS} = 10 V, I_D = 1.5 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		500	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		100	pF	
C_{rss}	Reverse Transfer Capacitance		40	pF	
Switching Characteristics (T_C = 200°C, *Figures 1, 2*)[3]					
$t_{d(on)}$	Turn-On Delay Time		40	ns	V_{DD} = 200 V, I_D = 1.5 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		50	ns	
$t_{d(off)}$	Turn-Off Delay Time		100	ns	
t_f	Fall Time		50	ns	
Q_g	Total Gate Charge		15	nC	V_{GS} = 10 V, I_D = 4.0 A V_{DD} = 200 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF320/321/720/721		1.6	V	I_S = 3.0 A; V_{GS} = 0 V
	IRF322/323/722/723		1.5	V	I_S = 2.5 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	450		ns	I_F = 3.0 A; dI_S/dt = 100 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

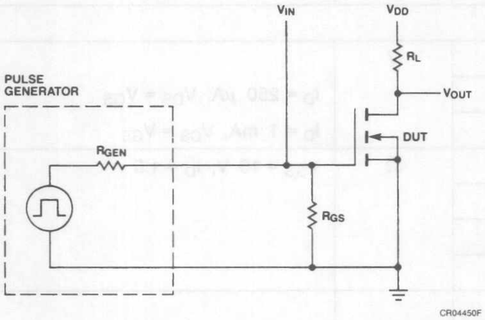
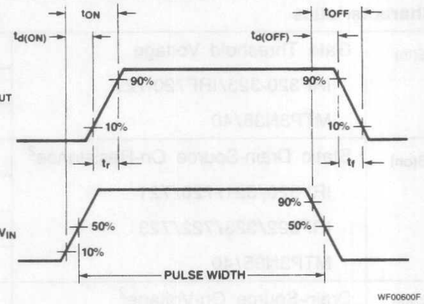


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

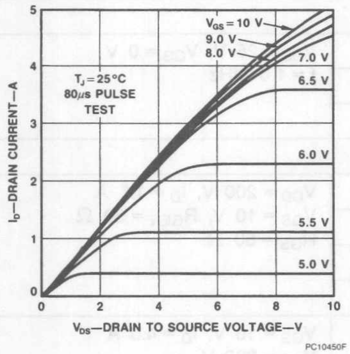


Figure 4 Static Drain to Source Resistance vs Drain Current

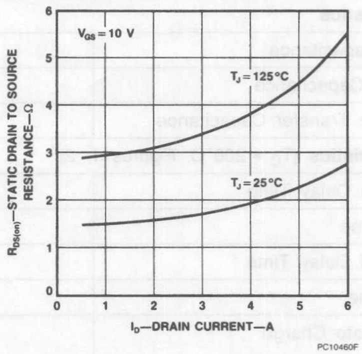


Figure 5 Transfer Characteristics

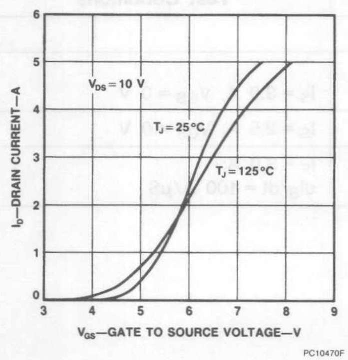
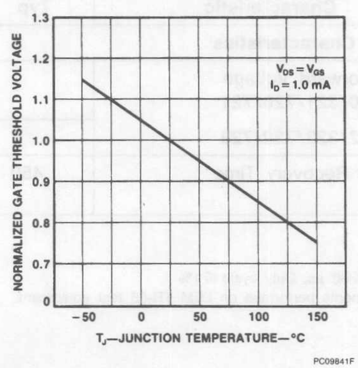


Figure 6 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 7 Capacitance vs Drain to Source Voltage

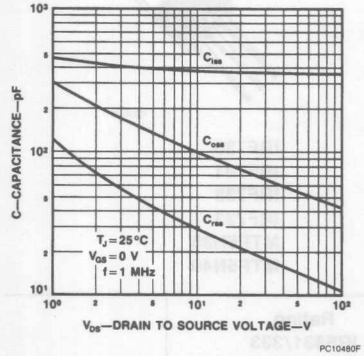


Figure 8 Gate to Source Voltage vs Total Gate Charge

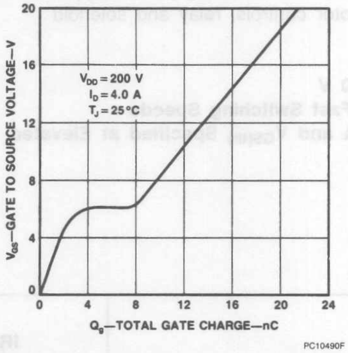


Figure 9 Forward Biased Safe Operating Area for IRF320-323 and IRF720-723

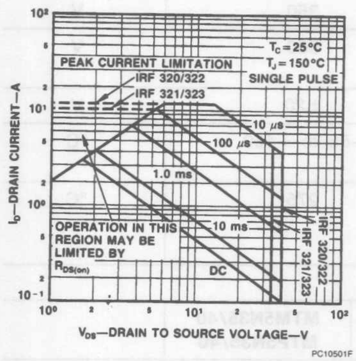


Figure 10 Transient Thermal Resistance vs Time for IRF320-323 and IRF720-723

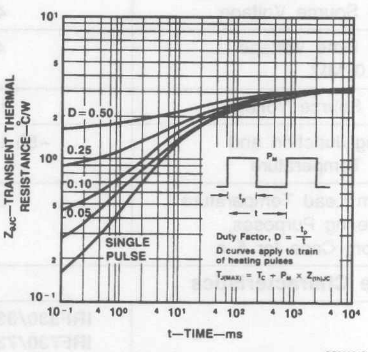


Figure 11 Forward Biased Safe Operating Area for MTP3N35/3N40

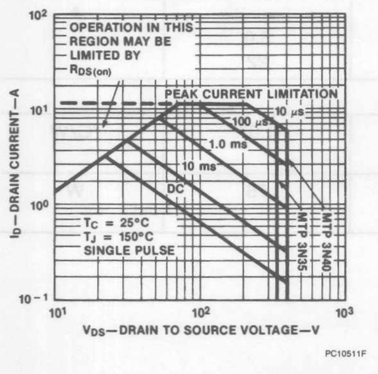
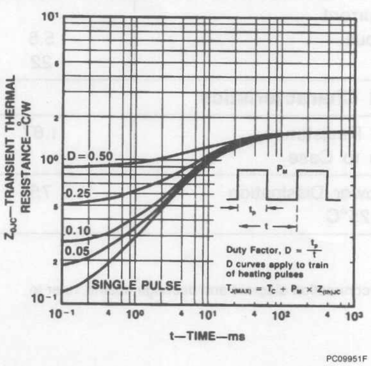


Figure 12 Transient Thermal Resistance vs Time for MTP3N35/3N40



Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

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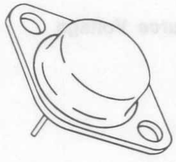
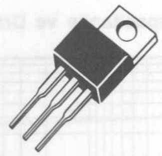


IRF330
IRF331
IRF332
IRF333
MTM5N35
MTM5N40

TO-220AB



IRF730
IRF731
IRF732
IRF733
MTP5N35
MTP5N40

Maximum Ratings

Symbol	Characteristic	Rating IRF330/332 IRF730/732 MTM/MTP5N40	Rating IRF331/333 IRF731/733 MTM/MTP5N35	Unit
V_{DSS}	Drain to Source Voltage	400	350	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1.0$ MΩ	400	350	V
V_{GS}	Gate to Source Voltage	± 20	± 20	V
T_J, T_{stg}	Operating Junction and Storage Temperature	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF330/331 IRF730/731	IRF332/333 IRF732/733	MTM5N35/40 MTP5N35/40	
$R_{DS\ (on)}$	Static Drain-to-Source On Resistance	1.0	1.5	1.0	Ω
I_D	Drain Current				A
	Continuous	5.5	4.5	5.0	
	Pulsed	22	22	22	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	1.67	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	75	75	75	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF330/332/730/732	400			
	IRF331/333/731/733	350			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current			nA	V_{GS} = ± 20 V, V_{DS} = 0 V
	IRF330-333		± 100		
	IRF730-733		± 500		
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 3.0 A
	IRF330/331/730/731		1.0		
	IRF332/333/732/733		1.5		
g_{fs}	Forward Transconductance	3.0		S (℧)	V_{DS} = 10 V, I_D = 3.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		900	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		300	pF	
C_{rss}	Reverse Transfer Capacitance		80	pF	
Switching Characteristics (T_C = 25°C, *Figures 12, 13*)					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 175 V, I_D = 3.0 A V_{GS} = 10 V, R_{GEN} = 15 Ω R_{GS} = 15 Ω
t_r	Rise Time		35	ns	
$t_{d(off)}$	Turn-Off Delay Time		55	ns	
t_f	Fall Time		35	ns	
Q_g	Total Gate Charge		30	nC	V_{GS} = 10 V, I_D = 7.0 A V_{DD} = 180 V
Symbol	**Characteristic**	**Typ**	**Max**	**Unit**	**Test Conditions**
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF330/331/730/731		1.6	V	I_S = 5.5 A; V_{GS} = 0 V
	IRF332/333/732/733		1.5	V	I_S = 4.5 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	400		ns	I_S = 5.5 A; dI_S/dt = 100 A/μS

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 5.0 mA
	MTM/MTP5N40	400			
	MTM/MTP5N35	350			
I_{DSS}	Zero Gate Voltage Drain Current		0.25	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V
			2.5	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 100°C
I_{GSS}	Gate-Body Leakage Current		± 500	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.5	V	I_D = 1.0 mA, V_{DS} = V_{GS}
		1.5	4.0	V	I_D = 1.0 mA, V_{DS} = V_{GS} T_C = 100°C
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]		1.0	Ω	V_{GS} = 10 V, I_D = 2.5 A
$V_{DS(on)}$	Drain-Source On-Voltage[2]		2.5	V	V_{GS} = 10 V, I_D = 2.5 A
			6.2	V	V_{GS} = 10 V, I_D = 5.0 A
			5.0	V	V_{GS} = 10 V, I_D = 2.5 A T_C = 100°C
g_{fs}	Forward Transconductance	2.0		S (℧)	V_{DS} = 10 V, I_D = 2.5 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		1200	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		300	pF	
C_{rss}	Reverse Transfer Capacitance		80	pF	
Switching Characteristics (T_C = 25°C, *Figures 12, 13*)[3]					
$t_{d(on)}$	Turn-On Delay Time		50	ns	V_{DD} = 25 V, I_D = 2.5 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		100	ns	
$t_{d(off)}$	Turn-Off Delay Time		200	ns	
t_f	Fall Time		100	ns	
Q_g	Total Gate Charge		30	nC	V_{GS} = 10 V, I_D = 7.0 A V_{DD} = 180 V

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figures 4-6 for IRF332/333/732/733 only.

Figure 1 Output Characteristics

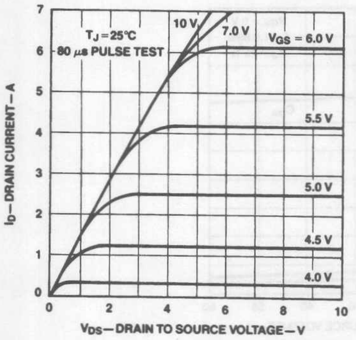


Figure 2 Static Drain to Source Resistance vs Drain Current

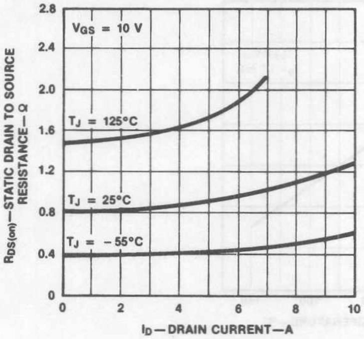


Figure 3 Transfer Characteristics

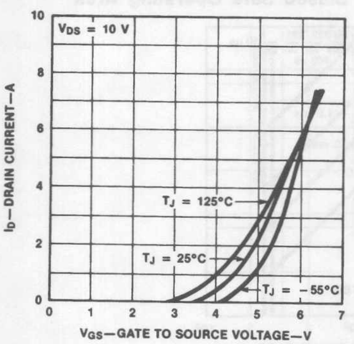


Figure 4 Output Characteristics

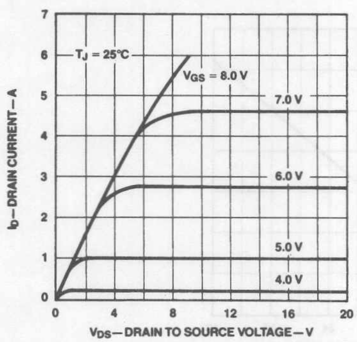


Figure 5 Static Drain to Source On-Resistance vs Drain Current

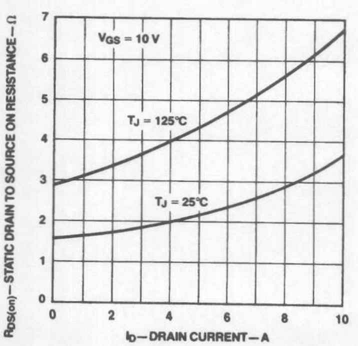
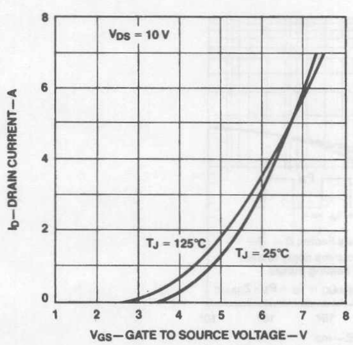


Figure 6 Transfer Characteristics



Typical Performance Curves (Cont.)

Figure 7 Temperature Variation of Gate to Source Threshold Voltage

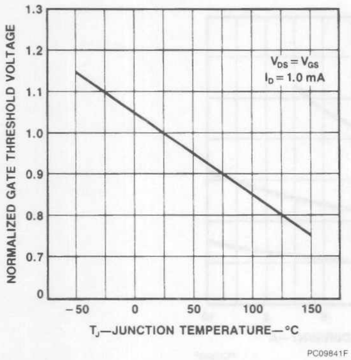


Figure 8 Capacitance vs Drain to Source Voltage

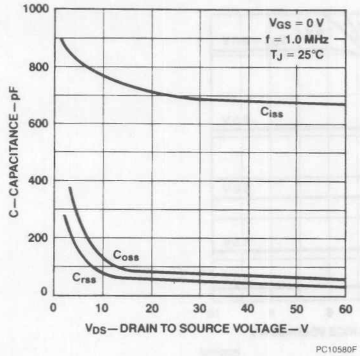


Figure 9 Gate to Source Voltage vs Total Gate Charge

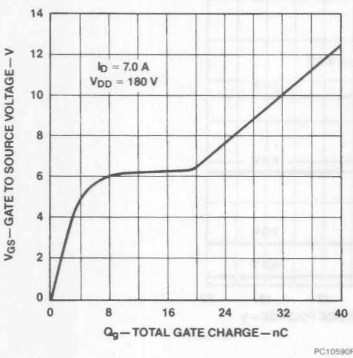


Figure 10 Forward Biased Safe Operating Area

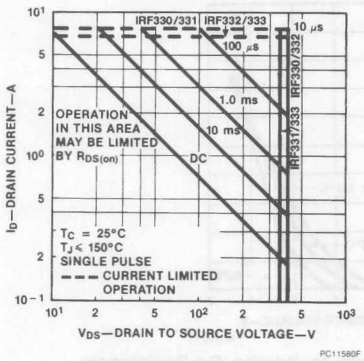
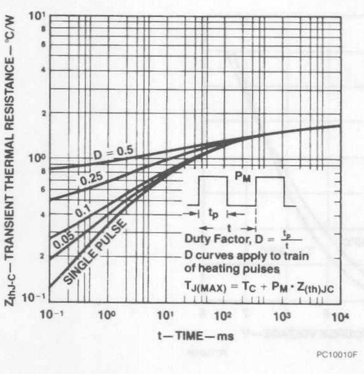


Figure 11 Transient Thermal Resistance



Typical Electrical Characteristics

Figure 12 Switching Test Circuit

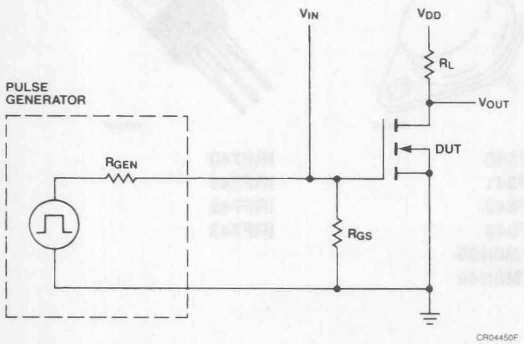
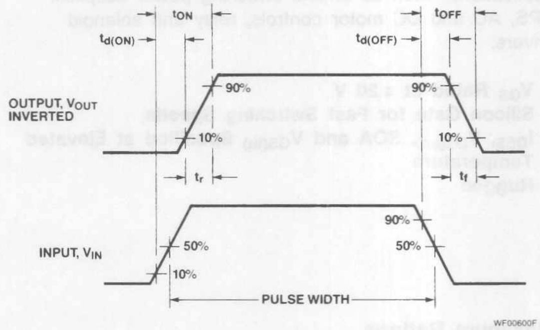


Figure 13 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF340-343/IRF740-743 MTM8N35/8N40 N-Channel Power MOSFETs, 10 A, 350 V/400 V

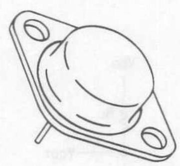
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

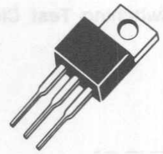
TO-204AA



IS00020F

IRF340
IRF341
IRF342
IRF343
MTM8N35
MTM8N40

TO-220AB



IS00010F

IRF740
IRF741
IRF742
IRF743

Maximum Ratings

Symbol	Characteristic	Rating IRF340/342 IRF740/742 MTM8N40	Rating IRF341/343 IRF741/743 MTM8N35	Unit
V_{DSS}	Drain to Source Voltage	400	350	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1.0$ MΩ	400	350	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction Temperature Storage Temperature	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF340/341 IRF740/741	IRF342/343 IRF742/743	MTM8N35 MTM8N40	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.55	0.80	0.55	Ω
I_D	Drain Current Continuous Pulsed	 10 40	 8 32	 8 48	A

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.0	1.0	0.83	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	125	125	150	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain-Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF340/342/740/742	400			
	IRF341/343/741/743	350			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current IRF340-343 IRF740-743		 ± 100 ± 500	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2] IRF340/341/740/741 IRF342/343/742/743		 0.55 0.80	Ω	V_{GS} = 10 V, I_D = 5.0 A
g_{fs}	Forward Transconductance	4.0		S (℧)	V_{DS} = 10 V, I_D = 5.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		1600	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		450	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	V_{DD} = 175 V, I_D = 5.0 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		15	ns	
$t_{d(off)}$	Turn-Off Delay Time		90	ns	
t_f	Fall Time		35	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 400 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF340/341/740/741 IRF342/343/742/743		 2.0 1.9	 V V	 I_S = 10 A; V_{GS} = 0 V I_S = 8 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	600		ns	I_S = 10 A; dI_S/dt = 100 A/μS

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain-Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 5.0 mA
	MTM8N40	400			
	MTM8N35	350			
I_{DSS}	Zero Gate Voltage Drain Current		0.25	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V
			2.5	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 100°C
I_{GSS}	Gate-Body Leakage Current		± 500	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.5	V	I_D = 1.0 mA, V_{DS} = V_{GS}
		1.5	4.0	V	I_D = 1.0 mA, V_{DS} = V_{GS} T_C = 100°C
$V_{DS(on)}$	Drain-Source On-Voltage[2]		2.2 5.3	V V	V_{GS} = 10 V; I_D = 4.0 A V_{GS} = 10 V; I_D = 8.0 A
			4.4	V	V_{GS} = 10 V, I_D = 4.0 A T_C = 100°C
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]		0.55	Ω	V_{GS} = 10 V, I_D = 4.0 A
g_{fs}	Forward Transconductance	3.0		S (℧)	V_{DS} = 10 V, I_D = 4.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		1800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		350	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)[3]					
$t_{d(on)}$	Turn-On Delay Time		60	ns	V_{DD} = 25 V, I_D = 4.0 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		150	ns	
$t_{d(off)}$	Turn-Off Delay Time		200	ns	
t_f	Fall Time		120	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 400 V

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ⩽ 80 μs, Duty cycle ⩽ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

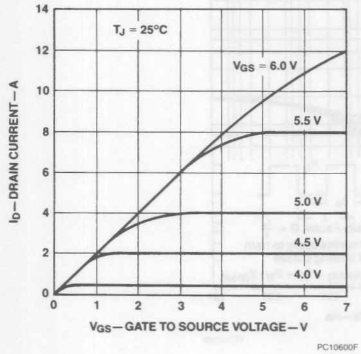


Figure 2 Static Drain to Source Resistance vs Drain Current

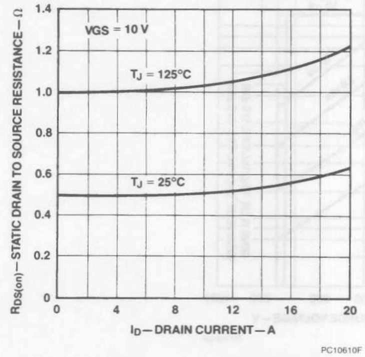


Figure 3 Transfer Characteristics

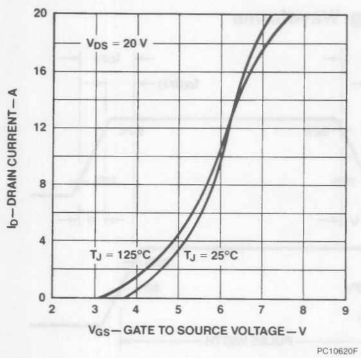


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

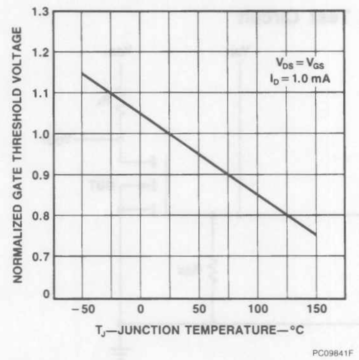


Figure 5 Capacitance vs Drain to Source Voltage

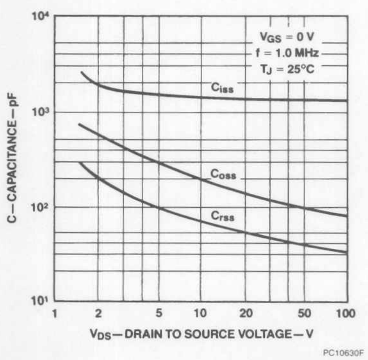
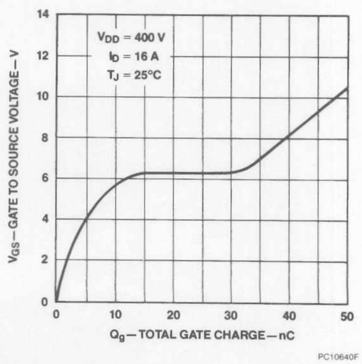


Figure 6 Gate to Source Voltage vs Total Gate Charge



Typical Performance Curves (Cont.)

Figure 7 Forward Biased Safe Operating Area

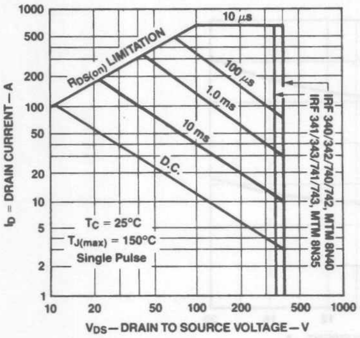
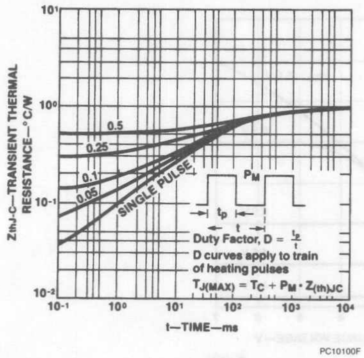


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

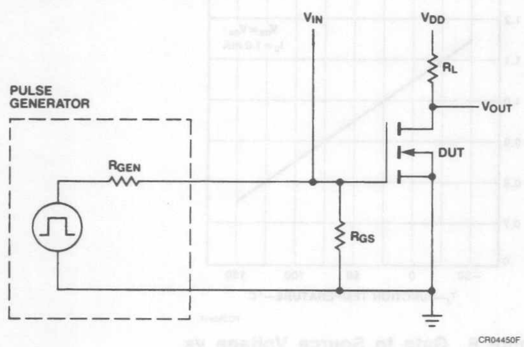
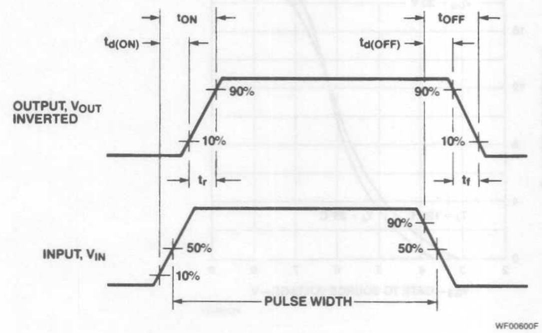


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF350-353 N-channel Power MOSFETs, 15 A, 350 V/400 V

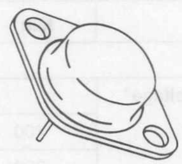
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

TO-204AA



IS00020F

IRF350
IRF351
IRF352
IRF353

Maximum Ratings

Symbol	Characteristic	Rating IRF350/352	Rating IRF351/353	Unit
V_{DSS}	Drain to Source Voltage	400	350	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 1.0\ M\Omega$	400	350	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF350/351	IRF352/353	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.3	0.4	Ω
I_D	Drain Current			A
	Continuous	15	13	
	Pulsed	60	52	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	150	150	W

Notes
For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0$ V, $I_D = 250$ μA
	IRF350/352	400			
	IRF351/353	350			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		±100	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 250$ μA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 8.0$ A
	IRF350/351		0.3		
	IRF352/353		0.4		
g_{fs}	Forward Transconductance	8.0		S (℧)	$V_{DS} = 10$ V, $I_D = 8.0$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		3000	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V, f = 1.0 MHz
C_{oss}	Output Capacitance		600	pF	
C_{rss}	Reverse Transfer Capacitance		200	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	$V_{DD} = 180$ V, $I_D = 8.0$ A, $V_{GS} = 10$ V, $R_{GEN} = 4.7$ Ω, $R_{GS} = 4.7$ Ω
t_r	Rise Time		65	ns	
$t_{d(off)}$	Turn-Off Delay Time		150	ns	
t_f	Fall Time		75	ns	
Q_g	Total Gate Charge		120	nC	$V_{GS} = 10$ V, $I_D = 16$ A, $V_{DD} = 400$ V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF350/351		1.6	V	$I_S = 15$ A; $V_{GS} = 0$ V
	IRF352/353		1.5	V	$I_S = 13$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time	600		ns	$I_S = 15$ A; $dI_S/dt = 100$ A/μS

Notes

1. $T_J = +25°C$ to $+150°C$
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%

Typical Performance Curves

Figure 1 Output Characteristics

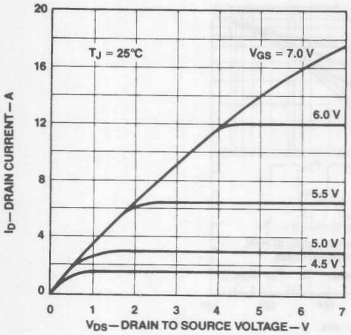


Figure 2 Static Drain to Source On Resistance vs Drain Current

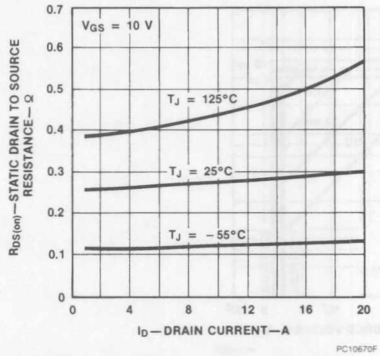


Figure 3 Transfer Characteristics

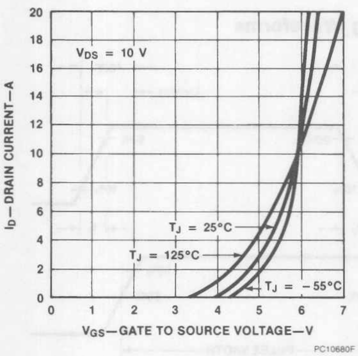


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

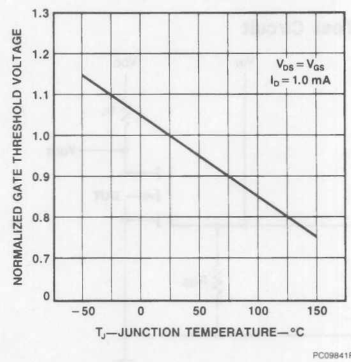


Figure 5 Capacitance vs Drain to Source Voltage

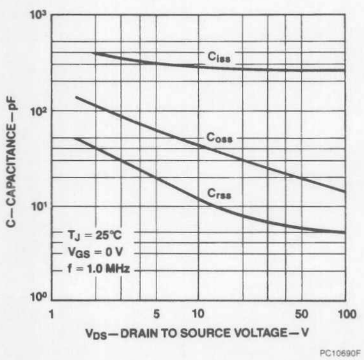
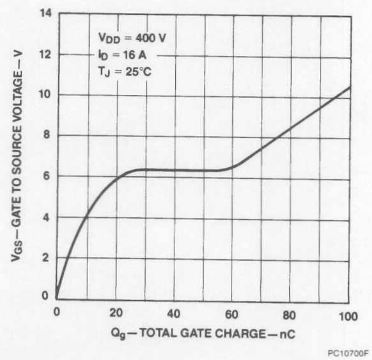


Figure 6 Gate to Source Voltage vs Total Gate Charge



Typical Performance Curves (Cont.)

