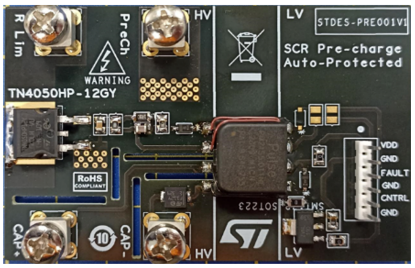
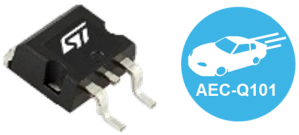
STDES-PRE001V1

Data brief

Pre-charge reference design for 400 V and 800 V battery



STDES-PRE001V1



TN4050HP-12GY

Product summary
STDES-PRE001V1

Key product
TN4050HP-12GY

Features

- 400 V or 800 V bus pre-charge with lower value of resistor or PTC
- High surge current capability for faster pre-charge
- 4 kV insulation between LV and HV
- Pre-charge with single MCU output (pulsed)
- Automatic detection of HV short condition at SCR turn-on
- Automatic stop of SCR with pre-charge PTC
- Pre-charge on NEGATIVE or POSITIVE terminal

Applications

- Solid-state pre-charge solution for BEV cars

Description

The STDES-PRE001V1 is a ready to use reference design that features a 40 A pre-charge thyristor. The reference design allows us to evaluate TN4050HP-12GY as 40 A switch for automotive DC applications.

The reference design includes a driving circuit featuring a pulse transformer, and a automated short circuit detection at SCR turn on.

The key product TN4050HP-12GY is an automotive qualified 40 A 1200 V thyristor assembled in surface mounted package D²PAK.

It offers 400 A surge peak current and overvoltage robustness V_{DSM} up to 1400 V. It also has an optimized creepage distance of 3.5 mm.

1 Getting started

Figure 1. **Pictograms**

Danger: *Use the STDES-PRE001V1 board only after applying a fire-resistant cover. The cover is not included in the board package.*

There is a danger of serious personal injury, property damage, or death due to electrical shock and burn hazards if the kit or components are improperly used or installed incorrectly.

Warning: *The kit is not electrically isolated from the high-voltage supply AC-DC input.*

The evaluation board is directly linked to the mains voltage. No insulation is ensured between the accessible parts and the high voltage. All measurement equipment must be isolated from the mains before powering the board.

When using an oscilloscope with the evaluation board, it must be isolated from the AC line. This prevents shock from occurring as a result of touching any single point in the circuit, but does no prevent shock when touching two or more points in the circuit.

Caution: During assembly, testing, and operation, the evaluation board poses several inherent hazards, including bare wires, moving or rotating parts and hot surfaces. All operations involving transportation, installation, use, and maintenance must be performed by skilled technical personnel who are familiar with the installation, use, and maintenance of power electronic systems.

The board has to be connected directly on the mains. Non-isolated parts at high-voltage levels are present on both sides of the PCB.

The high current flowing through the two SCRs generates heat: the board temperature can reach up to 150 °C at full power. Be aware that, due to the thermal inertia, the board could remain hot even after the current flow.

Workarea safety:

- The work area must be clean and tidy
- Do not work alone when boards are powered
- Protect the area against any unauthorized access by putting suitable barriers and signs
- A system architecture that supplies power to the evaluation board must be equipped with additional control and protective devices in accordance with the applicable safety requirements (that is, compliance with technical equipment and accident prevention rules).

Electrical safety:

- Remove the power supply from the evaluation board and electrical loads before performing any electrical measurement
- Arrange measurement setup, wiring, and configuration, paying attention to the high voltage section
- Once the setup is complete, power the board. Fuse protection is not included with this evaluation board.

Danger: *Do not touch the evaluation board when it is powered or immediately after it has been disconnected from the voltage supply as several parts and power terminals containing potentially energized capacitors need time to discharge, and heat-sink and transformers may still be very hot.*

Personal safety:

- Always wear suitable personal protective equipment, such as insulating gloves and safety glasses
- Take adequate precautions and install the board to prevent accidental touch
- Use protective shields, such as an insulating box with interlocks.

