

# Phase Control Thyristor

## Types N4650EA400 & N4650EA450

### Absolute Maximum Ratings

	VOLTAGE RATINGS	MAXIMUM LIMITS	UNITS
V <sub>DRM</sub>	Repetitive peak off-state voltage, (note 1)	4000-4500	V
V <sub>DSM</sub>	Non-repetitive peak off-state voltage, (note 1)	4000-4500	V
V <sub>R<sub>RRM</sub></sub>	Repetitive peak reverse voltage, (note 1)	4000-4500	V
V <sub>R<sub>RSM</sub></sub>	Non-repetitive peak reverse voltage, (note 1)	4100-4600	V

	OTHER RATINGS	MAXIMUM LIMITS	UNITS
I <sub>T(AV)</sub>	Mean on-state current. T <sub>sink</sub> =55°C, (note 2)	4650	A
I <sub>T(AV)</sub>	Mean on-state current. T <sub>sink</sub> =85°C, (note 2)	3300	A
I <sub>T(AV)</sub>	Mean on-state current. T <sub>sink</sub> =85°C, (note 3)	1860	A
I <sub>T(RMS)</sub>	Nominal RMS on-state current. T <sub>sink</sub> =25°C, (note 2)	9010	A
I <sub>T(d.c.)</sub>	D.C. on-state current. T <sub>sink</sub> =25°C, (note 4)	8220	A
I <sub>TSM</sub>	Peak non-repetitive surge t <sub>p</sub> =10ms, V <sub>RM</sub> =0.6V <sub>RRM</sub> , (note 5)	56	kA
I <sub>TSM2</sub>	Peak non-repetitive surge t <sub>p</sub> =10ms, V <sub>RM</sub> ≤10V, (note 5)	62	kA
I <sup>2</sup> t	I <sup>2</sup> t capacity for fusing t <sub>p</sub> =10ms, V <sub>RM</sub> =0.6V <sub>RRM</sub> , (note 5)	15.7×10 <sup>6</sup>	A <sup>2</sup> s
I <sup>2</sup> t	I <sup>2</sup> t capacity for fusing t <sub>p</sub> =10ms, V <sub>RM</sub> ≤10V, (note 5)	19.2×10 <sup>6</sup>	A <sup>2</sup> s
di <sub>T</sub> /dt	Maximum rate of rise of on-state current (repetitive), (Note 6)	150	A/μs
	Maximum rate of rise of on-state current (non-repetitive), (Note 6)	300	A/μs
V <sub>RGM</sub>	Peak reverse gate voltage	5	V
P <sub>G(AV)</sub>	Mean forward gate power	5	W
P <sub>GM</sub>	Peak forward gate power	30	W
V <sub>GD</sub>	Non-trigger gate voltage, (Note 7)	0.25	V
T <sub>HS</sub>	Operating temperature range	-40 to +125	°C
T <sub>stg</sub>	Storage temperature range	-40 to +150	°C

Notes: -

- 1) De-rating factor of 0.13% per °C is applicable for T<sub>j</sub> below 25°C.
- 2) Double side cooled, single phase; 50Hz, 180° half-sinewave.
- 3) Cathode side cooled, single phase; 50Hz, 180° half-sinewave.
- 4) Double side cooled.
- 5) Half-sinewave, 125°C T<sub>j</sub> initial.
- 6) V<sub>D</sub>=67% V<sub>DRM</sub>, I<sub>TM</sub>=4000A, I<sub>FG</sub>=2A, t<sub>r</sub>≤0.5μs, T<sub>case</sub>=125°C.
- 7) Rated V<sub>DRM</sub>.

**Characteristics**

	PARAMETER	MIN.	TYP.	MAX.	TEST CONDITIONS (Note 1)	UNITS
$V_{TM}$	Maximum peak on-state voltage	-	-	1.70	$I_{TM}=4000A$	V
$V_0$	Threshold voltage	-	-	0.977		V
$r_T$	Slope resistance	-	-	0.177		m $\Omega$
dv/dt	Critical rate of rise of off-state voltage	1000	-	-	$V_D=80\% V_{DRM}$ , Linear ramp, gate o/c	V/ $\mu$ s
$I_{DRM}$	Peak off-state current	-	-	200	Rated $V_{DRM}$	mA
$I_{RRM}$	Peak reverse current	-	-	200	Rated $V_{RRM}$	mA
$V_{GT}$	Gate trigger voltage	-	-	3.0	$T_j=25^\circ C$ , $V_D=10V$ , $I_T=3A$	V
$I_{GT}$	Gate trigger current	-	-	300		mA
$I_H$	Holding current	-	-	1000	$T_j=25^\circ C$	mA
$t_{gd}$	Gate controlled turn-on delay time	-	1.0	1.6	$I_{FG}=2A$ , $t_r=0.5\mu s$ , $V_D=67\%V_{DRM}$ , $I_{TM}=2000A$ , $di/dt=10A/\mu s$ , $T_j=25^\circ C$	$\mu$ s
$t_{gt}$	Turn-on time	-	3.5	5.0		$\mu$ s
$Q_{rr}$	Recovered Charge	-	14900	16000		$\mu$ C
$Q_{ra}$	Recovered Charge, 50% chord	-	8400	-	$I_{TM}=2000A$ , $t_p=2000\mu s$ , $di/dt=10A/\mu s$ , $V_r=100V$	$\mu$ C
$I_{rm}$	Reverse recovery current	-	295	-		A
$t_{rr}$	Reverse recovery time, 50% chord	-	57	-		$\mu$ s
$t_q$	Turn-off time	-	750	-	$I_{TM}=2000A$ , $t_p=2000\mu s$ , $di/dt=10A/\mu s$ , $V_r=100V$ , $V_{dr}=80\%V_{DRM}$ , $dV_{dr}/dt=20V/\mu s$	$\mu$ s
		-	1200	-	$I_{TM}=2000A$ , $t_p=2000\mu s$ , $di/dt=10A/\mu s$ , $V_r=100V$ , $V_{dr}=80\%V_{DRM}$ , $dV_{dr}/dt=200V/\mu s$	
$R_{thJK}$	Thermal resistance, junction to heatsink	-	-	0.005	Double side cooled	K/W
		-	-	0.012	Cathode side cooled	K/W
		-	-	0.009	Anode side cooled	K/W
F	Mounting force	76	-	93		kN
$W_t$	Weight	-	1.55	-		kg