Figure 7 Forward Biased Safe Operating Area

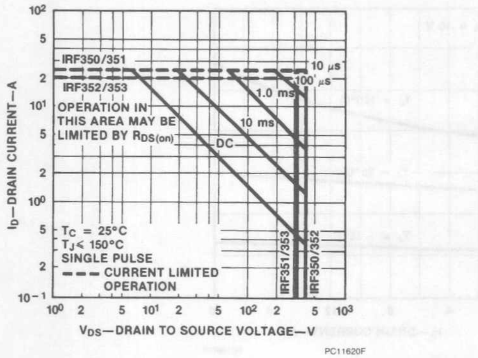
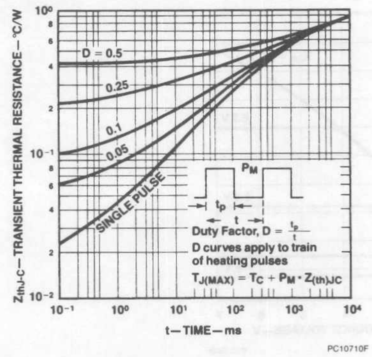


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

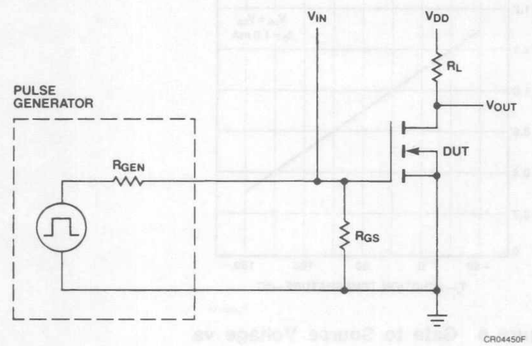
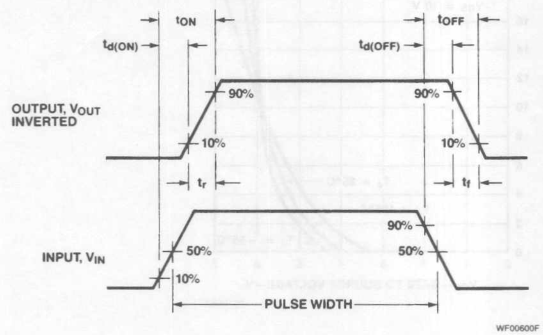


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF420-423/IRF820-823 MTP2N45/2N50 N-Channel Power MOSFETs, 3.0 A, 450 V/500 V

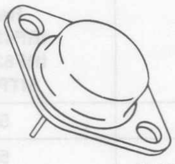
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ± 20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

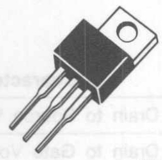
TO-204AA



IS00020F

IRF420
IRF421
IRF422
IRF423

TO-220AB



IS00010F

IRF820
IRF821
IRF822
IRF823
MTP2N45
MTP2N50

Product Summary

Part Number	V_{DSS}	$R_{DS(on)}$	I_D at $T_C = 25°C$	I_D at $T_C = 100°C$	Case Style
IRF420	500 V	3.0 Ω	2.5 A	1.5 A	TO-204AA
IRF421	450 V	3.0 Ω	2.5 A	1.5 A	
IRF422	500 V	4.0 Ω	2.0 A	1.0 A	
IRF423	450 V	4.0 Ω	2.0 A	1.0 A	
IRF820	500 V	3.0 Ω	2.5 A	1.5 A	TO-220AB
IRF821	450 V	3.0 Ω	2.5 A	1.5 A	
IRF822	500 V	4.0 Ω	2.0 A	1.0 A	
IRF823	450 V	4.0 Ω	2.0 A	1.0 A	
MTP2N45	450 V	4.0 Ω	3.0 A	2.0 A	
MTP2N50	500 V	4.0 Ω	3.0 A	2.0 A	

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Maximum Ratings

Symbol	Characteristic	Rating IRF420/422 IRF820/822 MTP2N50	Rating IRF421/423 IRF821/823 MTP2N45	Unit
V_{DSS}	Drain to Source Voltage[1]	500	450	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	500	450	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum Thermal Characteristics

		IRF420-423/ IRF820-823	MTP2N45/2N50	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	3.12	1.67	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	30/80	80	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	40	75	W
I_{DM}	Pulsed Drain Current[2]	10	10	A

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0\ V$, $I_D = 250\ \mu A$
	IRF420/422/820/822/ MTP2N50	500			
	IRF421/423/821/823/ MTP2N45	450			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0\ V$
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0\ V$, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current			nA	$V_{GS} = \pm 20\ V$, $V_{DS} = 0\ V$
	IRF420-423		±100		
	IRF820-823/MTP2N45/50		±500		

Electrical Characteristics (Cont.) ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF420-423/IRF820-823	2.0	4.0		$I_D = 250\ \mu A$, $V_{DS} = V_{GS}$
	MTP2N45/MTP2N50	2.0	4.5		$I_D = 1.0\ mA$, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10\ V$, $I_D = 1.0\ A$
	IRF420/421/820/821		3.0		
	IRF422/423/822/823		4.0		
	MTP2N45/50		4.0		
$V_{DS(on)}$	Drain-Source On-Voltage[2]				
	MTP2N45/50		10	V	$V_{GS} = 10\ V$; $I_D = 2.0\ A$
			8	V	$V_{GS} = 10\ V$; $I_D = 1.0\ A$ $T_C = 100°C$
g_{fs}	Forward Transconductance	1.0		S (℧)	$V_{DS} = 10\ V$, $I_D = 1.0\ A$
Dynamic Characteristics					
C_{iss}	Input Capacitance		400	pF	$V_{DS} = 25\ V$, $V_{GS} = 0\ V$ f = 1.0 MHz
C_{oss}	Output Capacitance		100	pF	
C_{rss}	Reverse Transfer Capacitance		40	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 1, 2*)[3]					
$t_{d(on)}$	Turn-On Delay Time		40	ns	$V_{DD} = 250\ V$, $I_D = 1.0\ A$ $V_{GS} = 10\ V$, $R_{GEN} = 50\ \Omega$ $R_{GS} = 50\ \Omega$
t_r	Rise Time		50	ns	
$t_{d(off)}$	Turn-Off Delay Time		60	ns	
t_f	Fall Time		60	ns	
Q_g	Total Gate Charge		15	nC	$V_{GS} = 10\ V$, $I_D = 3.0\ A$ $V_{DD} = 200\ V$

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage		1.4	V	$I_S = 2.5\ A$; $V_{GS} = 0\ V$
			1.3	V	$I_S = 2.0\ A$; $V_{GS} = 0\ V$
t_{rr}	Reverse Recovery Time	600		ns	$I_S = 2.5\ A$; $dI_S/dt = 100\ A/\mu S$

Notes

1. $T_J = +25°C$ to $+150°C$
2. Pulse width limited by T_J
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Electrical Characteristics

Figure 1 Switching Test Circuit

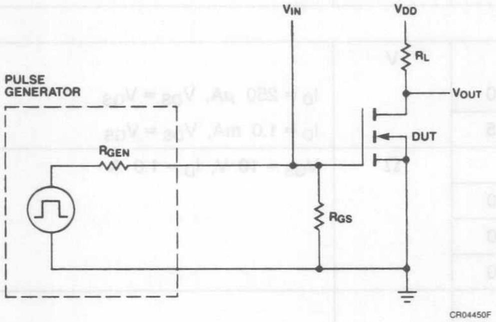
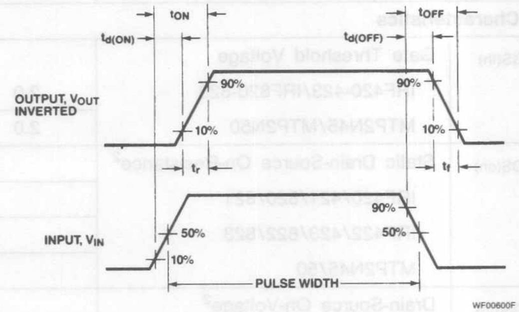


Figure 2 Switching Waveforms



Typical Performance Curves

Figure 3 Output Characteristics

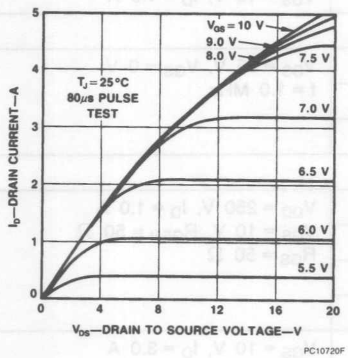


Figure 4 Static Drain to Source Resistance vs Drain Current

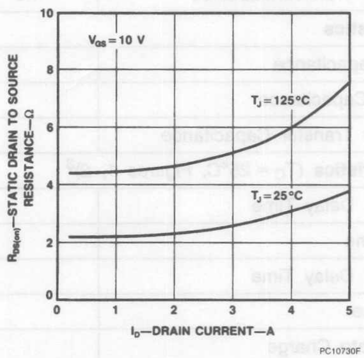


Figure 5 Transfer Characteristics

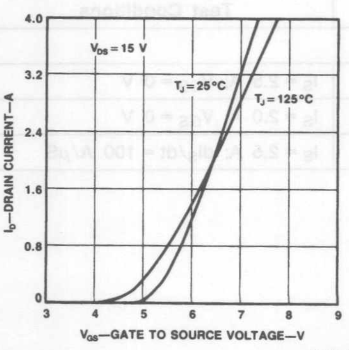
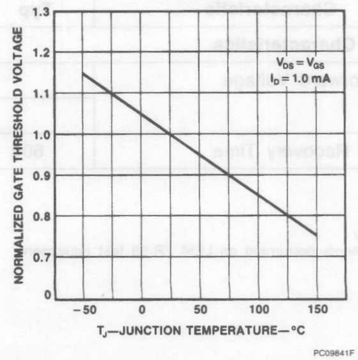


Figure 6 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 7 Capacitance vs Drain to Source Voltage

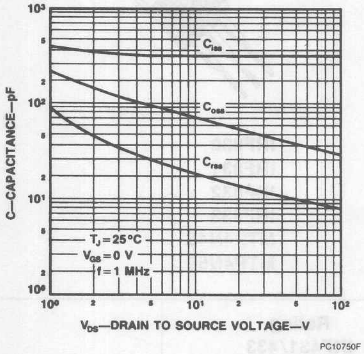


Figure 8 Gate to Source Voltage vs Total Gate Charge

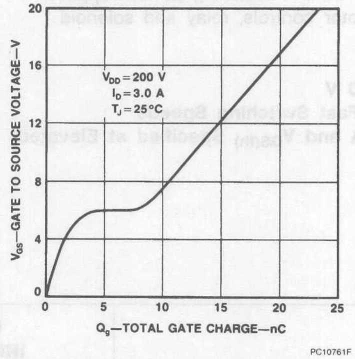


Figure 9 Forward Biased Safe Operating Area for IRF420-423 and IRF820-823

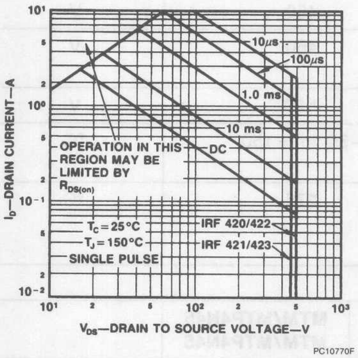


Figure 10 Transient Thermal Resistance vs Time for IRF420-423 and IRF820-823

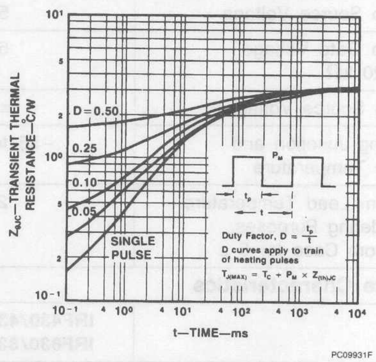


Figure 11 Forward Biased Safe Operating Area for MTP2N45/2N50

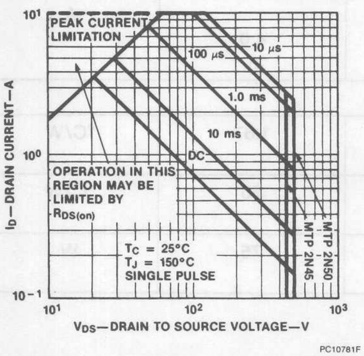
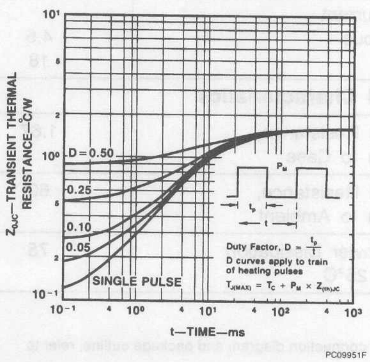


Figure 12 Transient Thermal Resistance vs Time for MTP2N45/2N50



N-Channel Power MOSFETs, 4.5 A, 450 V/500 V

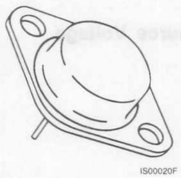
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

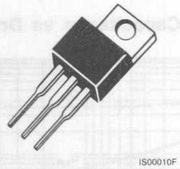
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

TO-204AA



IRF430
IRF431
IRF432
IRF433
MTM4N45
MTM4N50

TO-220AB



IRF830
IRF831
IRF832
IRF833
MTP4N45
MTP4N50

Maximum Ratings

Symbol	Characteristic	Rating IRF430/432 IRF830/832 MTM/MTP4N50	Rating IRF431/433 IRF831/833 MTM/MTP4N45	Unit
V_{DSS}	Drain to Source Voltage	500	450	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 20\ k\Omega$	500	450	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperature	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

Symbol	Characteristic	IRF430/431 IRF830/831	IRF432/433 IRF832/833	MTM/MTP4N45 MTM/MTP4N45	Unit
$R_{DS(on)}$	Static Drain-to-Source On Resistance	1.5	2.0	1.5	Ω
I_D	Drain Current Continuous Pulsed	4.5 18	4.0 16	4.0 10	A

Maximum Thermal Characteristics

Symbol	Characteristic	IRF430/431 IRF830/831	IRF432/433 IRF832/833	MTM/MTP4N45 MTM/MTP4N45	Unit
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.67	1.67	1.67	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	60	60	60	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	75	75	75	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF430/432/830/832	500			
	IRF431/433/831/833	450			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current			nA	V_{GS} = ± 20 V, V_{DS} = 0 V
	IRF430-433		± 100		
	IRF830-833		± 500		
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 2.5 A
	IRF430/431/830/831		1.5		
	IRF432/433/832/833		2.0		
g_{fs}	Forward Transconductance	2.5		S (℧)	V_{DS} = 10 V, I_D = 2.5 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		200	pF	
C_{rss}	Reverse Transfer Capacitance		60	pF	
Switching Characteristics (T_C = 25°C, *Figures 12, 13*)					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 225 V, I_D = 2.5 A V_{GS} = 10 V, R_{GEN} = 15 Ω R_{GS} = 15 Ω
t_r	Rise Time		30	ns	
$t_{d(off)}$	Turn-Off Delay Time		55	ns	
t_f	Fall Time		30	ns	
Q_g	Total Gate Charge		30	nC	V_{GS} = 10 V, I_D = 7.0 A V_{DS} = 180 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF430/431/830/831		1.4	V	I_S = 4.5 A; V_{GS} = 0 V
	IRF432/433/832/833		1.3	V	I_S = 4.0 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	600		ns	I_S = 4.5 A; dI_S/dt = 100 A/μS

Notes

1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 5.0 mA
	MTM/MTP4N50	500			
	MTM/MTP4N45	450			
I_{DSS}	Zero Gate Voltage Drain Current		0.25	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V
			2.5	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 100°C
I_{GSS}	Gate-Body Leakage Current		± 500	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.5	V	I_D = 1.0 mA, V_{DS} = V_{GS}
		1.5	4.0	V	I_D = 1.0 mA, V_{DS} = V_{GS}, T_C = 100°C
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]		1.5	Ω	V_{GS} = 10 V, I_D = 2.0 A
$V_{DS(on)}$	Drain-Source On-Voltage[2]		3.0	V	V_{GS} = 10 V, I_D = 2.0 V
			7.0	V	V_{GS} = 10 V, I_D = 4.0 A
			6.0	V	V_{GS} = 10 V, I_D = 4.0 A T_C = 100°C
g_{fs}	Forward Transconductance	2.0		S (℧)	V_{DS} = 10 V, I_D = 2.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		1200	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		300	pF	
C_{rss}	Reverse Transfer Capacitance		80	pF	
Switching Characteristics (T_C = 25°C, *Figures 12, 13*)[3]					
$t_{d(on)}$	Turn-On Delay Time		50	ns	V_{DD} = 25 V, I_D = 2.0 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		100	ns	
$t_{d(off)}$	Turn-Off Delay Time		200	ns	
t_f	Fall Time		100	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 7.0 A V_{DD} = 180 V

Notes

1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ⩽ 80 μs, Duty cycle ⩽ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves Figures 4-6 for IRF 432/433/832/833 only.

Figure 1 Output Characteristics

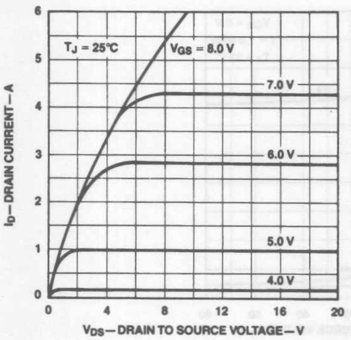


Figure 2 Static Drain to Source Resistance vs Drain Current

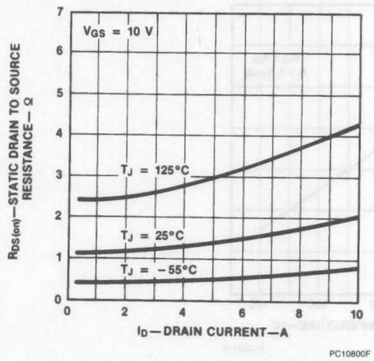


Figure 3 Transfer Characteristics

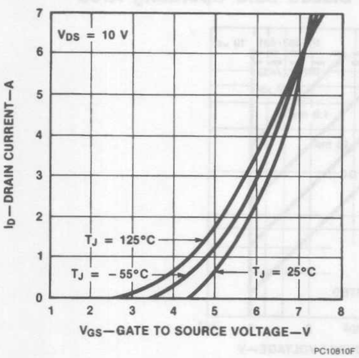


Figure 4 Output Characteristics

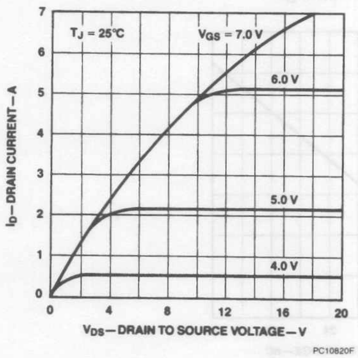


Figure 5 Static Drain to Source On Resistance vs Drain Current

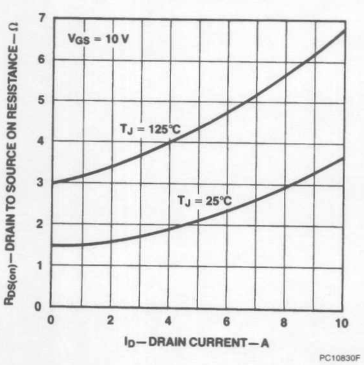
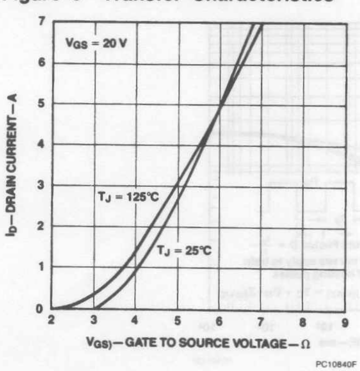


Figure 6 Transfer Characteristics



Typical Performance Curves (Cont.)

Figure 7 Temperature Variation of Gate to Source Threshold Voltage

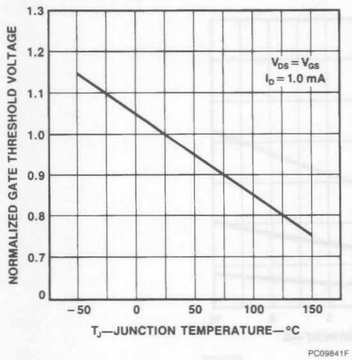


Figure 8 Capacitance vs Drain to Source Voltage

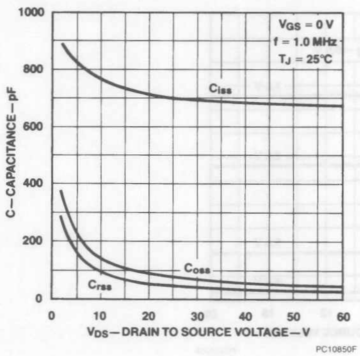


Figure 9 Gate to Source Voltage vs Total Gate Charge

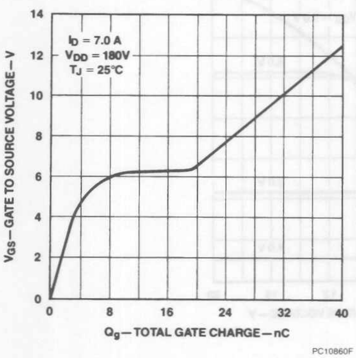


Figure 10 Forward Biased Safe Operating Area

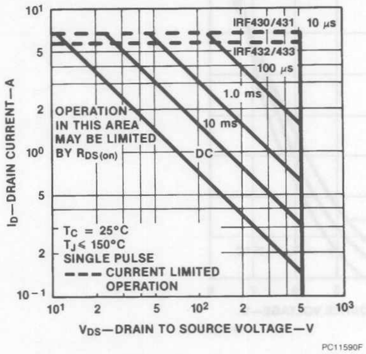
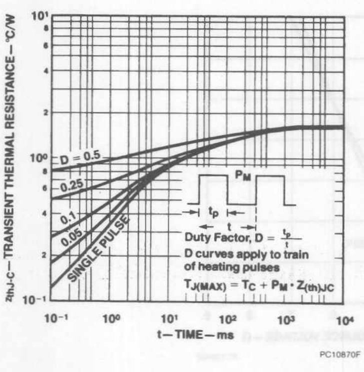


Figure 11 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 12 Switching Test Circuit

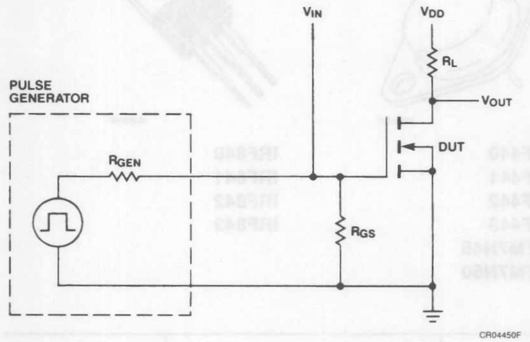
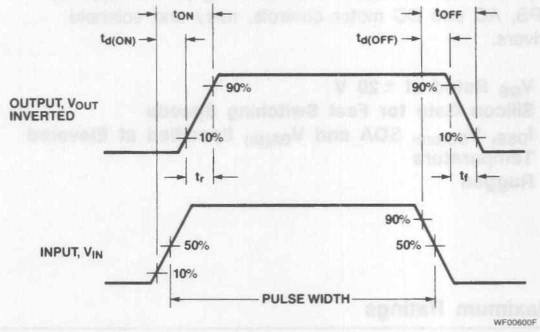


Figure 13 Switching Waveforms



FAIRCHILD
A Schlumberger Company

IRF440-443/IRF840-843 MTM7N45/7N50 N-Channel Power MOSFETs, 8 A, 450 V/500 V

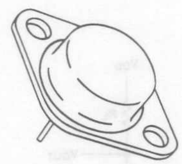
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

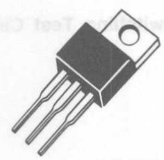
TO-204AA



IS00020F

IRF440
IRF441
IRF442
IRF443
MTM7N45
MTM7N50

TO-220AB



IS00010F

IRF840
IRF841
IRF842
IRF843

Maximum Ratings

Symbol	Characteristic	Rating IRF440/442 IRF840/842 MTM7N50	Rating IRF441/443 IRF841/843 MTM7N45	Unit
V_{DSS}	Drain to Source Voltage	500	450	V
V_{DGR}	Drain to Gate Voltage $R_{GS} = 20\ k\Omega$	500	450	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperature	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF440/441 IRF840/841	IRF442/443 IRF842/843	MTM7N45 MTM7N50	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.85	1.1	0.8	Ω
I_D	Drain Current Continuous Pulsed	 8 32	 7 28	 7 40	A

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.0	1.0	0.83	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	60	60	60	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	125	125	150	W

Notes
For information concerning connection diagram and package outline, refer to Section 7.

2

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 250 μA
	IRF440/442/840/842	500			
	IRF441/443/842/843	450			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = 0.8 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current			nA	V_{GS} = ± 20 V, V_{DS} = 0 V
	IRF440-443		± 100		
	IRF840-843		± 500		
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	I_D = 250 μA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 4.0 A
	IRF440/441/840/841		0.85		
	IRF442/443/842/843		1.10		
g_{fs}	Forward Transconductance	4.0		S (℧)	V_{DS} = 10 V, I_D = 4.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		1600	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		350	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	V_{DD} = 220 V, I_D = 4.0 A V_{GS} = 10 V, R_{GEN} = 4.7 Ω R_{GS} = 4.7 Ω
t_r	Rise Time		15	ns	
$t_{d(off)}$	Turn-Off Delay Time		90	ns	
t_f	Fall Time		30	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 400 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF440/441/840/841		2.0	V	I_S = 8.0 A; V_{GS} = V
	IRF442/443/842/843		1.9	V	I_S = 7.0 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	700		ns	I_S = 8.0 A; dI_S/dt = 100 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	V_{GS} = 0 V, I_D = 5.0 mA
	MTM7N50	500			
	MTM7N45	450			
I_{DSS}	Zero Gate Voltage Drain Current		0.25	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V
			2.5	mA	V_{DS} = 0.85 x Rated V_{DSS}, V_{GS} = 0 V, T_C = 100°C
I_{GSS}	Gate-Body Leakage Current		± 500	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.5	V	I_D = 1.0 mA, V_{DS} = V_{GS}
		1.5	4.0	V	I_D = 1.0 mA, V_{DS} = V_{GS} T_C = 100°C
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]		0.8	Ω	V_{GS} = 10 V, I_D = 3.5 A
$V_{DS(on)}$	Drain-Source On-Voltage[2]		2.8	V	V_{GS} = 10 V, I_D = 3.5 A
			7.0	V	V_{GS} = 10 V, I_D = 7.0 A
			5.6	V	V_{GS} = 10 V, I_D = 3.5 A T_C = 100°C
g_{fs}	Forward Transconductance	4.0		S (℧)	V_{DS} = 10 V, I_D = 4.0 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		1800	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		350	pF	
C_{rss}	Reverse Transfer Capacitance		150	pF	
Switching Characteristics (T_C = 25°C, *Figures 9, 10*)[3]					
$t_{d(on)}$	Turn-On Delay Time		60	ns	V_{DD} = 25 V, I_D = 3.5 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		150	ns	
$t_{d(off)}$	Turn-Off Delay Time		200	ns	
t_f	Fall Time		120	ns	
Q_g	Total Gate Charge		60	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 400 V

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

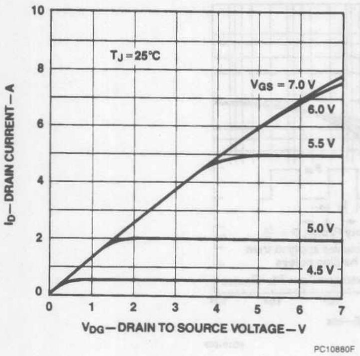


Figure 2 Static Drain to Source Resistance vs Drain Current

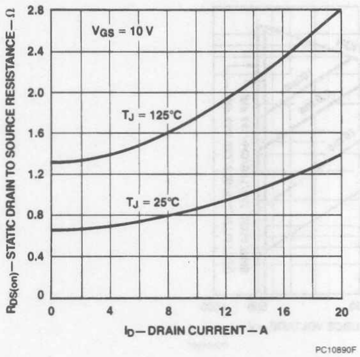


Figure 3 Transfer Characteristics

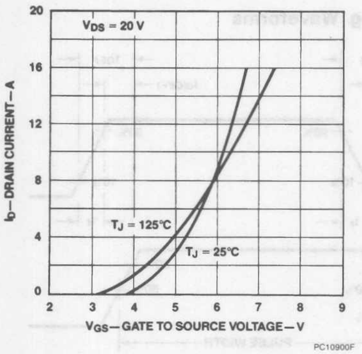


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

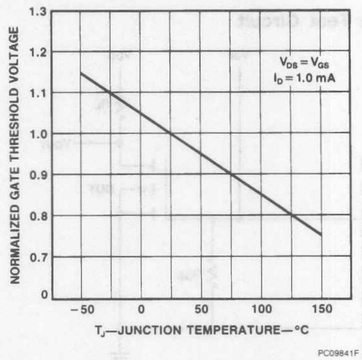


Figure 5 Capacitance vs Drain to Source Voltage

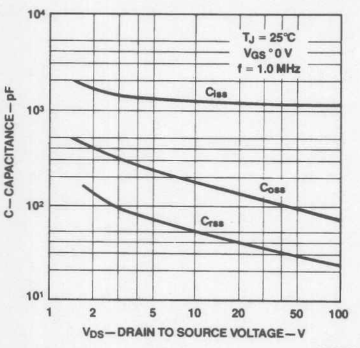
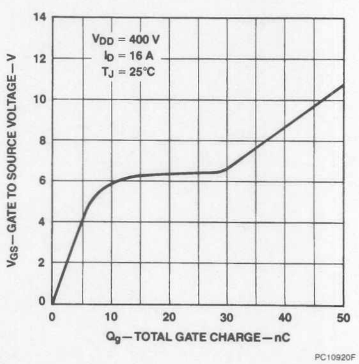


Figure 6 Gate to Source Voltage vs Total Gate Charge



Typical Performance Curves (Cont.)

