Tuesday, April 25, 2023

- 03:00 pm CEST | EMEA session
- 02:00 pm EDT | Americas session

Webinar

Active Discharge and Pre-charge of EV High Voltage Power Bus

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Active Discharge of EV High Voltage Power Bus

1. Why do we need to discharge HV Bus ?
2. How can we discharge HV bus ?
3. Benchmarking Discharge Switch
4. Why using THYRISTOR ?
5. THYRISTOR Product range
6. Reference Design for HV Bus discharge
7. How to diagnose the discharge function ?
8. Live demo of Diagnostic and HV bus Discharge

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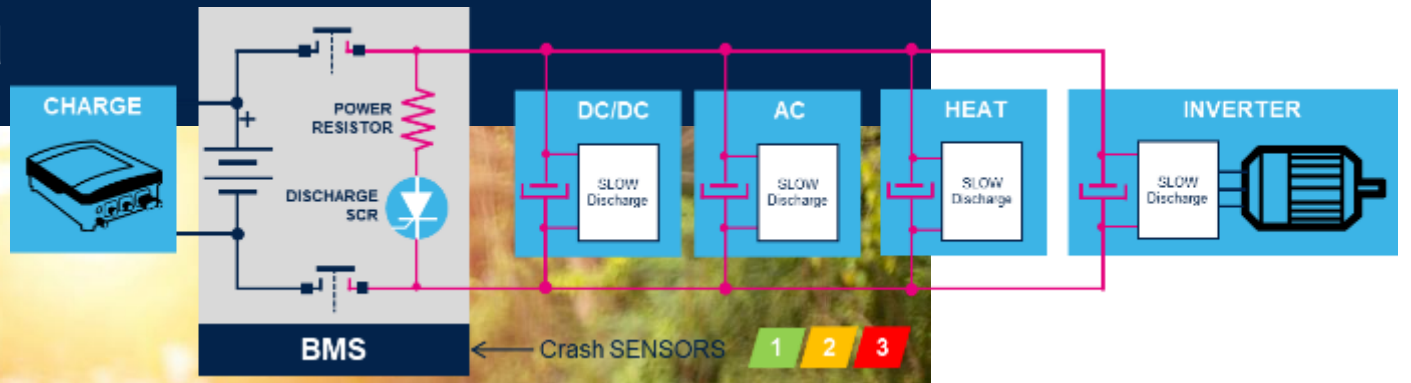
BMS Active Discharge with THYRISTOR

Fast Discharge prevents Fire hazard



In critical events the HV system shall be actively discharged to prevent short circuit fire and electrical shocks by residual voltage.

The battery voltage is disconnected by a separate disconnection unit.

All DC Capacitors are discharged in power resistors with minimal value in order to minimize the discharge time

Safety Requirement in **ISO-6469** specify discharge in less than 10s but SCR Discharge in few milliseconds will limit the risk of Fire.

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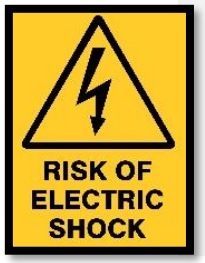
ISO 6469 – Part 4
Post crash electrical safety

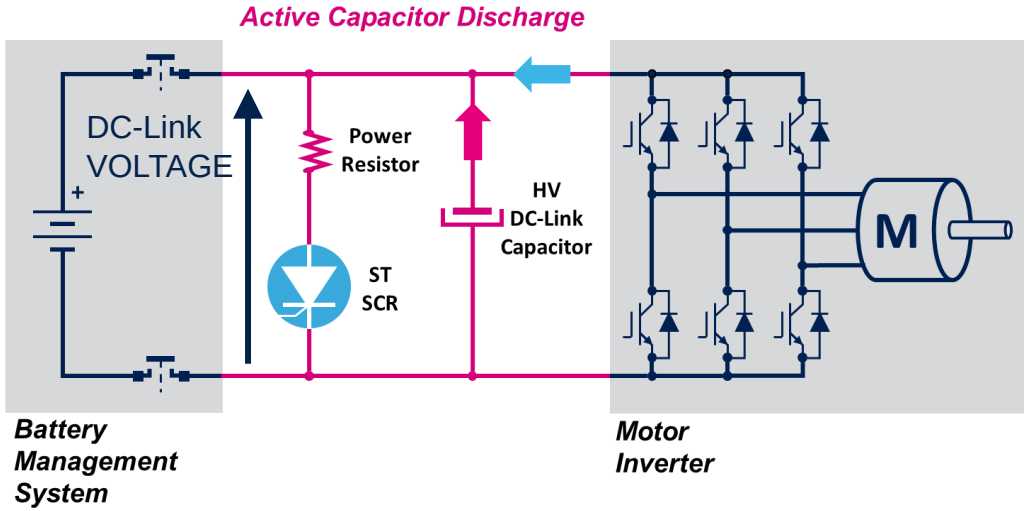


5.2.2 Voltage limit

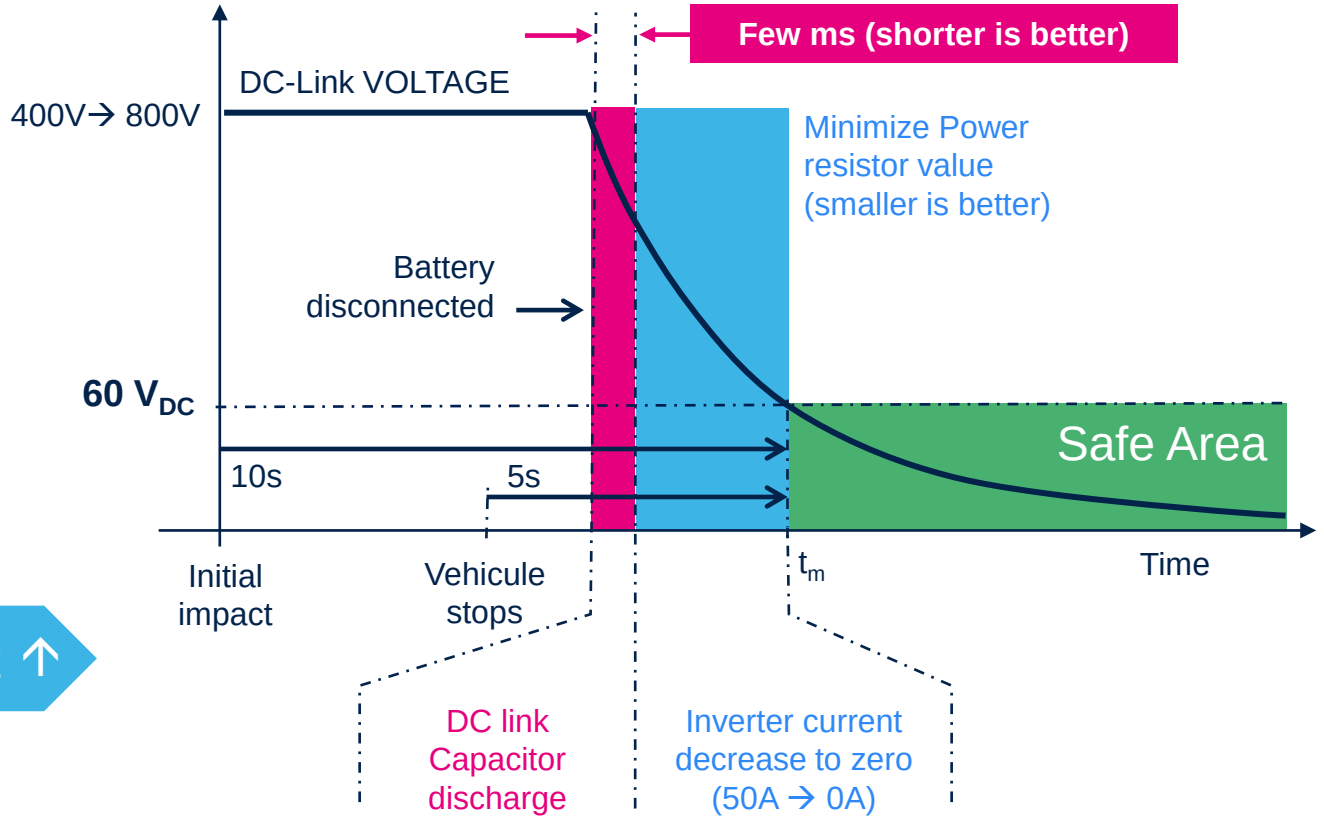
The voltages V_b, V_1, and V_2 (see Figure 1) of the voltage class B electric circuits shall be equal to or less than 30 V a.c. (rms) or 60 V d.c. at a point in time t_m which is specified as

— either 10 s after the initial impact, if the vehicle comes to rest within 5 s after the initial impact, or

— 5 s after the vehicle comes to rest, if the vehicle does not come to rest within 5 s after the initial impact.



