

Advance Data

# High Power Sonic FRD

## Type E4000FD45E

**Absolute Maximum Ratings**

	VOLTAGE RATINGS	MAXIMUM LIMITS	UNITS
$V_{RRM}$	Repetitive peak reverse voltage, (note 1)	4500	V
$V_{RSM}$	Non-repetitive peak reverse voltage, (note 1)	4600	V
$V_{R(d.c.)}$	Maximum reverse d.c. voltage (note 1)	2800	V

	OTHER RATINGS (note 6)	MAXIMUM LIMITS	UNITS
$I_{F(AV)M}$	Mean forward current, $T_{sink}=55^{\circ}C$ , (note 2)	4210	A
$I_{F(AV)M}$	Mean forward current. $T_{sink}=100^{\circ}C$ , (note 2)	2610	A
$I_{F(AV)M}$	Mean forward current. $T_{sink}=100^{\circ}C$ , (note 3)	1730	A
$I_{F(AV)M}$	Mean forward current. $T_{sink}=100^{\circ}C$ , (note 4)	1485	A
$I_{F(RMS)}$	Nominal RMS forward current, $T_{sink}=25^{\circ}C$ , (note 2)	7940	A
$I_{F(d.c.)}$	D.C. forward current, $T_{sink}=25^{\circ}C$ , (note 5)	7120	A
$I_{FSM}$	Peak non-repetitive surge $t_p=10ms$ , $V_{RM}=60\%V_{RRM}$ , (note 6)	54.8	kA
$I_{FSM2}$	Peak non-repetitive surge $t_p=10ms$ , $V_{RM}\leq 10V$ , (note 6)	60.3	kA
$I^2t$	$I^2t$ capacity for fusing $t_p=10ms$ , $V_{RM}=60\%V_{RRM}$ , (note 6)	$15\times 10^6$	$A^2s$
$I^2t$	$I^2t$ capacity for fusing $t_p=10ms$ , $V_{RM}\leq 10V$ , (note 6)	$18.2\times 10^6$	$A^2s$
$P_{rr}$	Maximum non-repetitive peak reverse recovery power, (note 8)	16.3	MW
$T_{j op}$	Operating temperature range	-40 to +140	$^{\circ}C$
$T_{stg}$	Storage temperature range	-40 to +150	$^{\circ}C$

Notes:-

- De-rating factor of 0.13% per  $^{\circ}C$  is applicable for  $T_j$  below  $25^{\circ}C$ .
- Double side cooled, single phase; 50Hz,  $180^{\circ}$  half-sinewave.
- Anode side cooled, single phase; 50Hz,  $180^{\circ}$  half-sinewave.
- Cathode side cooled, single phase; 50Hz,  $180^{\circ}$  half-sinewave.
- Double side cooled.
- Half-sinewave,  $140^{\circ}C$   $T_j$  initial.
- Current ( $I_F$ ) ratings have been calculated using  $V_{T0}$  and  $r_T$  (see page 2)
- $T_j=T_{j op}$ ,  $I_F=4000A$ ,  $di/dt=5000A/\mu s$   $V_r=2800V$  and  $L_s=120nH$ . Test circuit and sample waveforms are shown in diagram 1. IGBT type T2960BB45E used as switch.

**Characteristics**

	PARAMETER	MIN.	TYP.	MAX.	TEST CONDITIONS (Note 1)	UNITS
$V_{FM}$	Maximum peak forward voltage	-	3.30	3.50	$I_{FM}=4000A$	V
		-	-	5.04	$I_{FM}=8000A$	
$V_{T0}$	Threshold voltage	-	-	2.117	Current range 4210A -12630 A (Note 2)	V
$r_T$	Slope resistance	-	-	0.351		m $\Omega$
$V_{T01}$	Threshold voltage	-	-	2.08	Current range 4000A - 12000A	V
$r_{T1}$	Slope resistance	-	-	0.356		m $\Omega$
$V_{FRM}$	Maximum forward recovery voltage	-	-	190	$di/dt = 5000A/\mu s$	V
		-	-	90	$di/dt = 5000A/\mu s, T_j=25^\circ C$	
$I_{RRM}$	Peak reverse current	-	-	120	Rated $V_{RRM}$	mA
		-	-	2	Rated $V_{RRM}, T_j=25^\circ C$	
$Q_{rr}$	Recovered charge	-	5750	6350	$I_{FM}=4000A, t_p=1ms, di/dt=5000A/\mu s, V_r=2800V, 50\% \text{ Chord (note 3)}$	$\mu C$
$Q_{ra}$	Recovered charge, 50% Chord	-	2740	-		$\mu C$
$I_{rm}$	Reverse recovery current	-	3650	4000		A
$t_{rr}$	Reverse recovery time, 50% Chord	-	1.5	-		$\mu s$
$E_{rr}$	Reverse recovery energy loss	-	11.2	12.5		J
$R_{thJK}$	Thermal resistance, junction to heatsink	-	-	0.0035	Double side cooled	K/W
		-	-	0.0064	Anode side cooled	K/W
		-	-	0.0079	Cathode side cooled	K/W
F	Mounting force	75	-	85	(Note 4)	kN
$W_t$	Weight	-	2.25	-		kg

**Notes:-**

- 1) Unless otherwise indicated  $T_j=140^\circ C$ .
- 2)  $V_{T0}$  and  $r_T$  were used to calculate the current ratings illustrated on page one.
- 3) Figures 3-7 were compiled using these conditions. Test circuit and sample waveform are shown in diagram 1.
- 4) For clamp forces outside these limits, please consult factory.

**Additional information on Ratings and Characteristics**

1.0 De-rating Factor

A blocking voltage de-rating factor of 0.13% per °C is applicable to this device for T<sub>j</sub> below 25°C.

