

Provisional Data

## Medium Voltage Thyristor

### Types K3503F#450 to K3503F#520

(Development Type No. KX094FG450-520)

#### Absolute Maximum Ratings

	VOLTAGE RATINGS	MAXIMUM LIMITS	UNITS
$V_{DRM}$	Repetitive peak off-state voltage, (note 1)	4500-5200	V
$V_{DSM}$	Non-repetitive peak off-state voltage, (note 1)	4500-5200	V
$V_{RRM}$	Repetitive peak reverse voltage, (note 1)	4500-5200	V
$V_{RSM}$	Non-repetitive peak reverse voltage, (note 1)	4600-5300	V

	OTHER RATINGS	MAXIMUM LIMITS	UNITS
$I_{T(AV)M}$	Maximum average on-state current, $T_{case}=55^{\circ}C$ , (note 2)	3898	A
$I_{T(AV)M}$	Maximum average on-state current, $T_{sink}=55^{\circ}C$ , (note 2)	3503	A
$I_{T(AV)M}$	Maximum average on-state current, $T_{sink}=85^{\circ}C$ , (note 2)	2416	A
$I_{T(AV)M}$	Maximum average on-state current, $T_{sink}=85^{\circ}C$ , (note 3)	1472	A
$I_{T(RMS)}$	Nominal RMS on-state current, $T_{sink}=25^{\circ}C$ , (note 2)	6898	A
$I_{T(d.c.)}$	D.C. on-state current, $T_{sink}=25^{\circ}C$ , (note 4)	6021	A
$I_{TSM}$	Peak non-repetitive surge $t_p=10ms$ , $V_{rm}=0.6V_{RRM}$ , (note 5)	43.2	kA
$I_{TSM2}$	Peak non-repetitive surge $t_p=10ms$ , $V_{rm}\leq 10V$ , (note 5)	47.5	kA
$I^2t$	$I^2t$ capacity for fusing $t_p=10ms$ , $V_{rm}=0.6V_{RRM}$ , (note 5)	$9.33\times 10^6$	$A^2s$
$I^2t$	$I^2t$ capacity for fusing $t_p=10ms$ , $V_{rm}\leq 10V$ , (note 5)	$11.28\times 10^6$	$A^2s$
$(di/dt)_{cr}$	Critical rate of rise of on-state current (continuous, 50Hz), (Note 6)	250	
	Critical rate of rise of on-state current (repetitive, 60s), (Note 6)	500	A/ $\mu s$
	Critical rate of rise of on-state current (non-repetitive), (Note 6)	1000	
$V_{RGM}$	Peak reverse gate voltage	5	V
$P_{G(AV)}$	Mean forward gate power	5	W
$P_{GM}$	Peak forward gate power	50	W
$T_{j-op}$	Operating temperature range	-40 to +125	$^{\circ}C$
$T_{stg}$	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.
- Single side cooled, single phase; 50Hz,  $180^{\circ}$  half-sinewave.
- Double side cooled.
- Half-sinewave,  $125^{\circ}C$   $T_j$  initial.
- $V_D=67\% V_{DRM}$ ,  $I_{FG}=2A$ ,  $t_r\leq 0.5\mu s$ ,  $T_{case}=125^{\circ}C$ .

**Characteristics**

	PARAMETER	MIN.	TYP.	MAX.	TEST CONDITIONS (Note 1)	UNITS
V <sub>TM</sub>	Maximum peak on-state voltage	-	-	2.35	I <sub>TM</sub> =5000A	V
		-	-	3.44	I <sub>TM</sub> =10500A	V
V <sub>T0</sub>	Threshold voltage	-	-	1.375		V
r <sub>T</sub>	Slope resistance	-	-	0.196		mΩ
(dv/dt) <sub>cr</sub>	Critical rate of rise of off-state voltage	1000	-	-	V <sub>D</sub> =80% V <sub>DRM</sub> , linear ramp, gate o/c	V/μs
I <sub>DRM</sub>	Peak off-state current	-	-	300	Rated V <sub>DRM</sub>	mA
I <sub>RRM</sub>	Peak reverse current	-	-	300	Rated V <sub>RRM</sub>	mA
V <sub>GT</sub>	Gate trigger voltage	-	-	3.0	T <sub>J</sub> =25°C V <sub>D</sub> =10V, I <sub>T</sub> =3A	V
I <sub>GT</sub>	Gate trigger current	-	-	600		mA
V <sub>GD</sub>	Gate non-trigger voltage	-	-	0.25		Rated V <sub>DRM</sub>
I <sub>H</sub>	Holding current	-	-	1000	T <sub>J</sub> =25°C	mA
t <sub>gd</sub>	Gate-controlled turn-on delay time	-	1.5	3.0	V <sub>D</sub> =67% V <sub>DRM</sub> , I <sub>T</sub> =6000A, di/dt=10A/μs, I <sub>FG</sub> =2A, t <sub>r</sub> =0.5μs, T <sub>J</sub> =25°C	μs
t <sub>gt</sub>	Turn-on time	-	3.0	6.0		μs
Q <sub>rr</sub>	Recovered charge	-	8000	-	I <sub>TM</sub> =4000A, t <sub>p</sub> =2000μs, di/dt=10A/μs, V <sub>r</sub> =100V	μC
Q <sub>ra</sub>	Recovered charge, 50% Chord	-	5500	6500		μC
I <sub>rm</sub>	Reverse recovery current	-	230	-		A
t <sub>rr</sub>	Reverse recovery time	-	48	-		μs
t <sub>q</sub>	Turn-off time	-	800	-	I <sub>TM</sub> =4000A, t <sub>p</sub> =2000μs, di/dt=10A/μs, V <sub>r</sub> =100V, V <sub>dr</sub> =80%V <sub>DRM</sub> , dV <sub>dr</sub> /dt=20V/μs	μs
		-	1600	-	I <sub>TM</sub> =4000A, t <sub>p</sub> =2000μs, di/dt=10A/μs, V <sub>r</sub> =100V, V <sub>dr</sub> =80%V <sub>DRM</sub> , dV <sub>dr</sub> /dt=200V/μs	
R <sub>thJC</sub>	Thermal resistance, junction to case	-	-	0.0055	Double side cooled	K/W
R <sub>thJK</sub>	Thermal resistance, junction to heatsink	-	-	0.0065	Double side cooled	K/W
		-	-	0.0130	Single side cooled	K/W
F	Mounting force	81	-	99	Note 2	kN
W <sub>t</sub>	Weight	-	2.8	-		kg

Notes:-

- 1) Unless otherwise indicated T<sub>J</sub>=125°C.
- 2) For other clamp forces consult factory.

**Notes on rupture rated packages.**

This product is available with a non-rupture rated package.  
For additional details on these products, please consult factory.

