| | | |
|---|---|---|
| $V_{DRM}$ | = | 5500 V |
| $I_{TGQM}$ | = | 900 A |
| $I_{TSM}$ | = | $7.5 \times 10^3$ A |
| $V_{(T0)}$ | = | 1.65 V |
| $r_T$ | = | 2 mΩ |
| $V_{DC\text{-}link}$ | = | 3300 V |

# Reverse Conducting Integrated Gate-Commutated Thyristor

# 5SHX 10H6010

## PRELIMINARY

Doc. No. 5SYA1226-05 Aug 07

- **High snubberless turn-off rating**
- **Optimized for medium frequency (<1 kHz) and low turn-off losses**
- **High reliability**
- **High electromagnetic immunity**
- **Simple control interface with status feedback**
- **AC or DC supply voltage**
- **Suitable for series connection (contact factory)**

## Blocking

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Repetitive peak off-state voltage | $V_{DRM}$ | Gate Unit energized | | | 5500 | V |
| Permanent DC voltage for 100 FIT failure rate of RC-GCT | $V_{DC\text{-}link}$ | Ambient cosmic radiation at sea level in open air. Gate Unit energized | | | 3300 | V |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Repetitive peak off-state current | $I_{DRM}$ | $V_D = V_{DRM}$, Gate Unit energized | | | 20 | mA |

## Mechanical data (see Fig. 20, 21)

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Mounting force | $F_m$ | | 18 | 20 | 22 | kN |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Pole-piece diameter | $D_p$ | ± 0.1 mm | | 63 | | mm |
| Housing thickness | H | | 26.0 | | 26.5 | mm |
| Weight | m | | | | 1.7 | kg |
| Surface creepage distance | $D_s$ | Anode to Gate | 33 | | | mm |
| Air strike distance | $D_a$ | Anode to Gate | 13 | | | mm |
| Length | l | ± 1.0 mm | | 296 | | mm |
| Height | h | ± 1.0 mm | | 48 | | mm |
| Width IGCT | w | ± 1.0 mm | | 208 | | mm |

Note 1 Maximum rated values indicate limits beyond which damage to the device may occur

# GCT Data

## On-state (see Fig. 3 to 6, 23)

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Max. average on-state current | $I_{T(AV)M}$ | Half sine wave, $T_C$ = 85 °C, Double side cooled | | | 350 | A |
| Max. RMS on-state current | $I_{T(RMS)}$ | | | | 560 | A |
| Max. peak non-repetitive surge on-state current | $I_{TSM}$ | $t_p$ = 10 ms, $T_j$ = 115 °C, sine wave after surge: $V_D = V_R$ = 0 V | | | $7.5\times10^3$ | A |
| Limiting load integral | $I^2t$ | | | | $281\times10^3$ | $A^2s$ |
| Max. peak non-repetitive surge on-state current | $I_{TSM}$ | $t_p$ = 1 ms, $T_j$ = 115 °C, sine wave after surge: $V_D = V_R$ = 0 V | | | $15\times10^3$ | A |
| Limiting load integral | $I^2t$ | | | | $112\times10^3$ | $A^2s$ |
| Critical rate of rise of on-state current | $di_T/dt_{cr}$ | For higher $di_T/dt$ and current lower than 50 A an external retrigger pulse is required. | | | TBD | A/µs |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| On-state voltage | $V_T$ | $I_T$ = 900 A, $T_j$ = 115 °C | | | 3.45 | V |
| Threshold voltage | $V_{(T0)}$ | $T_j$ = 115 °C $I_T$ = 200...2000 A | | | 1.65 | V |
| Slope resistance | $r_T$ | | | | 2 | mΩ |

## Turn-on switching (see Fig. 23, 25)

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Critical rate of rise of on-state current | $di_T/dt_{cr}$ | f = 500 Hz, $T_j$ = 115 °C, $I_T$ = 900 A, $V_D$ = 3300 V | | | 285 | A/µs |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Turn-on delay time | $t_{don}$ | $V_D$ = 3300 V, $T_j$ = 115 °C $I_T$ = 900 A, di/dt = $V_D$ / $L_i$ $L_i$ = 11.5 µH $C_{CL}$ = 2 µF, $L_{CL}$ = 0.6 µH | | | 3 | µs |
| Turn-on delay time status feedback | $t_{don\ SF}$ | | | | 7 | µs |
| Rise time | $t_r$ | | | | 1 | µs |
| Turn-on energy per pulse | $E_{on}$ | | | | 0.5 | J |

## Turn-off switching (see Fig. 7, 8, 23, 25)

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Max. controllable turn-off current | $I_{TGQM}$ | $V_{DM} \le V_{DRM}$, $T_j$ = 115 °C, $V_D$ = 3300 V, $R_S$ = 1.25 Ω, $C_{CL}$ = 2 µF, $L_{CL} \le$ 0.6 µH | | | 900 | A |
| Max. controllable turn-off current | $I_{TGQM}$ | $V_{DM} \le V_{DRM}$, $T_j$ = 115 °C, $V_D$ = 3900 V, $R_S$ = 1.25 Ω, $C_{CL}$ = 2 µF, $L_{CL} \le$ 0.6 µH | | | 460 | A |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Turn-off delay time | $t_{doff}$ | $V_D$ = 3300 V, $T_j$ = 115 °C $V_{DM} \le V_{DRM}$, $R_S$ = 1.25 Ω $I_{TGQ}$ = 900 A, $L_i$ = 11.5 µH $C_{CL}$ = 2 µF, $L_{CL}$ = 0.6 µH, | | | 6 | µs |
| Turn-off delay time status feedback | $t_{doff\ SF}$ | | | | 7 | µs |
| Turn-off energy per pulse | $E_{off}$ | | | | 4.8 | J |

# Diode Data

## On-state (see Fig. 9 to 12, 24, 25)

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Max. average on-state current | $I_{F(AV)M}$ | Half sine wave, $T_C$ = 85 °C | | | 170 | A |
| Max. RMS on-state current | $I_{F(RMS)}$ | | | | 260 | A |
| Max. peak non-repetitive surge current | $I_{FSM}$ | $t_p$ = 10 ms, $T_{vj}$ = 115°C, $V_R$ = 0 V | | | $7.6\times10^3$ | A |
| Limiting load integral | $I^2t$ | | | | $288.8\times10^3$ | $A^2s$ |
| Max. peak non-repetitive surge current | $I_{FSM}$ | $t_p$ = 1 ms, $T_{vj}$ = 115°C, $V_R$ = 0 V | | | $17.5\times10^3$ | A |
| Limiting load integral | $I^2t$ | | | | $153\times10^3$ | $A^2s$ |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| On-state voltage | $V_F$ | $I_F$ = 900 A, $T_{vj}$ = 115°C | | | 6.4 | V |
| Threshold voltage | $V_{(F0)}$ | $T_{vj}$ = 115°C<br>$I_F$ = 200...2000 A | | | 2.53 | V |
| Slope resistance | $r_F$ | | | | 4.3 | mΩ |