2.0 ABCD Constants

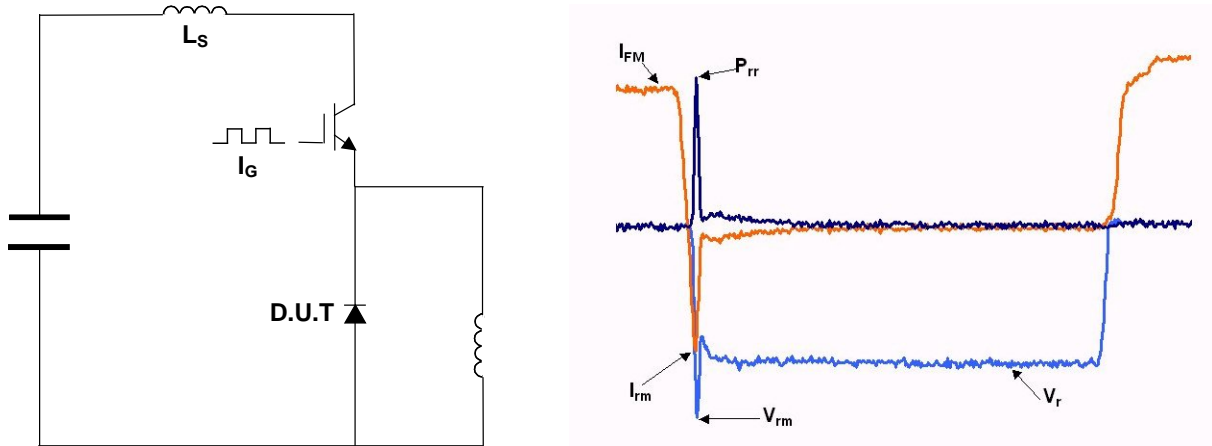
These constants (applicable only over current range of V<sub>F</sub> characteristic in Figure 1) are the coefficients of the expression for the forward characteristic given below:

$$V_F = A + B \cdot \ln(I_F) + C \cdot I_F + D \cdot \sqrt{I_F}$$

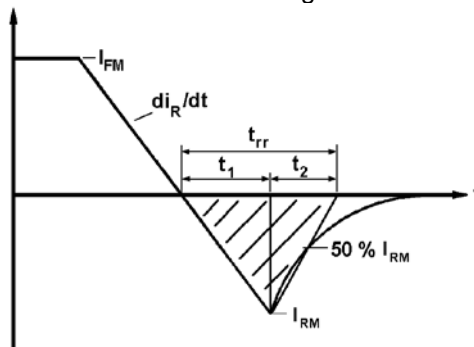
where I<sub>F</sub> = instantaneous forward current.

3.0 Reverse recovery ratings

Diagram 1 – Reverse Recovery test circuit and sample waveform



(i) Q<sub>ra</sub> is based on 50% I<sub>rm</sub> chord as shown in Figure below.



(ii) Q<sub>rr</sub> is based on a 150µs integration time.

i.e.

$$Q_{rr} = \int_0^{150\mu s} i_{rr} \cdot dt$$

(iii)

$$K \text{ Factor} = \frac{t_1}{t_2}$$

#### 4.0 Reverse Recovery Loss

The following procedure is recommended for use where it is necessary to include reverse recovery loss.

From waveforms of recovery current obtained from a high frequency shunt (see Note 1) and reverse voltage present during recovery, an instantaneous reverse recovery loss waveform must be constructed. Let the area under this waveform be E joules per pulse. A new sink temperature can then be evaluated from:

$$T_{SINK} = T_{J(MAX)} - E \cdot [k + f \cdot R_{th(J-Hs)}]$$

Where k = 0.2314 (°C/W)/s

E = Area under reverse loss waveform per pulse in joules (W.s.)

f = Rated frequency in Hz at the original sink temperature.

R<sub>th(J-Hs)</sub> = d.c. thermal resistance (°C/W)

The total dissipation is now given by:

$$W_{(tot)} = W_{(original)} + E \cdot f$$

##### NOTE 1 - Reverse Recovery Loss by Measurement

This device has a low reverse recovered charge and peak reverse recovery current. When measuring the charge, care must be taken to ensure that:

(a) AC coupled devices such as current transformers are not affected by prior passage of high amplitude forward current.

(b) A suitable, polarised, clipping circuit must be connected to the input of the measuring oscilloscope to avoid overloading the internal amplifiers by the relatively high amplitude forward current signal.

(c) Measurement of reverse recovery waveform should be carried out with an appropriate critically damped snubber, connected across diode anode to cathode. The formula used for the calculation of this snubber is shown below:

$$R^2 = 4 \cdot \frac{V_r}{C_s \cdot di/dt}$$

Where: V<sub>r</sub> = Commutating source voltage

C<sub>s</sub> = Snubber capacitance

R = Snubber resistance

#### 5.0 Computer Modelling Parameters

##### 5.1 Device Dissipation Calculations

$$I_{AV} = \frac{-V_{T0} + \sqrt{V_{T0}^2 + 4 \cdot ff^2 \cdot r_T \cdot W_{AV}}}{2 \cdot ff^2 \cdot r_T}$$

Where V<sub>T0</sub> = 2.117V, r<sub>T</sub> = 0.351mΩ

$ff$  = form factor (normally unity for fast diode applications)

$$W_{AV} = \frac{\Delta T}{R_{th}}$$

$$\Delta T = T_{j(MAX)} - T_K$$

## 5.2 Calculation of $V_F$ using ABCD Coefficients

The forward characteristic  $I_F$  Vs  $V_F$ , on page 6 is represented in two ways;

- (i) the well established  $V_{T0}$  and  $r_T$  tangent used for rating purposes and
- (ii) a set of constants A, B, C, and D forming the coefficients of the representative equation for  $V_F$  in terms of  $I_F$  given below:

$$V_F = A + B \cdot \ln(I_F) + C \cdot I_F + D \cdot \sqrt{I_F}$$

The constants, derived by curve fitting software, are given in this report for both hot and cold characteristics. The resulting values for  $V_F$  agree with the true device characteristic over a current range, which is limited to that plotted.

