MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.334 Power Electronics — Issued: April 1, 2013
Design Project — Due: May 13, 2013

In this project you are to design a buck converter with the following specifications:

Input voltage range:	20 V to 30 V
Input voltage transient limit[1]:	44 V for up to 1 ms
Output Power Range (resistive load):	50 W to 150 W
Output Voltage (static requirement):	12 V ± 3%
Output Voltage (transient limits)[2]:	12 V ± 20%
Allowed output voltage ripple (p-p, any load):	100 mV
Allowed input current ripple (p-p, ideal source):	100 mA
Minimum efficiency (across voltage, load):	85%
Ambient temperature range	-20ºC to +50ºC

As part of this project, you need to:

1. Design and specify numerical component values for the power stage, input filter, and output filter.
2. Specify the power devices and heatsink(s).
3. Specify/design the passive components (e.g. capacitors and inductors) for the power stage and input and output filters.
4. Design a feedback controller that results in a stable closed-loop system across line (input voltage) and load variations and also meets the static and transient control requirements. (A mathematical description of the controller coupled with supporting simulations is sufficient.)

You should provide sufficient analysis and simulation to validate that the proposed design will meet the specifications. Datasheets for a set of components (such as power devices, inductor cores, etc.) are provided for your use. Reasonable departures from this component set are permitted but datasheets with sufficient design data must be provided for any such departures. (Note that pre-designed components, such as EMI filters, wound inductors, and converters are *not* permissible.) Provided below are some guidelines to help you with the design:

Power Devices and Heat Sinks

When specifying each power device you must ensure that the device junction temperature remains sufficiently (e.g., at least 25ºC) below the allowable maximum junction temperature (typ. 150ºC) under all operating conditions. A first step is to make approximate calculations of device losses, including conduction and switching losses. For switching losses of the power MOSFET you may assume linear rise and fall of the current waveforms, and use the nominal

[1] The converter must me able to survive this input voltage transient, but does not have to run during the transient.
[2] The voltage should not vary outside this range during steps between minimum and maximum load.

delay, rise, and fall times provided in the datasheet. You may neglect the switching losses associated with the diode. Note that the on-state resistance of a power MOSFET varies with junction temperature; this variation is specified in the data sheet.

Once device losses are calculated, you should select heat sink(s) with sufficiently low thermal resistance to limit the junction temperature of the devices to acceptable levels. (Junction-to-Case thermal resistances are provided in the device datasheets.) You should assume a maximum 40ºC ambient temperature when sizing the heat sink(s).

Passive Components

Ripple current capability is an important consideration when specifying capacitors. (For example, the filter capacitor at the input of a buck converter must sustain substantial ripple.) Another important consideration for filtering capability is the equivalent series resistance (ESR) of the capacitor. (For example, the output ripple voltage may be larger than expected for the selected capacitance value due to the drop across the ESR.) At higher frequencies, the capacitor equivalent series inductance (ESL) also becomes important. When specifying a capacitor, you must validate that the ripple capability of the capacitor is not exceeded, and must account for ESR (and possibly ESL) when calculating ripple voltage on the capacitor.

A set of square-cut ferrite cores is provided for the design of the converter and input filter inductors. Various values of A_L (nH for one turn) are available in each core (recall that inductance is proportional to the number of turns squared.) For 3F3 core material you may assume a maximum allowable flux density of 3000 gauss (0.3 T). You should also assume a maximum allowable current density in the windings of 500 A/cm^2. (Of course, the specified windings must fit within the winding area of the core.) For simplicity, you may neglect inductor core and winding losses and inductor temperature rise.

For those who are ambitious, the inductor losses and temperature rises may be calculated and a design selected such that the inductor does not overheat. (A centerpost temperature rise of 50°C over the 40°C ambient is reasonable.) To do so, you should compute the (approximate) losses in the inductor (as the sum of winding and core losses) and multiply by the thermal resistance of the core to find the inductor centerpost temperature rise. Winding power loss may be (crudely) approximated as the dc winding resistance times the rms inductor current squared. (In more sophisticated calculations, skin effect may be considered in the windings.) Core power loss in a 3F3 material core can be computed by approximating the ac flux in the core as sinusoidal, and calculating the core loss as:

$$P_{core} = C_M \cdot f^{\alpha} \cdot (B_{ac,pk})^{\beta} \cdot V_{core}$$

where P_{core} is the core loss in mW, C_M is the loss density coefficient, f is the switching frequency in Hz, $B_{ac,pk}$ is the peak *ac* flux swing in T, and V_{core} is the volume of the core in cm^3. Empirical values for C_M, α, and β are shown for 3F3 material over various switching frequency ranges in Table 1. Note that these values are only approximate curve fits to measured loss for sinusoidal drive over limited ranges; computed values should thus be used conservatively.

Frequency range	C_M	α	β
100 – 300 kHz	$2.5x10^{-4}$	1.63	2.45
300 – 500 kHz	$2\ x10^{-5}$	1.8	2.5
500 – 1000 kHz	$3.6x10^{-9}$	2.4	2.25

Table 1 Core loss curve fit data for 3F3 Ferrite material at 100ºC core temperature. Data extracted from Ferroxcube Application Note "Design of Planar Power Transformers."

For the cores provided, the thermal resistance values are as follows: RM6 is 60°C/W, RM8 is 38°C/W, RM10 is 30°C/W, RM12 is 23°C/W, and RM14 is 19°C/W.

Feedback Control Design

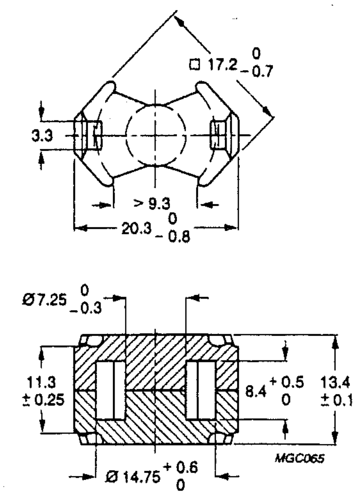
The controller can be designed using linearized, averaged models of the converter. The closed loop system should be stable and well damped for *all* allowed values of input voltage and output resistance, so you should design for the worst case. (Note that the buck converter is particularly simple in terms of control design.) Because the static voltage variation is small, an integral control component is useful for eliminating steady state error. Voltage-mode control (i.e. duty-ratio control) using a PI controller is one design option. You should specify the control law mathematically (e.g. as a transfer function from error voltage to duty ratio). Ambitious students may provide a circuit implementation of such a controller (with a duty ratio signal of specified scaling at the output). We will not consider the PWM modulator, gate drive, or several other circuit design issues in this paper design. You should provide clear validation (analysis and simulation) that the control design is acceptable. As part of this, you should demonstrate that the output voltage will remain within the allowed transient limits during step changes in load (between minimum and maximum values).

YOUR REPORT SHOULD INCLUDE A COVER PAGE THAT CLEARLY AND CONCISELY STATES THE SELECTION / DESIGN OF EACH ELEMENT OF YOUR SYSTEM (E.G., INCLUDING THE DESIGN OF THE INDUCTORS, SELECTED DEVICES AND HEAT SINKS, ETC.) AND STATES THE KEY OPERATING PARAMETERS (E.G., INCLUDING SWITCHING FREQUENCY, COMPENSATOR TRANSFER FUNCTION). THE SELECTED DESIGN VALUES MUST BE JUSTIFIED IN THE BODY OF THE REPORT. THE COVER PAGE SHOULD ALSO INCLUDE A TABLE THAT STATES HOW THE PREDICTED PERFORMANCE COMPARES TO THE CONVERTER SPECIFICATION REQUIREMENTS ON PAGE 1.

CORE SETS

Effective core parameters

SYMBOL	PARAMETER	VALUE	UNIT
$\Sigma(l/A)$	core factor (C1)	0.680	mm^{-1}
V_e	effective volume	1325	mm^3
l_e	effective length	30.0	mm
A_e	effective area	44.1	mm^2
A_{min}	minimum area	39.6	mm^2
m	mass of set	≈7.7	g



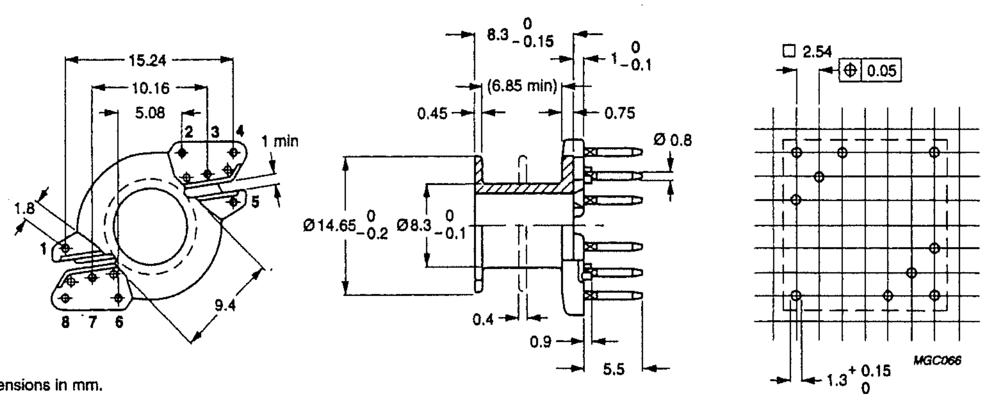
Dimensions in mm.

Fig.1 RM7/I core set.

Core sets for general purpose transformers and power applications

Clamping force 40 ±20 N.

GRADE	A_L (nH)	μ_e	AIR GAP (μm)	TYPE NUMBER
3F3 sup	100 ±3%	≈56	≈800	RM7/I-3F3-A100
	160 ±3%	≈89	≈400	RM7/I-3F3-A160
	250 ±3%	≈139	≈200	RM7/I-3F3-A250
	2500 ±25%	≈1390	≈0	RM7/I-3F3



Dimensions in mm.

Fig.2 RM7/I coil former.

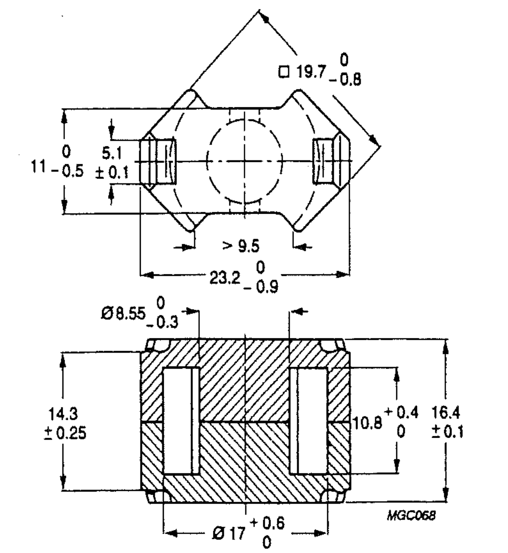
Winding data for RM7/I coil former

NUMBER OF SECTIONS	NUMBER OF PINS	PIN POSITIONS USED	AVERAGE LENGTH OF TURN (mm)	WINDING AREA (mm^2)	WINDING WIDTH (mm)	TYPE NUMBER
1	4	1, 2, 5, 6	35	21	6.85	CSV-RM7-1S-4P
1	8	all	35	21	6.85	CSV-RM7-1S-8P
2	8	all	35	2 × 9.8	2 × 3.2	CSV-RM7-2S-8P

CORE SETS

Effective core parameters

SYMBOL	PARAMETER	VALUE	UNIT
$\Sigma(l/A)$	core factor (C1)	0.604	mm^{-1}
V_e	effective volume	2440	mm^3
l_e	effective length	38.4	mm
A_e	effective area	63.0	mm^2
A_{min}	minimum area	55.4	mm^2
m	mass of set	≈12.0	g



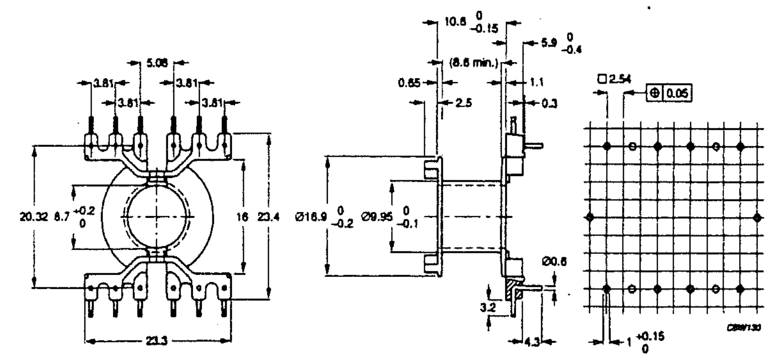
Dimensions in mm.

Fig.1 RM8/I core set.

Core sets for general purpose transformers and power applications

Clamping force 30 ±10 N.

GRADE	A_L (nH)	μ_e	AIR GAP (μm)	TYPE NUMBER
3F3	100 ±3%	≈50	≈1100	RM8/I-3F3-A100
	160 ±3%	≈77	≈550	RM8/I-3F3-A160
	250 ±3%	≈120	≈300	RM8/I-3F3-A250
	315 ±3%	≈151	≈250	RM8/I-3F3-A315
	400 ±3%	≈192	≈180	RM8/I-3F3-A400
	3000 ±25%	≈1440	≈0	RM8/I-3F3



Dimensions in mm.

Fig.2 RM8/I coil former (DIL).

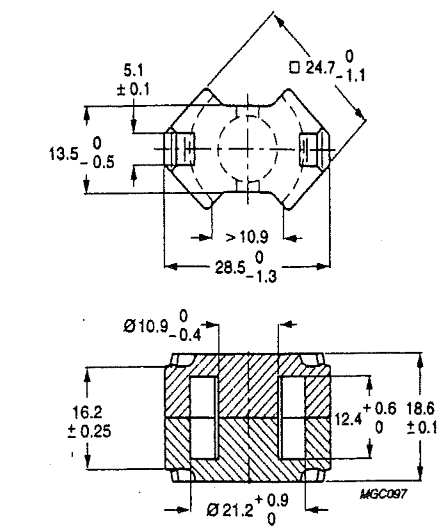
Winding data for RM8/I coil former (DIL)

NUMBER OF SECTIONS	AVERAGE LENGTH OF TURN (mm)	WINDING AREA (mm^2)	WINDING WIDTH (mm)	TYPE NUMBER
1	42	30.9	8.6	CPV-RM8/I-1S-12PD

CORE SETS

Effective core parameters

SYMBOL	PARAMETER	VALUE	UNIT
Σ(I/A)	core factor (C1)	0.462	mm^{-1}
V_e	effective volume	4310	mm^3
l_e	effective length	44.6	mm
A_e	effective area	96.6	mm^2
A_{min}	minimum area	80.9	mm^2
m	mass of set	≈22	g



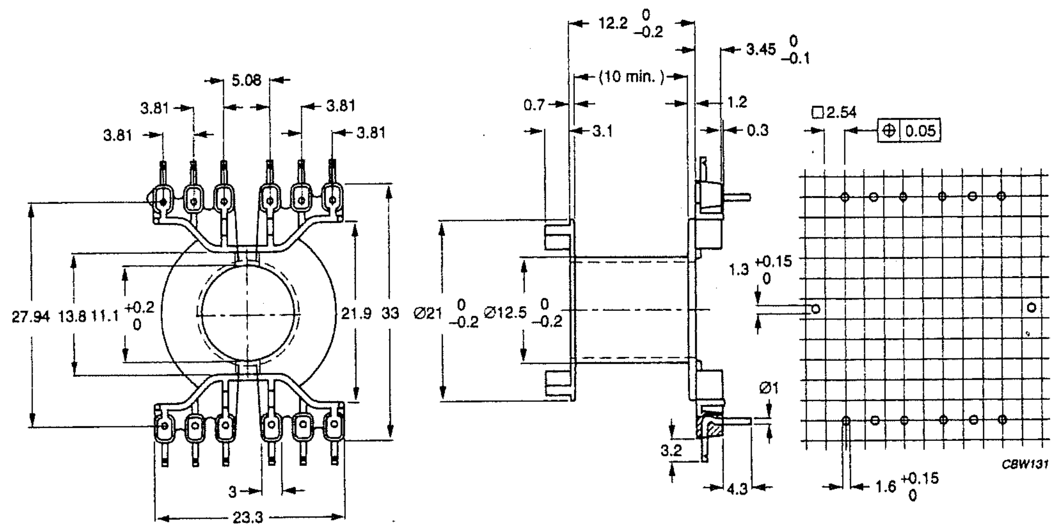
Dimensions in mm.

Fig.1 RM10/I core set.

Core sets for general purpose transformers and power applications

Clamping force 60 ±20 N.

GRADE	A_L (nH)	μ_e	AIR GAP (μm)	TYPE NUMBER
3F3	160 ±3%	≈59	≈900	RM10/I-3F3-A160
	250 ±3%	≈92	≈500	RM10/I-3F3-A250
	315 ±3%	≈116	≈400	RM10/I-3F3-A315
	400 ±3%	≈147	≈300	RM10/I-3F3-A400
	630 ±3%	≈232	≈150	RM10/I-3F3-A630
	4050 ±25%	≈1490	≈0	RM10/I-3F3



Dimensions in mm.

Fig.2 RM10/I coil former (DIL).

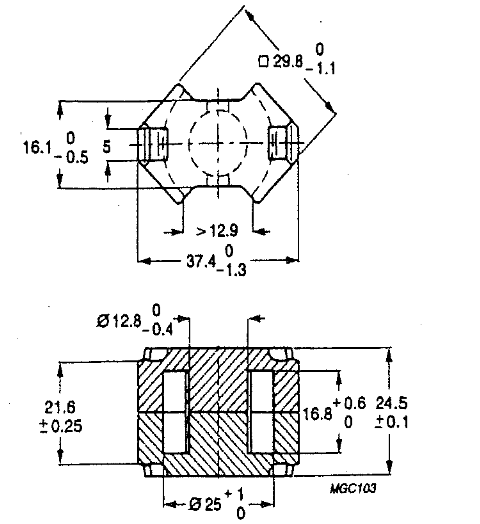
Winding data for RM10/I coil former (DIL)

NUMBER OF SECTIONS	AVERAGE LENGTH OF TURN (mm)	WINDING AREA (mm^2)	WINDING WIDTH (mm)	TYPE NUMBER
1	52	44.2	10.0	CPV-RM10/I-1S-12PD

CORE SETS

Effective core parameters

SYMBOL	PARAMETER	VALUE	UNIT
Σ(I/A)	core factor (C1)	0.388	mm^{-1}
V_e	effective volume	8340	mm^3
l_e	effective length	56.6	mm
A_e	effective area	146	mm^2
A_{min}	minimum area	125	mm^2
m	mass of set	≈45	g



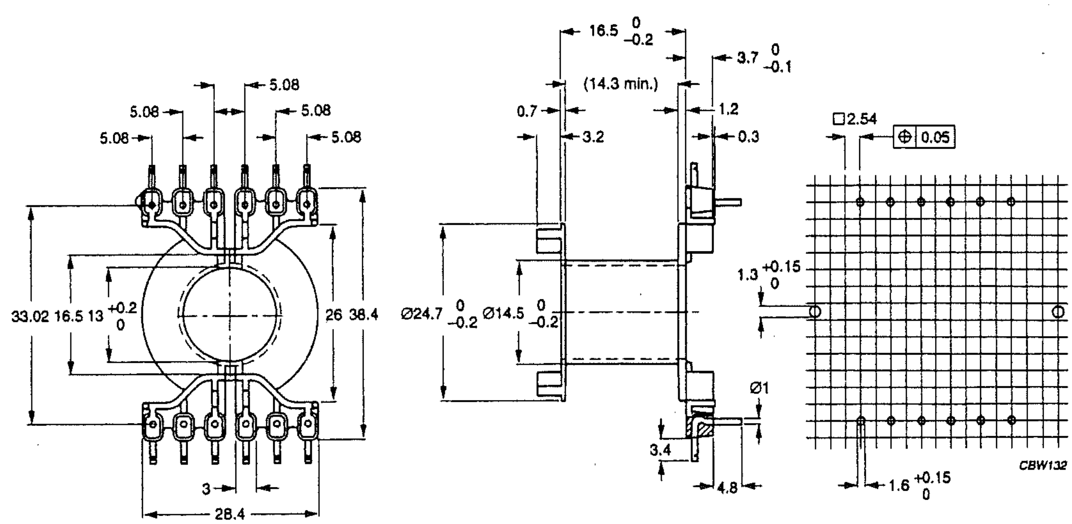
Dimensions in mm.

Fig.1 RM12/I core set.

Core sets for general purpose transformers and power applications

Clamping force 70 ±20 N.

GRADE	A_L (nH)	μ_e	AIR GAP (μm)	TYPE NUMBER
3F3	160 ±3%	≈49	≈1400	RM12/I-3F3-A160
	250 ±3%	≈77	≈800	RM12/I-3F3-A250
	315 ±5%	≈97	≈550	RM12/I-3F3-A315
	400 ±5%	≈123	≈450	RM12/I-3F3-A400
	630 ±5%	≈196	≈300	RM12/I-3F3-A630
	5050 ±25%	≈1560	≈0	RM12/I-3F3



Dimensions in mm.

Fig.2 RM12/I coil former (DIL).

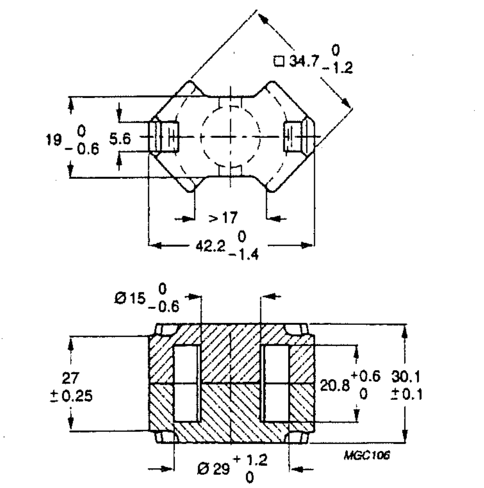
Winding data for RM12/I coil former (DIL)

NUMBER OF SECTIONS	AVERAGE LENGTH OF TURN (mm)	WINDING AREA (mm^2)	WINDING WIDTH (mm)	TYPE NUMBER
1	61	75.0	14.3	CPV-RM12/I-1S-12PD

CORE SETS

Effective core parameters

SYMBOL	PARAMETER	VALUE	UNIT
Σ(I/A)	core factor (C1)	0.353	mm^{-1}
V_e	effective volume	13900	mm^3
l_e	effective length	70.0	mm
A_e	effective area	198	mm^2
A_{min}	minimum area	168	mm^2
m	mass of set	≈74	g



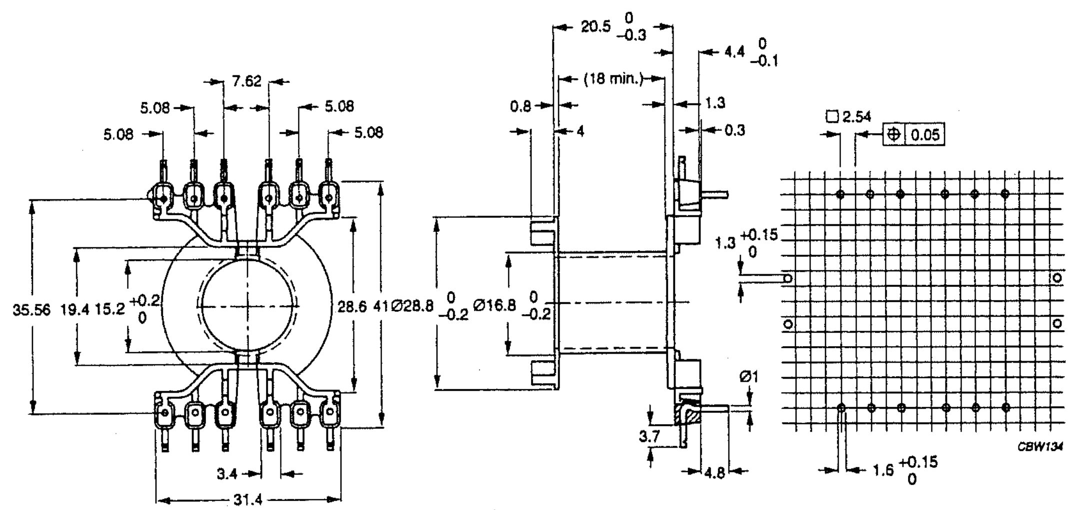
Dimensions in mm.

Fig.1 RM14/I core set.

Core sets for general purpose transformers and power applications

Clamping force 80 ±20 N.

GRADE	A_L (nH)	μ_e	AIR GAP (µm)	TYPE NUMBER
3F3	250 ±3%	≈70	≈950	RM14/I-3F3-A250
	315 ±3%	≈88	≈700	RM14/I-3F3-A315
	400 ±3%	112	≈550	RM14/I-3F3-A400
	630 ±5%	≈177	≈250	RM14/I-3F3-A630
	1000 ±5%	≈281	≈150	RM14/I-3F3-A1000
	5700 ±25%	≈1600	≈0	RM14/I-3F3



Dimensions in mm.

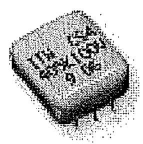
Fig.3 RM14/I coil former; 12-pins (DIL).

Winding data for 12-pins RM14/I coil former (DIL)

NUMBER OF SECTIONS	AVERAGE LENGTH OF TURN (mm)	WINDING AREA (mm^2)	WINDING WIDTH (mm)	TYPE NUMBER
1	71	111.0	18.0	CPV-RM14/I-1S-12PD

Capacitor Types

CS4 CS6



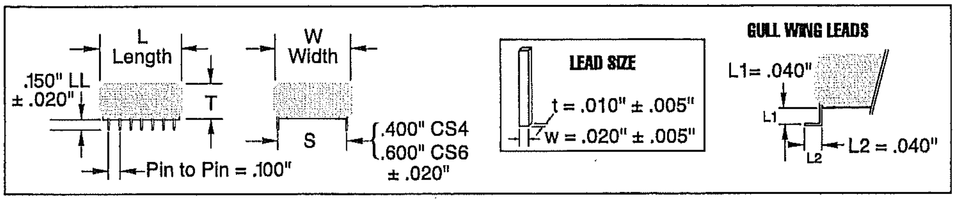
CAPSTICK®

- **Surface mount capability**
- **Ideal for high frequency switching power supplies and DC to DC converters**
- **Low ESR/ESL**
- **High ripple current/ High capacitance**
- **Operating temperature range: -55°C to 125°C**
- **Volumetrically efficient**
- **Made in U.S.A.**

Voltage Ratings Note:

Like all film capacitors, Capstick capacitors have "true" voltage ratings and unlike other dielectric systems require no voltage deratings for maximizing reliability (MTBF) or use life. With FIT rates of well under 5 FIT when used at rated voltage, these units provide only a positive contribution to circuit MTBF calculations.

Circuit designers requiring 500 volt ratings in other dielectric systems for their 370 volt input applications are being penalized by that system's inherent deficiencies. In the film capacitor industry if a device is rated at a certain voltage, then the device is designed to be fully functional and reliable at that voltage for the life of the equipment. Many leading edge circuit designs take advantage of a film capacitor's inherent reliability at rated voltage to both reduce board size and improve performance.