Figure 7 Forward Biased Safe Operating Area Curves

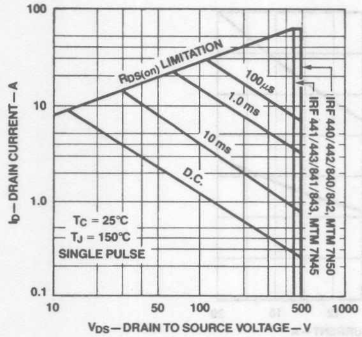
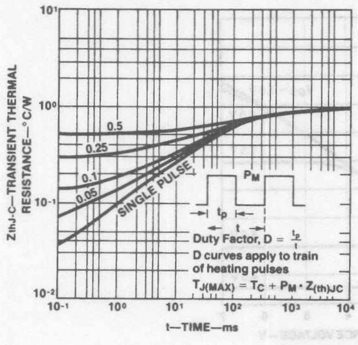


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

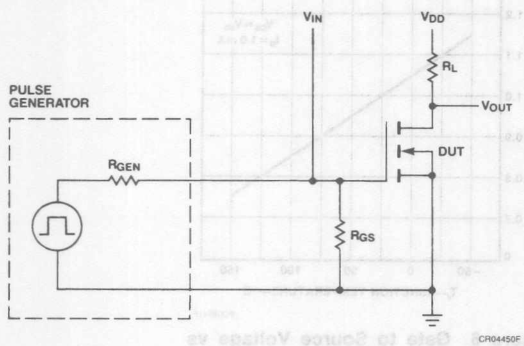
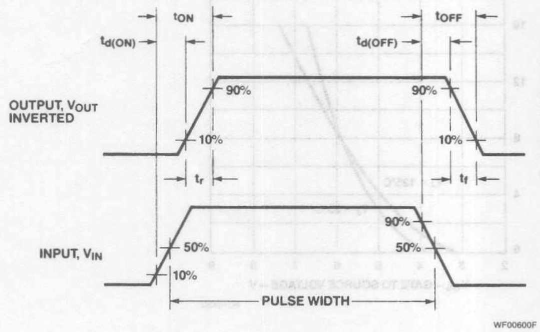


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF450-453
N-Channel Power MOSFETs, 15 A, 450 V/500 V

Power And Discrete Division

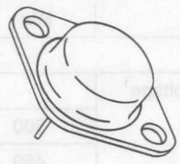
2

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high voltage, high speed applications, such as off-line switching power supplies, UPS, AC and DC motor controls, relay and solenoid drivers.

- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, SOA and $V_{GS(th)}$ Specified at Elevated Temperature**
- **Rugged**

TO-204AA



IRF450
IRF451
IRF452
IRF453

Maximum Ratings

Symbol	Characteristic	Rating IRF450/452	Rating IRF451/453	Unit
V_{DSS}	Drain to Source Voltage	500	450	V
V_{DGR}	Drain to Gate Voltage R_{GS} = 20 kΩ	500	450	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	-55 to +150	-55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF450/451	IRF452/453	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.4	0.5	Ω
I_D	Drain Current			A
	Continuous	13	12	
	Pulsed	52	48	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	0.83	0.83	°C/W
P_D	Total Power Dissipation at T_C = 25°C	150	150	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0$ V, $I_D = 250$ μA
	IRF450/452	500			
	IRF451/453	450			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		±100	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.0	4.0	V	$I_D = 250$ μA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 7.0$ A
	IRF450/451		0.4		
	IRF452/453		0.5		
g_{fs}	Forward Transconductance	6.0		S (℧)	$V_{DS} = 10$ V, $I_D = 7.0$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		3000	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V
C_{oss}	Output Capacitance		600	pF	f = 1.0 MHz
C_{rss}	Reverse Transfer Capacitance		200	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 9, 10*)					
$t_{d(on)}$	Turn-On Delay Time		35	ns	$V_{DD} = 210$ V, $I_D = 7.0$ A
t_r	Rise Time		50	ns	$V_{GS} = 10$ V, $R_{GEN} = 4.7$ Ω
$t_{d(off)}$	Turn-Off Delay Time		150	ns	$R_{GS} = 4.7$ Ω
t_f	Fall Time		70	ns	
Q_g	Total Gate Charge		120	nC	$V_{GS} = 10$ V, $I_D = 16$ A, $V_{DD} = 400$ V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF450/451		1.4	V	$I_S = 13$ A; $V_{GS} = 0$ V
	IRF452/453		1.3	V	$I_S = 12$ A; $V_{GS} = 0$ V
t_{rr}	Reverse Recovery Time	800		ns	$I_F = 13$ A; $dI_F/dt = 100$ A/μS

Notes

1. $T_J = +25°C$ to $+150°C$
2. Pulse test: Pulse width ≤ 20 μs, Duty cycle ≤ 1%

2

Typical Performance Curves

Figure 1 Output Characteristics

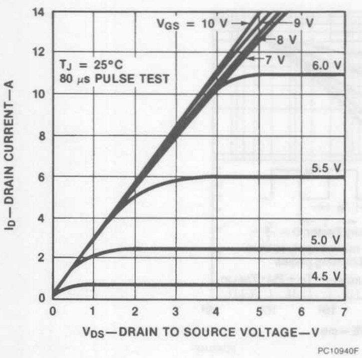


Figure 2 Static Drain to Source Resistance vs Drain Current

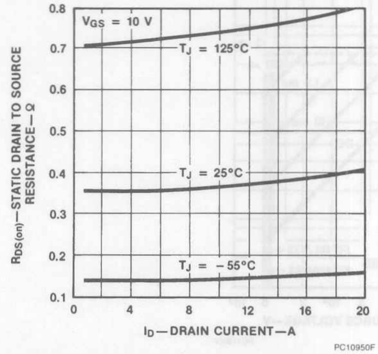


Figure 3 Transfer Characteristics

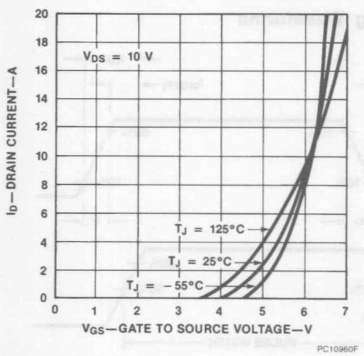


Figure 4 Temperature Variation of Gate to Source Threshold Voltage

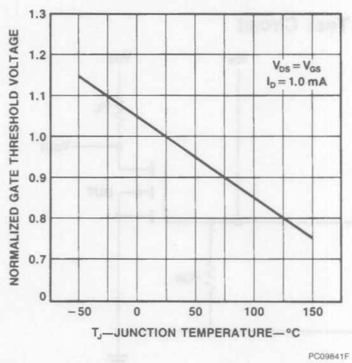


Figure 5 Capacitance vs Drain to Source Voltage

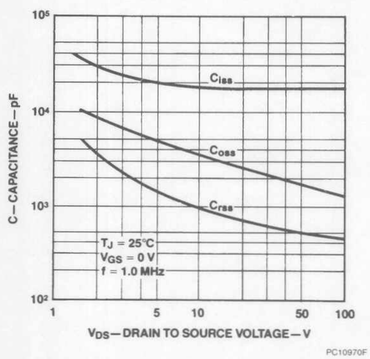
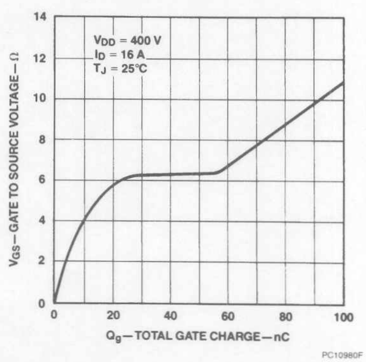


Figure 6 Gate to Source Voltage vs Total Gate Charge



Typical Performance Curves (Cont.)

Figure 7 Forward Biased Safe Operating Area

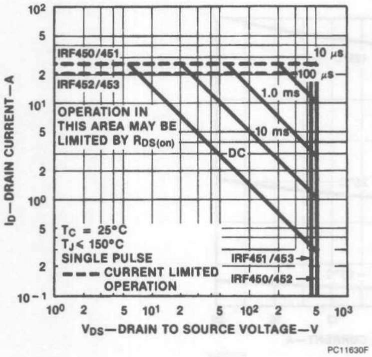
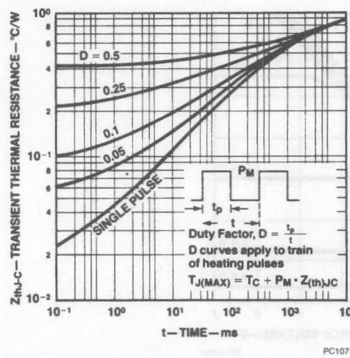


Figure 8 Transient Thermal Resistance vs Time



Typical Electrical Characteristics

Figure 9 Switching Test Circuit

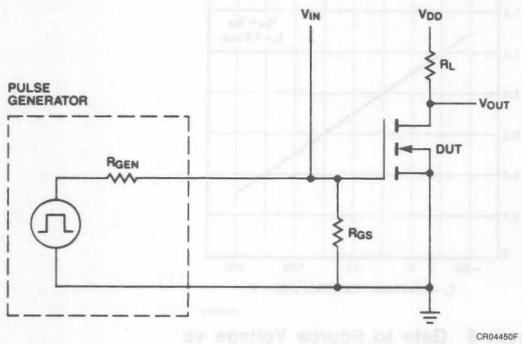
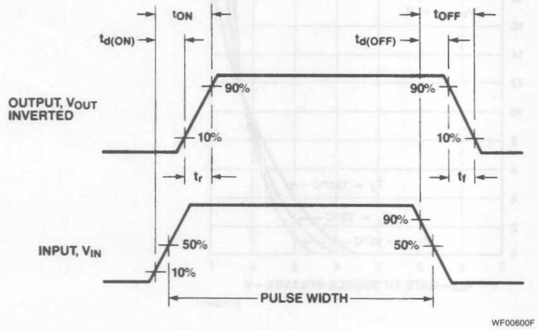


Figure 10 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF510-513
MTP4N08/4N10
N-Channel Power MOSFETs, 5.5 A, 60-100 V

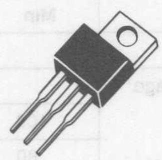
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-220AB



IS00010F

IRF510
IRF511
IRF512
IRF513
MTP4N08
MTP4N10

Maximum Ratings

Symbol	Characteristic	Rating IRF510/512 MTP4N10	Rating MTP4N08	Rating IRF511/513	Unit
V_{DSS}	Drain to Source Voltage[1]	100	80	60	V
V_{DGR}	Drain to Gate Voltage[1] $R_{GS} = 20\ k\Omega$	100	80	60	V
V_{GS}	Gate to Source Voltage	±20	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	275	°C

Maximum On-State Characteristics

		IRF510/511	IRF512/513	MTP4N08/10	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.60	0.80	0.80	Ω
I_D	Drain Current				A
	Continuous at $T_C = 25°C$	4.0	3.5	5.0	
	Continuous at $T_C = 100°C$	2.5	2.0	3.5	
	Pulsed	16	14	14	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	6.4	6.4	2.5	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	80	80	80	°C/W
P_D	Total Power Dissipation at $T_C = 25°C$	20	20	50	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0$ V, $I_D = 250$ μA
	IRF510/512/MTP4N10	100			
	MTP4N08	80			
	IRF511/513	60			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		±500	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF510-513	2.0	4.0		$I_D = 250$ μA, $V_{DS} = V_{GS}$
	MTP4N08/10	2.0	4.5		$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 2.0$ A
	IRF510/511		0.60		
	IRF512/513/MTP4N08/4N10		0.80		
$V_{DS(on)}$	Drain-Source On-Voltage[2]		4.8	V	$V_{GS} = 10$ V; $I_D = 4.0$ A
	MTP4N08/4N10		3.2	V	$V_{GS} = 10$ V; $I_D = 2.0$ A; $T_C = 100°C$
g_{fs}	Forward Transconductance	1.0		S (℧)	$V_{DS} = 10$ V, $I_D = 2.0$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		200	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{oss}	Output Capacitance		100	pF	
C_{rss}	Reverse Transfer Capacitance		30	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 11, 12*)[3]					
$t_{d(on)}$	Turn-On Delay Time		20	ns	$V_{DD} = 50$ V, $I_D = 2.0$ A $V_{GS} = 10$ V, $R_{GEN} = 50$ Ω $R_{GS} = 50$ Ω
t_r	Rise Time		25	ns	
$t_{d(off)}$	Turn-Off Delay Time		25	ns	
t_f	Fall Time		20	ns	
Q_g	Total Gate Charge		7.5	nC	$V_{GS} = 10$ V, $I_D = 8.0$ A $V_{DD} = 40$ V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage			V	
	IRF510/511		2.5		I_S = 4.0 A; V_{GS} = 0 V
	IRF512/513		2.0		I_S = 3.5 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	230		ns	I_S = 4.0 A; dI_S/dt = 25 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

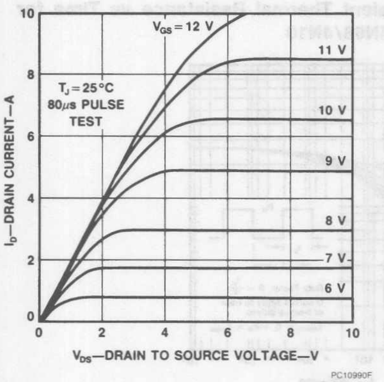


Figure 2 Static Drain to Source Resistance vs Drain Current

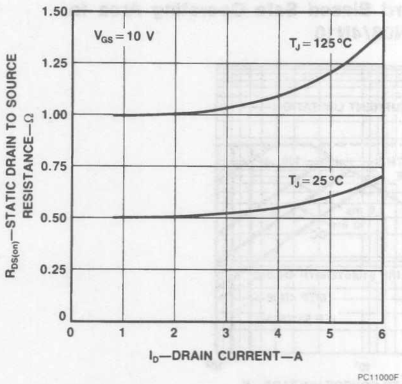


Figure 3 Transfer Characteristics

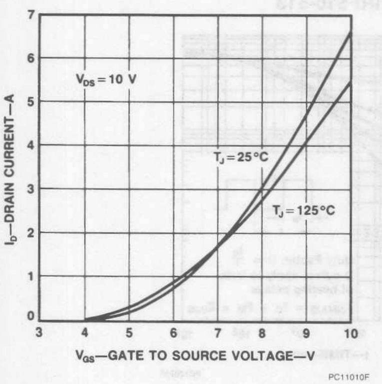
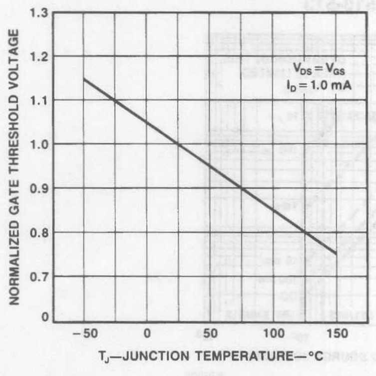


Figure 4 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 5 Capacitance vs Drain to Source Voltage

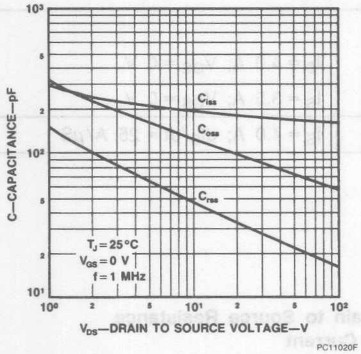


Figure 6 Gate to Source Voltage vs Total Gate Charge

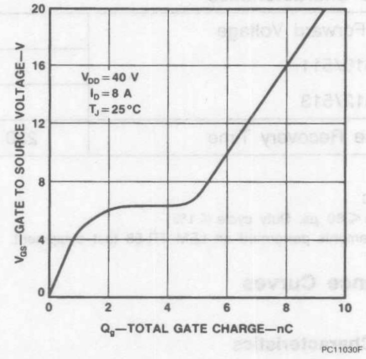


Figure 7 Forward Biased Safe Operating Area for MTP4N08/4N10

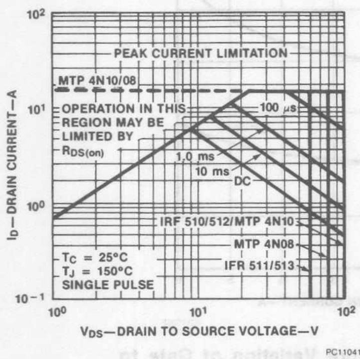


Figure 8 Transient Thermal Resistance vs Time for MTP4N08/4N10

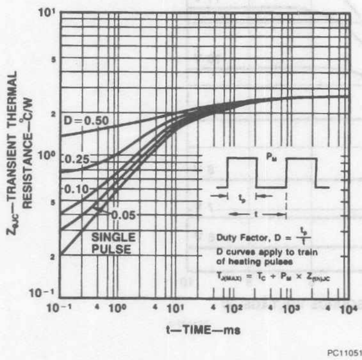


Figure 9 Forward Biased Safe Operating Area for IRF510-513

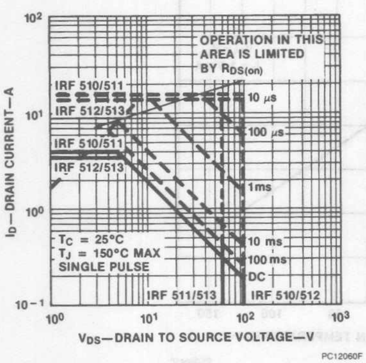
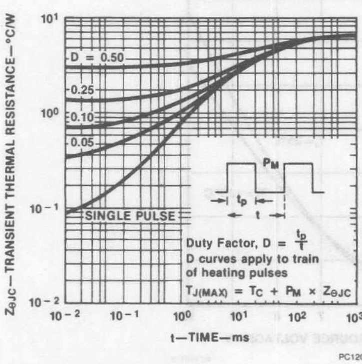


Figure 10 Transient Thermal Resistance vs Time for IRF510-513



Typical Electrical Characteristics

Figure 11 Switching Test Circuit

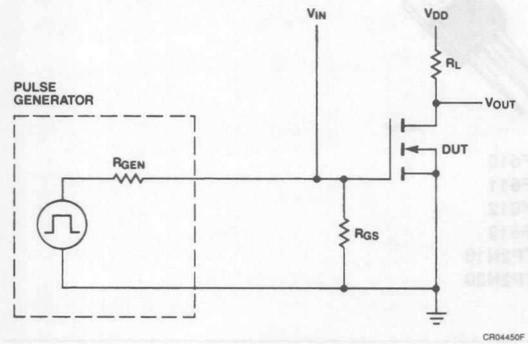
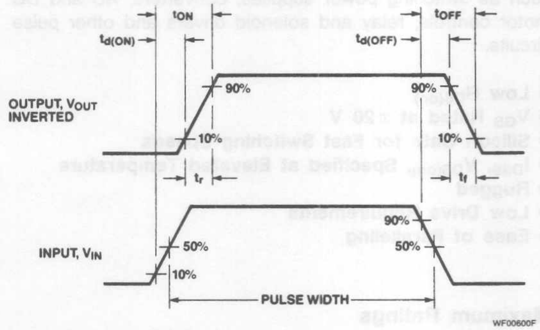


Figure 12 Switching Waveforms



FAIRCHILD
A Schlumberger Company

IRF610-613
MTP2N18/2N20
N-Channel Power MOSFETs, 3.5 A, 150-200 V

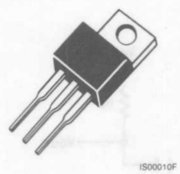
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid drivers and other pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-220AB



IRF610
IRF611
IRF612
IRF613
MTP2N18
MTP2N20

Maximum Ratings

Symbol	Characteristic	Rating IRF610/612 MTP2N20	Rating MTP2N18	Rating IRF611/613	Unit
V_{DSS}	Drain to Source Voltage[1]	200	180	150	V
V_{DGR}	Drain to Gate Voltage[1] R_{GS} = 20 kΩ	200	180	150	V
V_{GS}	Gate to Source Voltage	±20	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	275	°C

Maximum On-State Characteristics

		IRF610/611	MTP2N18/20	IRF612/613	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	1.5	1.8	2.4	Ω
I_D	Drain Current				A
	Continuous at T_C = 25°C	2.5	3.25	2.0	
	Continuous at T_C = 100°C	1.5	2.25	1.25	
	Pulsed	10	9.0	8.0	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	6.4	2.5	6.4	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	80	80	80	°C/W
P_D	Total Power Dissipation at T_C = 25°C	20	50	20	W

Notes
For information concerning connection diagram and package outline, refer to Section 7.

2

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0$ V, $I_D = 250$ μA
	IRF610/612/MTP2N20	200			
	MTP2N18	180			
	IRF611/613	150			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			1000	μA	$V_{DS} = 0.8 \times$ Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		± 500	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF610-613	2.0	4.0		$I_D = 250$ μA, $V_{DS} = V_{GS}$
	MTP2N18/20	2.0	4.5		$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 1.25$ A
	IRF610/611		1.5		
	IRF612/613		2.4		$I_D = 1.0$ A
	MTP2N18/20		1.8		
$V_{DS(on)}$	Drain-Source On-Voltage[2]		4.4	V	$V_{GS} = 10$ V; $I_D = 2.0$ A
	MTP2N18/2N20		3.6	V	$V_{GS} = 10$ V; $I_D = 1.0$ A; $T_C = 100°C$
g_{fs}	Forward Transconductance	0.8		S (℧)	$V_{DS} = 10$ V, $I_D = 1.25$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		200	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{oss}	Output Capacitance		80	pF	
C_{rss}	Reverse Transfer Capacitance		25	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 11, 12*)[3]					
$t_{d(on)}$	Turn-On Delay Time		15	ns	$V_{DD} = 50$ V, $I_D = 1.25$ A $V_{GS} = 10$ V, $R_{GEN} = 50$ Ω $R_{GS} = 50$ Ω
t_r	Rise Time		25	ns	
$t_{d(off)}$	Turn-Off Delay Time		15	ns	
t_f	Fall Time		15	ns	
Q_g	Total Gate Charge		7.5	nC	$V_{GS} = 10$ V, $I_D = 3.0$ A $V_{DD} = 45$ V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage IRF610/611		2.0	V	I_S = 2.5 A; V_{GS} = 0 V
	IRF612/613		1.8	V	I_S = 2.0 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	290		ns	I_S = 2.5 A; dI_S/dt = 25 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

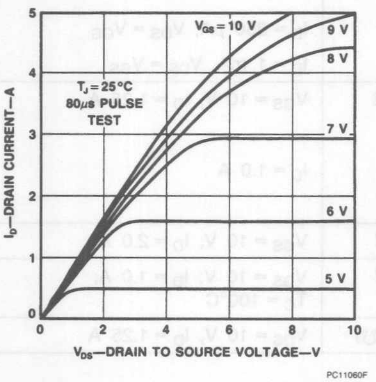


Figure 2 Static Drain to Source Resistance vs Drain Current

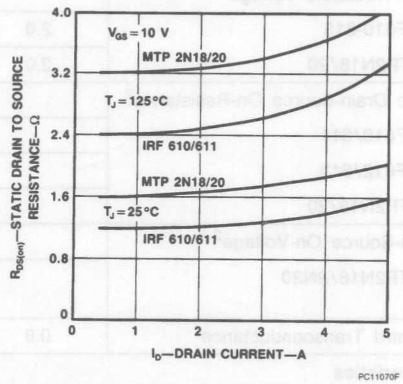


Figure 3 Transfer Characteristics

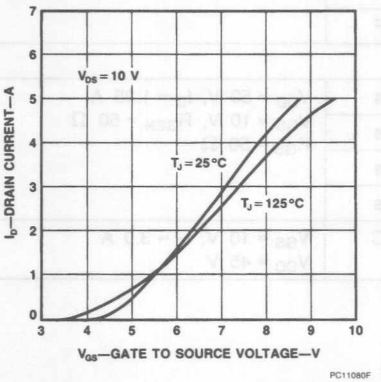
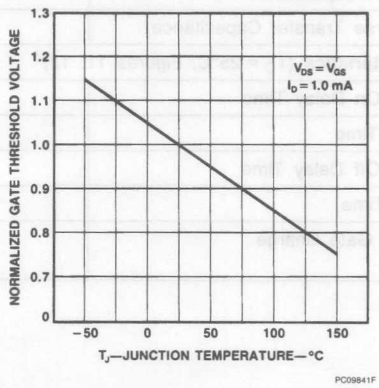


Figure 4 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 5 Capacitance vs Drain to Source Voltage

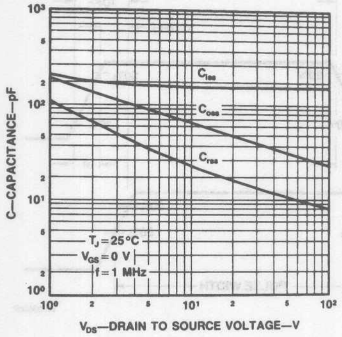


Figure 6 Gate to Source Voltage vs Total Gate Charge

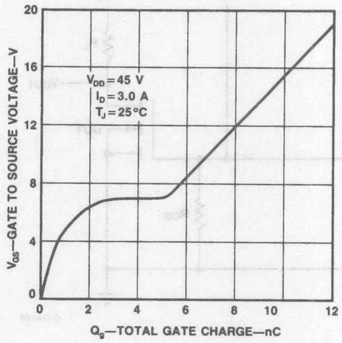


Figure 7 Forward Biased Safe Operating Area for MTP2N18/2N20

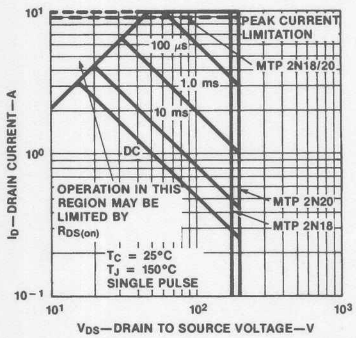


Figure 8 Transient Thermal Resistance vs Time for MTP2N18/2N20

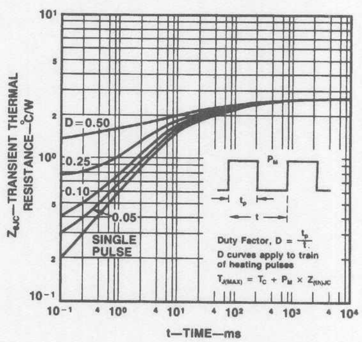


Figure 9 Forward Biased Safe Operating Area for IRF610-613

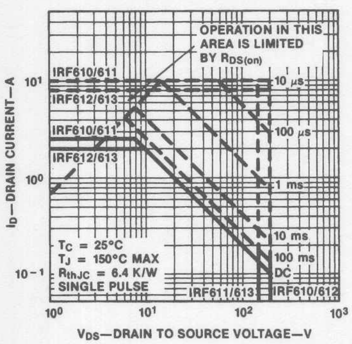
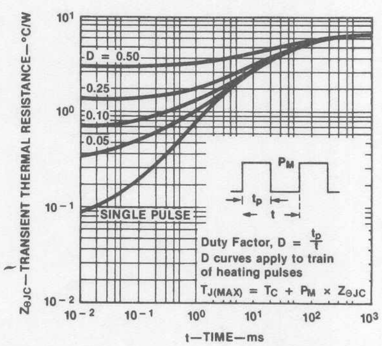


Figure 10 Transient Thermal Resistance for IRF610-613



Typical Electrical Characteristics

Figure 11 Switching Test Circuit

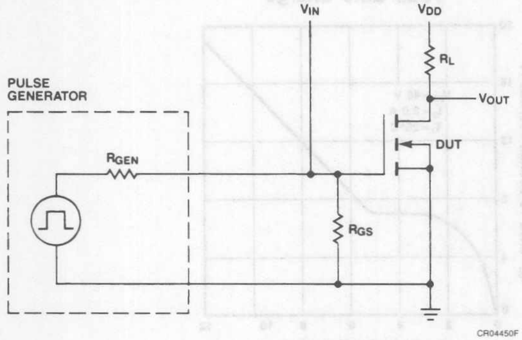
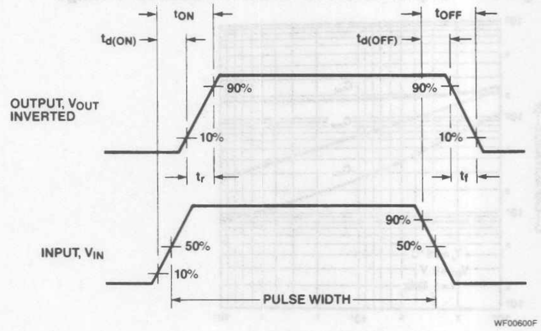


Figure 12 Switching Waveforms



FAIRCHILD

A Schlumberger Company

IRF710-713 MTP2N35/2N40 N-Channel Power MOSFETs, 2.25 A, 350-400 V

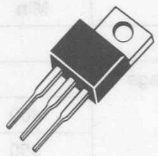
Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs designed especially for high speed applications, such as switching power supplies, converters, AC and DC motor controls, relay and solenoid driver and high energy pulse circuits.

- **Low $R_{DS(on)}$**
- **V_{GS} Rated at ±20 V**
- **Silicon Gate for Fast Switching Speeds**
- **I_{DSS}, $V_{DS(on)}$, Specified at Elevated Temperature**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-220AB



IS00010F

IRF710
IRF711
IRF712
IRF713
MTP2N35
MTP2N40

Maximum Ratings

Symbol	Characteristic	Rating IRF710/712 MTP2N40	Rating IRF711/713 MTP2N35	Unit
V_{DSS}	Drain to Source Voltage[1]	400	350	V
V_{DGR}	Drain to Gate Voltage[1] R_{GS} = 20 kΩ	400	350	V
V_{GS}	Gate to Source Voltage	±20	±20	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C

Maximum On-State Characteristics

		IRF710-711	IRF712-713	MTP2N35/40	Unit
$R_{DS(on)}$	Static Drain-to-Source On Resistance	3.6	5.0	5.0	Ω
I_D	Drain Current				A
	Continuous at T_C = 25°C	1.5	1.4	1.3	
	Continuous at T_C = 100°C	1.0	0.9	0.8	
	Pulsed	6.0	5.0	5.0	

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	6.4	6.4	2.5	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	80	80	80	°C/W
P_D	Total Power Dissipation at T_C = 25°C	20	20	50	W

Notes

For information concerning connection diagram and package outline, refer to Section 7.