	25°C Coefficients	140°C Coefficients
A	0.5072773	0.3876015
B	0.09488308	0.04303578
C	-0.04691904x10 <sup>-3</sup>	0.1538236x10 <sup>-3</sup>
D	0.03609312	0.03389388

**Curves**

Figure 1 – Forward characteristics of limit device

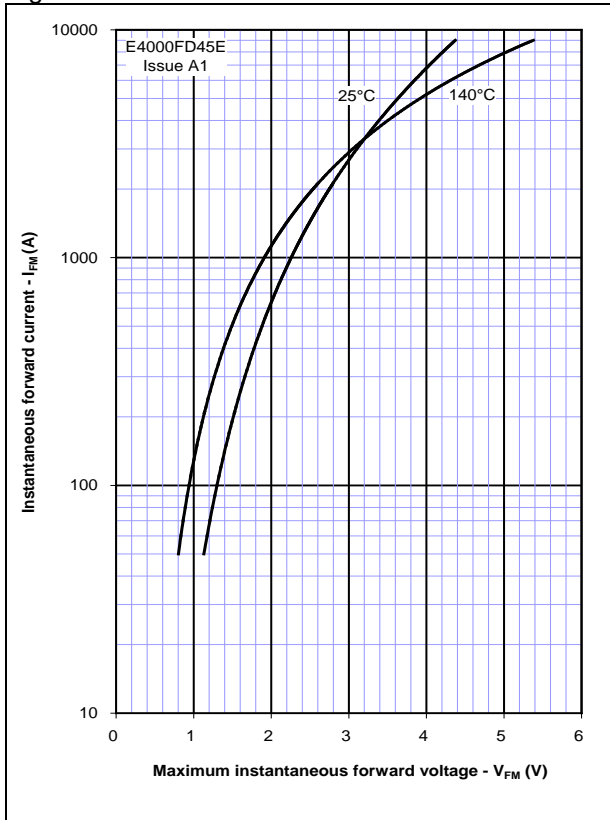


Figure 2 – Maximum forward recovery voltage

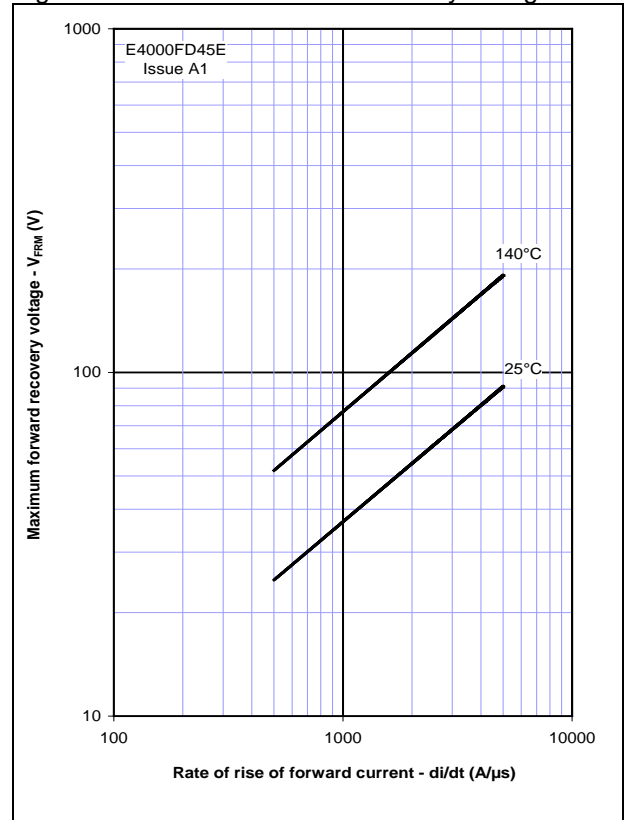


Figure 3 – Maximum recovered charge,  $Q_{rr}$

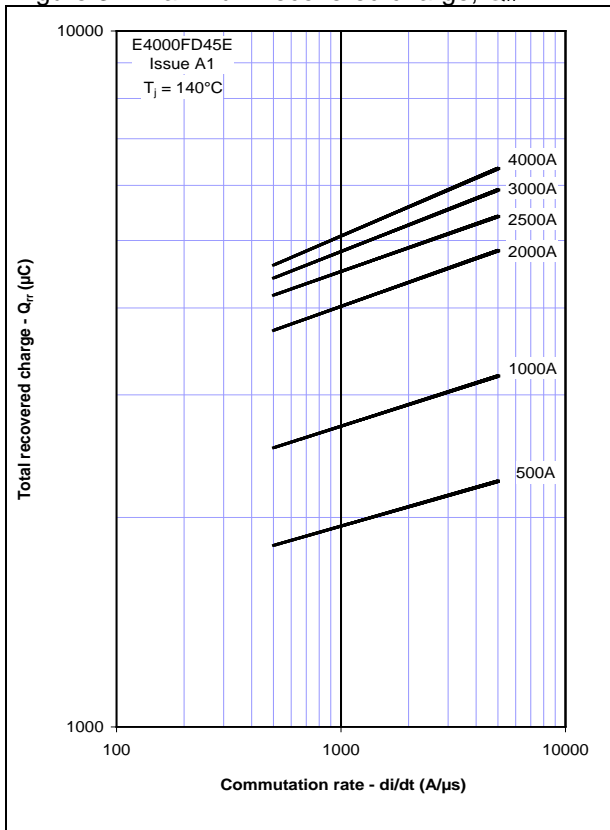


Figure 4 – Maximum recovery charge,  $Q_{ra}$  (50% chord)