2 Pinout and recommendation

Figure 2. STDES-PRE001V1 main components

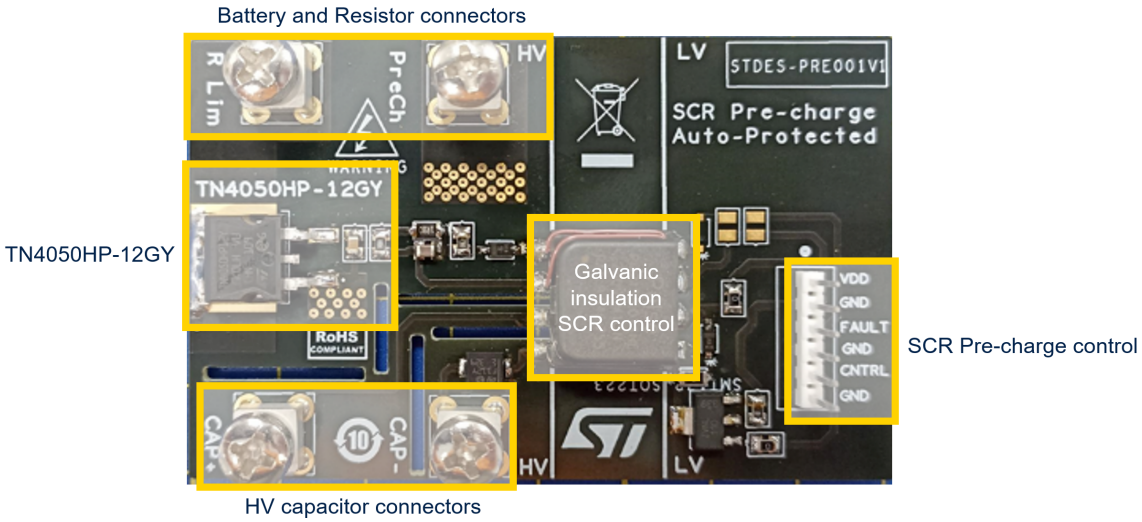
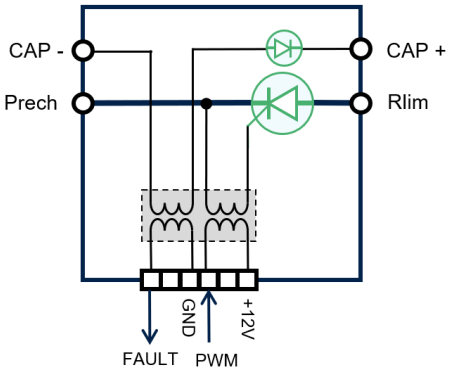


Table 1. Pin assignement

Pins reference	Definition
CAP+	Positive HV voltage capacitor
CAP-	Negative HV capacitor
Prech	Battery connection
Rlim	Inrush current limiter resistor
GND	Low voltage ground reference
VDD	DC power supply
CNTRL	PMW control signal
FAULT	Do not connect

The power connectors, Prech, Rlim, CAP+ and CAP- should be connected as needed in the DC application.