Time to 60V ↓ → R ↓ → Discharge Current ↑



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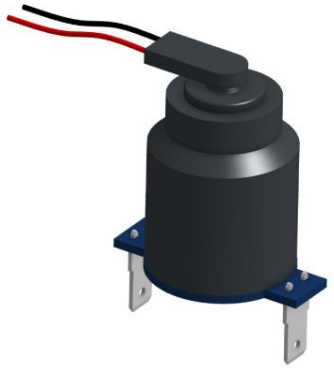
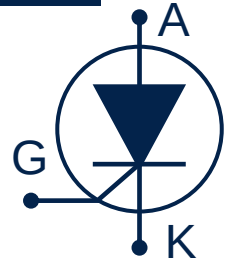
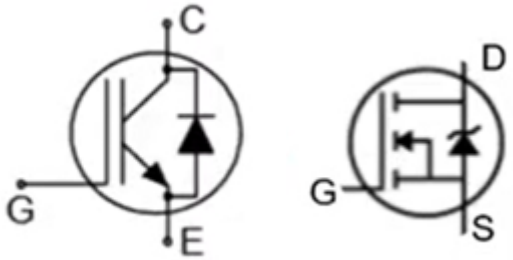
HV Capacitive discharge SWITCH Benchmark



FOCUS





	PyroSwitch	THYRISTOR	IGBT / MOSFET
Switch	Close	Close	Close / Open
Discharge	Single	Multiple	Multiple
Fails	SHORT	SHORT	OPEN
Peak Current	5000A	Up to 3000A	< 100A
Size	25 x 30 x 60 mm	6.5 x 9.7 x 2.3 mm	6.5 x 9.7 x 2.3 mm
Price	✪✪✪	✪	✪✪

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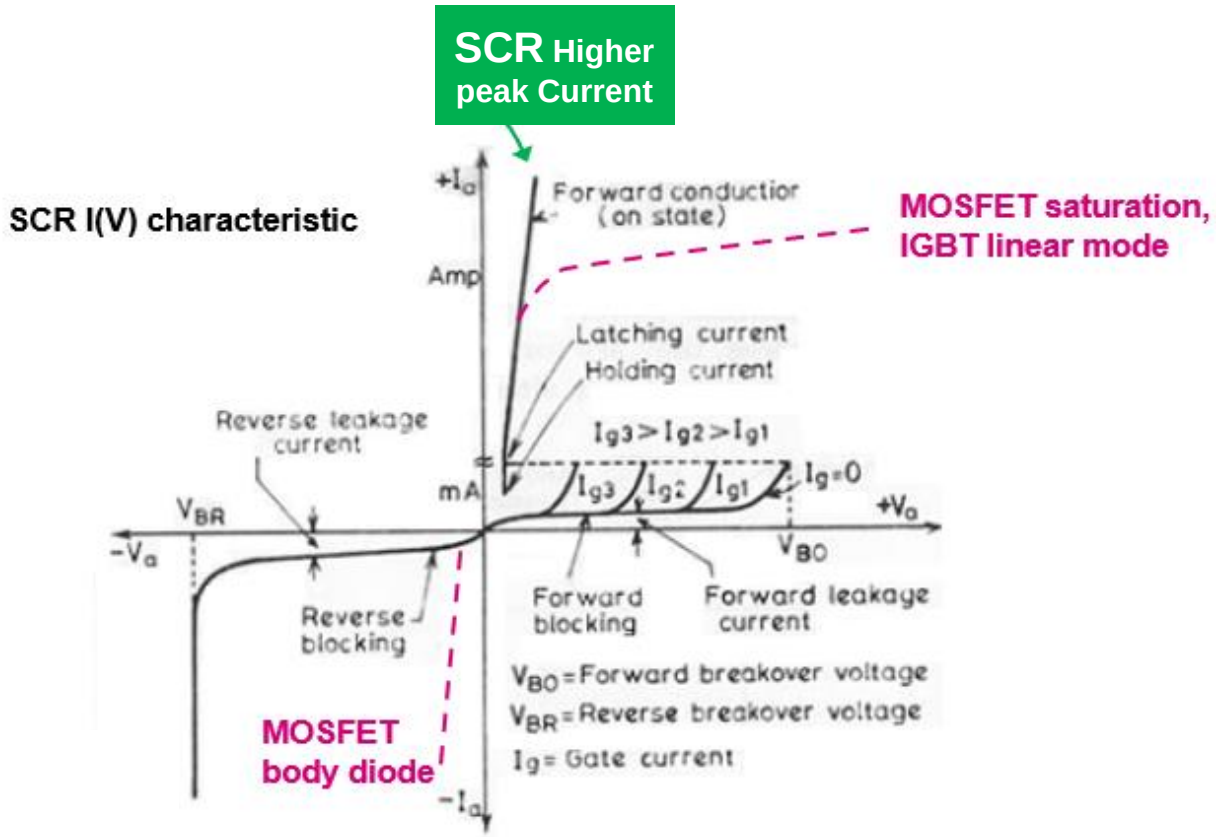
Why using SCR for HV discharge ?



MOSFET & IGBT are turned ON with Gate Voltage

MOSFET Peak current will be limited by Saturation region

IGBT Peak current will be limited by linear Mode

SCR is latched by Gate current pulse

Once the SCR is latched, gate current can be removed

SCR Peak current is much higher than MOSFET or IGBT

For HV Capacitive Discharge, only SCR are able to support >2000A @ 1ms

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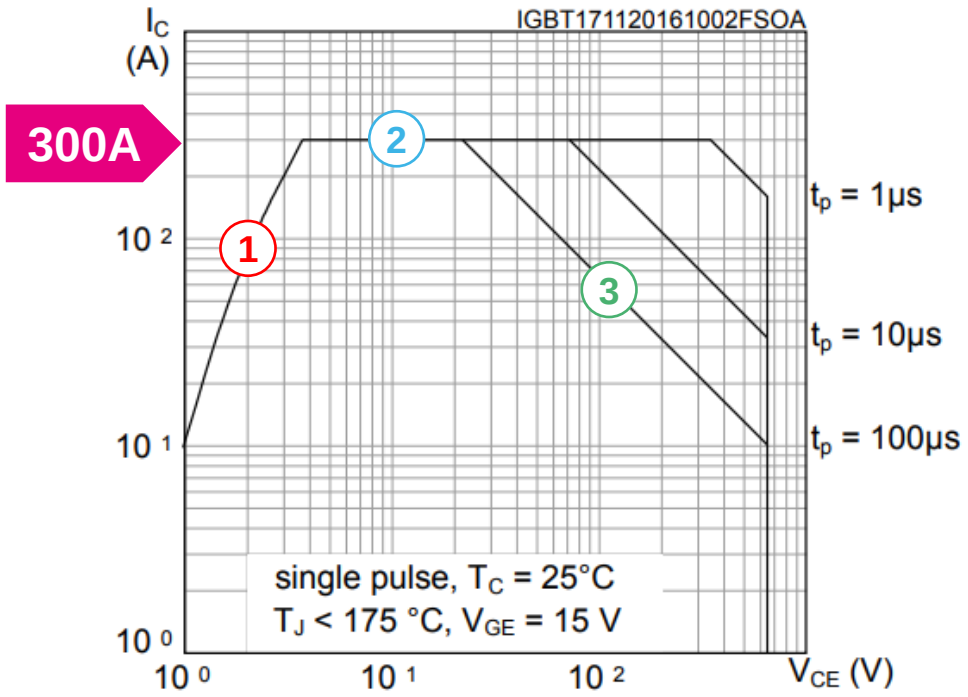
Why using SCR for HV discharge ?

Figure 8. Forward bias safe operating area

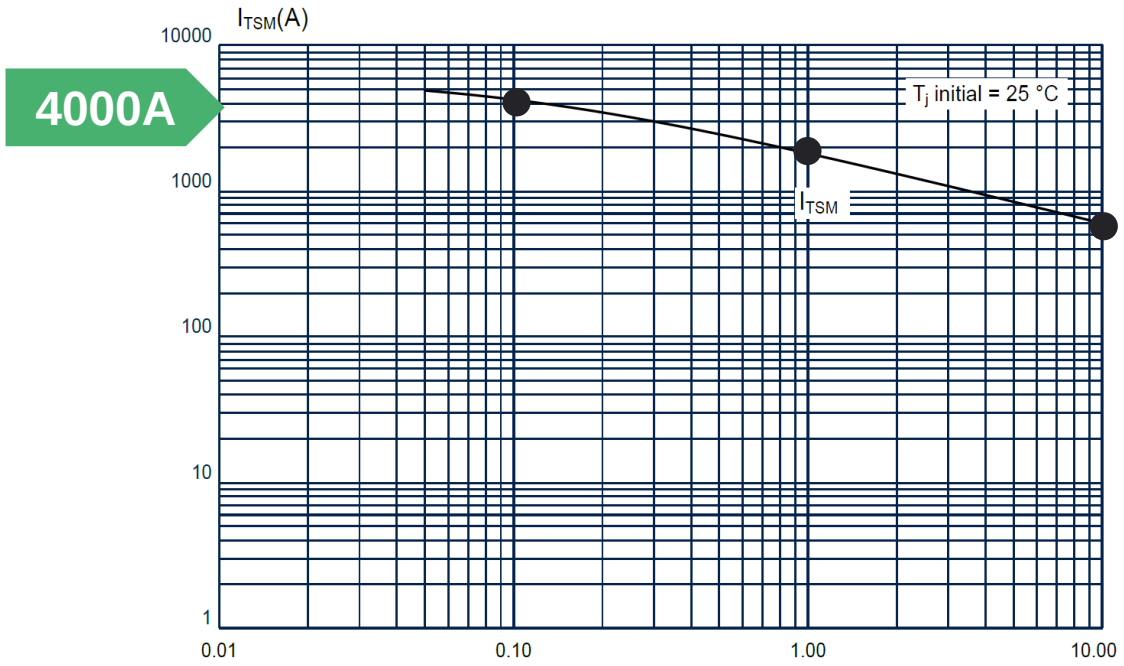


Safe Operating Area (IGBT example) is defined by

1. Collector-Emiter Saturation voltage (V_{CEsat})
2. Maximum Collector Current
3. Thermal limit (Max junction temperature)

Why using SCR for HV discharge ?