## Turn-on (see Fig. 24, 25)

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Peak forward recovery voltage | $V_{FRM}$ | $dI_F/dt$ = 350 A/µs, $T_{vj}$ = 115°C | | | 80 | V |
| | | $dI_F/dt$ = 1600 A/µs, $T_{vj}$ = 115°C | | | 250 | V |

## Turn-off (see Fig. 13 to 17, 24, 25)

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Max. decay rate of on-state current | $di/dt_{crit}$ | $I_{FM}$ = 900 A, $T_{vj}$ = 115 °C<br>$V_{DClink}$ = 3900 V | | | 285 | A/µs |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Reverse recovery current | $I_{RM}$ | $I_{FM}$ = 900 A, $V_{DC\text{-}Link}$ = 3300 V<br>$-dI_F/dt$ = 285 A/µs, $L_{CL}$ = 0.6 µH<br>$C_{CL}$ = 2 µF, $R_S$ = 1.25 Ω,<br>$T_{vj}$ = 115°C, $D_{CL}$ = 5SDF 02D6004 | | | 430 | A |
| Reverse recovery charge | $Q_{rr}$ | | | | TBD | µC |
| Turn-off energy | $E_{rr}$ | | | | 2.6 | J |

# Gate Unit Data

## Power supply (see Fig. 18, 19)

***Maximum rated values*** *Note 1*

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Gate Unit voltage (Connector X1) | $V_{GIN,RMS}$ | AC square wave amplitude (15 kHz - 100kHz) or DC voltage. No galvanic isolation to power circuit. | 28 | | 40 | V |
| Min. current needed to power up the Gate Unit | $I_{GIN\ Min}$ | Rectified average current see application note 5SYA 2031 | 1.1 | | | A |
| Gate Unit power consumption | $P_{GIN\ Max}$ | | | | 80 | W |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Internal current limitation | $I_{GIN\ Max}$ | Rectified average current limited by the Gate Unit | | | 7 | A |

## Optical control input/output 2) (see Fig. 23)

***Maximum rated values*** *Note 1*

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Min. on-time | $t_{on}$ | | 40 | | | µs |
| Min. off-time | $t_{off}$ | | 40 | | | µs |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Optical input power | $P_{on\ CS}$ | CS: Command signal SF: Status feedback Valid for 1mm plastic optical fiber (POF) | -15 | | -1 | dBm |
| Optical noise power | $P_{off\ CS}$ | | | | -45 | dBm |
| Optical output power | $P_{on\ SF}$ | | -19 | | -1 | dBm |
| Optical noise power | $P_{off\ SF}$ | | | | -50 | dBm |
| Pulse width threshold | $t_{GLITCH}$ | Max. pulse width without response | | | 400 | ns |
| External retrigger pulse width | $t_{retrig}$ | | 600 | | 1100 | ns |

2) Do not disconnect or connect fiber optic cables while light is on.

## Connectors 2) (see Fig. 20 to 22)

| Parameter | Symbol | Description |
|---|---|---|
| Gate Unit power connector | X1 | AMP: MTA-156, Part Number 641210-5 3) |
| LWL receiver for command signal | CS | Avago, Type HFBR-2528 4) |
| LWL transmitter for status feedback | SF | Avago, Type HFBR-1528 4) |

2) Do not disconnect or connect fiber optic cables while light is on.

3) AMP, www.amp.com

4) Avago Technologies, www.avagotech.com

## Visual feedback (see Fig. 22)

| Parameter | Symbol | Description | Color |
|---|---|---|---|
| Gate OFF | LED1 | "Light" when GCT is off | (green) |
| Gate ON | LED2 | "Light" when gate-current is flowing | (yellow) |
| Fault | LED3 | "Light" when not ready / Failure | (red) |
| Power supply voltage OK | LED4 | "Light" when power supply is within specified range | (green) |

# Thermal

***Maximum rated values*** [Note 1]

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Junction operating temperature | $T_{vj}$ | | 0 | | 115 | °C |
| Storage temperature range | $T_{stg}$ | | -40 | | 60 | °C |
| Ambient operational temperature | $T_a$ | | 0 | | 60 | °C |

***Characteristic values***

| Parameter | Symbol | Conditions | min | typ | max | Unit |
|---|---|---|---|---|---|---|
| Thermal resistance junction-to-case of GCT | $R_{th(jc)}$ | Double side cooled | | | 25 | K/kW |
| Thermal resistance case-to-heatsink of GCT | $R_{th(ch)}$ | Diode not dissipating | | | 8 | K/kW |
| Thermal resistance junction-to-case of Diode | $R_{th(jc)}$ | Double side cooled | | | 42 | K/kW |
| Thermal resistance case-to-heatsink of Diode | $R_{th(ch)}$ | GCT not dissipating | | | 8 | K/kW |

**Analytical function for transient thermal impedance:**

$$Z_{thJC}(t) = \sum_{i=1}^{n} R_i(1 - e^{-t/\tau_i})$$

**GCT**

| i | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $R_i$(K/kW) | 15.295 | 5.736 | 2.684 | 1.289 |
| $\tau_i$(s) | 0.4820 | 0.0758 | 0.0076 | 0.0023 |

**Diode**

| i | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $R_i$(K/kW) | 25.199 | 9.964 | 4.491 | 2.347 |
| $\tau_i$(s) | 0.4963 | 0.0802 | 0.0076 | 0.0023 |

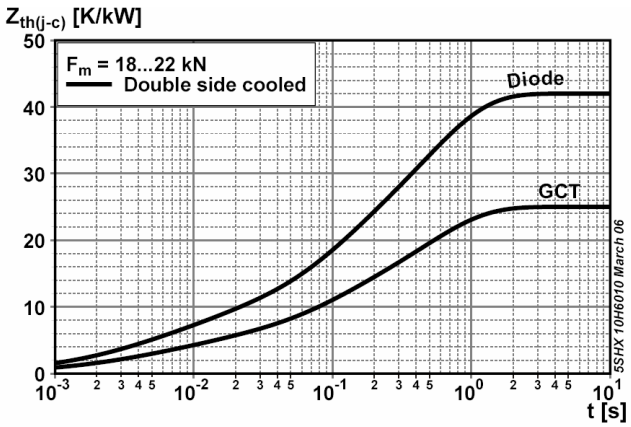



**Fig. 1** Transient thermal impedance (junction-to-case) vs. time (max. values)

**Max. Turn-off current for Lifetime operation**

- calculated lifetime of on-board capacitors 20 years
- with slightly forced air cooling (air velocity > 0.5 m/s)
- strong air cooling allows for increased ambient temperature