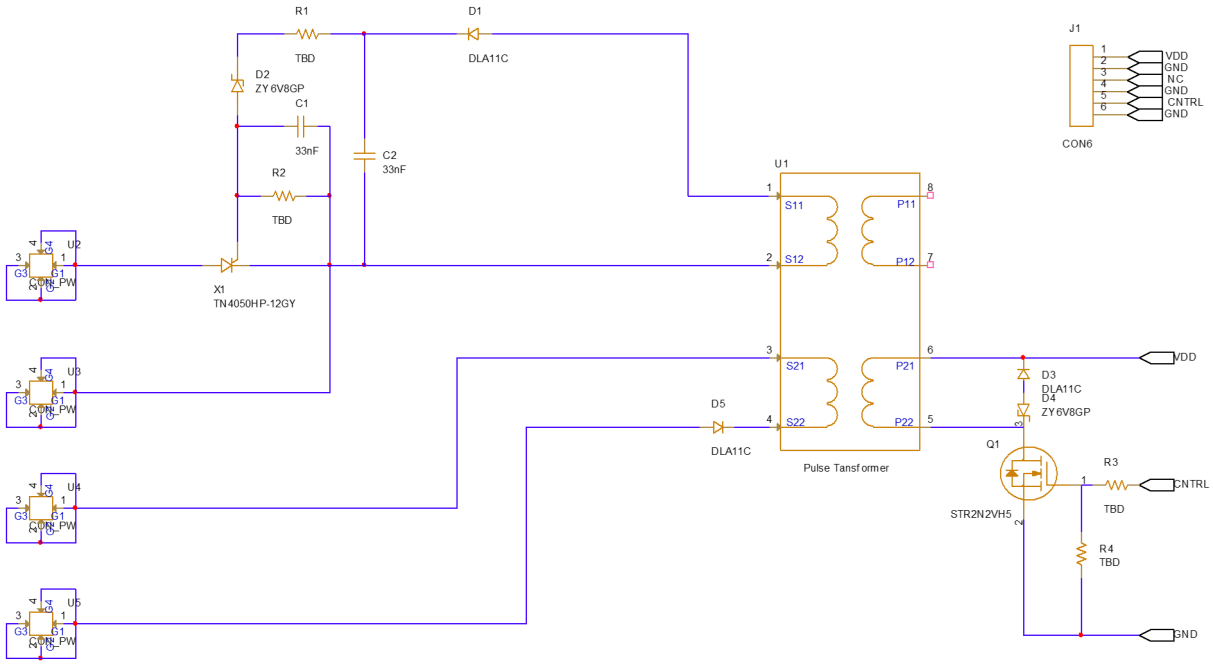
Figure 3. STDES-PRE001V1 pinout



To test the reference design, one signal is to be provided from the microcontroller to drive the pre-charge thyristors. GND and VCC have to be connected as well.

