

# Phase Control Thyristor Module

## Types MCO740-20io1 to MCO740-22io1

### Absolute Maximum Ratings

|                               |              |
|-------------------------------|--------------|
| $V_{RRM}$<br>$V_{DRM}$<br>[V] | Type         |
| 2000                          | MCO740-20io1 |
| 2200                          | MCO740-22io1 |

|           | VOLTAGE RATINGS                                     | MAXIMUM LIMITS | UNITS |
|-----------|-----------------------------------------------------|----------------|-------|
| $V_{DRM}$ | Repetitive peak off-state voltage <sup>1)</sup>     | 2000-2200      | V     |
| $V_{DSM}$ | Non-repetitive peak off-state voltage <sup>1)</sup> | 2000-2200      | V     |
| $V_{RRM}$ | Repetitive peak reverse voltage <sup>1)</sup>       | 2000-2200      | V     |
| $V_{RSM}$ | Non-repetitive peak reverse voltage <sup>1)</sup>   | 2100-2300      | V     |

|                       | OTHER RATINGS                                                                                                 |                         | MAXIMUM LIMITS       | UNITS            |
|-----------------------|---------------------------------------------------------------------------------------------------------------|-------------------------|----------------------|------------------|
| I <sub>T(AV)M</sub>   | Maximum average on-state current, T <sub>c</sub> =55°C <sup>2)</sup>                                          |                         | 1190                 | A                |
| I <sub>T(AV)M</sub>   | Maximum average on-state current, T <sub>c</sub> =88°C <sup>2)</sup>                                          |                         | 740                  |                  |
| I <sub>T(AV)M</sub>   | Maximum average on-state current. T <sub>c</sub> =85°C <sup>2)</sup>                                          |                         | 793                  |                  |
| I <sub>T(RMS)M</sub>  | Nominal RMS on-state current, T <sub>c</sub> =25°C <sup>2)</sup>                                              |                         | 2389                 |                  |
| I <sub>T(d.c.)</sub>  | D.C. on-state current, T <sub>c</sub> =25°C <sup>2)</sup>                                                     |                         | 1978                 |                  |
| I <sub>TSM</sub>      | Peak non-repetitive surge t <sub>p</sub> =10ms, V <sub>rm</sub> =60%V <sub>RRM</sub> <sup>3)</sup>            |                         | 32.7                 | kA               |
| I <sub>TSM2</sub>     | Peak non-repetitive surge t <sub>p</sub> =10ms, V <sub>rm</sub> ≤10V <sup>3)</sup>                            |                         | 36.0                 | kA               |
| I <sup>2</sup> t      | I <sup>2</sup> t capacity for fusing t <sub>p</sub> =10ms, V <sub>rm</sub> =60%V <sub>RRM</sub> <sup>3)</sup> |                         | 5.35×10 <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 <sup>3)</sup>                 |                         | 6.48×10 <sup>6</sup> | A <sup>2</sup> s |
| (di/dt) <sub>cr</sub> | Critical rate of rise of on-state current <sup>4)</sup>                                                       | (continuous, 50Hz)      | 75                   | A/μs             |
|                       |                                                                                                               | (repetitive, 50Hz, 60s) | 150                  |                  |
|                       |                                                                                                               | (non-repetitive)        | 300                  |                  |
| V <sub>RGM</sub>      | Peak reverse gate voltage                                                                                     |                         | 5                    | V                |
| P <sub>G(AV)</sub>    | Mean forward gate power                                                                                       |                         | 4                    | W                |
| P <sub>GM</sub>       | Peak forward gate power                                                                                       |                         | 30                   | W                |
| V <sub>ISOL</sub>     | Isolation Voltage <sup>5)</sup>                                                                               |                         | 3500                 | V                |
| T <sub>Vj op</sub>    | Operating temperature range                                                                                   |                         | -40 to +125          | °C               |
| T <sub>stg</sub>      | Storage temperature range                                                                                     |                         | -40 to +150          | °C               |

### Notes:

- De-rating factor of 0.13% per  $^{\circ}C$  is applicable for  $T_{vj}$  below  $25^{\circ}C$ .
- Single phase; 50 Hz,  $180^{\circ}$  half-sinewave.
- Half-sinewave,  $125^{\circ}C$   $T_{vj}$  initial.
- $V_D = 67\% V_{DRM}$ ,  $I_{FG} = 2\ A$ ,  $t_r \leq 0.5\mu s$ ,  $T_c = 125^{\circ}C$ .
- AC RMS voltage, 50 Hz, 1min test