TBD

**Fig. 2** Max. turn-off current vs. frequency for lifetime operation

# GCT Part

**Max. on-state characteristic model:**

$$V_{T25} = A_{Tvj} + B_{Tvj} \cdot I_T + C_{Tvj} \cdot \ln(I_T + 1) + D_{Tvj} \cdot \sqrt{I_T}$$

Valid for $i_T$ = TBD – TBD A

| $A_{25}$ | $B_{25}$ | $C_{25}$ | $D_{25}$ |
|---|---|---|---|
| TBD | TBD | TBD | TBD |

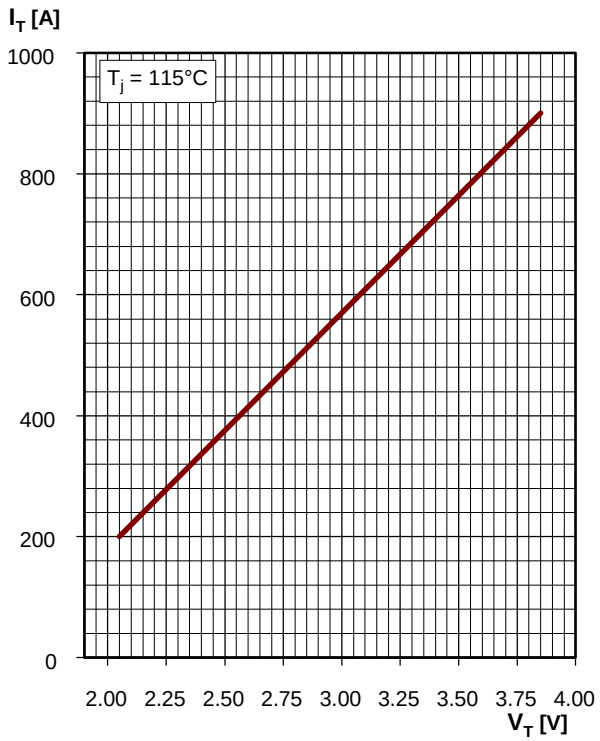



**Fig. 3** GCT on-state voltage characteristics

**Max. on-state characteristic model:**

$$V_{T115} = A_{Tvj} + B_{Tvj} \cdot I_T + C_{Tvj} \cdot \ln(I_T + 1) + D_{Tvj} \cdot \sqrt{I_T}$$