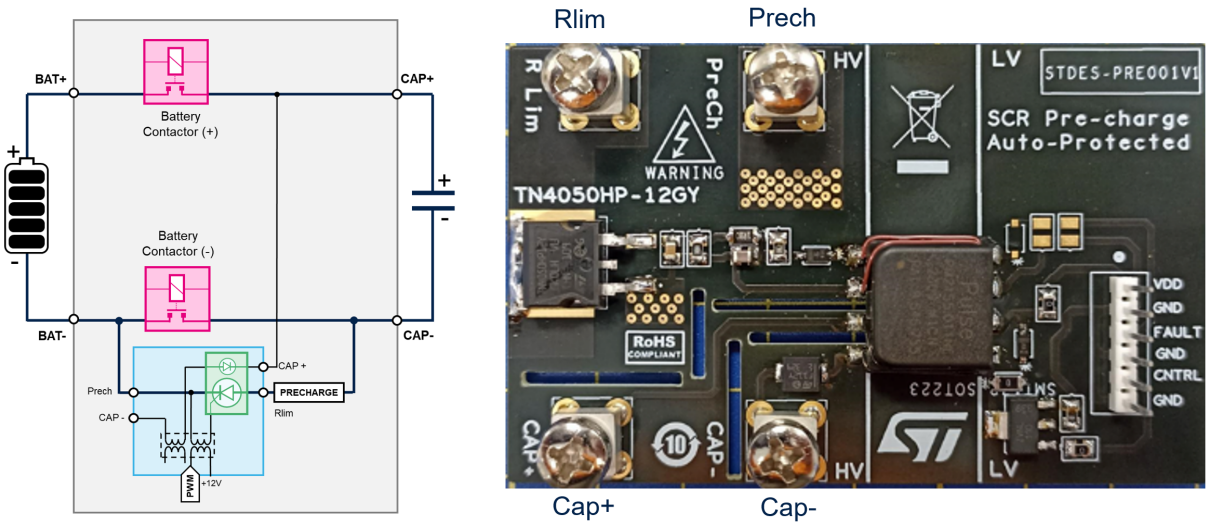
3 Schematics

Figure 4. **STDES-PRE001V1 schematic**



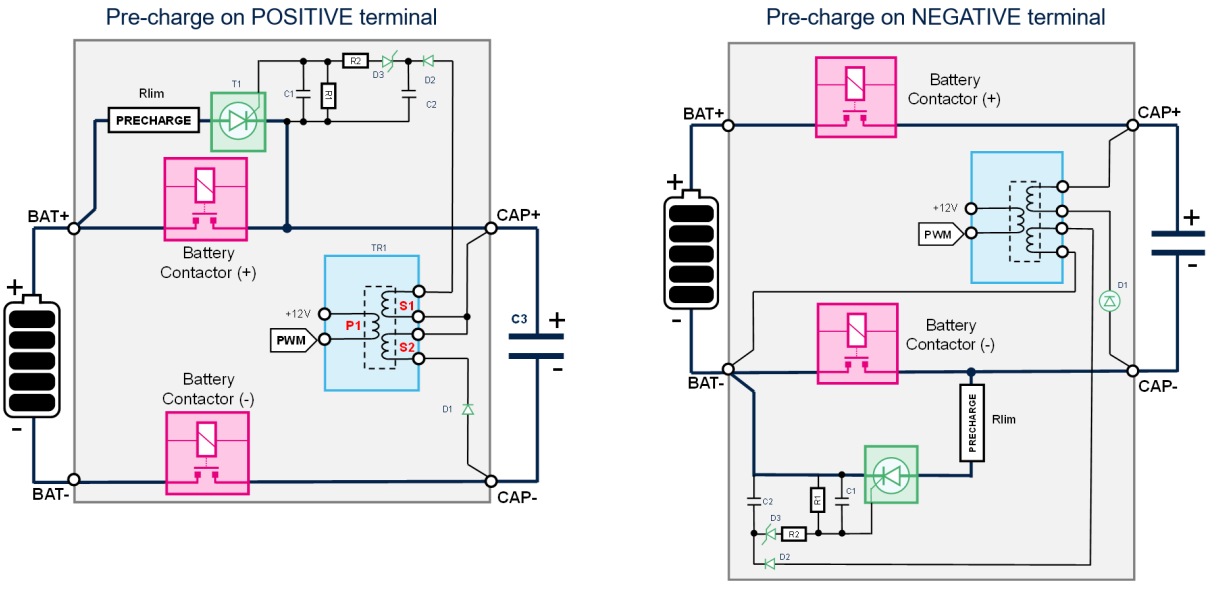
4 Getting started

Figure 5. Pinout of DC pre-charge using STDES-PRE001V1



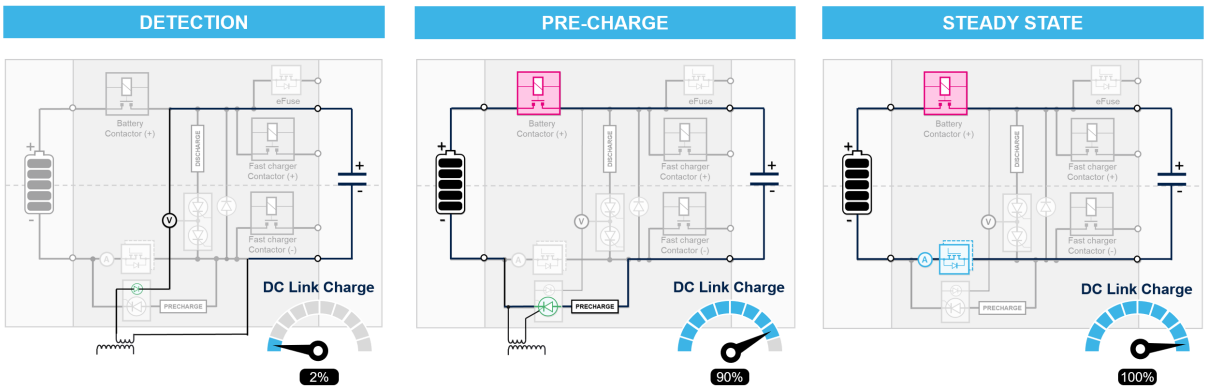
The pre-charge is activated through the primary side of a dual output pulse transformer. A PWM input, connected to the CNTRL pin of connector 1, is required to activate the secondary side of pulse transformer that is trigger the thyristor gate.