Figure 7. Non repetitive surge peak on-state current



SCR has a specification for Non repetitive Current

4000A for Peak Current of 0.1ms

2000A for Peak Current of 1ms

600A for Peak Current of 10ms

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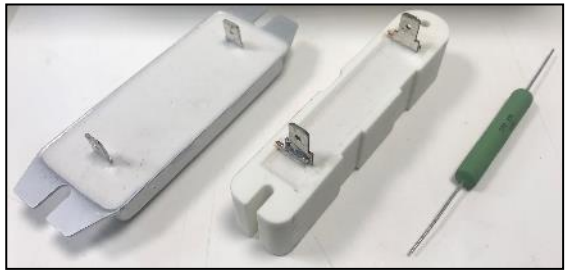
BMS HV Capacitor Discharge dedicated SCR Products

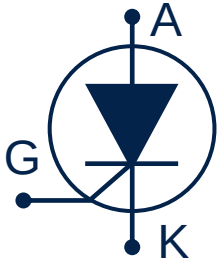
Battery Voltage	Discharge Energy	Discharge Resistance	SCR PN#	Breakdown Voltage	Peak Current	Current rise dI/dt	Package
400V	300 Joules	> 0.2 Ohms	Pre-production release **TN4035HA-8**	> 800V	< 2000A	< 450 A/µs	D2PAK
800V	1100 Joules	> 0.2 Ohms	ES release Apr '23 **TN13050HA-12**	> 1200V	< 4000A	< 450 A/µs	TO247

Discharge Power Resistors



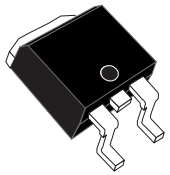
1100 J 0.6Ω | 1000 J 0.2Ω | 90 J 3Ω

THYRISTOR



High Current clip assembly

D2PAK



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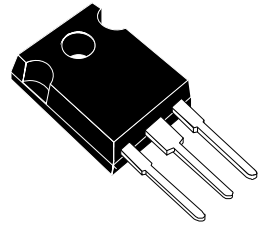

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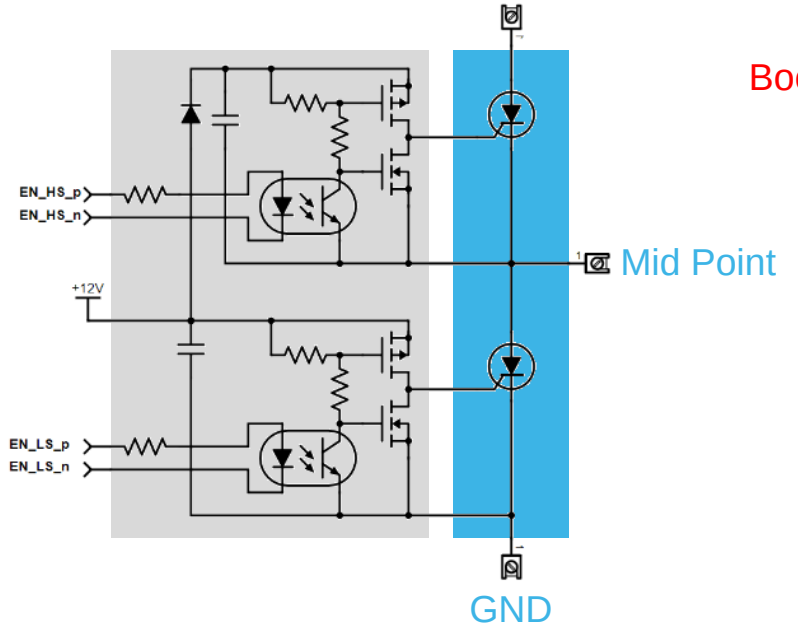
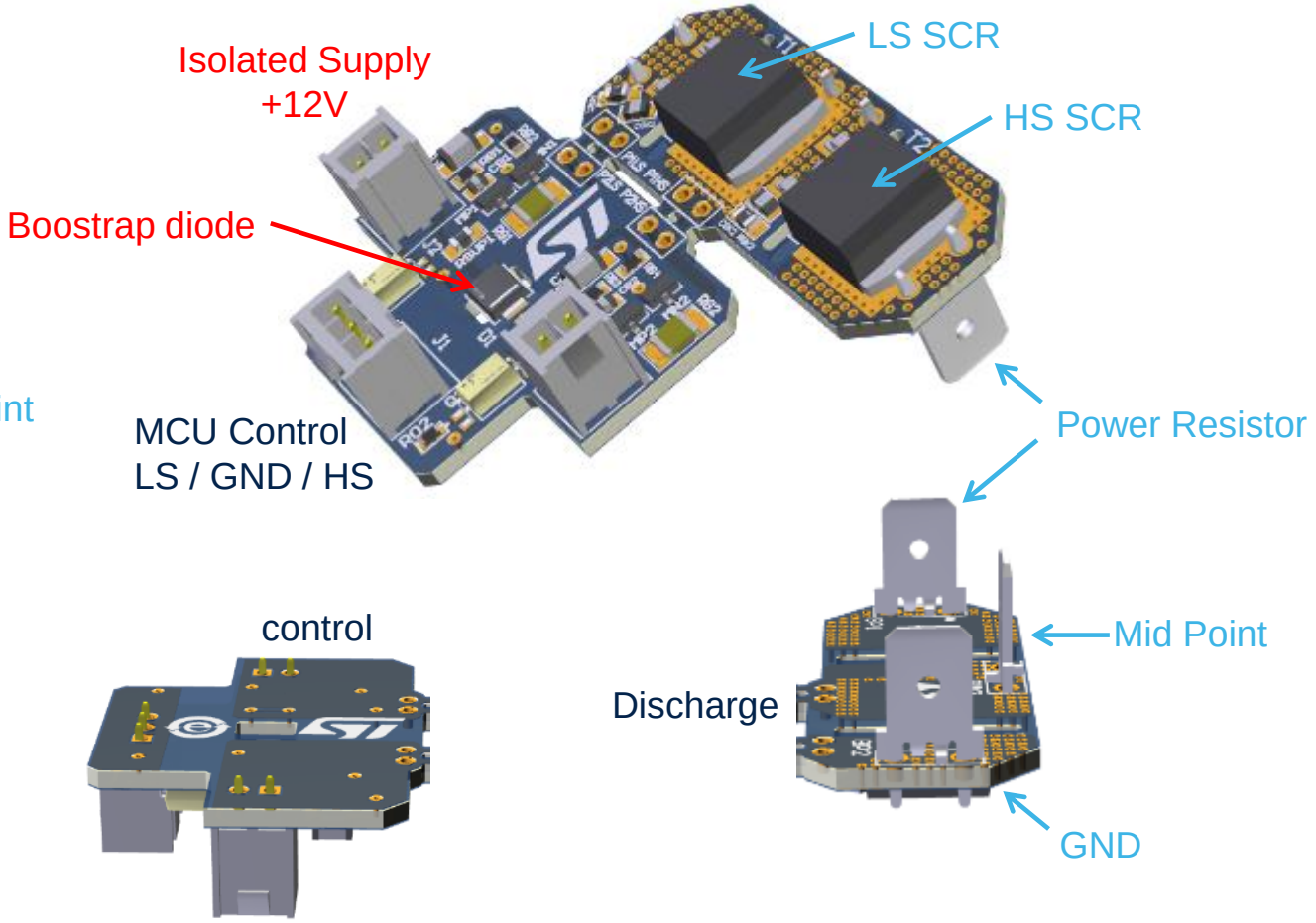
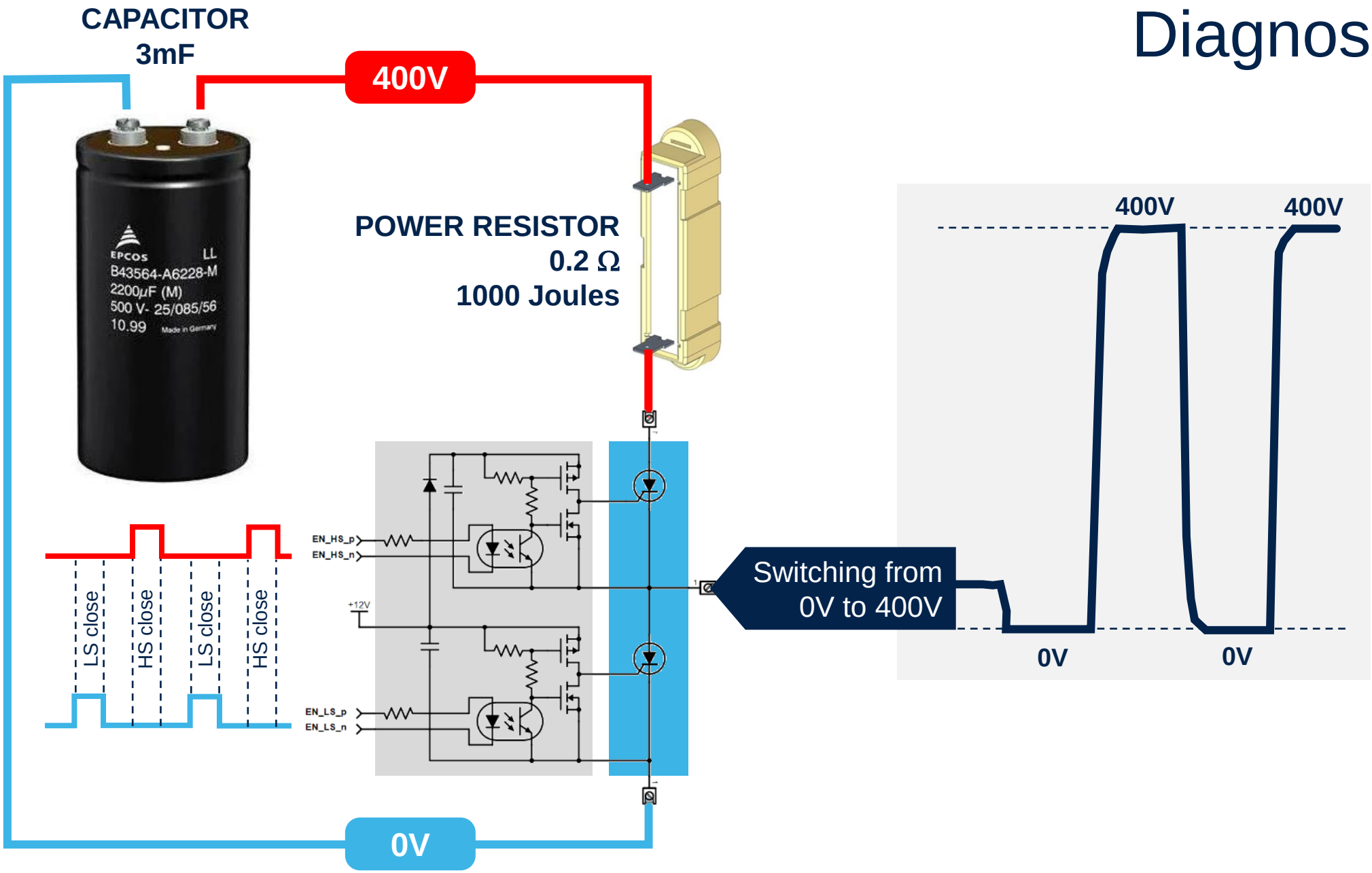
STDES-DIS001 Evaluation Board