**Notes on Ratings and Characteristics****1.0 Voltage Grade Table**

Voltage Grade	$V_{DRM}$ $V_{DSM}$ $V_{RRM}$ V	$V_{RSM}$ V	$V_D$ $V_R$ DC V
45	4500	4600	2100
46	4600	4700	2120
48	4800	4900	2160
50	5000	5100	2200
52	5200	5300	2240

**2.0 Extension of Voltage Grades**

This report is applicable to other voltage grades when supply has been agreed by Sales/Production.

**3.0 De-rating Factor**

A blocking voltage de-rating factor of 0.13%/°C is applicable to this device for  $T_j$  below 25°C.

**4.0 Repetitive dv/dt**

Standard dv/dt is 1000V/μs.

**5.0 Frequency Ratings**

The curves illustrated in figures 17 & 18 are for guidance only and are superseded by the maximum ratings shown on page 1. For operation above line frequency, please consult the factory for assistance.

**6.0 Snubber Components**

When selecting snubber components, care must be taken not to use excessively large values of snubber capacitor or excessively small values of snubber resistor. Such excessive component values may lead to device damage due to the large resultant values of snubber discharge current. If required, please consult the factory for assistance.

**7.0 Rate of rise of on-state current**

The maximum un-primed rate of rise of on-state current must not exceed 400A/μs at any time during turn-on on a non-repetitive basis. For repetitive performance, the on-state rate of rise of current must not exceed 200A/μs at any time during turn-on. Note that these values of rate of rise of current apply to the total device current including that from any local snubber network.

**8.0 Square wave frequency ratings**

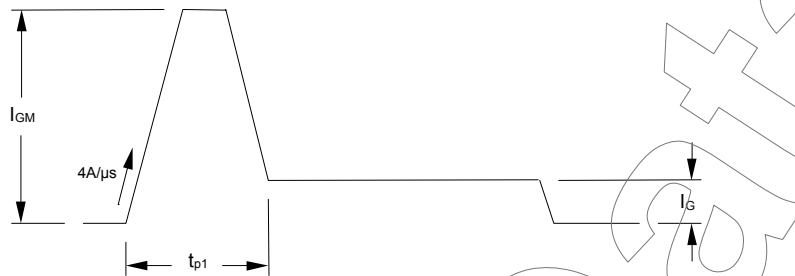
These ratings are given for load component rate of rise of on-state current of 50A/μs.

**9.0 Duty cycle lines**

The 100% duty cycle is represented on the frequency ratings by a straight line. Other duties can be included as parallel to the first.

**10.0 Gate Drive**

The nominal requirement for a typical gate drive is illustrated below. An open circuit voltage of at least 30V is assumed. This gate drive must be applied when using the full di/dt capability of the device.



The magnitude of  $I_{GM}$  should be between five and ten times  $I_{GT}$ , which is shown on page 2. Its duration ( $t_{p1}$ ) should be 20μs or sufficient to allow the anode current to reach ten times  $I_L$ , whichever is greater. Otherwise, an increase in pulse current could be needed to supply the necessary charge to trigger. The 'back-porch' current  $I_G$  should remain flowing for the same duration as the anode current and have a magnitude in the order of 1.5 times  $I_{GT}$ .

**11.0 Computer Modelling Parameters**

11.1 Device Dissipation Calculations

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

and:

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

$$\Delta T = T_{j\max} - T_K$$

Where  $V_{T0}=1.375V$ ,  $r_T=0.196m\Omega$ ,

$R_{th}$  = Supplementary thermal impedance, see table below and

$ff$  = Form factor, see table below.

Supplementary Thermal Impedance

Conduction Angle	30°	60°	90°	120°	180°	270°	d.c.
Square wave Double Side Cooled	0.00717	0.00707	0.00698	0.00689	0.00673	0.00652	0.0065
Square wave Single Side Cooled	0.0137	0.01359	0.01349	0.0134	0.01323	0.01301	0.013
Sine wave Double Side Cooled	0.00709	0.00697	0.00687	0.00678	0.00654		
Sine wave Single Side Cooled	0.0136	0.01348	0.01337	0.01328	0.01303		

Form Factors

Conduction Angle	30°	60°	90°	120°	180°	270°	d.c.
Square wave	3.464	2.449	2	1.732	1.414	1.149	1
Sine wave	3.98	2.778	2.22	1.879	1.57		

### 11.2 Calculating $V_T$ using ABCD Coefficients

The on-state characteristic  $I_T$  vs.  $V_T$ , 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, D, forming the coefficients of the representative equation for  $V_T$  in terms of  $I_T$  given below:

$$V_T = A + B \cdot \ln(I_T) + C \cdot I_T + D \cdot \sqrt{I_T}$$

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

25°C Coefficients		125°C Coefficients	
A	1.2360916	A	1.8312616
B	0.1436956	B	-0.1132993
C	$2.127247 \times 10^{-4}$	C	$1.470865 \times 10^{-4}$
D	-0.02214526	D	$7.046997 \times 10^{-3}$

### 11.3 D.C. Thermal Impedance Calculation

$$r_t = \sum_{p=1}^{p=n} r_p \cdot \left( 1 - e^{-\frac{t}{\tau_p}} \right)$$

Where  $p = 1$  to  $n$ ,  $n$  is the number of terms in the series and:

- $t$  = Duration of heating pulse in seconds.
- $r_t$  = Thermal resistance at time  $t$ .
- $r_p$  = Amplitude of  $p_{th}$  term.
- $\tau_p$  = Time Constant of  $r_{th}$  term.

The coefficients for this device are shown in the tables below:

D.C. Double Side Cooled				
Term	1	2	3	4
$r_p$	$3.424745 \times 10^{-3}$	$1.745273 \times 10^{-3}$	$8.532017 \times 10^{-4}$	$3.457329 \times 10^{-4}$
$\tau_p$	1.125391	0.1878348	0.02788979	$8.430889 \times 10^{-3}$

D.C. Single Side Cooled				
Term	1	2	3	4
$r_p$	$8.375269 \times 10^{-3}$	$2.518437 \times 10^{-3}$	$1.193758 \times 10^{-3}$	$7.45432 \times 10^{-4}$
$\tau_p$	8.929845	0.4711304	0.08221244	0.01221961