## 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
40	4000	4100	2400
45	4500	4600	2700

### 2.0 Extension of Voltage Grades

This report is applicable to other and higher 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 Computer Modelling Parameters

#### 5.1 Device Dissipation Calculations

$$I_{AV} = \frac{-V_0 + \sqrt{V_0^2 + 4 \cdot ff \cdot r_s \cdot W_{AV}}}{2 \cdot ff \cdot r_s} \quad \text{and:} \quad W_{AV} = \frac{\Delta T}{R_{th}}$$

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

Where  $V_0=0.977V$ ,  $r_s=0.177m\Omega$ ,

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

$ff$  = Form factor, see table below.

Supplementary Thermal Impedance							
Conduction Angle	30°	60°	90°	120°	180°	270°	d.c.
Square wave Double Side Cooled	0.00556	0.00549	0.00543	0.00538	0.00527	0.00514	0.00500
Square wave Cathode Side Cooled	0.01292	0.01285	0.01278	0.01271	0.01259	0.01244	0.01200
Sine wave Double Side Cooled	0.00551	0.00543	0.00537	0.00531	0.00515		
Sine wave Cathode Side Cooled	0.01286	0.01277	0.01270	0.01263	0.01245		

Form Factors							
Conduction Angle	30°	60°	90°	120°	180°	270°	d.c.
Square wave	3.46	2.45	2	1.73	1.41	1.15	1
Sine wave	3.98	2.78	2.22	1.88	1.57		

### 5.2 Calculating $V_T$ using ABCD Coefficients

The on-state characteristic  $I_T$  vs.  $V_T$ , on page 5 is represented in two ways;

- (i) the well established  $V_o$  and  $r_s$  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	1.254701	A	0.9310573
B	$7.754636 \times 10^{-3}$	B	-0.03021167
C	$1.26163 \times 10^{-4}$	C	$1.10532 \times 10^{-4}$
D	$-3.395382 \times 10^{-3}$	D	$9.124054 \times 10^{-3}$

### 5.3 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.

D.C. Double Side Cooled			
Term	1	2	3
$r_p$	$2.761048 \times 10^{-3}$	$1.738044 \times 10^{-3}$	$5.209655 \times 10^{-4}$
$\tau_p$	0.8332002	0.1416775	0.01436119

D.C. Cathode Side Cooled			
Term	1	2	3
$r_p$	$9.855141 \times 10^{-3}$	$1.983482 \times 10^{-3}$	$4.775474 \times 10^{-4}$
$\tau_p$	4.147275	0.1396446	0.0116827