400V Battery **TN4035HA-8**





Diagnostic



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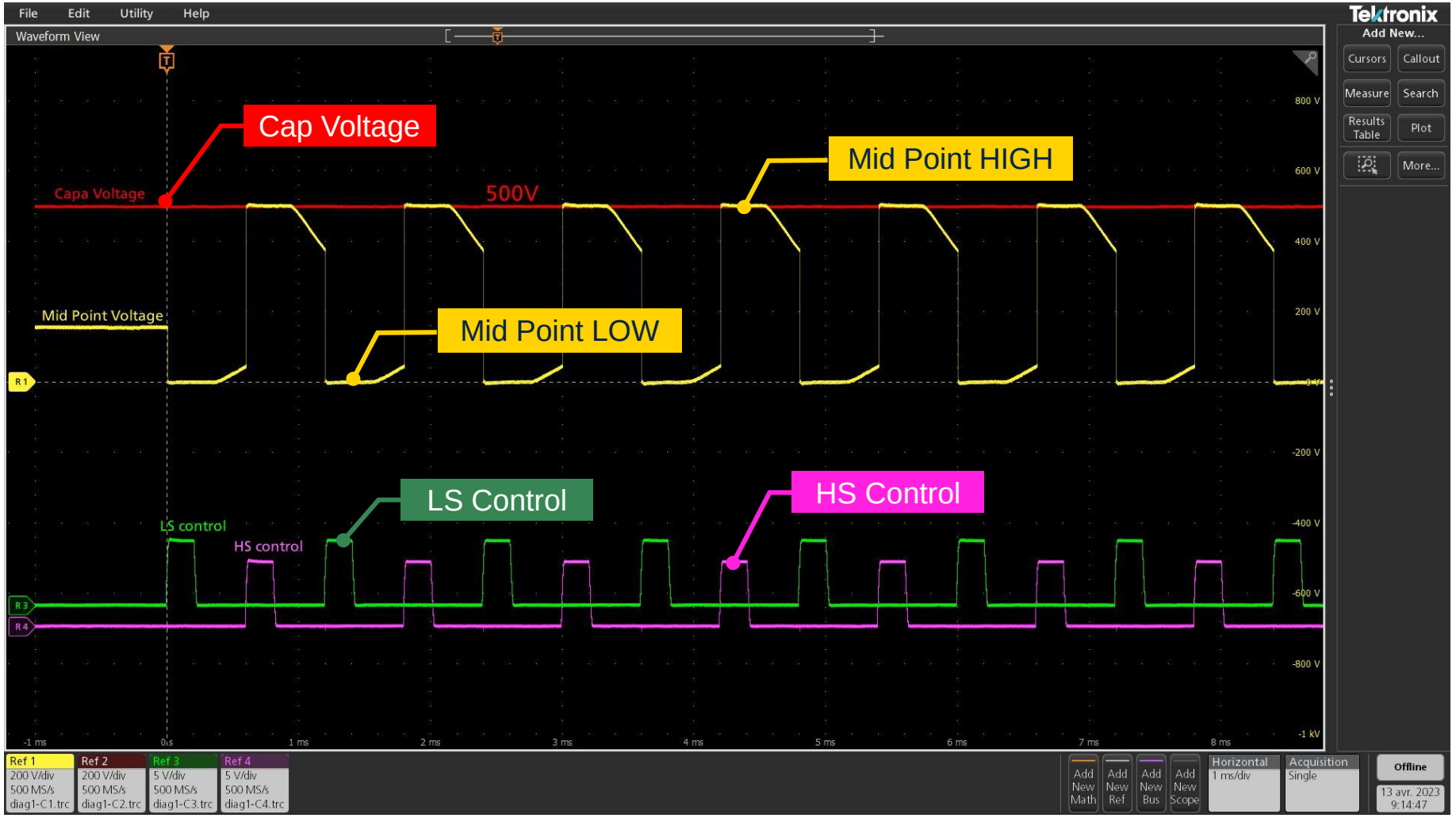
Capacitive discharge Diagnostic

500V, 2.25 mF, 0.3 Ohms



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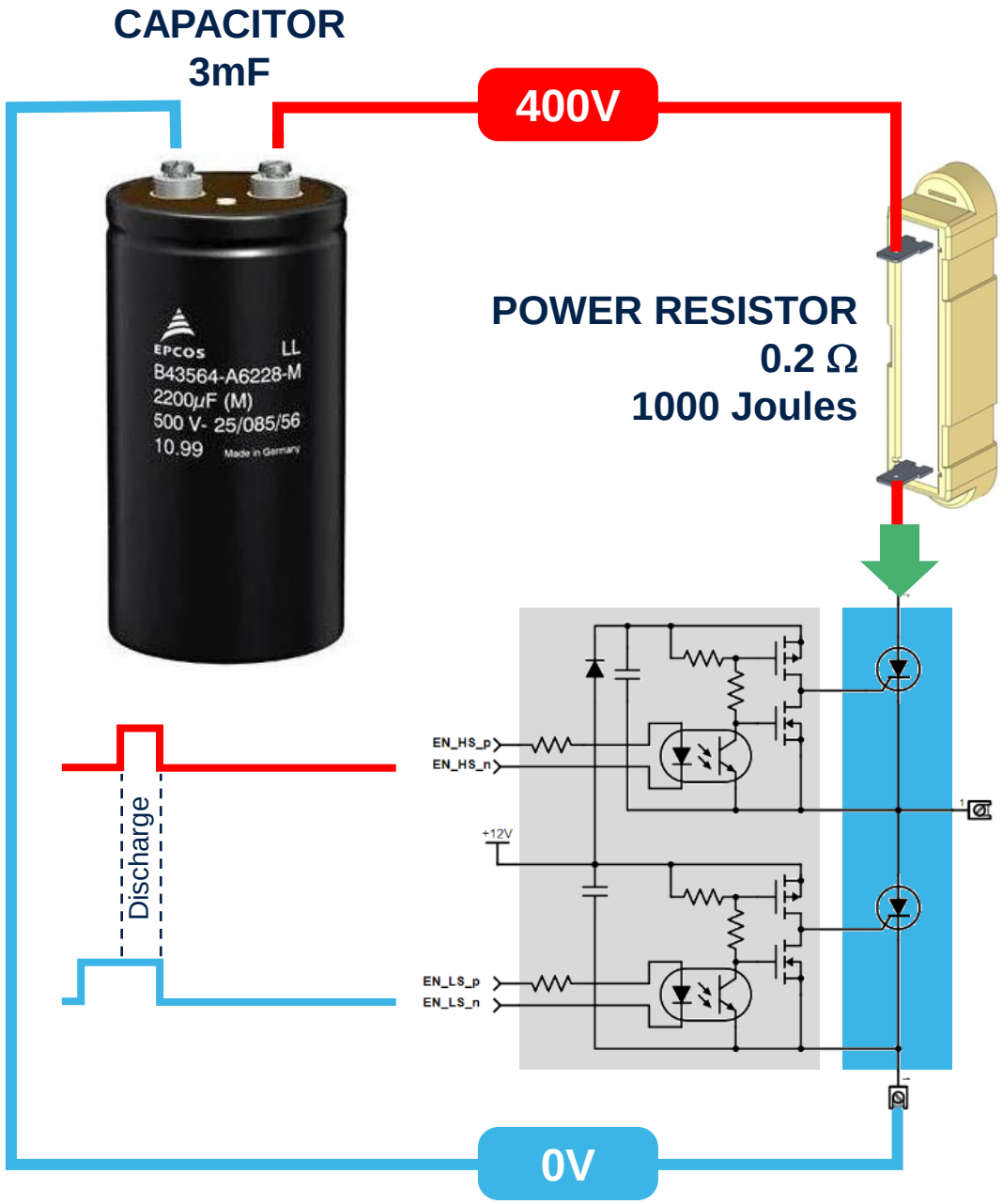
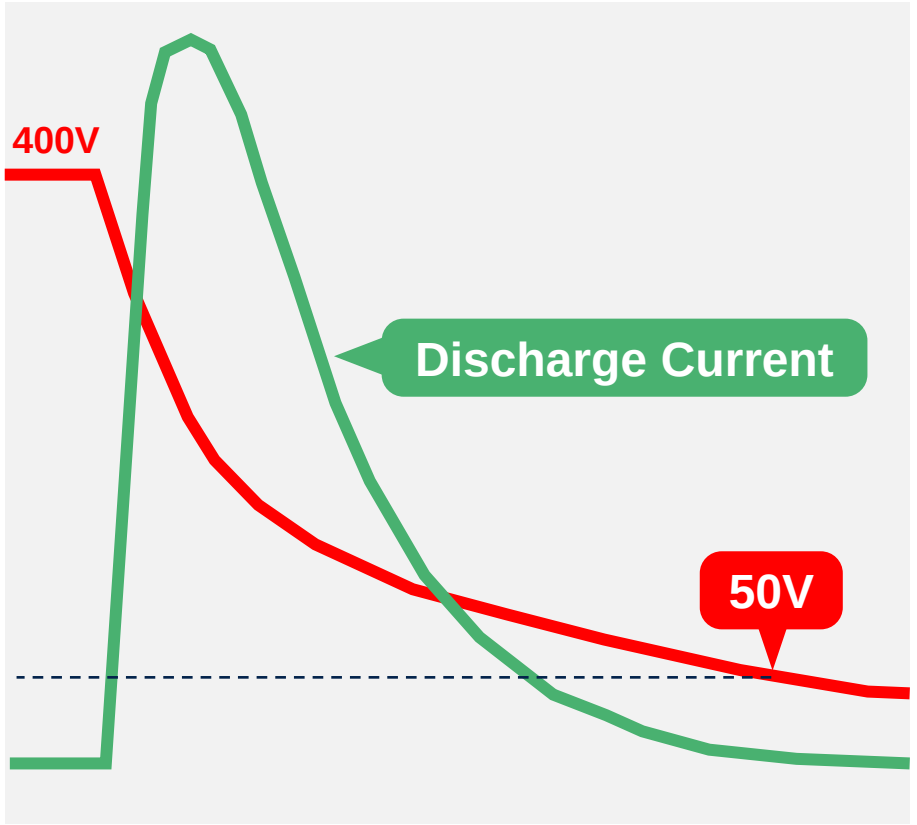
Discharge