**Curves**

Figure 1 - On-state characteristics of Limit device

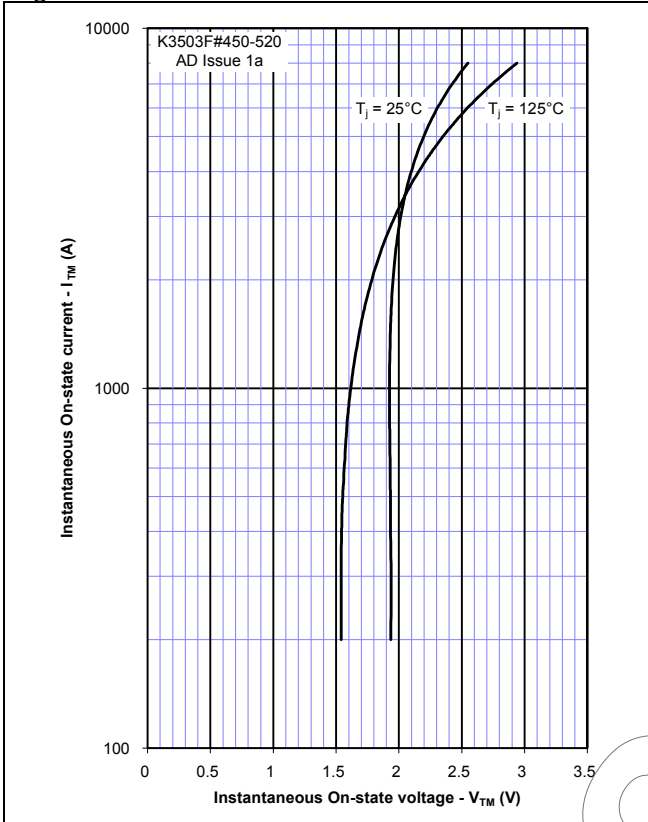


Figure 2 - Transient thermal impedance

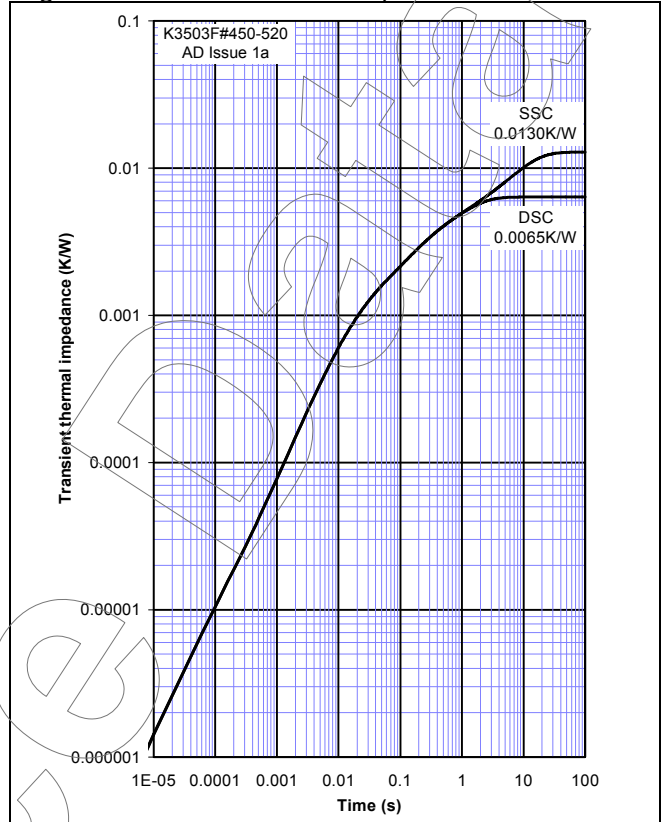


Figure 3 - Gate characteristics - Trigger limits

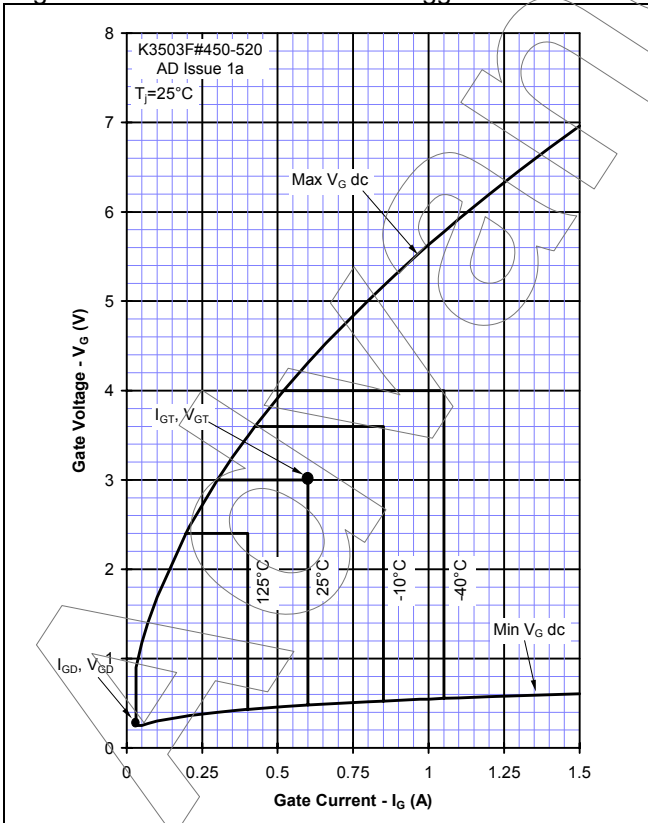


Figure 4 - Gate characteristics - Power curves

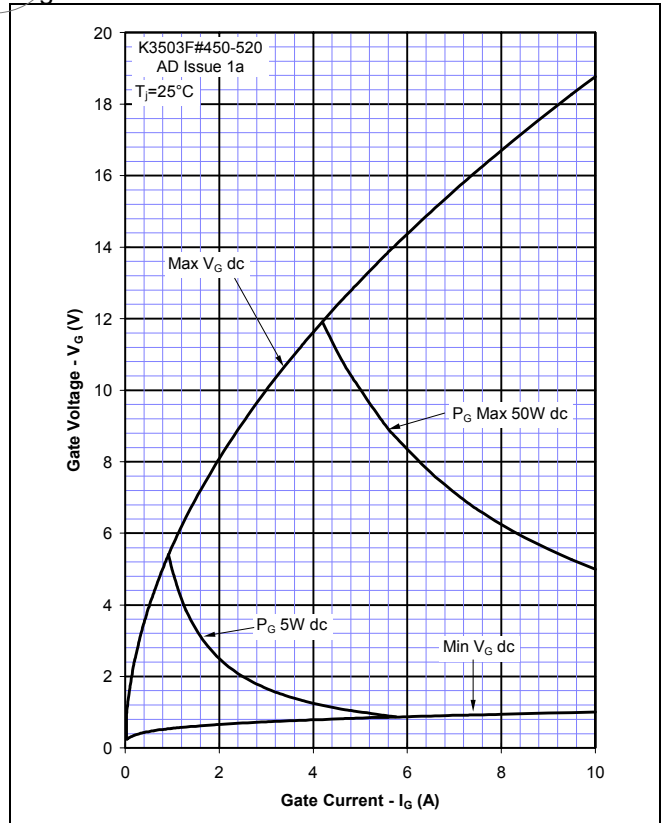


Figure 5 - Total recovered charge,  $Q_{rr}$