Figure 6. Pre-charge polarity option



The pre-charge reference design can be connected to *POSITIVE* or *NEGATIVE* polarity. In the example shown in Figure 6, it is connected to *NEGATIVE* polarity and it is by-passed by Negative contactor after pre-charge is done.

Figure 7. Example of operation for 800 V pre-charge

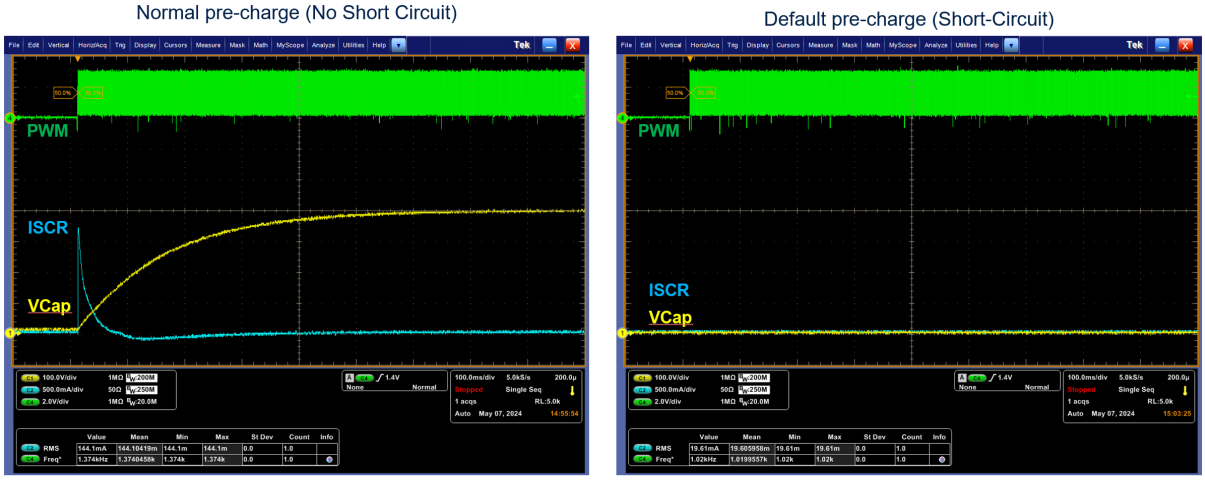


Once the PWM signal is applied to the primary side of the pulse transformer, the secondary winding voltage start to pre-charge the external capacitor via a diode. This initial charging is used to detect a potential short circuit across the capacitor that could prevent the voltage to increase while charging. If a short circuit is present, the secondary winding of the pulse transformer is also shorted, and this prevent driving the thyristor. This *DETECTION* is important to avoid connecting the battery to a shorted high voltage bus.

If the Capacitor is not shorted, the secondary winding of the pulse transformer supply gate current to the thyristor to latch it in a closed state. Once closed, the Battery is pre-charging the Capacitor via a pre-charge resistor to limit the peak current during *PRE-CHARGE*. The pre-charge resistor should be selected so that the peak current is less than 400 A.

The pre-charge is terminated as soon as the contactor is closed. In *STEADY STATE*, the contactor in parallel to the SCR + resistor is closed. It conduct most of the current and current through the thyristor is not be enough to keep it close. Thyristor open automatically without external command from the microcontroller.