Capacitance µF	PF Code	DC Voltage	ESRΩ @ 500 KHz	RMS Current @ 500 KHz	Max Dimensions (inches) W x T x L	# Leads per side	Type
.47	474	500	.011	6.2	.700 x .320 x .625	4	CS6
1.0	105	500	.008	9.5	.700 x .320 x 1.135	8	CS6
.33	334	400	.012	6.0	.700 x .320 x .435	3	CS6
.47	474	400	.011	6.2	.700 x .320 x .460	3	CS6
1.0	105	400	.008	9.5	.700 x .320 x .880	7	CS6
2.0	205	100	.009	8.3	.500 x .250 x .450	3	CS4
4.0	405	100	.007	11.5	.500 x .250 x .450	3	CS4
4.7	475	100	.006	12.2	.500 x .250 x .525	3	CS4
10.0	106	100	.003	15.3	.500 x .250 x .995	7	CS4
10.0	106	50	.003	15.3	.500 x .320 x .620	5	CS4
20.0	206	50	.0025	17.8	.500 x .320 x 1.150	9	CS4

ELECTRICAL

CAPACITANCE RANGE
0.33 µF to 20.0 µF @ 1KHz

VOLTAGE RANGE
50, 100, 400, 500 VDC

TOLERANCE
± 10% (K)

DISSIPATION FACTOR
≤1.0% @ 1KHz

INSULATION RESISTANCE
≥1,000 Megohm x µF.
Need not exceed 1,000 Megohms
Test voltage @ one minute:

Rated Voltage	≤100 VDC	>100VDC
Test Voltage	10 VDC	100VDC

DIELECTRIC STRENGTH
1.3 x Rated Voltage: 50/100/500 V
1.6 x Rated Voltage: 400 V

TEMPERATURE COEFFICIENT
+6% from -55°C to 85°C

SELF INDUCTANCE
<6nH (Typical) CS6
<4nH (Typical) CS4

PHYSICAL

CONSTRUCTION
Non-inductively constructed with metallized polyester dielectric.
MLP, Multilayer Polymer.

LEAD MATERIAL
Tinned Cu Alloy Lead Frame

LEAD SPACING
.600" (15.0mm) nominal CS6,
.400" (10.0mm) nominal CS4

CASE
UL94V0 Rated Epoxy Coating

COMPONENT MARKING
ITW, Type, Capacitance Code, Tolerance Code, and Voltage

TEMPERATURE RANGE
-55°C to 85°C, with no voltage derating: 50/100 V*
-55°C to 125°C, with no voltage derating: 400/500 V
* For use at 125°C derate voltage by 50%.

PACKAGING
Anti-static Tube

HOW TO ORDER

EXAMPLE: 4.0 µF ±10% 100 VDC =

PF CODE		TOLERANCE	VOLTAGE	TYPE	LEAD STYLE
405		K	100	CS4	
334	405	K = ± 10%	050 = 50 VDC	CS4	Add "G" to part number if Gull-wing leads required
474	475		100 = 100 VDC	CS6	
105	106		400 = 400 VDC		
205	206		500 = 500 VDC		

CS/CB Performance Characteristics
@ 85° C

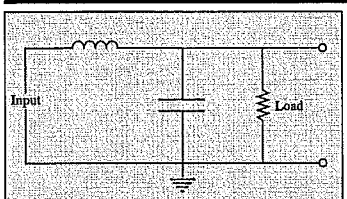
MAXIMUM RMS CURRENT (AMPS) VS. FREQUENCY

Value µF	Rated VDC	1 KHz	10 KHz	100 KHz	500 KHz	1MHz
.47	500	0.8	1.9	3.9	6.2	7.1
1.0	500	1.1	2.4	5.9	9.5	10.6
.33	400	0.7	1.3	3.5	6.0	6.9
.47	400	0.8	1.9	3.9	6.2	7.0
1.0	400	1.1	2.4	5.9	9.5	10.5
2.0	100	0.4	2.6	6.0	8.3	8.9
4.0	100	1.9	4.2	10.2	11.5	12.0
4.7	100	2.0	4.5	10.8	12.2	12.6
10.0	100	4.3	9.9	14.1	15.3	15.6
10.0	50	4.2	9.7	14.0	15.3	15.6
20.0	50	9.3	13.3	16.7	17.8	18.0

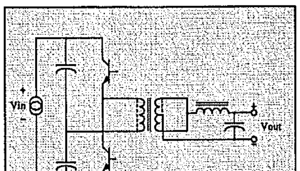
MAXIMUM RMS VOLTAGE VS. FREQUENCY

Value µF	Rated VDC	1 KHz	10 KHz	100 KHz	500 KHz	1MHz
.47	500	250	64	13.1	4.2	2.4
1.0	500	176	38	9.4	3.0	1.6
.33	400	250	64	17.2	6.9	4.0
.47	400	250	64	13.1	4.2	2.4
1.0	400	176	38	9.4	3.0	1.6
2.0	100	35	21	4.7	1.3	0.7
4.0	100	35	18	4.2	1.0	0.4
4.7	100	35	18	3.7	0.8	0.3
10.0	100	35	18	2.2	0.5	0.3
10.0	50	35	18	2.2	0.5	0.2
20.0	50	35	18	1.3	0.3	0.1

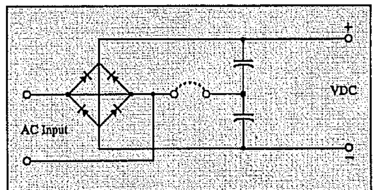
TYPICAL APPLICATIONS



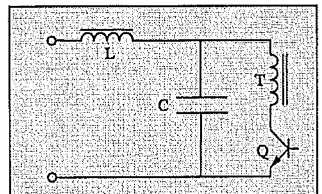
Output Filter



High Voltage Input Filter



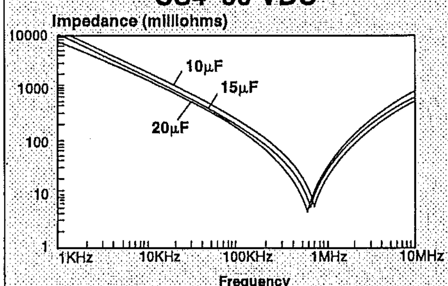
AC & Quasi AC Input



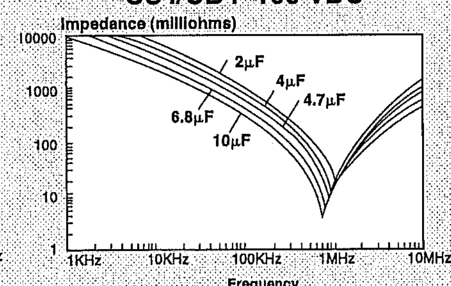
Low Pass

TYPICAL IMPEDANCE VS. FREQUENCY

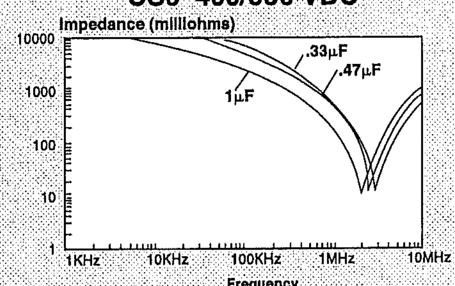
CS4 50 VDC



CS4/CB4 100 VDC

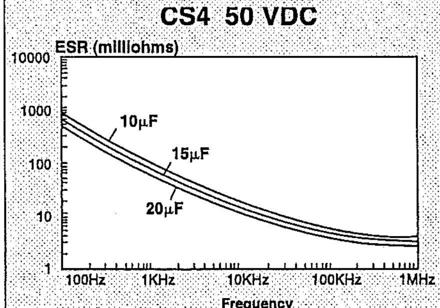


CS6 400/500 VDC

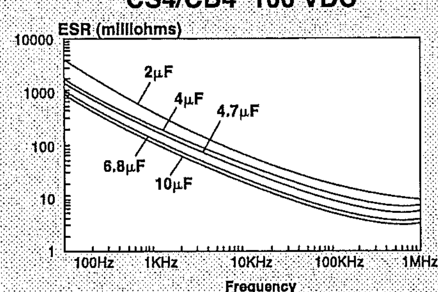


TYPICAL ESR VS. FREQUENCY

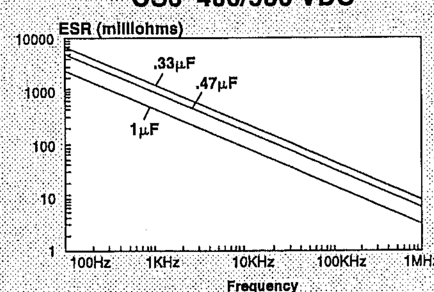
CS4 50 VDC



CS4/CB4 100 VDC



CS6 400/500 VDC



U767D Series

Standard Voltage Ratings - VH/Radial Lead

Aluminum Electrolytic

Rated Voltage (WVDC)	Capacitance (µF)	Catalog Part Number	Nominal Case Size* D x L (inches)	ESR (mΩ) at +25°C 120Hz Max.	ESR (mΩ) at +25°C 20k-100kHz ±30%	Maximum Impedance (mΩ) at +25°C,100kHz	Maximum Ripple Current (A rms) at +85°C 120Hz	Maximum Ripple Current (A rms) at +85°C 20kHz
16 Volts 20 Volts Surge	3,900	U767D16VH392M25X29LL	1.000 x 1.125	51.0	15.0	21	5.37	9.04
	8,200	U767D16VH822M25X41LL	1.000 x 1.625	26.0	9.0	14	8.62	12.87
	12,000	U767D16VH123M25X54LL	1.000 x 2.125	18.0	7.0	11	11.51	16.19
	15,000	U767D16VH153M25X67LL	1.000 x 2.625	14.0	5.9	9	14.26	19.23
	18,000	U767D16VH183M25X79LL	1.000 x 3.125	12.0	5.0	8	16.59	22.44
	22,000	U767D16VH223M25X92LL	1.000 x 3.625	10.0	4.2	8	19.43	26.18
25 Volts 32 Volts Surge	1,200	U767D25VH122M19X29LL	0.750 x 1.125	114.0	32.0	39	3.01	5.30
	1,500	U767D25VH152M19X41LL	0.750 x 1.625	85.0	22.0	29	4.00	6.91
	2,200	U767D25VH222M19X41LL	0.750 x 1.625	58.0	19.0	26	4.86	7.44
	3,900	U767D25VH392M19X54LL	0.750 x 2.125	40.0	13.0	19	6.53	10.01
	4,700	U767D25VH472M19X67LL	0.750 x 2.625	31.0	11.0	16	8.25	11.97
	5,600	U767D25VH562M19X79LL	0.750 x 3.125	26.0	9.4	13	9.57	13.95
	1,800	U767D25VH182M22X29LL	0.875 x 1.125	74.0	21.0	27	4.09	6.75
	3,300	U767D25VH332M22X41LL	0.875 x 1.625	44.0	13.4	19	6.09	9.72
	3,900	U767D25VH392M22X41LL	0.875 x 1.625	37.0	11.9	17	6.67	10.30
	5,600	U767D25VH562M22X54LL	0.875 x 2.125	25.0	8.8	12	9.04	13.33
	6,800	U767D25VH682M22X67LL	0.875 x 2.625	20.0	6.9	10	11.04	16.48
	8,200	U767D25VH822M22X79LL	0.875 x 3.125	16.0	6.0	9	13.33	19.10
	2,700	U767D25VH272M25X29LL	1.000 x 1.125	55.0	15.0	21	5.17	9.04
	4,700	U767D25VH472M25X41LL	1.000 x 1.625	28.0	9.0	14	8.32	12.87
	6,800	U767D25VH682M25X54LL	1.000 x 2.125	20.0	7.0	11	10.91	16.19
	10,000	U767D25VH103M25X67LL	1.000 x 2.625	16.0	5.9	9	13.33	19.23
	12,000	U767D25VH123M25X79LL	1.000 x 3.125	13.0	5.0	8	15.95	22.44
	15,000	U767D25VH153M25X92LL	1.000 x 3.625	10.0	4.2	8	19.43	26.18
35 Volts 44 Volts Surge	820	U767D35VH821M19X29LL	0.750 x 1.125	130.0	32.0	39	2.82	5.30
	1,000	U767D35VH102M19X41LL	0.750 x 1.625	105.0	22.0	29	3.61	6.91
	1,500	U767D35VH152M19X41LL	0.750 x 1.625	70.0	19.0	26	4.42	7.44
	2,200	U767D35VH222M19X54LL	0.750 x 2.125	48.0	13.0	19	5.96	10.01
	3,300	U767D35VH332M19X67LL	0.750 x 2.625	37.0	11.0	16	7.44	11.97
	3,900	U767D35VH392M19X79LL	0.750 x 3.125	30.0	9.4	13	8.91	13.95
	1,200	U767D35VH122M22X29LL	0.875 x 1.125	90.0	21.0	27	3.72	6.75
	2,200	U767D35VH222M22X41LL	0.875 x 1.625	45.0	11.9	17	6.03	10.30
	2,700	U767D35VH272M22X54LL	0.875 x 2.125	38.0	10.2	15	7.39	12.41
	3,300	U767D35VH332M22X54LL	0.875 x 2.125	31.0	8.8	12	8.12	13.33
	4,700	U767D35VH472M22X67LL	0.875 x 2.625	24.0	6.9	10	10.08	16.48
	5,600	U767D35VH562M22X79LL	0.875 x 3.125	19.0	6.0	9	12.23	19.10
	1,800	U767D35VH182M25X29LL	1.000 x 1.125	67.0	15.0	21	4.69	9.04
	3,300	U767D35VH332M25X41LL	1.000 x 1.625	34.0	9.0	14	7.55	12.87
	4,700	U767D35VH472M25X54LL	1.000 x 2.125	23.0	7.0	11	10.19	16.19
	6,800	U767D35VH682M25X67LL	1.000 x 2.625	18.0	5.9	9	12.58	19.23
	8,200	U767D35VH822M25X79LL	1.000 x 3.125	15.0	5.0	8	14.85	22.44
	10,000	U767D35VH103M25X92LL	1.000 x 3.625	13.0	4.2	8	17.03	26.18

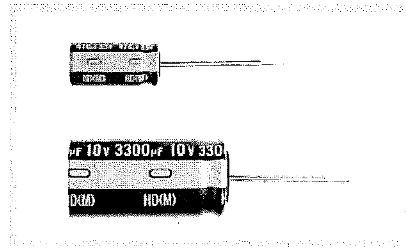
*The case sizes in table are with no sleeve, refer to diagrams for case sizes with sleeve.

U767D LARGE TUBULARS - 125°C

HD series

High Ripple Low Impedance

- Lower impedance at high frequency range.
- Smaller case size and high ripple current.

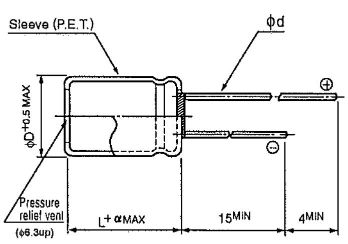


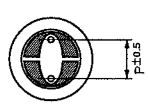
HC ← Low Impedance — **HD** — Smaller → HV

■Specifications

Item	Performance Characteristics							
Category Temperature Range	−40 ~ +105°C							
Rated Voltage Range	6.3 ~ 50V							
Rated Capacitance Range	22 ~ 6800µF							
Capacitance Tolerance	±20% at 120Hz, 20°C							
Leakage Current	After 2 minutes' application of rated voltage, leakage current is not more than 0.01CV or 3 (µA), whichever is greater.							
tan δ	Rated voltage (V)	6.3	10	16	25	35	50	120Hz 20°C
	tan δ (MAX.)	0.22	0.19	0.16	0.14	0.12	0.10	
	For capacitance of more than 1000µF, add 0.02 for every increase of 1000µF.							
Stability at Low Temperature	Rated voltage (V)	6.3	10	16	25	35	50	120Hz
	Impedance ratio ZT / Z20 (MAX.) Z-25°C / Z+20°C	2	2	2	2	2	2	
	Impedance ratio ZT / Z20 (MAX.) Z-40°C / Z+20°C	3	3	3	3	3	3	
Endurance	After an application of D.C. bias voltage plus the rated ripple current for 5000 hours (ϕD ≦ 6.3 : 2000 hours, ϕD=8 : 3000 hours, ϕD=10 : 4000 hours) at 105°C the peak voltage shall not exceed the rated D.C. voltage, capacitors meet the characteristic requirements listed below.							
	Capacitance change	Within ± 25% of initial value						
	tan δ	200% or less of initial specified value						
	Leakage current	Initial specified value or less						
Marking	Printed with white color letter on black sleeve.							

■Radial Lead Type





α	
	(L < 20) 1.5
	(L ≧ 20) 2.0

(mm)

ϕD	5	6.3	8	10	12.5	16
P	2.0	2.5	3.5	5.0	5.0	7.5
ϕd	0.5	0.5	0.6	0.6	*0.6	0.8

*In case L > 25 for the ϕ12.5 dia. unit, lead dia. ϕ d = 0.8mm.

Type numbering system (Example : 10V 3300µF)

1 2 3 4 5 6 7 8 9 10 11 12

U H D 1 A 3 3 2 M H D □

- 12: Size code
- 10–11: Configuration ※
- 9: Capacitance tolerance (±20%)
- 6–8: Rated Capacitance (3300µF)
- 4–5: Rated voltage (10V)
- 2–3: Series name
- 1: Type

※ Configuration

ϕD	Pb-free leadwire Pb-free PET sleeve	Sn-Pb finished leadwire PVC sleeve (containing Pb)
5	DD	DH
6.3	ED	EH
8·10	PD	PH
12.5·16	HD	HH

※ Please contact to us if other configurations are required.

Please refer to page 19, 20, 21 about the formed or taped product spec.
Please refer to page 3 for the minimum order quantity.

- Dimension table in next page.

HD series

■Standard ratings

Cap.(μF)	Code	35 (1V) Case size φD × L (mm)	35 (1V) Impedance (Ω MAX.) 20°C / 100kHz	35 (1V) Impedance (Ω MAX.) −10°C / 100kHz	35 (1V) Rated ripple (mA rms) 105°C / 100kHz	50 (1H) Case size φD × L (mm)	50 (1H) Impedance (Ω MAX.) 20°C / 100kHz	50 (1H) Impedance (Ω MAX.) −10°C / 100kHz	50 (1H) Rated ripple (mA rms) 105°C / 100kHz
22	220					5 × 11	0.34	1.18	238
33	330	5 × 11	0.30	1.0	250				
56	560	6.3 × 11	0.13	0.41	405	6.3 × 11	0.14	0.50	385
100	101					8 × 11.5	0.074	0.22	724
120	121					8 × 15	0.061	0.18	950
150	151	8 × 11.5	0.072	0.22	760	10 × 12.5	0.061	0.18	979
180	181					8 × 20	0.046	0.14	1190
220	221	8 × 15	0.056	0.17	995	10 × 16	0.042	0.12	1370
		▲10 × 12.5	0.053	0.16	1030				
270	271	8 × 20	0.041	0.13	1250	10 × 20	0.030	0.090	1580
330	331	10 × 16	0.038	0.12	1430	10 × 25	0.028	0.085	1870
470	471	10 × 20	0.023	0.069	1820	12.5 × 20	0.027	0.068	2050
560	561	10 × 25	0.022	0.066	2150	12.5 × 25	0.023	0.059	2410
680	681	12.5 × 20	0.021	0.053	2360	12.5 × 31.5	0.021	0.052	2860
820	821					12.5 × 35.5	0.019	0.051	2960
						▲16 × 20	0.023	0.059	2730
1000	102	12.5 × 25	0.018	0.045	2770	16 × 25	0.021	0.056	3010
1200	122	12.5 × 31.5	0.016	0.041	3290				
		▲16 × 20	0.018	0.045	3140				
1500	152	12.5 × 35.5	0.015	0.039	3400				
1800	182	16 × 25	0.016	0.043	3460				

▲ : In this case, [6] will be put at 12th digit of type numbering system.

• Frequency coefficient of rated ripple current

Cap. (μF) \ Frequency	50Hz	120Hz	1kHz	10kHz	100kHz
22 ~ 33	0.45	0.55	0.75	0.90	1.00
39 ~ 330	0.60	0.70	0.85	0.95	1.00
390 ~ 1000	0.65	0.75	0.90	0.98	1.00
1200 ~ 6800	0.75	0.80	0.95	1.00	1.00

LXG Series

Standard Voltage Ratings - VN/Snap Mount

ALUMINUM ELECTROLYTIC

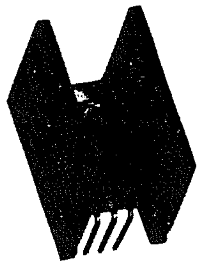
Rated Voltage (WVDC)	Capacitance (μF)	Catalog Part Number	Nominal Case Size* D×L (mm)	Maximum ESR (Ω) at +20°C, 120Hz	Maximum Impedance (mΩ) at +20°C, 30kHz	Maximum Ripple Current (A rms) at +105°C, 120Hz
25 Volts 32 Volts Surge	8,200	LXG25VN822M35X25T2	35 × 25	0.061	65	2.19
	12,000	LXG25VN123M35X30T2	35 × 30	0.041	45	2.76
	15,000	LXG25VN153M35X35T2	35 × 35	0.033	38	3.16
	18,000	LXG25VN183M35X40T2	35 × 40	0.028	30	3.61
	27,000	LXG25VN273M35X50T2	35 × 50	0.018	23	4.7
35 Volts 44 Volts Surge	2,200	LXG35VN222M22X25T2	22 × 25	0.188	120	1.1
	3,300	LXG35VN332M22X30T2	22 × 30	0.126	100	1.42
	3,900	LXG35VN392M22X35T2	22 × 35	0.106	80	1.58
	4,700	LXG35VN472M22X40T2	22 × 40	0.088	70	1.78
	6,800	LXG35VN682M22X50T2	22 × 50	0.061	50	2.26
	3,300	LXG35VN332M25X25T2	25.4 × 25	0.126	90	1.41
	3,900	LXG35VN392M25X30T2	25.4 × 30	0.106	70	1.58
	5,600	LXG35VN562M25X35T2	25.4 × 35	0.074	60	1.98
	6,800	LXG35VN682M25X40T2	25.4 × 40	0.061	50	2.24
	8,200	LXG35VN822M25X50T2	25.4 × 50	0.051	40	2.57
	4,700	LXG35VN472M30X25T2	30 × 25	0.088	70	1.77
	5,600	LXG35VN562M30X30T2	30 × 30	0.074	50	1.98
	8,200	LXG35VN822M30X35T2	30 × 35	0.051	40	2.5
	10,000	LXG35VN103M30X40T2	30 × 40	0.041	35	2.86
	12,000	LXG35VN123M30X50T2	30 × 50	0.035	25	3.32
	5,600	LXG35VN562M35X25T2	35 × 25	0.074	65	2.03
	8,200	LXG35VN822M35X30T2	35 × 30	0.051	45	2.55
	10,000	LXG35VN103M35X35T2	35 × 35	0.041	38	2.88
	12,000	LXG35VN123M35X40T2	35 × 40	0.035	30	3.3
	18,000	LXG35VN183M35X50T2	35 × 50	0.023	23	4.29
50 Volts 63 Volts Surge	1,500	LXG50VN152M22X25T2	22 × 25	0.221	120	1.02
	1,800	LXG50VN182M22X30T2	22 × 30	0.184	100	1.17
	2,200	LXG50VN222M22X35T2	22 × 35	0.151	80	1.33
	2,700	LXG50VN272M22X40T2	22 × 40	0.123	70	1.51
	3,900	LXG50VN392M22X50T2	22 × 50	0.085	50	1.91
	1,800	LXG50VN182M25X25T2	25.4 × 25	0.184	90	1.17
	2,700	LXG50VN272M25X30T2	25.4 × 30	0.123	70	1.47
	3,300	LXG50VN332M25X35T2	25.4 × 35	0.10	60	1.7
	3,900	LXG50VN392M25X40T2	25.4 × 40	0.085	50	1.89
	5,600	LXG50VN562M25X50T2	25.4 × 50	0.059	40	2.38
	2,700	LXG50VN272M30X25T2	30 × 25	0.123	70	1.5
	3,300	LXG50VN332M30X30T2	30 × 30	0.10	50	1.7
	4,700	LXG50VN472M30X35T2	30 × 35	0.071	40	2.11
	5,600	LXG50VN562M30X40T2	30 × 40	0.059	35	2.39
	6,800	LXG50VN682M30X50T2	30 × 50	0.049	25	2.79
	3,300	LXG50VN332M35X25T2	35 × 25	0.10	65	1.74
	4,700	LXG50VN472M35X30T2	35 × 30	0.071	45	2.16
	5,600	LXG50VN562M35X35T2	35 × 35	0.059	38	2.41
	6,800	LXG50VN682M35X40T2	35 × 40	0.049	30	2.78
	10,000	LXG50VN103M35X50T2	35 × 50	0.033	23	3.57
63 Volts 79 Volts Surge	1,000	LXG63VN102M22X25T2	22 × 25	0.249	120	1.0
	1,200	LXG63VN122M22X30T2	22 × 30	0.207	100	1.15
	1,500	LXG63VN152M22X35T2	22 × 35	0.166	80	1.32
	1,800	LXG63VN182M22X40T2	22 × 40	0.138	70	1.49
	2,700	LXG63VN272M22X50T2	22 × 50	0.092	50	1.92
	1,200	LXG63VN122M25X25T2	25.4 × 25	0.207	90	1.15
	1,800	LXG63VN182M25X30T2	25.4 × 30	0.138	70	1.45
	2,200	LXG63VN222M25X35T2	25.4 × 35	0.113	60	1.67
	2,700	LXG63VN272M25X40T2	25.4 × 40	0.092	50	1.9
	3,300	LXG63VN332M25X50T2	25.4 × 50	0.075	40	2.2
	1,800	LXG63VN182M30X25T2	30 × 25	0.138	70	1.48
	2,200	LXG63VN222M30X30T2	30 × 30	0.113	50	1.68

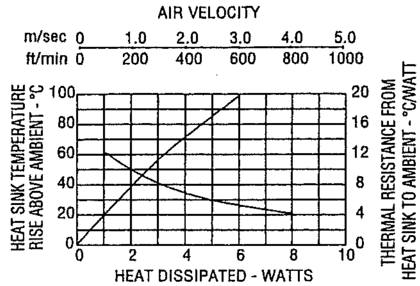
*The case sizes in table are with no sleeve, refer to diagrams for case sizes with sleeve.