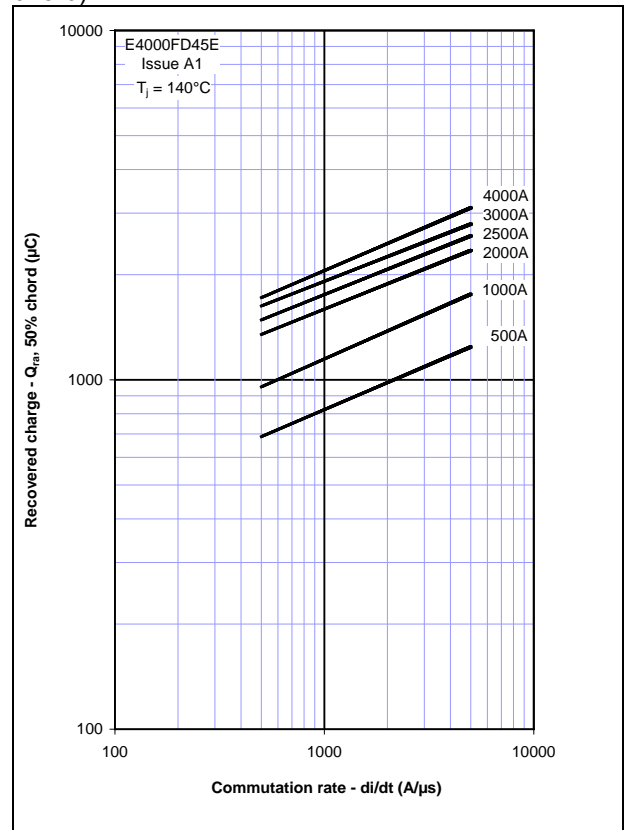


Figure 5 - Maximum reverse current,  $I_{rm}$

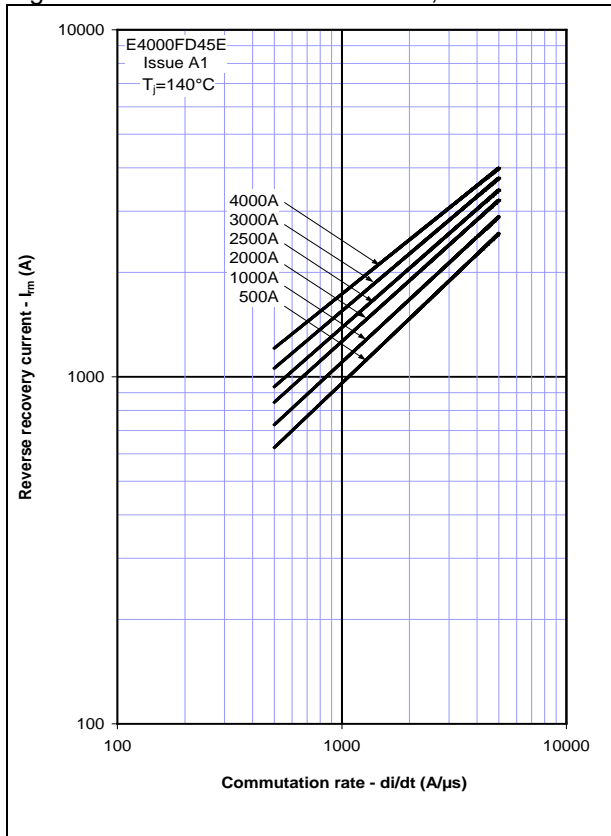


Figure 6 - Maximum recovery time,  $t_{rr}$  (50% chord)