**Characteristics**

|                       | PARAMETER                                  | MIN. | TYP. | MAX.   | TEST CONDITIONS <sup>1)</sup>                                                                                                                          | UNITS |
|-----------------------|--------------------------------------------|------|------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| V <sub>TM</sub>       | Maximum peak on-state voltage              | -    | -    | 1.45   | I <sub>TM</sub> =2220A                                                                                                                                 | V     |
|                       |                                            | -    | -    | 1.65   | I <sub>TM</sub> =3000A                                                                                                                                 | V     |
| V <sub>T0</sub>       | Threshold voltage                          | -    | -    | 0.833  |                                                                                                                                                        | V     |
| r <sub>T</sub>        | Slope resistance                           | -    | -    | 0.210  |                                                                                                                                                        | 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                     | -    | -    | 2      | Rated V <sub>DRM</sub> , T <sub>J</sub> =25°C                                                                                                          | mA    |
|                       |                                            | -    | -    | 100    | Rated V <sub>DRM</sub>                                                                                                                                 |       |
| I <sub>RRM</sub>      | Peak reverse current                       | -    | -    | 2      | Rated V <sub>RRM</sub> , T <sub>J</sub> =25°C                                                                                                          | mA    |
|                       |                                            | -    | -    | 100    | Rated V <sub>RRM</sub>                                                                                                                                 |       |
| V <sub>GT</sub>       | Gate trigger voltage                       | -    | -    | 2.5    | T <sub>vj</sub> = 25°C, V <sub>D</sub> = 10 V, I <sub>T</sub> = 3 A                                                                                    | V     |
| I <sub>GT</sub>       | Gate trigger current                       | -    | -    | 250    |                                                                                                                                                        | mA    |
| I <sub>H</sub>        | Holding current                            | -    | -    | 450    | T <sub>vj</sub> = 25°C                                                                                                                                 | mA    |
| I <sub>L</sub>        | Latching current                           | -    | -    | 1000   | T <sub>vj</sub> = 25°C                                                                                                                                 | mA    |
| t <sub>gd</sub>       | Gate controlled turn-on delay time         | -    | 0.8  | 2.0    | V <sub>D</sub> =67% V <sub>DRM</sub> , I <sub>T</sub> =2000A, 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                               | -    | 1.4  | 3.0    |                                                                                                                                                        |       |
| Q <sub>rr</sub>       | Recovered Charge                           | -    | 4000 | -      | I <sub>TM</sub> =1000A, t <sub>p</sub> =1000μs, di/dt=10A/μs, V <sub>r</sub> =50V                                                                      | μC    |
| Q <sub>ra</sub>       | Recovered Charge, 50% chord                | -    | 2300 | 2600   |                                                                                                                                                        | μC    |
| I <sub>rm</sub>       | Reverse recovery current                   | -    | 155  | -      |                                                                                                                                                        | A     |
| t <sub>rr</sub>       | Reverse recovery time, 50% chord           | -    | 30   | -      |                                                                                                                                                        | μs    |
| t <sub>q</sub>        | Turn-off time                              | -    | 375  | -      | I <sub>TM</sub> =1000A, t <sub>p</sub> =1000μs, di/dt=10A/μs, V <sub>r</sub> =50V, V <sub>dr</sub> =80%V <sub>DRM</sub> , dV <sub>dr</sub> /dt=20V/μs  | μs    |
|                       |                                            | -    | 650  | -      | I <sub>TM</sub> =1000A, t <sub>p</sub> =1000μs, di/dt=10A/μs, V <sub>r</sub> =50V, 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       | -    | -    | 0.0405 |                                                                                                                                                        | K/W   |
| R <sub>thCH</sub>     | Thermal resistance, case to heatsink       | -    | -    | 0.0100 |                                                                                                                                                        | K/W   |
| F <sub>1</sub>        | Mounting torque (to heatsink)              | 5.1  | -    | 6.9    |                                                                                                                                                        | Nm    |
| F <sub>2</sub>        | Mounting torque (to terminals)             | 16.2 | -    | 19.8   |                                                                                                                                                        | Nm    |
| W <sub>t</sub>        | Weight                                     | -    | 2.2  | -      |                                                                                                                                                        | kg    |

**Notes:**

1) Unless otherwise indicated T<sub>vj</sub>=125°C.

## Notes on Ratings and Characteristics

### 1.0 Voltage Grade Table

| Voltage Grade | $V_{DRM}$ $V_{DSM}$ $V_{RRM}$<br>V | $V_{RSM}$<br>V | $V_D$ $V_R$<br>DC V |
|---------------|------------------------------------|----------------|---------------------|
| 20            | 2000                               | 2100           | 1250                |
| 22            | 2200                               | 2300           | 1350                |

### 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  $T_{vj}$  below 25°C.

### 4.0 Repetitive dv/dt

Standard dv/dt is 1000V/μs.

### 5.0 Snubber Components

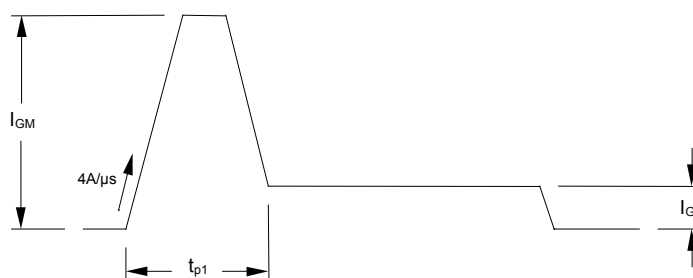
When selecting snubber components, care must be taken not to use excessively large values of snubber capacitor or excessively small values of snubber resistor. Such excessive component values may lead to device damage due to the large resultant values of snubber discharge current. If required, please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

### 6.0 Rate of rise of on-state current

The maximum un-primed rate of rise of on-state current must not exceed 300A/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 150A/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.

### 7.0 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  $I_{GT}$ .

## 8.0 Computer Modelling Parameters

### 8.1 Thyristor dissipation calculations

$$I_{AV} = \frac{-V_{T0} + \sqrt{V_{T0}^2 + 4 \cdot ff^2 \cdot r_T \cdot W_{AV}}}{2 \cdot ff^2 \cdot r_T} \quad \text{and:} \quad W_{AV} = \frac{\Delta T}{R_{th}}$$

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

Where  $V_{T0} = 0.833 \text{ V}$ ,  $r_T = 0.21 \text{ m}\Omega$ .

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

$ff$  = Form factor, see table below.

| Supplementary Thermal Impedance (Junction to Case) |        |        |        |        |        |        |        |
|----------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Conduction Angle                                   | 30°    | 60°    | 90°    | 120°   | 180°   | 270°   | d.c.   |
| Square wave                                        | 0.0456 | 0.0449 | 0.0440 | 0.0433 | 0.0423 | 0.0411 | 0.0405 |
| Sine wave                                          | 0.0448 | 0.0439 | 0.0431 | 0.0421 | 0.0409 |        |        |

| 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  |       |      |

### 8.2 Calculating thyristor $V_T$ using ABCD coefficients – For loss calculations

The on-state characteristic,  $I_T$  vs.  $V_T$ , 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                 | 0.7730476                  | A                  | -0.2378519                |
| B                 | 0.07410681                 | B                  | 0.2685822                 |
| C                 | $1.691121 \times 10^{-4}$  | C                  | $3.595580 \times 10^{-4}$ |
| D                 | $-7.725044 \times 10^{-3}$ | D                  | -0.02813815               |