**Curves**

Figure 1 - On-state characteristics of Limit device

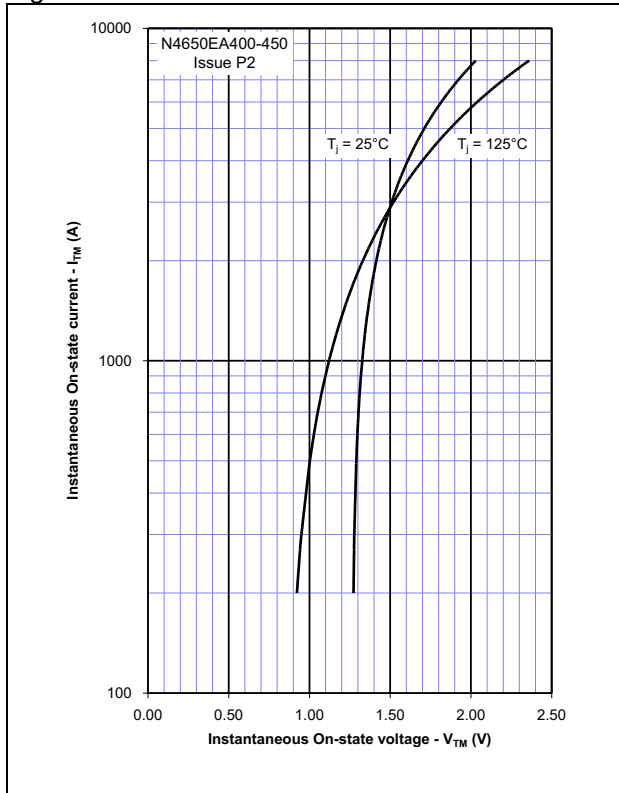


Figure 2 - Transient Thermal Impedance

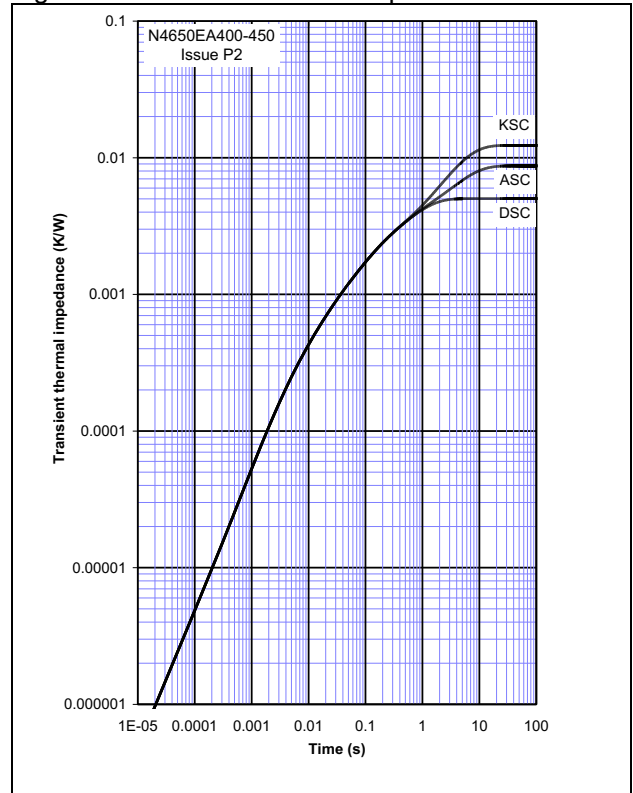


Figure 3 - Gate Characteristics - Trigger Limits

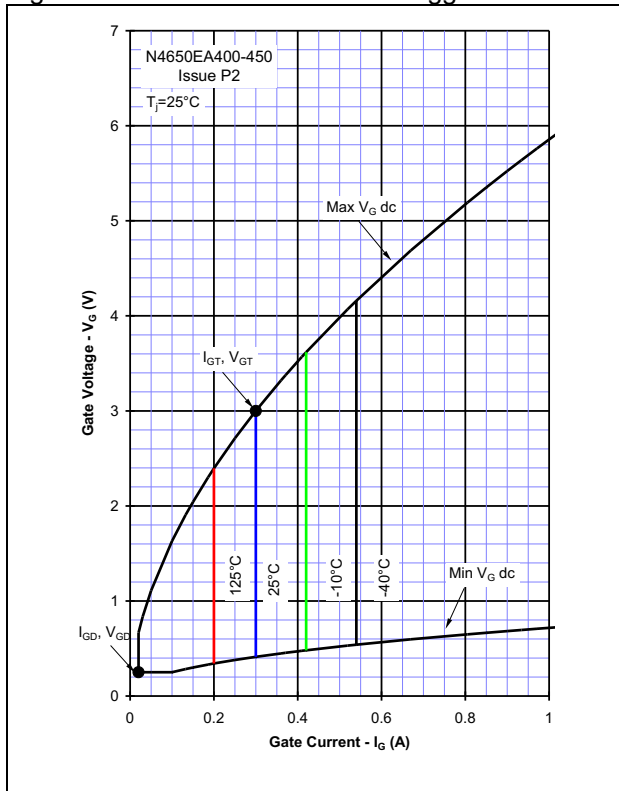


Figure 4 - Gate Characteristics - Power Curves

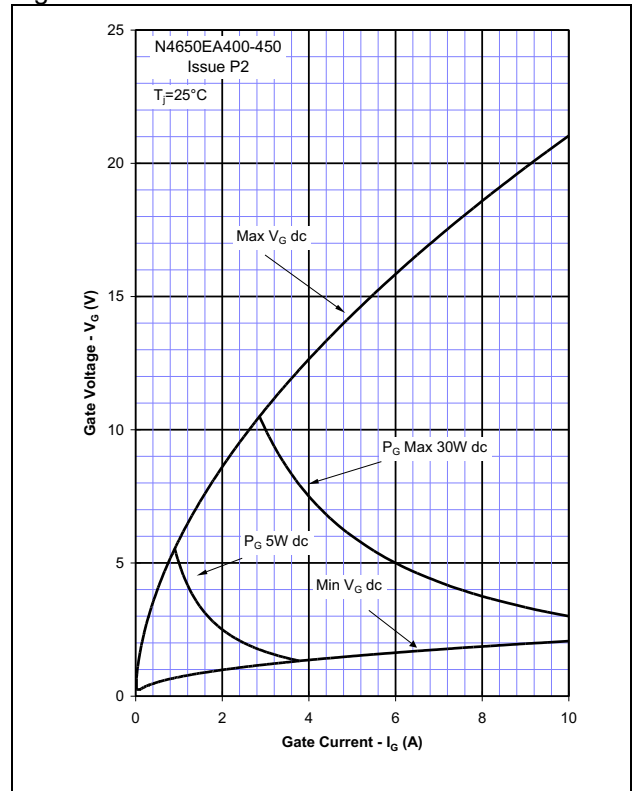


Figure 5 – Recovered Charge,  $Q_{rr}$