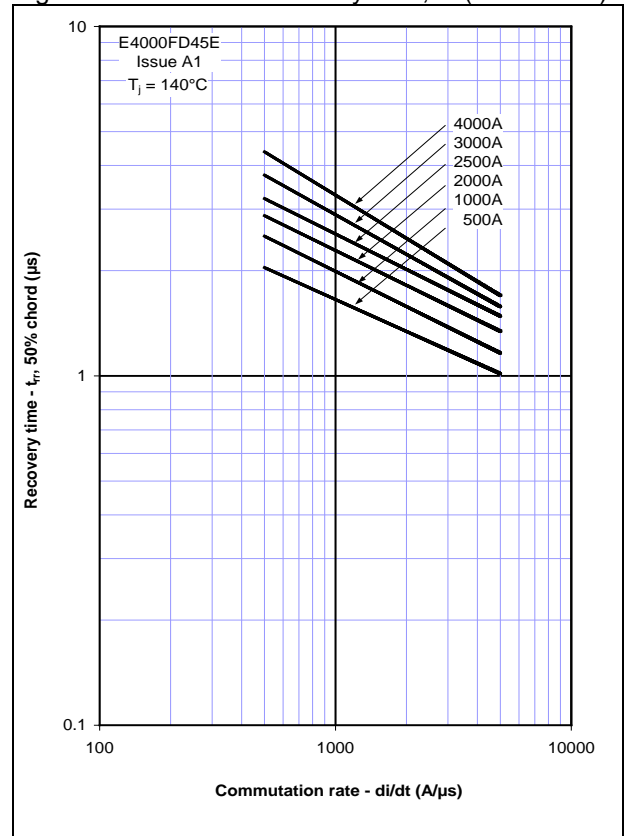


Figure 7 - Typical reverse recovery energy per pulse

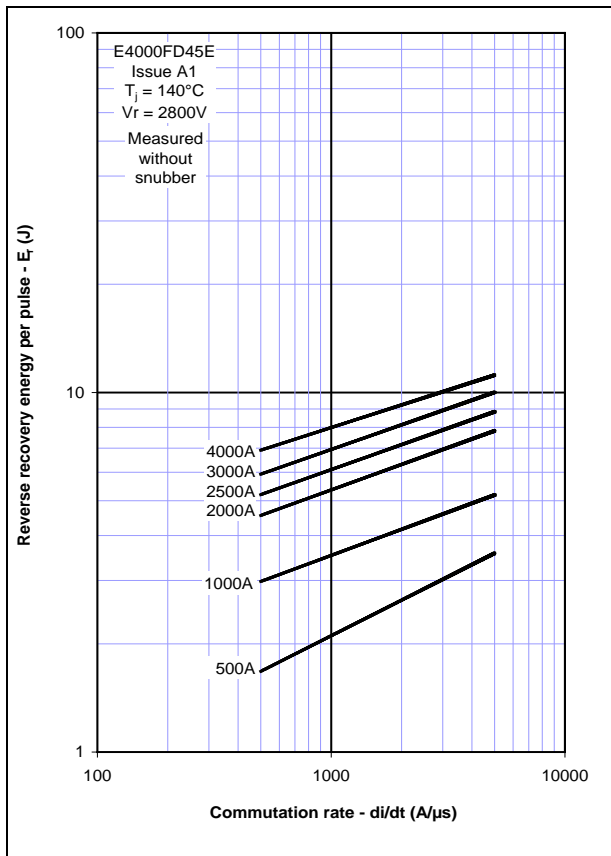


Figure 8 - Sine wave energy per pulse

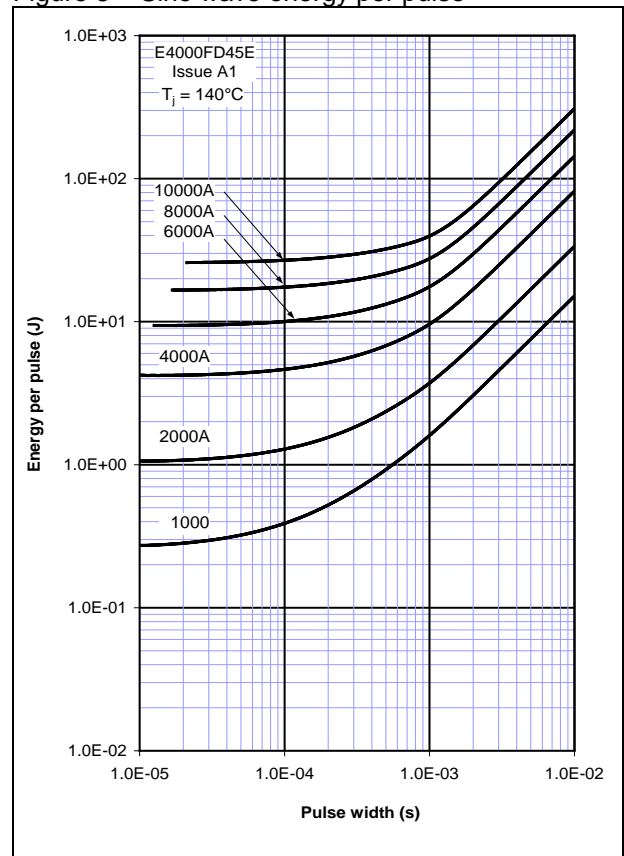


Figure 9 - Sine wave frequency vs. pulse width

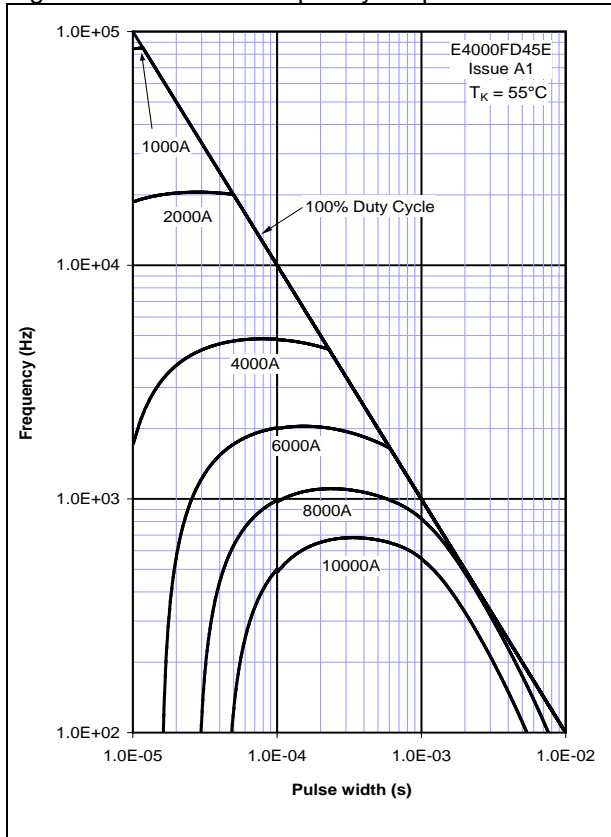


Figure 10 – Sine wave frequency vs. pulse width