## 8.3 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  $n$

- $n$  = 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. Junction to Case |                      |          |           |                           |                           |                      |
|-----------------------|----------------------|----------|-----------|---------------------------|---------------------------|----------------------|
| Term                  | 1                    | 2        | 3         | 4                         | 5                         | 6                    |
| $r_p$                 | $1.0 \times 10^{-5}$ | 0.016708 | 0.018317  | $4.346771 \times 10^{-3}$ | $1.004820 \times 10^{-3}$ | $1.0 \times 10^{-5}$ |
| $\tau_p$              | 2.460066             | 0.999836 | 21.998376 | $9.793053 \times 10^{-3}$ | 2.003674                  | 5.007343             |

## 9.0 Reverse recovery ratings

- (i)  $Q_{rr}$  is based on 50%  $I_{RM}$  chord as shown in Fig. 1

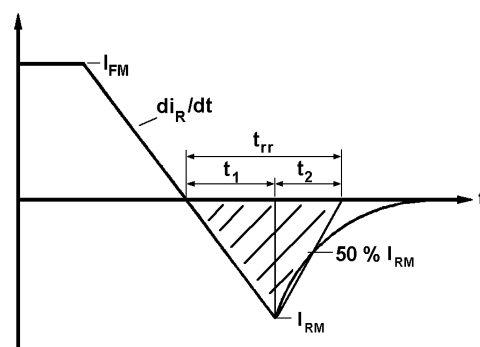


Fig. 1

- (ii)  $Q_{rr}$  is based on a 150  $\mu s$  integration time i.e.

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

- (iii)