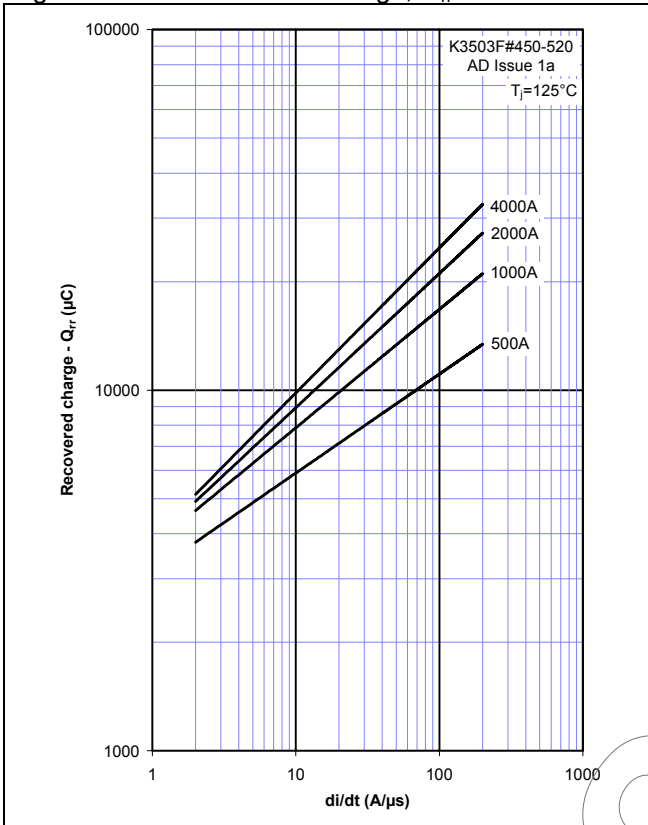


Figure 6 - Recovered charge,  $Q_{ra}$  (50% chord)

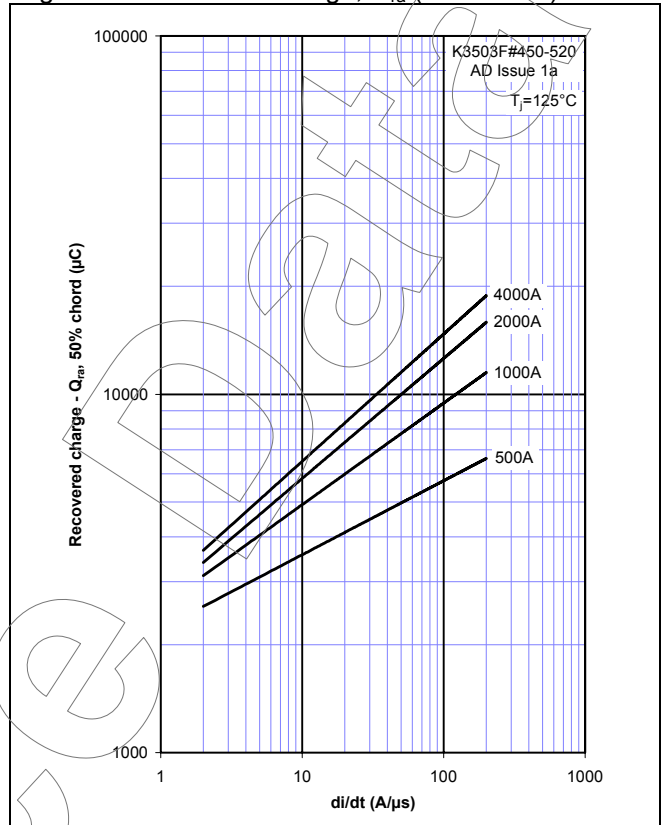


Figure 7 - Peak reverse recovery current,  $I_{rm}$

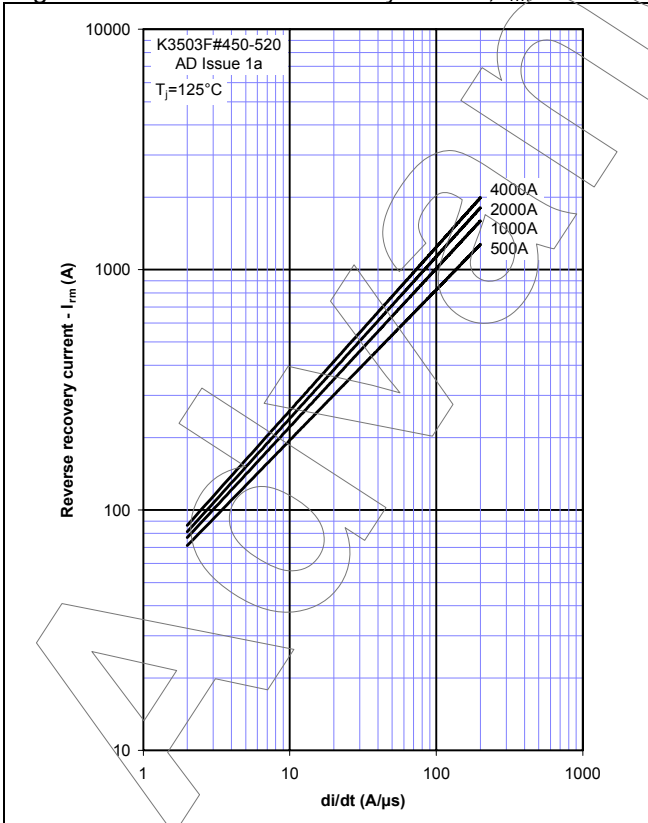


Figure 8 - Maximum recovery time,  $t_{rr}$  (50% chord)

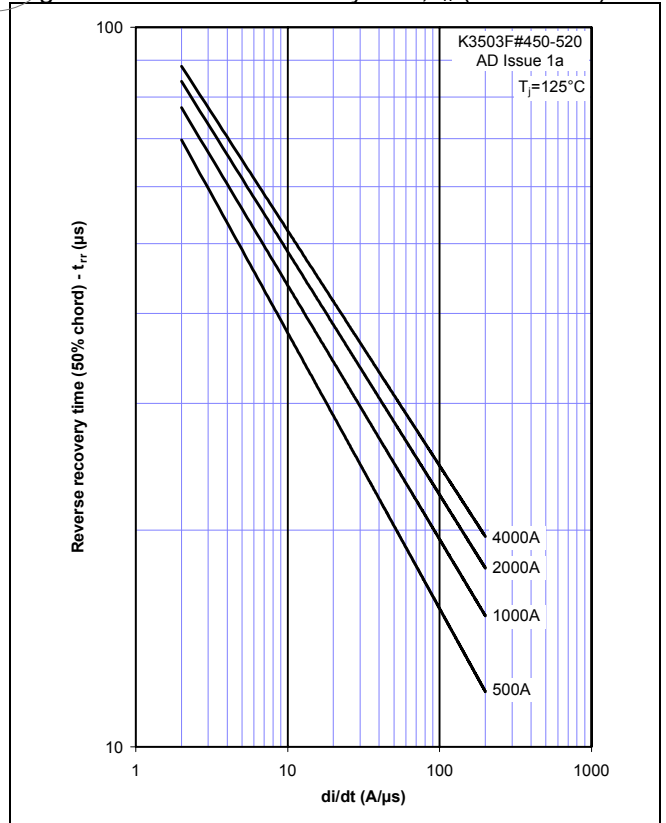


Figure 9 – On-state current vs. Power dissipation – Double Side Cooled (Sine wave)