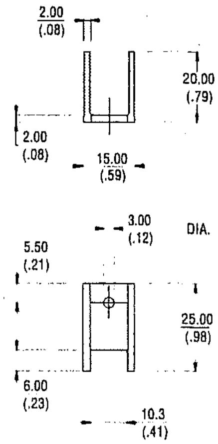
ML26AA

TO-220

Model	R_θ (°C/W)
ML26AA	17.9







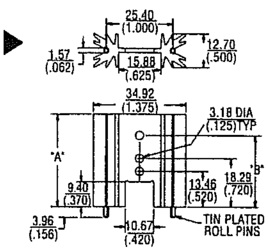
6098 Series, ML73 Series

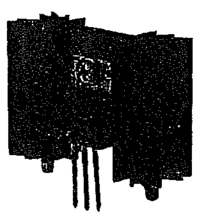
TO-220 TO-202

Model	Dim. A mm (inches)	Dim. B mm (inches)	R_θ (°C/W)
6098B	25.40 (1.000)		14.0
6099B	38.10 (1.500)	25.40 (1.000)	11.0
6100B	50.80 (2.000)	25.40 (1.000)	9.0
6101B	63.50 (2.500)	25.40 (1.000)	7.1

Model	Dim. A mm (inches)	R_θ (°C/W)
ML73/1	25 (.984)	14.0
ML73/1.5	38 (1.50)	11.0
ML73/2	50 (1.97)	9.0

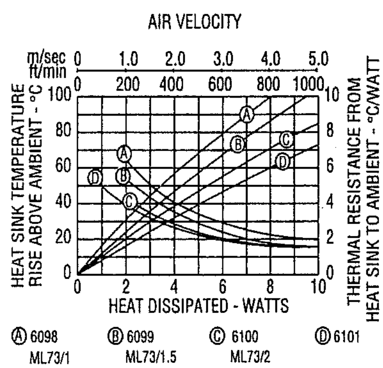
6098 Series ▶



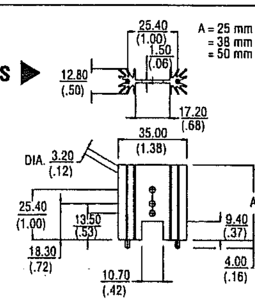


◀ **6098B**

Accepts CLP-204



ML73 Series ▶



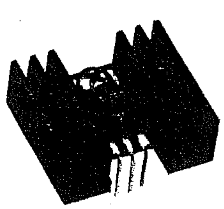
Notes: *(6098 Series) To order optional solderable roll pin with shoulder, add "-P2" after model number, e.g. 6098B-P2. Shoulder washer is 1.27 +.38/-.13 (.050 +.015/-.005) thick. These parts are also available without roll pins: 6090B is 25.40mm (1.0") tall without roll pins, 6091B is 38.10mm (1.5") tall without roll pins, and 6092B is 50.80mm (2.0") tall without roll pins. See information on roll pins on page A28.*

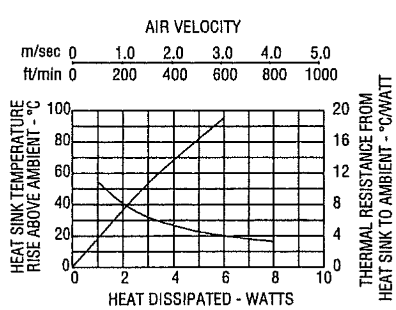
The Productivity Enhancements shown in the circles above are for use with the 6098 Series only

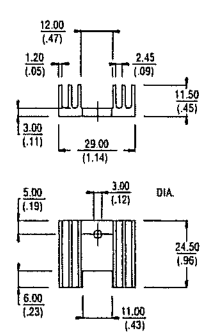
ML24

TO-220

Model	R_θ (°C/W)
ML24	16.7







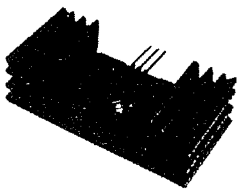
HEAT SINKS

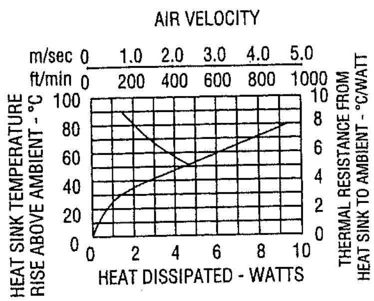
Redpoint Thermalloy www.redtherm.co.uk

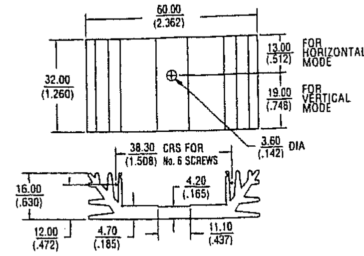
1.25GY-50

TO-220

Model	Orientation	R_θ (°C/W)
1.25GY-50	Horizontal	6.8
	Vertical	8.8





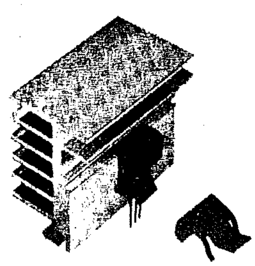


KM Series

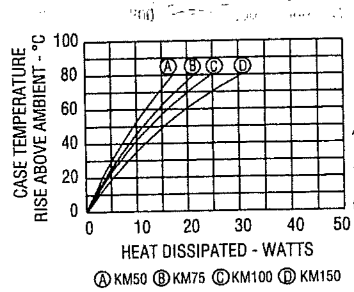
TO-220 TO-218

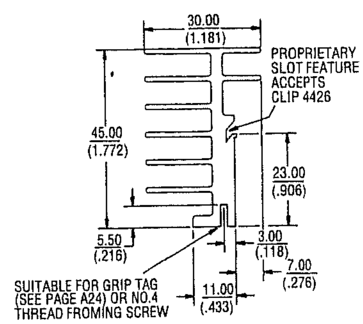
Clips: 4426 (TO-220) 4473 (TO-218/ TO-247) 4525 (TO-220) 4597 (TO-218/ TO-247)

Model	Length mm (inches)	R_θ (°C/W)
KM50-1	50.00 (1.969)	4.8
KM75-1	75.00 (2.953)	3.7
KM100-1	100.00 (3.937)	3.3
KM150-1	150.00 (5.906)	2.7



▲ **KM75-1 + 4426 Clip**



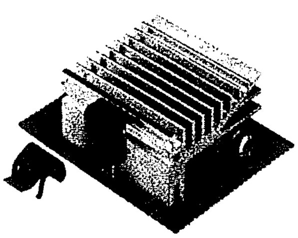


KL Series

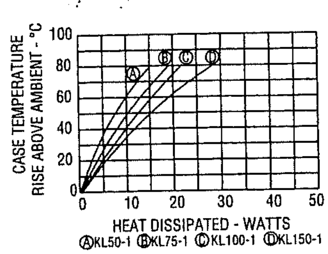
TO-220 TO-218

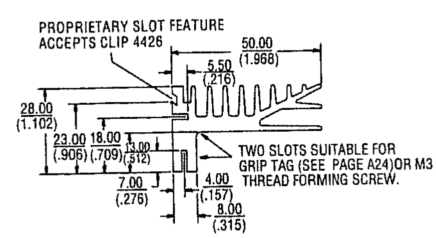
Clips: 4426 (TO-220) 4473 (TO-218/ TO-247) 4525 (TO-220) 4597 (TO-218/ TO-247)

Model	Length mm (inches)	R_θ (°C/W)
KL50-1	50.00 (1.969)	5.2
KL75-1	75.00 (2.953)	4.3
KL100-1	100.00 (3.937)	3.4
KL150-1	150.00 (5.906)	2.9



▲ **KL75-1 + 4426 Clip**





EXTRUDED HEAT SINKS (RTH VALUES FOR 3" SECTION) WWW.AAVID.COM

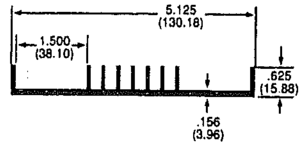
EXTRUSIONS

Conversion Chart

Given:	Multiply By:	To Obtain:
in²/in	2.54	cm²/cm
lb/ft	1.5	gm/mm
°C/W/3"	1.02	°C/W/75mm

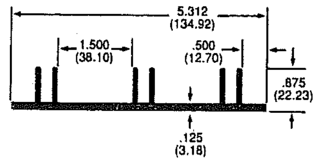
Note: The profiles are not to scale in relation to each other.

1



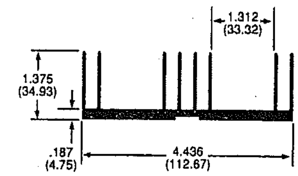
60470 19.0 in²/in 1.4lb/ft 3.7°C/W/3in

2



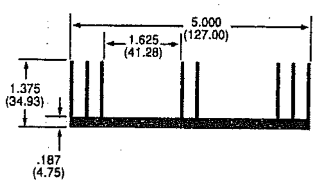
60845* 21.0 in²/in 1.2lb/ft 3.3°C/W/3in

3



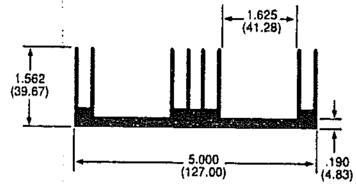
60120 27.0 in²/in 1.8lb/ft 2.6°C/W/3in

4



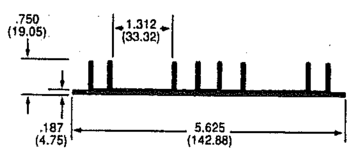
60715* 29.4 in²/in 1.9lb/ft 2.4°C/W/3in

5



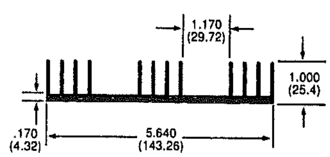
61525 30.5 in²/in 2.3lb/ft 2.3°C/W/3in

6



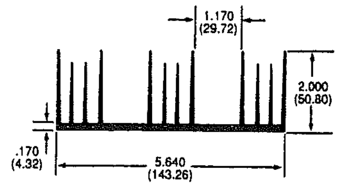
61545* 20.7 in²/in 1.8lb/ft 3.4°C/W/3in

7



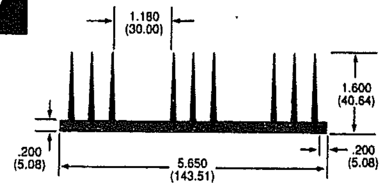
62460 31.6 in²/in 2.1lb/ft 2.2°C/W/3in

8



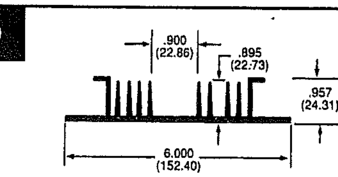
62410* 51.8 in²/in 2.7lb/ft 1.5°C/W/3in

9



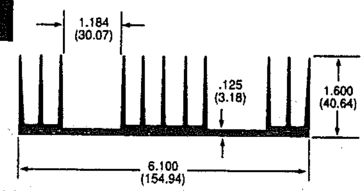
61910 36.9 in²/in 2.5lb/ft 1.9°C/W/3in

10



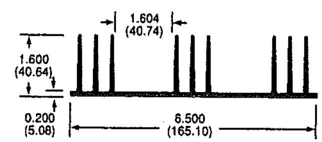
62790 29.8 in²/in 2.0lb/ft 2.2°C/W/3in

11



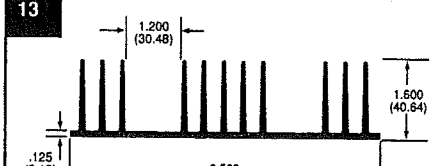
61690 43.7 in²/in 2.6lb/ft 1.6°C/W/3in

12



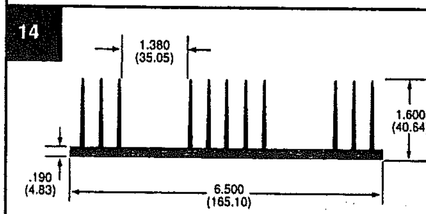
65545 37.9 in²/in 2.8lb/ft 1.8°C/W/3in

13



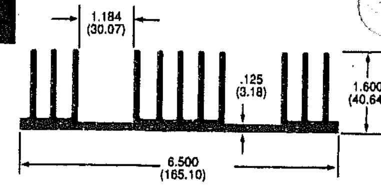
61200* 45.7 in²/in 2.4lb/ft 1.6°C/W/3in

14



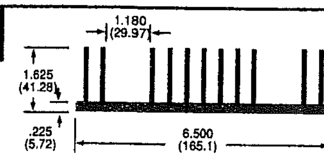
61715 44.4 in²/in 2.9lb/ft 1.5°C/W/3in

15



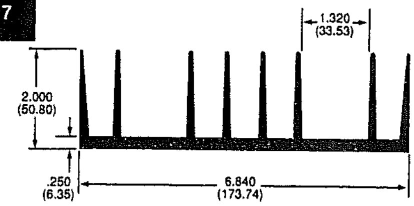
61440 44.3 in²/in 2.8lb/ft 1.5°C/W/3in

16



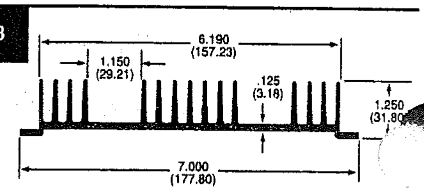
64985 44.2 in²/in 1.7lb/ft 1.6°C/W/3in

17



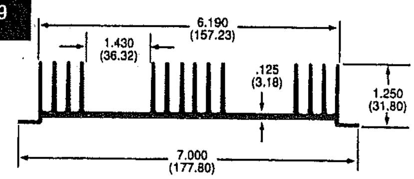
60795 42.2 in²/in 4.2lb/ft 1.7°C/W/3in

18



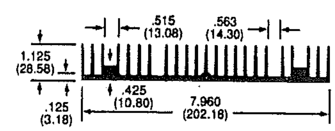
61340* 44.5 in²/in 2.4lb/ft 1.6°C/W/3in

19



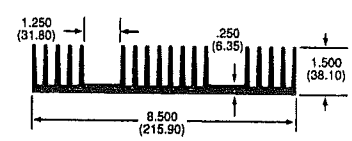
61265 42.8 in²/in 2.3lb/ft 1.6°C/W/3in

20



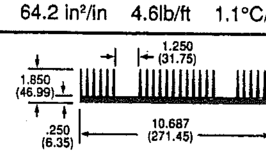
62435* 61.0 in²/in 3.0lb/ft 1.2°C/W/3in

21



62495 64.2 in²/in 4.6lb/ft 1.1°C/W/3in

22



63910 95.5 in²/in 7.5lb/ft 0.7°C/W/3in

 AAVID ENGINEERING, INC. One Kool Path, P.O. Box 400, Laconia, NH 03247 Tel 603-528-3400, FAX 603-528-1478, TWX 510-298-1127

SIL-PAD[(]
TECHNICAL DATA

SIL-PAD 400®

Sil-Pad 400 is the original Sil-Pad material. Sil-Pad 400 is a composite of silicone rubber and fiberglass. It is flame retardant and is specially formulated for use as a thermally conductive insulator. Primary use is to electrically isolate power sources from heat sinks. Sil-Pad 400 has excellent mechanical and physical characteristics. Surfaces are pliable and allow complete surface contact with excellent heat dissipation. Sil-Pad 400 actually improves its thermal resistance with age. The reinforcing fiberglass gives excellent cut-through resistance and Sil-Pad 400 is non-toxic and resists damage from cleaning agents. *Contact the factory for special thicknesses of Sil-Pad 400.*

SIL-PAD 600®

Sil-Pad 600 is an alumina / boron nitride loaded silicone elastomer which provides higher thermal performance than standard materials while remaining cost competitive.

SIL-PAD 1000®

Sil-Pad 1000 is a composite of silicone rubber and fiberglass. It is boron nitride filled and offers low thermal resistance. Sil-Pad 1000 is non-toxic and resists damage from cleaning agents. It includes a flame retardant and is specially formulated for use as a thermally conductive insulator. Sil-Pad 1000 has the same excellent mechanical and physical characteristics of our Sil-Pad 400 material while offering a 35% reduction in thermal resistance.

SIL-PAD 1500®

Sil-Pad 1500 offers enhanced thermal performance in a fiberglass reinforced material. It is designed for high performance thermal applications while meeting specific cost considerations.

Table 3

	SIL-PAD 400(.009)	SIL-PAD 400(.007)	SIL[illegible] 600[illegible]	SIL-PAD 1000	SIL-PAD 1500	SIL-PAD 2000	SIL-PAD K-4	SIL-PAD K-6	SIL-PAD K-10	Q-PAD	POLY-PAD 400	PO[illegible]
Color	Gray	Gray	Green	Pink	Green	White	Gray	Blue/Green	Beige	Black	Mauve	[illegible]
Thermal Resistance, °C/watt	.50	.45	0.35	0.35	0.23	0.2	.40	.30	0.2	0.1	0.4	
Dielectric Constant, 1000 (Hz)	5.5	5.5	5.0	4.5	4	4.0	5.0	4.0	3.7	N/A	5.5	
Continuous Use Temp. °C	-60 to +180	-60 to +180	-60 to +180	-60 to +180	-60 to +180	-60 to +200	-60 to +180	-60 to +180	-60 to +180	-60 +160	-20 to +150	
Thermal Conductivity W/m-K nominal	0.9	0.9	1.0	1.2	2.0	3.5	0.9	1.1	1.3	2.5	0.9	
Thickness Inches	.009±.001	.007±.001	.009 ±.001	.009±.001	.010±.001	.015±.001	.006±.001	.006±.001	.006±.001	.006±.001	.009±.001	.0[illegible]
(mm)	(.23±.025)	(.18±.025)	(.23±.025)	(.23±.025)	(.25 ±.025)	(.38 ±.025)	(.15 ±.025)	(.15 ±.025)	(.15 ±.025)	(.15 ±.025)	(.23±.025)	(.2[illegible]
Volume Resistivity, Ohm Metre Typical Normal	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	1.0×10^{11}	1.0×10^{12}	1.0×10^{12}	1.0×10^{12}	1.0×10^{2}	1.0×10^{11}	1.[illegible]
Moist	1.5×10^{8}	1.5×10^{8}		1.5×10^{8}								
Breakdown Voltage (minimum AC)	4500	3500	4500	4500	4000	4000	6000	6000	6000	N/A	4500	
Thermal Vacuum Weight Loss Percent (TML) Max. As Manufactured	.40	.40		.22		0.26	.28		.36	0.59		
Post Cure 24 HRS. 440°F, 225 °C	.25	.25				0.07						
Volatile Condensable Material, Percent, Maximum (CVCM) As Manufactured	.11	.11		.08		0.10	.07		.09	0.23		
Post Cure 24 HRS. 440°F, 225 °C	.07	.07				0.03						
Hardness, Shore A	85	85	85	85	80	80	90	90	90	90	90	
Specific Gravity	2.0-2.1	2.0-2.1	1.8	1.5	1.5	1.5					2.0-2.1	
Tensile Strength, Kpsi, Typical	3	3	3	4	1	1	5	5	5	4	7	
45° to warp and fill* (MPa)	(20)	(20)	(20)	(30)	(10)	(10)	(35)	(35)	(35)	(30)	(50)	
Breaking Strength, Lbs/Inch	100	100	100	100	65	65	30	30	30	25	100	
kN/m	18	18	18	18	11	11	5	5	5	4	18	
Elongation, % 45° to warp and fill*	40	40	40	40	20	20	40	40	40	4	10	
Construction	Silicone/ Fiberglass	Silicone/ Fiberglass	Silicone/ Fiberglass	Silicone/ Fiberglass	Silicone/ Fiberglass	Silicone/ Fiberglass	Silicone/ Kapton	Silicone/ Kapton	Silicone/ Kapton	Silicone/ Alum Foil	Polyester/ Fiberglass	Po[illegible] Fi[illegible]

SI conversions are approximations and are not intended to be exact.

* ASTM is currently adapting the measurement of tensile strength and elongation of thermally conductive electrical insulation materials at 45° to the warp and fill direction of the reinforcing fiberglass as a standard test method.

SIL-PAD 2000®

Sil-Pad 2000 is Bergquist's high performance, high reliability thermally conductive insulator. Sil-Pad 2000 is designed for demanding military/aerospace and commercial applications. In these applications, Sil-Pad 2000 complies with military standards.

This boron nitride loaded silicone elastomer is formulated to maximize the thermal and dielectric performance of the filler/binder matrix. The result is a "grease-free", conformable material capable of meeting or exceeding the thermal and electrical requirements of high reliability electronic packaging applications.

SIL-PAD K-4®

Bergquist's Sil-Pad K-4 is designed and developed in conjunction with DuPont. Sil-Pad K-4 combines the thermal transfer properties of well known Sil-Pad rubber with high dielectric strength, physically tough DuPont Kapton MT® film. Kapton MT® is a specially developed film which has high thermal conductivity. The result is a durable insulator that withstands high voltages, requires no thermal grease to transfer heat, is available in customized shapes and sizes and saves time and costs while increasing productivity.

SIL-PAD K-6®

Sil-Pad K-6 is a medium performance Kapton based thermally conductive insulator. Thermally conductive Kapton MT® film is coated with an aluminum oxide/boron nitride filled silicone elastomer to deliver "boron nitride" performance. Kapton film provides a continuous physically tough dielectric barrier against "cut-through" and resultant assembly failures.

SIL-PAD K-10®

Sil-Pad K-10 is a high performance insulator which combines Kapton MT

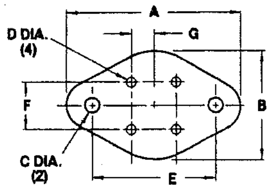
Polyimide film with boron nitrid[e] silicone rubber. K-10 is designed [to] replace ceramic insulators such a[s] Beryllium Oxide, Boron Nitride, [and] Alumina which are expensive an[d] [break] easily. K-10 eliminates breakage [and costs] much less than ceramics.

SIL-PAD 200®

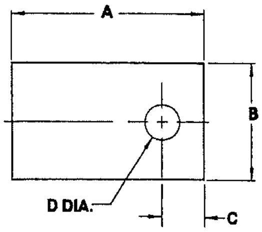
Ask about Sil-Pad 200, our [...] non-reinforced 30 mil to 125 mil [...] to 3 mm) material. Sil-Pad 200 is [...] use as a gasket or for filling voids [...] mounting surfaces in an assembly

SIL-PAD THERMAL INTERFACE PADS BERGQUIST CORP. WWW.BERGQUISTCOMPANY.COM/THERM.HTML

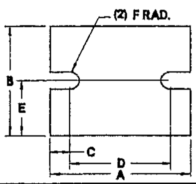
SIL-PAD® Standard Configurations



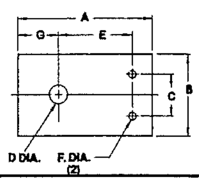
4 Lead TO-66	Part Number Suffix	"A"	"B"	"C"	"D"	"E"	"F"	"G"
	-84	1.312	.762	.140	.062	.960	.200	.100



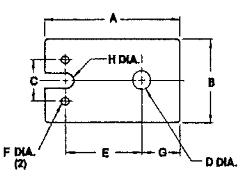
Plastic Power	Part Number Suffix	"A"	"B"	Dimensions "C"	"D"		Part Number Suffix	"A"	Dimensions "B"	"C"	"D"
TO-126	-50	.437	.312	.140	.093	Various	-62	.750	.600	.240	.150
TO-126	-60	.437	.312	.140	.122	Various	-63	.750	.600	.240	.115
Various	-64	.500	.385	.170	.120	Various	-56	.855	.562	.218	.125
TO-202	-55	.610	.560	.245	.125	Various	-52	.855	.630	.230	.093
Various	-51	.687	.562	.218	.125	TO-218	-90	.860	.740	.200	.160
Various	-35	.710	.500	.160	.141	Various	-68	1.125	.625	.200	.145
Various	-61	.750	.410	.225	.156	Various	-70	1.410	.810	.355	.147
TO-220						Various	-102	.866	.650	.217	.142
(Clip Mount)	-43	.750	.500			Various	-103	.750	.800	.150	.160
TO-220	-54	.750	.500	.187	.147	TO-3P	-104	1.000	.750	.300	.140
TO-220	-58	.750	.500	.187	.125		-122	1.140	.810	.355	.147



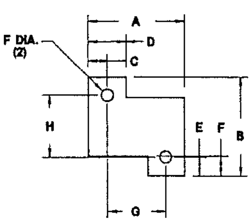
Power Module	Part Number Suffix	"A"	"B"	"C"	"D"	"E"	"F"
	-67	1.500	.900	.150	1.200	.450	.075
	-101	2.500	2.000	.344	1.812	1.000	.156



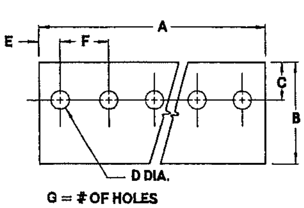
Plastic Power	Part Number Suffix	"A"	"B"	"C"	"D"	"E"	"F"	"G"
	-57	.910	.500	.200	.125	.580	.046	.265
	-89	.983	.750	.432	.156	.665	.101	.217



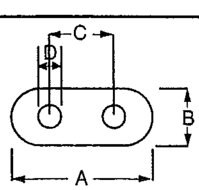
Plastic Power	Part Number Suffix	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"
	-66	1.000	.500	.200	.141	.626	.046	.219	.032
	-123	1.614	1.102		.118			.157	



Power Resistors	Part Number Suffix	"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	"I"
RH-25	-94	1.187	1.205	.234	.469	.212	.156	.719	.781	.140
RH-50	-95	2.093	1.265	.265	.530	.210	.255	1.563	.845	.140
RH-5	-96	.725	.771	.140	.280	.140	.156	.445	.491	.093
RH-10	-97	.805	.890	.127	.250	.130	.190	.551	.630	.121
RH-25	-98	1.150	1.180	.231	.425	.190	.270	.688	.800	.147
RH-50	-99	1.965	1.236	.198	.404	.132	.263	1.569	.972	.130



TO-220 Multiples	Part Number Suffix	"A"	"B"	"C"	"D"	"E"	"F"	# Of Holes
2 Parts	-34	1.000	.750	.187	.125	.250	.500	2
3 Parts	-36	1.500	.750	.187	.125	.250	.500	3
	-37	2.000	.750	.187	.125	.250	.500	4
	-38	2.500	.750	.187	.125	.250	.500	5
	-39	3.000	.750	.187	.125	.250	.500	6
	-40	3.500	.750	.187	.125	.250	.500	7
	-41	4.000	.750	.187	.125	.250	.500	8



Quarz	Part Number Suffix	"A"	"B"	"C"	"D"
	-115	.472	.196	.192	.031

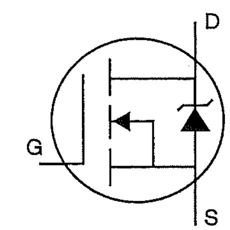
International
IOR Rectifier

PD - 91354A

IRFZ24N

HEXFET® Power MOSFET

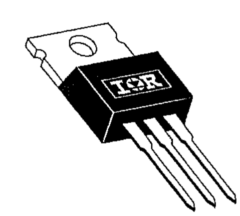
- Advanced Process Technology
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated



V_{DSS} = 55V

$R_{DS(on)}$ = 0.07Ω

I_D = 17A



TO-220AB

Description

Fifth Generation HEXFET® power MOSFETs from International Rectifier utilize advanced processing techniques to achieve the lowest possible on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETs are well known for, provides the designer with an extremely efficient device for use in a wide variety of applications.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.

Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	17	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	12	
I_{DM}	Pulsed Drain Current ①	68	
P_D @T_C = 25°C	Power Dissipation	45	W
	Linear Derating Factor	0.30	W/°C
V_{GS}	Gate-to-Source Voltage	±20	V
E_{AS}	Single Pulse Avalanche Energy ②	71	mJ
I_{AR}	Avalanche Current①	10	A
E_{AR}	Repetitive Avalanche Energy①	4.5	mJ
dv/dt	Peak Diode Recovery dv/dt ③	5.0	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	——	3.3	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	——	0.50	——	
$R_{\theta JA}$	Junction-to-Ambient	——	——	62	

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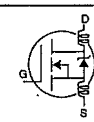
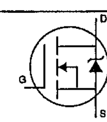
Electrical Characteristics @ $T_J = 25°C$ (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	—	—	V	$V_{GS} = 0V$, $I_D = 250\mu A$
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.052	—	V/°C	Reference to 25°C, $I_D = 1mA$
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.07	Ω	$V_{GS} = 10V$, $I_D = 10A$ ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	—	4.0	V	$V_{DS} = V_{GS}$, $I_D = 250\mu A$
g_{fs}	Forward Transconductance	4.5	—	—	S	$V_{DS} = 25V$, $I_D = 10A$
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	$V_{DS} = 55V$, $V_{GS} = 0V$
		—	—	250		$V_{DS} = 44V$, $V_{GS} = 0V$, $T_J = 150°C$
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	$V_{GS} = 20V$
	Gate-to-Source Reverse Leakage	—	—	-100		$V_{GS} = -20V$
Q_g	Total Gate Charge	—	—	20	nC	$I_D = 10A$
Q_{gs}	Gate-to-Source Charge	—	—	5.3		$V_{DS} = 44V$
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	7.6		$V_{GS} = 10V$, See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	4.9	—	ns	$V_{DD} = 28V$
t_r	Rise Time	—	34	—		$I_D = 10A$
$t_{d(off)}$	Turn-Off Delay Time	—	19	—		$R_G = 24\Omega$
t_f	Fall Time	—	27	—		$R_D = 2.6\Omega$, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.) 
L_S	Internal Source Inductance	—	7.5	—		from package and center of die contact
C_{iss}	Input Capacitance	—	370	—	pF	$V_{GS} = 0V$
C_{oss}	Output Capacitance	—	140	—		$V_{DS} = 25V$
C_{rss}	Reverse Transfer Capacitance	—	65	—		$f = 1.0MHz$, See Fig. 5

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	17	A	MOSFET symbol showing the 
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	68		integral reverse p-n junction diode.
V_{SD}	Diode Forward Voltage	—	—	1.3	V	$T_J = 25°C$, $I_S = 10A$, $V_{GS} = 0V$ ④
t_{rr}	Reverse Recovery Time	—	56	83	ns	$T_J = 25°C$, $I_F = 10A$
Q_{rr}	Reverse RecoveryCharge	—	120	180	nC	di/dt = 100A/μs ④

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11)

② $V_{DD} = 25V$, starting $T_J = 25°C$, $L = 1.0mH$ $R_G = 25\Omega$, $I_{AS} = 10A$. (See Figure 12)

③ $I_{SD} \leq 10A$, $di/dt \leq 280A/\mu s$, $V_{DD} \leq V_{(BR)DSS}$, $T_J \leq 175°C$

④ Pulse width ≤ 300μs; duty cycle ≤ 2%.

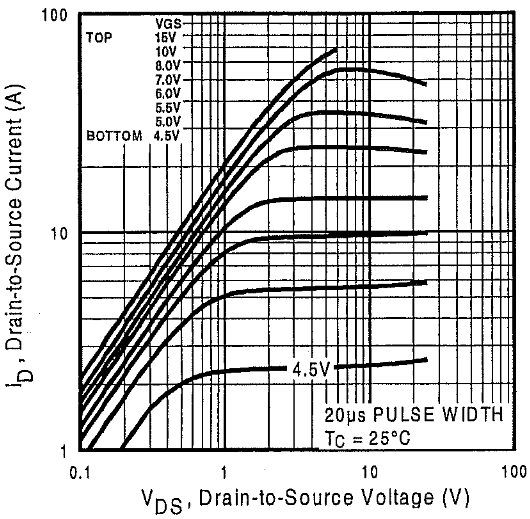


Fig 1. Typical Output Characteristics, $T_J = 25°C$

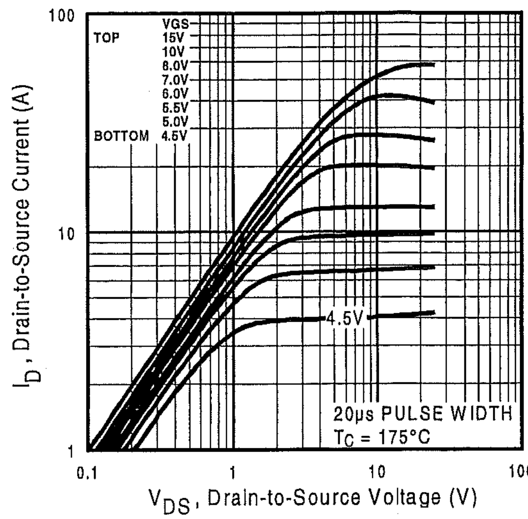


Fig 2. Typical Output Characteristics, $T_J = 175°C$

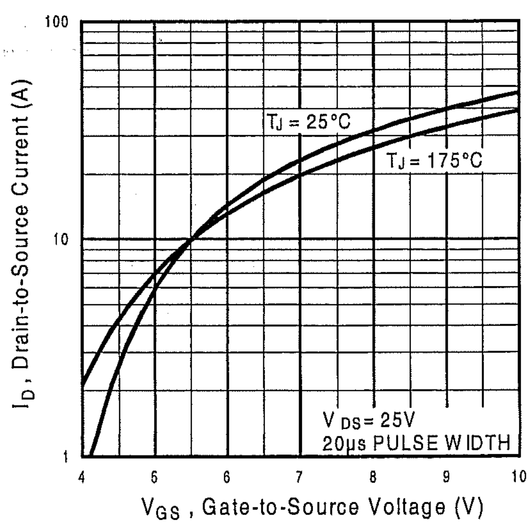


Fig 3. Typical Transfer Characteristics

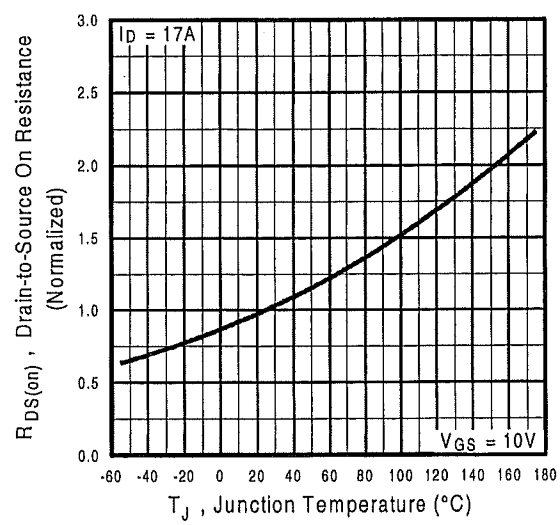


Fig 4. Normalized On-Resistance Vs. Temperature

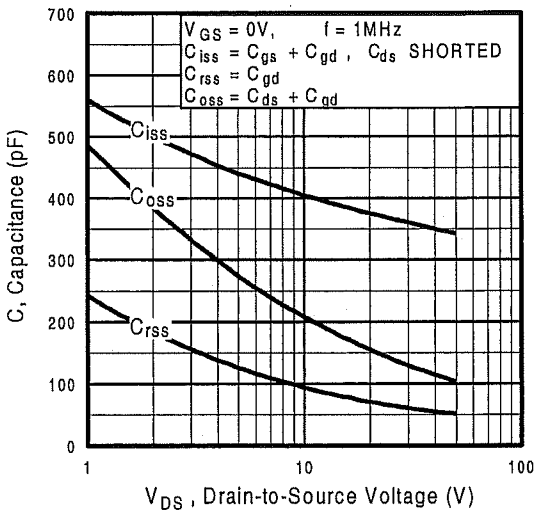


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

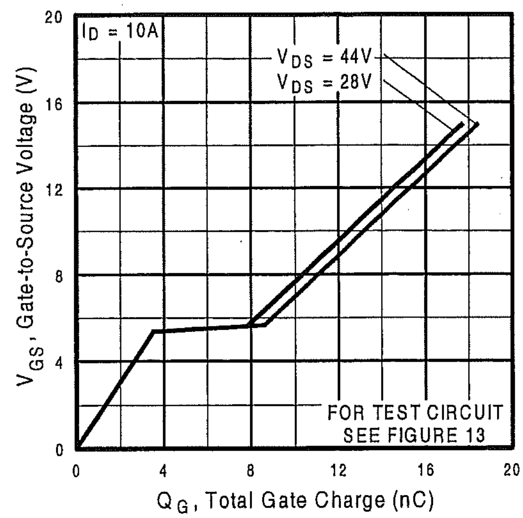


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

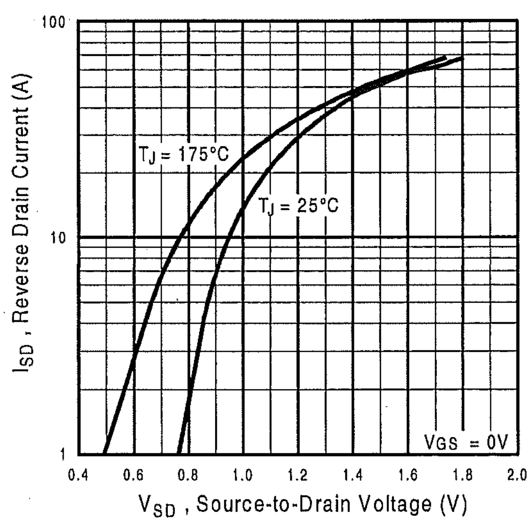


Fig 7. Typical Source-Drain Diode Forward Voltage

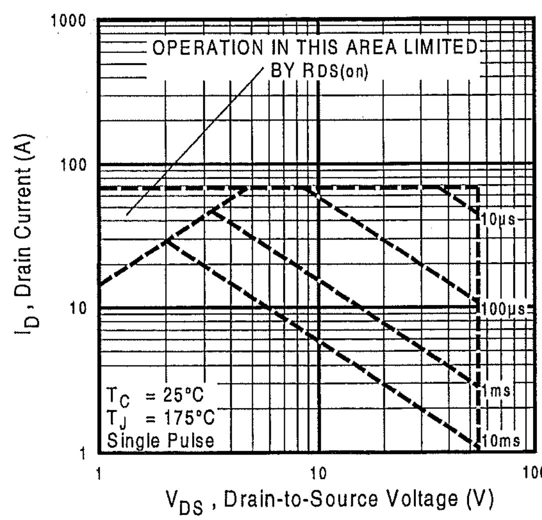
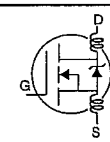
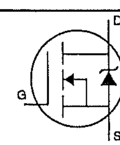


Fig 8. Maximum Safe Operating Area

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	—	—	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.052	—	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(ON)}$	Static Drain-to-Source On-Resistance	—	—	0.040	Ω	V_{GS} = 10V, I_D = 16A ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	—	4.0	V	V_{DS} = V_{GS}, I_D = 250μA
g_{fs}	Forward Transconductance	6.5	—	—	S	V_{DS} = 25V, I_D = 16A
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	V_{DS} = 55V, V_{GS} = 0V
		—	—	250		V_{DS} = 44V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 20V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -20V
Q_g	Total Gate Charge	—	—	34	nC	I_D = 16A
Q_{gs}	Gate-to-Source Charge	—	—	6.8		V_{DS} = 44V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	14		V_{GS} = 10V, See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	7.0	—	ns	V_{DD} = 28V
t_r	Rise Time	—	49	—		I_D = 16A
$t_{d(off)}$	Turn-Off Delay Time	—	31	—		R_G = 18Ω
t_f	Fall Time	—	40	—		R_D = 1.8Ω, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.)
L_S	Internal Source Inductance	—	7.5	—		from package and center of die contact 
C_{iss}	Input Capacitance	—	700	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	240	—		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	—	100	—		f = 1.0MHz, See Fig. 5

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	29	A	MOSFET symbol showing the
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	100		integral reverse p-n junction diode. 
V_{SD}	Diode Forward Voltage	—	—	1.6	V	T_J = 25°C, I_S = 16A, V_{GS} = 0V ④
t_{rr}	Reverse Recovery Time	—	57	86	ns	T_J = 25°C, I_F = 16A
Q_{rr}	Reverse Recovery Charge	—	130	200	nC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11)

② V_{DD} = 25V, starting T_J = 25°C, L = 410μH R_G = 25Ω, I_{AS} = 16A. (See Figure 12)

③ $I_{SD} \le$ 16 A, di/dt $\le$ 420A/μs, $V_{DD} \le V_{(BR)DSS}$, $T_J \le$ 175°C

④ Pulse width $\le$ 300μs; duty cycle $\le$ 2%.