Figure 8. Normal and default pre-charge



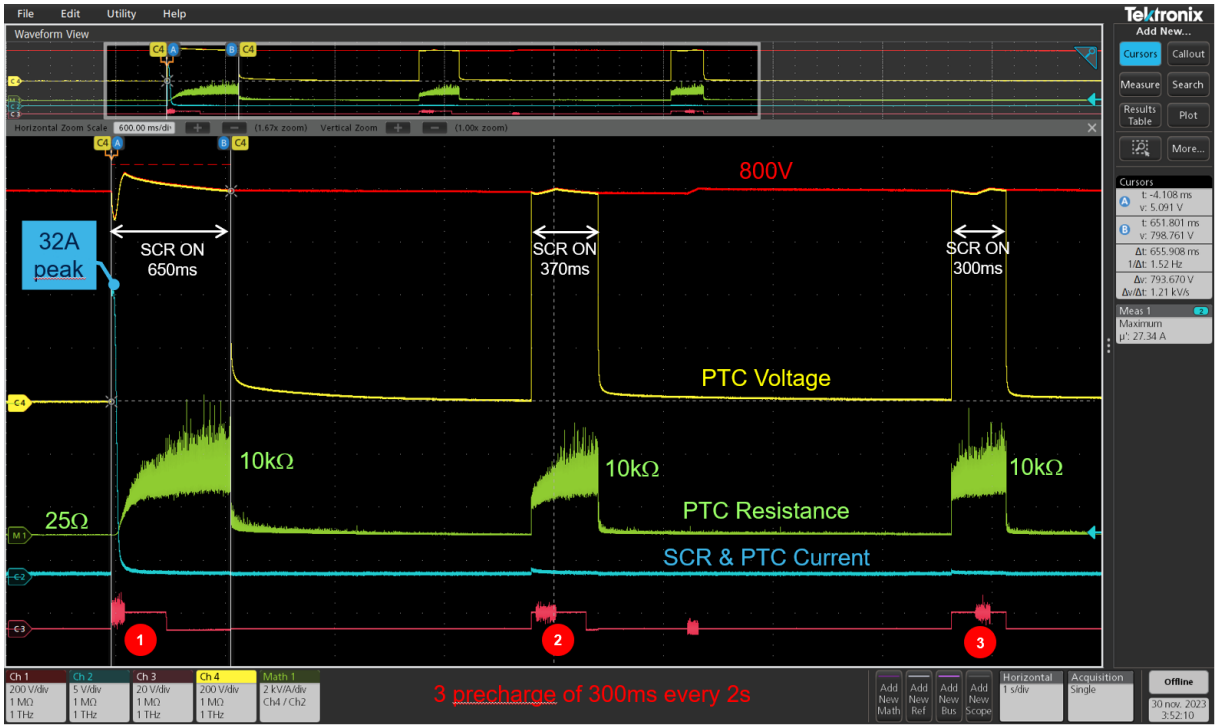
VBAT = 400 VDC / PWM = 50 kHz with Duty cycle = 20%

Using a positive temperature coefficient resistor (PTC)

Another solution to pre-charge the capacitor is to use a PTC instead of a standard pre-charge resistor. This also protect the system because in case of short circuit the PTC resistor value increase and the current through the thyristor decrease below the holding current. This automatically stop the pre-charge.

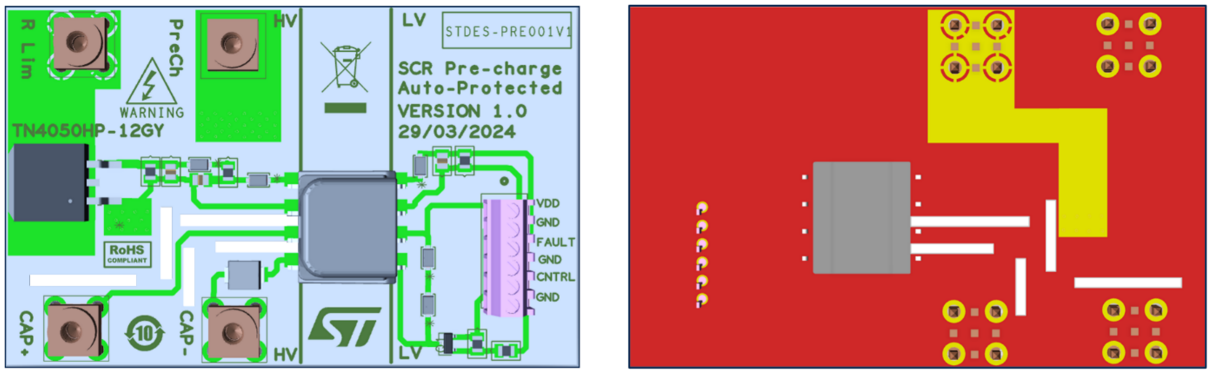
Figure 8 shows a case where the pre-charge thyristor is activated on a short circuit. The PTC take 650 ms to heat up to a value that unlatch the thyristor. A total of 3 unsuccessful, attempts can be made before reporting the pre-charge error.