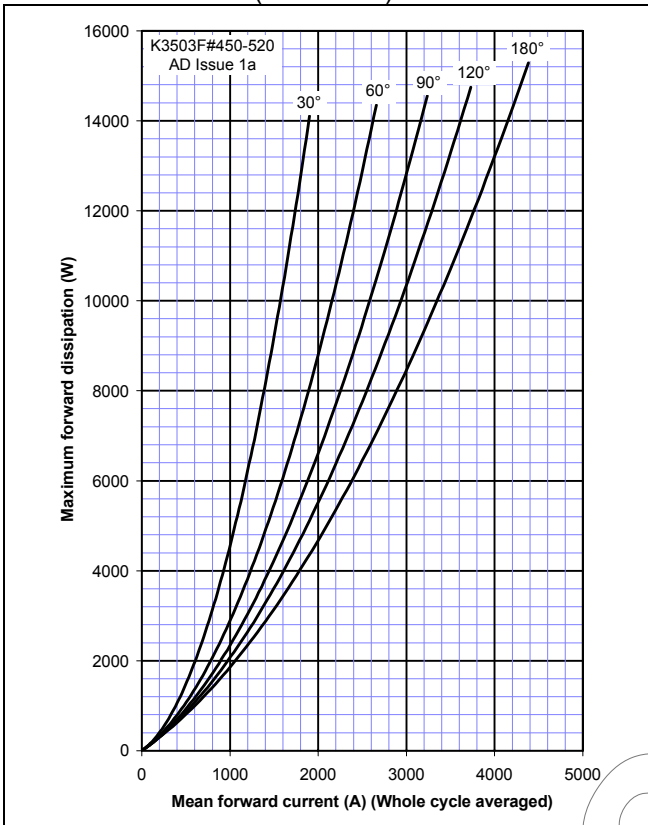


Figure 10 – On-state current vs. Heatsink temperature - Double Side Cooled (Sine wave)

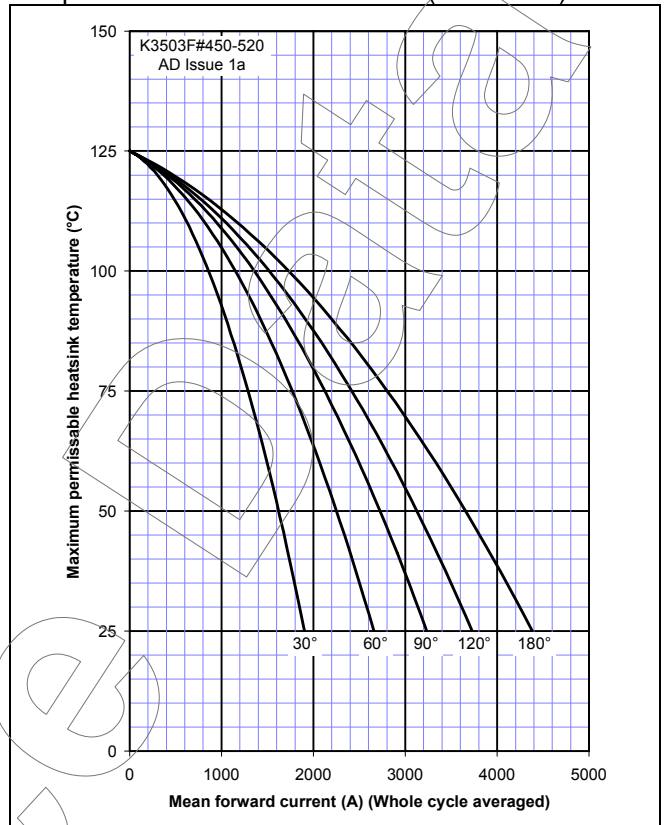


Figure 11 – On-state current vs. Power dissipation – Double Side Cooled (Square wave)

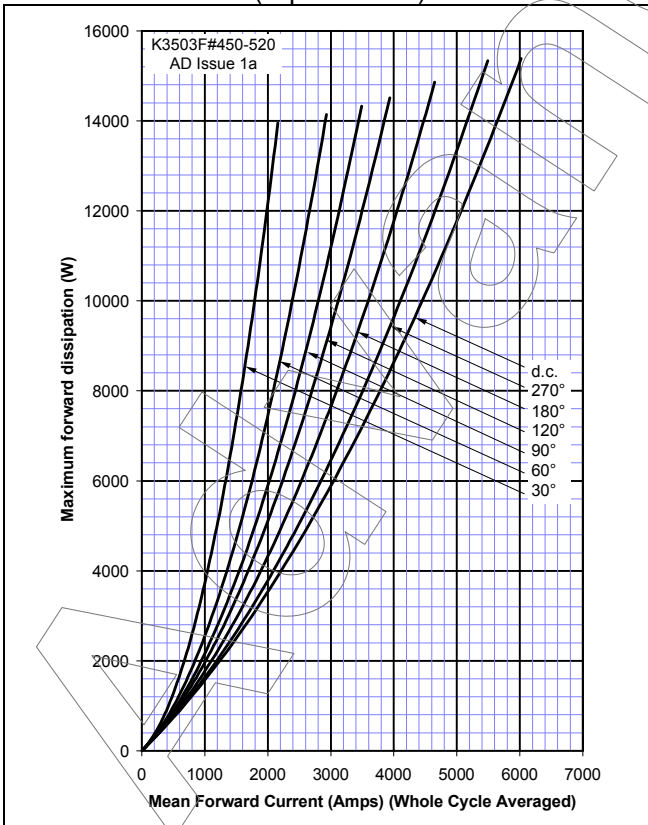


Figure 12 – On-state current vs. Heatsink temperature – Double Side Cooled (Square wave)