Electrical Characteristics ($T_C = 25°C$ unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]			V	$V_{GS} = 0$ V, $I_D = 250$ μA
	IRF710/712/MTP2N40	400			
	IRF711/713/MTP2N35	350			
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, $V_{GS} = 0$ V
			1000	μA	$V_{DS} = 0.8$ x Rated V_{DSS}, $V_{GS} = 0$ V, $T_C = 125°C$
I_{GSS}	Gate-Body Leakage Current		± 500	nA	$V_{GS} = \pm 20$ V, $V_{DS} = 0$ V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage			V	
	IRF710-713	2.0	4.0		$I_D = 250$ μA, $V_{DS} = V_{GS}$
	MTP2N35/2N40	2.0	4.5		$I_D = 1$ mA, $V_{DS} = V_{GS}$
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	$V_{GS} = 10$ V, $I_D = 0.8$ A
	IRF710/711		3.6		
	IRF712/713/MTP2N35/40		5.0		
$V_{DS(on)}$	Drain-Source On-Voltage[2]		13	V	$V_{GS} = 10$ V, $I_D = 2.0$ A
	MTP2N35/2N40		10	V	$V_{GS} = 10$ V, $I_D = 1.0$ A, $T_C = 100°C$
g_{fs}	Forward Transconductance	0.5		S (℧)	$V_{DS} = 10$ V, $I_D = 0.8$ A
Dynamic Characteristics					
C_{iss}	Input Capacitance		200	pF	$V_{DS} = 25$ V, $V_{GS} = 0$ V f = 1.0 MHz
C_{oss}	Output Capacitance		50	pF	
C_{rss}	Reverse Transfer Capacitance		15	pF	
Switching Characteristics ($T_C = 25°C$, *Figures 11, 12*)[3]					
$t_{d(on)}$	Turn-On Delay Time		10	ns	$V_{DD} = 200$ V, $I_D = 0.8$ A $V_{GS} = 10$ V, $R_{GEN} = 50$ Ω $R_{GS} = 50$ Ω
t_r	Rise Time		20	ns	
$t_{d(off)}$	Turn-Off Delay Time		10	ns	
t_f	Fall Time		15	ns	
Q_g	Total Gate Charge		7.5	nC	$V_{GS} = 10$ V, $I_D = 2.0$ A $V_{DD} = 200$ V

Electrical Characteristics (Cont.) (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage				
	IRF710/711		1.6	V	I_S = 1.5 A; V_{GS} = 0 V
	IRF712/713		1.5	V	I_S = 1.3 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	380		ns	I_S = 1.5 A; dI_S/dt = 25 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

Typical Performance Curves

Figure 1 Output Characteristics

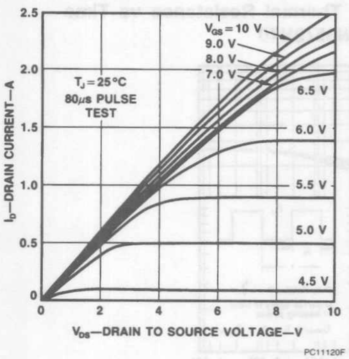


Figure 2 Static Drain to Source Resistance vs Drain Current

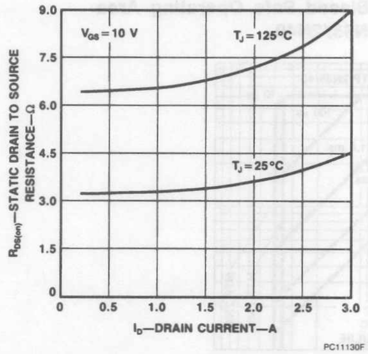


Figure 3 Transfer Characteristics

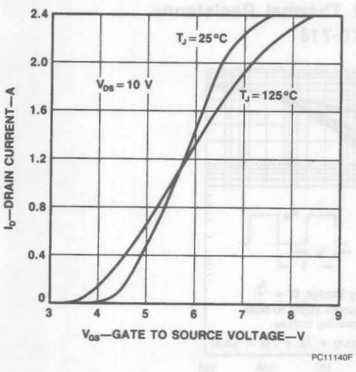
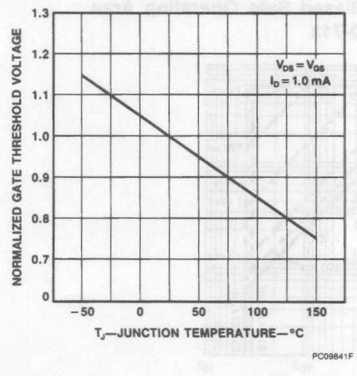


Figure 4 Temperature Variation of Gate to Source Threshold Voltage



Typical Performance Curves (Cont.)

Figure 5 Capacitance vs Drain to Source Voltage

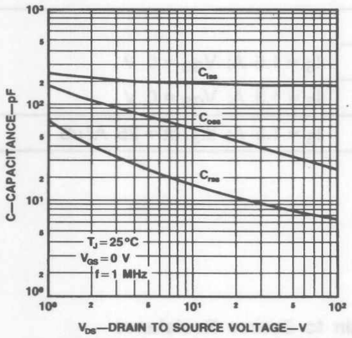


Figure 6 Gate to Source Voltage vs Total Gate Charge

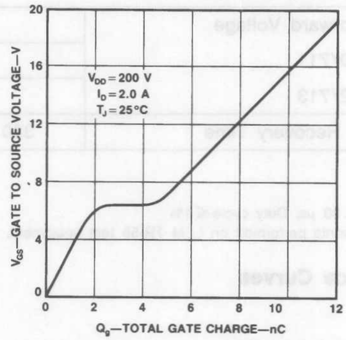


Figure 7 Forward Biased Safe Operating Area for MTP2N35/2N40

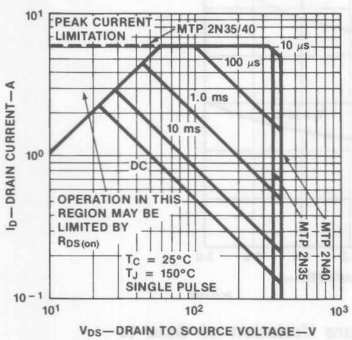


Figure 8 Transient Thermal Resistance vs Time for MTP2N35/2N40

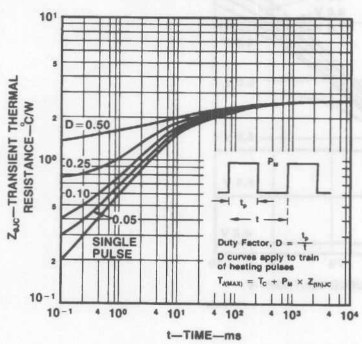


Figure 9 Forward Biased Safe Operating Area for IRF710-713

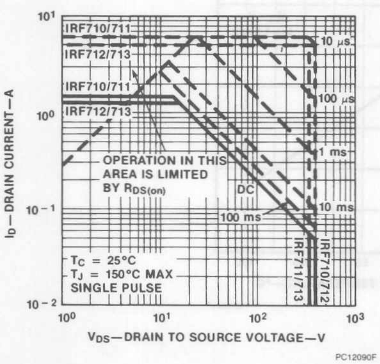
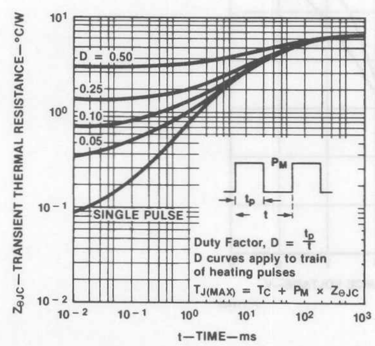


Figure 10 Transient Thermal Resistance for IRF710-713



2

Typical Electrical Characteristics

Figure 11 Switching Test Circuit

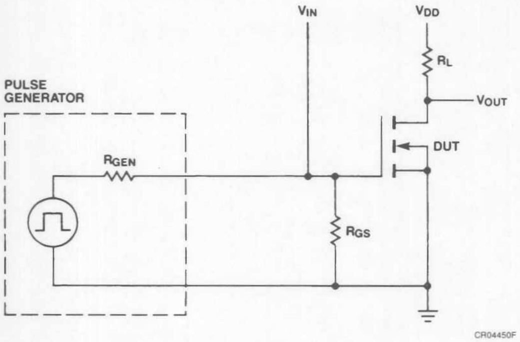
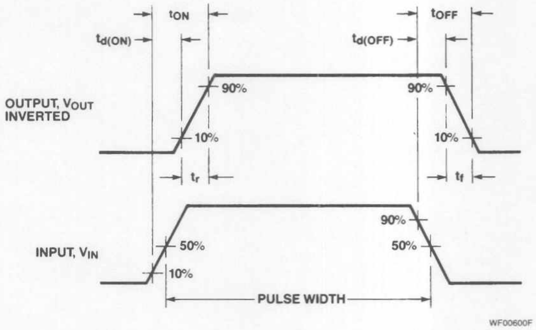


Figure 12 Switching Waveforms



FAIRCHILD
A Schlumberger Company

FRC Series
Ultra-Fast Rectifier Dice

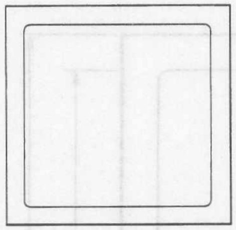
Power And Discrete Division

Description

These devices are ultrafast, reverse recovery, epitaxial rectifiers supplied in die form for use in hybrid assemblies. The dice are manufactured to the same high quality standards used in Fairchild's standard series of TO-204 and TO-220 offerings.

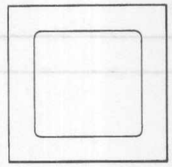
- **50 V – 200 V_{RRM}**
- **Ultrafast 35ns Recovery Times**
- **Soft Recovery (S > 0.5)**
- **Low Recovery Currents**
- **Low Forward Voltage Drops**

R082



FRC1605
FRC1610
FRC1615
FRC1620

R072



CD02300F

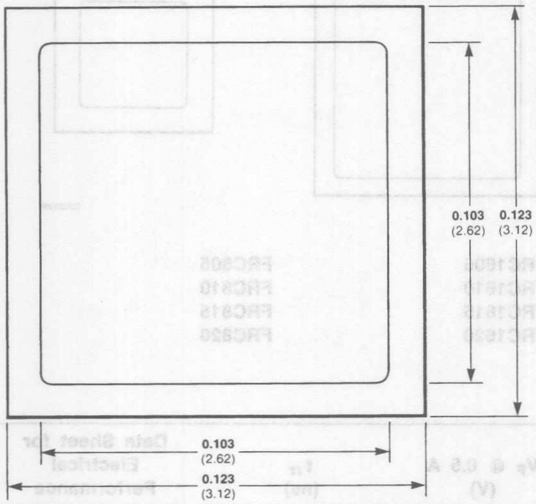
FRC805
FRC810
FRC815
FRC820

Electrical Characteristics

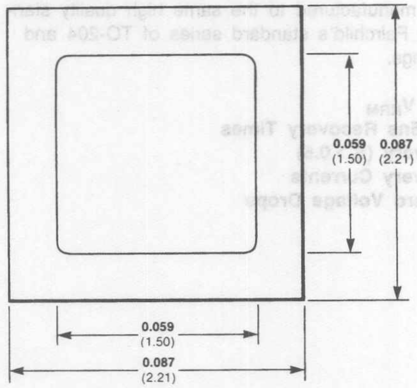
Part Number	V_{RRM} (V)	I_{rrm} (μA)	V_F @ 0.5 A (V)	t_{rr} (ns)	Data Sheet for Electrical Performance
FRC805	50	10	0.750	35	FRP805
FRC810	100	10	0.750	35	FRP810
FRC815	150	10	0.750	35	FRP815
FRC820	200	10	0.750	35	FRP820
FRC1605	50	25	0.725	35	FRP1605
FRC1610	100	25	0.725	35	FRP1610
FRC1615	150	25	0.725	35	FRP1615
FRC1620	200	25	0.725	35	FRP1620

Die Dimensions

R082



R072



Notes:
1. Dimension Tolerances ±0.0005 in. (0.013mm)
2. Thickness of all die types is 0.010 in. (250μ)

CR05510F

Probe Testing

Each die is probed and electrically tested to the limits specified in the Electrical Characteristics Table. However, high current parameters and thermal characteristics specified in the packaged device data sheets cannot be tested or guaranteed in die form because of the power dissipation limits of unmounted die and current handling limits of probe tips. These parameters are:

Thermal Resistance

Forward Voltage Drop at Rated Current

Reverse Recovery Characteristics at Rated Current

Surge Current

Metallization

The cathode metallization on all rectifier dice is chromium-silver, deposited to an approximate thickness of 9,000 Angstroms. This metallization is suitable for die mounting using a variety of solders, such as 95/5 Pb/Sn, 92.5/5.0/2.5 Pb/In/Ag, 92.5/5.0/2.5 Pb/Sn/Ag and 65/25/10 Sn/Ag/Sb.

The wire bonding metallization for the anode connection is aluminum with a 1% silicon content. This metallization is deposited to a minimum thickness of 6 microns.

Packaging and Handling

All rectifier dice are supplied in plastic trays (also known as waffle pack) with cavities to contain the dice. The trays and their covers are made from STAT-PRO™ 150, which is a black, conductive, glass-filled polypropylene. The trays are 4 inches square and contain 100 of either type dice.

Dice should be handled with Teflon™ tipped vacuum pencils to prevent mechanical damage.

Storage

Upon receipt of the dice, they should be stored as soon as practical in an inert atmosphere, such as dry nitrogen, to prevent oxidation of the bond pad and solder mount-down areas.

Wire Bonding

Ultra-sonic bonding using aluminum wire with an elongation of 10% is recommended for making electrical connections to the anode bonding pad of the dice. Optimum wire sizes for this bonding have been chosen based on surge current ratings of encapsulated dice and are shown in the following table:

Die Type	Anode Wire Diameter (in.)
FRC8__	0.015 in.
FRC16__	2 x 0.015 or 0.020

FRC Series
Ultrafast Rectifier Dice

Die Mounting and Encapsulation

Refer to IFRC Series (Power MOSFET Dice) for a discussion of mounting and encapsulation considerations.

Special Requirements

The factory should be consulted regarding requirements for alternate cathode metallization, more stringent visual inspections and lot qualification by quality conformance inspection of encapsulated dice.

Fairchild would be pleased to consider any other special requirements.

FAIRCHILD

A Schlumberger Company

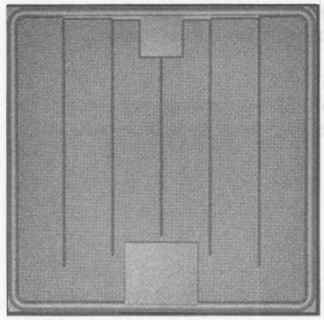
IRFC Series N-Channel Power MOSFET Dice

Preliminary Specification

Power And Discrete Division

Description

These devices are n-channel, enhancement mode, power MOSFETs supplied in die form for use in hybrid assemblies. The dice described herein are manufactured with the same reliable silicon-gate technology used in Fairchild's standard series of TO-204 and TO-220 packaged power MOSFETs.



- **50 V to 500 V, V_{DSS} Ratings**
- **Up to 40 A $I_{D(max)}$**
- **Down to 55 mΩ $R_{DS(on)}$ maximum**
- **High Density Cell Design**
- **Silicon Nitride Passivated**
- **Chromium-Silver Back Metal**

Table 1 Electrical Characteristics (at 25°C Ambient Temperature)

Part Number	V_{DSS} (V)	I_{DSS} at V_{DSS} (μA)	Die Size Ref.	$R_{DS(on)}$ at $I_D = 2.0$ A & $V_{GS} = 10$ V (Ω)	I_{GSS} at $V_{GS} = 20$ V (nA)	$V_{GS(th)}$ at $I_D = 250$ μA & $V_{DS} = V_{GS}$ (V)		Data Sheet For Electrical Characteristics
	Min	Max		Max	Max	Min	Max	
FMC20N05	50	250	DB2	0.085	100	2.0	4.0	FMP20N05
IRFC110	100	250	D01	0.60	100	2.0	4.0	IRF510
IRFC120	100	250	D02	0.30	100	2.0	4.0	IRF120
IRFC130	100	250	D03	0.18	100	2.0	4.0	IRF130
IRFC140	100	250	D04	0.085	100	2.0	4.0	IRF140
IRFC150	100	250	D05	0.055	100	2.0	4.0	IRF150
IRFC210	200	250	D01	1.50	100	2.0	4.0	IRF610
IRFC220	200	250	D02	0.80	100	2.0	4.0	IRF220
IRFC230	200	250	D03	0.40	100	2.0	4.0	IRF230
IRFC240	200	250	D04	0.18	100	2.0	4.0	IRF240
IRFC250	200	250	D05	0.085	100	2.0	4.0	IRF250
IRFC310	400	250	D01	3.60	100	2.0	4.0	IRF710
IRFC320	400	250	D02	1.80	100	2.0	4.0	IRF320
IRFC330	400	250	D03	1.00	100	2.0	4.0	IRF330
IRFC340	400	250	D04	0.55	100	2.0	4.0	IRF340
IRFC350	400	250	D05	0.30	100	2.0	4.0	IRF350
IRFC420	500	250	D02	3.00	100	2.0	4.0	IRF420
IRFC430	500	250	D03	1.50	100	2.0	4.0	IRF430
IRFC440	500	250	D04	0.85	100	2.0	4.0	IRF440
IRFC450	500	250	D05	0.40	100	2.0	4.0	IRF450

IRFC Series
N-Channel Power MOSFET Dice

Probe Testing

Each die is probed and electrically tested to the limits specified in the preceding table. However, because of power dissipation limitations imposed by testing the dice unmounted, certain DC and thermal parameters specified in the packaged device data sheets cannot be tested and guaranteed in die form.

These parameters, which also depend on the user's die mounting methods and materials, are:

Power Dissipation	P_D
Thermal Resistance	$R_{\theta JC}$
Safe Operating Area	SOA
On Resistance at Rated Current	$R_{DS(on)}$

On resistance is, however, tested and guaranteed at a drain current of 1.0 A as shown in the *Table 1*.

The following parameters can be guaranteed by design to meet the limits specified in the appropriate packaged device data sheets:

Forward Transconductance	g_{fs}
Input Capacitance	C_{iss}
Output Capacitance	C_{oss}
Reverse Transfer Capacitance	C_{rss}
Turn-on Delay Time	$t_{d(on)}$
Rise Time	t_r
Turn-off Delay Time	$t_{d(off)}$
Fall Time	t_f
Total Gate Charge	Q_g

Visual Inspection

All MOSFET dice are visually screened to a 1.0% A.Q.L. in accordance with MIL-STD-750, Method 2072 to the extent that this method is applicable to MOSFET dice. Fairchild's die visual inspection specification (NRP-127575) is available upon request.

100% die visual inspection is available as an option. See special requirements.

Metallization

The drain metallization on all MOSFET dice is chromium-silver, deposited to a thickness of approximately 9,000 Angstroms. This metallization is suitable for die mounting using a variety of solders, such as 95/5 Pb/Sn, 92.5/5.0/2.5 Pb/In/Ag, 92.5/5.0/2.5 Pb/Sn/Ag and 65/25/10 Sn/Ag/Sb.

The exposed bonding pads for source and gate connections of the dice are aluminum with a 1% silicon content. This metallization is deposited to a minimum thickness of 20,000 Angstroms.

Packaging and Handling

All MOSFET dice are supplied in plastic trays with cavities which contain the dice (sometimes known as waffle pack). The trays are two inches by two inches and full trays contain the following number of dice:

Die Size Reference	Quantity
D01	100
D02	100
DB2	100
D03	49
D04	36
D05	36

The trays and their covers are made from STAT-PRO™ 150 which is a black, conductive, glass-filled polypropylene.

The tray/cover combination is held together with natural polypropylene retaining clips and shipped in an electrostatic shielding bag. Extreme care should be taken when removing the clips to ensure that the tray and cover are not separated. Only after the clips have been remove should the cover be carefully lifted from the tray in order to access the dice.

Dice should be handled with Teflon™ tipped vacuum pencils at ESD work station to prevent mechanical and ESD damage.

Storage

Upon removal of the retaining clips and cover from the tray, the dice must be stored in an inert atmosphere as soon as possible, such as dry nitrogen, to prevent oxidation of the bond pad areas.

Die Mounting

All of the commonly used header and substrate materials, such as copper, nickel-plated copper and gold-plated molybdenum, beryllia and alumina, are acceptable for die mounting. The substrate should be freed of oxides prior to assembly either by chemical cleaning or pre-firing in a reducing atmosphere.

Before die attach, it is recommended that the dice be cleaned by using a one minute de-ionized water wash followed by two one minute rinses in an iso-propyl alcohol agitated bath. Drying should be accomplished in a 70°C nitrogen chamber.

Die mounting, using a suitable preform, is generally achieved using a profiled belt furnace in a hydrogen, forming gas or nitrogen atmosphere. Although the zone temperature settings will depend on the mass of the assembly and fixturing and the belt speed, the die temperature must not exceed 400°C.

3

Other die mounting methods, including the use of conductive epoxies, may be used but their limitations and effects on the device performance should be clearly understood.

Wire Bonding

Ultra-sonic bonding using aluminum wire with an elongation of 10% is recommended for making electrical connections to the source and gate bonding pads of the dice.

Optimum wire sizes for wire bonding are shown in the following table:

Die Type	Source Wire Dia. (Inches)	Gate Wire Dia. (Inches)
FMC20N05	0.015	0.006
IRFC110	0.006	0.006
IRFC120	0.006	0.006
IRFC130	0.010	0.008
IRFC140	0.015	0.008
IRFC150	0.020	0.008
IRFC210	0.006	0.006
IRFC220	0.006	0.006
IRFC230	0.008	0.008
IRFC240	0.015	0.008
IRFC250	0.020	0.008
IRFC310	0.006	0.006
IRFC320	0.006	0.006
IRFC330	0.008	0.008
IRFC340	0.015	0.008
IRFC350	0.015	0.008
IRFC420	0.006	0.006
IRFC430	0.008	0.008
IRFC440	0.015	0.008
IRFC450	0.015	0.008

Wire size may be varied but account must be taken of bond pad size (maximum limit) and current handling requirements (minimum limit).

Encapsulation

Prior to encapsulation, the die and assembly should be maintained in a moisture free environment since leakage currents are particularly sensitive to the presence of moisture on the die surface.

For high voltage devices (IRFC420, IRFC430, IRFC440 and IRFC450), it is recommended that a high grade silicone conformal coating, such as Dow Corning R-6101, be used to cover the die and die bond wire structures. This coating will eliminate any possibility of die surface discharge through ionization in the high voltage dice.

For all other die types, if the final package is to be non-hermetic, a coating such as Dow Corning RTV3140 or equivalent is recommended to be similarly applied. For hermetic packages, this coating is optional.

Cleaning of the die/assembly in a Freon vapor degreaser is also recommended prior to the application of any coatings.

Immediately prior to encapsulation, a two hour, 150°C bake should be performed to remove any accumulated surface moisture from assemblies containing both coated and uncoated dice.

Special Requirements

The factory should be consulted regarding requirements for alternate back metallization, more stringent visual inspections and lot qualification by quality conformance inspection of encapsulated dice.

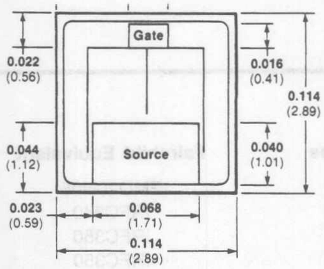
Fairchild would also be pleased to consider any other special requirements.

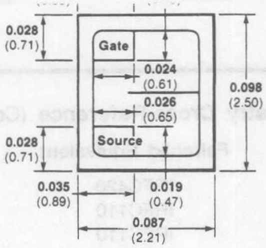
Power MOSFET Die Industry Cross-Reference

Industry Type	Fairchild Equivalent
IRFC113	IRFC110
IRFC123	IRFC120
IRFC133	IRFC130
IRFC143	IRFC140
IRFC153	IRFC150
IRFC213	IRFC210
IRFC223	IRFC220
IRFC233	IRFC230
IRFC243	IRFC240
IRFC253	IRFC250
IRFC313	IRFC310
IRFC323	IRFC320
IRFC333	IRFC330
IRFC343	IRFC340
IRFC353	IRFC350
IRFC423	IRFC420
IRFC433	IRFC430
IRFC443	IRFC440
IRFC453	IRFC450
MTC2N18	IRFC210
MTC2N20	IRFC210
MTC2N35	IRFC310
MTC2N40	IRFC310
MTC2N45	IRFC420

Power MOSFET Die Industry Cross-Reference (Cont.)

Industry Type	Fairchild Equivalent	Industry Type	Fairchild Equivalent
MTC2N50	IRFC420	MTC15N05	FMD20N05
MTC4N08	IRFC110	MTC15N20	IRFC240
MTC4N10	IRFC110	MTC15N35	IRFC350
MTC4N45	IRFC430	MTC15N40	IRFC350
MTC4N50	IRFC430	MTC15N45	IRFC450
MTC5N18	IRFC220	MTC15N50	IRFC450
MTC5N20	IRFC220	MTC30N18	IRFC250
MTC5N35	IRFC330	MTC30N20	IRFC250
MTC5N40	IRFC330	MTC40N08	IRFC150
MTC7N45	IRFC440	MTC40N10	IRFC150
MTC7N50	IRFC440	PCF3N45	IRFC420
MTC8N08	IRFC120	PCF8N18	IRFC230
MTC8N10	IRFC120	PCF10N45	IRFC450
MTC8N18	IRFC230	PCF12N08	IRFC130
MTC8N20	IRFC230	PCF18N08	IRFC140
MTC8N35	IRFC340	PCF25N18	IRFC250
MTC8N40	IRFC340	PCF35N08	IRFC150
MTC12N08	IRFC130	SIRF450	IRFC450
MTC12N10	IRFC130	SIRF451	IRFC450
MTC15N18	IRFC240	SIRF452	IRFC450
		SIRF453	IRFC450





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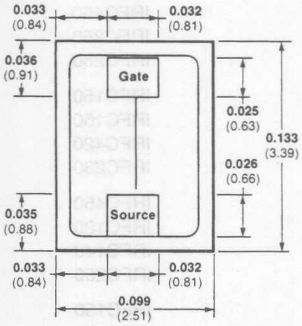

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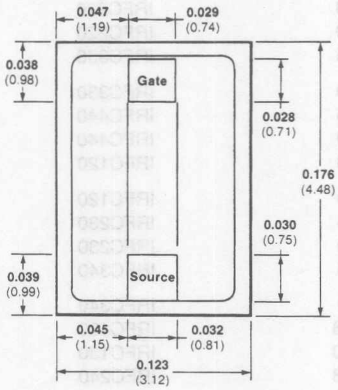

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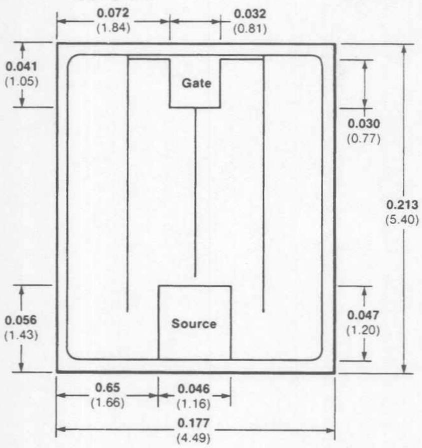

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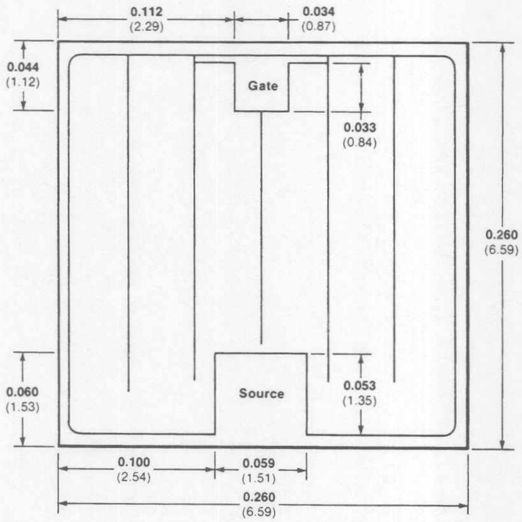


CR05520F

Notes

1. Dimension Tolerances: ± 0.0005 in
   ± 0.013 mm
2. Overall length and width are reduced by approximately 0.002 inches after sawing.
3. Thickness of all die types is 0.020 inches ± 0.002.

FAIRCHILD

A Schlumberger Company

BUZ71/71A N-Channel Power MOSFETs, 14 A, 50 V

Advance Information

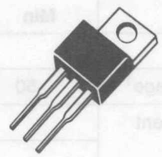
Power And Discrete Division

Description

These devices are very low $R_{DS(on)}$, 50 V, n-channel, enhancement mode, power MOSFETs especially designed to serve the low voltage, high speed, switching markets. Typical applications are SMPS for telecommunication and instrumentation, DC motor controls, emitter switching, synchronous rectification, and systems that are operated from low voltage batteries, such as automotive and portable equipment, etc.

- **Extremely Low $R_{DS(on)}$**
- **V_{GS} Rated at ± 30 V**
- **Silicon Gate for Fast Switching Speeds**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-220AB



IS00010F

BUZ71
BUZ71A

Maximum Ratings

Symbol	Characteristic	Rating BUZ71	Rating BUZ71A	Unit
V_{DSS}	Drain to Source Voltage[1]	50	50	V
V_{DGR}	Drain to Gate Voltage[1] R_{GS} = 20 kΩ	50	50	V
V_{GS}	Gate to Source Voltage	± 30	± 30	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	275	275	°C
Maximum On-State Characteristics				
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.10	0.12	Ω
I_D	Drain Current Continuous Pulsed	 14 48	 13 48	A
Maximum Thermal Characteristics				
$R_{\theta JC}$	Thermal Resistance, Junction to Case	3.1	3.1	°C/W
P_D	Total Power Dissipation at T_C = 25°C	40	40	W

Electrical Characteristics (T_C = 25°C unless otherwise noted)

Symbol	Characteristic	Min	Max	Unit	Test Conditions
Off Characteristics					
$V_{(BR)DSS}$	Drain Source Breakdown Voltage[1]	50		V	V_{GS} = 0 V, I_D = 1 mA
I_{DSS}	Zero Gate Voltage Drain Current		250	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V
			1000	μA	V_{DS} = Rated V_{DSS}, V_{GS} = 0 V, T_C = 125°C
I_{GSS}	Gate-Body Leakage Current		± 100	nA	V_{GS} = ± 20 V, V_{DS} = 0 V
On Characteristics					
$V_{GS(th)}$	Gate Threshold Voltage	2.1	4.0	V	I_D = 10 mA, V_{DS} = V_{GS}
$R_{DS(on)}$	Static Drain-Source On-Resistance[2]			Ω	V_{GS} = 10 V, I_D = 6.0 A
	BUZ71		0.10		
	BUZ71A		0.12		
g_{fs}	Forward Transconductance	3		S	V_{DS} = 10 V, I_D = 6 A
Dynamic Characteristics					
C_{iss}	Input Capacitance		650	pF	V_{DS} = 25 V, V_{GS} = 0 V f = 1.0 MHz
C_{oss}	Output Capacitance		450	pF	
C_{rss}	Reverse Transfer Capacitance		280	pF	
Switching Characteristics (T_C = 25°C)[3]					
$t_{d(on)}$	Turn-On Delay Time		30	ns	V_{DD} = 30 V, I_D = 3 A V_{GS} = 10 V, R_{GEN} = 50 Ω R_{GS} = 50 Ω
t_r	Rise Time		85	ns	
$t_{d(off)}$	Turn-Off Delay Time		90	ns	
t_f	Fall Time		110	ns	
Q_g	Total Gate Charge		20	nC	V_{GS} = 10 V, I_D = 12 A V_{DD} = 40 V

Symbol	Characteristic	Typ	Max	Unit	Test Conditions
Source-Drain Diode Characteristics					
V_{SD}	Diode Forward Voltage		2.2	V	I_S = 12 A; V_{GS} = 0 V
t_{rr}	Reverse Recovery Time	120		ns	I_S = 12 A; dI_S/dt = 100 A/μS

Notes
1. T_J = +25°C to +150°C
2. Pulse test: Pulse width ≤ 80 μs, Duty cycle ≤ 1%
3. Switching time measurements performed on LEM TR-58 test equipment.