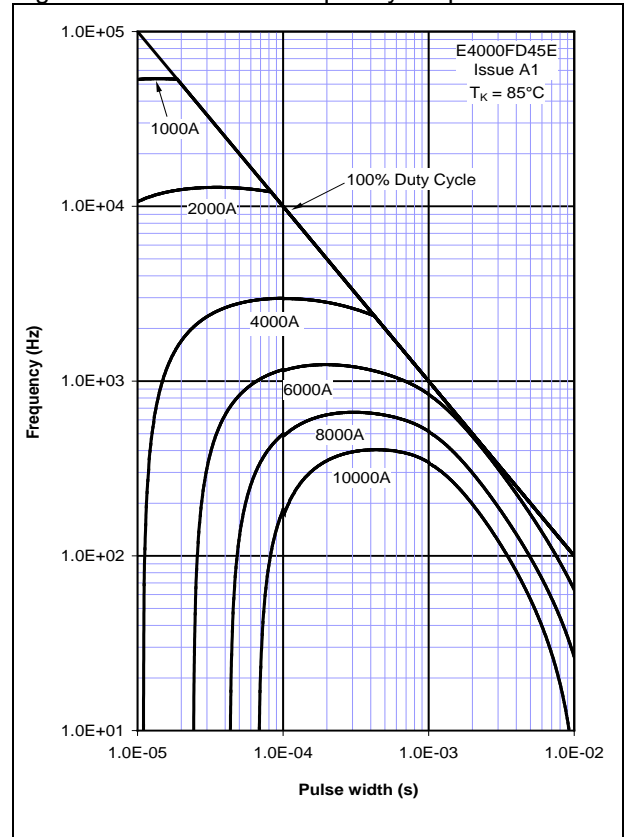


Figure 11 - Square wave energy per pulse

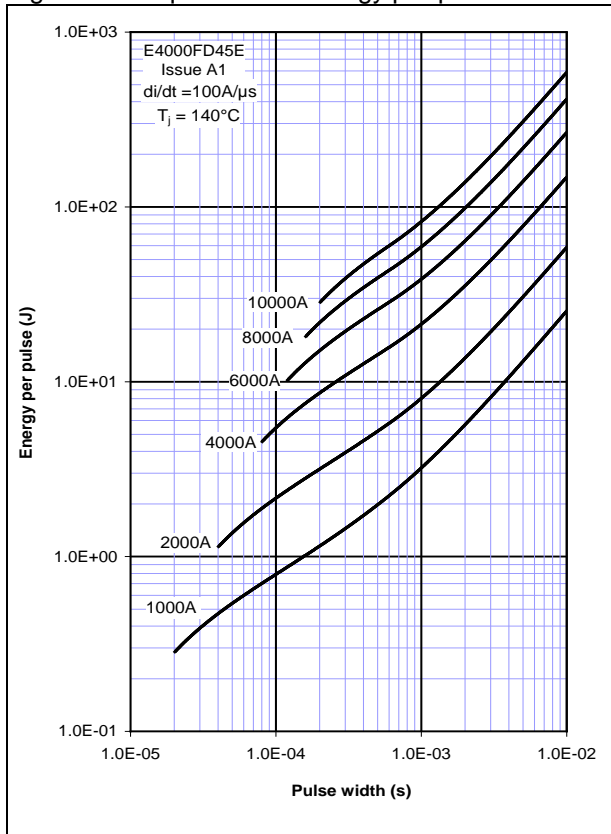


Figure 12 – Square wave energy per pulse

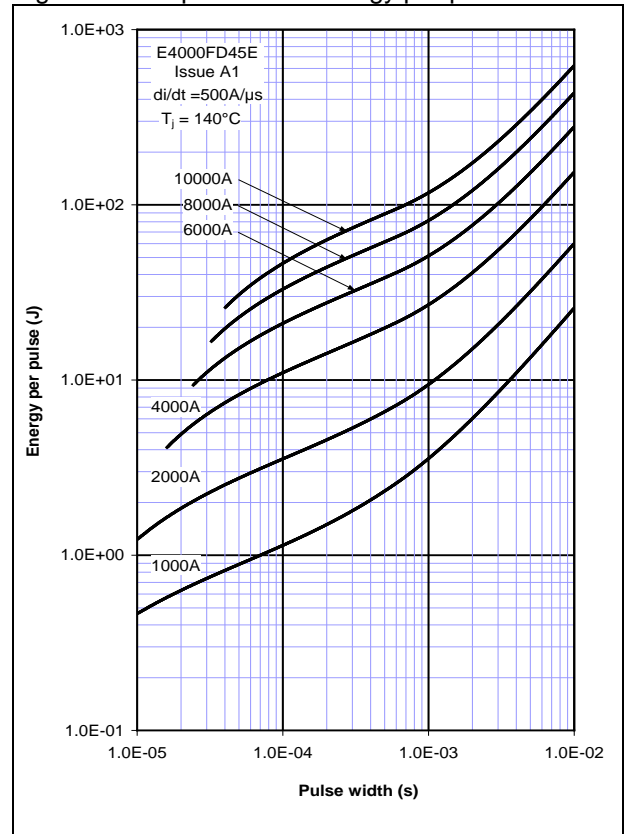




Figure 13 - Square wave frequency vs pulse width

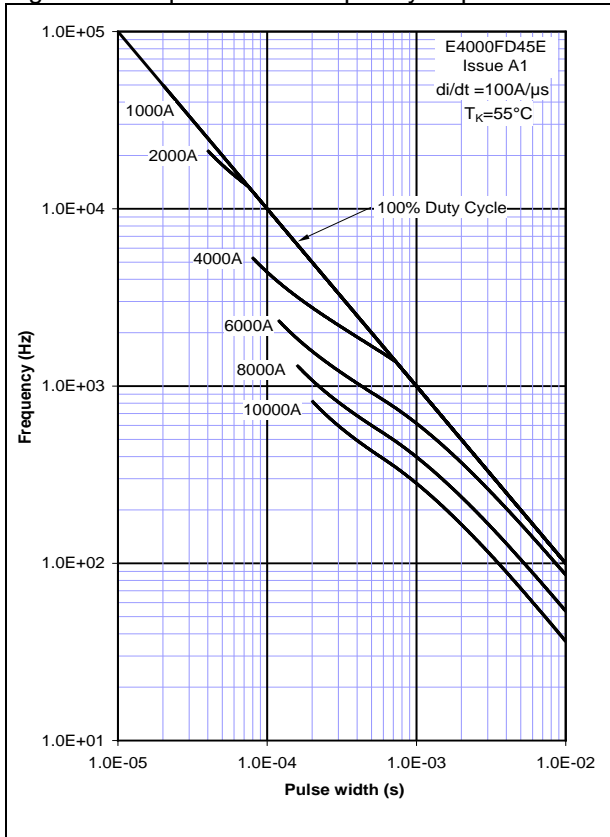


Figure 14 - Square wave frequency vs pulse width

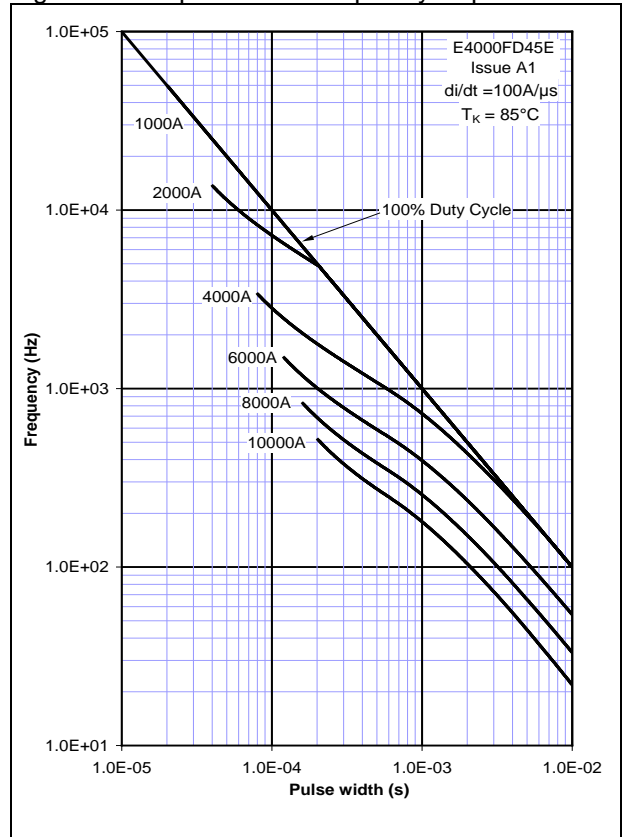