Valid for $i_T$ = TBD – TBD A

| $A_{115}$ | $B_{115}$ | $C_{115}$ | $D_{115}$ |
|---|---|---|---|
| TBD | TBD | TBD | TBD |

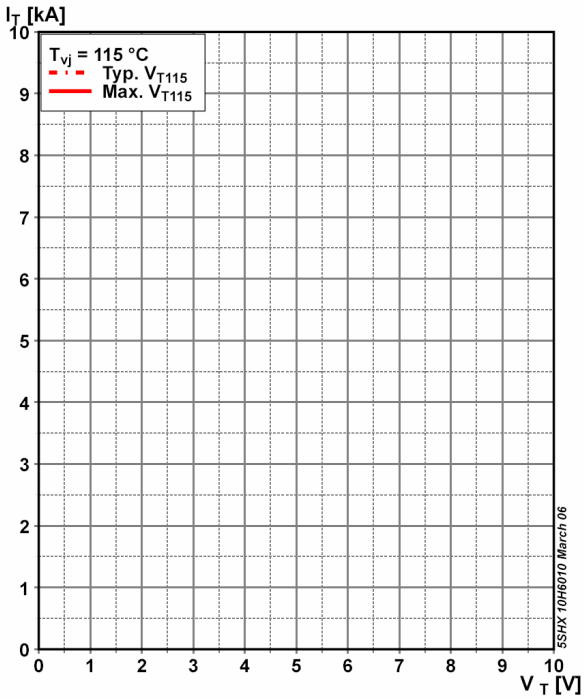



**Fig. 4** GCT on-state voltage characteristics

TBD

**Fig. 5** GCT surge on-state current vs. pulse length, half-sine wave

TBD

**Fig. 6** GCT surge on-state current vs. number of pulses, half-sine wave, 10 ms, 50Hz

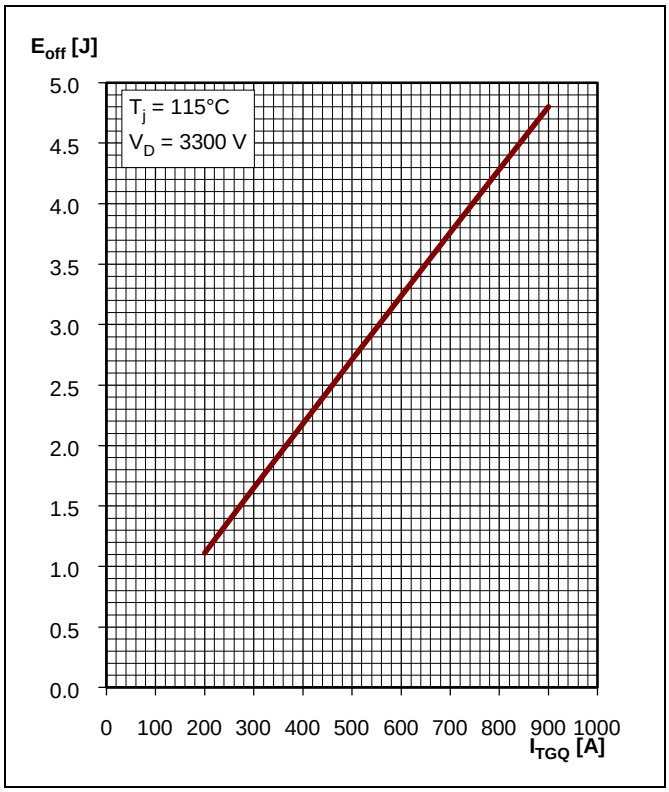



**Fig. 7** GCT turn-off energy per pulse vs. turn-off current

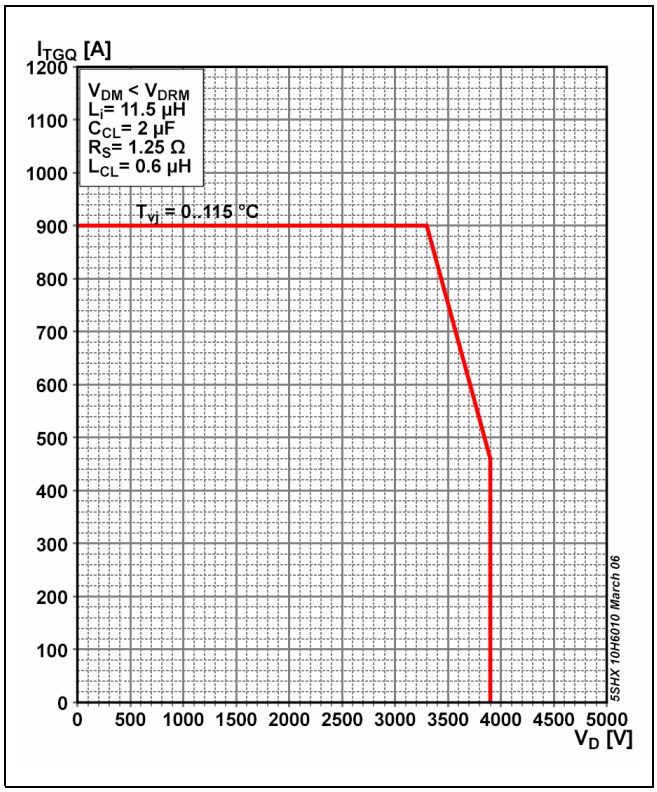



**Fig. 8** GCT Safe Operating Area

# Diode Part

**Max. on-state characteristic model:**

$$V_{F25} = A_{Tvj} + B_{Tvj} \cdot I_T + C_{Tvj} \cdot \ln(I_T + 1) + D_{Tvj} \cdot \sqrt{I_T}$$

Valid for $I_F$ = TBD – TBD A

| $A_{25}$ | $B_{25}$ | $C_{25}$ | $D_{25}$ |
|---|---|---|---|
| TBD | TBD | TBD | TBD |

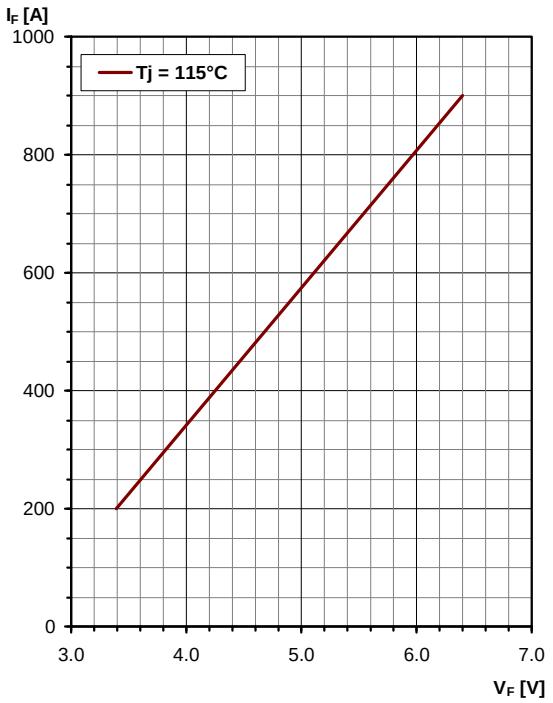



**Fig. 9** Diode on-state voltage characteristics

**Max. on-state characteristic model:**

$$V_{F115} = A_{Tvj} + B_{Tvj} \cdot I_T + C_{Tvj} \cdot \ln(I_T + 1) + D_{Tvj} \cdot \sqrt{I_T}$$