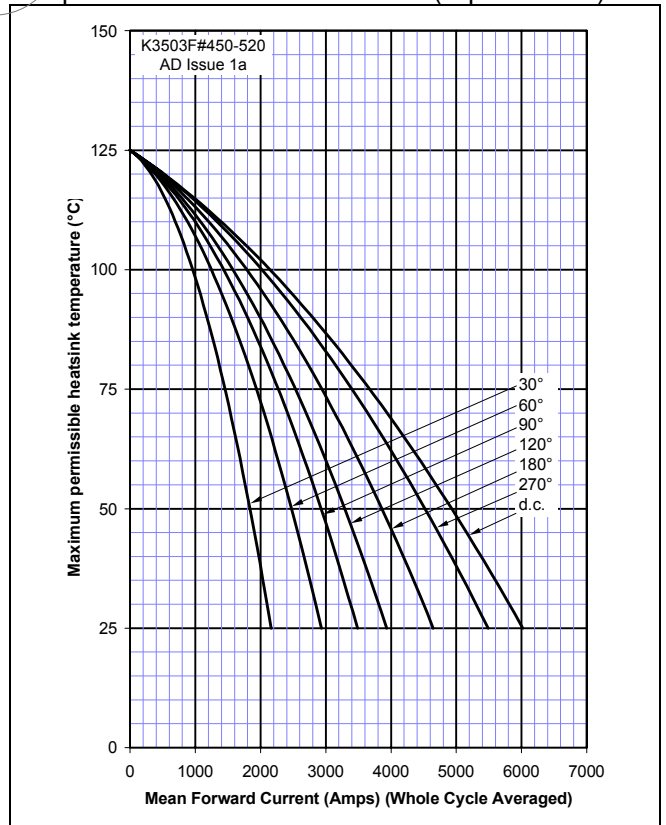




Figure 13 – On-state current vs. Power dissipation – Single Side Cooled (Sine wave)

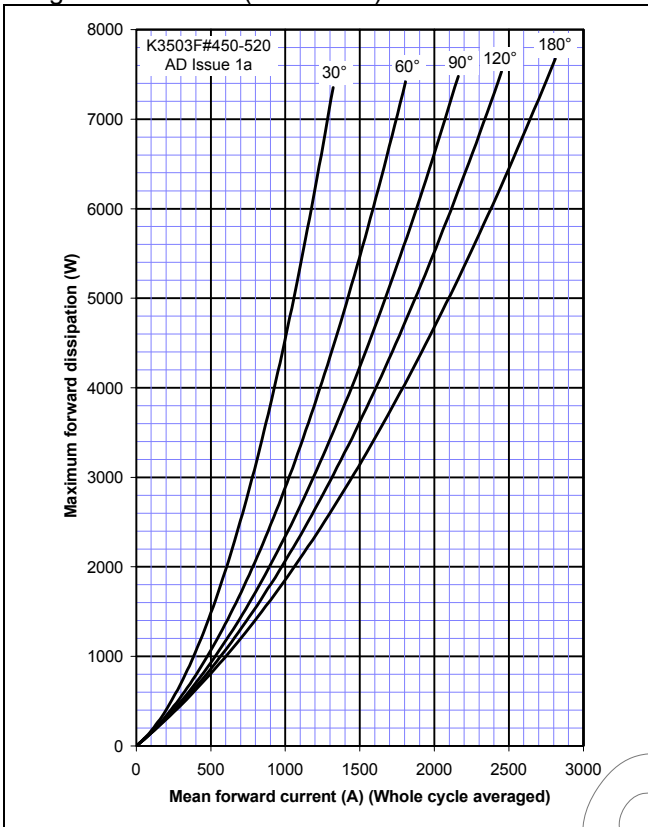


Figure 14 – On-state current vs. Heatsink temperature – Single Side Cooled (Sine wave)

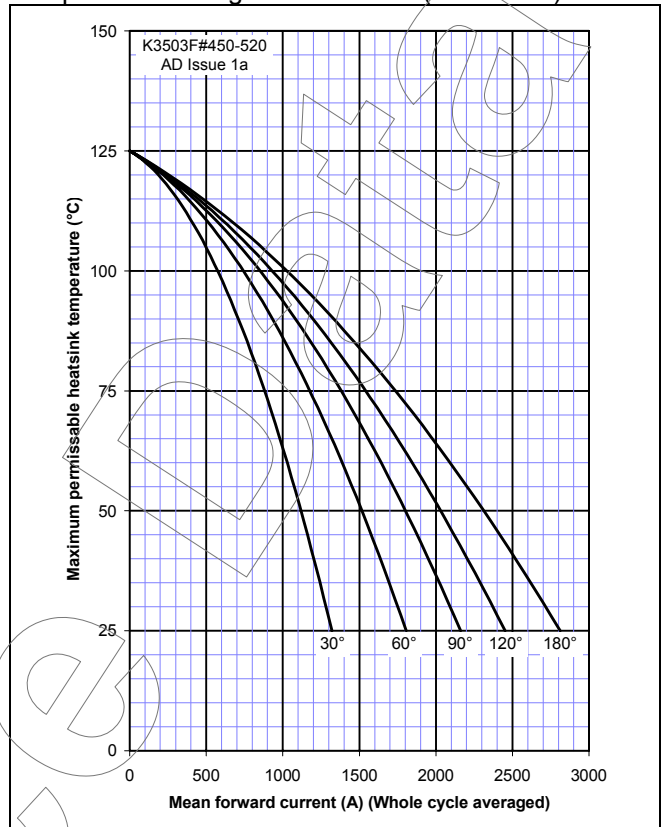


Figure 15 – On-state current vs. Power dissipation – Single Side Cooled (Square wave)

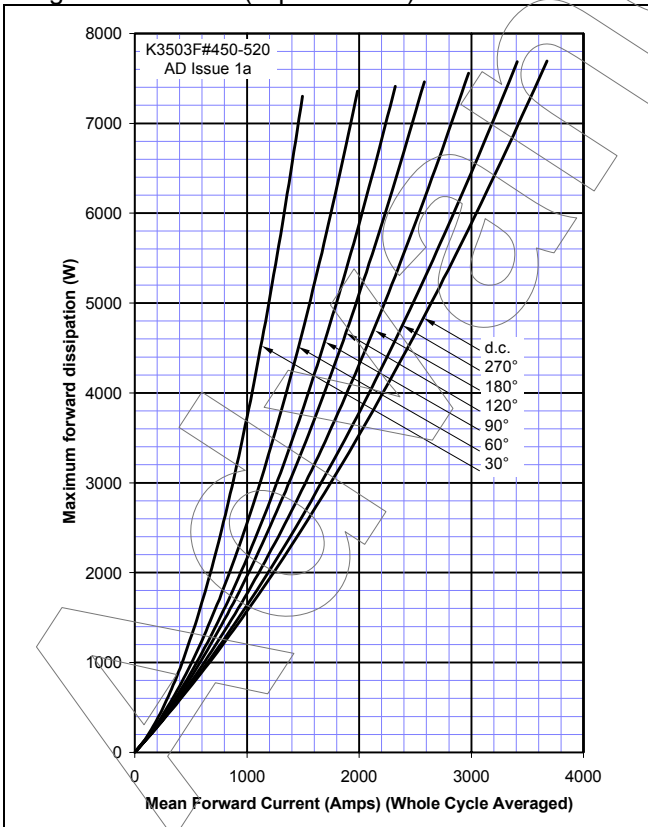


Figure 16 – On-state current vs. Heatsink temperature – Single Side Cooled (Square wave)