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

**Curves**

Figure 1 – On-state characteristics of Limit device

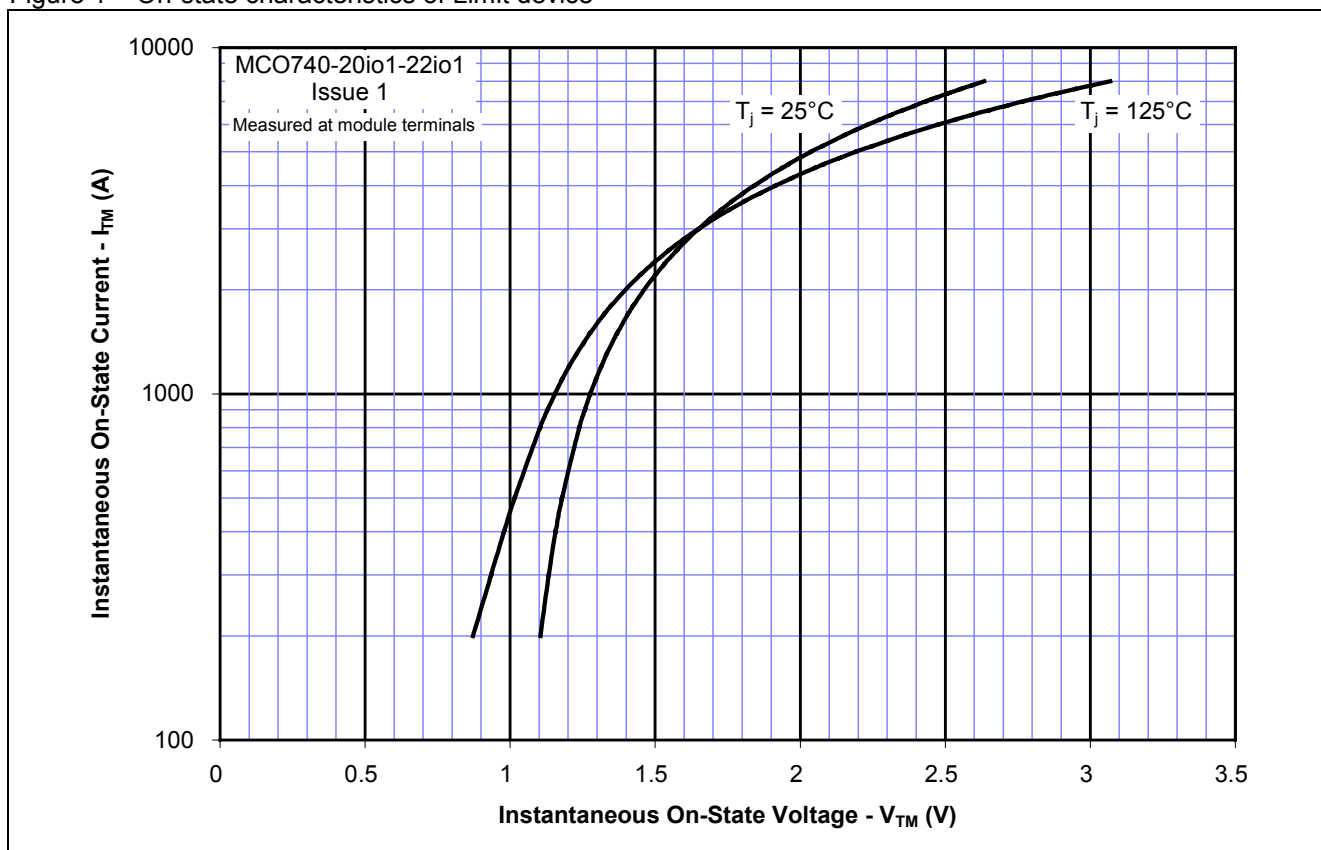


Figure 2 – Gate characteristics – Trigger limits

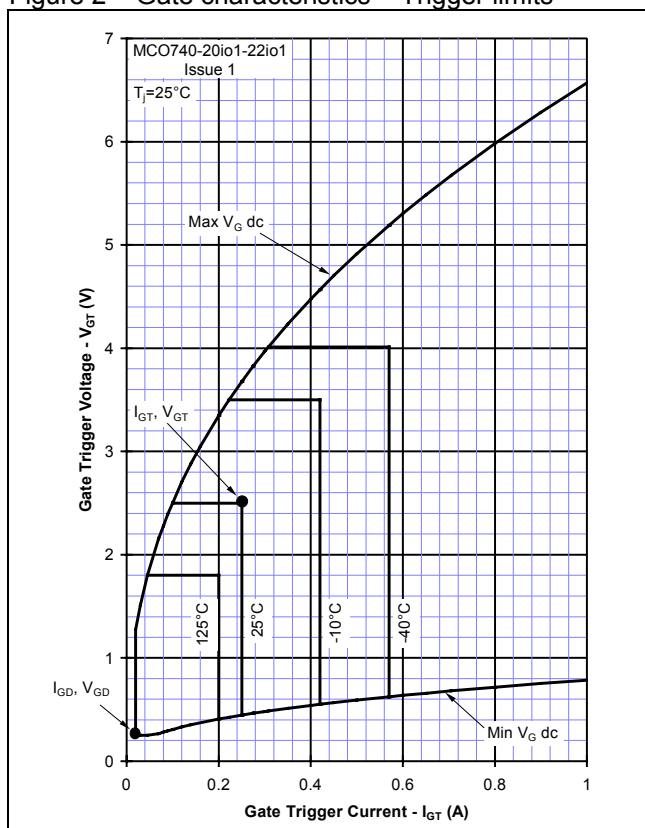


Figure 3 – Gate characteristics – Power curves

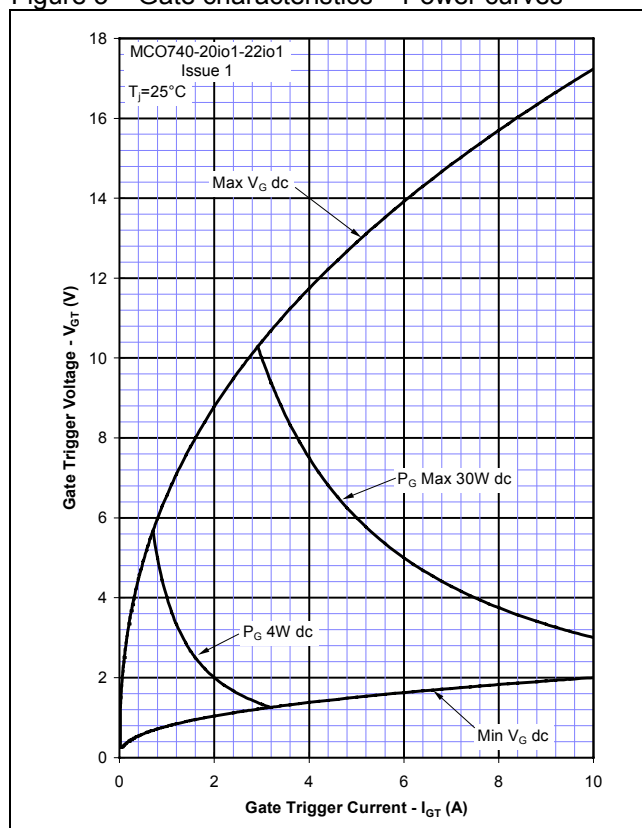