FAIRCHILD

A Schlumberger Company

FMP35N05/FMP30N05 N-Channel Power MOSFETs, 30-35 A, 50 V

Advance Information

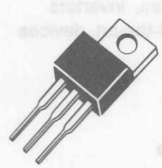
Power And Discrete Division

Description

These devices are very low $R_{DS(on)}$, 50 V, n-channel, enhancement mode, power MOSFETs especially designed to serve the low voltage, high speed, switching markets. Typical applications are SMPS for telecommunication and instrumentation, DC motor controls, emitter switching, synchronous rectification, and systems that are operated from low voltage batteries, such as automotive and portable equipment, etc.

- **Extremely Low $R_{DS(on)}$**
- **V_{GS} Rated at ±30 V**
- **Silicon Gate for Fast Switching Speeds**
- **Rugged**
- **Low Drive Requirements**
- **Ease of Paralleling**

TO-220AB



IS00010F

FMP35N05
FMP30N05

Maximum Ratings

Symbol	Characteristic	Rating FMP35N05	Rating FMP30N05	Unit
V_{DSS}	Drain to Source Voltage	50	50	V
V_{DGR}	Drain to Gate Voltage R_{GS} = 20 kΩ	50	50	V
V_{GS}	Gate to Source Voltage	±30	±30	V
T_J, T_{stg}	Operating Junction and Storage Temperatures	−55 to +150	−55 to +150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/8″ From Case for 5 s	300	300	°C

Maximum On-State Characteristics

		FMP35N05	FMP30N05	
$R_{DS(on)}$	Static Drain-to-Source On Resistance	0.04	0.05	Ω
I_D	Drain Current Continuous at T_C = 25°C Continuous at T_C = 100°C	 35 22	 30 20	A

Maximum Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.25	1.25	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	60	60	°C/W
P_D	Total Power Dissipation at T_C = 25°C	100	100	W

FAIRCHILD

A Schlumberger Company

FRP860 Series Ultra-fast POWERplanar™ Rectifiers

Advance Information

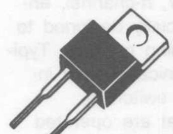
Power And Discrete Division

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **150°C Operating Junction Temperature**
- **Popular TO-220AC Package**

TO-220AC



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FRP860
FRP850
FRP840

Maximum Ratings

Symbol	Rating	FRP860	FRP850	FRP840	Unit
V_{RRM} V_{RSM} V_R	Peak Repetitive Reverse Voltage Non-repetitive Peak Reverse Voltage DC Blocking Voltage	600 600 600	500 500 500	400 400 400	V
$I_{F(AV)}$	Average Rectified Forward Current, $T_C = 120°C$, Rated V_R	8	8	8	A
I_{FRM}	Peak Repetitive Forward Current Rated V_R, 50% Duty Cycle, Square Wave, 20 kHz, $T_C = 120°C$	16	16	16	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Surge Applied at Rate Load Conditions Halfwave, Single Phase, 60 Hz	80	80	80	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	°C

Thermal Characteristics

Symbol	Rating	FRP860	FRP850	FRP840	Unit
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case	2.0	2.0	2.0	°C/W

Electrical Characteristics

Symbol	Rating	FRP860	FRP850	FRP840	Unit
$V_{FM}^{(1)}$	Maximum Instantaneous Forward Voltage $I_F = 8.0$ A, $T_C = 25°C$	1.5	1.5	1.5	V
$I_{RRM}^{(1)}$	Maximum Instantaneous Repetitive Reverse Current Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	2.0 25	2.0 25	2.0 25	mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 8$ A; $dI_F/dt = 100$ A/μS	75	75	75	ns
$I_{R(REC)}$	Maximum Reverse Recovery Current $I_F = 8$ A, $dI_F/dt = 100$ A/μs, $V_R = V_{RRM}$	5.0	5.0	5.0	A

1. Pulse Test: Pulse Width = 300 μS. Duty Cycle ≤ 2.0%.

FAIRCHILD
A Schlumberger Company

FR3200CC Series Ultra-Fast POWERplanar™ Rectifiers

Advance Information

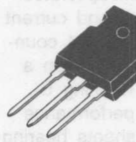
Power And Discrete Division

Description

Designed for use in switching power supplies, inverters and as free-wheeling diodes, these state-of-the-art devices have the following features:

- **Ultrafast 35 ns Reverse Recovery Time**
- **Soft Recovery (S > 0.5)**
- **Low $I_{R(REC)}$**
- **150°C Operating Junction Temperature**

TO-247



IS00050F

FRP3205CC
FRP3210CC
FRP3215CC
FRP3220CC

Maximum Ratings

Symbol	Rating	FRP3205CC	FRP3210CC	FRP3215CC	FRP3220CC	Unit
V_{RRM} V_{RSM} V_R	Peak Repetitive Reverse Voltage Non-repetitive Peak Reverse Voltage DC Blocking Voltage	50 50 50	100 100 100	150 150 150	180 200 180	V
$I_{F(AV)}$	Average Rectified Forward Current, $T_C = 130°C$, Rated V_R	32	32	32	32	A
I_{FRM}	Peak Repetitive Forward Current Rated V_R, 50% Duty Cycle, Square Wave, 20 kHz, $T_C = 107°C$	64	64	64	64	A
I_{FSM}	Non-repetitive Peak Surge Current per Diode, Surge Applied at Rate Load Conditions Halfwave, Single Phase, 60 Hz	200	200	200	200	A
T_J, T_{stg}	Operating Junction Temperature and Storage Temperature	−55 to +150	−55 to +150	−55 to +150	−55 to +150	°C

Thermal Characteristics

Symbol	Rating	FRP3205CC	FRP3210CC	FRP3215CC	FRP3220CC	Unit
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case	1.0	1.0	1.0	1.0	°C/W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	60	60	60	60	

Electrical Characteristics per Diode

Symbol	Rating	FRP3205CC	FRP3210CC	FRP3215CC	FRP3220CC	Unit
V_{FM}(1)	Maximum Instantaneous Forward Voltage $I_F = 16$ A, $T_C = 150°C$ $I_F = 16$ A, $T_C = 25°C$	 0.80 0.95	 0.80 0.95	 0.80 0.95	 0.80 0.95	V
I_{RRM}(1)	Maximum Instantaneous Repetitive Reverse Current Rated DC Voltage, $T_C = 125°C$ Rated DC Voltage, $T_C = 25°C$	 10 25	 10 25	 10 25	 10 25	 mA μA
t_{rr}	Maximum Reverse Recovery Time $I_F = 1.0$ A; $dI_F/dt = 50$ A/μS $I_F = 16$ A; $dI_F/dt = 100$ A/μS	 35 50	 35 50	 35 50	 35 50	ns
$I_{R(REC)}$	Maximum Reverse Recovery Current $I_F = 16$ A, $dI_F/dt = 100$ A/μs, $V_R = V_{RRM}$	2.5	2.5	2.5	2.5	A

1. Pulse Test: Pulse Width = 300 μS. Duty Cycle ≤ 2.0%.

FAIRCHILD

A Schlumberger Company

TO-247 Encapsulated N-Channel Power MOSFETs, 8-60 A, 50-500 V

Advance Information

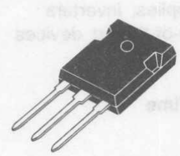
Power And Discrete Division

Description

These high power n-channel MOSFETs are encapsulated in a TO-247 housing to attain superior thermal and current handling performance in comparison to their TO-204 counterparts. The TO-247 case facilitates their mounting on a PC board, attaching them to heat sinks and meeting UL and VDE safety requirements. The electrical performance of the die can be found in the specification sheets bearing the part number listed below minus the middle letter "P", eg. consult the IRF440 specification for the electrical characteristics of the IRFP440 part.

- **Isolated mounting hole**
- **Vertical mounting**
- **0.10" creep and strike distances**
- **All copper header**

TO-247



IS00050F

Product Summary

Part Number	V_{DSS} (V)	$R_{DS(on)}$ (Ohms)	I_D at $T_C = 25°C$ (A)	P_D at $T_C = 25°C$ (W)
FMP60N05	50 V	0.025 Ω	60 A	150 W
FMP55N05	50 V	0.030 Ω	55 A	150 W
IRFP151	60 V	0.055 Ω	45 A	250 W
IRFP153	60 V	0.080 Ω	38 A	250 W
IRFP141	60 V	0.085 Ω	28 A	150 W
IRFP143	60 V	0.110 Ω	26 A	150 W
IRFP150	100 V	0.055 Ω	45 A	250 W
IRFP152	100 V	0.080 Ω	38 A	250 W
IRFP140	100 V	0.085 Ω	28 A	150 W
IRFP142	100 V	0.110 Ω	26 A	150 W
IRFP251	150 V	0.085 Ω	38 A	250 W
IRFP253	150 V	0.120 Ω	32 A	250 W
IRFP241	150 V	0.180 Ω	20 A	150 W
IRFP243	150 V	0.220 Ω	18 A	150 W
IRFP250	200 V	0.085 Ω	38 A	250 W
IRFP252	200 V	0.120 Ω	38 A	250 W
IRFP240	200 V	0.180 Ω	20 A	150 W
IRFP242	200 V	0.220 Ω	18 A	150 W
IRFP351	350 V	0.300 Ω	20 A	250 W
IRFP353	350 V	0.400 Ω	17 A	250 W
IRFP341	350 V	0.550 Ω	11 A	150 W
IRFP343	350 V	0.800 Ω	9 A	150 W
IRFP350	400 V	0.300 Ω	20 A	250 W
IRFP352	400 V	0.400 Ω	17 A	250 W
IRFP340	400 V	0.550 Ω	11 A	150 W
IRFP342	400 V	0.800 Ω	9 A	150 W
IRFP451	450 V	0.400 Ω	17 A	250 W
IRFP453	450 V	0.500 Ω	15 A	250 W
IRFP441	450 V	0.850 Ω	9 A	150 W
IRFP443	450 V	1.100 Ω	8 A	150 W
IRFP450	500 V	0.400 Ω	17 A	250 W
IRFP452	500 V	0.500 Ω	15 A	250 W
IRFP440	500 V	0.850 Ω	9 A	150 W
IRFP442	500 V	1.100 Ω	8 A	150 W

Application Notes/ESD

FAIRCHILD

A Schlumberger Company

Introduction to Power Supplies

Application Note PD-4

Power And Discrete Division

Introduction

Virtually every piece of electronic equipment, eg. computers and their peripherals, calculators, TV and hi-fi equipment, and instruments, is powered from a DC power source, be it a battery or a DC power supply. Most of this equipment requires not only DC voltage but voltage that is also well filtered and regulated. Since power supplies are so widely used in electronic equipment, these devices now comprise a worldwide segment of the electronics market in excess of $5 billion annually.

There are three types of electronic power conversion devices in use today which are classified as follows according to their input and output voltages: 1) the AC/DC power supply; 2) DC/DC converter; 3) the DC/AC inverter. Each has its own area of use but this paper will only deal with the first two, which are the most commonly used.

A power supply converting AC line voltage to DC power must perform the following functions at high efficiency and at low cost:

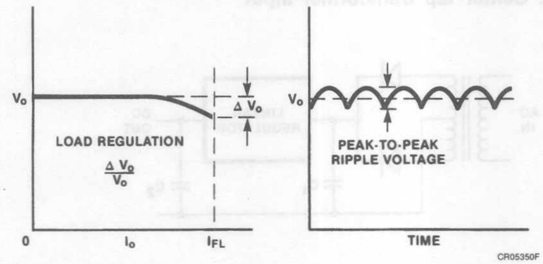
1) Rectification: Convert the incoming AC line voltage to DC voltage.
2) Voltage transformation: Supply the correct DC voltage level(s).
3) Filtering: Smooth the ripple of the rectified voltage.
4) Regulation: Control the output voltage level to a constant value irrespective of line, load and temperature changes.
5) Isolation: Separate electrically the output from the input voltage source.
6) Protection: Prevent damaging voltage surges from reaching the output; provide back-up power or shut down during a brown-out.

An ideal power supply would be characterized by supplying a smooth and constant output voltage regardless of variations in line voltage, load current or ambient temperature at 100% conversion efficiency. *Figure 1* compares a real power supply to this ideal one and further illustrates some power supply terms.

Linear Power Supplies

Figure 2 illustrates two common linear power supply circuits in current use. Both circuits employ full-wave rectification to reduce ripple voltage to capacitor C1. The bridge rectifier circuit has a simple transformer but current must flow through two diodes. The center-tapped configuration is preferred for low output voltages since there is just one diode voltage drop. For 5 V and 12 V outputs, Schottky barrier diodes are commonly used since they have lower

Figure 1 Idealized Power Supply



voltage drops than equivalently rated ultra-fast types, which further increases power conversion efficiency. However, each diode must withstand twice the reverse voltage that a diode sees in a full-wave bridge for the same input voltage.

The linear voltage regulator behaves as a variable resistance between the input and the output as it provides the precise output voltage. One of the limitations to the efficiency of this circuit is due to the fact that the linear device must drop the difference in voltage between the input and output. Consequently the power dissipated by the linear device is $(V_i - V_o) \times I_o$. While these supplies have many desirable characteristics, such as simplicity, low output ripple, excellent line and load regulation, fast response time to load or line changes and low EMI, they suffer from low efficiency and occupy large volumes. Switching power supplies are becoming popular because they offer better solutions to these problems.

Switching Power Supplies

Pulse Width Modulation

In the early 60's, switching regulators started to be designed for the military, who would pay a premium for light weight and efficiency. One way to control average power to a load is to control average voltage applied to it. This can be done by opening and closing a switch in rapid fashion as is being done in *Figure 3*.

The average voltage seen by the load resistor R is equal to:

$$V_{o(avg)} = (t_{(on)}/T) \times V_i \quad \text{(A)}$$

Reducing $t_{(on)}$ reduces $V_{o(avg)}$. This method of control is referred to as pulse width modulation (PWM).

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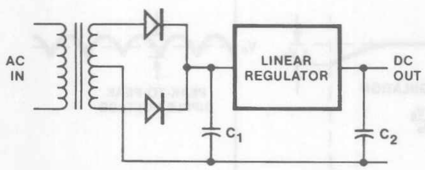
Figure 2 Linear Voltage Regulator
a. Center tap transformer input



b. Full-wave bridge input

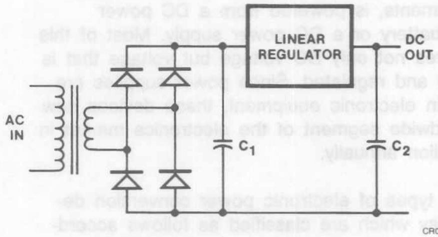


Figure 3 Example of Pulse Width Modulation

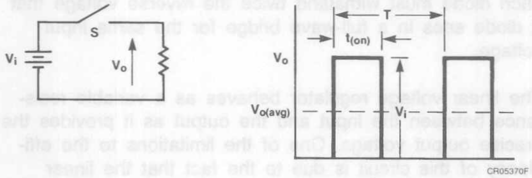
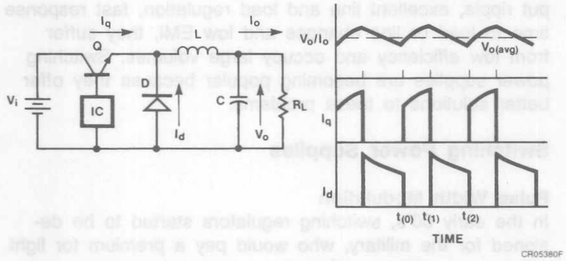


Figure 4 Buck Regulator Circuit with Voltage and Current Waveforms



Buck Regulator

As we shall see, there are many different switching voltage regulator designs. The first one to be considered because of its simplicity is the buck regulator *(Figure 4)*, also known as a step-down regulator since the output voltage as given by equation (A) is less than the input voltage. A typical application is to reduce the standard military bus voltage of 28 V to 5 V to power TTL logic.

At time t_0 in *Figure 4*, the controller, having sensed that the output voltage V_O is too low, turns on the pass transistor to build up current in L, which also starts to recharge capacitor C. At a predetermined level of V_O, the controller switches off the pass transistor Q, which forces the current to free wheel around the path consisting of L, C, and the ultra-fast rectifier D. This effectively transfers the energy stored in the inductor L to the capacitor. Inductor and capacitor sizes are inversely proportional to switching frequency, which accounts for the increasing power density of switching power supplies. Power MOSFETs are rapidly replacing bi-polar transistors as the pass transistor because of their high frequency capability. Since the pass transistor must not only carry load current but reverse recovery current of diode D, an ultra-fast recovery diode is mandatory.

Boost Regulator

A second type of regulator shown in *Figure 5* is capable of boosting the input voltage. Applications for this circuit would be to increase 5 V battery sources to 15 V for CMOS circuits or even to 150 V for electro-luminescent displays.

The concept of this circuit is still the same as the previous, namely to transfer the energy stored in the inductor into the capacitor. The inductor current can ramp up quickly when the transistor switch is closed at time $t_{(0)}$ since the full input voltage is applied to it. The transistor is turned off at time $t_{(1)}$ which forces the inductor current to charge up the capacitor through the ultra-fast diode D. Since the energy stored in the inductor is equal to $L \times I \times I/2$, the PWM IC can increase V_O by increasing its own on-time to increase the peak inductor current before switching. The transfer function is:

$$V_O = V_{in}\ (T/(T - t_{(on)}))$$

Figure 5 Boost Regulator and Associated I/V waveforms

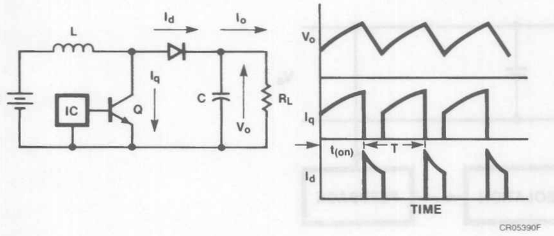


Figure 6 Inverting Regulator and I/V Waveforms

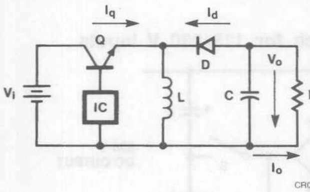
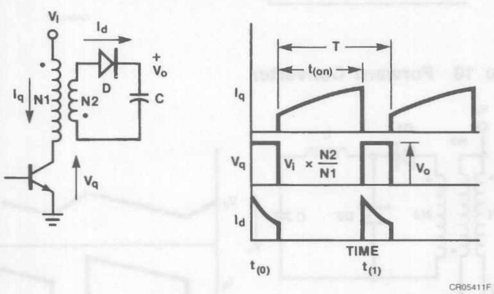


Figure 7 Flyback Converter



Inverting Regulator

Figure 6 shows a switching circuit which produces an output voltage with the opposite polarity of the input voltage. This circuit works in the same fashion as the boost converter but has achieved the voltage inversion by exchanging positions of the transistor and inductor. The circuit is also known as a buck-boost regulator since the absolute magnitude of the output voltage can be higher or lower than the input voltage, depending upon the ratio of on-time to off-time of the pass transistor.

Flyback Converter

The three previous regulators are suitable for low voltage control when no electrical isolation is required. However in off-line switchers operating from 110/220 V mains, electrical isolation is an absolute must. This is achieved by using a transformer in place of the inductor. The flyback converter shown in *Figure 7* is commonly used in power supplies up through 150 W, which is sufficient for most personal computers, many test instruments, video terminals and the like.

Since the transformer operates at high frequency, its size is much smaller than a 50/60 Hz transformer shown in *Figure 2*. Within certain frequency limits, transformer size is inversely proportional to frequency.

Inspection of the switching waveforms in *Figure 7* shows that the circuit behaves very similarly to the boost regulator. The transformer should be regarded as an inductor with two windings, one for storing energy in the transformer core and the other for dumping the core energy into the output capacitor. Current increases in the primary of the transformer during the on-time of the transistor ($t_{(0)} - t_{(1)}$) but note that no secondary current flows because the secondary voltage reverse biases diode D. When the transistor turns off, the transformer voltage polarities reverse because its magnetic field wants to maintain current flow. Secondary current can now flow through the diode to charge up the output capacitor. The output voltage is given by the basic PWM equation times the transformer turns ration (N2/N1):

$$V_o = V_{in} \times (t_{(on)}/(T - t_{(on)})) \times (N2/N1)$$

Voltage control is achieved by controlling the transistor on-time to control the peak primary current.

The flyback converter is well suited for multiple output and high voltage power supplies since the transformer inductance replaces the filter inductor(s). The major disadvantages which limit its use to lower wattage supplies are:

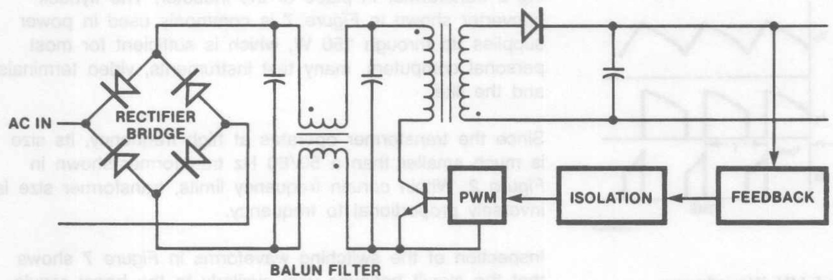
1. The output ripple voltage is high because of half-wave charging of the output capacitor.
2. The transistor must block $2 \times V_{in}$ during turn-off.
3. The transformer is driven in only one direction, which necessitates a larger core, ie more expensive, in a flyback design than for an equivalent design using a forward or push-pull design.

Off-line Switching Supply

Based on the flyback regulator circuit, a complete off-line switching supply is shown in *Figure 8*. The supply is called "off-line" because the DC voltage to the switch is developed right from the AC line.

The circuit also shows the feedback loop completed from the output back to the switching transistor. This feedback loop must have isolation in order for the DC output to be

Figure 8 Complete flyback switching supply



isolated from the AC line. This is normally accomplished by a small transformer or opto-coupler.

Switching power supplies designed for international usage must have selectable AC input voltage ranges of 115 V and 230 V. *Figure 9* shows how this is accomplished for many switching power supplies.

Forward Converter
Although the forward converter is not as well-known as the flyback converter, it is becoming increasingly popular for power supplies in the 100-500 W range. *Figure 10* shows the basic circuit of the forward converter. When the transistor is switched on, current rises linearly in the primary and secondary current also flows through diode D1 into the inductor and capacitor. When the transistor switch is opened, inductor current continues to free-wheel through the capacitor and diode D2. This converter will have less ripple since the capacitor is being continuously charged, an advantage of particular interest in high current supplies.

The relationship between input and output for this circuit configuration is:

$$V_o = V_{in} \times (N2/N1) \times (t_{(on)}/T) \quad \text{(D)}$$

Note that the transformer shown in the above figure has been wound with a third winding and series diode D3. The purpose of this winding is to transfer the magnetizing energy in the core back to the DC supply so it does not have to be dissipated in the transistor switch or some other voltage suppressor. The turns ratio N3/N1 limits the peak voltage seen by the transistor and is normally chosen equal to 1 so that the forward converter can run at 50% duty cycle. Under this condition, the transistor must block $2 \times V_{in}$ during turn-off.

Figure 9 Selector switch for 115/230 V inputs

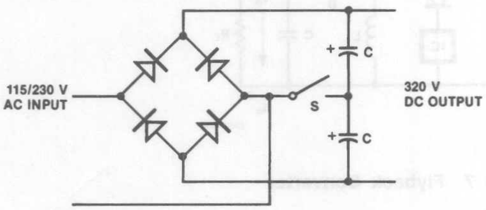
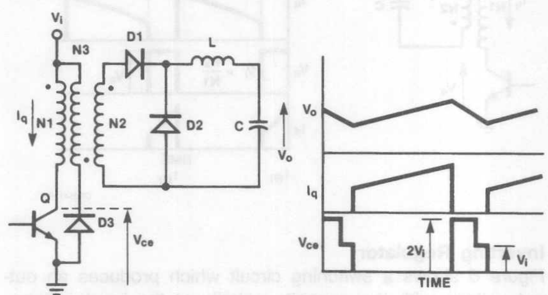


Figure 10 Forward Converter



Symmetrical Converters

Push-Pull Converter
The circuit for this best-known and widely used converter is shown in *Figure 11*.

Transistors Q1 and Q2 are alternately switched on for time period $t_{(on)}$. This subjects the transformer core to an alternating voltage polarity to maximize its usefulness. The transfer function still follows the basic PWM formula but there is the added factor 2 because both transistors alternately conduct for a portion of the switching cycle.

$$V_o = 2 \times V_{in} \times (N2/N1) \times (t_{(on)}/T)$$

The presence of a dead time period $t_{(d)}$ is required to avoid having both transistors conduct at the same time, which would be the same as turning the transistors on into a short circuit. The output ripple frequency is twice the operating frequency which reduces the size of the LC filter components. Note the anti-parallel diodes connected across each transistor switch. They perform the same function as diode D3 in the forward converter, namely to return the magnetization energy to the input voltage whenever a transistor turns off.

Compared to the following symmetrical converters, this circuit has the advantage that the transistor switches share a common signal return line. Its chief disadvantages are that the transformer center-tap connection complicates the transformer design and the primary windings must be tightly coupled in order to avoid voltage spikes when each transistor is turning off.

Half-Bridge Converter
This converter *(Figure 12)* operates in much the same fashion as the previous push-pull circuit.

The input capacitors C1 and C2 split the input voltage equally so that when either transistor turns on, the transformer primary sees $V_{in}/2$. Consequently note no factor of "2" in the following transfer equation:

$$V_o = V_{in} \times (N2/N1) \times (t_{(on)}/T)$$

Since the two transistors are connected in series, they never see more than the input voltage V_{in} plus the inevitable switching transient voltages. The necessity of a dead time is even more obvious here since the simultaneous conduction of both transistors results in a dead short across the input supply. Anti-parallel ultra-fast diodes return the magnetization energy as in the push-pull circuit but alternately to capacitors C1 and C2. This circuit has the slight inconvenience of requiring an isolated base drive to Q1, but since most practical base drive circuits use a transformer for isolation, this shortcoming is hardly worth noting.

Figure 11 Push-pull Converter

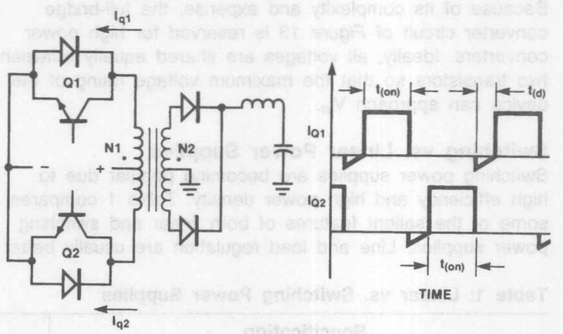


Figure 12 Half-bridge converter circuit

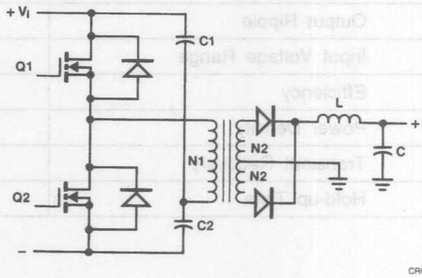
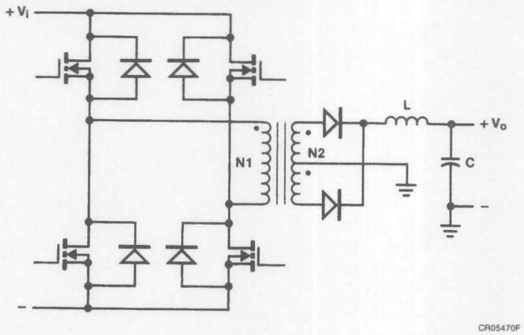


Figure 13 Full-bridge converter circuit



Full-Bridge Converter
Because of its complexity and expense, the full-bridge converter circuit of *Figure 13* is reserved for high power converters. Ideally, all voltages are shared equally between two transistors so that the maximum voltage rating of the device can approach V_{in}.

Switching vs. Linear Power Supplies

Switching power supplies are becoming popular due to high efficiency and high power density. *Table 1* compares some of the salient features of both linear and switching power supplies. Line and load regulation are usually better with linear supplies, sometimes by as much as an order of magnitude, but switching power supplies frequently use linear post-regulators to improve output regulation.

DC-DC CONVERTERS

DC-DC converters are widely used to transform and distribute DC power in systems and instruments. DC power is usually available to a system in the form of a system power supply or battery. This power may be in the form of 5 V, 28 V, 48 V or other DC voltages. All of the previously discussed circuits are applicable to this type of duty. Since voltages are low, isolation is not usually required.

Table 1: Linear vs. Switching Power Supplies

Specification	Linear	Switcher
Line Regulation	0.02 – 0.05%	0.05 – 0.1%
Load Regulation	0.02 – 0.1%	0.1 – 1.0%
Output Ripple	0.5 – 2 mV RMS	25 – 100 mV P-P
Input Voltage Range	± 10%	± 20%
Efficiency	40 – 55%	60 – 80%
Power Density	0.5 W/cu. in.	2 – 5 W/cu. in.
Transient Recovery	50 μs	300 μs
Hold-up Time	2 ms	30 ms

FAIRCHILD

A Schlumberger Company

Optimizing the Ultra-fast POWERplanar™ Rectifier Diode for Switching Power Supplies

Application Note PD-1

Ralph E. Locher, Power And Discrete Division

Introduction

A key device in all high voltage AC-DC power supplies is the ultrafast, reverse recovery rectifier diode. These diodes (D1 and D2 in *Figure 1*) not only play a major role in power supply efficiency but also can be major contributors to circuit electromagnetic interference (EMI) and even cause transistor failure if they are not selected correctly. One would assume that by now, this rectifier diode should approximate the behavior of an ideal switch, i.e., zero on-state voltage, no reverse leakage current and instantaneous turn-on. At first glance, the design of this single pn-junction device would appear to be quite straight forward but a review of the device equations reveals that many compromises must be made to optimize its performance. An understanding of these tradeoffs will allow the circuit designer to select the most appropriate rectifier diode.

Consider how the non-ideal behavior of rectifier D2 affects the circuit performance of the buck regulator in *Figure 1a*. The solid lines in *Figure 2a* depict the switching behavior of the transistor switch and rectifier in comparison to the waveforms (dashed lines) that represent an ideal rectifier. There are four differences between the two cases:

1. The most significant difference is that the peak collector current of the transistor switch (I_T in *Figure 2a*) at the end of turn-on (time t_2) has been increased by the magnitude of the peak reverse recovery current of the rectifier ($I_{R(REC)}$). Correspondingly, the peak power dissipation within the transistor has increased from P_T to P_T' as shown in *Figure 2c*.