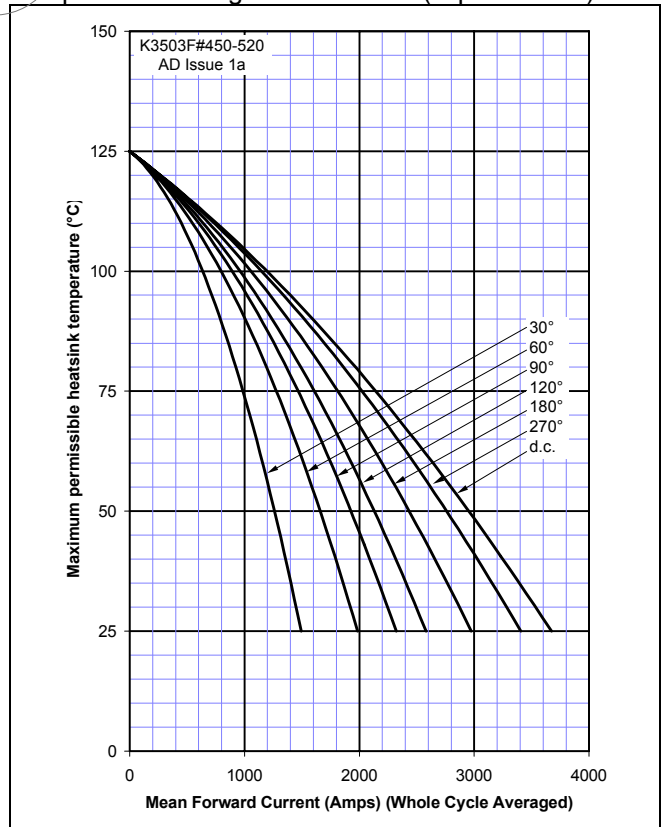


Figure 17 – Square Wave Frequency Ratings

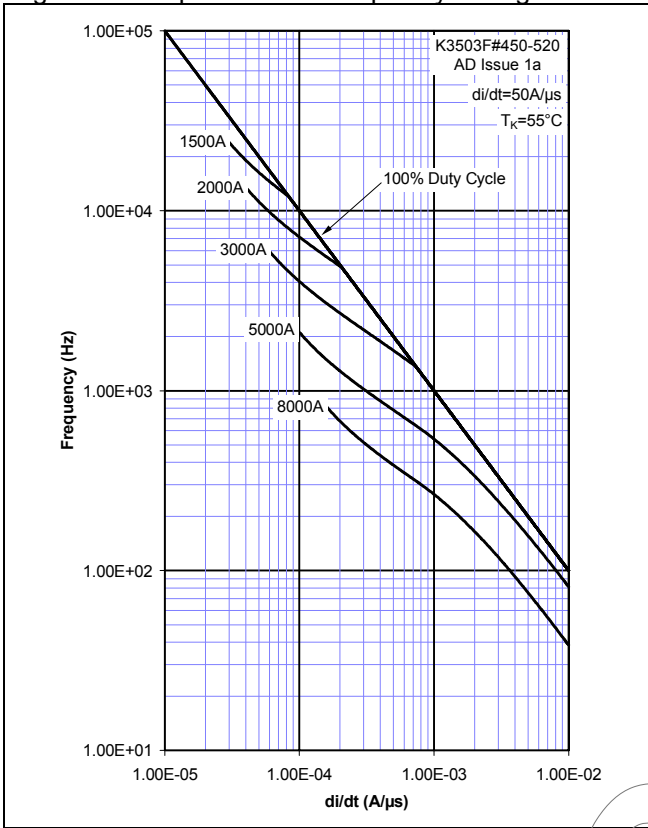


Figure 18 – Sine Wave Frequency Ratings

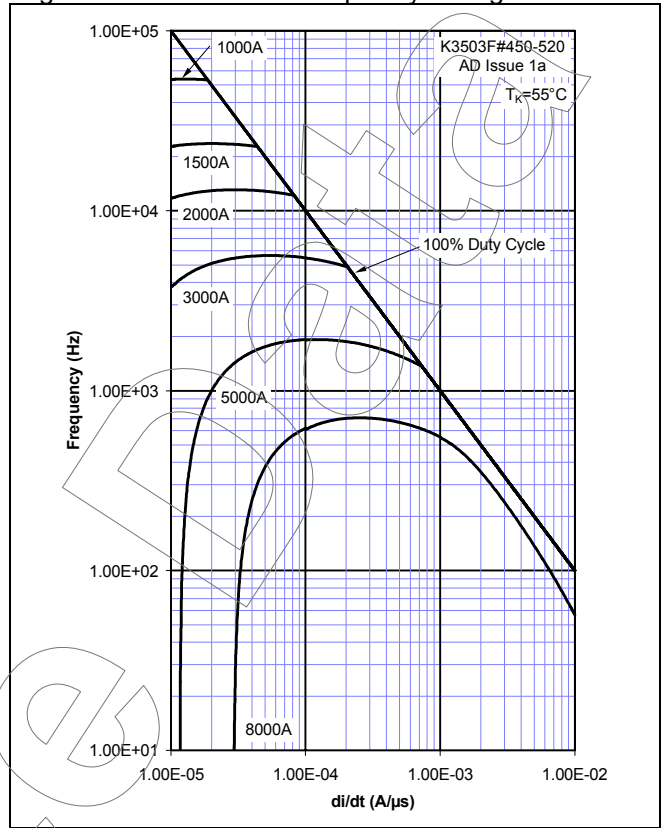
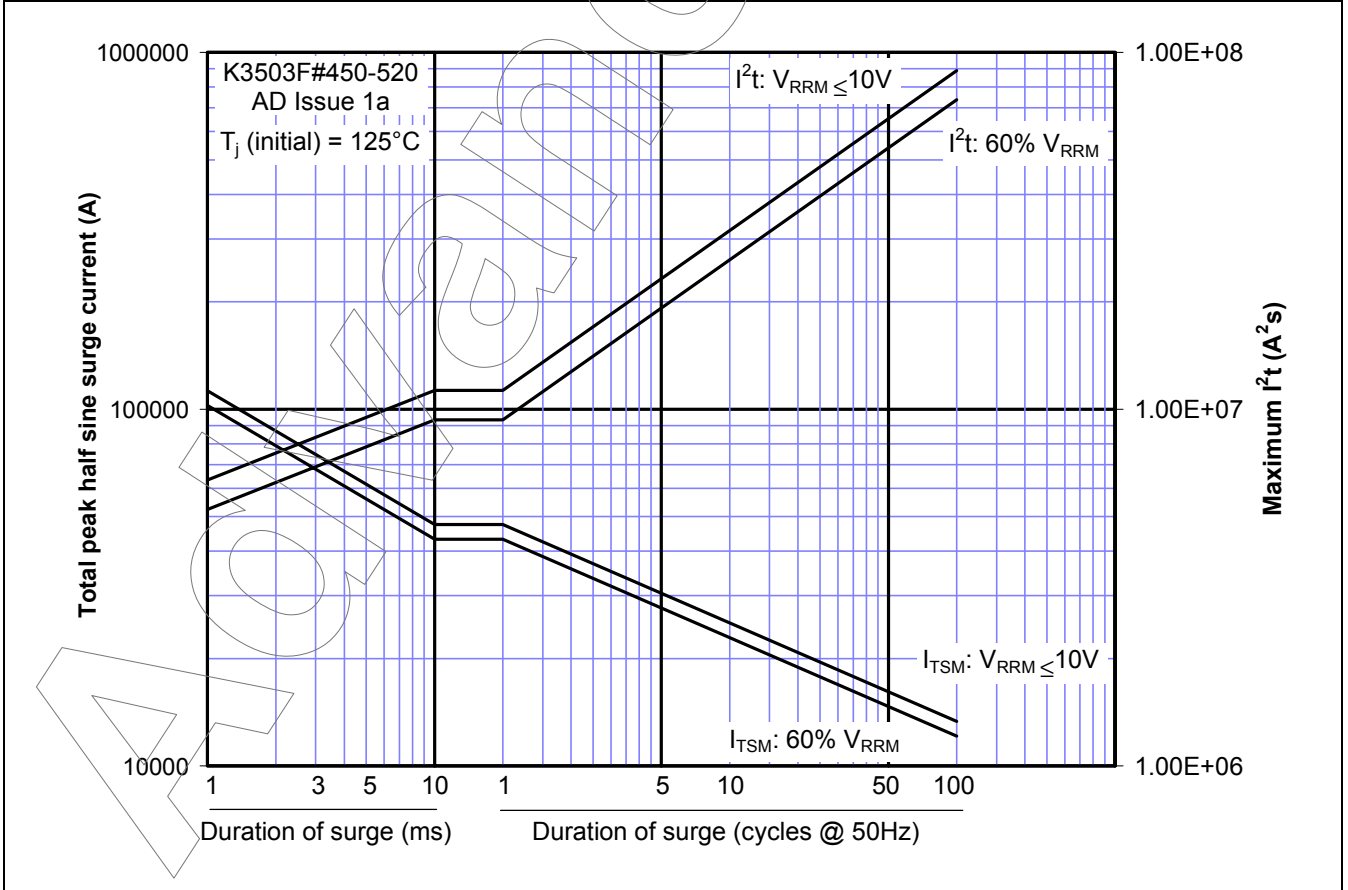
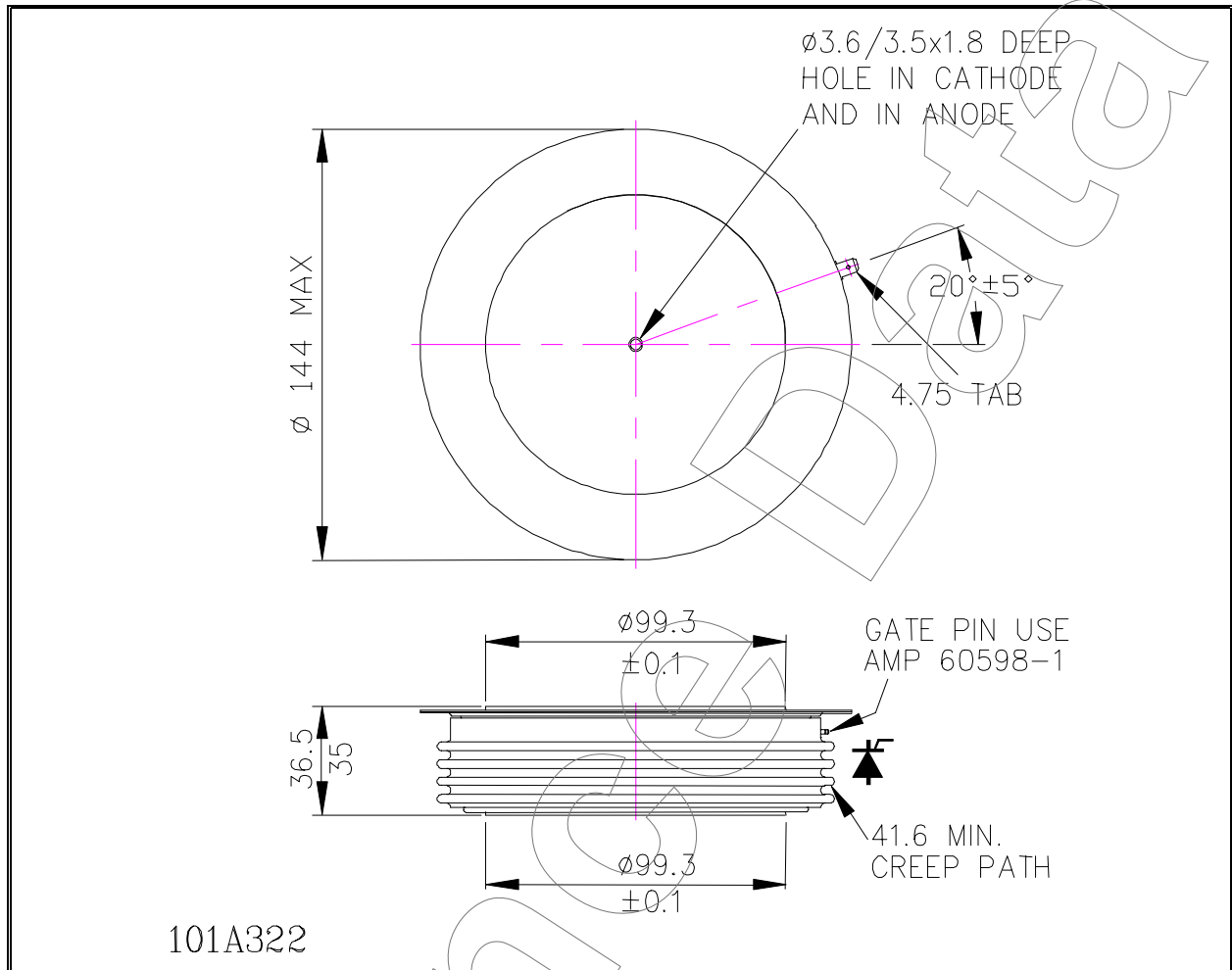


Figure 19 – Maximum Surge and  $I^2t$  Ratings



**Outline Drawing & Ordering Information**



ORDERING INFORMATION			
		(Please quote 10 digit code as below)	
<b>K3503</b>	<b>F</b> ◆	◆◆	<b>0</b>
Fixed Type Code	Outline Code FC = Standard capsule FT = Rupture rated capsule	Voltage code $V_{DRM/100}$ 45-52	Fixed turn-off time code

Typical order code: K3503FT480 – 4800V  $V_{DRM}$ ,  $V_{RRM}$ , 36.5mm clamp height, rupture rated capsule.

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