Figure 15 - Square wave frequency vs pulse width

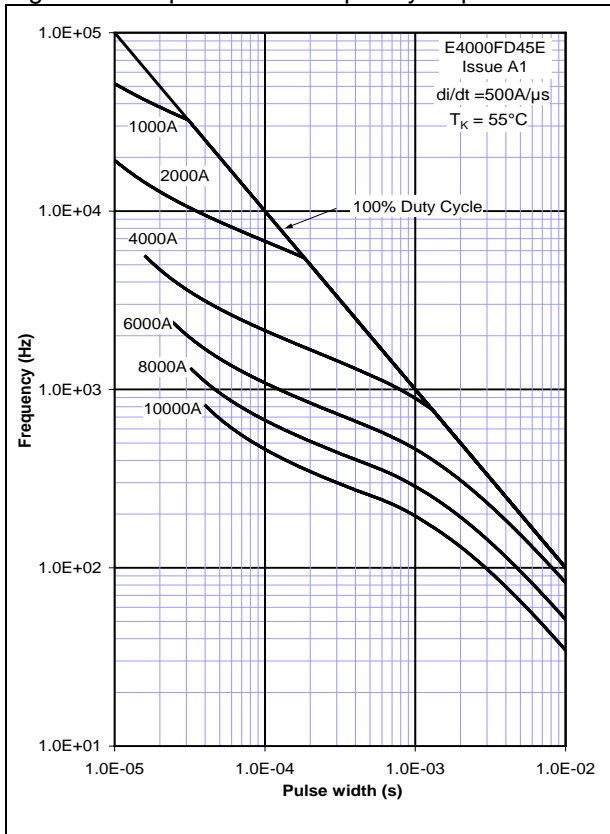


Figure 16 - Square wave frequency vs pulse width

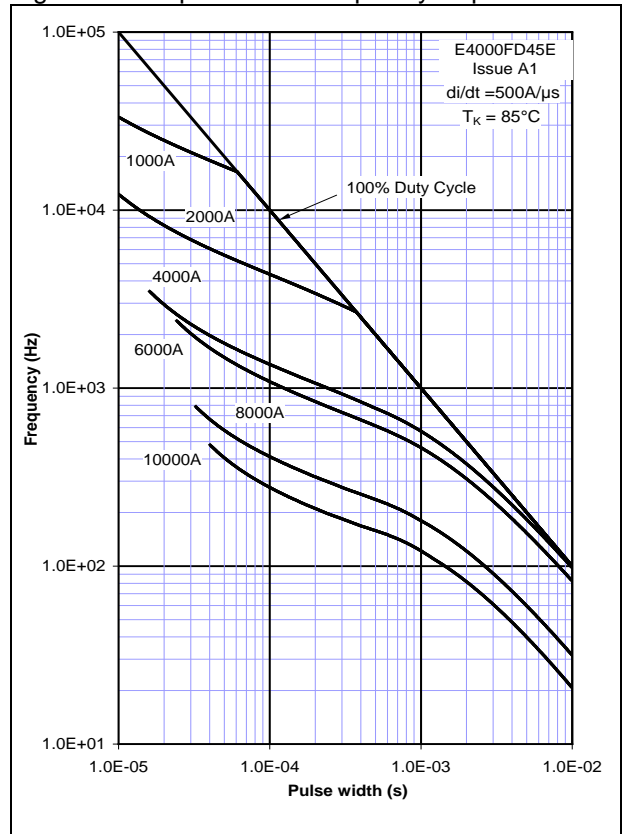


Figure 17 – Safe operating area

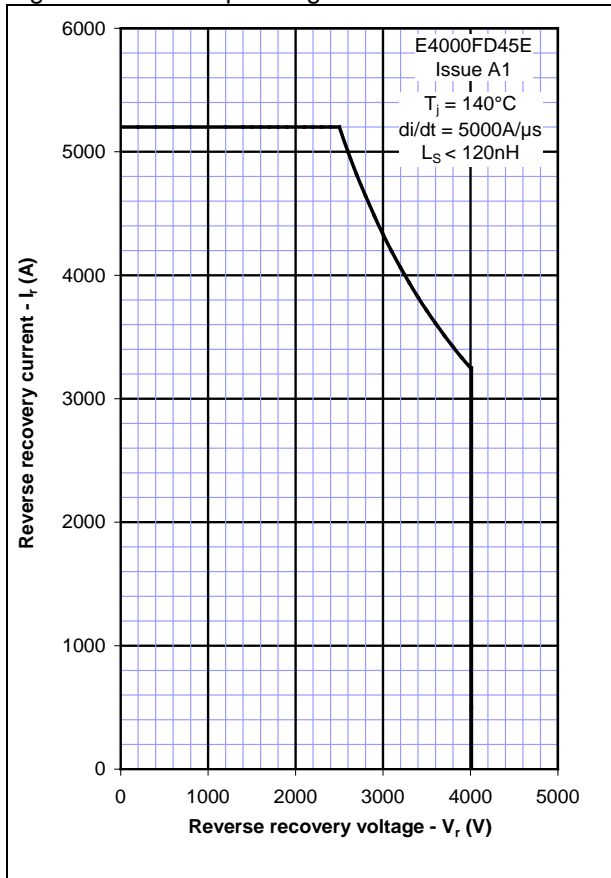


Figure 18 – Transient thermal impedance

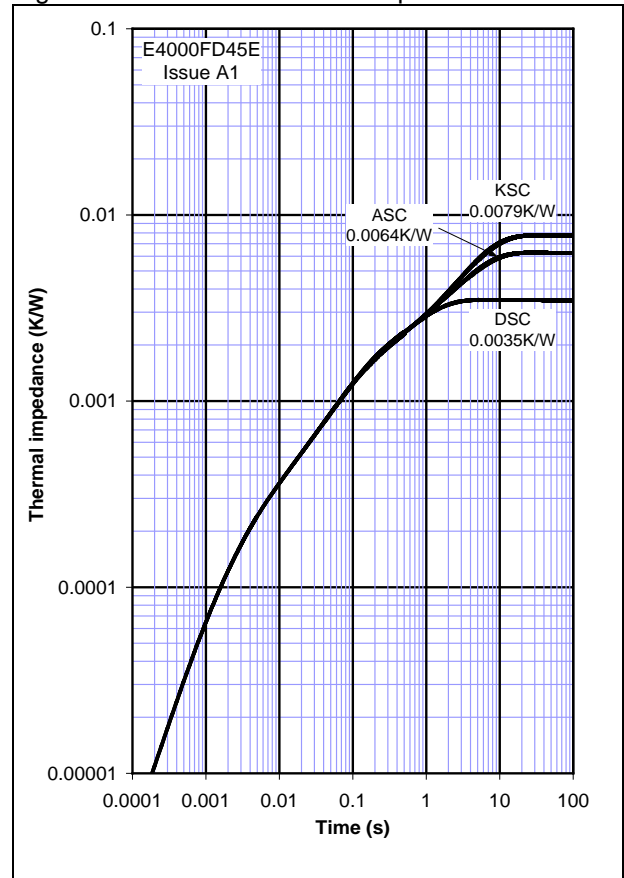