2. The maximum transistor voltage V_T at turn-off ($t_4 - t_6$ in *Figure 2a*) has been increased by the dynamic voltage drop of the rectifier during turn-on. Since buck regulators generally run at low voltages, this increase has a minimal effect. However, it is more significant in the forward converter circuit of Figure 1b and in bridge circuits operating from high bus voltages where the voltage margins cannot be as generous.

Figure 1a Buck Regulator to Step-down Input Voltage V_{IN}

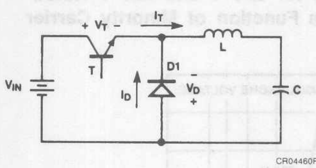


Figure 1b Forward Converter

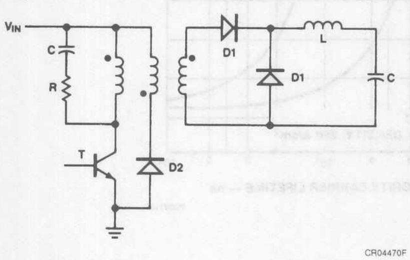
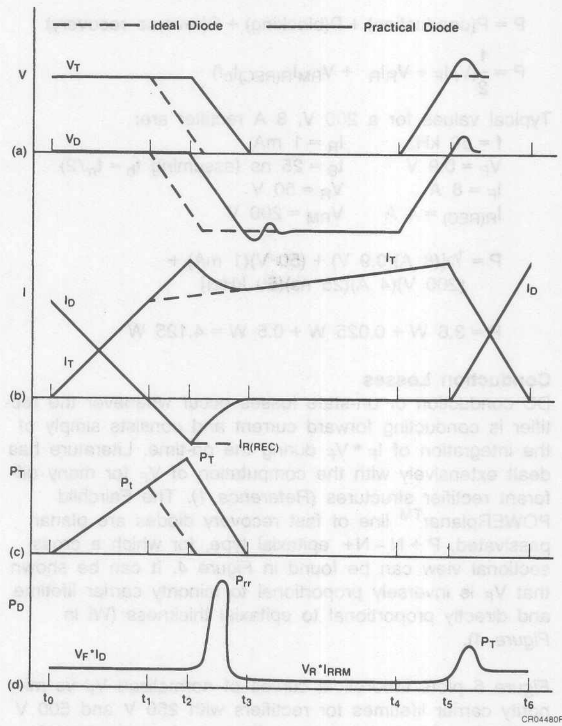


Figure 2 Transistor and Rectifier Voltage and Current Waveforms for the Buck Regulator in *Figure 1a*

a) Transistor and rectifier voltage waveforms
b) Transistor and rectifier current waveforms
c) Transistor power dissipation
d) Rectifier power dissipation



3. Since the rectifier is not ideal, its power dissipation consists of the following components:
   a. Conduction loss ($V_F * I_F$) during the on-time.
   b. Turn-off loss during time $t_2 - t_3$ and turn-on loss during time $t_5 - t_6$ (*Figure 2d*).
   c. Reverse blocking loss ($V_R * I_R$) during period $t_3 - t_5$.
4. The rectifier regains its reverse blocking capability at time t_2. A "snappy" rectifier that quickly turns off $I_{R(REC)}$ will contribute much more EMI than a "soft" fast recovery rectifier.

A better transistor switch will intensify rather than improve the shortcomings of the fast recovery rectifier, so it is necessary to consider more fully the conduction and switching behavior of the rectifier diode.

Power Losses in the Ultra-fast Rectifier Diode

Consider the idealized rectifier current and voltage waveforms in *Figure 3* for a 50 kHz buck regulator. Power dissipation within the rectifier for a 50% duty factor is:

$$P = P(\text{conduction}) + P(\text{blocking}) + P(\text{reverse recovery})$$

$$P = \frac{1}{2}(V_F I_F + V_R I_R \; + V_{RM} I_{R(REC)} t_b f)$$

Typical values for a 200 V, 8 A rectifier are:

$f = 50$ kHz	$I_R = 1$ mA
$V_F = 0.9$ V	$t_B = 25$ ns (assuming $t_b = t_{rr}/2$)
$I_F = 8$ A	$V_R = 50$ V
$I_{R(REC)} = 4$ A	$V_{RM} = 200$ V

$$P = \tfrac{1}{2}[(8\ \text{A})(0.9\ \text{V}) + (50\ \text{V})(1\ \text{mA}) + (200\ \text{V})(4\ \text{A})(25\ \text{ns})(50\ \text{kHz})]$$

$$P = 3.6\ \text{W} + 0.025\ \text{W} + 0.5\ \text{W} = 4.125\ \text{W}$$

Conduction Losses

DC conduction or on-state losses occur whenever the rectifier is conducting forward current and consists simply of the integration of $I_F * V_F$ during the on-time. Literature has dealt extensively with the computation of V_F for many different rectifier structures *(Reference 1)*. The Fairchild POWERplanar™ line of fast recovery diodes are planar passivated, P + N – N+ epitaxial type, for which a cross-sectional view can be found in *Figure 4*. It can be shown that V_F is inversely proportional to minority carrier lifetime and directly proportional to epitaxial thickness (Wi in *Figure 4*).

Figure 5 plots theoretical curves of normalized V_F vs minority carrier lifetimes for rectifiers with 250 V and 500 V avalanche voltage breakdown. Since t_{rr} is approximately equal to minority carrier lifetime, it is apparent that high current pn-junction rectifiers are limited to 20-50 ns re-

Figure 3 Representative Current and Voltage Waveforms for the Rectifier in the Buck Regulator found in *Figure 1a*

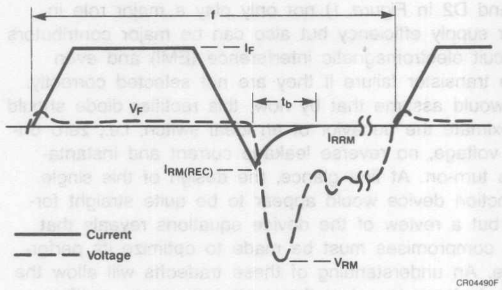


Figure 4 Cross-sectional View of a PLANARpower™, P + N – N+, Fast Recovery Rectifier

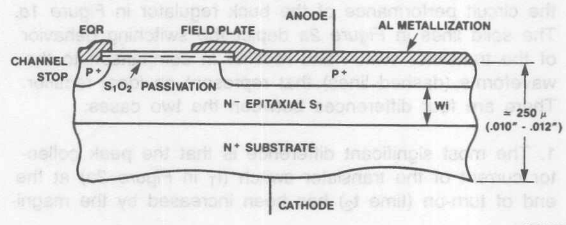
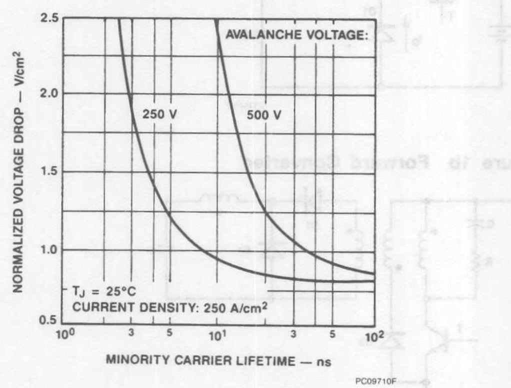


Figure 5 Normalized V_F for 250 V and 500 V Rated Rectifiers as a Function of Minority Carrier Lifetime



verse recovery times because V_F dramatically increases for minority carrier lifetimes less than these. It is also apparent that the V_F curves have a broad minima around 10-30 ns so that another reason to select this value of minority carrier lifetime is that V_F becomes independent of small changes in minority carrier lifetime due to manufacturing tolerances.

It is immediately obvious that the key to maximizing current through the rectifier is to minimize V_F. However at 200 kHz, reverse recovery losses will quadruple to 4 W, so that increasing attention must be paid to this parameter as operating frequency is raised.

Reverse Blocking Losses

Planar passivation techniques have reduced surface leakage currents (I_R) to a negligible amount so that the principle reverse leakage current is recombination current in the space charge region. Some of the many methods to control minority carrier lifetimes are electron or neutron irradiation and gold or platinum diffusion, each with its own advantages and disadvantages. For 200 V, ultrafast recovery rectifiers, gold diffusion still represents the best compromise between speed, V_F, I_R and "soft" recovery.

A drawback to gold diffusion is its relatively high reverse leakage current. It should be pointed out that the reliability of the gold-diffused product is the same as other rectifiers (all other factors being equal), since this leakage current is a bulk and not a surface phenomenon. *Figure 6* illustrates the dependency of recombination current on junction temperature and minority carrier lifetime, which is inversely proportional to the amount of gold in the depletion region. Experimental leakage test results have been plotted in *Figure 6* for the Fairchild 8 A and 16 A series of rectifiers (FRP820 and FRP1620 respectively) at 100°C, 125°C and 150°C. These points indicate that the low current injection level lifetime ranges form 20 – 30 ns and is relatively independent of T_J. Since reliability design guidelines specify that the rectifiers be operated at one-half their voltage rating and 25 – 50°C below their maximum junction temperature, the expected leakage currents in well designed power supplies will run less than 1 mA.

Reverse Recovery Losses

All pn-junction rectifiers, operating in the forward direction, store charge in the form of excess minority carriers. The amount of stored charge is proportional to the magnitude of the forward current. The process by which a rectifier diode is brought out of conduction and returned to its block state is called commutation. *Figure 7* shows an expanded view of current commutation, also called reverse recovery. Starting at time t_0, the rectifier is switched from its forward conducting state at a specified current ramp rate ($-dI_F/dt$). The current ramp rate will be determined by the external circuit (E/L) or the turn-on time of a transistor switch. During the time $t_1 - t_2$, the stored charge within the rectifier is able to supply more current than the circuit requires, so that the rectifier behaves like a short circuit. Stored charge is depleted both by the reverse recovery current and recombination within the rectifier. Eventually the stored charge dwindles to the point that a depletion region around the junction starts to grow, allowing the rectifier to regain its reverse blocking voltage capability (t_2). From a circuit-design standpoint, the most important parameters are the peak reverse recovery current and "S", the softness factor. A "snappy" rectifier will produce a large amplitude voltage transient and contribute significantly to electro-magnetic interference. *Figure 8* illustrates the actual reverse recovery of two rectifier diodes. The peak voltage of the snappy rectifier is 175 V compared to

Figure 6 Regeneration Current for Gold-doped, P + N – N+ Rectifier Diodes

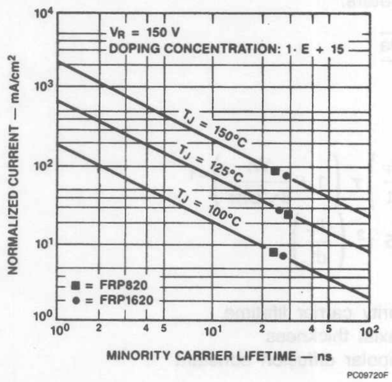
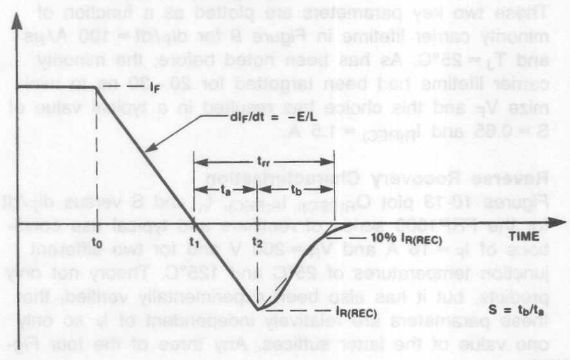


Figure 7 Expanded View of Current Commutation in a Rectifier Diode



142 V peak for the FRP820, the higher voltage resulting from both the higher $I_{R(REC)}$ and the fact that the reverse recovery current decays to zero in a shorter time.

The relative snappiness of a rectifier may be defined quantitatively by dividing the reverse recovery time t_{rr} into two subperiods, t_a and t_b, as shown in *Figure 7*. The softness factor "S" is simply the ratio t_b/t_a. A rectifier with a low value S factor will be more likely to produce dangerous voltage transients, but it will also dissipate less reverse recovery energy than a high S factor rectifier. A reasonable compromise between these two conflicting constraints would be to design a rectifier with $S = 1$ ($t_a = t_b$). The S factors of the FRP820 rectifier and the competitive device in *Figure 8* are 0.55 and 0.31 respectively.

Only recently has it become possible to model the ramp recovery in p-i-n rectifiers *(References 2, 3)* and the following equations have proved useful in predicting reverse recovery parameters.

$$t_{rr} = \frac{Wi\sqrt{\tau/Da}}{8}$$

$$S = \frac{Wi}{4\sqrt{Da\tau}}$$

$$I_{R(REC)} = \left(\frac{dI_F}{dt}\right)\tau\left(1 + \frac{Wi}{8\sqrt{Da\tau}}\right)^{-1}$$

$$Q_{R(REC)} = 0.5\ \tau^2\left(\frac{dI_F}{dt}\right)$$

where:

τ = minority carrier lifetime
Wi = epitaxial thickness
Da = ambipolar diffusion constant

The blocking voltage rating of the rectifier primarily determines Wi; but for a given Wi, note that a short minority lifetime not only decreases $I_{R(REC)}$ but happily increases S. These two key parameters are plotted as a function of minority carrier lifetime in *Figure 9* for $dI_F/dt = 100\ A/\mu s$ and $T_J = 25°C$. As has been noted before, the minority carrier lifetime had been targetted for 20 – 30 ns to minimize V_F and this choice has resulted in a typical value of $S = 0.65$ and $I_{R(REC)} = 1.5$ A.

Reverse Recovery Characterization

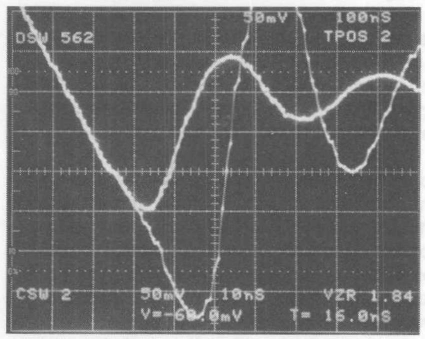
Figures 10-13 plot $Q_{R(REC)}$, $I_{R(REC)}$, t_{rr} and S versus dI_F/dt for the FRP1600 series of rectifiers and typical use conditions of $I_F = 16$ A and $V_R = 200$ V and for two different junction temperatures of 25°C and 125°C. Theory not only predicts, but it has also been experimentally verified, that these parameters are relatively independent of I_F so only one value of the latter suffices. Any three of the four *Figures 10 – 13* completely specifies the reverse recovery behavior of the rectifier. Since S and T_{rr} vary the least over the plotting dI_F/dt range, it is convenient to formulate reverse recovery energy loss P in microwatts in terms of the circuit parameters V_R and dI_F/dt:

$$P = \frac{V_R\left(\frac{dI_F}{dt}\right)f}{2\ S}\left(\frac{St_{rr}}{1+S}\right)^2 10^{-3}\ (\mu W)$$

where:

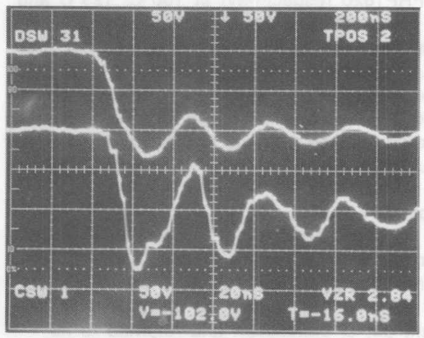
V_R = peak reverse voltage
dI_F/dt = ramp rate (A/µs)
f = operating frequency (kHz)

Figure 8 Comparison of Reverse Recovery of the FRP820 Series Rectifier to a Snappy Rectifier



Test Conditions
$T_J = 25°C$
$I_F = 8$ A
$dI_F/dt = 100\ A/\mu s$

I = 0.5 A/DIV
T = 10 ns/DIV



Test Conditions
$T_J = 25°C$
$I_F = 8$ A
$dI_F/dt = 100\ A/\mu s$

V = 50V/DIV
H = 10 ns/DIV

Figure 9 Theoretical Plots of $I_{R(REC)}$ and S vs Minority Carrier Lifetime

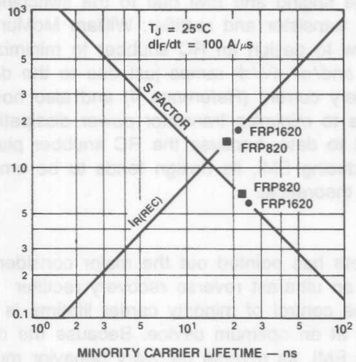


Figure 10 Reverse Recovery Current for the FRM/FRP1620 Series Rectifiers

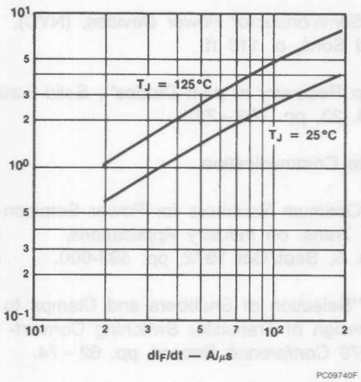


Figure 11 Reverse Recovery Charge for the FRM/FRP1600 Series Rectifier Diodes

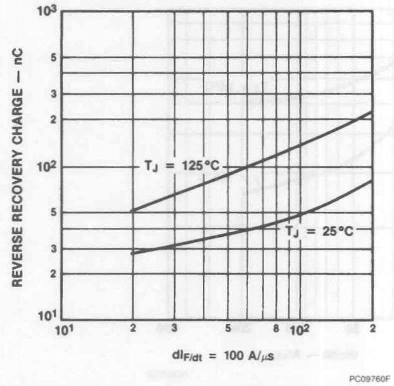


Figure 12 Reverse Recovery Time of the FRM/FRP1600 Series Rectifier Diodes

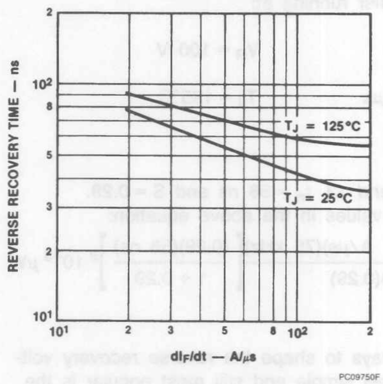
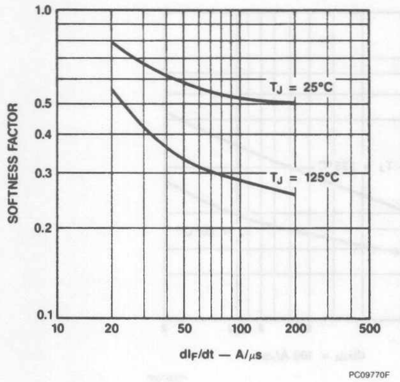


Figure 13 Softness Factor S for the FRM/FRP1600 Series Rectifier Diodes



Example: Calculate the reverse recovery power loss for the FRP1620 rectifier running at:

$I_F = 16$ A $\quad V_R = 100$ V

$dI_F/dt = 100$ A/µs $\quad T_J = 125°C$

$f = 75$ kHz

From *Figures 12 and 13*, $t_{rr} = 56$ ns and $S = 0.29$. Substituting these values in the above equation:

$$P = \frac{(100\ \text{V})(100\ \text{A}/\mu\text{s})(75\ \text{kHz})}{(2)(0.29)} \left[\frac{(0.29)(56\ \text{ns})}{1 + 0.29} \right]^2 10^{-3}\ \mu\text{W}$$

$P = 0.205$ W

There are many ways to shape the reverse recovery voltage spike. The most simple and still most popular is the RC snubber circuit connected across the primary of the transformer in *Figure 1b.* This serves the dual purpose of suppressing voltage ringing and EMI due to the switching action of both the transistor and rectifier. William McMurray has shown how to design an RC snubber to minimize voltage transients and/or dV/dt ramps just due to the diode reverse recovery current *(Reference 4)* and also how to design snubbers to minimize transistor power dissipation *(Reference 5).* But to date, because the RC snubber plays a major role in reducing EMI, its design tends to be empirical rather than theoretical.

Conclusion

This application note has pointed out the major considerations in designing an ultrafast reverse recovery rectifier and shown that the control of minority carrier lifetime is the key in arriving at an optimum device. Because the diode contributes to EMI, its reverse recovery behavior must be carefully controlled and characterized in order to guarantee similar performance from lot to lot.

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1. S.K. Ghandhi, *Semiconductor Power Devices,* (NYC), John Wiley and Sons, p. 110 ff.

2. F. Berz, "Ramp Recovery in p-i-n Diodes", *Solid-State Electronics,* Vol. 23, pp. 783 – 792.

3. C.M. Hu, Private Communication

4. W.McMurray, "Optimum Snubbers for Power Semiconductors", *IEEE Trans. on Industry Applications,* Vol. 1A – 8, No. 5, Sept/Oct 1972, pp. 593-600.

5. W. McMurray, "Selection of Snubbers and Clamps to Optimize the Design of Transistor Switching Converters", *PESC 1979 Conference Record,* pp. 62 – 74.

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Introduction to Power MOSFETs and Their Applications

Application Note PD-3, January 1985

Philip Dunning & Ralph Locher, Power And Discrete Div.

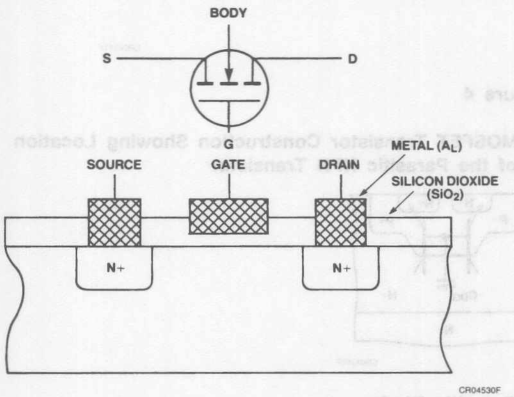
Introduction

The high voltage power MOSFETs that are available today are n-channel, enhancement-mode, double diffused, Metal-Oxide-Silicon, Field Effect Transistors. They perform the same function as NPN, bipolar junction transistors except the former are voltage controlled in contrast to the current controlled bi-polar devices. Today MOSFETs owe their ever-increasing popularity to their high input impedance and to the fact that being a majority carrier device, they do not suffer from minority carrier storage time effects, thermal runaway, or second breakdown.

MOSFET Operation

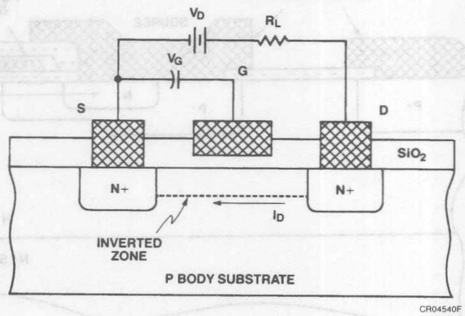
An understanding of the operation of MOSFETs can best be gleaned by first considering the lateral MOSFET shown in *Figure 1*.

Figure 1 Lateral N-Channel MOSFET Cross-section



With no electrical bias applied to the gate G, no current can flow in either direction underneath the gate because there will always be a blocking PN junction. When the gate is forward biased with respect to the source S, as shown in *Figure 2*, the free hole carriers in the p-epitaxial layer are repelled away from the gate area creating a channel, which allows electrons to flow from the source to the drain. Note that since the holes have been repelled from the gate channel, the electrons are the "majority carriers" by default. This mode of operation is called "enhancement" but it is easier to think of enhancement mode of operation as the device being "normally off", i.e., the switch blocks current until it receives a signal to turn on. The opposite is depletion mode, which is a normally "on" device.

Figure 2 Lateral MOSFET Transistor Biased for Forward Current Conduction



The advantages of the lateral MOSFET are:

1. Low gate signal power requirement. No gate current can flow into the gate after the small gate oxide capacitance has been charged.

2. Fast switching speeds because electrons can start to flow from drain to source as soon as the channel opens. The channel depth is proportional to the gate voltage and pinches closed as soon as the gate voltage is removed, so there is no storage time effect as occurs in bipolar transistors.

The major disadvantages are:

1. High resistance channels. In normal operation, the source is electrically connected to the substrate. With no gate bias, the depletion region extends out from the N+ drain in a pseudo-hemispherical shape. The channel length L cannot be made shorter than the minimum depletion width required to support the rated voltage of the device.

2. Channel resistance may be decreased by creating wider channels but this is costly since it uses up valuable silicon real estate. It also slows down the switching speed of the device by increasing its gate capacitance.

Enter vertical MOSFETs!

The high voltage MOSFET structure (also known as DMOS) is shown in *Figure 3*.

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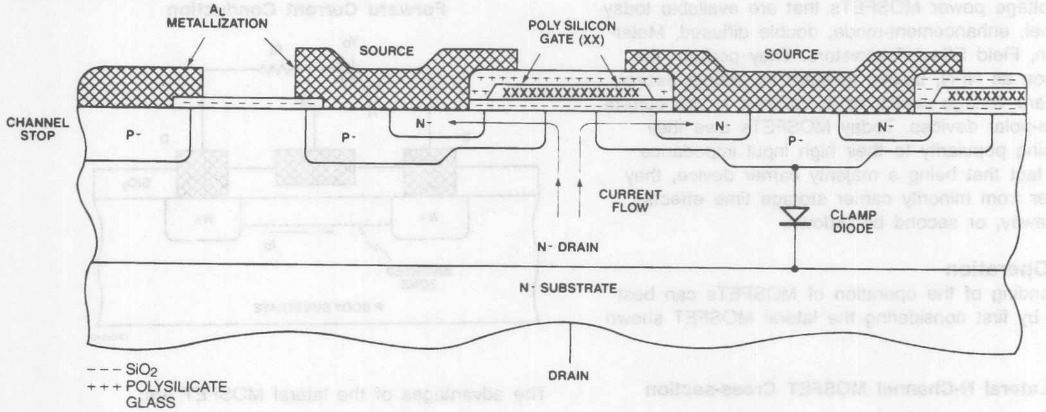
Figure 3 Vertical DMOS Cross-sectional View



The current path is created by inverting the p-layer underneath the gate by the identical method in the lateral FETs. Source current flows underneath this gate area and then vertically through the drain, spreading out as it flows down. A typical MOSFET consists of many thousands of N+ sources conducting in parallel. This vertical geometry makes possible lower on-state resistances ($R_{DS(on)}$) for the same blocking voltage and faster switching than the lateral FET.

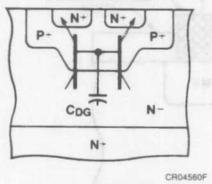
There are many vertical construction designs possible, e.g., V-groove and U-groove, and many source geometries, e.g., squares, triangles, hexagons, etc. All commercially available power MOSFETs with blocking voltages greater than 300 V are manufactured similarly to *Figure 3.* The many considerations that determine the source geometry are $R_{DS(on)}$, input capacitance, switching times and transconductance.

Parasitic Diode

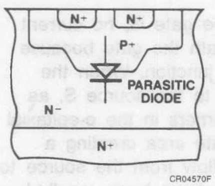
Early versions of MOSFETs were very susceptible to voltage breakdown due to voltage transients and also had a tendency to turn on under high rates of rise of drain-to-source voltage (dV/dt), both resulting in catastrophic failures. The dV/dt turn-on was due to the inherent parasitic NPN transistor incorporated within the MOSFET, shown schematically in *Figure 4a.* Current flow needed to charge up junction capacitance C_{DG} acts like base current to turn on the parasitic NPN.

Figure 4

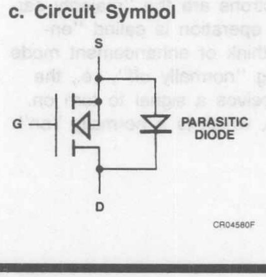
a. MOSFET Transistor Construction Showing Location of the Parasitic NPN Transistor



b. Parasitic Diode



c. Circuit Symbol



The parasitic NPN action is suppressed by shorting the N+ source to the P+ body using the source metallization. This now creates an inherent PN diode in anti-parallel to the MOSFET transistor *(see Figure 4b)*. Because of its extensive junction area, the current ratings and thermal resistance of this diode are the same as the power MOSFET. This parasitic diode does exhibit a very long reverse recovery time and large reverse recovery current due to the long minority carrier lifetimes in the N-drain layer, which precludes the use of this diode except for very low frequency applications, e.g., motor control circuit shown in *Figure 5*. However in high frequency applications, the parasitic diode must be parallelled externally by an ultra-fast rectifier to ensure that the parasitic diode does not turn on. Allowing it to turn on will substantially increase the device power dissipation due to the reverse recovery losses within the diode and also leads to higher voltage transients due to the larger reverse recovery current.

Controlling the MOSFET

A major advantage of the power MOSFET is its very fast switching speeds. The drain current is strictly proportional to gate voltage so that the theoretically perfect device could switch in 50-200 ps, the time it takes the carriers to flow from source to drain. Since the MOSFET is a majority carrier device, a second reason why it can outperform the bipolar junction transistor is that its turn-off is not delayed by minority carrier storage time in the base. A MOSFET begins to turn off as soon as its gate voltage drops down to its threshold voltage.

Switching Behavior

Figure 6 illustrates a simplified model for the parasitic capacitances of a power MOSFET and switching voltage waveforms with a resistive load.

There are several different phenomena occurring during turn-on. Referring to the same figure:

Time interval $t_1 < t < t_2$:

The initial turn-on delay time $t_{d(on)}$ is due to the length of time it takes V_{GS} to rise exponentially to the threshold voltage $V_{GS(th)}$. From *Figure 6*, the time constant can be seen to be $R_S \times C_{GS}$. Typical turn-on delay times for the Fairchild IRF330 are:

$$t_{d(on)} = R_S \times C_{GS} \times \ln(1 - V_{GS(th)}/V_{PK}) \qquad (1)$$

For an assumed gate signal generator impedance of R_S of 50 Ω and C_{GS} of 600 pf, t_d comes to 11 ns. Note that since the signal source impedance appears in the t_d equation, it is very important to pay attention to the test conditions used in measuring switching times.

Physically one can only measure input capacitance C_{iss}, which consists of C_{GS} in parallel with C_{DG}. Even though $C_{GS} >> C_{DG}$, the latter capacitance undergoes a much larger voltage excursion so its effect on switching time cannot be neglected.