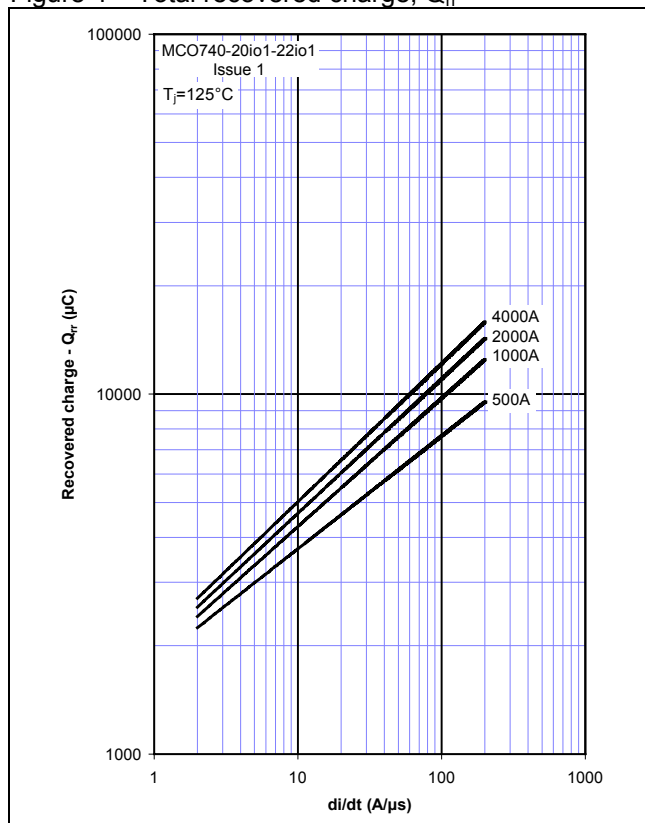
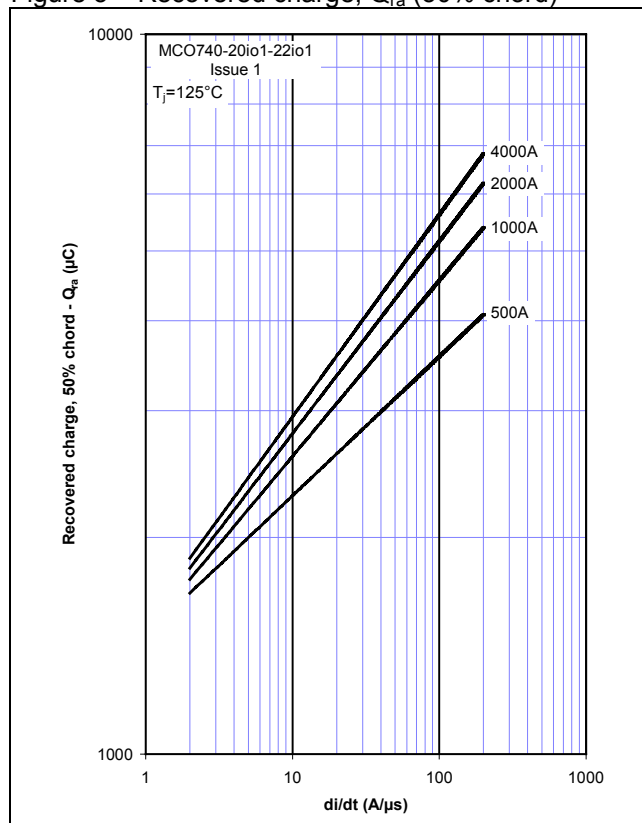
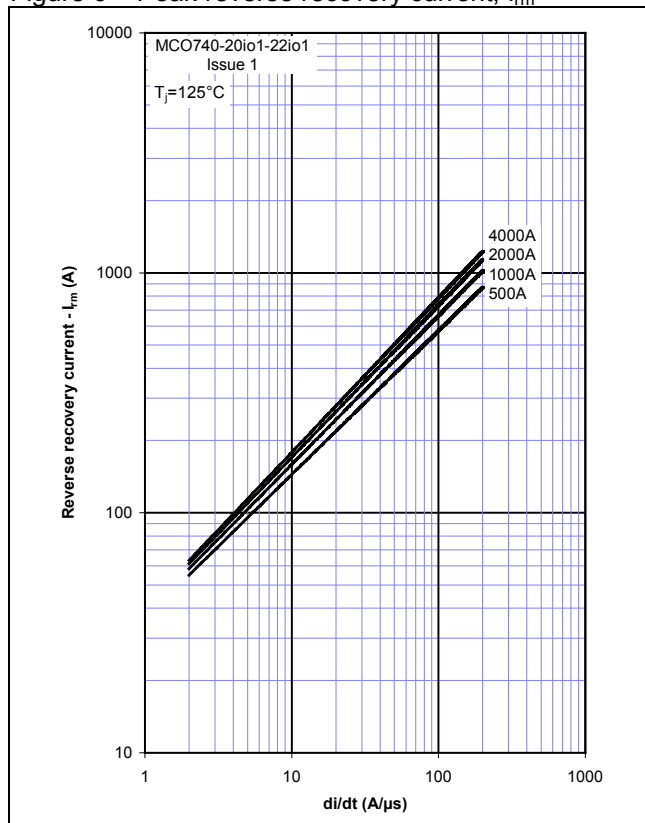
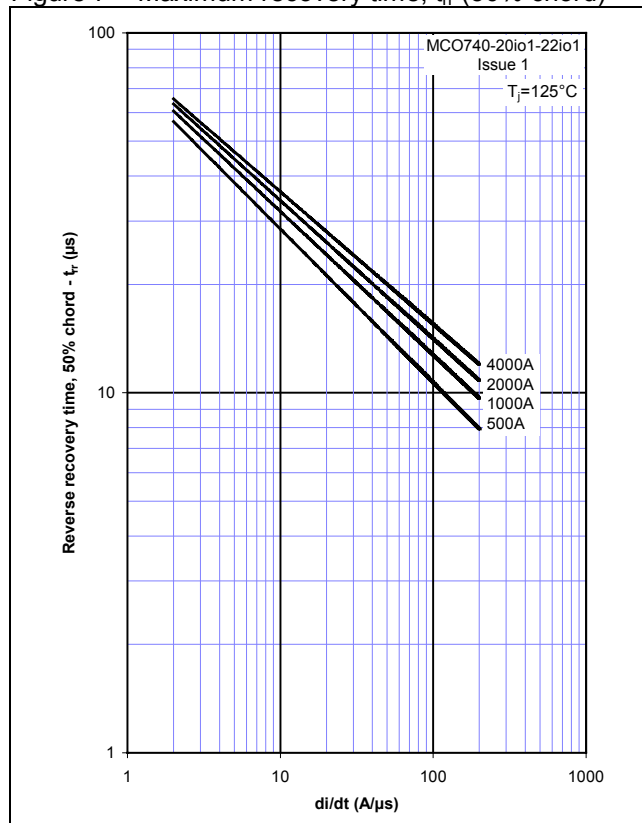
Figure 4 – Total recovered charge,  $Q_{rr}$ Figure 5 – Recovered charge,  $Q_{ra}$  (50% chord)Figure 6 – Peak reverse recovery current,  $I_{rm}$ Figure 7 – Maximum recovery time,  $t_{rr}$  (50% chord)