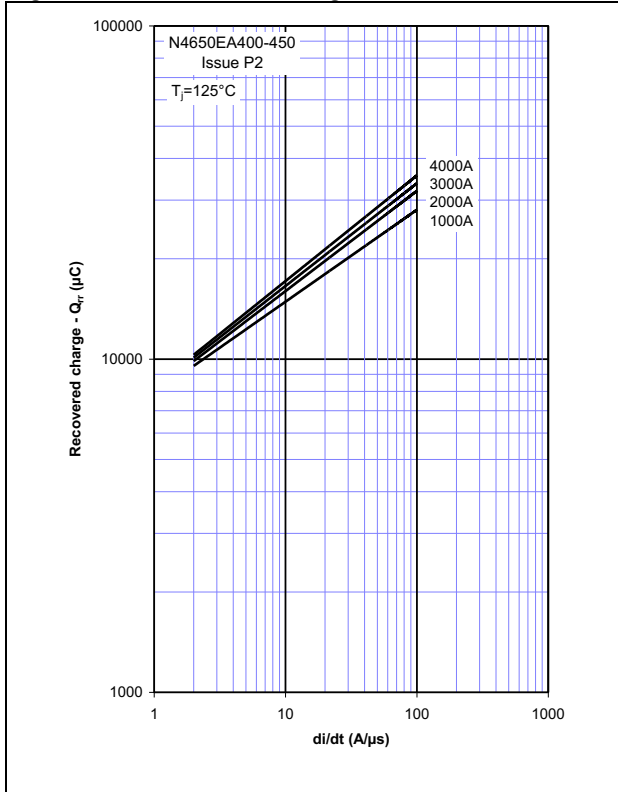


Figure 6 – Recovered charge,  $Q_{ra}$  (50% chord)

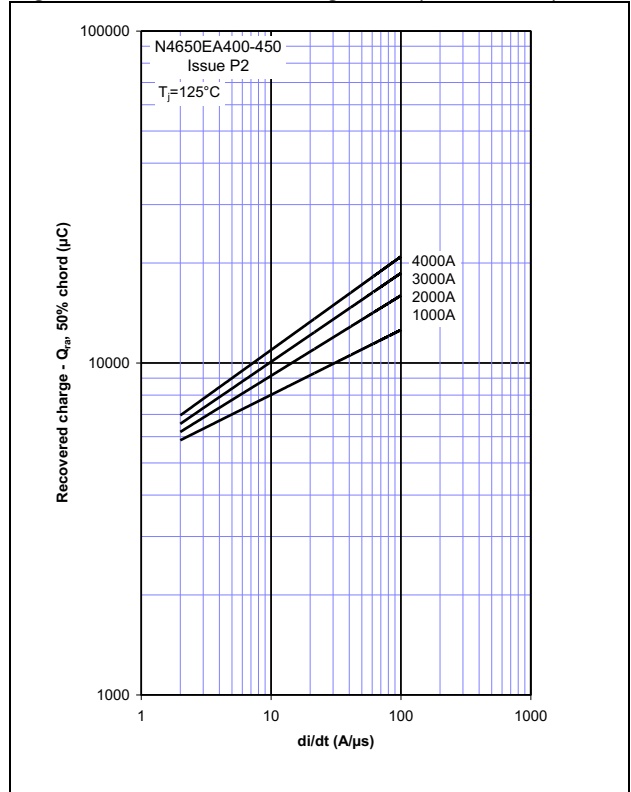


Figure 7 – Reverse recovery current,  $I_{rm}$

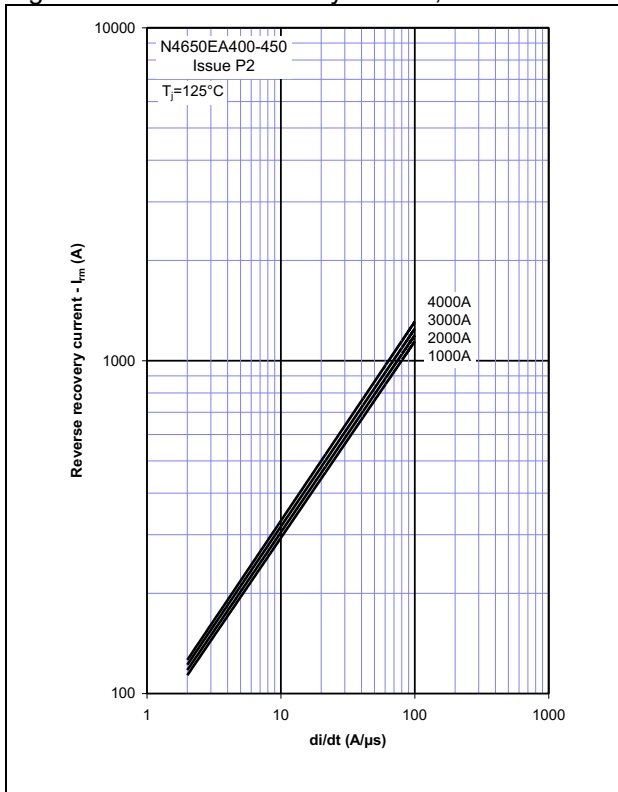


Figure 8 – Reverse recovery time,  $t_{rr}$

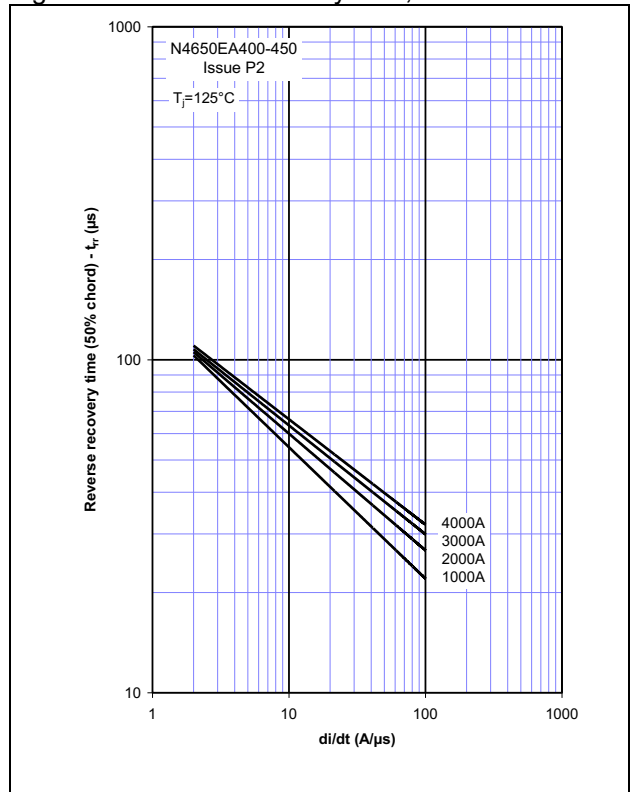


Figure 9 – On-state current vs. Power dissipation – Double Side Cooled (Sine wave)