Figure 5 Full-wave Motor Control Circuit

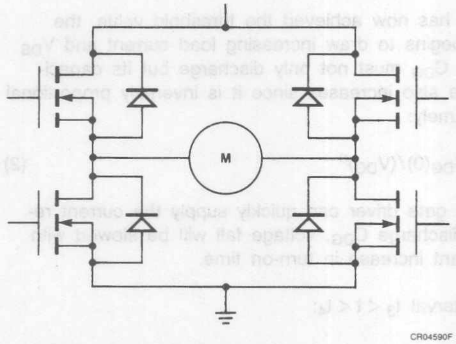
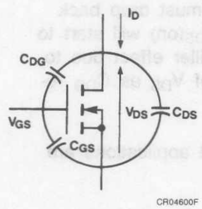
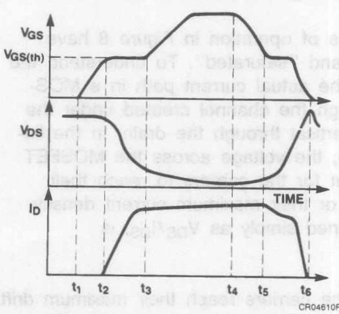


Figure 6

a. MOSFET Capacitance Model for Power MOSFET



b. Switching Waveforms for Resistive Load



Plots of C_{iss}, C_{rss} and C_{oss} for the Fairchild IRF330 are shown in *Figure 7* below. The charging and discharging of C_{DG} is analogous to the "Miller" effect that was first discovered with electron tubes and dominates the next switching interval.

Time interval $t_2 < t < t_3$:

Since V_{GS} has now achieved the threshold value, the MOSFET begins to draw increasing load current and V_{DS} decreases. C_{DG} must not only discharge but its capacitance value also increases since it is inversely proportional to V_{DG}, namely:

$$C_{DG} = C_{DG}(0)/(V_{DG})^n \qquad (2)$$

Unless the gate driver can quickly supply the current required to discharge C_{DG}, voltage fall will be slowed with the attendant increase in turn-on time.

Time interval $t_3 < t < t_4$:

The MOSFET is now on so the gate voltage can rise to the overdrive level.

Turn-off interval $t_4 < t < t_6$:

Turn-off occurs in reverse order. V_{GS} must drop back close to the threshold value before $R_{DS}(on)$ will start to increase. As V_{DS} starts to rise, the Miller effect due to C_{DG} re-occurs and impedes the rise of V_{DS} as C_{DG} recharges to V_{CC}.

Specific gate drive circuits for different applications are discussed and illustrated below.

MOSFET Characterization

The output characteristics (I_D vs V_{DS}) of the Fairchild IRF330 are illustrated in *Figures 8 and 9*.

The two distinct regions of operation in *Figure 8* have been labeled "linear" and "saturated". To understand the difference, recall that the actual current path in a MOSFET is horizontal through the channel created under the gate oxide and then vertical through the drain. In the linear region of operation, the voltage across the MOSFET channel is not sufficient for the carriers to reach their maximum drift velocity or their maximum current density. The static $R_{DS(on)}$, defined simply as V_{DS}/I_{DS}, is a constant.

As V_{DS} is increased, the carriers reach their maximum drift velocity and the current amplitude cannot increase. Since the device is behaving like a current generator, it is said to have high output impedance. This is the so-called "saturation" region. One should also note that in comparing MOSFET operation to a bipolar transistor, the linear and saturated regions of the bipolar are just the opposite to the MOSFET. The equal spacing between the output I_D curves for constant steps in V_{GS} indicates that the transfer characteristic in *Figure 9* will be linear in the saturated region.

Importance of Threshold Voltage

Threshold voltage $V_{GS(th)}$ is the minimum gate voltage that initiates drain current flow. $V_{GS(th)}$ can be easily measured on a Tektronix 576 curve tracer by connecting the gate to the drain and recording the required drain voltage for a specified drain current, typically 250 μA or 1 mA. $V_{GS(th)}$

Figure 7 Typical Capacitances of the Fairchild IRF330

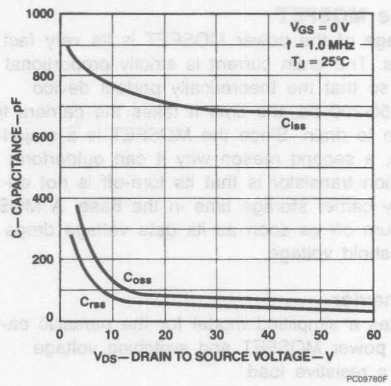
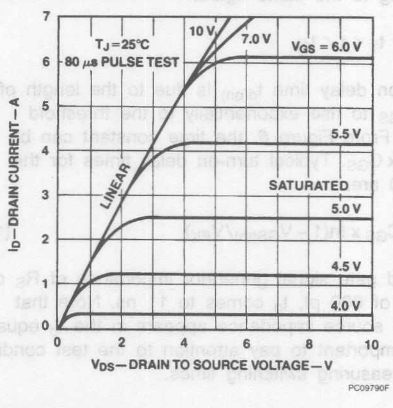


Figure 8 Output Characteristics



in *Figure 9* is 3.5 V. While a high value of $V_{GS(th)}$ can apparently lengthen turn-on delay time, a low value for power MOSFET is undesirable for the following reasons:

1. $V_{GS(th)}$ has a negative temperature coefficient −7 mV/°C.

2. The high gate impedance of a MOSFET makes it susceptible to spurious turn-on due to gate noise.

3. One of the more common modes of failure is gate-oxide voltage punch-through. Low $V_{GS(th)}$ requires thinner oxides, which lowers the gate oxide voltage rating.

Power MOSFET Thermal Model

Like all other power semiconductor devices, MOSFETs operate at elevated junction temperatures. It is important to observe their thermal limitations in order to achieve acceptable performance and reliability. Specification sheets contain information on maximum junction temperature ($T_{J(max)}$), safe areas of operation, current ratings and electrical characteristics as a function of T_J where appropriate. However, since it is still not possible to cover all contingencies, it is still important that the designer perform some junction calculations to ensure that the device operate within its specifications.

Figure 10 shows an elementary, steady-state, thermal model for any power semiconductor and the electrical analogue. The heat generated at the junction flows through the silicon pellet to the case or tab and then to the heat sink. The junction temperature rise above the surrounding environment is directly proportional to this heat flow and the junction-to-ambient thermal resistance. The following equation defines the steady state thermal resistance $R_{(th)JC}$ between any two points x and y:

$$R_{(th)JC} = (T_y - T_x)/P \quad (3)$$

where:

T_x = average temperature at point x (°C)
T_y = average temperature at point y (°C)
P = average heat flow in watts.

Note that for thermal resistance to be meaningful, two temperature reference points must be specified. Units for $R_{(th)JC}$ are °C/W.

The thermal model show symbolically the locations for the reference points of junction temperature, case temperature, sink temperature and ambient temperature. These temperature references define the following thermal references:

$R_{(th)JC}$: Junction-to-case thermal resistance.
$R_{(th)CS}$: Case-to-sink thermal resistance.
$R_{(th)SA}$: Sink-to-ambient thermal resistance.

Since the thermal resistances are in series:

$$R_{(th)JA} = R_{(th)JC} + R_{(th)CS} + R_{(th)SA}. \quad (4)$$

The design and manufacture of the device determines $R_{(th)JC}$ so that while $R_{(th)JC}$ will vary somewhat from device to device, it is the sole responsibility of the manufacturer to guarantee a maximum value for $R_{(th)JC}$. Both the user and manufacturer must cooperate in keeping $R_{(th)CS}$ to an acceptable maximum and finally the user has sole responsibility for the external heat sinking.

Figure 9 Transfer Characteristics

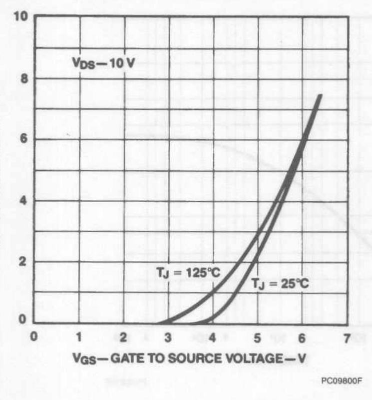
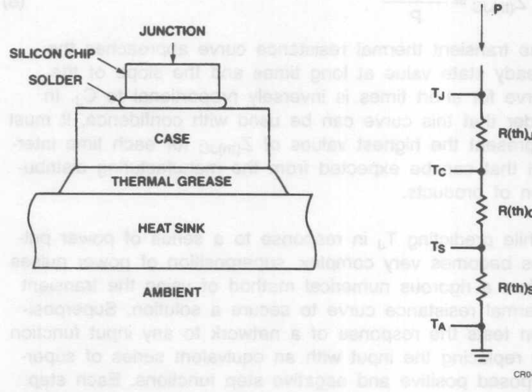


Figure 10 MOSFET Steady State Thermal Resistance Model



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By inspection of *Figure 10*, one can write an expression for T_J:

$$T_J = T_A + P \times [R_{(th)JC} + R_{(th)CS} + R_{(th)SA}] \quad (5)$$

While this appears to be a very simple formula, the major problem in using it is due to the fact that the power dissipated by the MOSFET depends upon T_J. Consequently one must use either an iterative or graphical solution to find the maximum $R_{(th)SA}$ to ensure stability. But an explanation of transient thermal resistance is in order to handle the case of pulsed applications.

Use of steady state thermal resistance is not satisfactory for finding peak junction temperatures for pulsed applications. Plugging in the peak power value results in overestimating the actual junction temperature while using the average power value underestimates the peak junction temperature value at the end of the power pulse. The reason for the discrepancy lies in the thermal capacity of the semiconductor and its housing, i.e., its ability to store heat and to cool down before the next pulse.

The modified thermal model for the MOSFET is shown in *Figure 11*. The normally distributed thermal capacitances have been lumped into single capacitors labelled C_J, C_C, and C_S. This simplification assumes current is evenly distributed across the silicon chip and that the only significant power losses occur in the junction. When a step pulse of heating power P is introduced at the junction, *Figure 12a* shows that T_J will rise at an exponential rate to some steady state value dependent upon the response of the thermal network. When the power input is terminated at time t_2, T_J will decrease along the curve indicated by T_{cool} in *Figure 12a* back to its initial value. Transient thermal resistance at time t is thus defined as:

$$Z_{(th)JC} = \frac{\Delta T_{JC}(t)}{P} \quad (6)$$

The transient thermal resistance curve approaches the steady state value at long times and the slope of the curve for short times is inversely proportional to C_J. In order that this curve can be used with confidence, it must represent the highest values of $Z_{(th)JC}$ for each time interval that can be expected from the manufacturing distribution of products.

While predicting T_J in response to a series of power pulses becomes very complex, superposition of power pulses offers a rigorous numerical method of using the transient thermal resistance curve to secure a solution. Superposition tests the response of a network to any input function by replacing the input with an equivalent series of superimposed positive and negative step functions. Each step function must start from zero and continue to the time for which T_J is to be computed. For example, *Figure 13* illustrates a typical train of heating pulses.

Figure 11 Transient Thermal Resistance Model

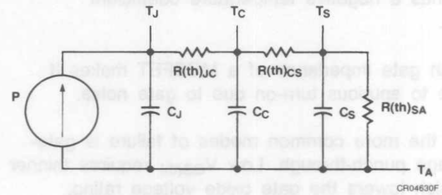
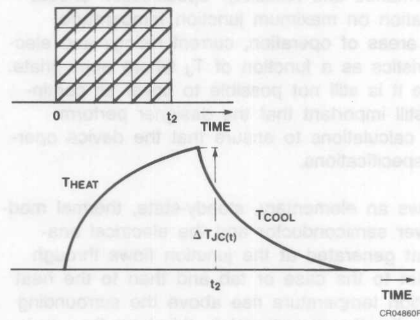
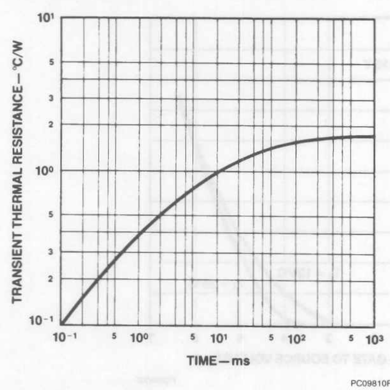


Figure 12

a. Junction Temperature Response to a Step Pulse of Heating Power



b. Transient Thermal Resistance Curve for Fairchild IRF330 MOSFET



T_J at time t is given by:

$$T_J(t) = T_J(0) + \sum_{i=0}^{\eta} P_i[Z_{(th)JC}(t_n - t_i) - Z_{(th)JC}(t_n - t_{i+1})] \quad (7)$$

The usual use condition is to compute the peak junction temperature at thermal equilibrium for a train of equal amplitude power pulses as shown in *Figure 14*.

To further simplify this calculation, the bracketed expression in equation (G) has been plotted for all Fairchild power MOSFETs, as exemplified by the plot of $Z_{(th)JC}$ in *Figure 14b*. From this curve, one can readily calculate T_J if one knows P_M, $Z_{(th)JC}$ and T_C using the expression:

$$T_J = T_C + P_M \times Z_{(th)JC} \quad (8)$$

Example: Compute the maximum junction temperature for a train of 25 W, 200 μs wide heating pulses repeated every 2 ms. Assume a case temperature of 95°C.

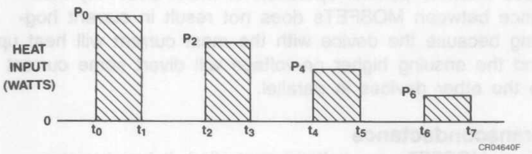
Duty factor = 0.1

From *Figure 14b*: $Z_{(th)JC}$ = .55°C/W

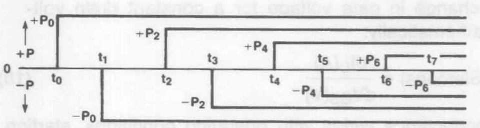
Substituting into equation (H):
$T_{J(max)}$ = 95 + 25 x .55 = 108.75°C

Figure 13 Use of Superposition to Determine Peak T_J

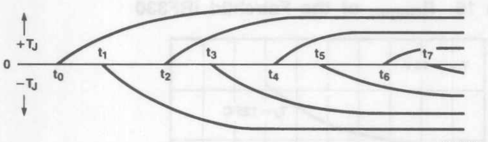
a. Heat Input



b. Equivalent Heat Input by Superposition of Power Pulses



c. Junction temperature response to individual power pulses of b



d. Actual T_J

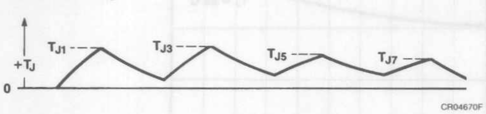
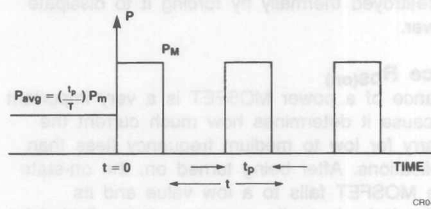
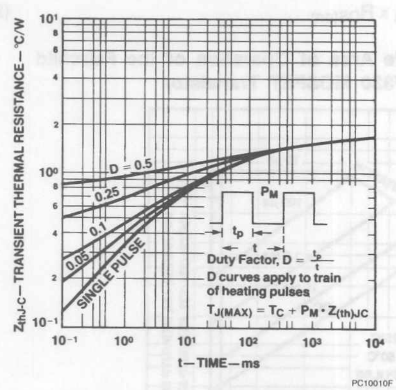


Figure 14

a. Train of Power Pulses



b. Normalized Z_{thJC} for Fairchild IRF330 for Power Pulses Typified in 14a



Safe Area of Operation

The power MOSFET is not subject to forward or reverse bias second breakdown, which can easily occur in bipolar junction transistors. Second breakdown is a potentially catastrophic condition in bi-polar transistors caused by thermal hot spots in the silicon as the transistor turns on or off. However in the MOSFET, the carriers travel through the device much as if it were a bulk semiconductor, which exhibits a positive temperature coefficient of 0.6%/°C. If current attempts to self-constrict to a localized area, the increasing temperature of the spot will raise the spot resistance due to the positive temperature coefficient of the bulk silicon. The ensuing higher voltage drop will tend to redistribute the current away from the hot spot. *Figure 15* delineates the safe areas of operation of the Fairchild IRF330 device.

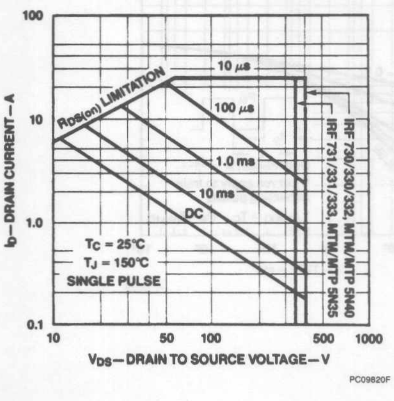
Note that the safe area boundaries are only thermally limited and exhibit no derating for second breakdown. This shows that while the MOSFET transistor is very rugged, it may still be destroyed thermally by forcing it to dissipate too much power.

On-resistance $R_{DS(on)}$

The on-resistance of a power MOSFET is a very important parameter because it determines how much current the device can carry for low to medium frequency (less than 200 kHz) applications. After being turned on, the on-state voltage of the MOSFET falls to a low value and its $R_{DS(on)}$ is defined simply as its on-state voltage divided by on-state current. When conducting current as a switch, the conduction losses P_C are:

$$P_C = I^2_{D(RMS)} \times R_{DS(on)} \tag{9}$$

Figure 15 Safe Area of Operation of the Fairchild IRF330 MOSFET Transistor



To minimize $R_{DS(on)}$, the applied gate signal should be large enough to maintain operation in the linear or ohmic region as shown in *Figure 8*. All Fairchild MOSFETs will conduct their rated current for $V_{GS} = 10$ V, which is also the value used to generate the curves of $R_{DS(on)}$ vs I_D and T_J that are shown in *Figure 16* for the Fairchild IRF330. Since $R_{DS(on)}$ increases with T_J, *Figure 16* plots this parameter as a function of current for room ambient and elevated temperatures.

Note that as the drain current rises, $R_{DS(on)}$ also increases once I_D exceeds the rated current value. Because the MOSFET is a majority carrier device, the component of $R_{DS(on)}$ due to the bulk resistance of the N– silicon in the drain region increases with temperature as well. While this must be taken into account to avoid thermal runaway, it does facilitate parallel operation of MOSFETs. Any inbalance between MOSFETs does not result in current hogging because the device with the most current will heat up and the ensuing higher on-voltage will divert some current to the other devices in parallel.

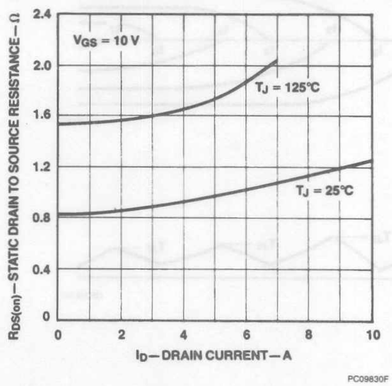
Transconductance

Since MOSFETs are voltage controlled, it has become necessary to resurrect the term transconductance g_{fs}, commonly used in the past with electron tubes. Referring to *Figure 8*, g_{fs} equals the change in drain current divided by the change in gate voltage for a constant drain voltage. Mathematically:

$$g_{fs}\ (\text{Siemens}) = \frac{dI_D(A)}{dV_{GS}(V)} \tag{10}$$

Transconductance varies with operating conditions, starting at 0 for $V_{GS} < V_{GS(th)}$ and peaking at a finite value when the device is fully saturated. It is very small in the ohmic region because the device cannot conduct any more cur-

Figure 16 $R_{DS(on)}$ of the Fairchild IRF330



rent. Typically g_{fs} is specified at half the rated current and for $V_{DS} = 20$ V. Transconductance is useful in designing linear amplifiers and does not have any significance in switching power supplies.

Gate Drive Circuits for Power MOSFETs

The drive circuit for a power MOSFET will affect its switching behavior and its power dissipation. Consequently the type of drive circuitry depends upon the application. If on-state power losses due to $R_{DS(on)}$ will predominate, there is little point in designing a costly drive circuit. This power dissipation is relatively independent of gate drive as long as the gate-source voltage exceeds the threshold voltage by several volts and an elaborate drive circuit to decrease switching times will only create additional EMI and voltage ringing. In contrast, the drive circuit for a device switching at 200 kHz or more will affect the power dissipation since switching losses are a significant part of the total power dissipation.

Compared to a bi-polar junction transistor, the switching losses in a MOSFET can be made much smaller but these losses must still be taken into consideration. Examples of several typical loads along with the idealized switching waveforms and expressions for power dissipation are given in *Figures 17 to 19.*

Their power losses can be calculated from the general expression:

$$P_D = \left(\frac{1}{T} \int_0^T I_D(t) \cdot V_{DS}(t)dt \right) \cdot f_s \qquad (11)$$

where: f_s = Switching frequency.

For the idealized waveforms shown in the figures, the integration can be approximated by the calculating areas of triangles:

Resistive load:

$$P_D = \frac{V^2_{DD}}{R} \left[\frac{t_{(on)} + t_{(off)}}{6} + R_{DS(on)} \cdot T \right] \cdot f_s$$

Inductive load:

$$P_D = \frac{V_{CL}\ I_m\ t_{(off)} f_s}{2} + P_c$$

where:

P_C = conduction loss during period T.

Capacitive load:

$$P_D = \left(\frac{CV^2_{DD}}{2} + \frac{V^2_{DD} R_{DS(on)}}{R^2}\ T \right) f_s$$

Gate losses and blocking losses can usually be neglected. Using these equations, the circuit designer is able to estimate the required heat sink. A final heat run in a controlled temperature environment is necessary to ensure thermal stability.

Figure 17 Resistive Load Switching Waveforms

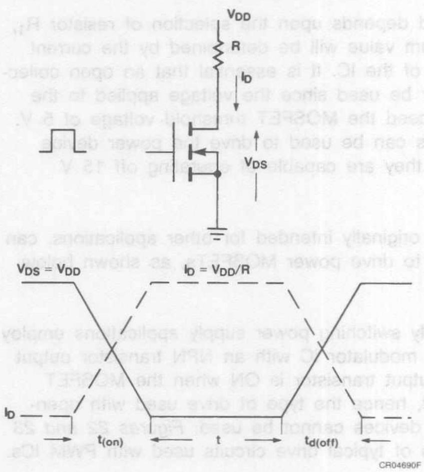
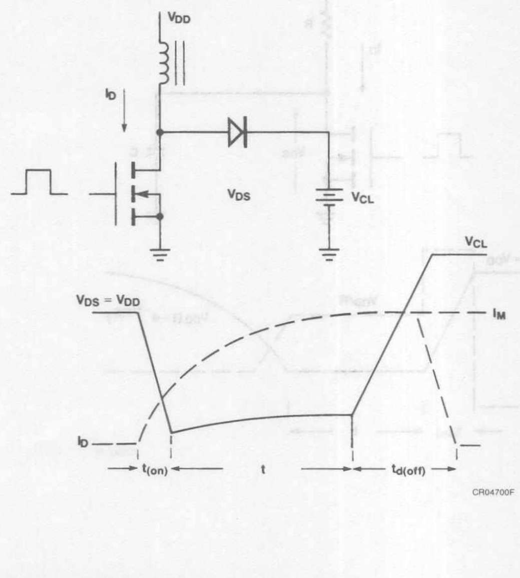


Figure 18 Clamped Inductive Load Switching Waveforms



Since a MOSFET is essentially voltage controlled, the only gate current required is that necessary to charge the input capacitance C_{iss}. In contrast to a 10 ampere bipolar transistor, which may require a base current of 2 amperes to ensure saturation, a power MOSFET can be driven directly by CMOS or open-collector TTL logic circuit similar to that in *Figure 20*.

Turn-on speed depends upon the selection of resistor R_1, whose minimum value will be determined by the current sinking rating of the IC. It is essential that an open collector TTL buffer be used since the voltage applied to the gate must exceed the MOSFET threshold voltage of 5 V. CMOS devices can be used to drive the power device directly since they are capable of operating off 15 V supplies.

Interface ICs, originally intended for other applications, can also be used to drive power MOSFETs, as shown below in *Figure 21*.

Most frequently switching power supply applications employ a pulse width modulator IC with an NPN transistor output stage. This output transistor is ON when the MOSFET should be ON, hence the type of drive used with open-collector TTL devices cannot be used. *Figures 22 and 23* give examples of typical drive circuits used with PWM ICs.

Figure 19 Capacitive Load Switching Waveforms

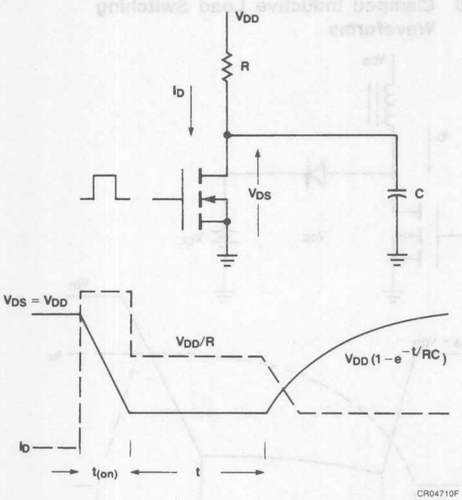


Figure 20 Open Collector TTL Drive Circuit

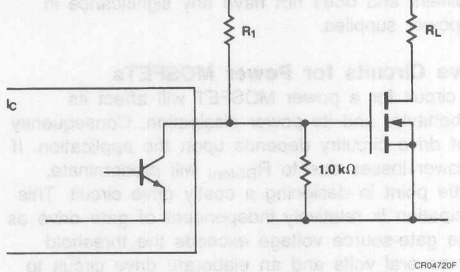


Figure 21 Interface ICs Used to Drive Power MOSFETs

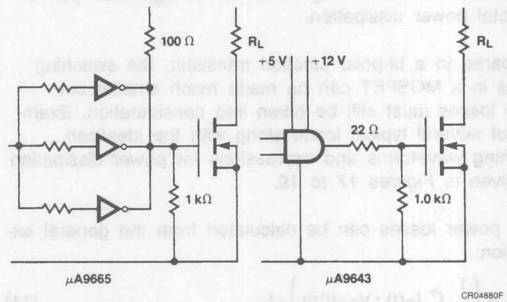
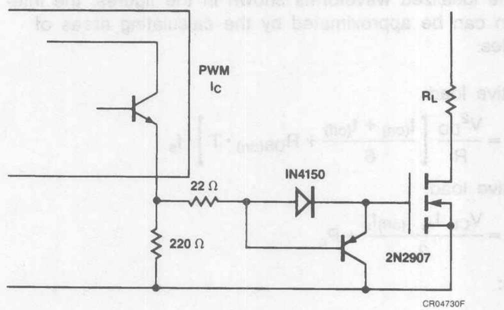


Figure 22 Circuit for PWM IC Driving MOSFET The PNP Transistor Speeds Up Turn-off



Isolation: Off-line switching power supplies use power MOSFETs in a half-bridge configuration because inexpensive, high voltage devices with low $R_{DS(on)}$ are not available.

Since one of the power devices is connected to the positive rail, its drive circuitry is also floating at a high potential. The most versatile method of coupling the drive circuitry is to use a pulse transformer. Pulse transformers are also normally used to isolate the logic circuitry from the MOSFETs operating at high voltage to protect it from a MOSFET failure.

The zener diode shown in *Figure 25* is included to reset the pulse transformer quickly. The duty cycle can approach 50% with a 12 V zener diode. For better performance at turn-off, a PNP transistor can be added as shown in *Figure 26.*

Figure 27 illustrates an alternate method to reverse bias the MOSFET during turn-off by inserting a capacitor in series with the pulse transformer. The capacitor also ensures that the pulse transformer will not saturate due to DC bias.

Figure 23 Emitter Follower with Speed-up Capacitor

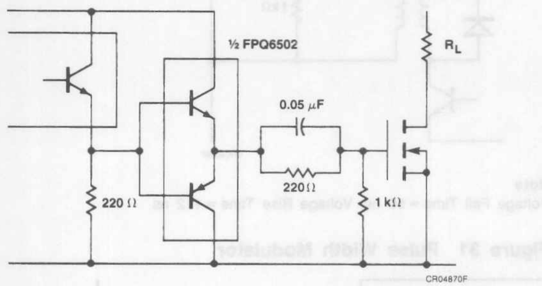


Figure 24 Half-bridge configuration

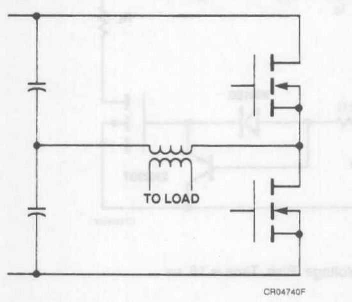


Figure 25 Simple Pulse Transformer Drive Circuit The Transistor May Be a Part of a PWM IC If Applicable

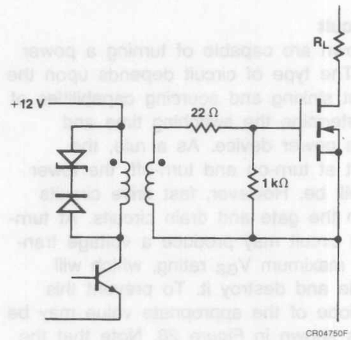


Figure 26 Improved Performance at Turn-off With a Transistor

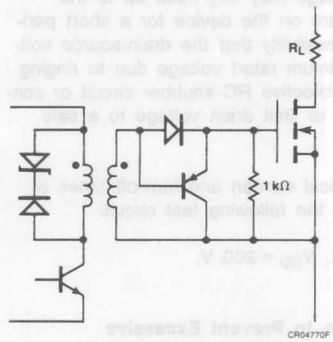
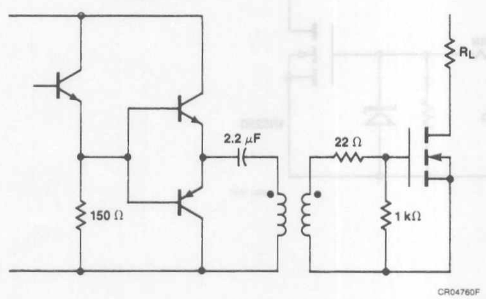


Figure 27 Emitter Follower Driver with Speed-up Capacitor



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Opto-isolators may also be used to drive power MOSFETs but their long switching times make them suitable only for low frequency applications.

Selecting a Drive Circuit

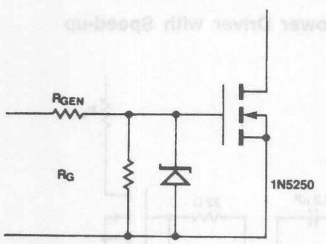
Any of the circuits shown are capable of turning a power MOSFET on and off. The type of circuit depends upon the application. The current sinking and sourcing capabilities of the drive circuit will determine the switching time and switching losses of the power device. As a rule, the higher the gate current at turn-on and turn-off, the lower the switching losses will be. However, fast drive circuits may produce ringing in the gate and drain circuits. At turn-on, ringing in the gate circuit may produce a voltage transient in excess of the maximum V_{GS} rating, which will puncture the gate oxide and destroy it. To prevent this occurrence, a zener diode of the appropriate value may be added to the circuit as shown in *Figure 28*. Note that the zener should be mounted as close as possible to the device.