Figure 8 – On-state current vs. Power dissipation – Sine wave

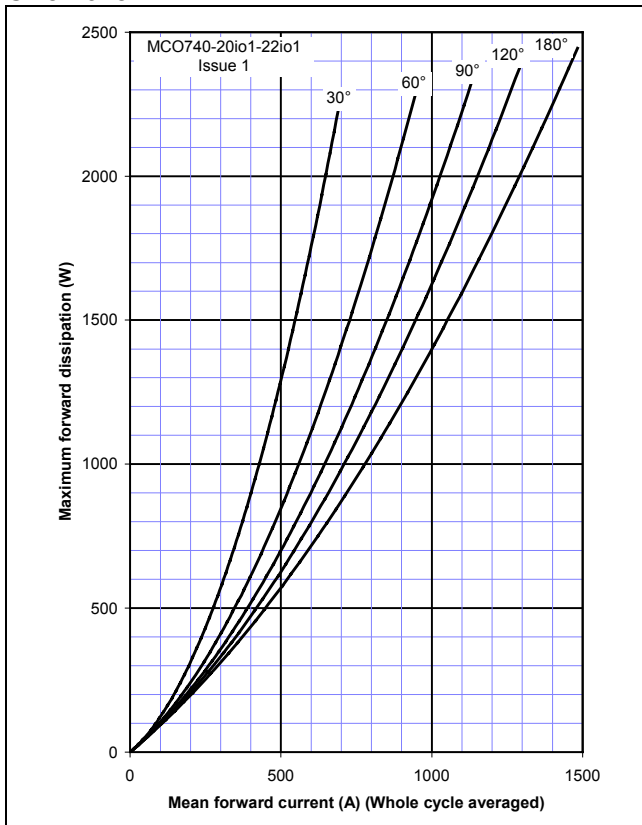


Figure 9 – On-state current vs. Heatsink temperature – Sine wave

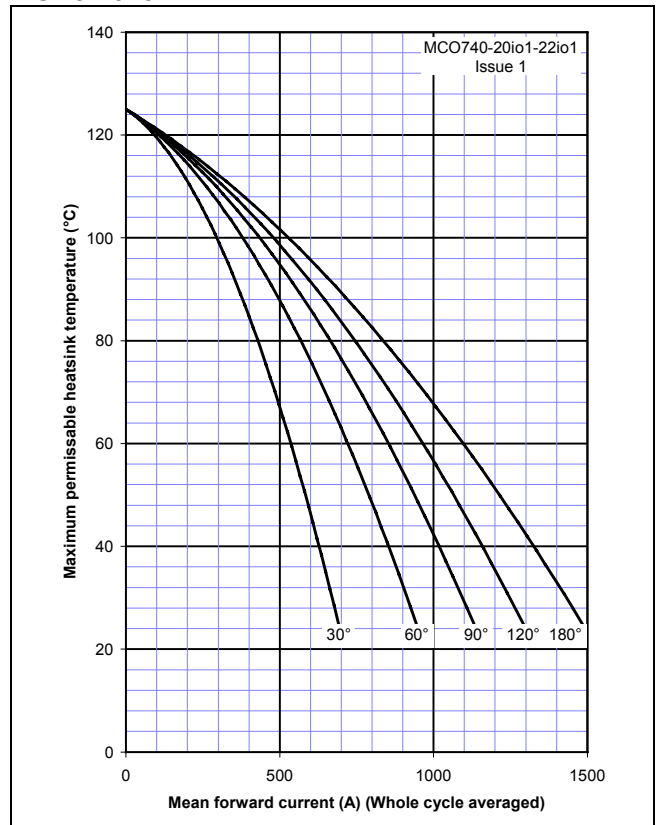


Figure 10 – On-state current vs. Power dissipation – Square wave

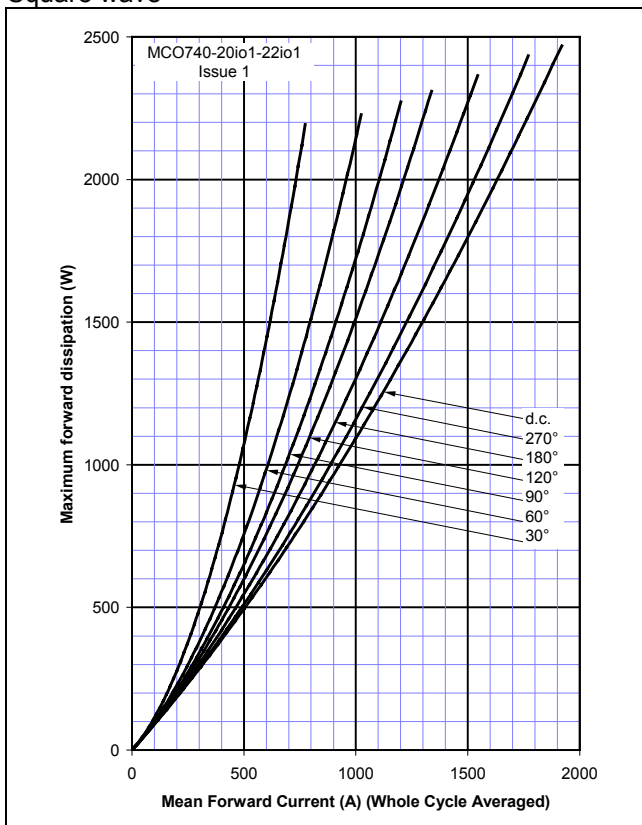


Figure 11 – On-state current vs. Heatsink temperature – Square wave

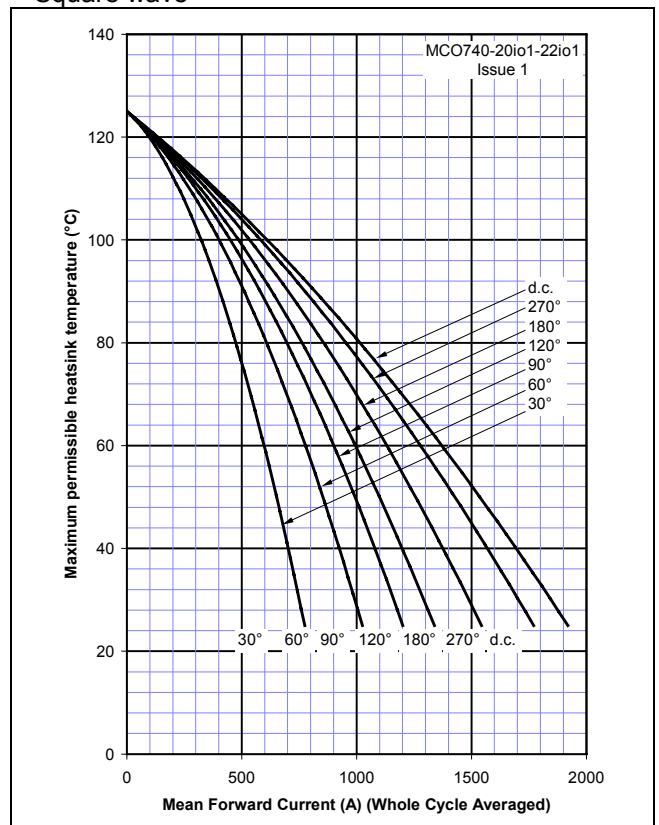


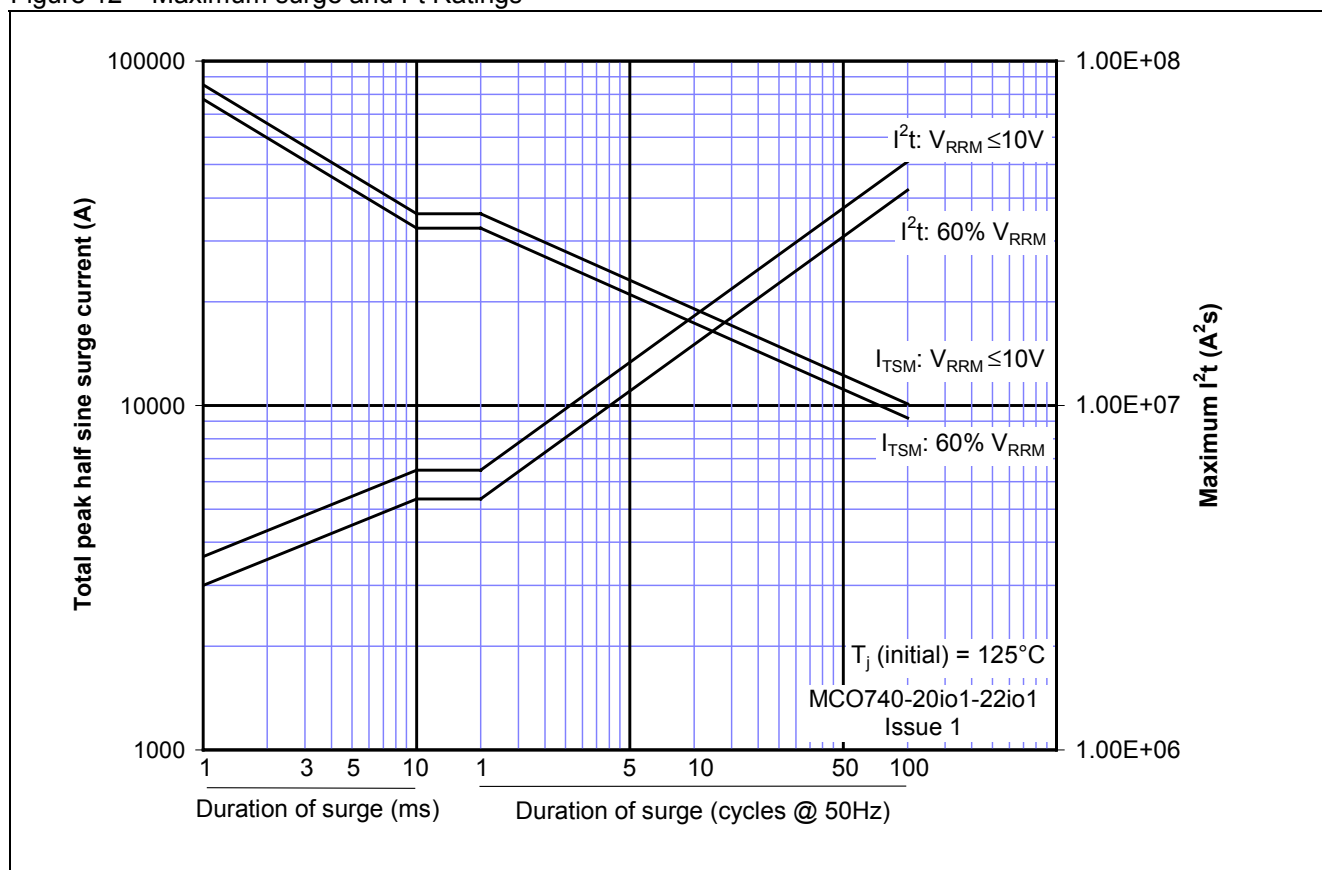
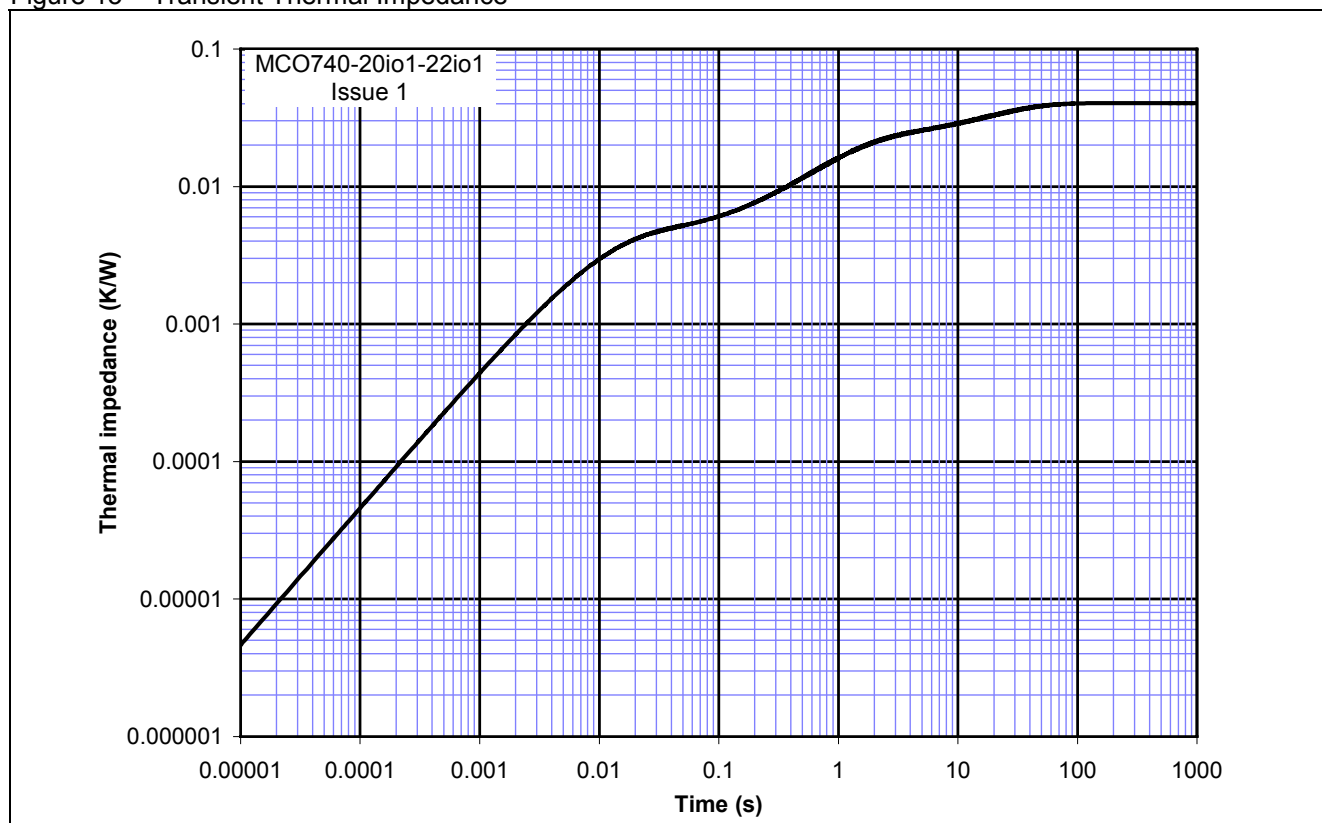