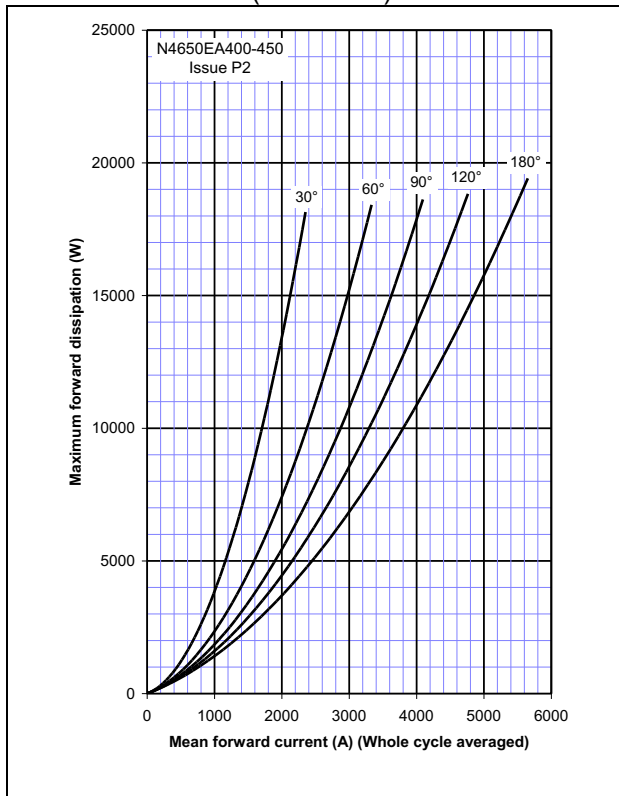


Figure 10 – On-state current vs. Heatsink temperature - Double Side Cooled (Sine wave)

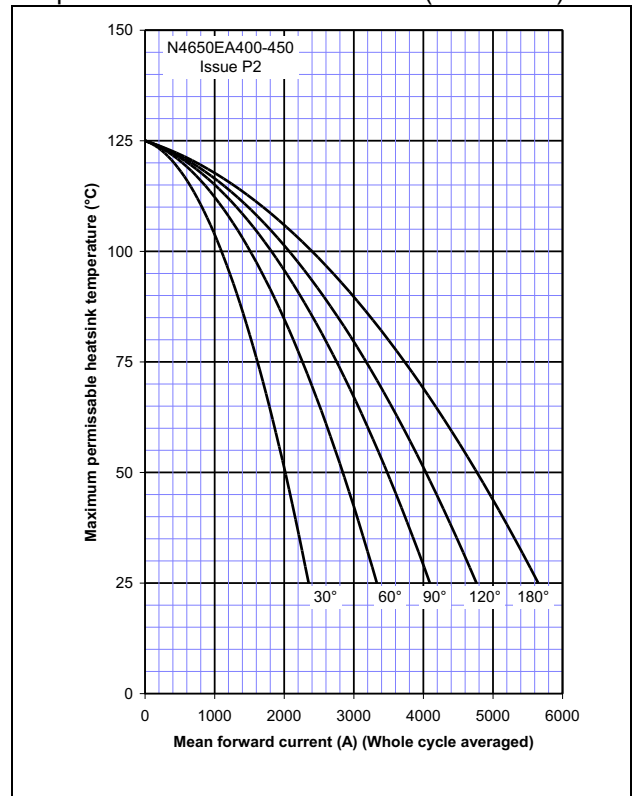


Figure 11 – On-state current vs. Power dissipation – Double Side Cooled (Square wave)

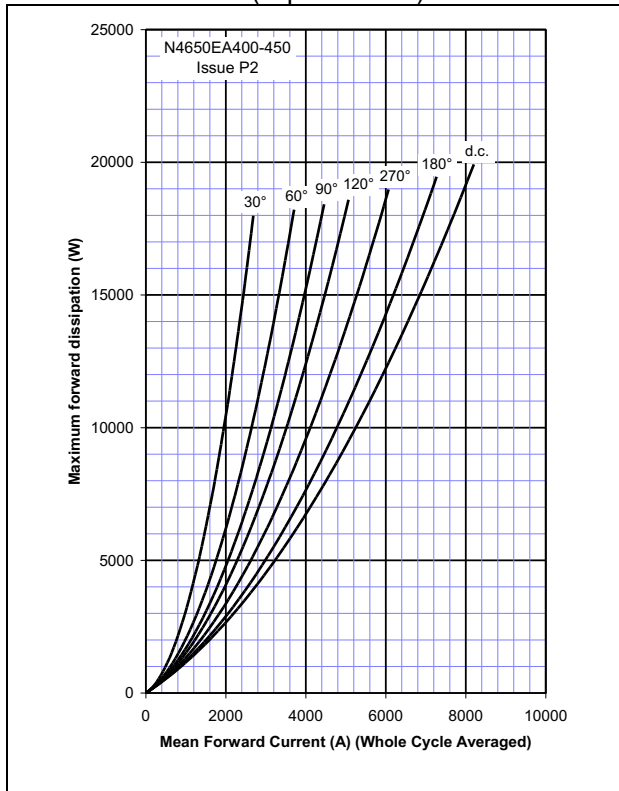


Figure 12 – On-state current vs. Heatsink temperature - Double Side Cooled (Square wave)