At turn-off, the gate voltage may ring back up to the threshold voltage and turn on the device for a short period. There is also the possibility that the drain-source voltage will exceed its maximum rated voltage due to ringing in the drain circuit. A protective RC snubber circuit or zener diode may be added to limit drain voltage to a safe level.

Figures 29 – 34 give typical turn-on and turn-off times of various drive circuits for the following test circuit:

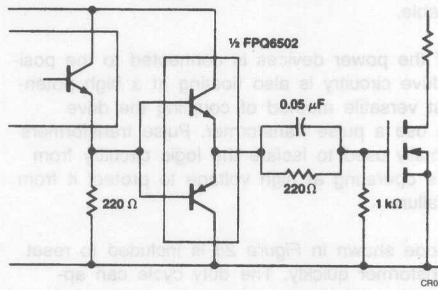
Device: Fairchild IRF450, V_{DD} = 200 V,
Load = 33 Ω resistor.

Figure 28 Zener Diode to Prevent Excessive Gate-Source Voltages



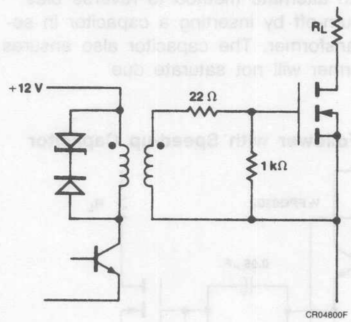
Drive Circuit Turn-on/Turn-off Times

Figure 29 Emitter Follower PWM



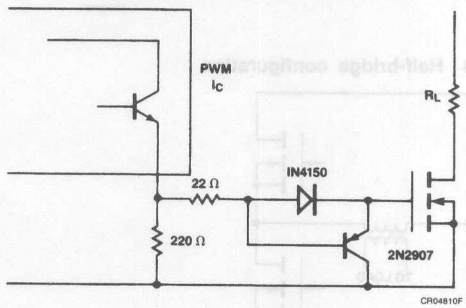
Note
Voltage Fall Time = 17 ns, Voltage Rise Time = 20 ns

Figure 30 Simple Pulse Transformer



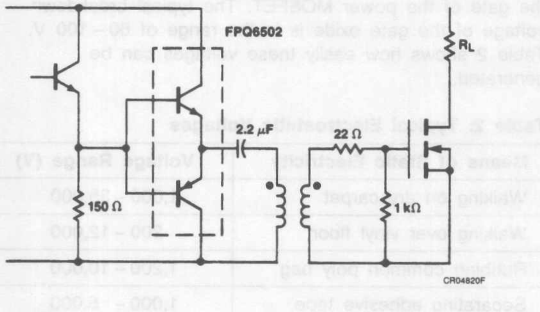
Note
Voltage Fall Time = 50 ns, Voltage Rise Time = 112 ns

Figure 31 Pulse Width Modulator



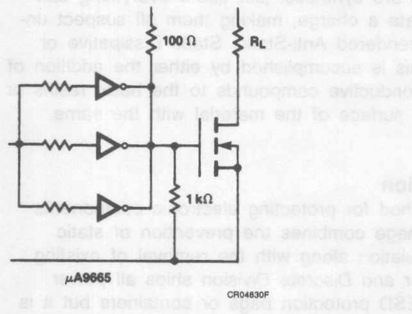
Note
Voltage Fall Time = 50 ns, Voltage Rise Time = 16 ns

Figure 32 Pulse Transformer with Speed-up Capacitor



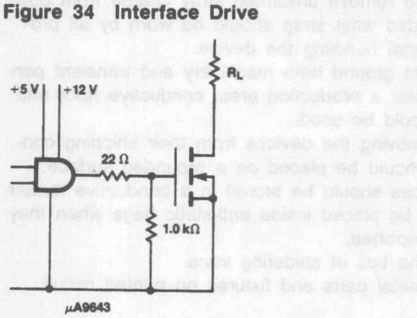
Note
Voltage Fall Time = 63 ns, Voltage Rise Time = 74 ns

Figure 33 Interface Drive



Note
Voltage Fall Time = 200 ns, Voltage Rise Time = 84 ns

Figure 34 Interface Drive



Note
Voltage Fall Time = 70 ns, Voltage Rise Time = 30 ns

FAIRCHILD

A Schlumberger Company

Protecting Power MOSFETs from Static Electricity

Product Bulletin PD-1

Power And Discrete Division

One of the potential problems in the handling of power MOSFETs is damage due to the discharge of static electricity. Since Electro-Static Discharge (ESD) can cause degradation or complete component failure, it is necessary that these components be handled in static safe work stations and that all personnel be trained to handle these components safely.

ESD Basics

Static electricity is generated by the simple separation of any two non-conductive surfaces. Note that rubbing is not necessary, but only separation. As the materials are separated, one surface becomes positively charged and the other negatively charged according to their position in the Triboelectric Series Table shown below. Power MOSFETs can be affected by either a discharge or an electric field caused by the presence of this charge, so the presence of either polarity is cause for concern.

Table 1 – Triboelectric Series

Substance	Charge Range
Air	Greatest Positive Charge
Human Skin	
Glass	
Mica	
Human hair	
Nylon	
Wool	
Silk	
Paper	
Cotton	
Wood	
Hard rubber	
Acetate rayon	
Polyester	
Polyurethane	
PVC	
Teflon	Greatest Negative Charge

From this table, it can be seen that cotton is relatively neutral. Materials that do not hold moisture are the most significant contributors to ESD because moisture lowers their resistivity and, therefore, the relative humidity in the work environment plays a major role in the magnitude of ESD voltage.

ESD damage is caused by the build-up of static charge on the gate of the power MOSFET. The typical breakdown voltage of the gate oxide is in the range of 60 – 100 V. Table 2 shows how easily these voltages can be generated.

Table 2: Typical Electrostatic Voltages

Means of Static Electricity	Voltage Range (V)
Walking on dry carpet	1,000 – 35,000
Walking over vinyl floor	200 – 12,000
Rubbing common poly bag	1,200 – 10,000
Separating adhesive tape	1,000 – 5,000

People and plastics are the biggest culprits in the generation of static electricity. Since most items found in a manufacturing area are synthetic, just about everything can and will generate a charge, making them all suspect unless they are rendered Anti-Static, Static Dissipative or Conductive. This is accomplished by either the addition of anti-static or conductive compounds to the basic resins or by coating the surface of the material with the same compounds.

ESD Protection

The basic method for protecting electronic components from ESD damage combines the prevention of static charge accumulation along with the removal of existing charges. Power and Discrete Division ships all power MOSFETs in ESD protection bags or containers but it is recommended that special handling guidelines be adhered to to insure that no damage occurs during subsequent inspection and manufacturing operations.

1. In order to remove unwanted stray charge from operators, a grounded wrist strap should be worn by all production personnel handling the device.
2. In order to ground both machinery and transient personnel that enter a production area, conductive floor and table mats should be used.
3. When removing the devices from their shipping containers, they should be placed on a grounded surface.
4. The devices should be stored in a conductive material and should be placed inside anti-static bags when they are being transported.
5. Ground the tips of soldering irons.
6. Ground metal parts and fixtures on printed circuit cards.
7. Insert and remove the part only when power is off.
8. An ionized air blower may be used to neutralize static charges on non-conductive materials. This blower should provide a constant stream of both positive and negative ions.

Quality Assurance
and Reliability

Ordering Information
and Package Outlines

FAIRCHILD
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Quality Assurance and Reliability

Fairchild Committment to Quality

Wafer Fabrication

Fairchild's class 100 wafer fabrication areas which are dedicated to high technology products, such as power MOSFETs and ultra-fast rectifiers, are built incorporating the finest automated equipment available. Together with optimized designs and finely-tuned processes, these wafer fabs are capable of producing devices of the highest quality demanded by today's market. Minimizing wafer defect densities is the essential key to manufacturing large dice with high performance at low cost.

The wafer fab process flow, *shown in Figure 1,* includes many Q.A. gates and monitors, all part of the continuous quality improvement process which results in tight distribution of parameters, high yields and thus, quality, low cost products.

Assembly and Test

Fairchild power assembly and test product lines have been specifically designed to optimize cost and reliability of finished products. Todays major dedicated production lines are:

- Power metal can (TO-3)
- Power plastic (TO-220, TO-247)

Assembly and test production flows, together with QA gates and QA process monitors are *shown in Table 1 and Figure 2 for TO-3 and Figure 3 For TO-220.*

Table 1 TO-3 Assembly and Test, In-Line QA Monitors or SPC

Q.A. Monitor	Sample Size	Frequency	Test Performed	Criteria
Probe	5 Wafers 20 Die	Batch	Curve Tracer, I_{GSS} I_{DSS}, $V_{(BR)DSS}$, $V_{GS(th)}$ plus visual	A = 0, R = 1
Saw	AQL 1.5%	Wafer Batch	Visual: Scratches, Chips, Scribe Lines, Voids	AQL 1.5%
Die Attach	5 Units	1500 Units	Die Lift Test (Destructive), Solder Homogeneity and Thickness	AQL 1.5%
Wire Bond Mechanical	4 Wires	1500 Units	Pull Test (Destructive)	A = 0, R = 1
Wirebond Visual	5 Units	1500 Units	Bond Size, Wire Placement, Loop Height	A = 0, R = 1
Seal Visual	20 Units	1500 Units	Visual Inspection of weld, Glass, Cracks	A = 0, R = 1
Seal Gross Leak	20 Units	1500 Units	Bubble Test	A = 0, R = 1
Solder Dip	5 Units	1500 Units	Visual, Homogeneity, Solderability	A = 0, R = 1
Test	20 Units	1500 Units	DC Electricals, Misbinning	A = 0, R = 1
Mark	5 Units	1500 Units	Legibility, Mark Permanency	A = 0, R = 1

Figure 1 Power MOSFET Wafer Fabrication Flow

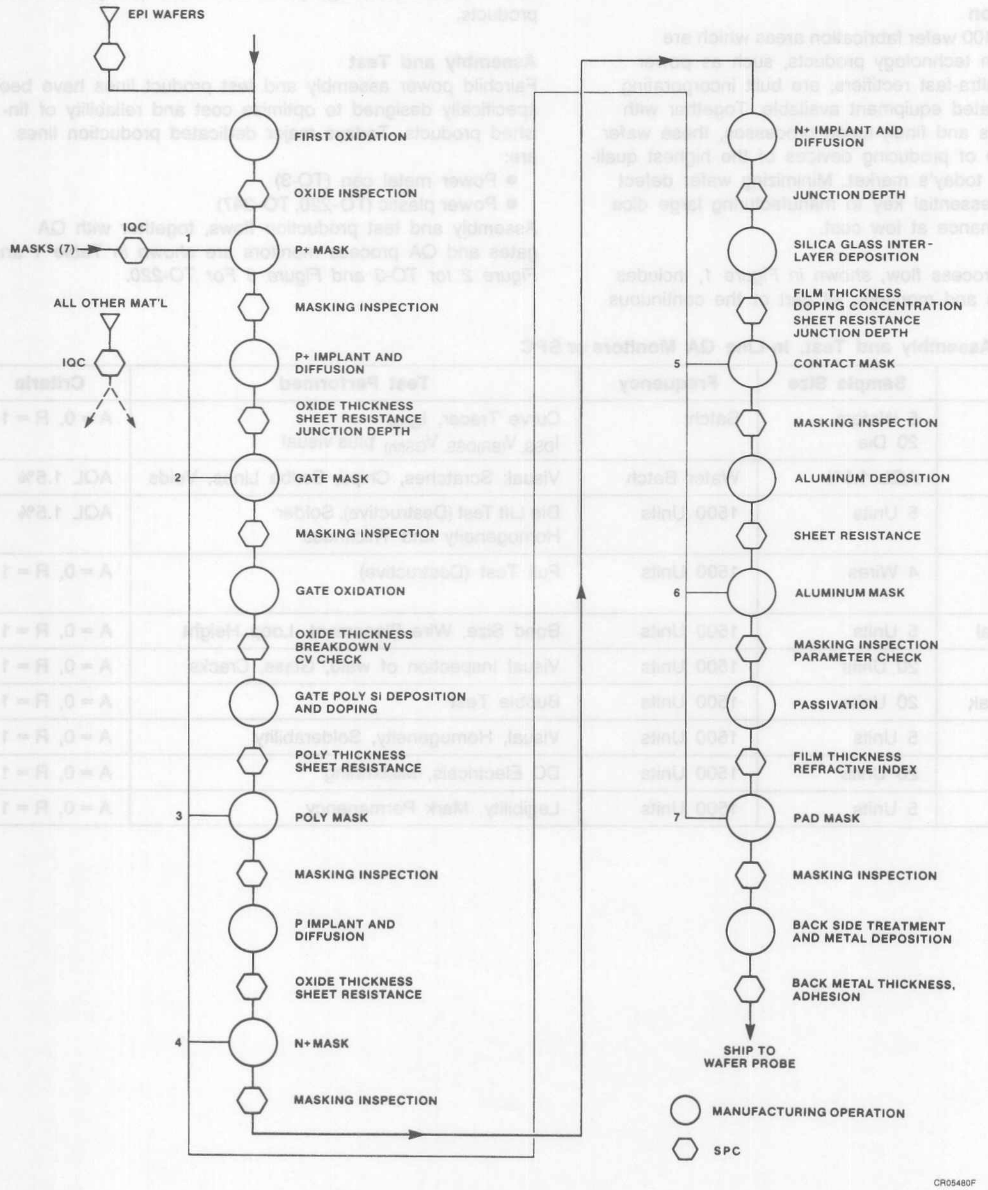


Figure 2 Power MOSFET's TO-3 Assembly and Test Flow

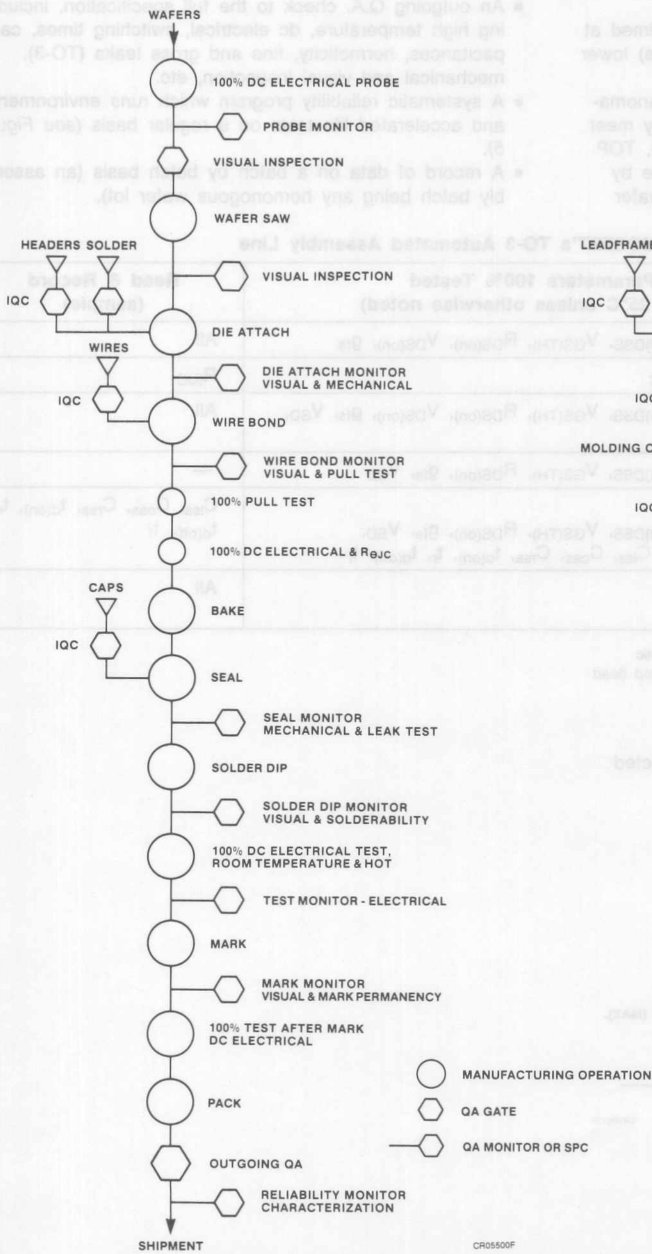
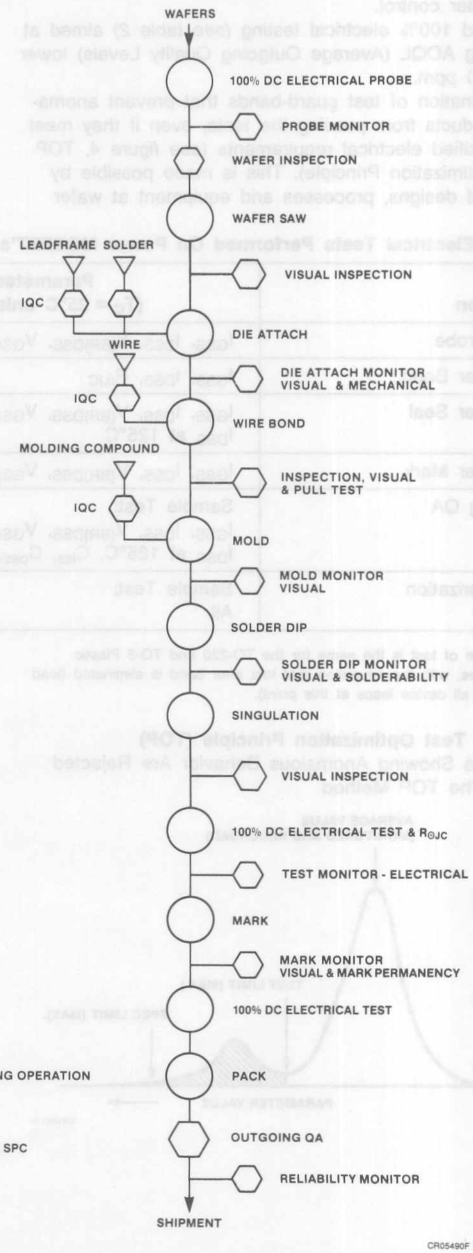


Figure 3 TO-220 Assembly and Test Flow, MOSFETs and Rectifiers



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The main features are:

- Frequent in-line monitors to insure that the process is kept under control.
- Repeated 100% electrical testing *(see table 2)* aimed at achieving AOQL (Average Outgoing Quality Levels) lower than 100 ppm.
- A combination of test guard-bands that prevent anomalous products from passing the tests, even if they meet the specified electrical requirements (*see figure 4*, TOP Test Optimization Principle). This is made possible by improved designs, processes and equipment at wafer fabrication level, the result of which is a tight and predictable distribution of electrical parameters.
- An outgoing Q.A. check to the full specification, including high temperature, dc electrical, switching times, capacitances, hermeticity, fine and gross leaks (TO-3), mechanical and visual inspection, etc.
- A systematic reliability program which runs environmental and accelerated life tests on a regular basis *(see Figure 5)*.
- A record of data on a batch by batch basis (an assembly batch being any homonogous wafer lot).

Table 2 Electrical Tests Performed On Power MOSFET's TO-3 Automated Assembly Line

Operation	Parameters 100% Tested (T_C = 25°C unless otherwise noted)	Read & Record (sample)
Wafer Probe	I_{GSS}, I_{DSS}, $V_{(BR)DSS}$, $V_{GS(TH)}$, $R_{DS(on)}$, $V_{DS(on)}$, g_{fs}	All
Test After Bond	I_{GSS}, I_{DSS}, $R_{\theta JC}$	$R_{\theta JC}$
Test After Seal	I_{GSS}, I_{DSS}, $V_{(BR)DSS}$, $V_{GS(TH)}$, $R_{DS(on)}$, $V_{DS(on)}$, g_{fs}, V_{SD}, I_{DSS} at 125°C	All
Test After Mark	I_{GSS}, I_{DSS}, $V_{(BR)DSS}$, $V_{GS(TH)}$, $R_{DS(on)}$, g_{fs}, V_{SD}	—
Outgoing QA	Sample Test: I_{GSS}, I_{DSS}, $V_{(BR)DSS}$, $V_{GS(TH)}$, $R_{DS(on)}$, g_{fs}, V_{SD}, I_{DSS} at 125°C, C_{iss}, C_{oss}, C_{rss}, $t_{d(on)}$, t_r, $t_{d(off)}$, t_f	C_{iss}, C_{oss}, C_{rss}, $t_{d(on)}$, t_r, $t_{d(off)}$, t_f
Characterization	Sample Test: All	All

The sequence of test is the same for the TO-220 and TO-3 Plastic Assembly lines, with the exception that test after bond is eliminated (lead frame shorts all device leads at this point).

Figure 4 Test Optimization Principle (TOP)
All Devices Showing Anomalous Behavior Are Rejected Through The TOP Method

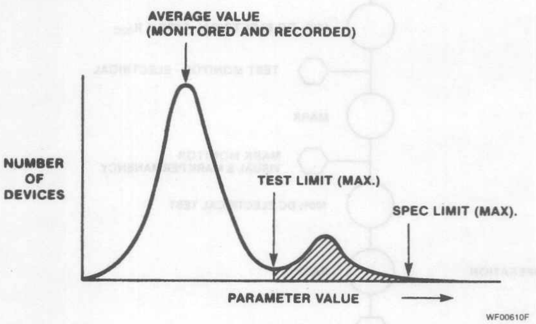
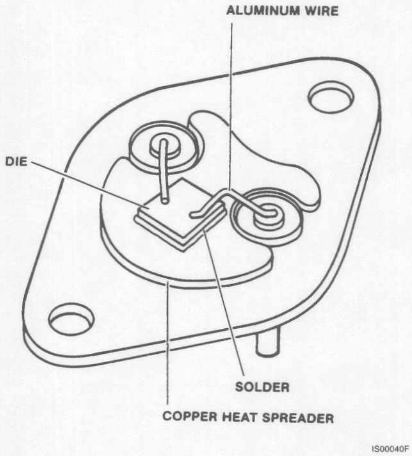


Figure 5 Control of TO-3 Assembly Quality



Component	Electric Tests	QA Monitors	Reliability Tests
Solder	$R_{\theta JC}$	• Die LIFT • Visual inspection	• Temp Cycles −55, +150°C • Power Cycles $\Delta T_C = 70°C$
Die	DC Electricals, Switching Times, Capacitances	• Visual Inspection	• HTRB: 80% $V_{(BR)DSS}$, $T_j = 150°C$ • HTS: 150°C • HTGB: 20 V, 150°C • OP LIFE: $T_J = 150°C$
Al. Wire	$R_{DS(on)}$, $V_{DS(on)}$, V_F	• Visual Inspection • Pull Test	• Temp Cycles −55 to +150°C • Power Cycles $\Delta T_C = 70°C$ • OP LIFE: $T_J = 150°C$

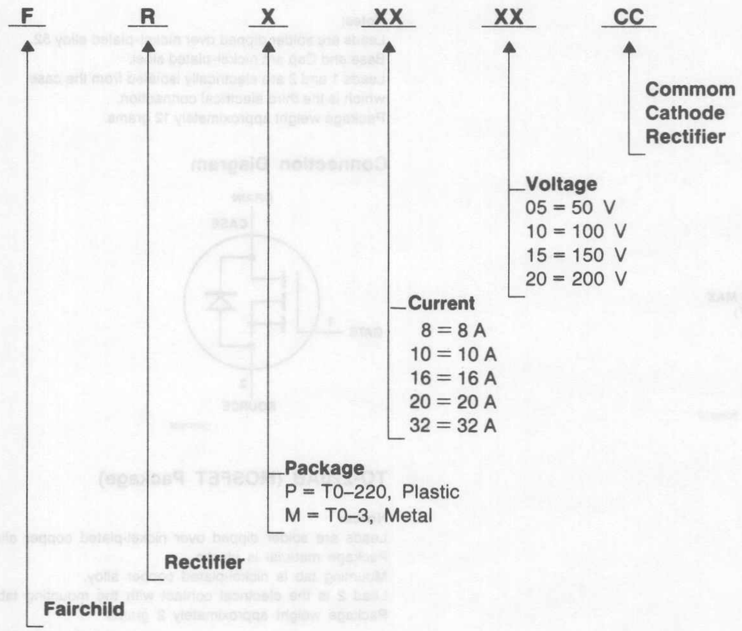
Summery
HTRB = High Temperature Reverse Bias
HTS = High Temperature Storage
HTGB = High Temperature Gate Bias
OPLIFE = Operating Life, Device Heat Sunk, Rated Power Applied

Ordering Information and Package Outlines

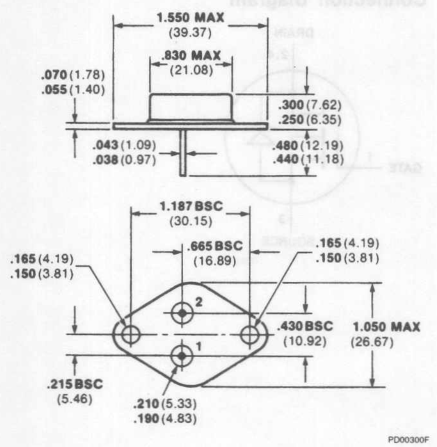
Ordering Information

Fairchild POWERplanar Rectifier Numbering System

— All devices should be ordered using the Fairchild part number as shown in this data book.



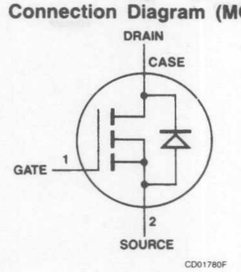
Package Outlines



TO-204AA

Notes:
Leads are solder dipped over nickel-plated alloy 52.
Base and Cap are nickel-plated steel.
Leads 1 and 2 are electrically isolated from the case which is the third electrical connection.
Package weight approximately 12 grams.

Connection Diagram (MOSFET)

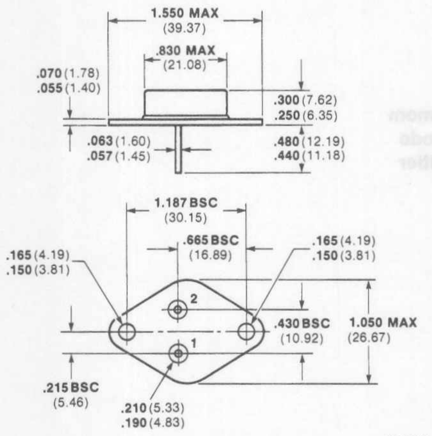


Notes:
TO-204AA and TO-204AE are shipped in 50 piece cavity antistatic trays.
TO-220AB and TO-220AC are shipped in 50 piece antistatic tubes.
All dimensions in inches (bold) and millimeters (parentheses).

Ordering Information and Package Outlines

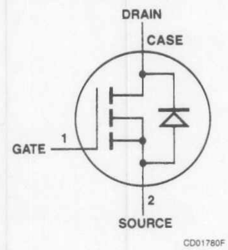
Package Outlines

TO-204AE

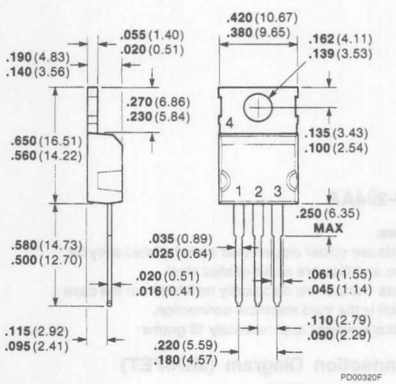


Notes:
Leads are solder dipped over nickel-plated alloy 52.
Base and Cap are nickel-plated steel.
Leads 1 and 2 are electrically isolated from the case which is the third electrical connection.
Package weight approximately 12 grams.

Connection Diagram

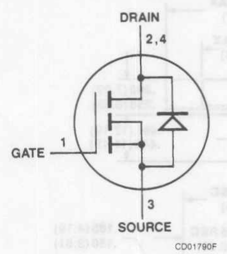


TO-220AB (MOSFET Package)



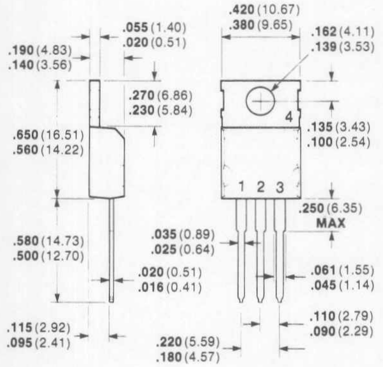
Notes:
Leads are solder dipped over nickel-plated copper alloy.
Package material is plastic.
Mounting tab is nickel-plated copper alloy.
Lead 2 is the electrical contact with the mounting tab.
Package weight approximately 2 grams.

Connection Diagram



Notes:
TO-204AA and TO-204AE are shipped in 50 piece cavity antistatic trays.
TO-220AB and TO-220AC are shipped in 50 piece antistatic tubes.
All dimensions in inches (bold) and millimeters (parentheses).

Package Outlines

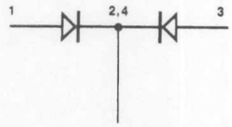


PD00330F

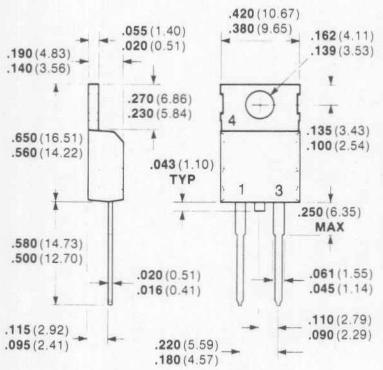
TO-220AB (Rectifier Package)

Notes:
Leads are solder-dipped over nickel-plated copper alloy.
Package material is plastic.
Mounting tab is nickel-plated copper alloy.
Lead 2 is the electrical contact with the mounting tab.
Package weight approximately 2 grams.

Connection Diagram



CD01820F



PD00340F

TO-220AC

Notes:
Leads are solder-dipped over nickel-plated copper alloy.
Package material is plastic.
Mounting tab is nickel-plated copper alloy.
Lead 1 is the electrical contact with the mounting tab.
Package weight approximately 2 grams.

Connection Diagram

CD01810F

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Notes:
TO-204AA and TO-204AE are shipped in 50 piece cavity antistatic trays.
TO-220AB and TO-220AC are shipped in 50 piece antistatic tubes.
All dimensions in inches (bold) and millimeters (parentheses).