Valid for $I_T$ = TBD – TBD A

| $A_{115}$ | $B_{115}$ | $C_{115}$ | $D_{115}$ |
|---|---|---|---|
| TBD | TBD | TBD | TBD |

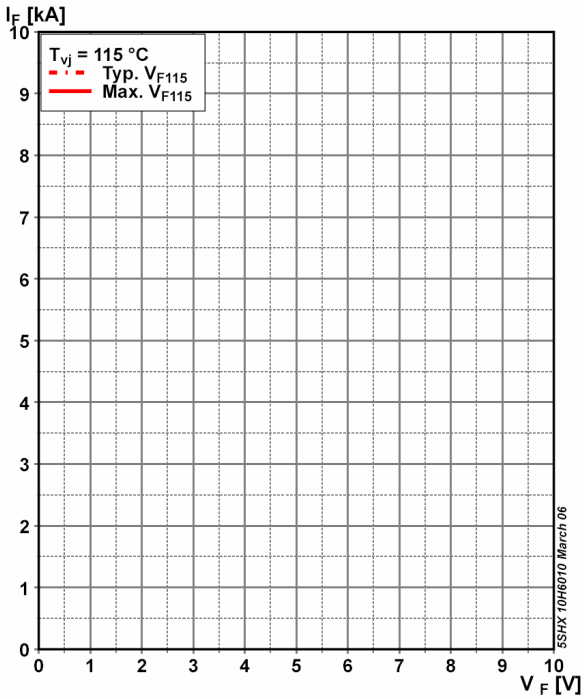



**Fig. 10** Diode on-state voltage characteristics

TBD

**Fig. 11** Diode surge on-state current vs. pulse length, half-sine wave

TBD

**Fig. 12** Diode surge on-state current vs. number of pulses, half-sine wave, 10 ms, 50Hz

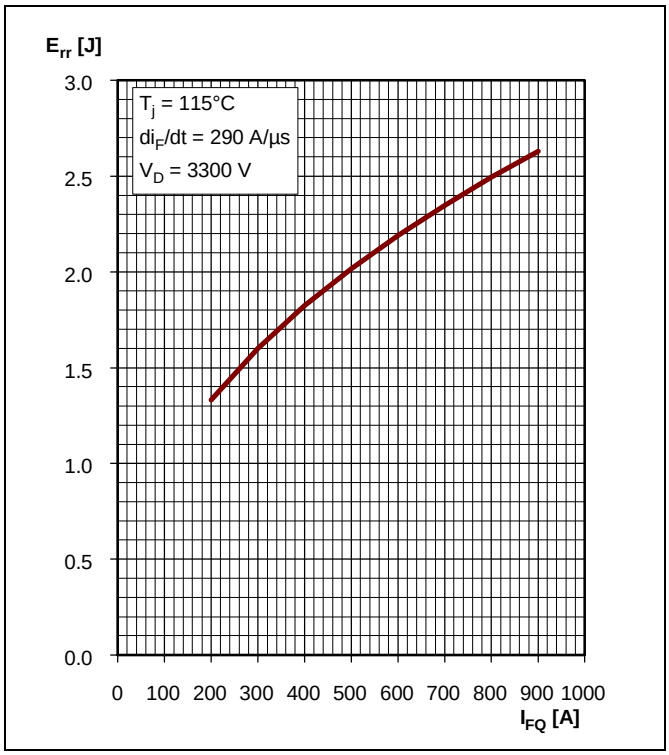



**Fig. 13** Upper scatter range of diode turn-off energy per pulse vs. turn-off current

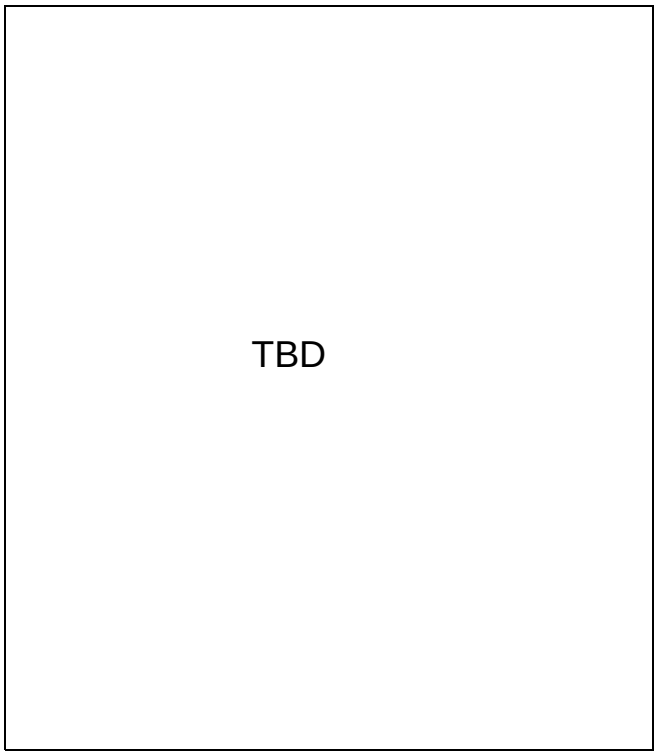



**Fig. 14** Upper scatter range of diode turn-off energy per pulse vs decay rate of on-state current

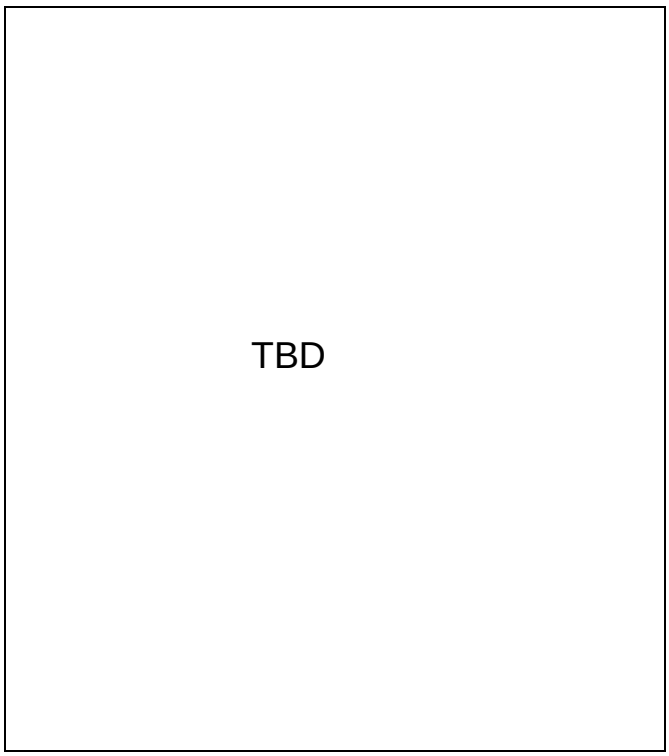