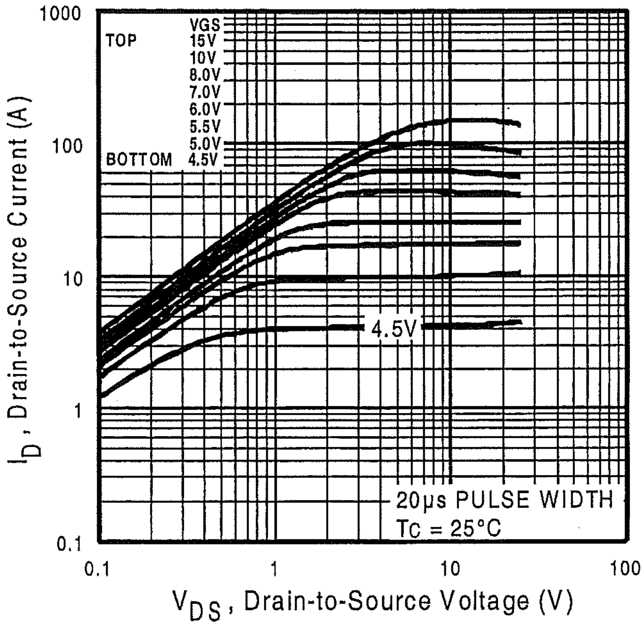


Fig 1. Typical Output Characteristics

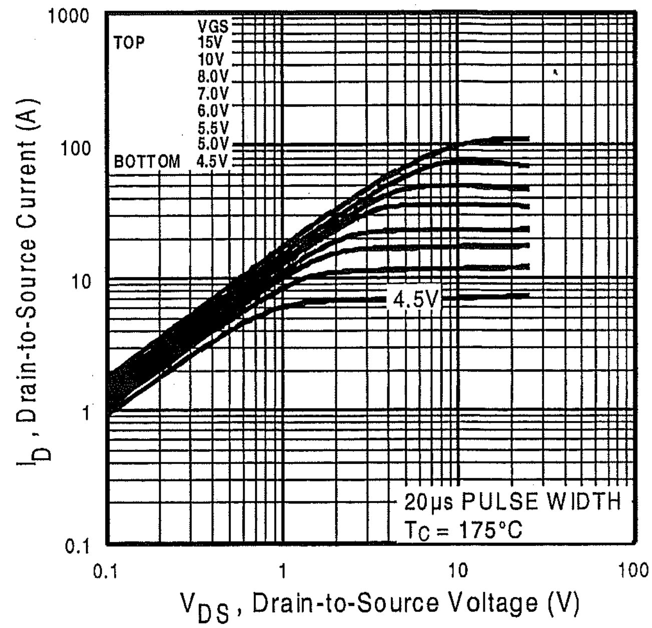


Fig 2. Typical Output Characteristics

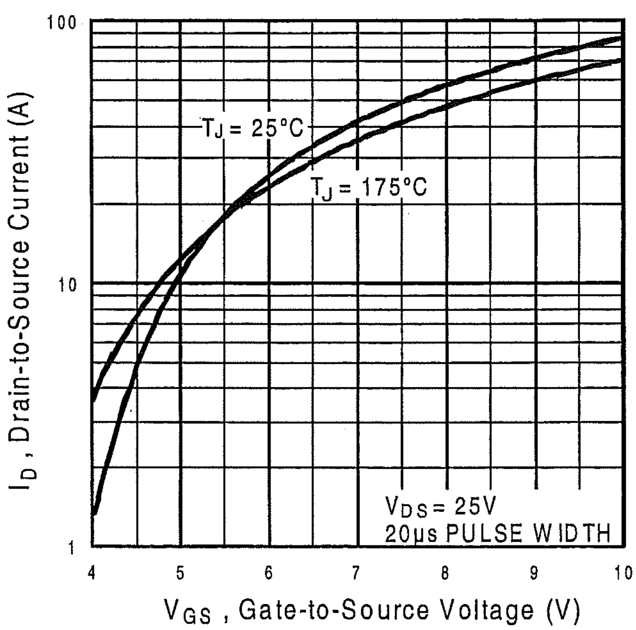


Fig 3. Typical Transfer Characteristics

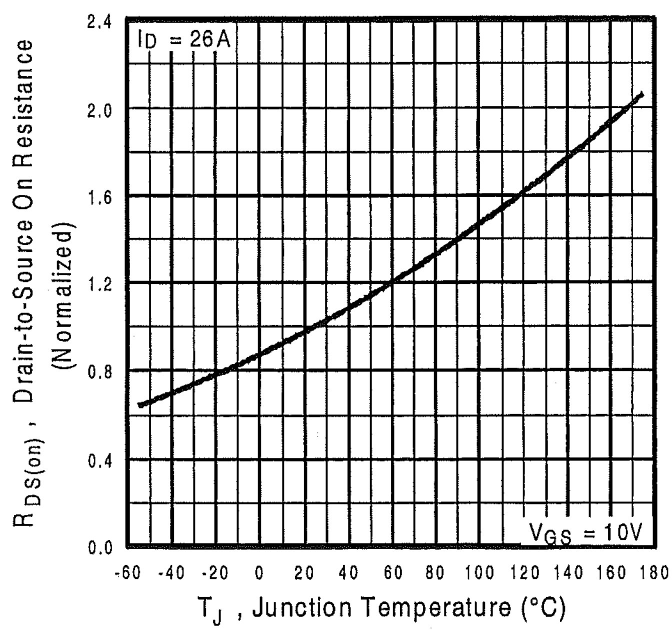


Fig 4. Normalized On-Resistance Vs. Temperature

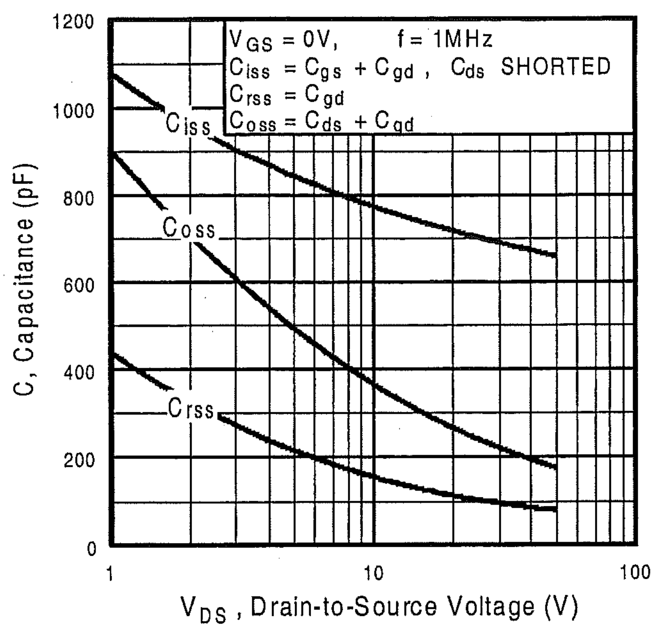


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

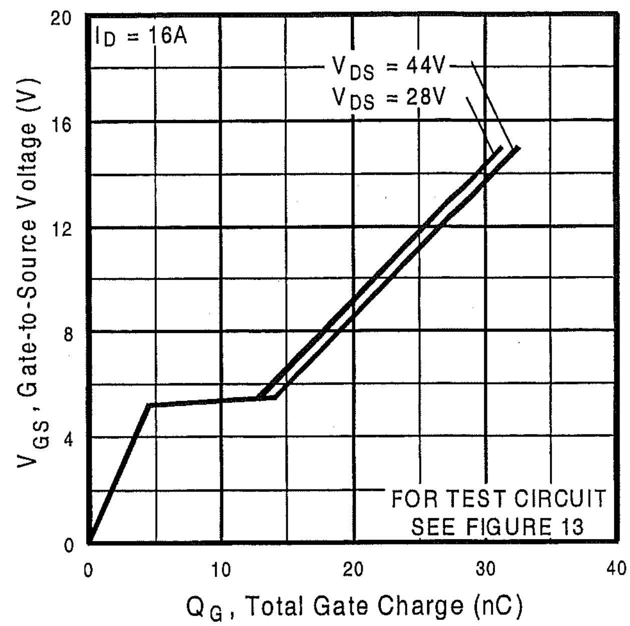


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

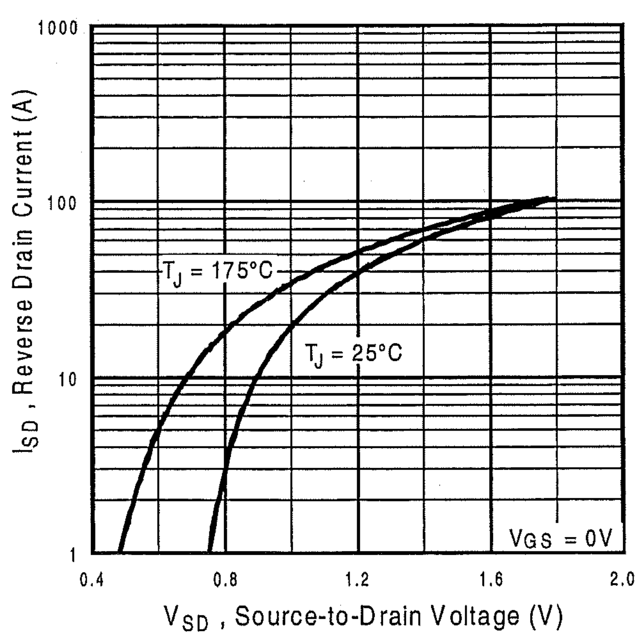


Fig 7. Typical Source-Drain Diode Forward Voltage

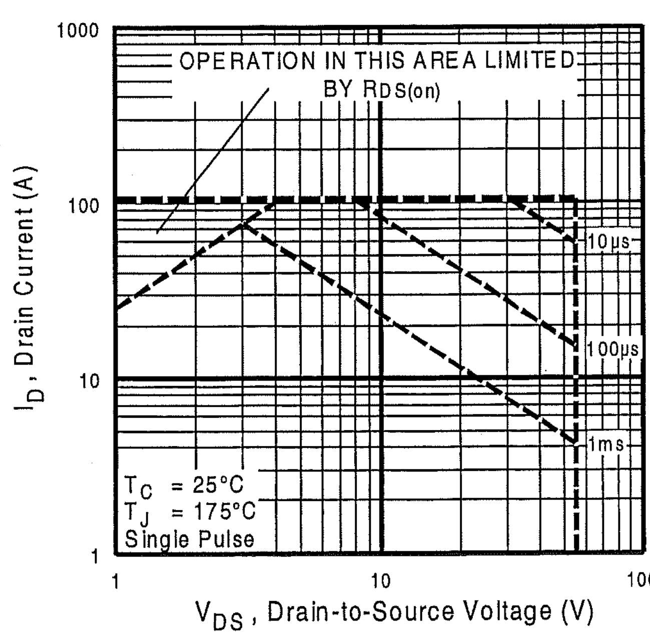


Fig 8. Maximum Safe Operating Area

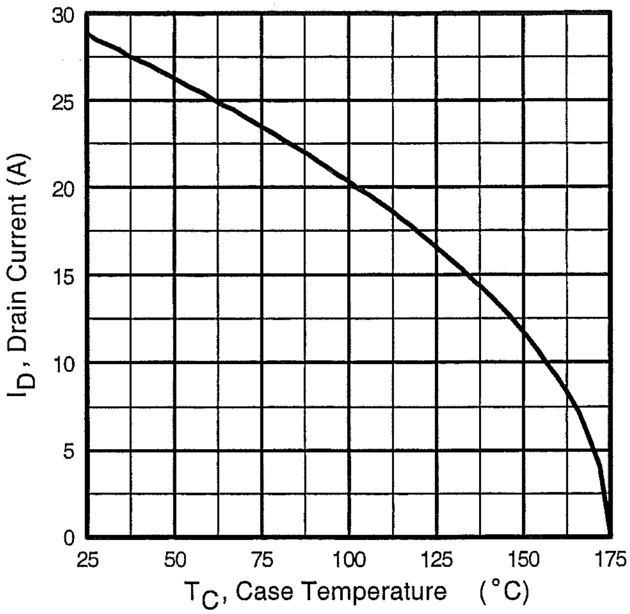


Fig 9. Maximum Drain Current Vs. Case Temperature

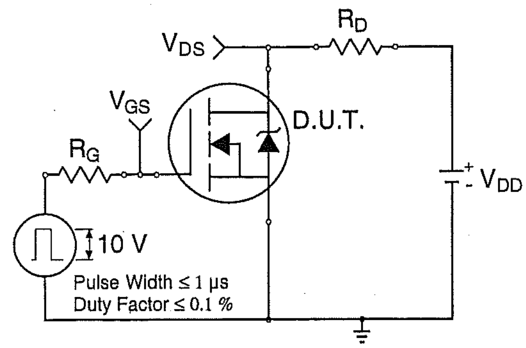


Fig 10a. Switching Time Test Circuit

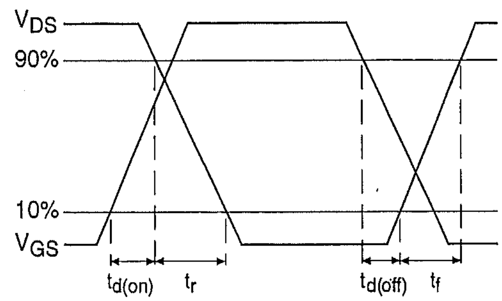


Fig 10b. Switching Time Waveforms

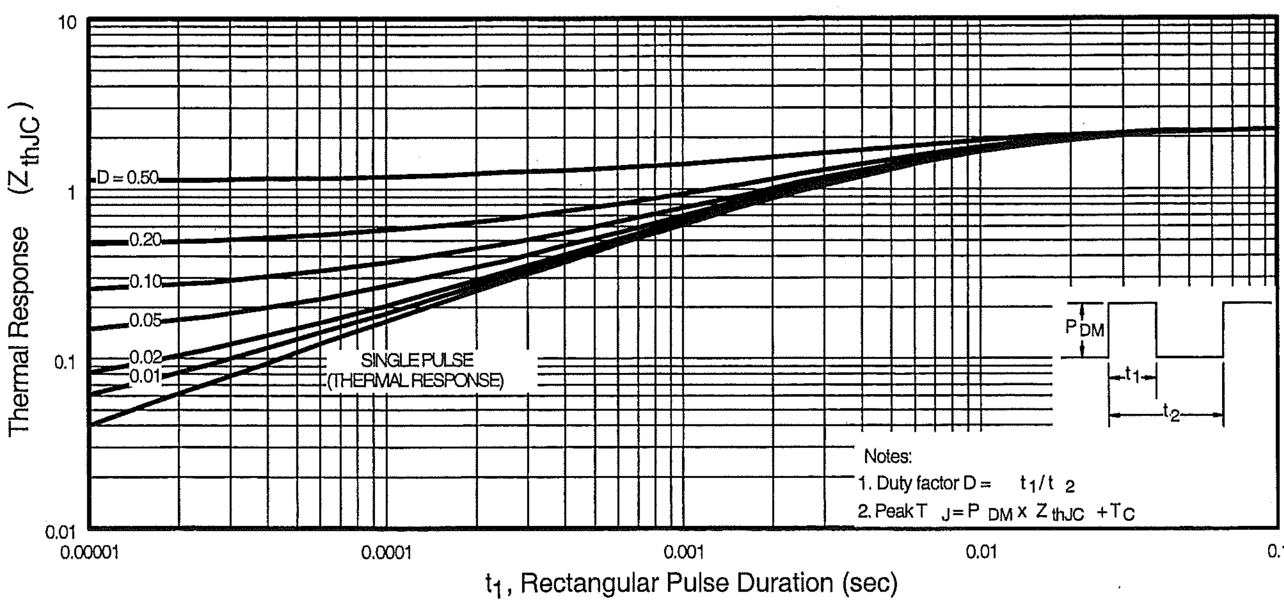


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

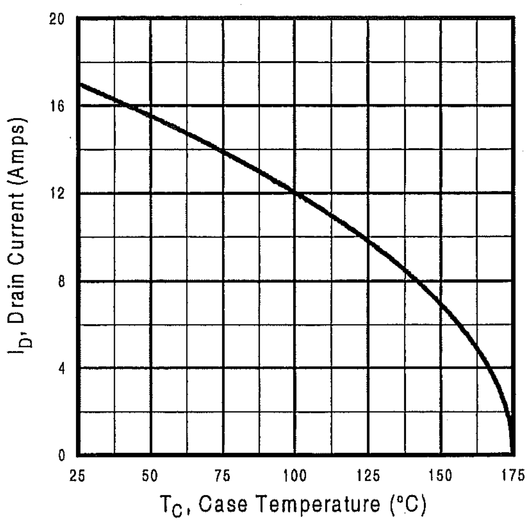


Fig 9. Maximum Drain Current Vs. Case Temperature

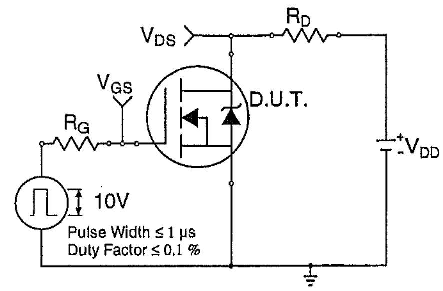


Fig 10a. Switching Time Test Circuit

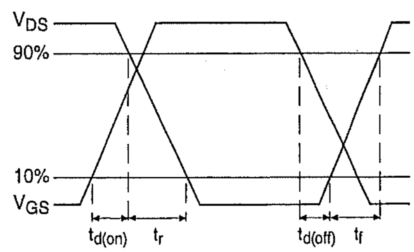


Fig 10b. Switching Time Waveforms

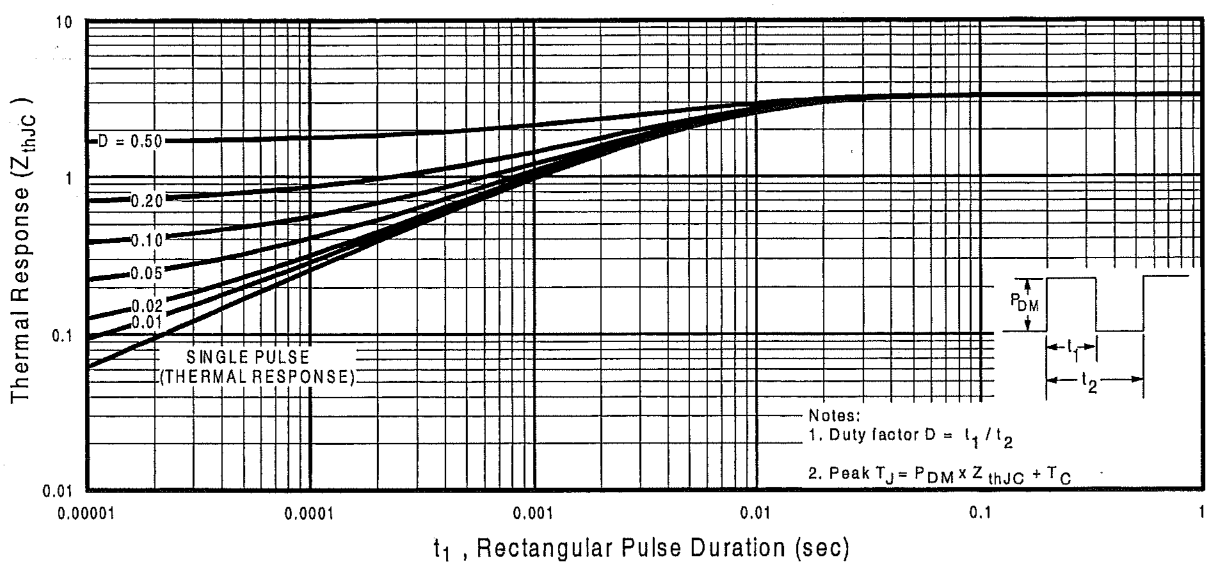


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

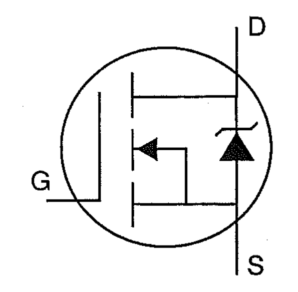
International
IOR Rectifier

PD -9.1276C

IRFZ34N

HEXFET® Power MOSFET

- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Ease of Paralleling



$V_{DSS} = 55V$

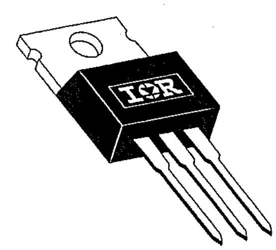
$R_{DS(on)} = 0.040\Omega$

$I_D = 29A$

Description

Fifth Generation HEXFETs from International Rectifier utilize advanced processing techniques to achieve the lowest possible on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET Power MOSFETs are well known for, provides the designer with an extremely efficient device for use in a wide variety of applications.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ $T_C = 25°C$	Continuous Drain Current, V_{GS} @ 10V	29	A
I_D @ $T_C = 100°C$	Continuous Drain Current, V_{GS} @ 10V	20	
I_{DM}	Pulsed Drain Current ①	100	
P_D @$T_C = 25°C$	Power Dissipation	68	W
	Linear Derating Factor	0.45	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
E_{AS}	Single Pulse Avalanche Energy②	65	mJ
I_{AR}	Avalanche Current①	16	A
E_{AR}	Repetitive Avalanche Energy①	6.8	mJ
dv/dt	Peak Diode Recovery dv/dt ③	5.0	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 srew	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	——	2.2	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	——	0.50	——	
$R_{\theta JA}$	Junction-to-Ambient	——	——	62	

8/25/97

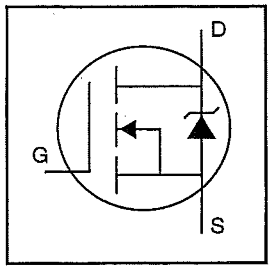
International
IOR Rectifier

PD - 94053

IRFZ44N

HEXFET® Power MOSFET

- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated



V_{DSS} = 55V

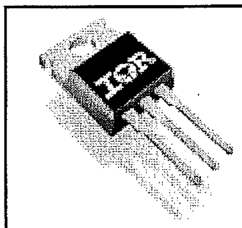
$R_{DS(on)}$ = 17.5mΩ

I_D = 49A

Description

Advanced HEXFET® Power MOSFETs from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



TO-220AB

Absolute Maximum Ratings

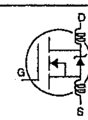
	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	49	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	35	
I_{DM}	Pulsed Drain Current ①	160	
P_D @T_C = 25°C	Power Dissipation	94	W
	Linear Derating Factor	0.63	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
I_{AR}	Avalanche Current①	25	A
E_{AR}	Repetitive Avalanche Energy①	9.4	mJ
dv/dt	Peak Diode Recovery dv/dt ③	5.0	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 srew	10 lbf•in (1.1N•m)	

Thermal Resistance

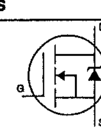
	Parameter	Typ.	Max.	Units
$R_{θJC}$	Junction-to-Case	——	1.5	°C/W
$R_{θCS}$	Case-to-Sink, Flat, Greased Surface	0.50	——	
$R_{θJA}$	Junction-to-Ambient	——	62	

01/03/01

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	—	—	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.058	—	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	17.5	mΩ	V_{GS} = 10V, I_D = 25A ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	—	4.0	V	V_{DS} = V_{GS}, I_D = 250μA
g_{fs}	Forward Transconductance	19	—	—	S	V_{DS} = 25V, I_D = 25A④
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	V_{DS} = 55V, V_{GS} = 0V
		—	—	250		V_{DS} = 44V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 20V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -20V
Q_g	Total Gate Charge	—	—	63	nC	I_D = 25A
Q_{gs}	Gate-to-Source Charge	—	—	14		V_{DS} = 44V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	23		V_{GS} = 10V, See Fig. 6 and 13
$t_{d(on)}$	Turn-On Delay Time	—	12	—	ns	V_{DD} = 28V
t_r	Rise Time	—	60	—		I_D = 25A
$t_{d(off)}$	Turn-Off Delay Time	—	44	—		R_G = 12Ω
t_f	Fall Time	—	45	—		V_{GS} = 10V, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.) from package and center of die contact 
L_S	Internal Source Inductance	—	7.5	—		
C_{iss}	Input Capacitance	—	1470	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	360	—		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	—	88	—		f = 1.0MHz, See Fig. 5
E_{AS}	Single Pulse Avalanche Energy②	—	530⑤	150⑥	mJ	I_{AS} = 25A, L = 0.47mH

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	49	A	MOSFET symbol showing the integral reverse p-n junction diode. 
I_{SM}	Pulsed Source Current (Body Diode)①	—	—	160		
V_{SD}	Diode Forward Voltage	—	—	1.3	V	T_J = 25°C, I_S = 25A, V_{GS} = 0V ④
t_{rr}	Reverse Recovery Time	—	63	95	ns	T_J = 25°C, I_F = 25A
Q_{rr}	Reverse Recovery Charge	—	170	260	nC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11)

② Starting T_J = 25°C, L = 0.48mH R_G = 25Ω, I_{AS} = 25A. (See Figure 12)

③ $I_{SD} \leq$ 25A, di/dt ≤ 230A/μs, $V_{DD} \leq V_{(BR)DSS}$, $T_J \leq$ 175°C

④ Pulse width ≤ 400μs; duty cycle ≤ 2%.

⑤ This is a typical value at device destruction and represents operation outside rated limits.

⑥ This is a calculated value limited to T_J = 175°C .

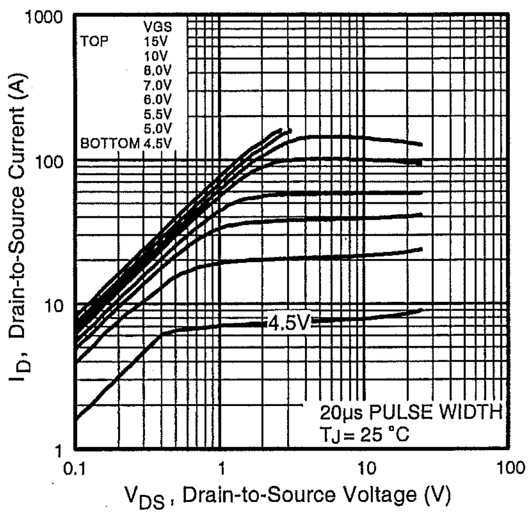


Fig 1. Typical Output Characteristics

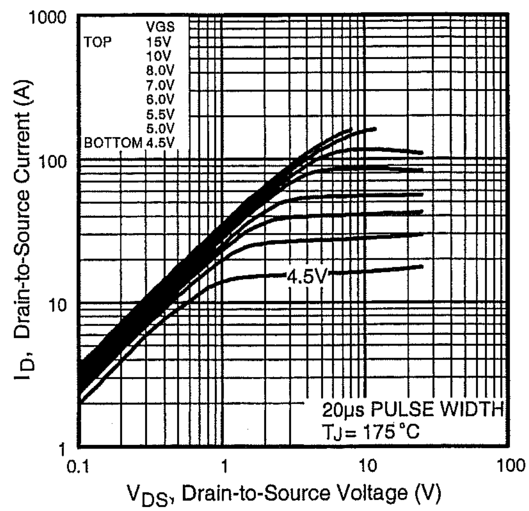


Fig 2. Typical Output Characteristics

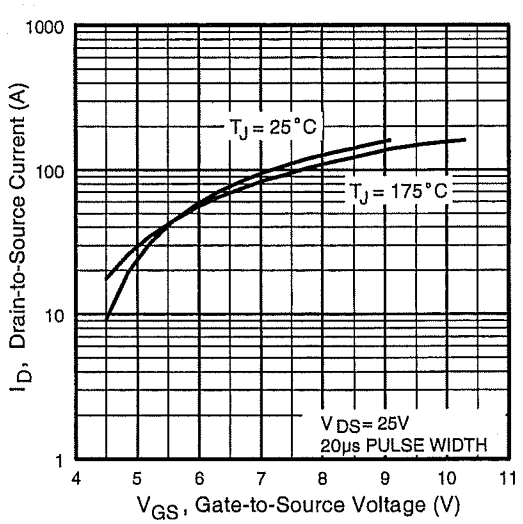


Fig 3. Typical Transfer Characteristics

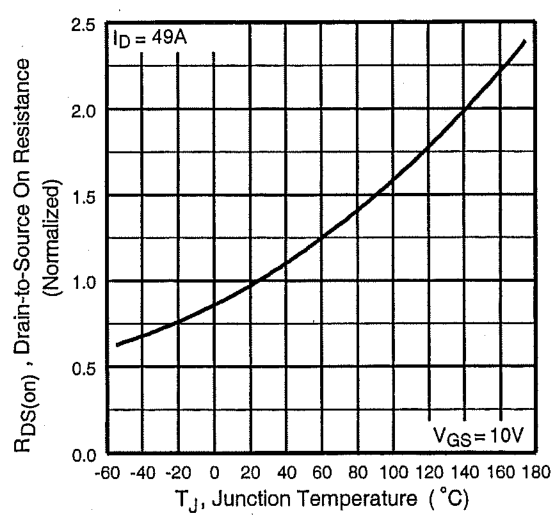


Fig 4. Normalized On-Resistance Vs. Temperature

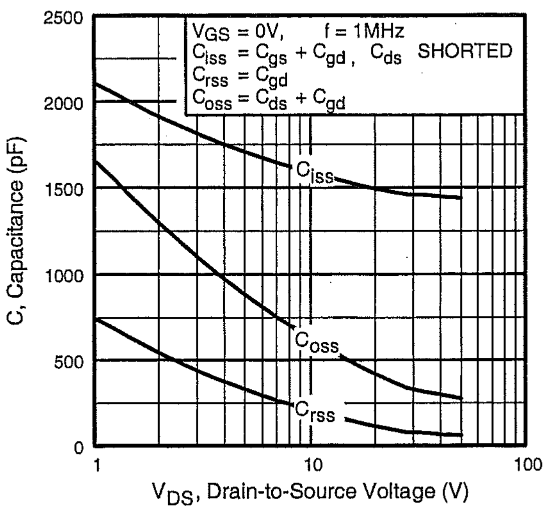


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

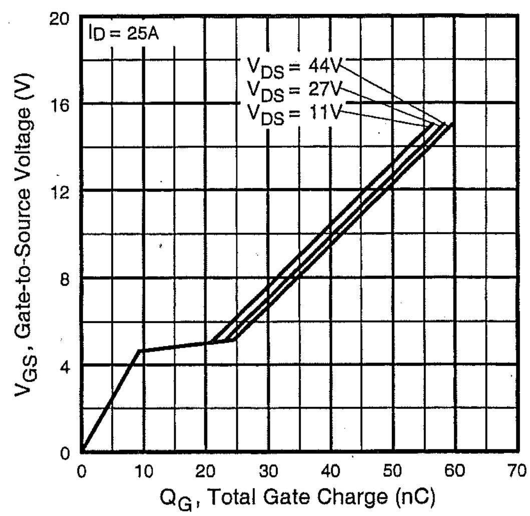


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

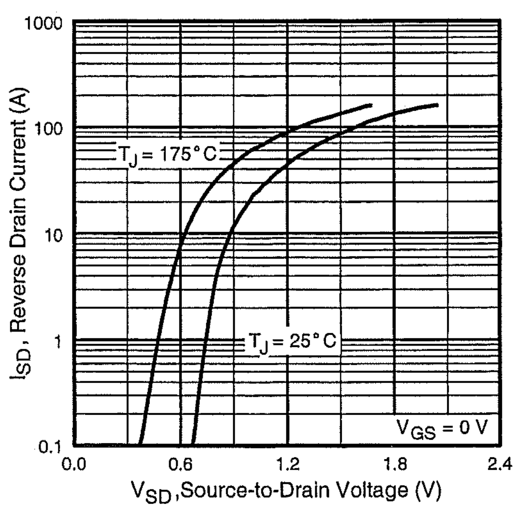


Fig 7. Typical Source-Drain Diode Forward Voltage

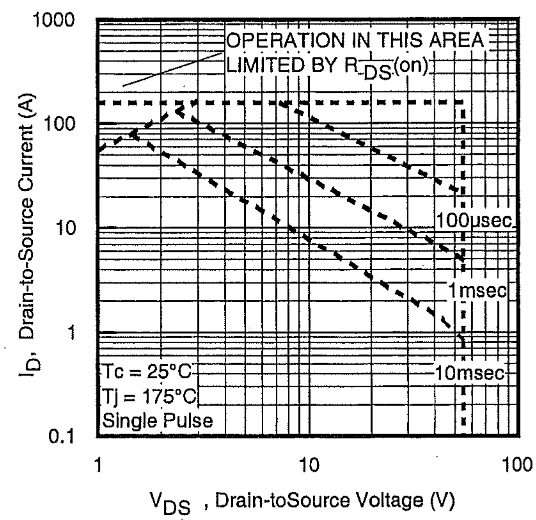


Fig 8. Maximum Safe Operating Area

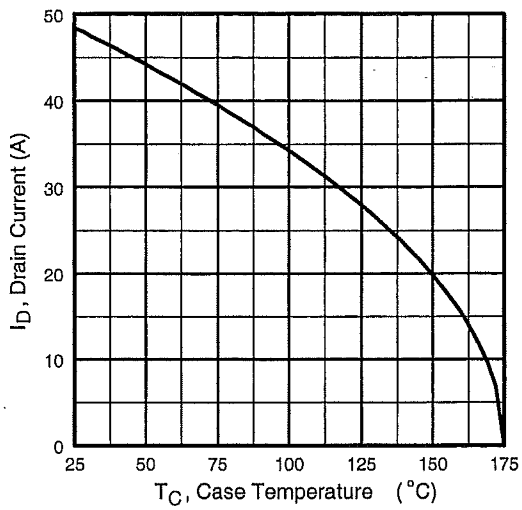


Fig 9. Maximum Drain Current Vs. Case Temperature

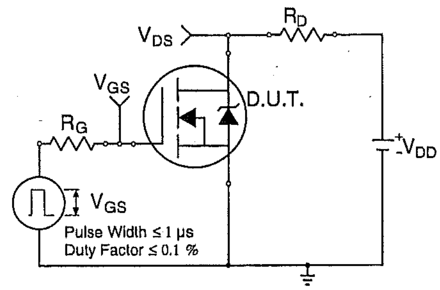


Fig 10a. Switching Time Test Circuit

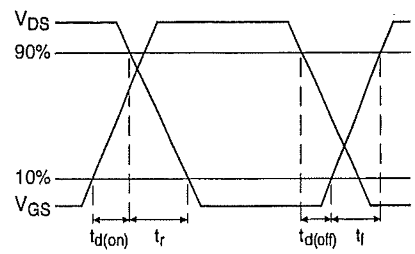


Fig 10b. Switching Time Waveforms

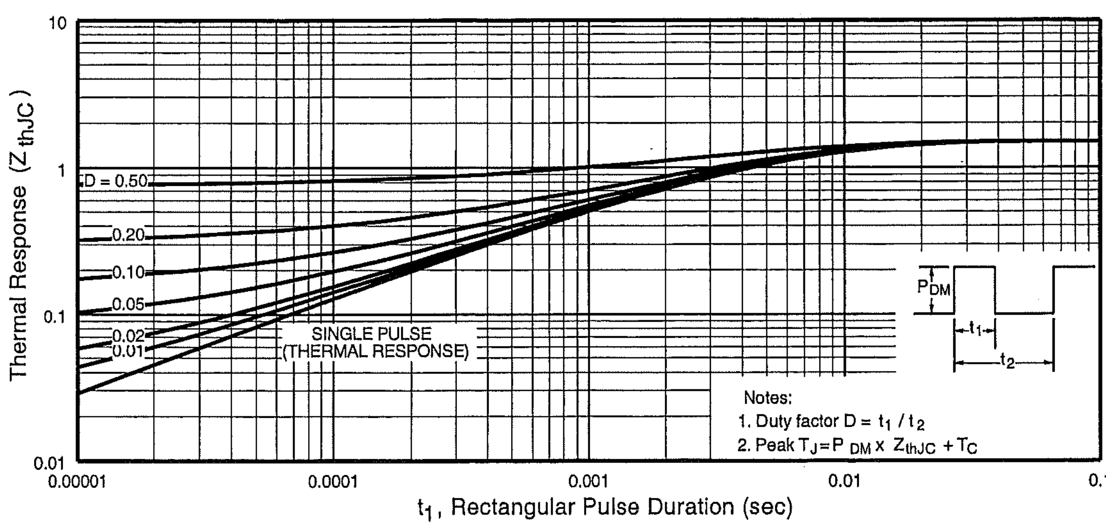


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

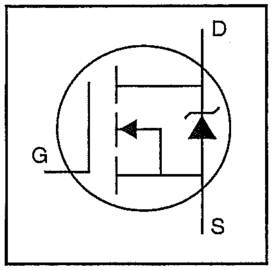
International
IOR Rectifier

PD - 91406

IRFZ48N

HEXFET® Power MOSFET

- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated



V_{DSS} = 55V

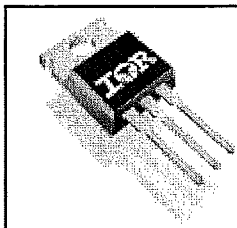
$R_{DS(on)}$ = 14mΩ

I_D = 64A

Description

Advanced HEXFET® Power MOSFETs from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



TO-220AB

Absolute Maximum Ratings

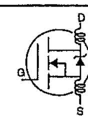
	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	64	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	45	
I_{DM}	Pulsed Drain Current ①	210	
P_D @T_C = 25°C	Power Dissipation	130	W
	Linear Derating Factor	0.83	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
I_{AR}	Avalanche Current①	32	A
E_{AR}	Repetitive Avalanche Energy①	13	mJ
dv/dt	Peak Diode Recovery dv/dt ③	5.0	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 srew	10 lbf•in (1.1N•m)	

Thermal Resistance

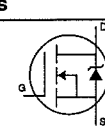
	Parameter	Typ.	Max.	Units
$R_{θJC}$	Junction-to-Case	—	1.15	°C/W
$R_{θCS}$	Case-to-Sink, Flat, Greased Surface	0.50	—	
$R_{θJA}$	Junction-to-Ambient	—	62	

1/3/01

Electrical Characteristics @ $T_J = 25°C$ (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	—	—	V	$V_{GS} = 0V$, $I_D = 250\mu A$
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.058	—	V/°C	Reference to 25°C, $I_D = 1mA$
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	14	mΩ	$V_{GS} = 10V$, $I_D = 32A$ ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	—	4.0	V	$V_{DS} = V_{GS}$, $I_D = 250\mu A$
g_{fs}	Forward Transconductance	24	—	—	S	$V_{DS} = 25V$, $I_D = 32A$④
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	$V_{DS} = 55V$, $V_{GS} = 0V$
		—	—	250		$V_{DS} = 44V$, $V_{GS} = 0V$, $T_J = 150°C$
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	$V_{GS} = 20V$
	Gate-to-Source Reverse Leakage	—	—	-100		$V_{GS} = -20V$
Q_g	Total Gate Charge	—	—	81	nC	$I_D = 32A$
Q_{gs}	Gate-to-Source Charge	—	—	19		$V_{DS} = 44V$
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	30		$V_{GS} = 10V$, See Fig. 6 and 13
$t_{d(on)}$	Turn-On Delay Time	—	12	—	ns	$V_{DD} = 28V$
t_r	Rise Time	—	78	—		$I_D = 32A$
$t_{d(off)}$	Turn-Off Delay Time	—	34	—		$R_G = 0.85\Omega$
t_f	Fall Time	—	50	—		$V_{GS} = 10V$, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.) from package and center of die contact 
L_S	Internal Source Inductance	—	7.5	—		
C_{iss}	Input Capacitance	—	1970	—	pF	$V_{GS} = 0V$
C_{oss}	Output Capacitance	—	470	—		$V_{DS} = 25V$
C_{rss}	Reverse Transfer Capacitance	—	120	—		$f = 1.0MHz$, See Fig. 5
E_{AS}	Single Pulse Avalanche Energy②	—	700⑤	190⑥	mJ	$I_{AS} = 32A$, $L = 0.37mH$

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	64	A	MOSFET symbol showing the integral reverse p-n junction diode. 
I_{SM}	Pulsed Source Current (Body Diode)①	—	—	210		
V_{SD}	Diode Forward Voltage	—	—	1.3	V	$T_J = 25°C$, $I_S = 32A$, $V_{GS} = 0V$ ④
t_{rr}	Reverse Recovery Time	—	68	100	ns	$T_J = 25°C$, $I_F = 32A$
Q_{rr}	Reverse Recovery Charge	—	220	330	nC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11)

② Starting $T_J = 25°C$, $L = 0.37mH$ $R_G = 25\Omega$, $I_{AS} = 32A$. (See Figure 12)

③ $I_{SD} \le 32A$, $di/dt \le 220A/\mu s$, $V_{DD} \le V_{(BR)DSS}$, $T_J \le 175°C$

④ Pulse width ≤ 400μs; duty cycle ≤ 2%.

⑤ This is the destructive value not limited to the thermal limit.

⑥ This is the thermal limited value.