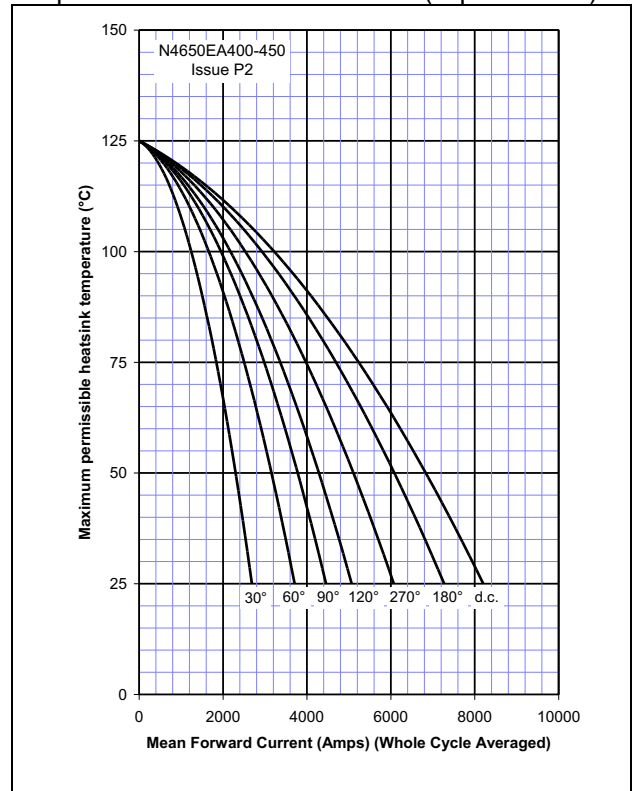


Figure 13 – On-state current vs. Power dissipation – Cathode Side Cooled (Sine wave)

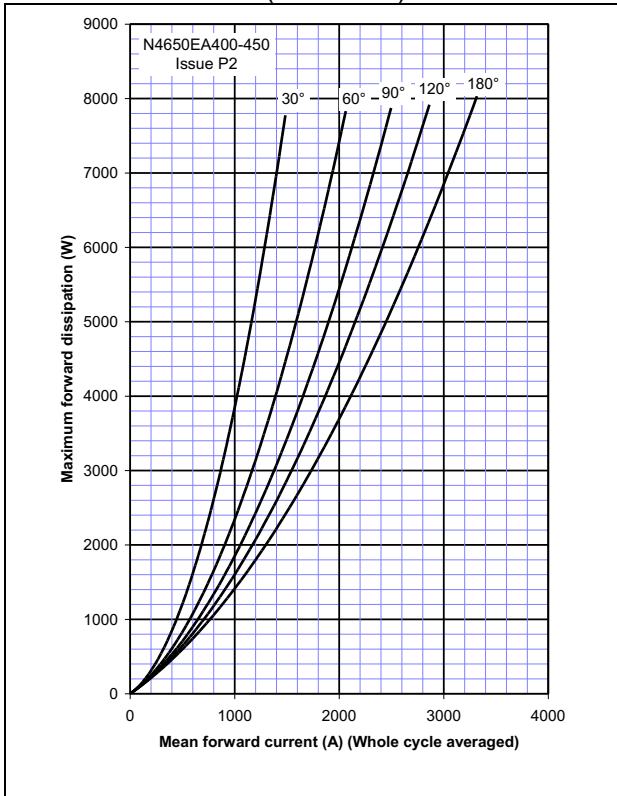


Figure 14 – On-state current vs. Heatsink temperature - Cathode Side Cooled (Sine wave)

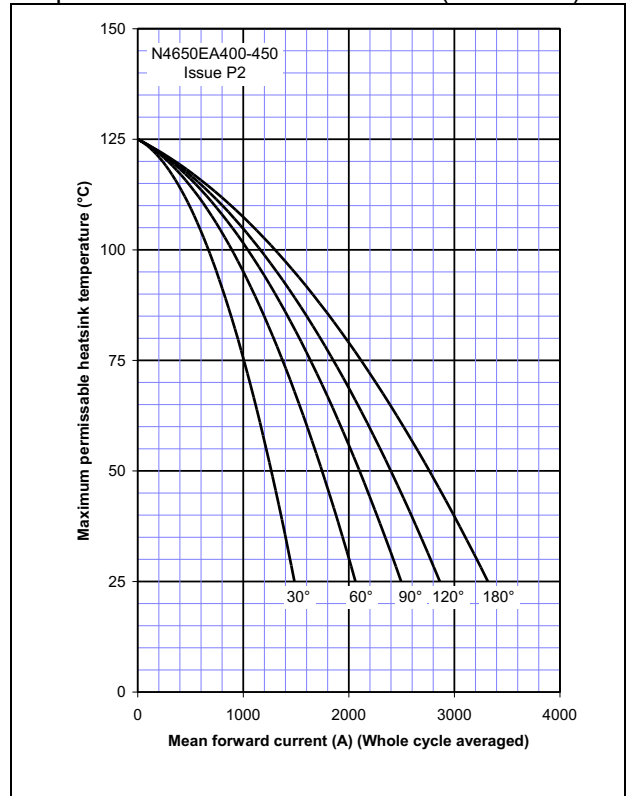


Figure 15 – On-state current vs. Power dissipation – Cathode Side Cooled (Square wave)