**Fig. 15** Upper scatter range of diode reverse recovery charge vs decay rate of on-state current

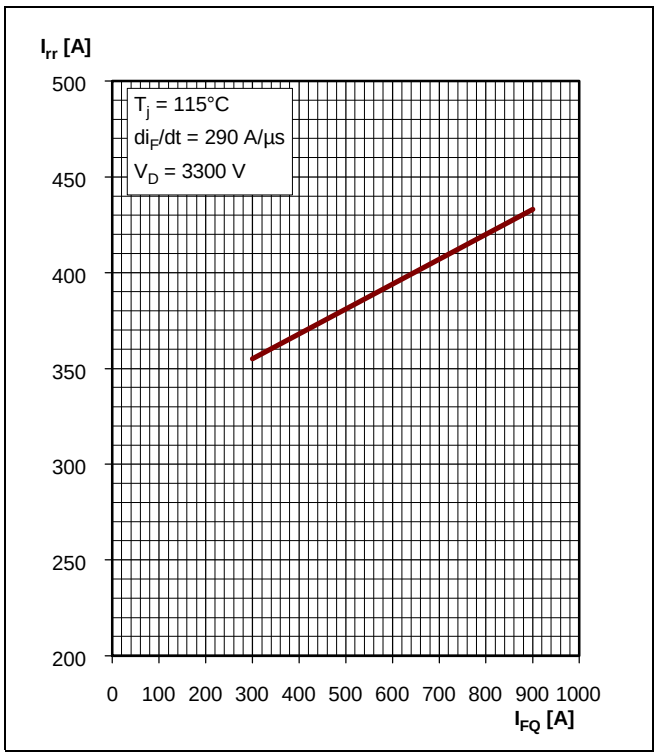



**Fig. 16** Upper scatter range of diode reverse recovery current vs decay rate of on-state current

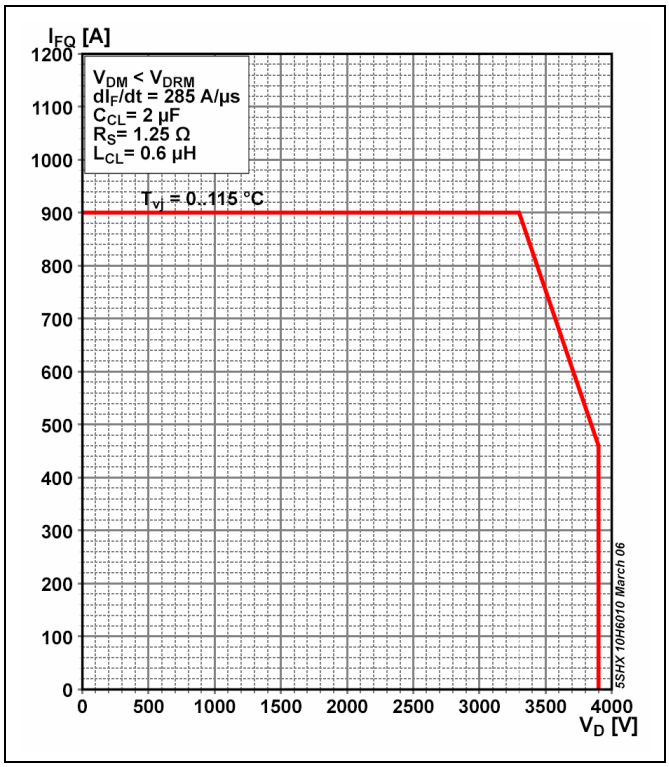



**Fig. 17** Diode Safe Operating Area

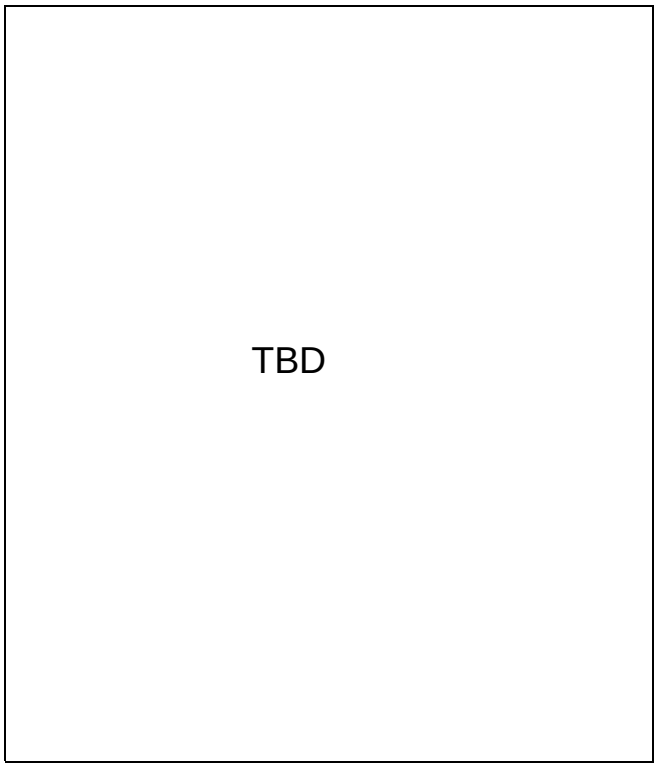



**Fig. 18** Max. Gate Unit input power in chopper mode

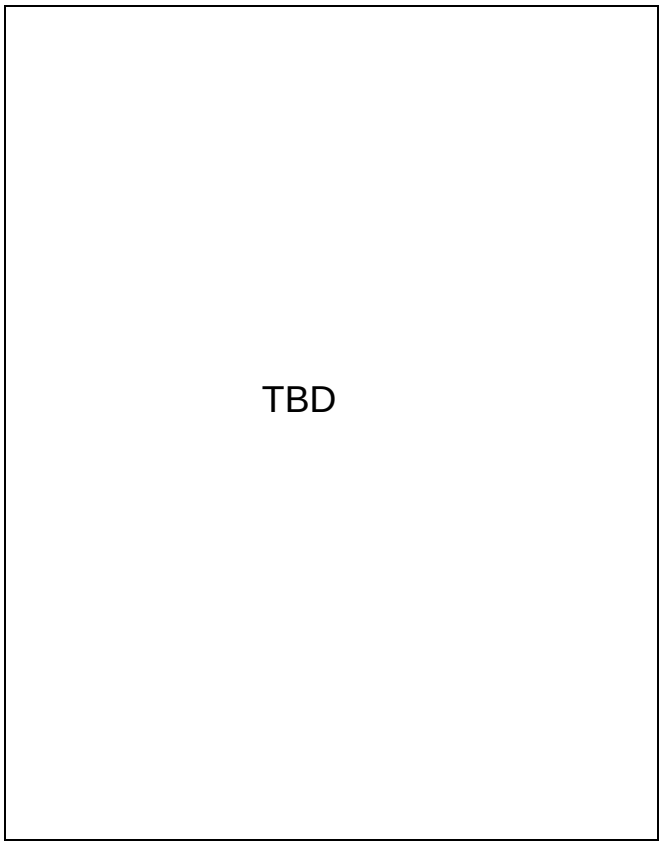



**Fig. 19** Burst capability of Gate Unit

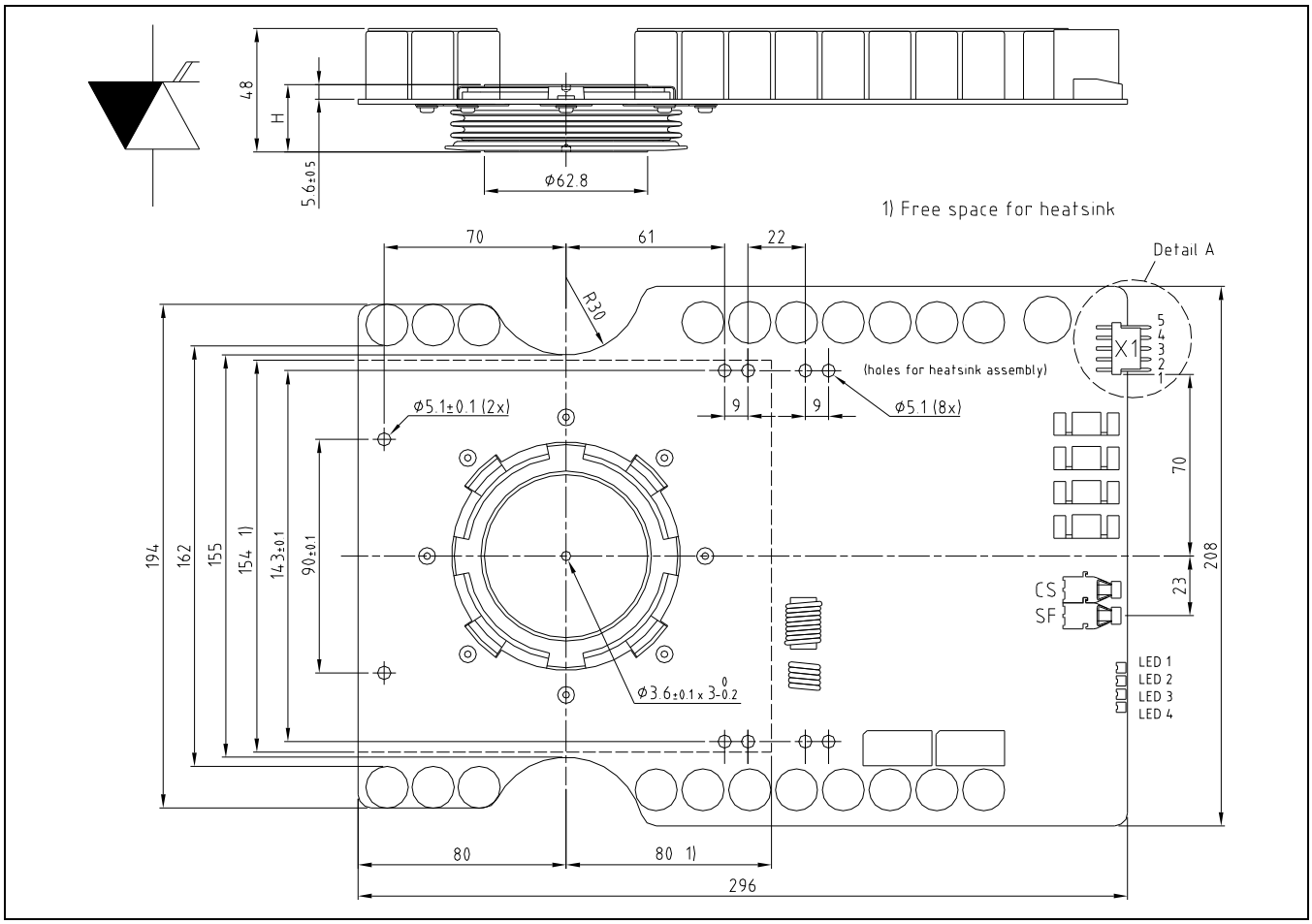
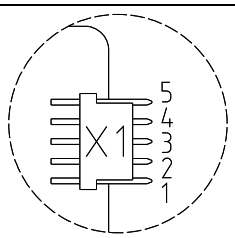