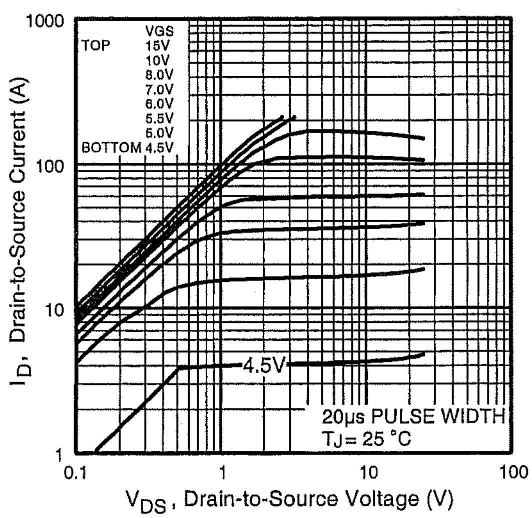


Fig 1. Typical Output Characteristics

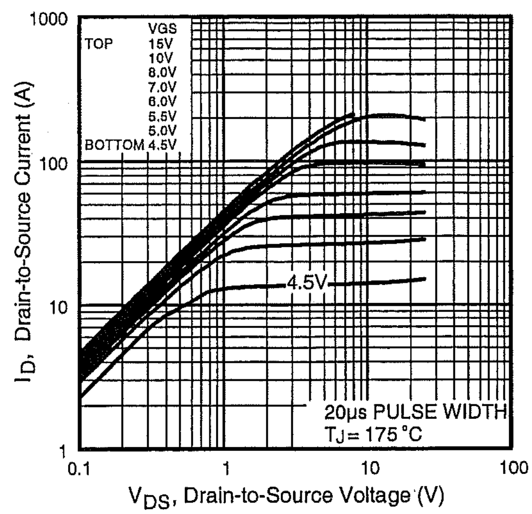


Fig 2. Typical Output Characteristics

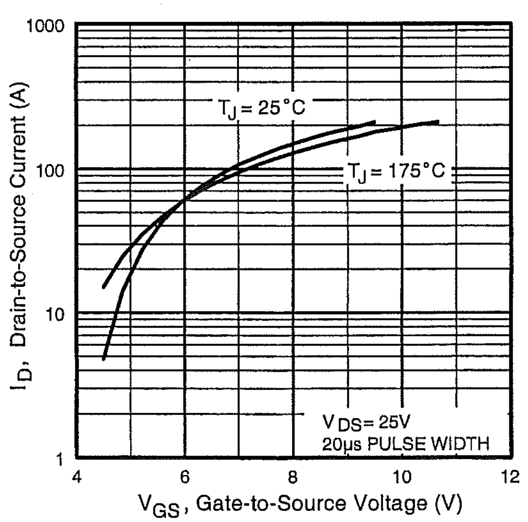


Fig 3. Typical Transfer Characteristics

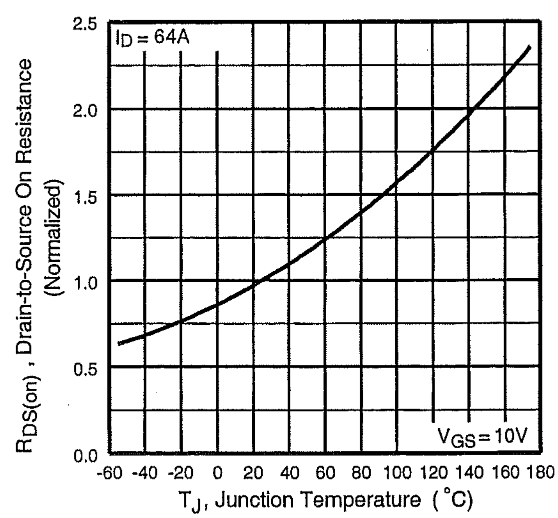


Fig 4. Normalized On-Resistance
Vs. Temperature

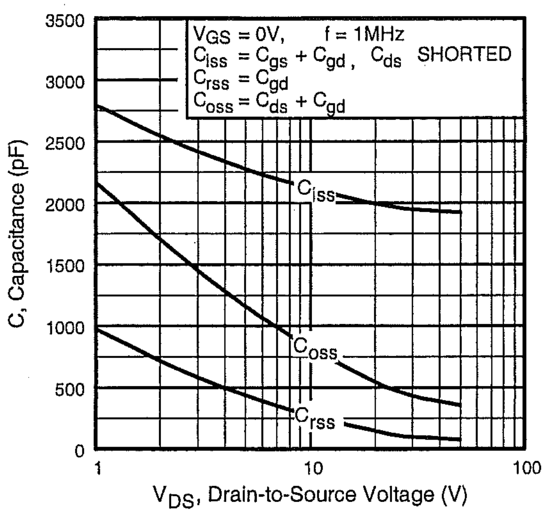


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

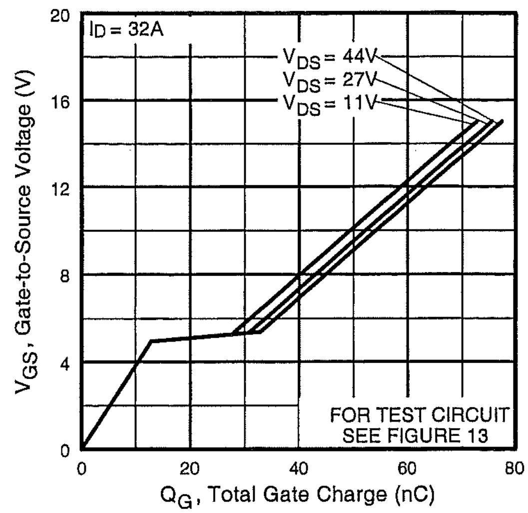


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

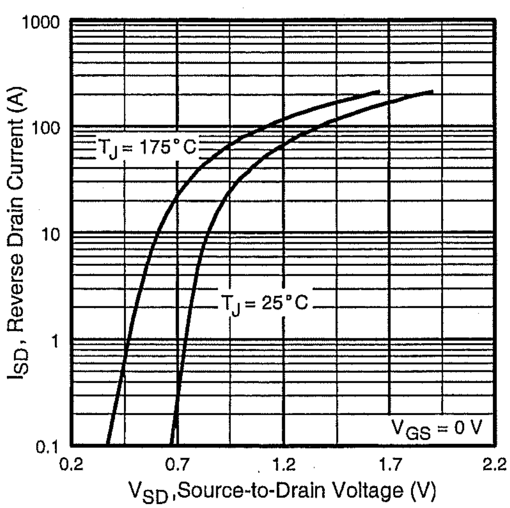


Fig 7. Typical Source-Drain Diode Forward Voltage

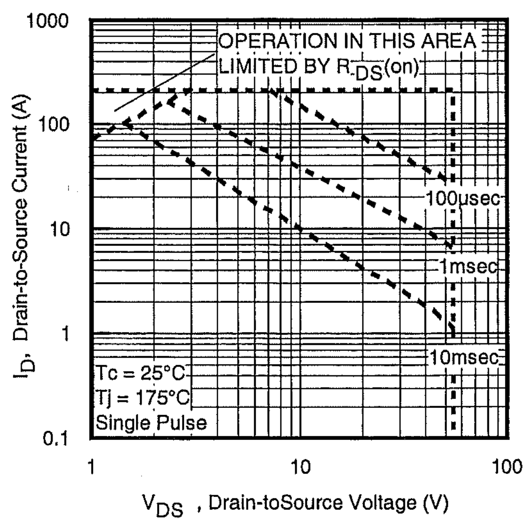


Fig 8. Maximum Safe Operating Area

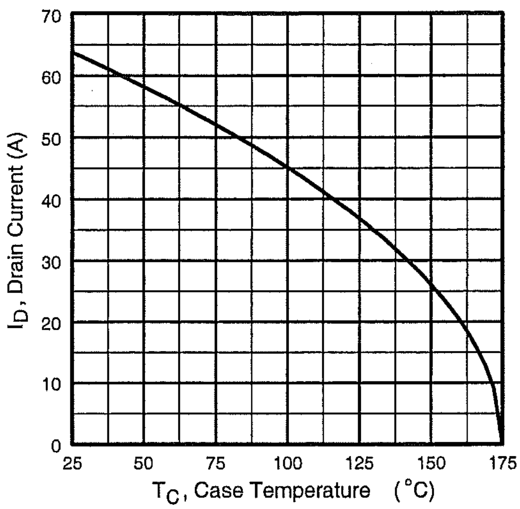


Fig 9. Maximum Drain Current Vs. Case Temperature

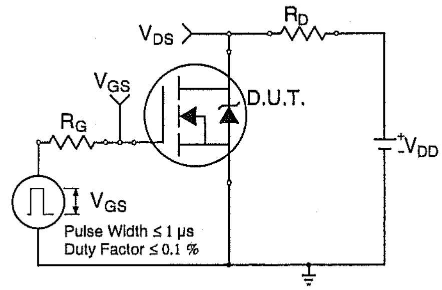


Fig 10a. Switching Time Test Circuit

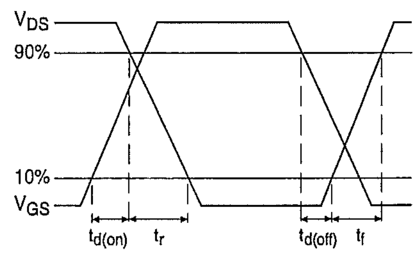


Fig 10b. Switching Time Waveforms

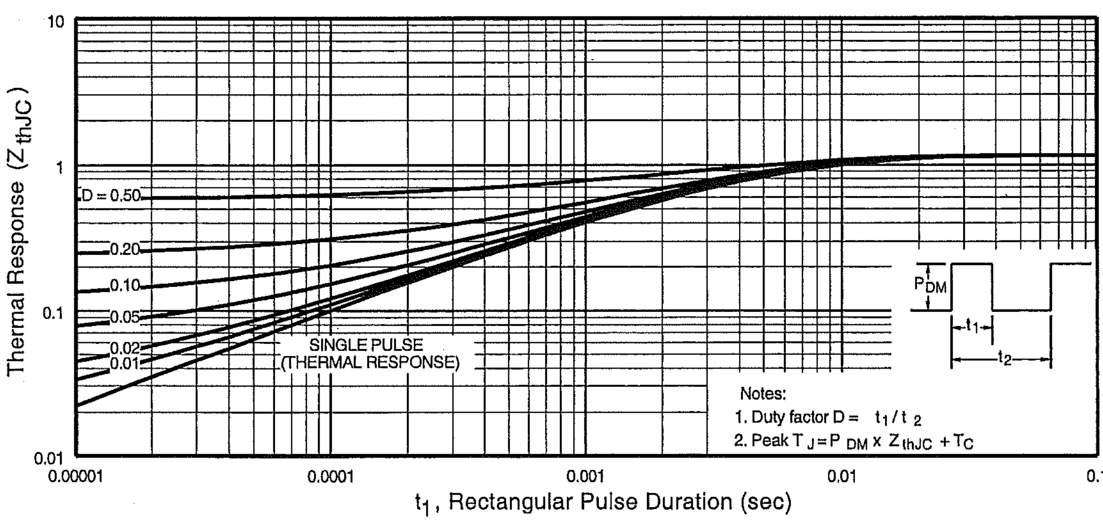


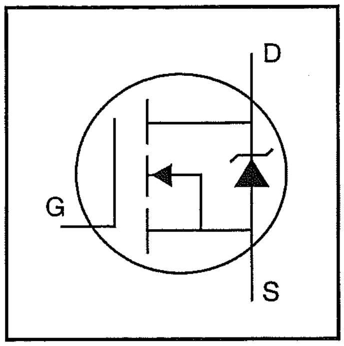
Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

International
IOR Rectifier

IRL2505

HEXFET® Power MOSFET

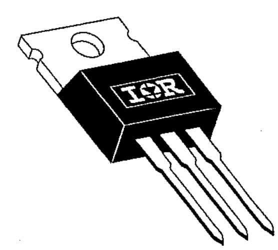
- Logic-Level Gate Drive
- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated



V_{DSS} = 55V

$R_{DS(on)}$ = 0.008Ω

I_D = 104A⑤



TO-220AB

Description

Fifth Generation HEXFETs from International Rectifier utilize advanced processing techniques to achieve the lowest possible on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET Power MOSFETs are well known for, provides the designer with an extremely efficient device for use in a wide variety of applications.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.

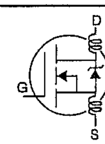
Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	104⑤	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	74	
I_{DM}	Pulsed Drain Current ①	360	
P_D @T_C = 25°C	Power Dissipation	200	W
	Linear Derating Factor	1.3	W/°C
V_{GS}	Gate-to-Source Voltage	±16	V
E_{AS}	Single Pulse Avalanche Energy ②	500	mJ
I_{AR}	Avalanche Current①	54	A
E_{AR}	Repetitive Avalanche Energy①	20	mJ
dv/dt	Peak Diode Recovery dv/dt ③	5.0	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

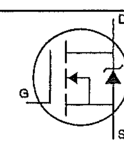
Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{θJC}$	Junction-to-Case	——	——	0.75	°C/W
$R_{θCS}$	Case-to-Sink, Flat, Greased Surface	——	0.50	——	
$R_{θJA}$	Junction-to-Ambient	——	——	62	

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	—	—	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.035	—	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.008	Ω	V_{GS} = 10V, I_D = 54A ④
		—	—	0.010		V_{GS} = 5.0V, I_D = 54A ④
		—	—	0.013		V_{GS} = 4.0V, I_D = 45A ④
$V_{GS(th)}$	Gate Threshold Voltage	1.0	—	2.0	V	V_{DS} = V_{GS}, I_D = 250μA
g_{fs}	Forward Transconductance	59	—	—	S	V_{DS} = 25V, I_D = 54A
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	V_{DS} = 55V, V_{GS} = 0V
		—	—	250		V_{DS} = 44V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 16V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -16V
Q_g	Total Gate Charge	—	—	130	nC	I_D = 54A
Q_{gs}	Gate-to-Source Charge	—	—	25		V_{DS} = 44V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	67		V_{GS} = 5.0V, See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	12	—	ns	V_{DD} = 28V
t_r	Rise Time	—	160	—		I_D = 54A
$t_{d(off)}$	Turn-Off Delay Time	—	43	—		R_G = 1.3Ω, V_{GS} = 5.0V
t_f	Fall Time		84			R_D = 0.50Ω, See Fig. 10 ④
L_D	Internal Drain Inductance	—	4.5	—	nH	Between lead, 6mm (0.25in.) 
L_S	Internal Source Inductance	—	7.5	—		from package and center of die contact
C_{iss}	Input Capacitance	—	5000	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	1100	—		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	—	390	—		f = 1.0MHz, See Fig. 5

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	104⑤	A	MOSFET symbol showing the 
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	360		integral reverse p-n junction diode.
V_{SD}	Diode Forward Voltage	—	—	1.3	V	T_J = 25°C, I_S = 54A, V_{GS} = 0V ④
t_{rr}	Reverse Recovery Time	—	140	210	ns	T_J = 25°C, I_F = 54A
Q_{rr}	Reverse RecoveryCharge	—	650	970	nC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11)

② V_{DD} = 25V, starting T_J = 25°C, L = 240μH R_G = 25Ω, I_{AS} = 54A. (See Figure 12)

③ $I_{SD} \le$ 54A, di/dt $\le$ 230A/μs, $V_{DD} \le V_{(BR)DSS}$, $T_J \le$ 175°C

④ Pulse width ≤ 300μs; duty cycle ≤ 2%.

⑤ Caculated continuous current based on maximum allowable junction temperature;for recommended current-handling of the package refer to Design Tip # 93-4

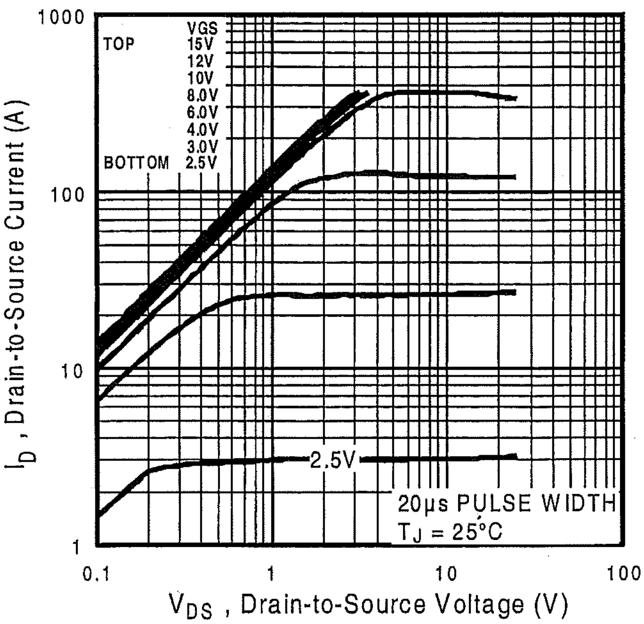


Fig 1. Typical Output Characteristics

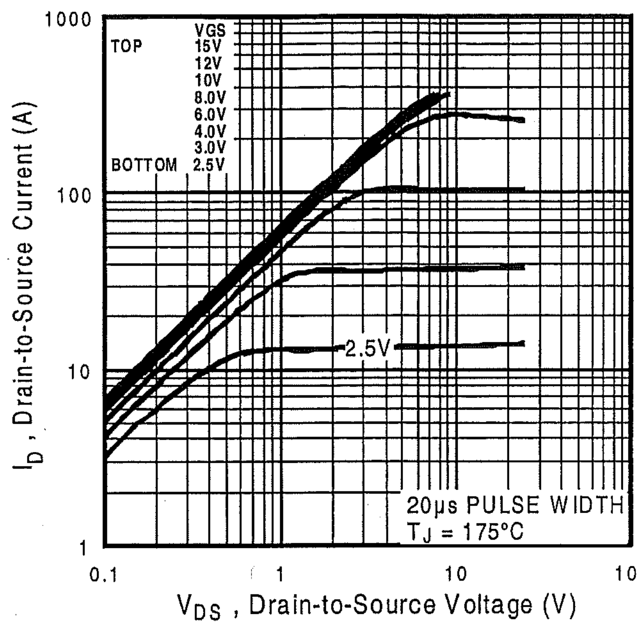


Fig 2. Typical Output Characteristics

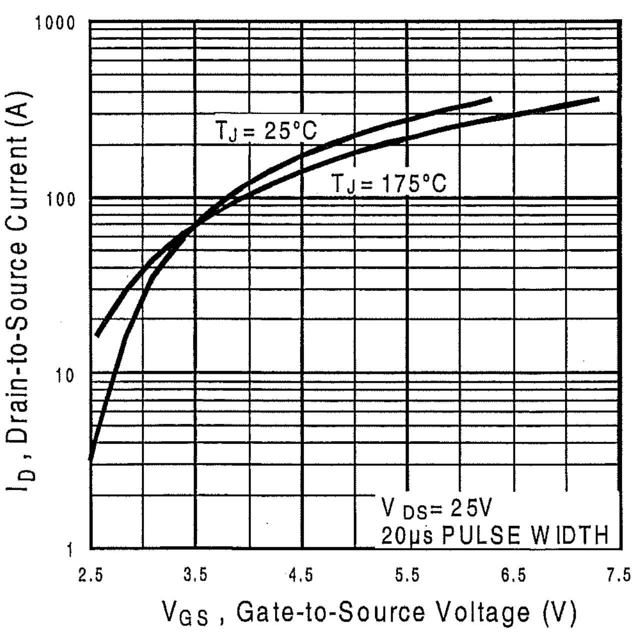


Fig 3. Typical Transfer Characteristics

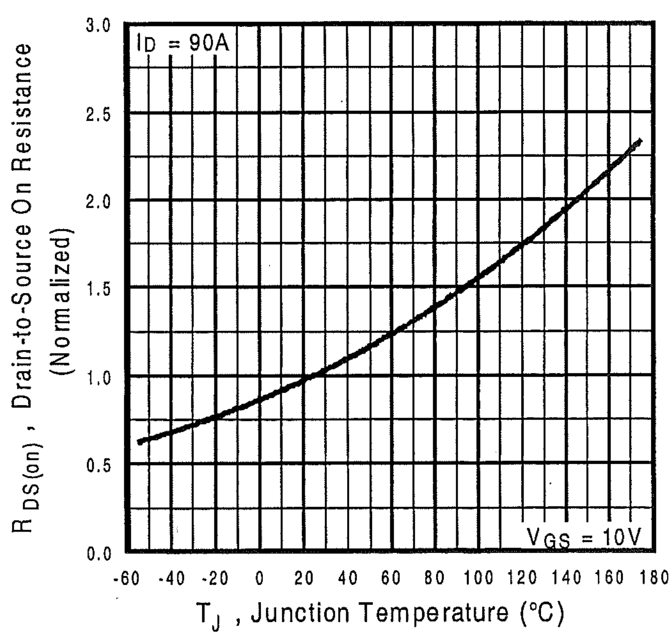


Fig 4. Normalized On-Resistance Vs. Temperature

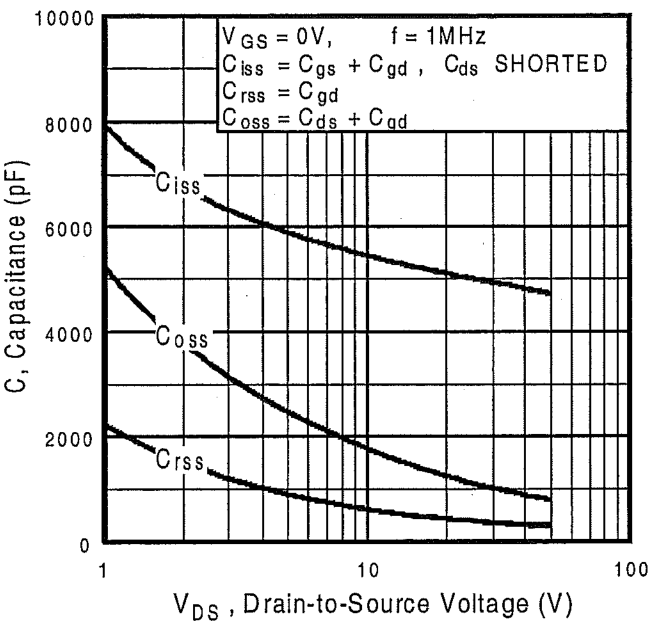


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

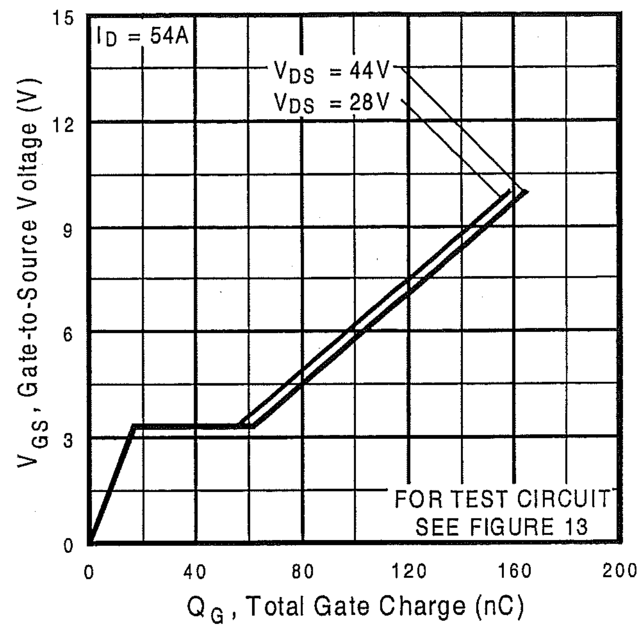


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

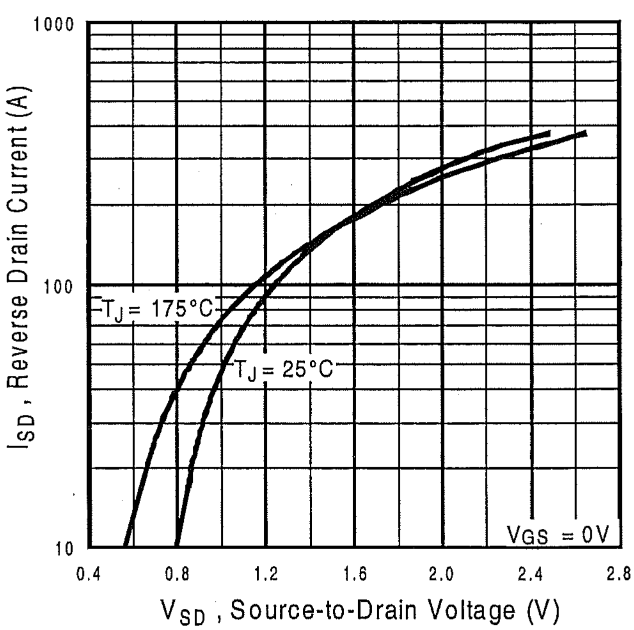


Fig 7. Typical Source-Drain Diode Forward Voltage

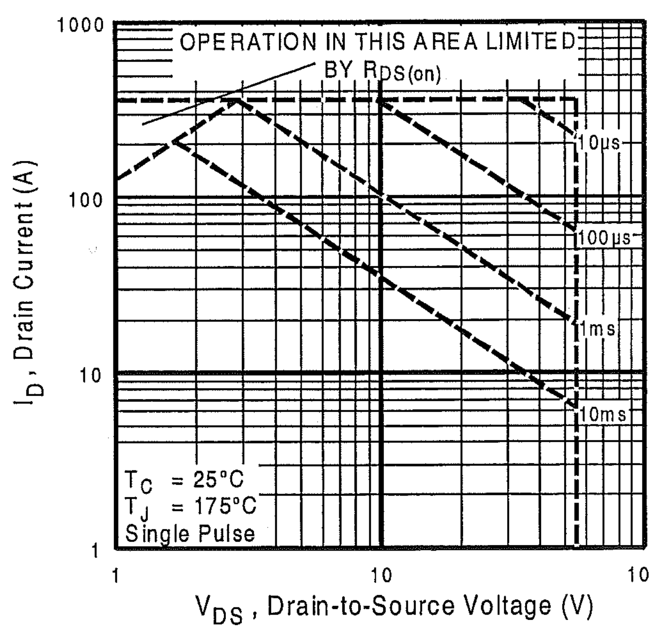


Fig 8. Maximum Safe Operating Area

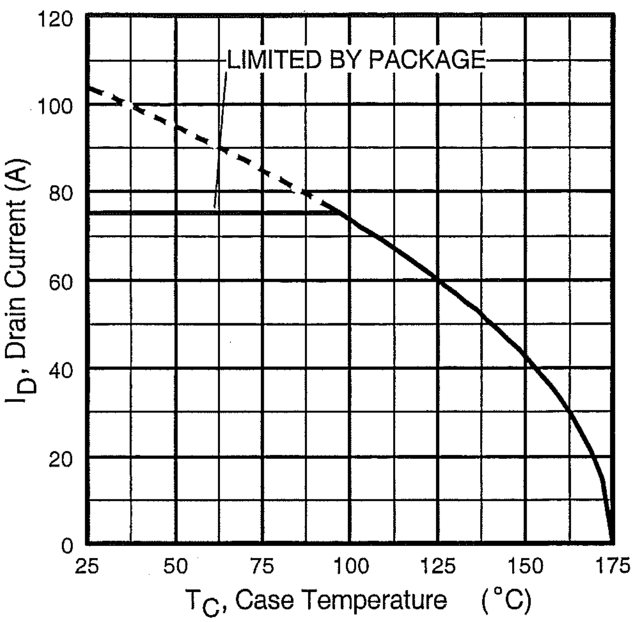


Fig 9. Maximum Drain Current Vs. Case Temperature

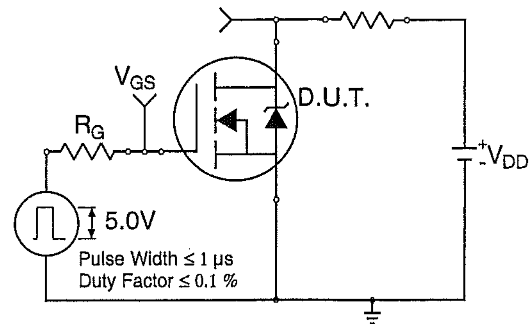


Fig 10a. Switching Time Test Circuit

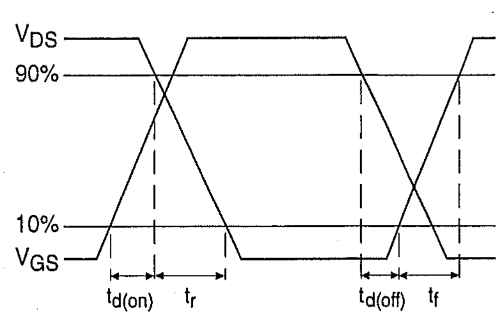


Fig 10b. Switching Time Waveforms

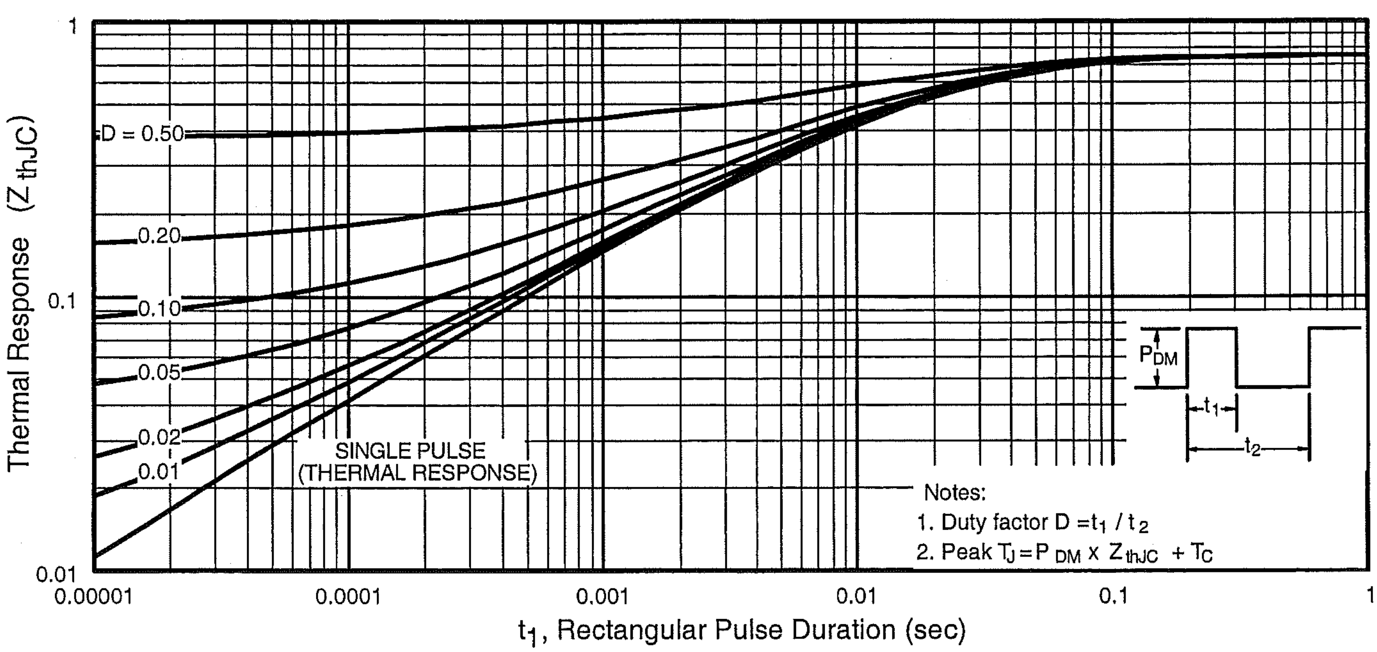


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

International
IOR Rectifier

MBR340

SCHOTTKY RECTIFIER

3.0 Amp

Major Ratings and Characteristics

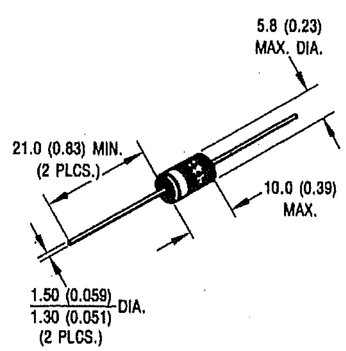
Characteristics	MBR340	Units
$I_{F(AV)}$ Rectangular waveform	3.0	A
V_{RRM}	30/40	V
I_{FSM} @tp = 5 μs sine	430	A
V_F @3 Apk, T_J=25°C	0.6	V
T_J	-40 to 150	°C

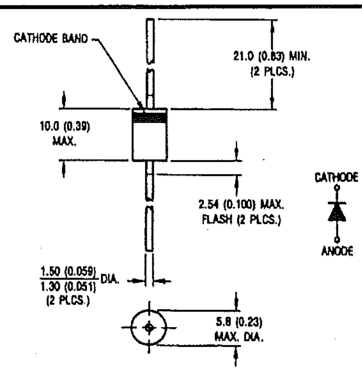
Description/Features

The MBR340 axial leaded Schottky rectifier has been optimized for very low forward voltage drop, with moderate leakage. Typical applications are in switching power supplies, converters, free-wheeling diodes, and reverse battery protection.