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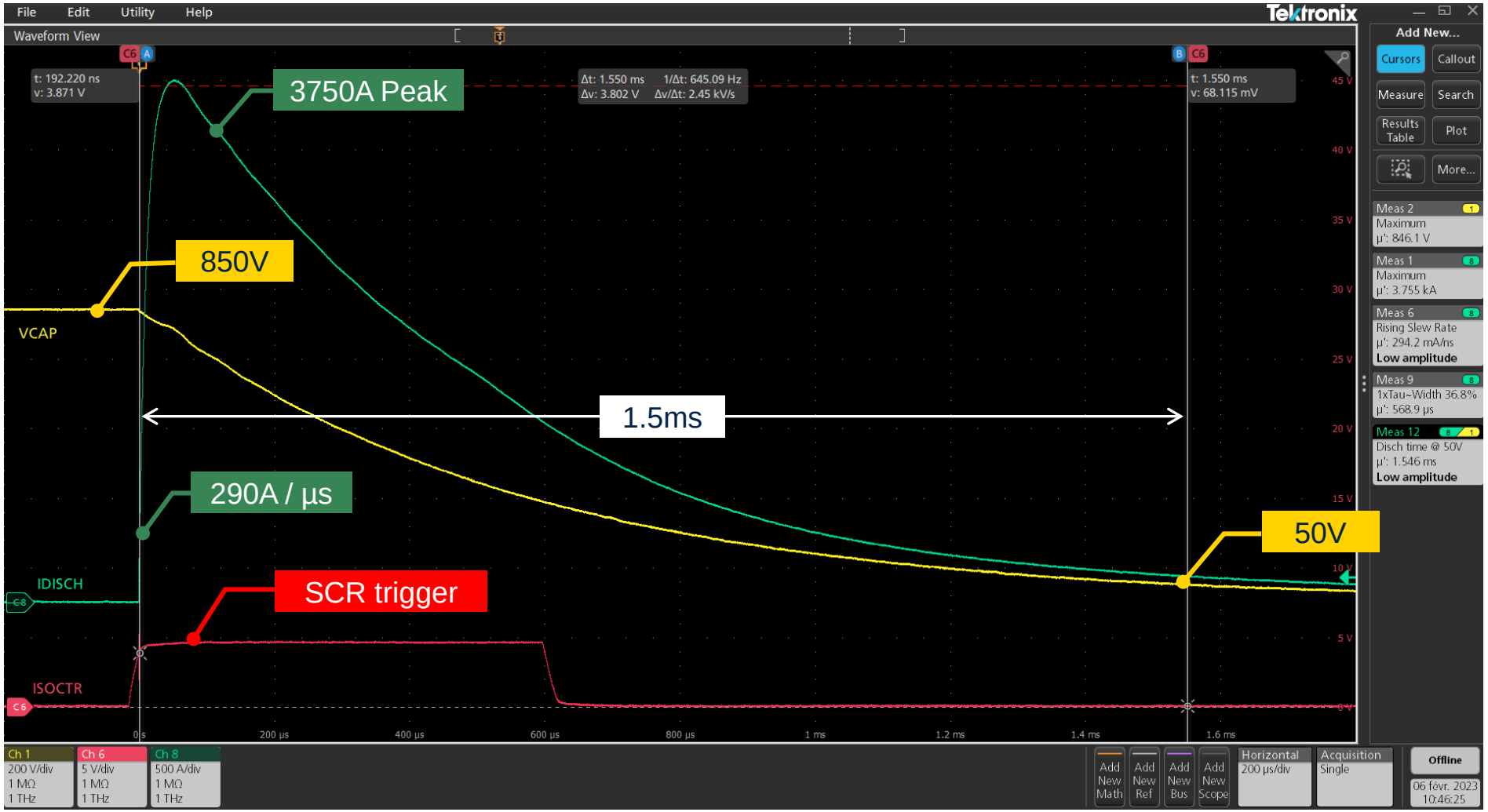
990 Joules Capacitive Discharge
850V, 2.75 mF, 0.2 Ohms



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Pre-charge of EV High Voltage Power Bus

DFD Tours

April 2023

Pre-charge of EV High Voltage Power Bus

1. Why do we need to pre-charge HV Bus ?
2. How to implement pre-charge with Thyristor ?
3. Benchmarking pre-charge Switch
4. What are the benefits of THYRISTOR pre-charge ?
5. Recommended SCR schematic control for precharge
6. How to detect HV Bus default ?
7. Webinar Take Away
8. THYRISTOR Product range

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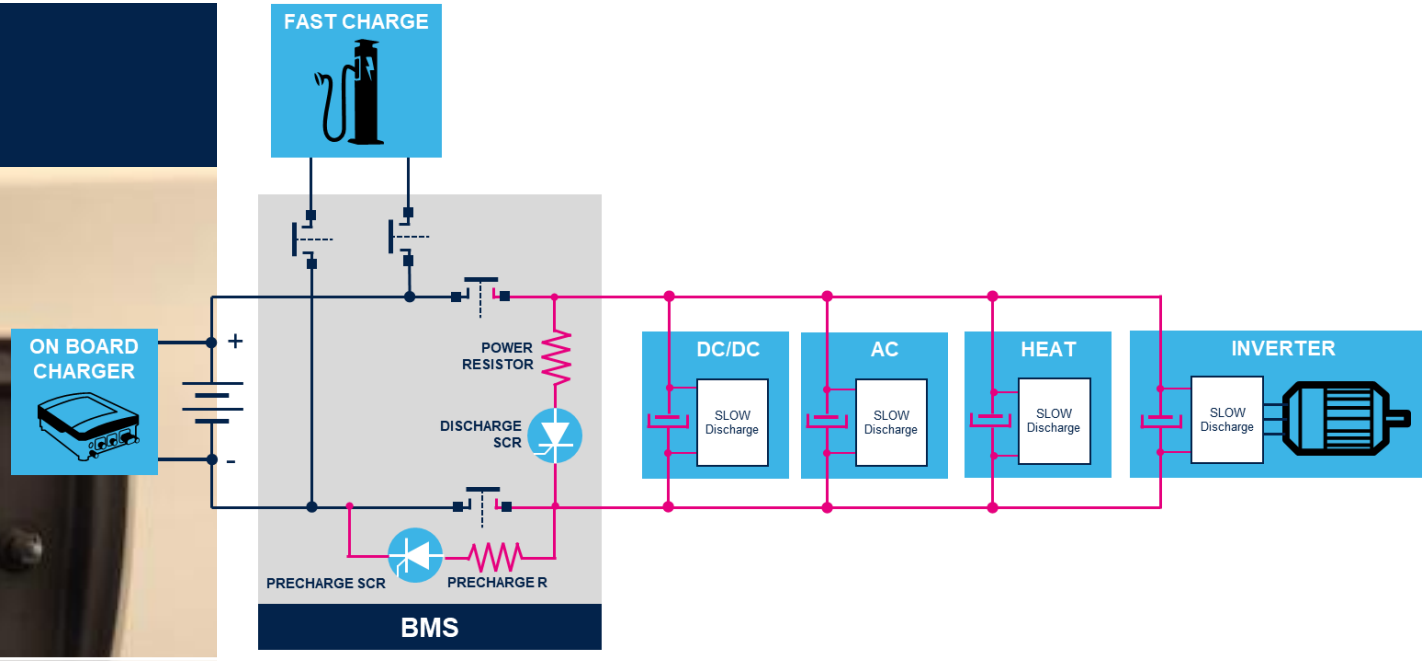
Active Pre-charge with THYRISTOR

Limit In-rush Current with THYRISTOR

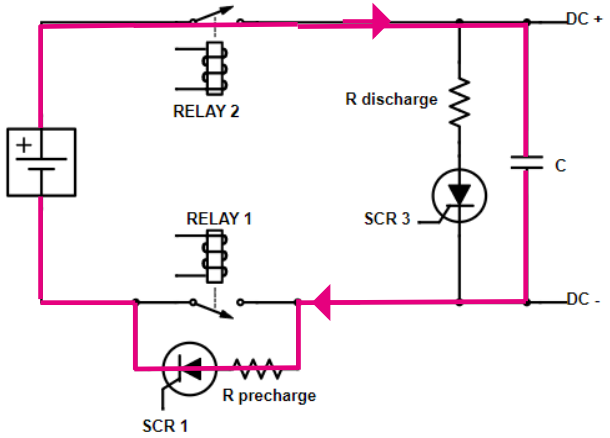


A **pre-charge** circuit is used to prevent stress and damage to the electric system by implementing a resistor and a switch to limit in-rush current

Pre-charge Relay are usually Electro-mechanical contactor used in Battery Management System (**BMS**) and Power distribution Unit (**PDU**)

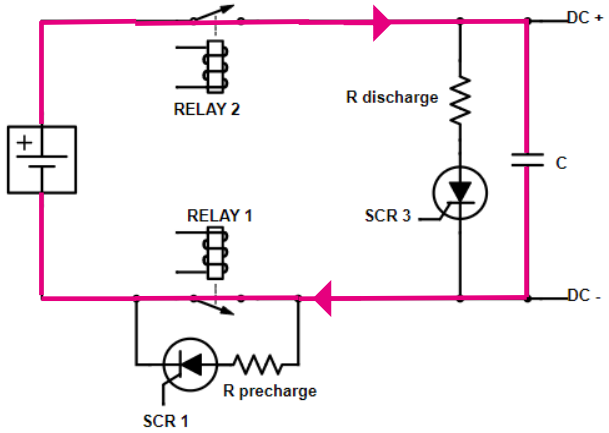
SCR can replace traditional pre-charged Relay for a more reliable, smaller, and more responsive Solid State solution compared to mechanical contacts which can wear out over time.