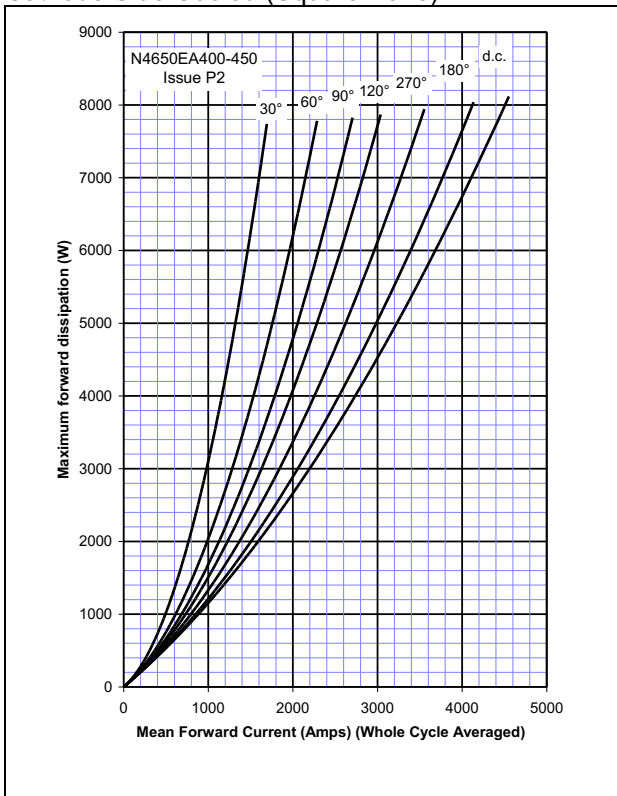


Figure 16 – On-state current vs. Heatsink temperature - Cathode Side Cooled (Square wave)