- Low profile, axial leaded outline
- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance
- Very low forward voltage drop
- High frequency operation
- Guard ring for enhanced ruggedness and long term reliability

CASE STYLE AND DIMENSIONS





Outline C - 16
Dimensions in millimeters and inches

Voltage Ratings

Part number	MBR340
V_R Max. DC Reverse Voltage (V)	40
V_{RWM} Max. Working Peak Reverse Voltage (V)	

Absolute Maximum Ratings

	Parameters	MBR340	Units	Conditions	
$I_{F(AV)}$	Max. Average Forward Current * See Fig. 4	3.0	A	50% duty cycle @ T_L = 92 °C, rectangular waveform With cooling fins	
I_{FSM}	Max. Peak One Cycle Non-Repetitive Surge Current * See Fig. 6	430	A	5µs Sine or 3µs Rect. pulse	Following any rated load condition and with rated V_{RRM} applied
		80		10ms Sine or 6ms Rect. pulse	

Electrical Specifications

	Parameters	MBR340	Units	Conditions	
V_{FM}	Max. Forward Voltage Drop * See Fig. 1 (1)	0.5	V	@ 1.0A	T_J = 25 °C
		0.6	V	@ 3.0A	
		0.85	V	@ 9.4A	
		0.37	V	@ 1.0A	T_J = 125 °C
		0.49	V	@ 3.0A	
		0.72	V	@ 9.4A	
I_{RM}	Max. Reverse Leakage Current * See Fig. 2 (1)	0.6	mA	T_J = 25 °C	V_R = rated V_R
		8	mA	T_J = 100 °C	
		20	mA	T_J = 125 °C	
C_T	Typical Junction Capacitance	190	pF	V_R = 5V_{DC} (test signal range 100Khz to 1Mhz) 25°C	
L_S	Typical Series Inductance	9.0	nH	Measured lead to lead 5mm from package body	
dv/dt	Max. Voltage Rate of Change (Rated V_R)	10000	V/µs		

(1) Pulse Width < 300µs, Duty Cycle <2%

Thermal-Mechanical Specifications

	Parameters	MBR340	Units	Conditions
T_J	Max. Junction Temperature Range	-40 to 150	°C	
T_{stg}	Max. Storage Temperature Range	-40 to 150	°C	
R_{thJL}	Typical Thermal Resistance Junction to Lead (2)	28	°C/W	DC operation (* See Fig. 4)
wt	Approximate Weight	1.2 (0.042)	g (oz.)	
	Case Style	C-16		

(2) Mounted 1 inch square PCB, thermal probe connected to lead 2mm from package

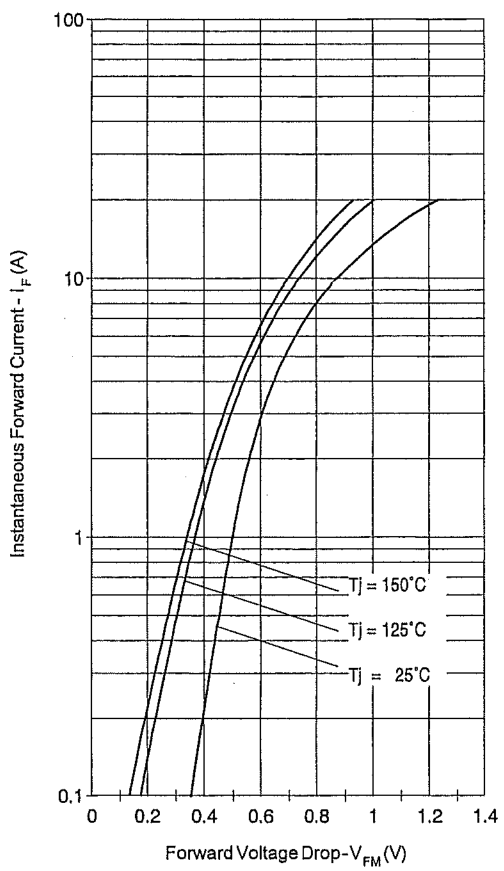


Fig. 1 - Max. Forward Voltage Drop Characteristics

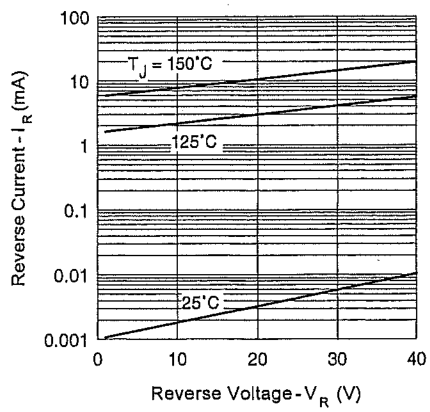


Fig. 2 - Typical Values Of Reverse Current Vs. Reverse Voltage

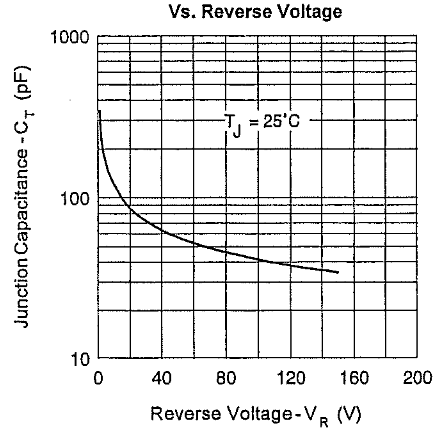


Fig. 3 - Typical Junction Capacitance Vs. Reverse Voltage

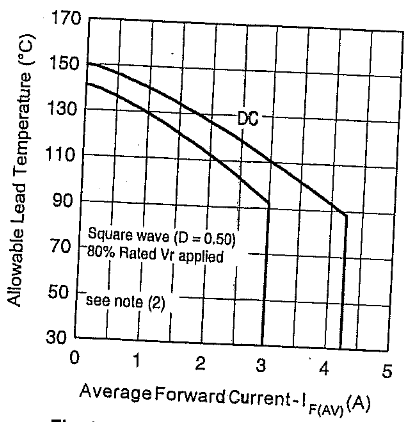


Fig. 4 - Max. Allowable Lead Temperature Vs. Average Forward Current

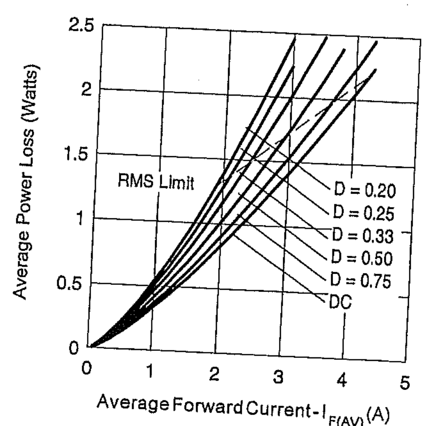


Fig. 5 - Forward Power Loss Characteristics

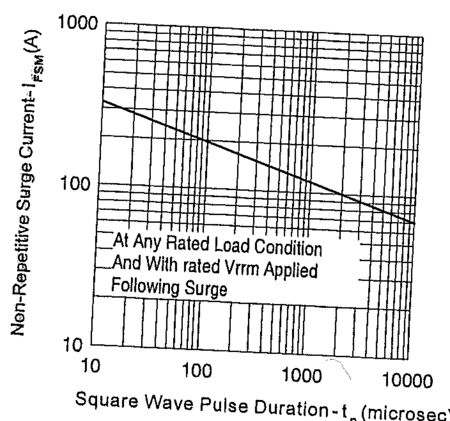


Fig. 6 - Max. Non-Repetitive Surge Current

(2) Formula used: $T_C = T_J - (Pd + Pd_{REV}) \times R_{thJC}$;
Pd = Forward Power Loss = $I_{F(AV)} \times V_{FM}$ @ ($I_{F(AV)}$ / D) (see Fig. 6);
Pd_{REV} = Inverse Power Loss = $V_{R1} \times I_R$ (1 - D); I_R @ V_{R1} = 80% rated V_R

Bulletin PD-20283 01/01

International
IOR Rectifier

6TQ...
6TQ...S

SCHOTTKY RECTIFIER

6 Amp

$I_{F(AV)}$ = 6Amp
V_R = 35 to 45V

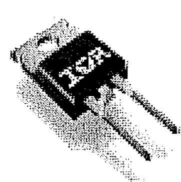
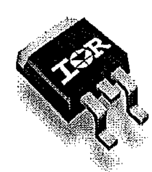
Major Ratings and Characteristics

Characteristics	6TQ	Units
$I_{F(AV)}$ Rectangular waveform	6	A
V_{RRM} range	35 to 45	V
I_{FSM} @tp=5µs sine	690	A
V_F @6Apk, T_J=125°C	0.53	V
T_J range	-55 to 175	°C

Description/Features

The 6TQ Schottky rectifier series has been optimized for low reverse leakage at high temperature. The proprietary barrier technology allows for reliable operation up to 175° C junction temperature. Typical applications are in switching power supplies, converters, free-wheeling diodes, and reverse battery protection.

- 175° C T_J operation
- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance
- Low forward voltage drop
- High frequency operation
- Guard ring for enhanced ruggedness and long term reliability

Case Styles	
10TQ...	10TQ... S
	
TO-220	D^2PAK

Voltage Ratings

	Part number	6TQ035	6TQ040	6TQ045
V_R	Max. DC Reverse Voltage (V)	35	40	45
V_{RWM}	Max. Working Peak Reverse Voltage (V)			

Absolute Maximum Ratings

	Parameters	6TQ	Units	Conditions	
$I_{F(AV)}$	Max. Average Forward Current * See Fig. 5	6	A	50% duty cycle @ T_C = 164° C, rectangular waveform	
I_{FSM}	Max. Peak One Cycle Non-Repetitive Surge Current * See Fig. 7	690	A	5µs Sine or 3µs Rect. pulse	Following any rated load condition and with rated V_{RRM} applied
		140		10ms Sine or 6ms Rect. pulse	
E_{AS}	Non-Repetitive Avalanche Energy	8	mJ	T_J = 25 °C, I_{AS} = 1.20 Amps, L = 11.10 mH	
I_{AR}	Repetitive Avalanche Current	1.20	A	Current decaying linearly to zero in 1 µsec Frequency limited by T_J max. V_A = 1.5 x V_R typical	

Electrical Specifications

	Parameters	6TQ	Units	Conditions	
V_{FM}	Max. Forward Voltage Drop (1) * See Fig. 1	0.60	V	@ 6A	T_J = 25 °C
		0.73	V	@ 12A	
		0.53	V	@ 6A	T_J = 125 °C
		0.64	V	@ 12A	
I_{RM}	Max. Reverse Leakage Current (1) * See Fig. 2	0.8	mA	T_J = 25 °C	V_R = rated V_R
		7	mA	T_J = 125 °C	
$V_{F(TO)}$	Threshold Voltage	0.35	V	T_J = T_J max.	
r_t	Forward Slope Resistance	18.23	mΩ		
C_T	Max. Junction Capacitance	400	pF	V_R = 5V_{DC}, (test signal range 100Khz to 1Mhz) 25 °C	
L_S	Typical Series Inductance	8.0	nH	Measured lead to lead 5mm from package body	
dv/dt	Max. Voltage Rate of Change (Rated V_R)	10,000	V/ µs		

(1) Pulse Width < 300µs, Duty Cycle < 2%

Thermal-Mechanical Specifications

	Parameters		6TQ	Units	Conditions
T_J	Max. Junction Temperature Range		-55 to 175	°C	
T_{stg}	Max. Storage Temperature Range		-55 to 175	°C	
R_{thJC}	Max. Thermal Resistance Junction to Case		2.2	°C/W	DC operation * See Fig. 4
R_{thCS}	Typical Thermal Resistance, Case to Heatsink		0.50	°C/W	Mounting surface, smooth and greased
wt	Approximate Weight		2 (0.07)	g (oz.)	
T	Mounting Torque	Min.	6 (5)	Kg-cm (lbf-in)	
		Max.	12 (10)		

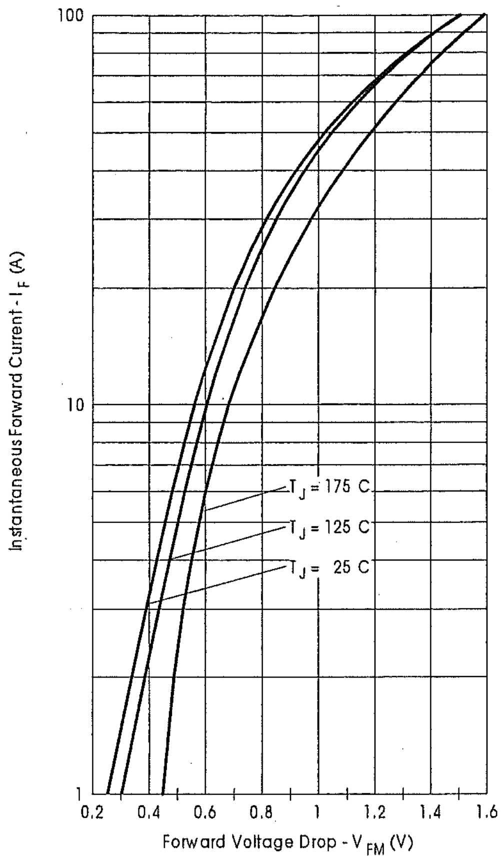


Fig. 1 - Maximum Forward Voltage Drop Characteristics

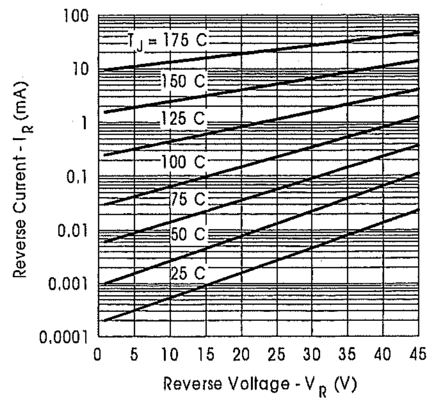


Fig. 2 - Typical Values of Reverse Current Vs. Reverse Voltage

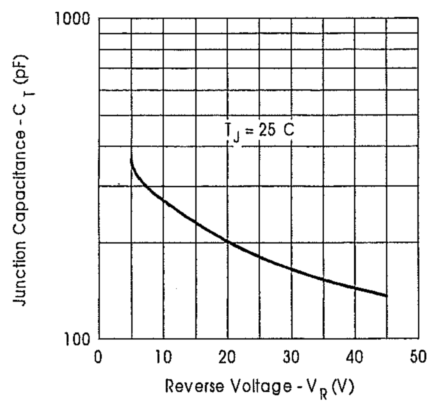


Fig. 3 - Typical Junction Capacitance Vs. Reverse Voltage

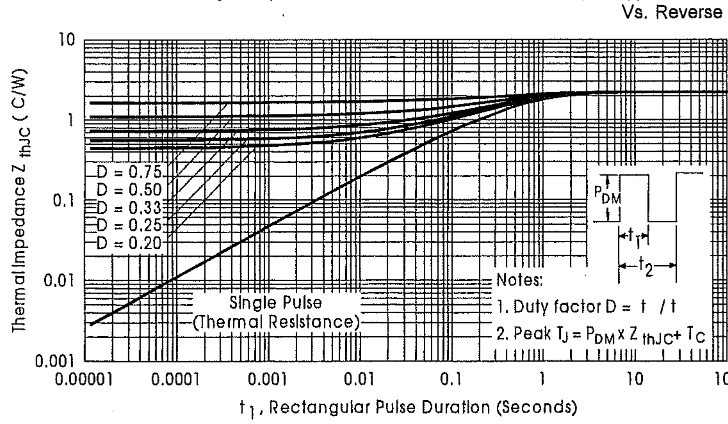


Fig. 4 - Maximum Thermal Impedance Z_{thJC} Characteristics

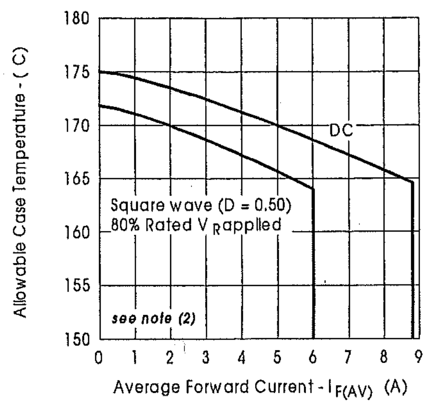


Fig. 5 - Maximum Allowable Case Temperature Vs. Average Forward Current

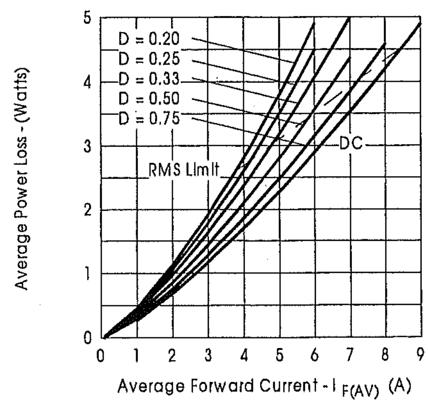


Fig. 6 - Forward Power Loss Characteristics

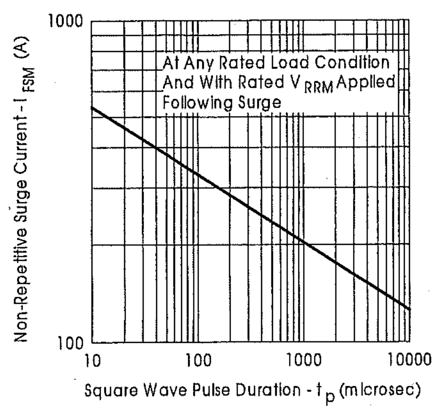


Fig. 7 - Maximum Non-Repetitive Surge Current

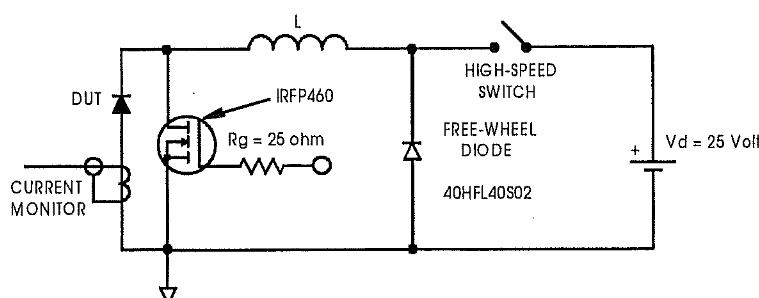


Fig. 8 - Unclamped Inductive Test Circuit

(2) Formula used: $T_C = T_J - (Pd + Pd_{REV}) \times R_{thJC}$;
Pd = Forward Power Loss = $I_{F(AV)} \times V_{FM}$ @ $(I_{F(AV)} / D)$ (see Fig. 6);
Pd_{REV} = Inverse Power Loss = $V_{R1} \times I_R (1 - D)$; I_R @ V_{R1} = 80% rated V_R

Bulletin PD-20057 01/01

International
IOR Rectifier

10TQ...
10TQ...S

SCHOTTKY RECTIFIER

10 Amp

$I_{F(AV)}$ = 10Amp
V_R = 35 to 45V

Major Ratings and Characteristics

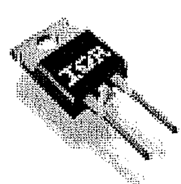
Characteristics	10TQ	Units
$I_{F(AV)}$ Rectangular waveform	10	A
V_{RRM}	35 to 45	V
I_{FSM} @tp=5μs sine	1050	A
V_F @10Apk, T_J=125°C	0.49	V
T_J range	-55 to 175	°C

Description/ Features

The 10TQ.. Schottky rectifier series has been optimized for low reverse leakage at high temperature. The proprietary barrier technology allows for reliable operation up to 175° C junction temperature. Typical applications are in switching power supplies, converters, free-wheeling diodes, and reverse battery protection.

- 175° C T_J operation
- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance
- Low forward voltage drop
- High frequency operation
- Guard ring for enhanced ruggedness and long term reliability

Case Styles

10TQ...	10TQ... S
	
TO-220	D^2PAK

Voltage Ratings

	Part number	10TQ035	10TQ040	10TQ045
V_R	Max. DC Reverse Voltage (V)	35	40	45
V_{RWM}	Max. Working Peak Reverse Voltage (V)			

Absolute Maximum Ratings

	Parameters	10TQ	Units	Conditions	
$I_{F(AV)}$	Max. Average Forward Current * See Fig. 5	10	A	50% duty cycle @ T_C = 151° C, rectangular wave form	
I_{FSM}	Max. Peak One Cycle Non-Repetitive Surge Current * See Fig. 7	1050	A	5μs Sine or 3μs Rect. pulse	Following any rated load condition and with rated V_{RRM} applied
		280		10ms Sine or 6ms Rect. pulse	
E_{AS}	Non-Repetitive Avalanche Energy	13	mJ	T_J = 25 °C, I_{AS} = 2 Amps, L = 6.5 mH	
I_{AR}	Repetitive Avalanche Current	2	A	Current decaying linearly to zero in 1 μsec Frequency limited by T_J max. V_A = 1.5 x V_R typical	

Electrical Specifications

	Parameters	10TQ	Units	Conditions	
V_{FM}	Max. Forward Voltage Drop (1) * See Fig. 1	0.57	V	@ 10A	T_J = 25 °C
		0.67	V	@ 20A	
		0.49	V	@ 10A	T_J = 125 °C
		0.61	V	@ 20A	
I_{RM}	Max. Reverse Leakage Current (1) * See Fig. 2	2	mA	T_J = 25 °C	V_R = rated V_R
		15	mA	T_J = 125 °C	
C_T	Max. Junction Capacitance	900	pF	V_R = 5V_{DC}, (test signal range 100Khz to 1Mhz) 25 °C	
L_S	Typical Series Inductance	8.0	nH	Measured lead to lead 5mm from package body	
dv/dt	Max. Voltage Rate of Change (Rated V_R)	10,000	V/ μs		

(1) Pulse Width < 300μs, Duty Cycle < 2%

Thermal-Mechanical Specifications

	Parameters		10TQ	Units	Conditions
T_J	Max. Junction Temperature Range		-55 to 175	°C	
T_{stg}	Max. Storage Temperature Range		-55 to 175	°C	
R_{thJC}	Max. Thermal Resistance Junction to Case		2.0	°C/W	DC operation * See Fig. 4
R_{thCS}	Typical Thermal Resistance, Case to Heatsink		0.50	°C/W	Mounting surface, smooth and greased
wt	Approximate Weight		2 (0.07)	g (oz.)	
T	Mounting Torque	Min.	6 (5)	Kg-cm (lbf-in)	
		Max.	12 (10)		