PDU functionality description



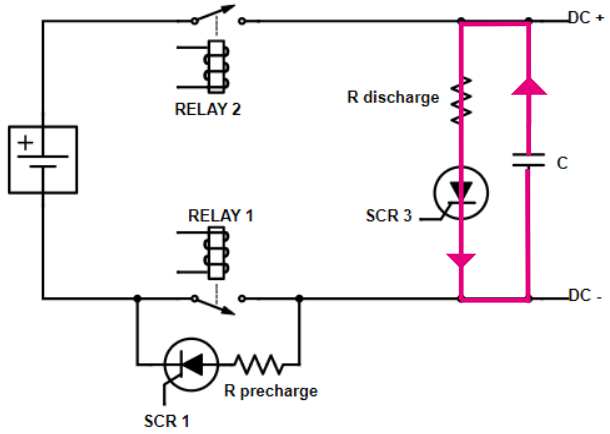
Pre-charge mode

- SCR1 & RELAY 2 are switched ON to charge input capacitance through the pre-charge resistance
- RELAY 1 is turned ON after precharge



Steady state mode

- Both relays are switched ON to take over the current conduction
- SCR switched OFF automatically since the current becomes lower than the holding current I_H



Discharge mode

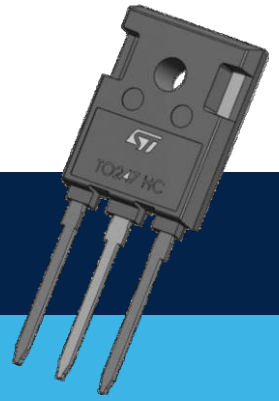
- Relays as switched OFF to disconnect the Battery
- SCR3 is switched ON, after the relays are OPEN, to discharge the Capacitance through the power resistance

Solid state switches benefits

Mechanical relays

- Slow switching speed
- Large size occupation on the PCB
- High power consumption
- Limited lifespan due to the degradation of the mechanical contacts
- EMI and noise generated due to mechanical contact bouncing
- Fire hazard due to arcing between contacts
- Metal contacts are subject to Welding

Solid state switches



- Fast switching time
- High power density handling in more compact packages
- Smaller and thinner form factor
- Higher reliability and increase of the life span by replacing mechanical contact
- Lower power consumption
- Safer solution without contact arcing

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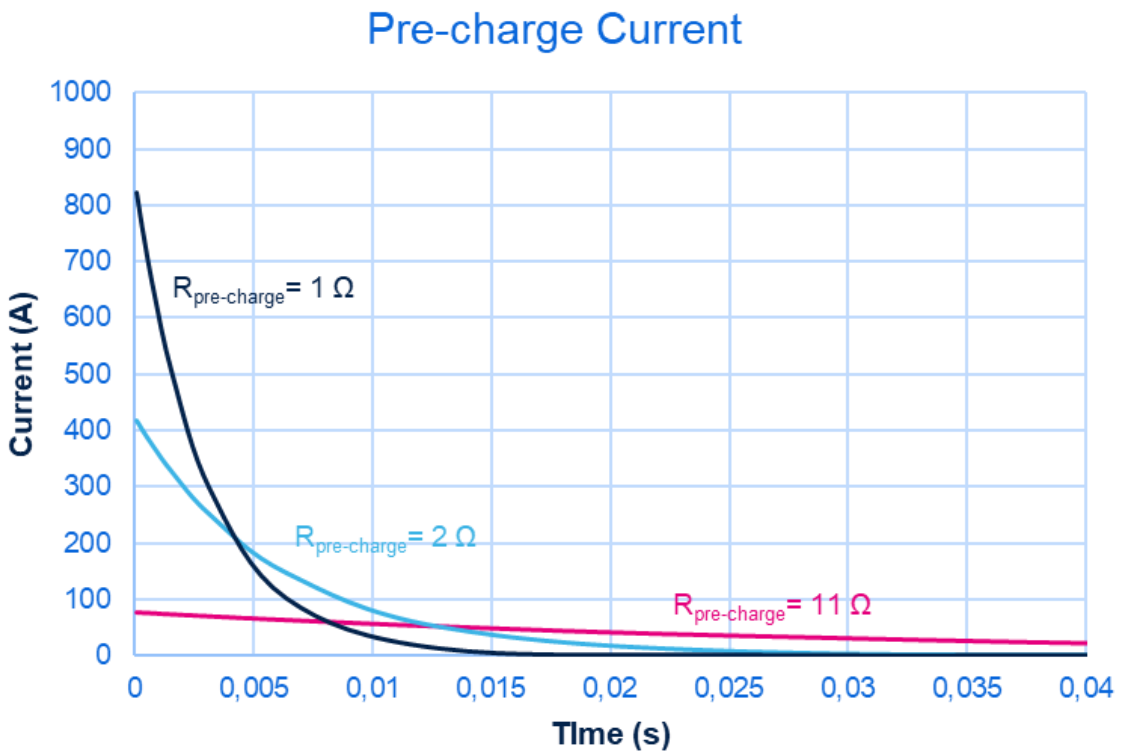
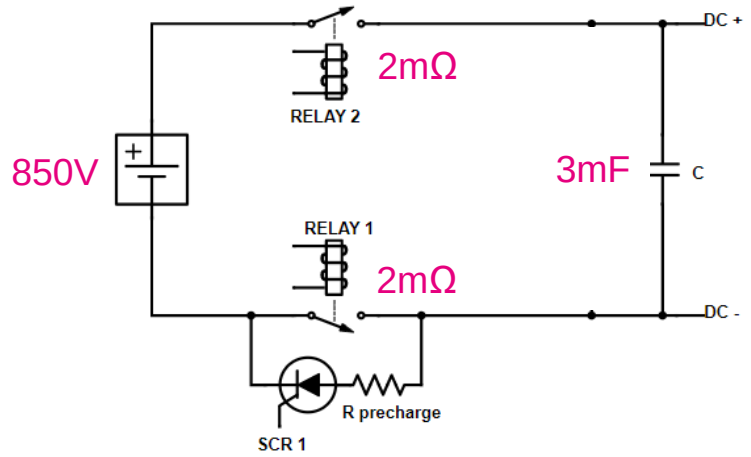
Pre-charge resistors impact on Pre-charge duration 1/2





Pre-charge design example

- The pre-charge resistor value has a key role at defining the pre-charge duration time.
- The higher the resistance, the slower the pre-charge.
- The Lower the resistance, the Higher the current.

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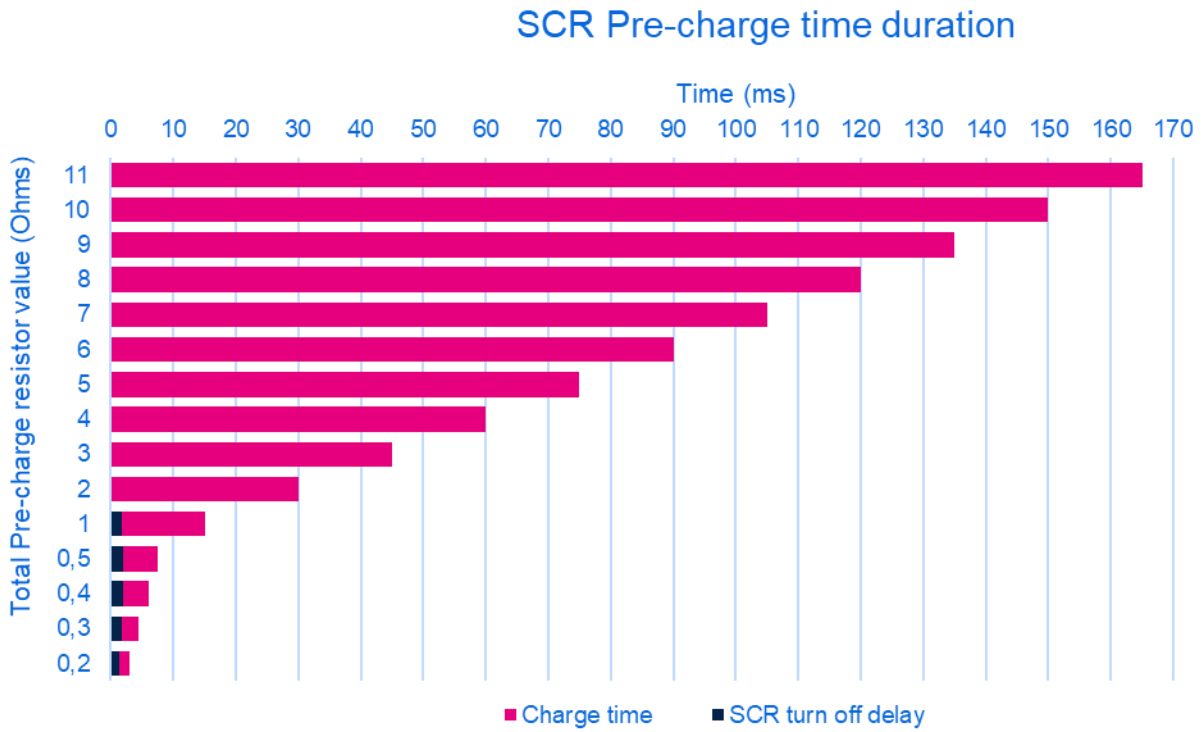
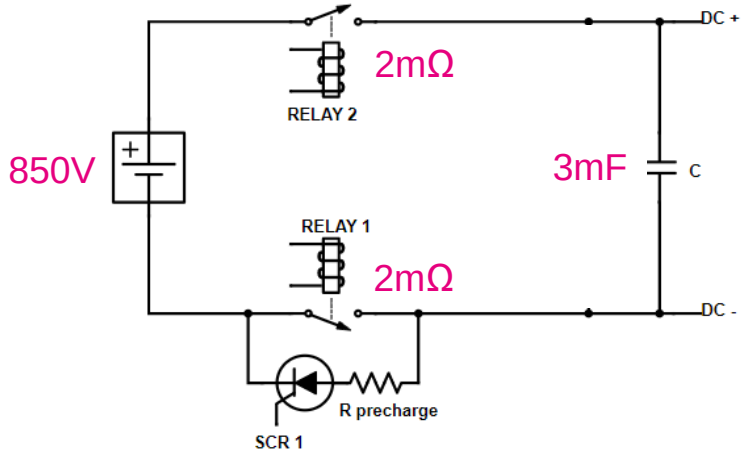
Pre-charge resistors impact on Pre-charge duration 2/2





Pre-charge design example

- Pre-charge current is going through the SCR (**Pink bars**)
- SCR must be selected according to the pre-charge resistance
- After pre-charge, the SCR will automatically turn OFF once the RELAY 1 is ON