**Fig. 20** Outline drawing; all dimensions are in millimeters and represent nominal values unless stated otherwise




1) $V_{GIN}$ (AC or DC+)
2) $V_{GIN}$ (AC or DC+)
3) Cathode
4) $V_{GIN}$ (AC or DC-)
5) $V_{GIN}$ (AC or DC-)

**Fig. 21** Detail A: pin out of supply connector X1.

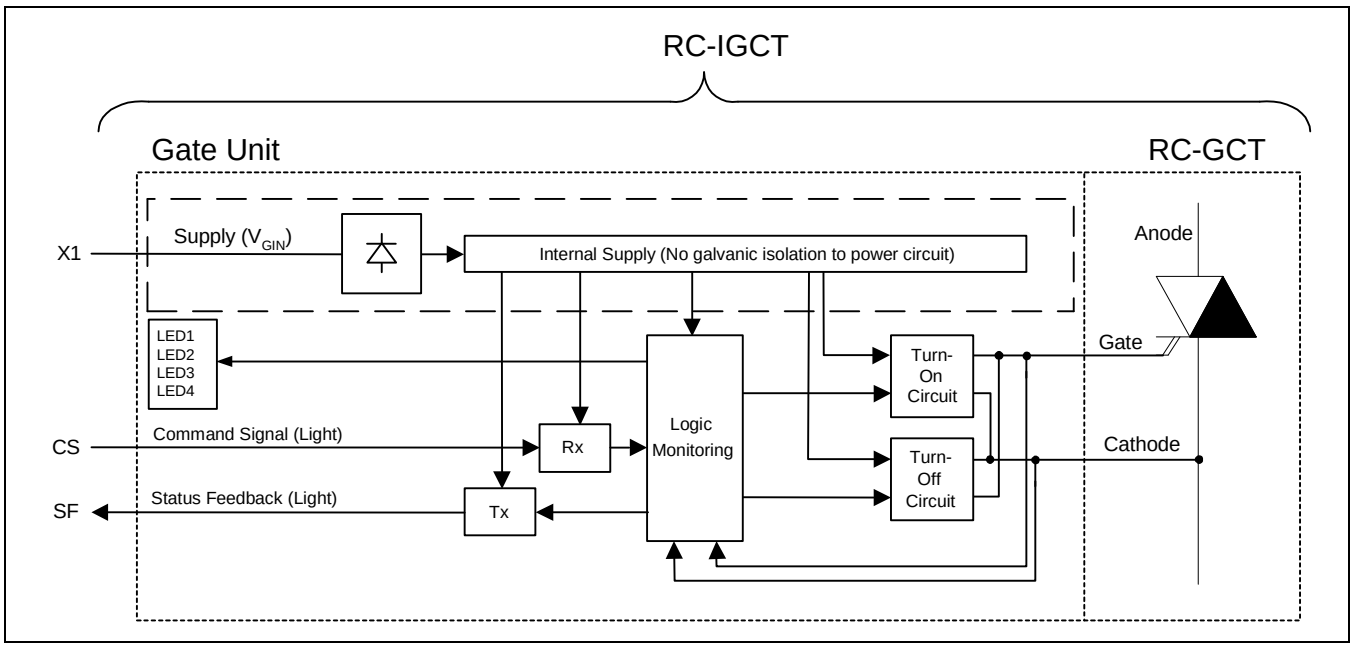



**Fig. 22** Block diagram

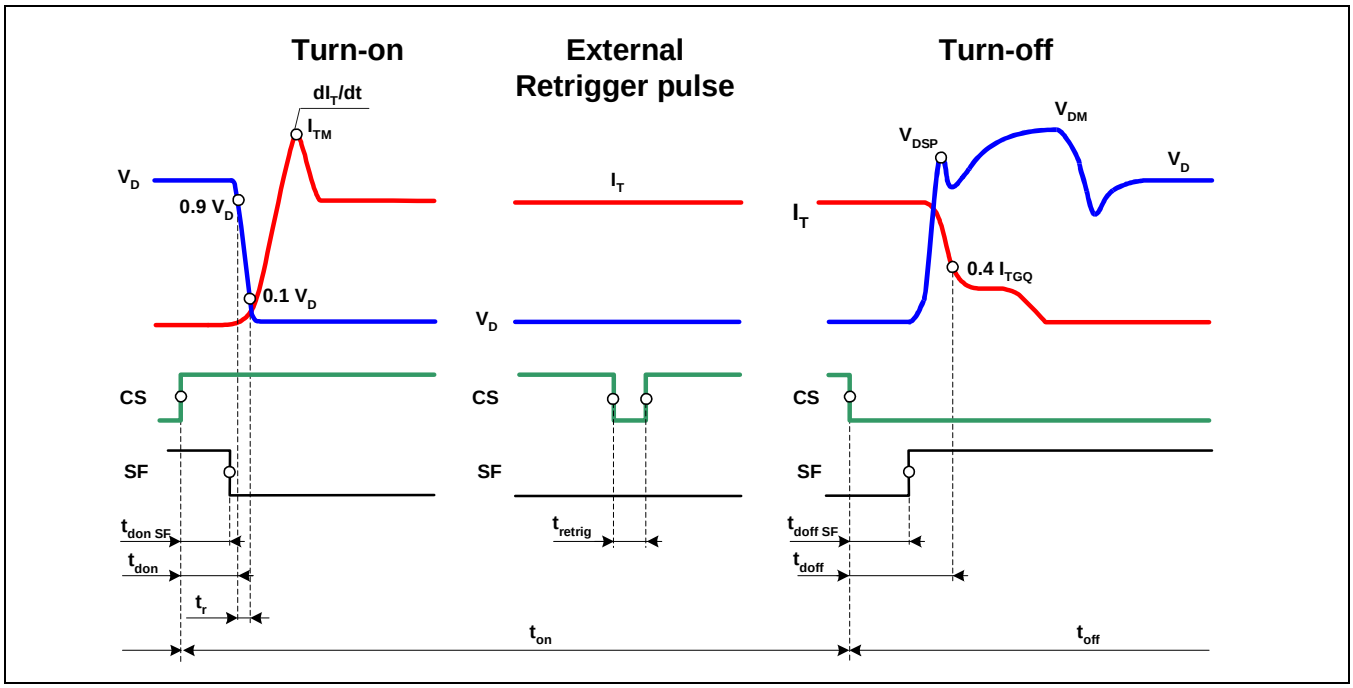



**Fig. 23** General current and voltage waveforms with IGCT-specific symbols

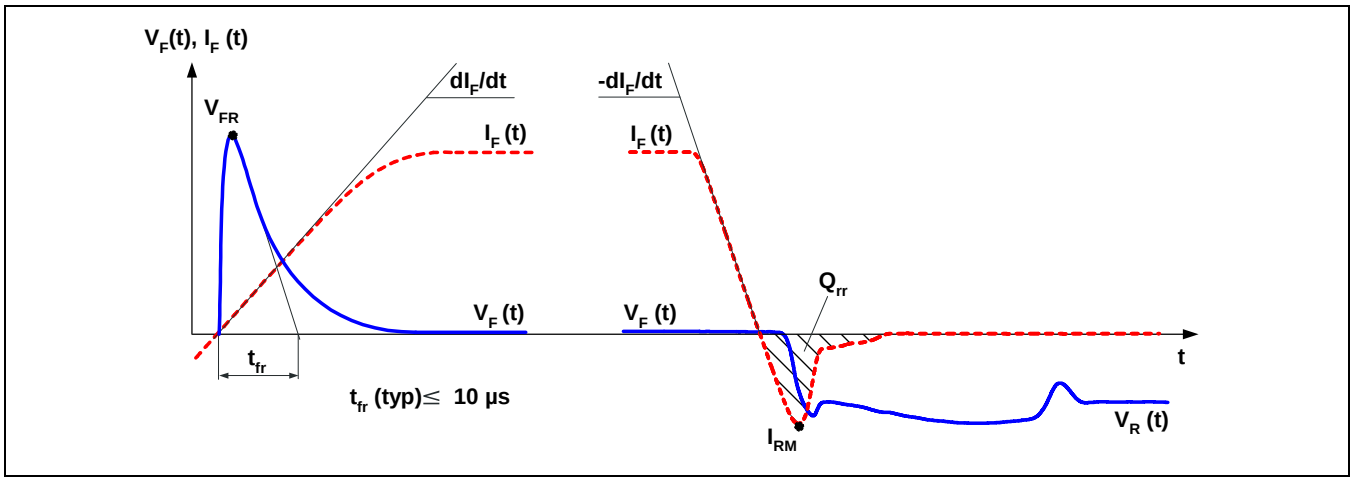



**Fig. 24** General current and voltage waveforms with Diode-specific symbols

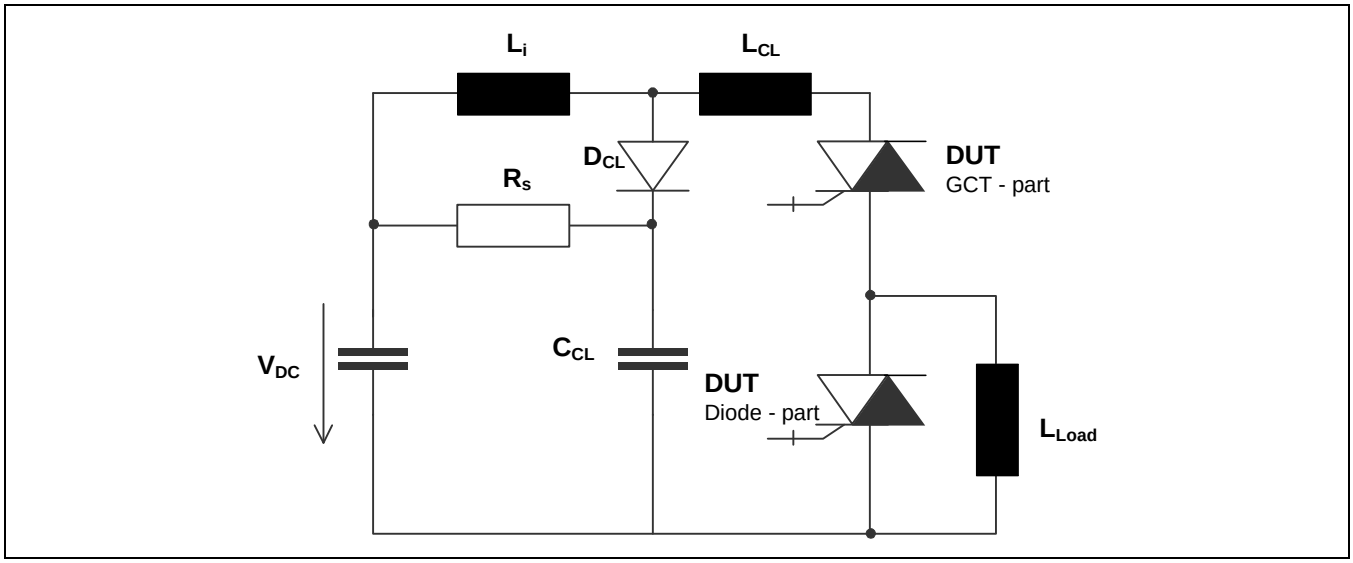



**Fig. 25** Test circuit

## Related documents:

| | |
|---|---|
| 5SYA 2031 | Applying IGCT Gate Units |
| 5SYA 2032 | Applying IGCTs |
| 5SYA 2036 | Recommendations regarding mechanical clamping of Press Pack High Power Semiconductors |
| 5SYA 2046 | Failure rates of IGCTs due to cosmic rays |
| 5SYA 2048 | Field measurements on High Power Press Pack Semiconductors |
| 5SYA 2051 | Voltage ratings of high power semiconductors |
| 5SZK 9107 | Specification of enviromental class for pressure contact IGCTs, OPERATION available on request, please contact factory |

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