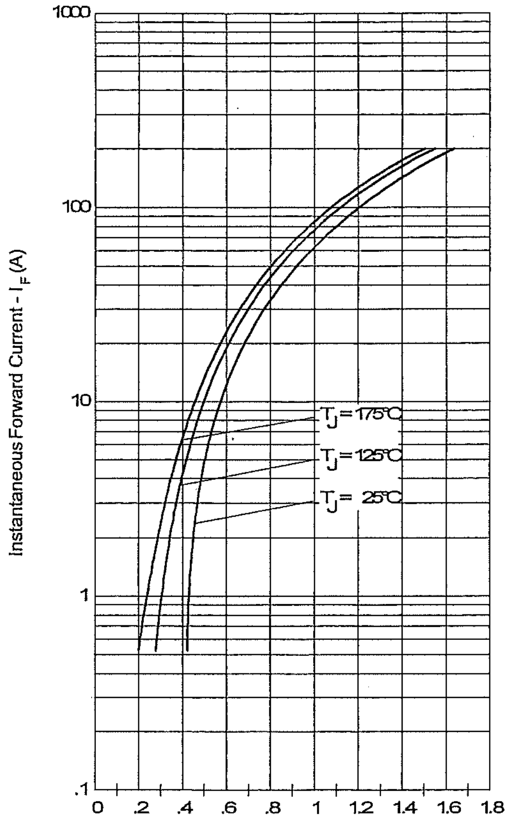


Fig. 1 - Maximum Forward Voltage Drop Characteristics

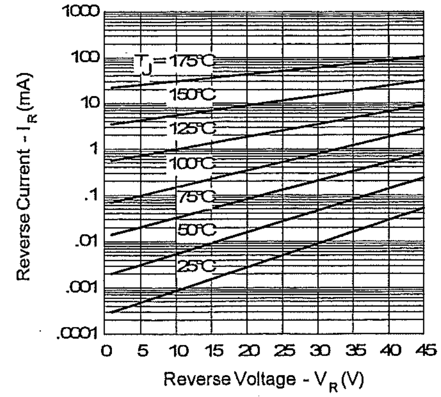


Fig. 2 - Typical Values of Reverse Current Vs. Reverse Voltage

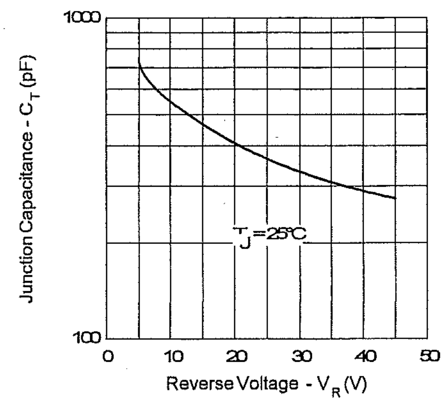


Fig. 3 - Typical Junction Capacitance Vs. Reverse Voltage

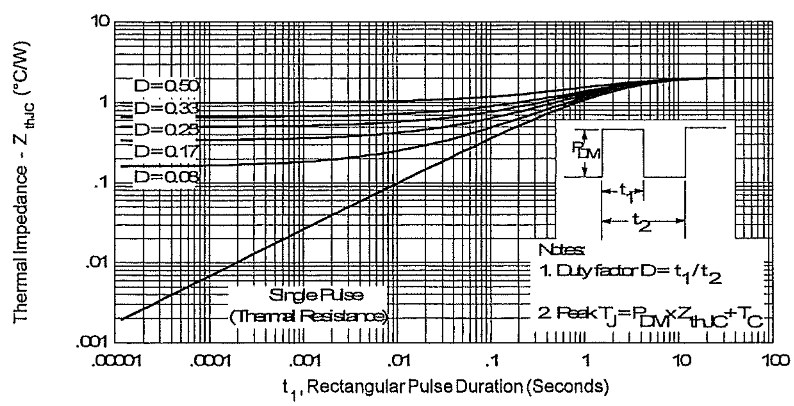


Fig. 4 - Maximum Thermal Impedance Z_{thJC} Characteristics

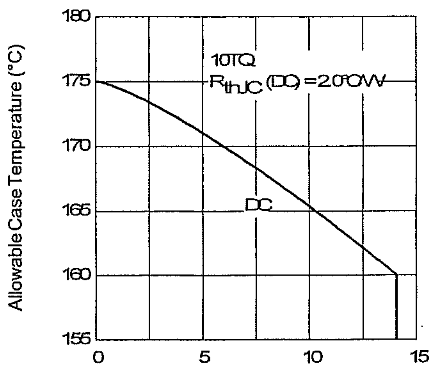


Fig. 5 - Maximum Allowable Case Temperature Vs. Average Forward Current

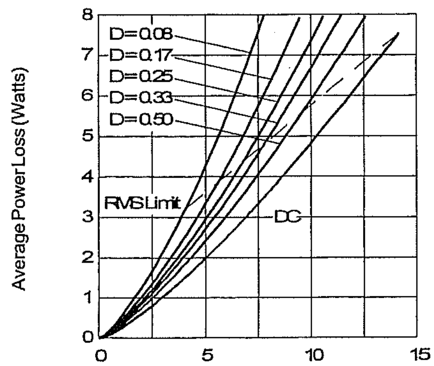


Fig. 6 - Forward Power Loss Characteristics

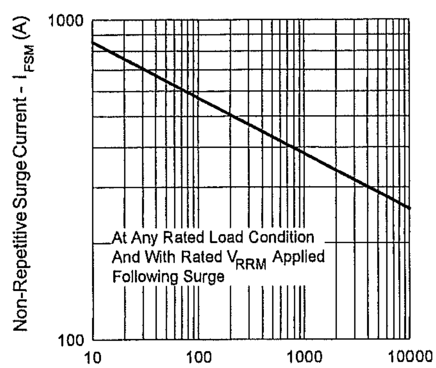


Fig. 7 - Maximum Non-Repetitive Surge Current

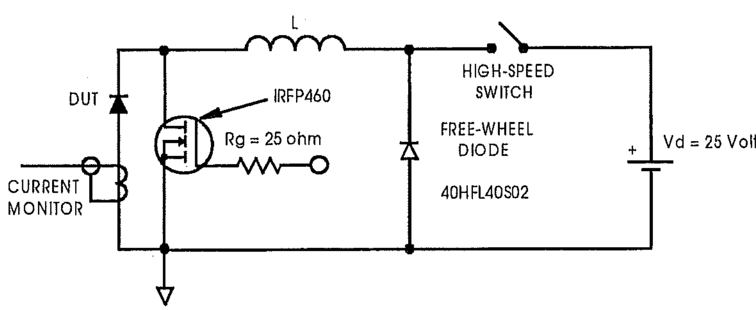


Fig. 8 - Unclamped Inductive Test Circuit

Bulletin PD-20178 rev. A 01/01

International
IOR Rectifier

18TQ...
18TQ...S

SCHOTTKY RECTIFIER

18 Amp

$I_{F(AV)}$ = 18Amp
V_R = 35 to 45V

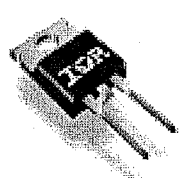
Major Ratings and Characteristics

Characteristics	18TQ	Units
$I_{F(AV)}$ Rectangular waveform	18	A
V_{RRM} range	35 to 45	V
I_{FSM} @tp = 5 μs sine	1800	A
V_F @18 Apk, T_J = 125°C	0.53	V
T_J range	- 55 to 175	°C

Description/Features

The 18TQ Schottky rectifier series has been optimized for low reverse leakage at high temperature. The proprietary barrier technology allows for reliable operation up to 175°C junction temperature. Typical applications are in switching power supplies, converters, free-wheeling diodes, and reverse battery protection.

- 175° C T_J operation
- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance
- Low forward voltage drop
- High frequency operation
- Guard ring for enhanced ruggedness and long term reliability

Case Styles	
18TQ...	18TQ... S
	
TO-220	D^2PAK

Voltage Ratings

	Part number	18TQ035	18TQ040	18TQ045
V_R	Max. DC Reverse Voltage (V)	35	40	45
V_{RWM}	Max. Working Peak Reverse Voltage (V)			

Absolute Maximum Ratings

	Parameters	18TQ	Units	Conditions	
$I_{F(AV)}$	Max. Average Forward Current * See Fig. 5	18	A	50% duty cycle @ T_C = 149° C, rectangular wave form	
I_{FSM}	Max. Peak One Cycle Non-Repetitive Surge Current * See Fig. 7	1800	A	5µs Sine or 3µs Rect. pulse	Following any rated load condition and with rated V_{RRM} applied
		390		10ms Sine or 6ms Rect. pulse	
E_{AS}	Non-Repetitive Avalanche Energy	24	mJ	T_J = 25 °C, I_{AS} = 3.6 Amps, L = 3.7 mH	
I_{AR}	Repetitive Avalanche Current	3.6	A	Current decaying linearly to zero in 1 µsec Frequency limited by T_J max. V_A = 1.5 x V_R typical	

Electrical Specifications

	Parameters	18TQ	Units	Conditions	
V_{FM}	Max. Forward Voltage Drop (1) * See Fig. 1	0.60	V	@ 18A	T_J = 25 °C
		0.72	V	@ 36A	
		0.53	V	@ 18A	T_J = 125 °C
		0.67	V	@ 36A	
I_{RM}	Max. Reverse Leakage Current (1) * See Fig. 2	2.5	mA	T_J = 25 °C	V_R = rated V_R
		25	mA	T_J = 125 °C	
C_T	Max. Junction Capacitance	1400	pF	V_R = 5V_{DC}, (test signal range 100Khz to 1Mhz) 25 °C	
L_S	Typical Series Inductance	8.0	nH	Measured lead to lead 5mm from package body	
dv/dt	Max. Voltage Rate of Change (Rated V_R)	10,000	V/ µs		

(1) Pulse Width < 300µs, Duty Cycle < 2%

Thermal-Mechanical Specifications

	Parameters		18TQ	Units	Conditions
T_J	Max. Junction Temperature Range		-55 to 175	°C	
T_{stg}	Max. Storage Temperature Range		-55 to 175	°C	
R_{thJC}	Max. Thermal Resistance Junction to Case		1.50	°C/W	DC operation * See Fig. 4
R_{thCS}	Typical Thermal Resistance, Case to Heatsink		0.50	°C/W	Mounting surface, smooth and greased
wt	Approximate Weight		2 (0.07)	g (oz.)	
T	Mounting Torque	Min.	6 (5)	Kg-cm (lbf-in)	
		Max.	12 (10)		

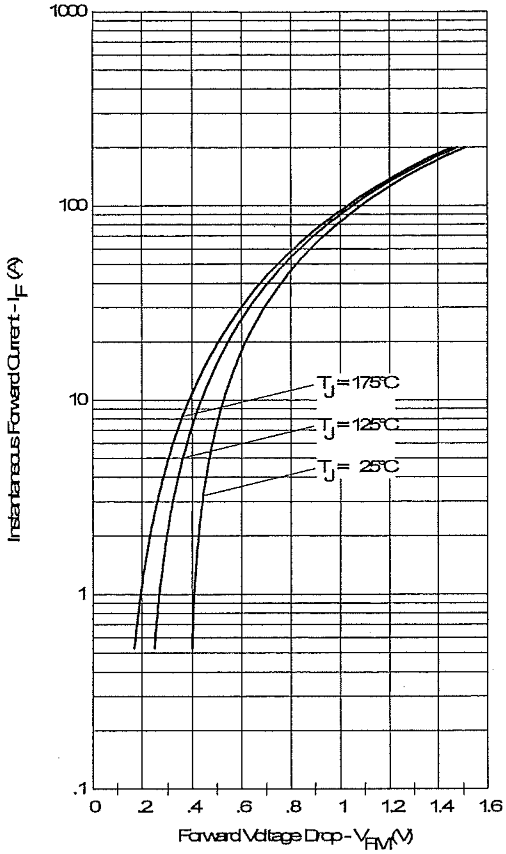


Fig. 1 - Maximum Forward Voltage Drop Characteristics

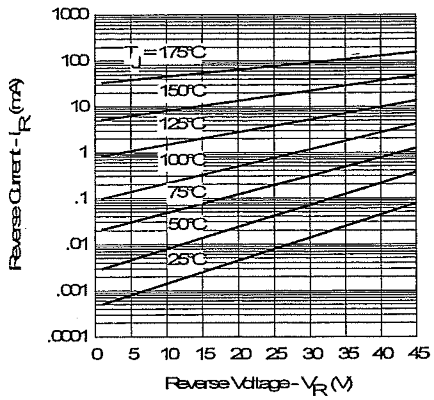


Fig. 2 - Typical Values of Reverse Current Vs. Reverse Voltage

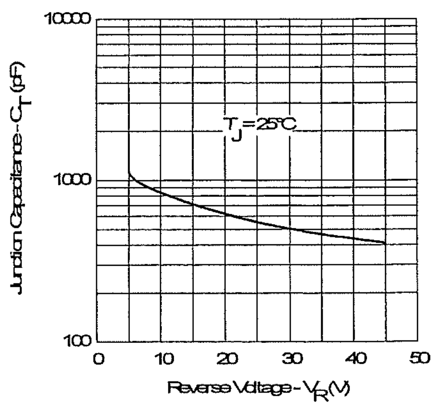


Fig. 3 - Typical Junction Capacitance Vs. Reverse Voltage

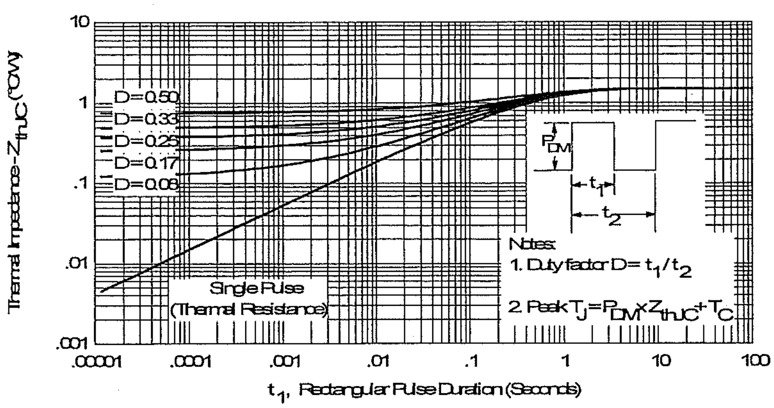


Fig. 4 - Maximum Thermal Impedance Z_{thJC} Characteristics

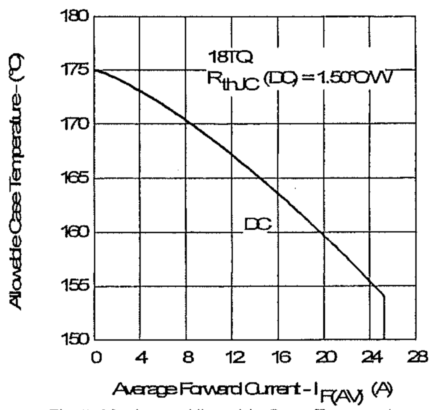


Fig. 5 - Maximum Allowable Case Temperature Vs. Average Forward Current

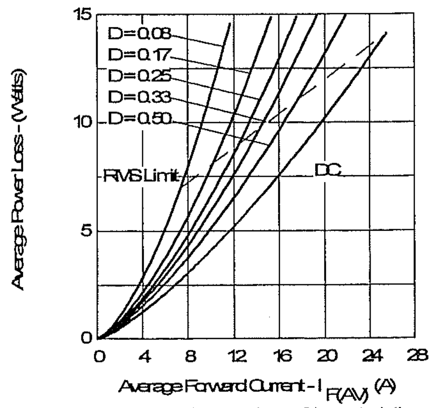


Fig. 6 - Forward Power Loss Characteristics

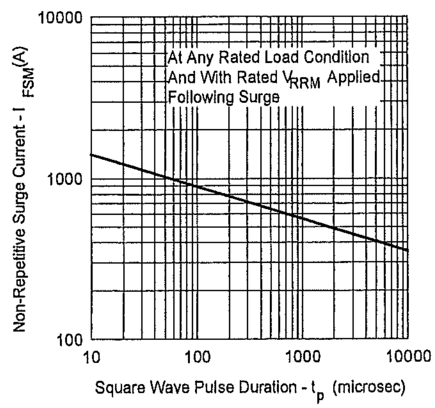


Fig. 7 - Maximum Non-Repetitive Surge Current

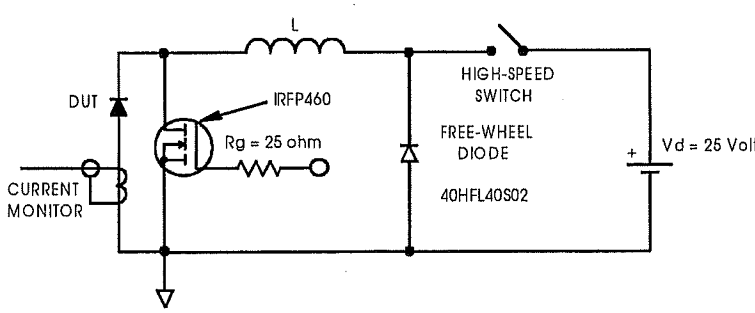


Fig. 8 - Unclamped Inductive Test Circuit

PD-2.297 rev. A 12/97

International
IOR Rectifier

30CPQ035
30CPQ040
30CPQ045

SCHOTTKY RECTIFIER

30 Amp

Major Ratings and Characteristics

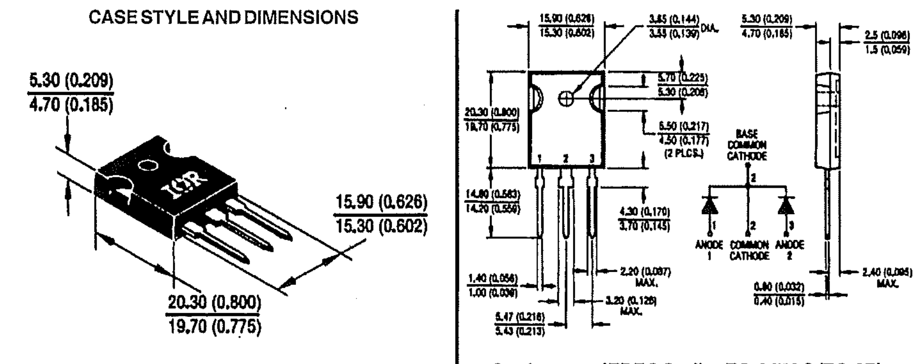
Characteristics	30CPQ...	Units
$I_{F(AV)}$ Rectangular waveform	30	A
V_{RRM}	35/40/45	V
I_{FSM} @ tp = 5 μs sine	1020	A
V_F @ 15 Apk, T_J = 125°C (per leg)	0.50	V
T_J	-55 to 150	°C

Description/Features

The 30CPQ... center tap Schottky rectifier has been optimized for very low forward voltage drop, with moderate leakage. The proprietary barrier technology allows for reliable operation up to 150° C junction temperature. Typical applications are in switching power supplies, converters, free-wheeling diodes, and reverse battery protection.

- 150° C T_J operation
- Center tap TO-247 package
- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance
- Very low forward voltage drop
- High frequency operation
- Guard ring for enhanced ruggedness and long term reliability

CASE STYLE AND DIMENSIONS



Conforms to JEDEC Outline TO-247AC (TO-3P)
Dimensions in millimeters and inches

Voltage Ratings

	Part number	30CPQ035	30CPQ040	30CPQ045
V_R	Max. DC Reverse Voltage (V)	35	40	45
V_{RWM}	Max. Working Peak Reverse Voltage (V)			

Absolute Maximum Ratings

	Parameters	30CPQ...	Units	Conditions	
$I_{F(AV)}$	Max. Average Forward Current * See Fig. 5	30	A	50% duty cycle @ T_C = 124°C, rectangular waveform	
I_{FSM}	Max. Peak One Cycle Non-Repetitive Surge Current (Per Leg) * See Fig. 7	1020	A	5µs Sine or 3µs Rect. pulse	Following any rated load condition and with rated V_{RRM} applied
		265		10ms Sine or 6ms Rect. pulse	
E_{AS}	Non-Repetitive Avalanche Energy (Per Leg)	20	mJ	T_J = 25°C, I_{AS} = 3 Amps, L = 4.4 mH	
I_{AR}	Repetitive Avalanche Current (Per Leg)	3	A	Current decaying linearly to zero in 1 µsec Frequency limited by T_J max. V_A = 1.5 x V_R typical	

Electrical Specifications

	Parameters	30CPQ...	Units	Conditions	
V_{FM}	Max. Forward Voltage Drop (Per Leg) * See Fig. 1 (1)	0.54	V	@ 15A	T_J = 25 °C
		0.68	V	@ 30A	
		0.50	V	@ 15A	T_J = 125 °C
		0.64	V	@ 30A	
I_{RM}	Max. Reverse Leakage Current (Per Leg) * See Fig. 2 (1)	1.75	mA	T_J = 25 °C	V_R = rated V_R
		70	mA	T_J = 125 °C	
C_T	Max. Junction Capacitance (Per Leg)	900	pF	V_R = 5V_{DC}, (test signal range 100Khz to 1Mhz) 25°C	
L_S	Typical Series Inductance (Per Leg)	7.5	nH	Measured lead to lead 5mm from package body	
dv/dt	Max. Voltage Rate of Change (Rated V_R)	10,000	V/ µs		

(1) Pulse Width < 300µs, Duty Cycle <2%

Thermal-Mechanical Specifications

	Parameters		30CPQ...	Units	Conditions
T_J	Max. Junction Temperature Range		-55 to 150	°C	
T_{stg}	Max. Storage Temperature Range		-55 to 150	°C	
R_{thJC}	Max. Thermal Resistance Junction to Case (Per Leg)		2.20	°C/W	DC operation * See Fig. 4
R_{thJC}	Max. Thermal Resistance Junction to Case (Per Package)		1.10	°C/W	DC operation
R_{thCS}	Typical Thermal Resistance, Case to Heatsink		0.24	°C/W	Mounting surface, smooth and greased
wt	Approximate Weight		6(0.21)	g(oz.)	
T	Mounting Torque	Min.	6(5)	Kg-cm (lbf-in)	Non-lubricated threads
		Max.	12(10)		
	Case Style		TO-247AC(TO-3P)		JEDEC

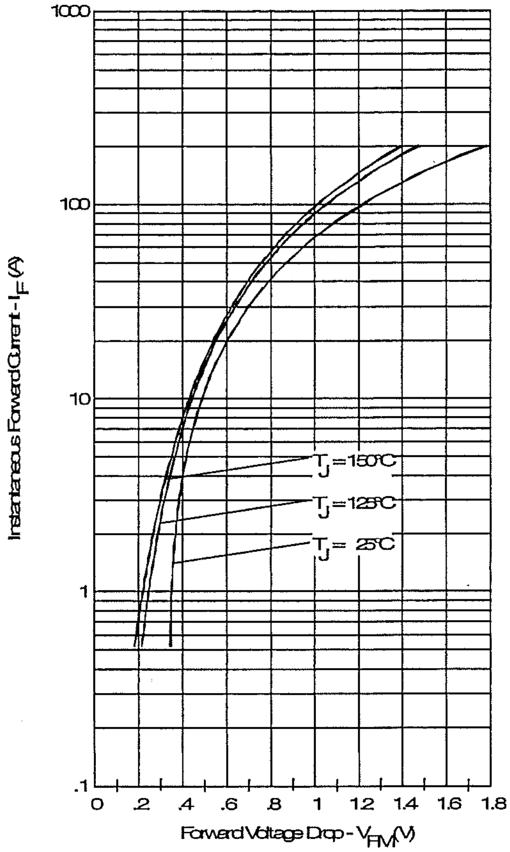


Fig. 1 - Max. Forward Voltage Drop Characteristics (Per Leg)

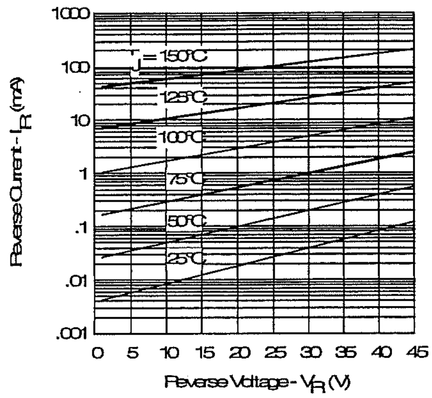


Fig. 2 - Typical Values Of Reverse Current Vs. Reverse Voltage (Per Leg)

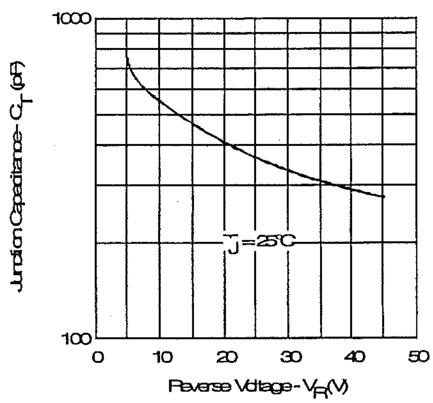


Fig. 3 - Typical Junction Capacitance Vs. Reverse Voltage (Per Leg)

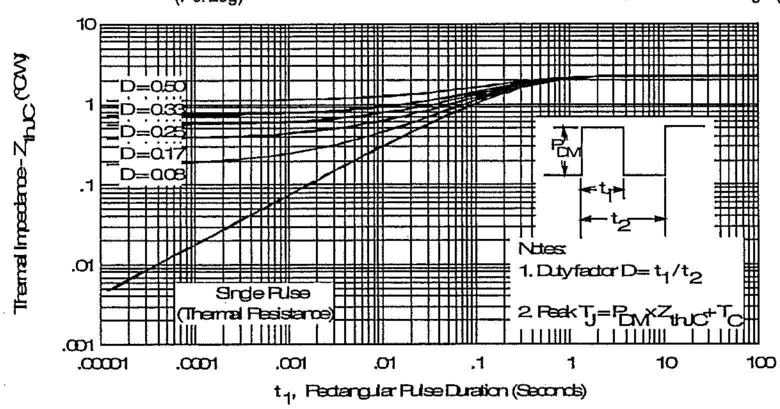


Fig. 4 - Max. Thermal Impedance Z_{thJC} Characteristics (Per Leg)

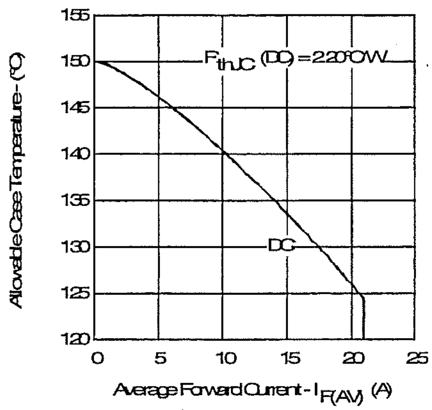


Fig. 5 - Max. Allowable Case Temperature Vs. Average Forward Current (Per Leg)

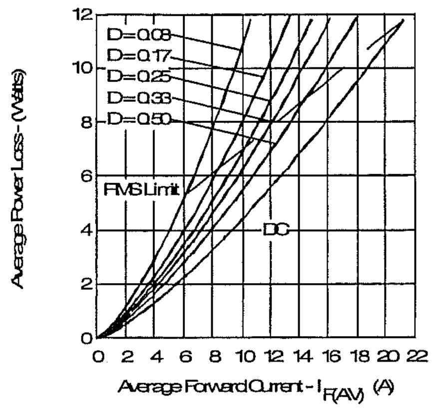


Fig. 6 - Forward Power Loss Characteristics (Per Leg)

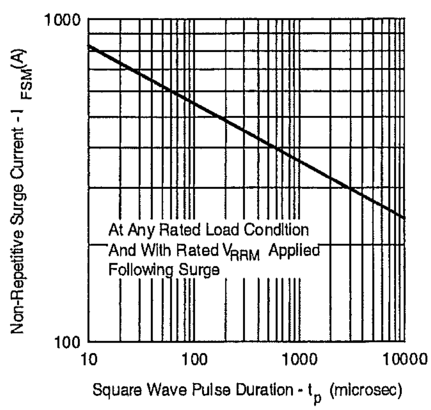


Fig. 7 - Max. Non-Repetitive Surge Current (Per Leg)

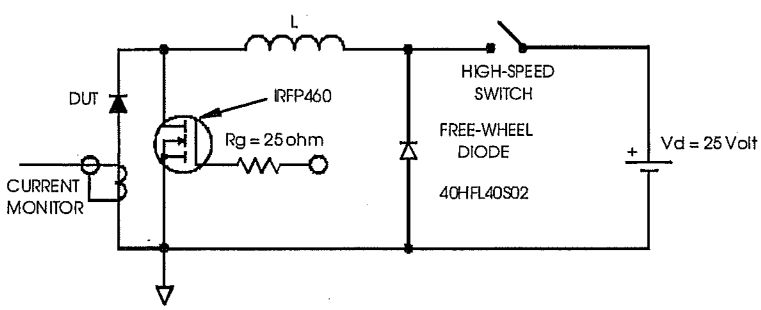


Fig. 8 - Unclamped Inductive Test Circuit