Figure 9. **Using a PTC as pre-charge resistor**



5 Layout

Figure 10. **STDES-PRE001V1 layout**

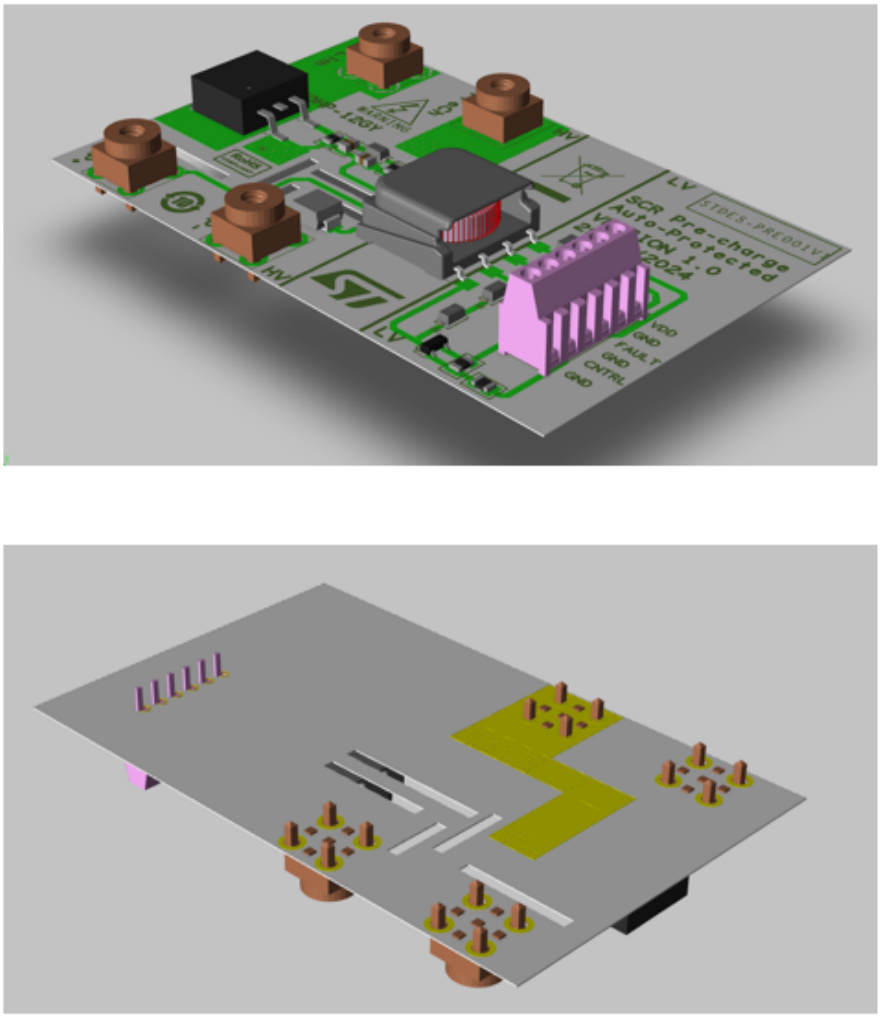


Top layer

Bottom layer

6 3D views

Figure 11. **STDES-PRE001V1 3D view**



7 BOM

Table 2. **STDES-PRE001V1 bill of materials**

Designator	Part	Description
D1, D3	DLA11C	Diode
D2, D4	ZY6V8GP	6.8 V zener diode
D5	STTH112-Y	1 A, 1200 V SMBflat, automtive grade ultratfast diode
R1		Resistor
R2		Resistor
R3		Resistor
R4		Resistor
C1		33 nF capacitor
C2		33 nF capacitor
X1	TN4050HP-12GY	40 A, 1200 V D²PAK automotive grade thyristor
Q1	STR2N2VH5	N-channel MOSFET
U1	PM2155	Dual pulse transformer
J1		2.5 mm pitch header 6 pins
CON1/2/3/4		Power connector

Revision history

Table 3. **Document revision history**

Date	Revision	Changes
11-Jun-2024	1	Initial release.