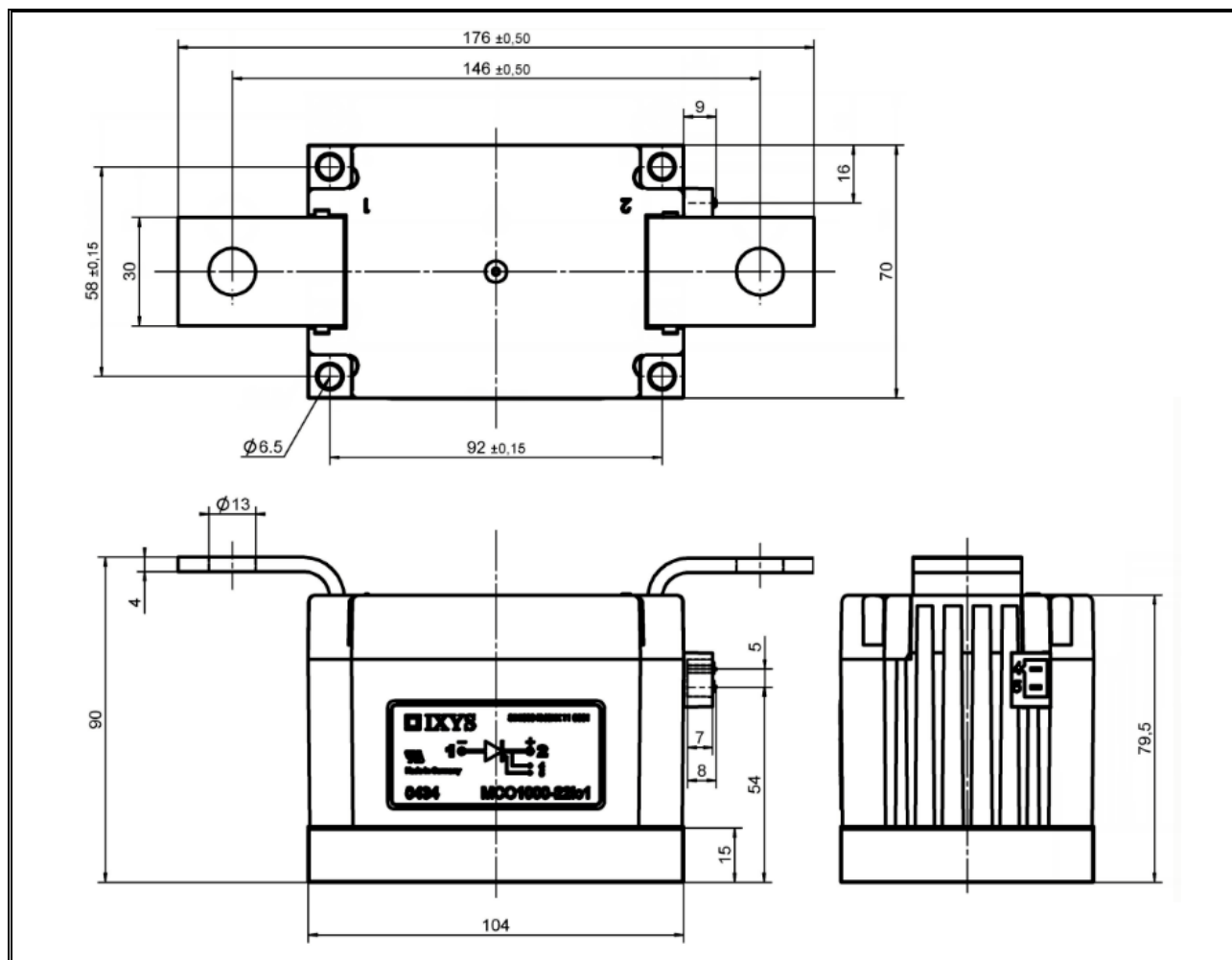
Figure 12 – Maximum surge and  $I^2t$  Ratings

Figure 13 – Transient Thermal Impedance



## Outline Drawing &amp; Ordering Information



## ORDERING INFORMATION

(Please quote 11 digit code as below)

| M                  | CO                          | 740                       | ◆◆                                     | io                                                        | 1                     |
|--------------------|-----------------------------|---------------------------|----------------------------------------|-----------------------------------------------------------|-----------------------|
| Fixed<br>Type Code | Fixed<br>Configuration code | Nominal Current<br>Rating | Voltage code<br>$V_{RRM}/100$<br>20-22 | i = Critical dv/dt 1000 V/μs<br>o = Typical turn-off time | Fixed<br>Version Code |

Typical order code: MCO740-20io1, 2000V  $V_{DRM}$ ,  $V_{RRM}$  thyristor module

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