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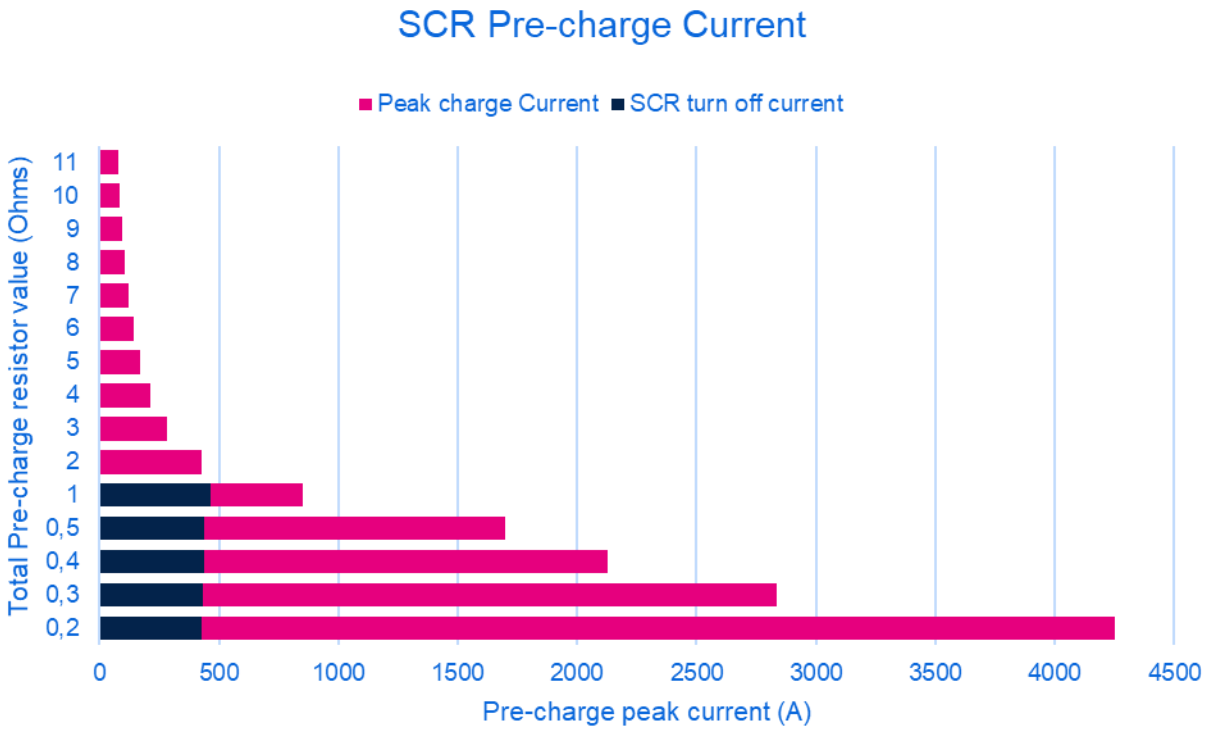
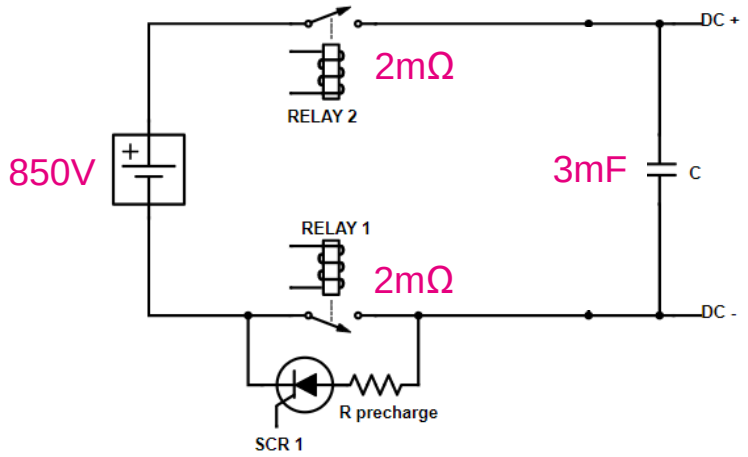
Pre-charge resistor’s impact on peak current





Pre-charge design example

- Thanks to its high current conduction capability, SCRs can conduct high current during small time duration
- When Pre-charge resistor value is below 1Ω, the relay can be turned ON when the SCR has reached the turn-off current
- SCRs enable using smaller pre-charge resistors

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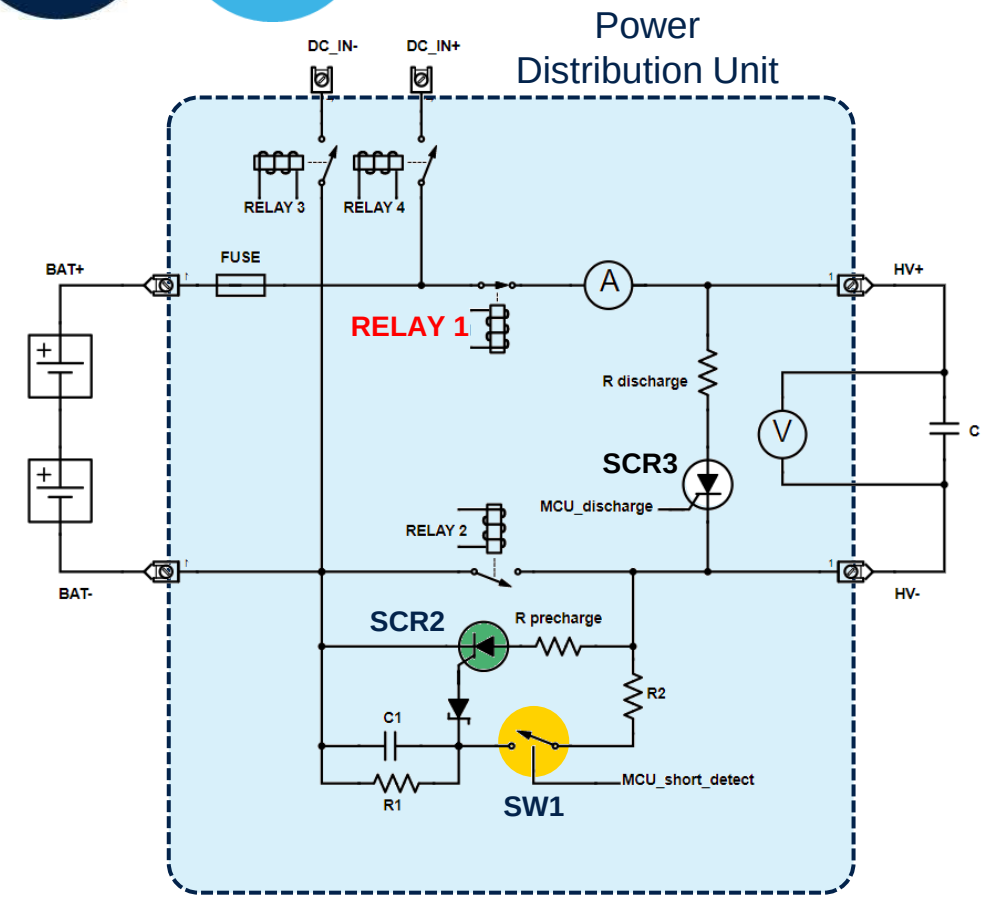
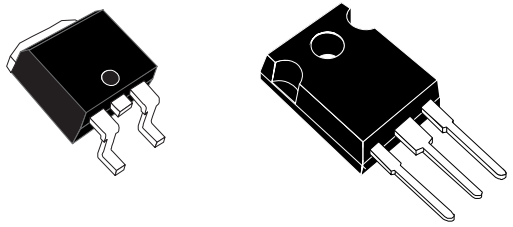
Pre-charge SCRs control suggestions



D2PAK **TO-247**



RELAY 1 *prevents leakage current in Disconnect Mode.*

SW1 *is used to detect SHORT circuit on HV DC Bus. Capacitor is charging thru SW1 that is activated by MCU.*

When the HV DC Bus is not shorted, **SCR2** *can be latched ON to enable Pre-charge safely.*

After Pre-charge, **RELAY 2** *will be turned ON and* **SCR2** *will unlatch as all current flow thru the relay.*

Mode	RELAY 1	SW1	SCR2	RELAY 2	SCR3
Disconnect	OFF	OFF	OFF	OFF	OFF
SHORT detection	**ON**	**ON**	OFF	OFF	OFF
Pre-charge	**ON**	OFF	**ON**	OFF	OFF
Steady State	**ON**	OFF	OFF	**ON**	OFF
Fast Discharge	OFF	OFF	OFF	OFF	**ON**

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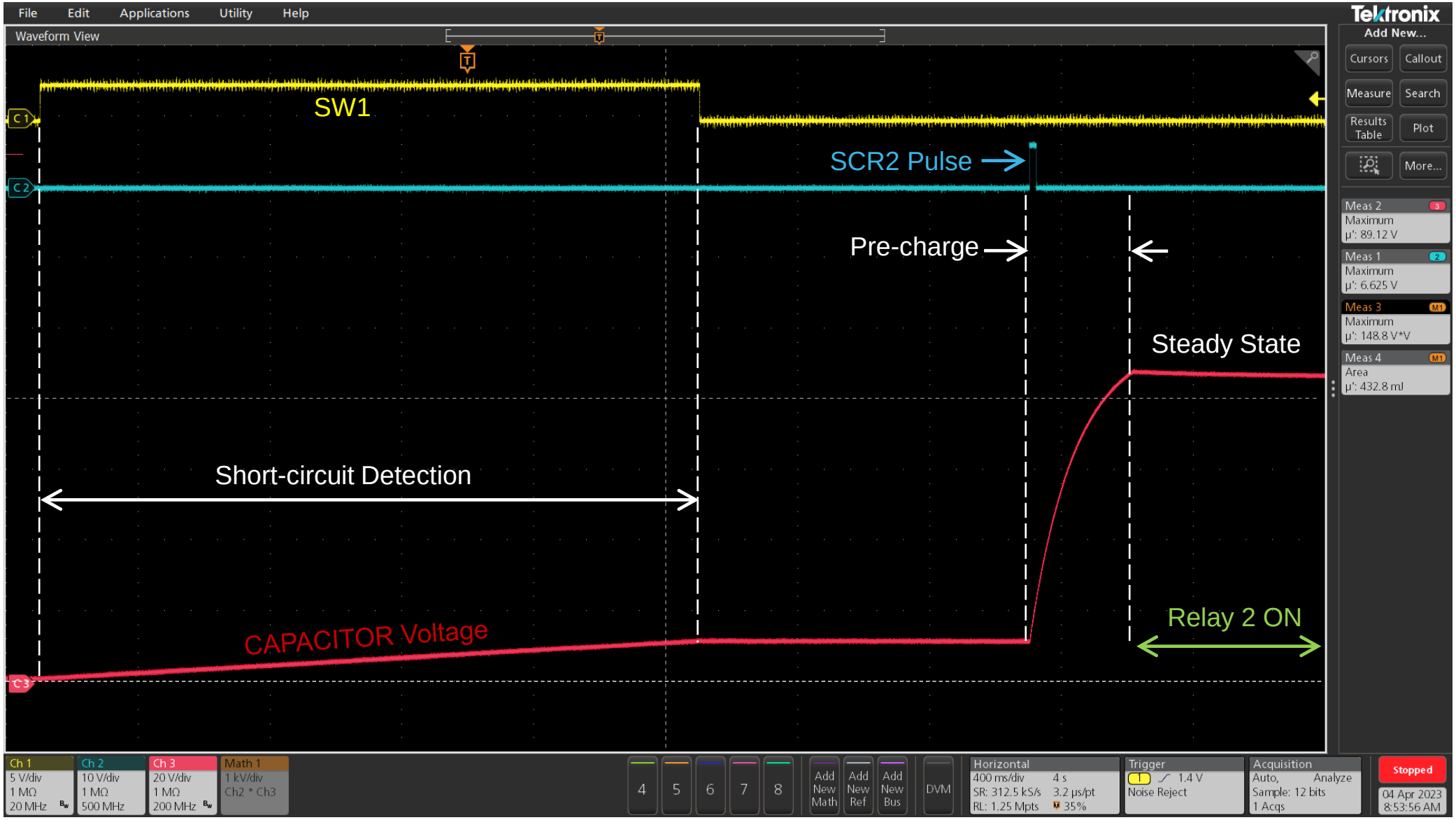
Short Circuit detection before pre-charge