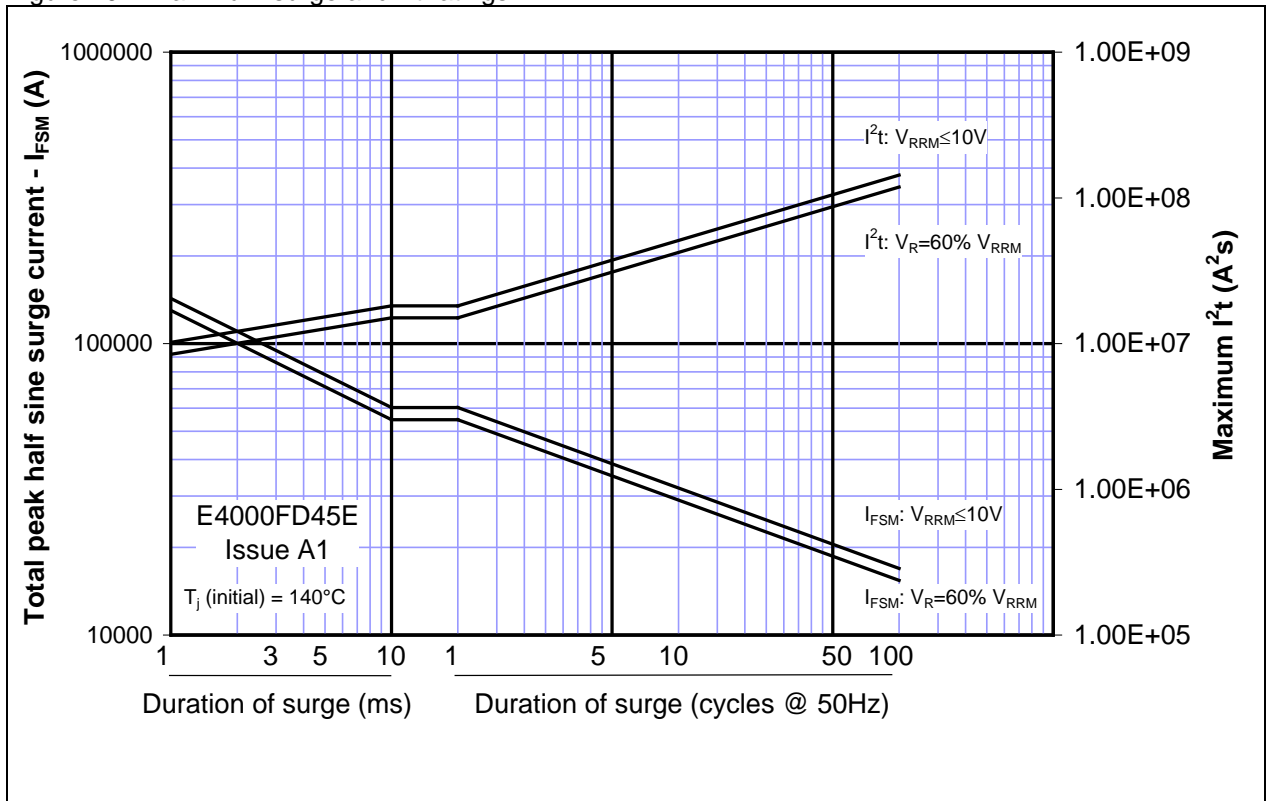
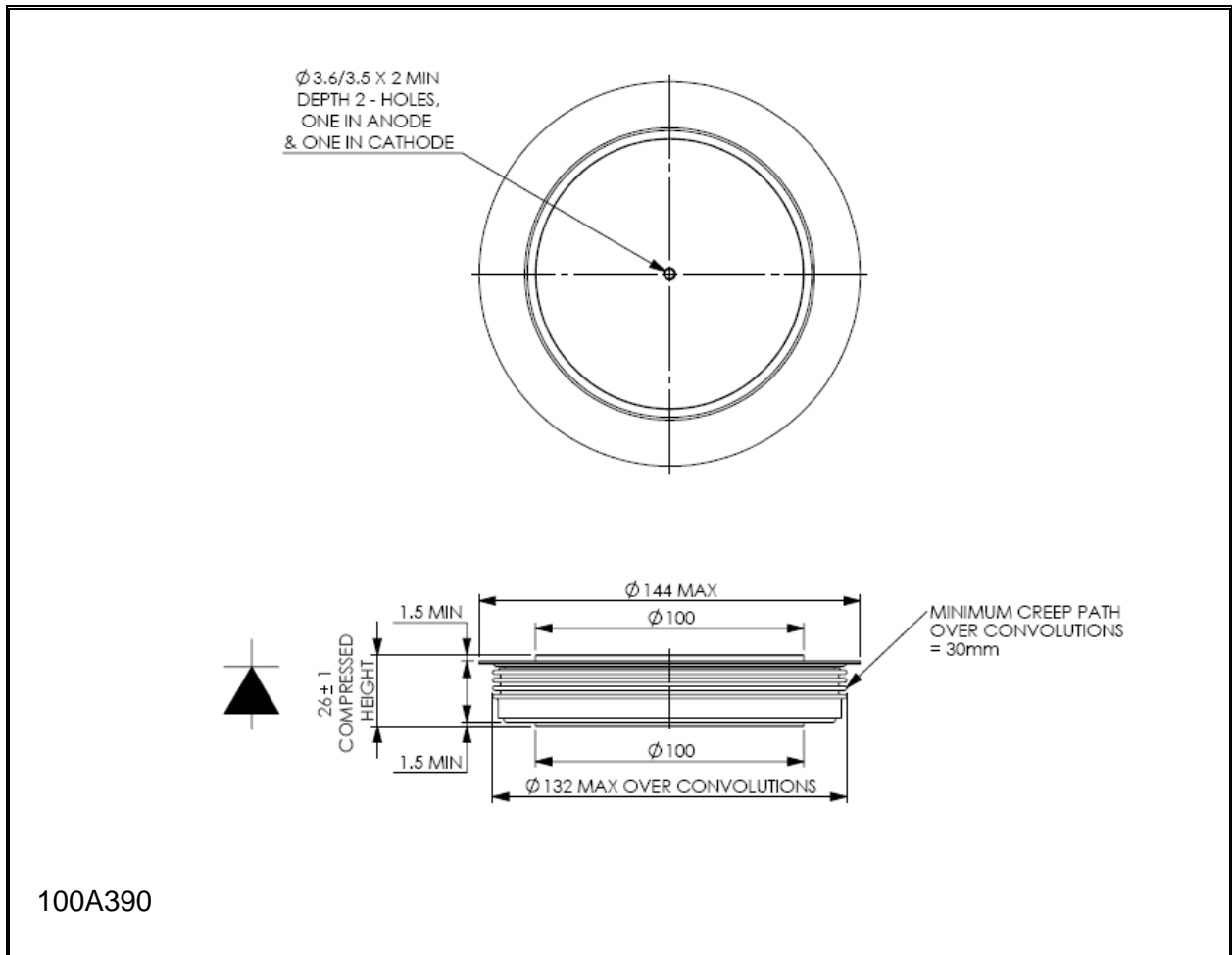



Figure 19 – Maximum surge and  $I^2t$  ratings



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100A390

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Order code: E4000FD45E – 4500V V <sub>RRM</sub> , 26mm clamp height capsule.			
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