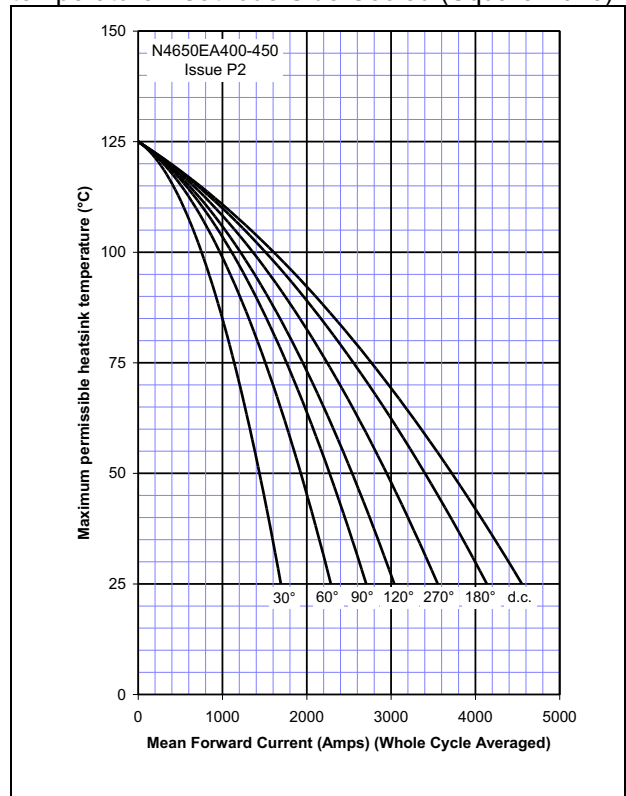
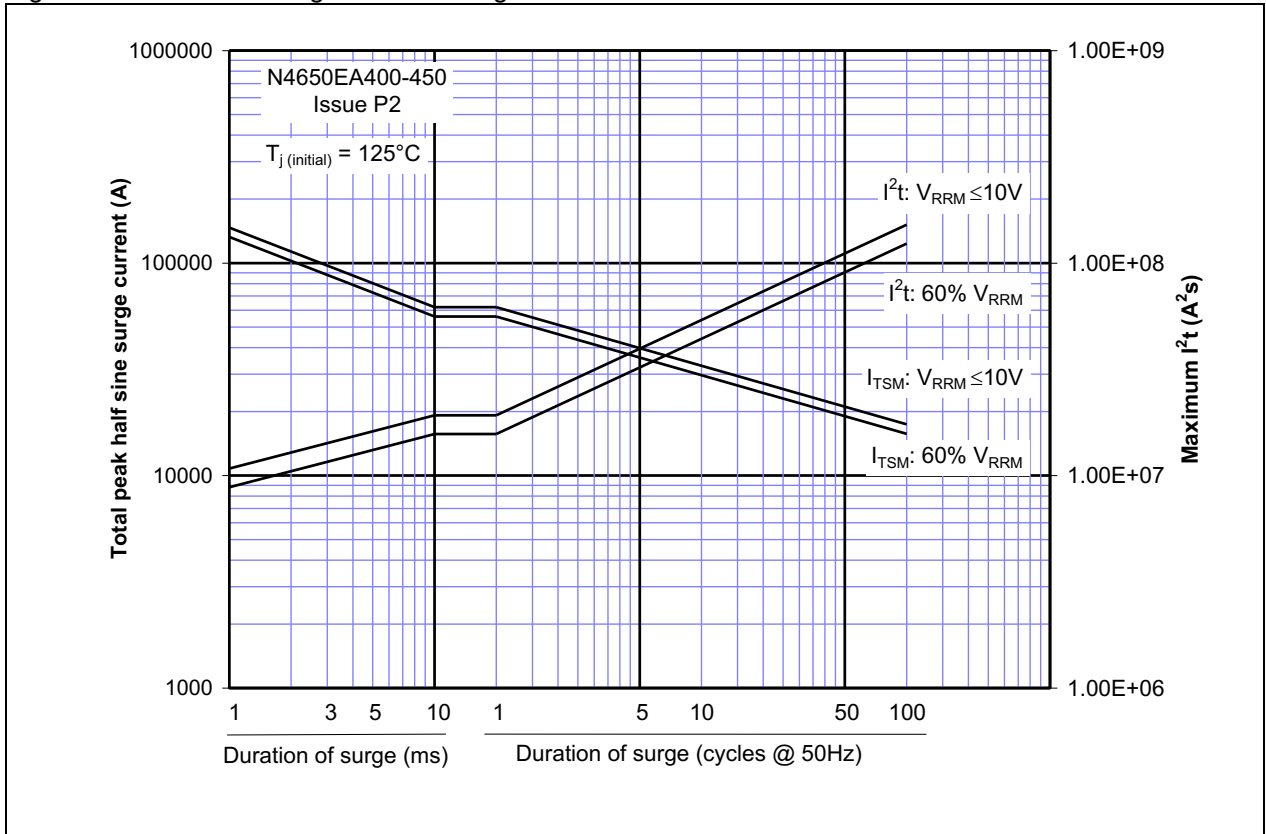
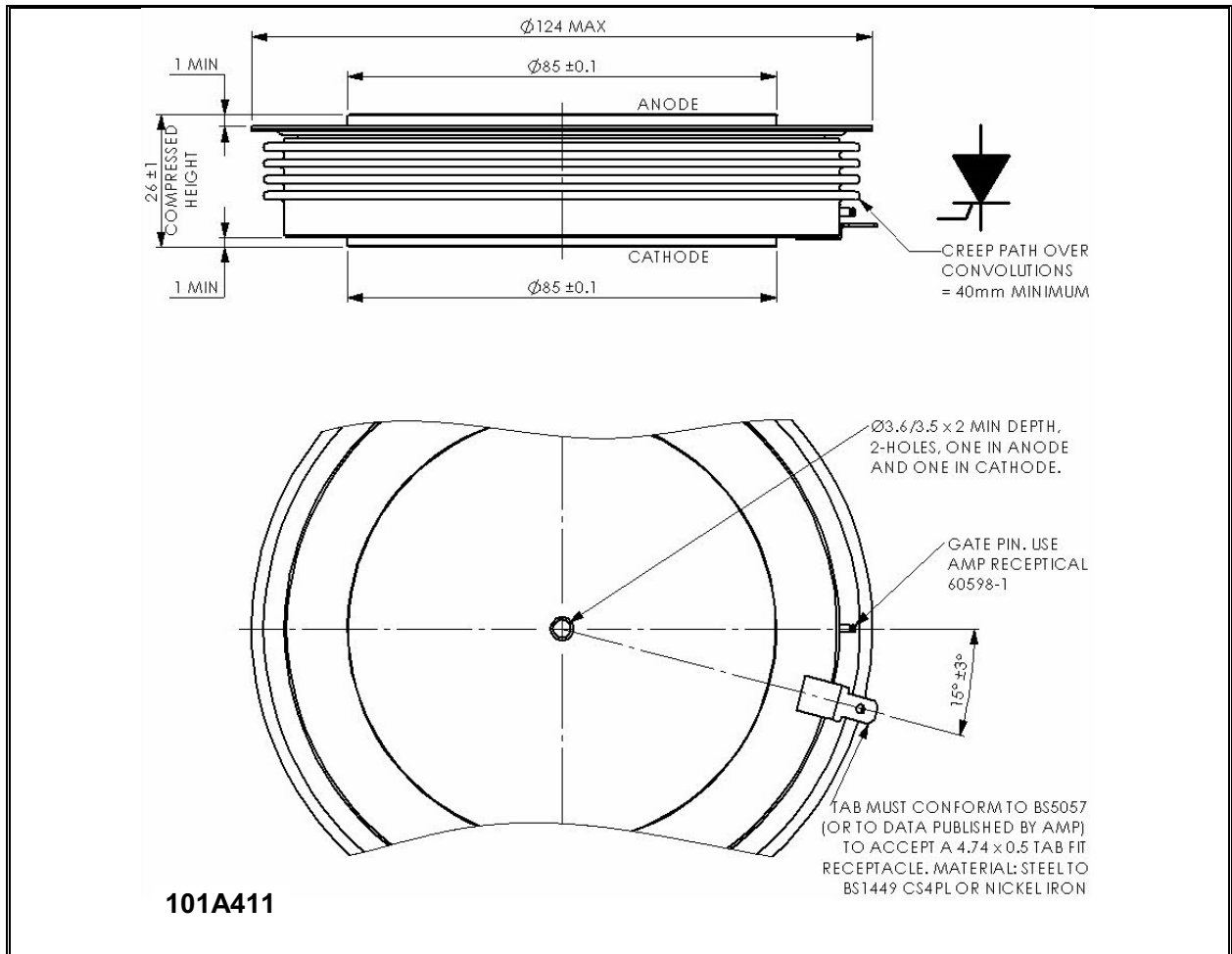




Figure 17 – Maximum surge and  $I^2t$  Ratings



**Outline Drawing & Ordering Information**



**ORDERING INFORMATION**

(Please quote 10 digit code as below)

<b>N4650</b>	<b>EA</b>	<b>◆ ◆</b>	<b>0</b>
Fixed Type Code	Fixed Outline Code	Voltage Code 40 & 45	Fixed turn-off time code

Typical order code: N4650EA450 – 4500V  $V_{DRM}$ ,  $V_{RRM}$ , 1000V/ $\mu\text{s}$  dv/dt, 26mm clamp height capsule.

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