TAKE AWAY

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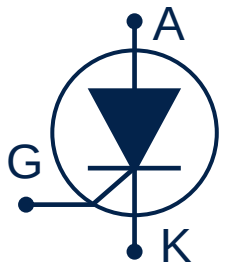
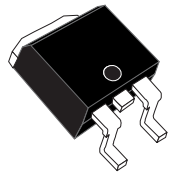
Active Discharge and Pre-charge of EV High Voltage Power Bus



400V BATTERY	SCR PN#	Breakdown Voltage	Peak Current	Current rise dI/dt	Package
Pre-charge R > 0.2 Ohms	**TN4035HA-8 ***	> 800V	< 2000A	< 450 A/µs	D2PAK
Discharge R > 0.2 Ohms	**TN4035HA-8 ***	> 800V	< 2000A	< 450 A/µs	D2PAK

* Production pre-release

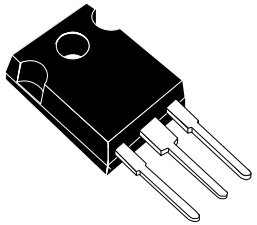
D2PAK



800V BATTERY	SCR PN#	Breakdown Voltage	Peak Current	Current rise dI/dt	Package
Pre-charge R > 0.2 Ohms	**TN13050HA-12 ***	> 1200V	< 4000A	< 450 A/µs	TO247
Discharge R > 0.2 Ohms	**TN13050HA-12 ***	> 1200V	< 4000A	< 450 A/µs	TO247

* Engineering samples

TO-247



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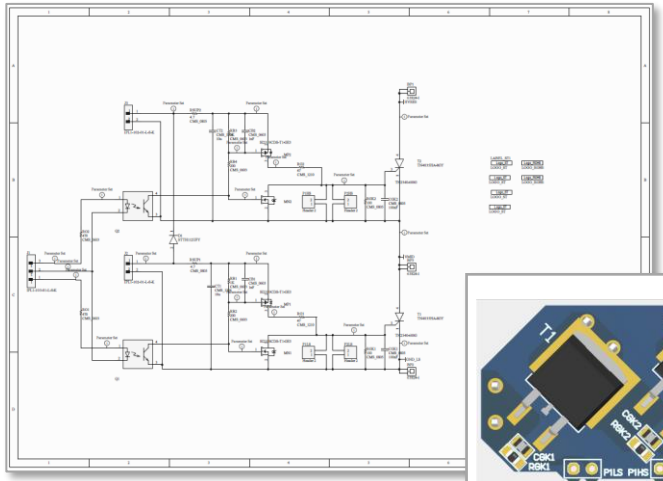
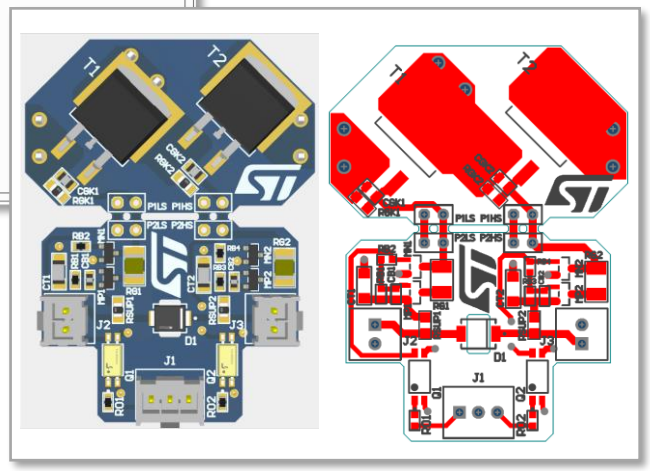
ST's Reference Design STDES-DIS001 Colaterals

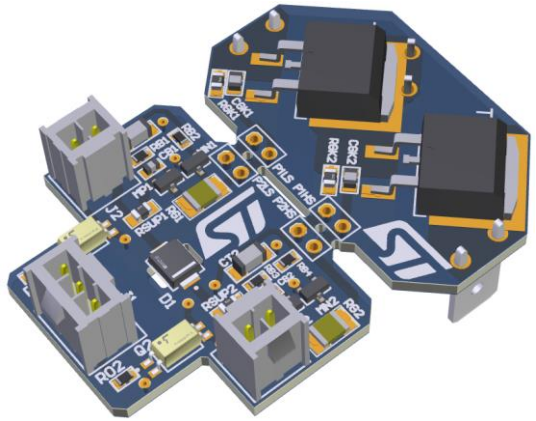
Board Schematic



Board Layout



Board sample



Data brief

STREF-DIS001V1
Data Brief

Active Discharge & Diagnostic for 400V Power Bus

Features

- 400V Active Discharge
- Discharge Capacitance up to 3mF
- Compatible with Discharge Resistor of 0.2Ω or greater
- Insulated SCR gate driver with Opto-transistors
- Require a 12V insulated supply
- Implement 2 SCR in series to allow Diagnostic

Applications

- High Voltage Capacitive Discharge
- Battery Management System (BMS)
- Power Distribution Unit (PDU)
- Uninterruptible power supply (UPS)
- Battery charger

Product summary
2xTN4035HA-8GY

Description

The STREF-DIS001V1 reference design allows you to evaluate Silicon Controlled Rectifier TN4035HA as a Discharge switch. It is suitable to discharge Capacitance up to 3mF connected on 400V Bus (800V Max).

This active discharge can be controlled thanks to an insulated gate drive implemented with opto-transistors. Thanks to TN4035HA Peak current Capability the Discharge resistor can be reduce to 0.2Ω in order to perform the discharge in few milliseconds.

2x TN4035HA are implemented on the reference design. One connected in High side and another connected on Low side. The mid-Point of these SCRs can be used in order to diagnose that both SCRs are functional before discharge. Also the diagnostic can be done after Discharge to verify the SCRs have not been damaged during the discharge.

Thanks to their excellent peak current rating TN4035HA are recommended for Fast Active Discharge of EV High Voltage Power Bus.

KEY FEATURES

- Active Discharge SCR for 400V battery.
- Reference design for **DIAGNOSTIC** & **DISCHARGE**
- Capability to support Multiple Discharges

KEY PRODUCTS

- **TN4035HA-8GY** allows 2000A peak
- **STTH112UFY** Boostrap diode
- Insulated gate control thanks to **opto transistor**

For support please contact SCR Technical Marketing and Application team

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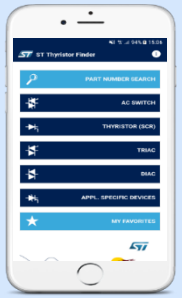
Your Design support & Tools

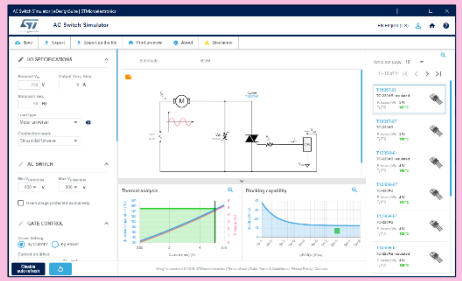
Portfolio & Datasheets



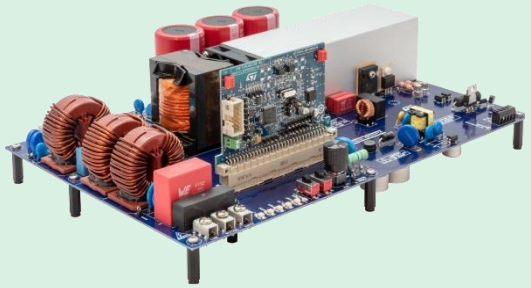
Selector Guide

E-Design suite

Intelligent design tools



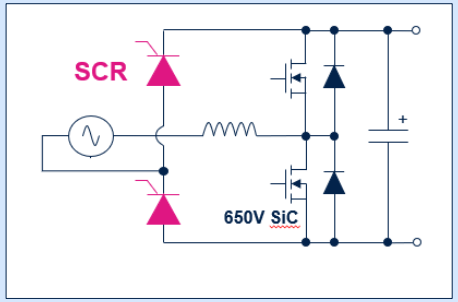
Reference Designs



Evaluation boards

Application Notes

Know-how & design tips



Please visit **www.st.com/en/thyristors-scr-and-ac-switches**

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Webinar Take Away

Active Discharge & Pre-charge with ST's latest THYRISTOR solutions

- Complete Product range including SCR, Microcontroller, Power device and Sense & Control Analog devices
- System solution with Evaluation board, Reference design, Schematic, Layout and Test results
- Innovative Product range including advanced packages for higher Power density
- Integrated High Volume Production Capability for Automotive & Industrial grade products

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Q&A

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