Getting started with the testing platform of SiC MOSFETs for HiP247-4 packages

Introduction

The STDES-SICGP4 is a testing platform reference design developed to test the high-speed switching performance of the ST's Silicon Carbide (SiC) MOSFETs. The platform implements a half-bridge configurations that supports HiP247-4 packages. By applying the appropriate digital signals and the correct input supplies, the board is able to generate the gate-driver commands to turn on/off the MOSFETs in the HB topology.

This platform allows testing the switching performance of the MOSFETs using the double-pulse test method.

The STDES-SICGP4 is a fully assembled kit developed for performance evaluation only, not available for sale.

Figure 1. STDES-SICGP4 reference design

Fully assembled board developed for performance evaluation only, not available for sale

1 Getting started

1.1 Safety precautions

Danger: *There is 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 DC input.*
- *The evaluation kit is directly linked to the high DC voltage. No insulation is ensured between some accessible parts and the high DC voltage.*
- *The high-side MOSFET source is switching, with reference to the common input voltage GND. All measurement equipment connected to this point must be isolated from the DC source before powering the board. It has to introduce a very low capacitance (<20 pF).*
- *You can supply the kit only through a DC source. Take care about the correct polarity.*

Caution: During assembly, testing, and operation, the evaluation kit poses several inherent hazards, including bare wires and hot surfaces.

All operations involving transportation, installation, use, and maintenance must be performed by skilled technical personnel who is familiar with the installation, use, and maintenance of power electronic systems.

Work area safety

- The work area must be clean and tidy.
- Do not work alone when the 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 kit 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 power supply from the evaluation kit and electrical loads before performing any electrical measurement.
- Arrange measurement setup, wiring, and configuration paying attention to high voltage sections.
- Once the setup is complete, power the kit.

Danger: *Do not touch the evaluation kit 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. Heat-sinks and transformers may still be very hot.*

The kit is not electrically isolated from the DC high voltage input.

Personal safety

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

Caution: The kit is not equipped by EMI filter. Additionally, the fast switching of power MOSFETs can lead to high frequency oscillations, generating radiated noise.

The EMI conductive radiated emission can cross the standards limits.

Conductive emissions

To keep conductive emissions under the limit defined by EN55032, the additional EMI filter introducing attenuation in level 10 dB must be implemented.

Radiated emission

To keep EMI radiated emissions under the limit defined by EN55032, the shield introducing the attenuation of EMI noise about 40 dB in the range of 30 MHz to 100 MHz has to be applied.

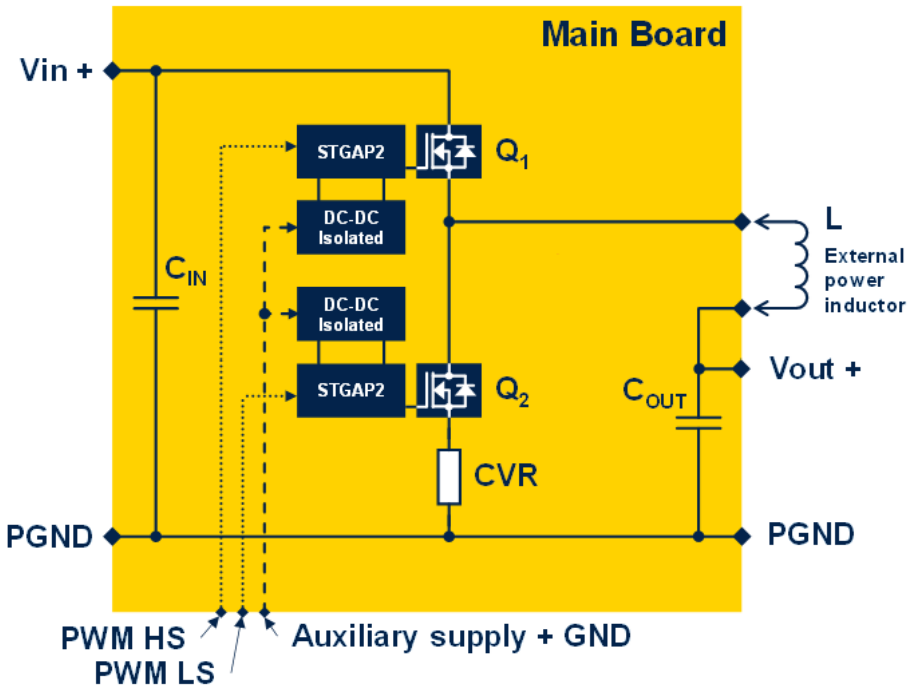
1.2 Overview

The testing board contains a half bridge (HB) structure based on two high voltage SiC MOSFETs. The MOSFETs are controlled through isolated gate drivers, which are supplied via isolated DC-DC converters.

The system requires the connection of an external inductor, a source, a load, an auxiliary supply, and PWM signals. It can be used to test the operation in buck or boost configuration. You can use a low inductance shunt or assemble a coaxial shunt to measure the current through the low-side MOSFET. Thus, the board can be used as a tool for double pulse test (DPT).

The complete solution consists of several blocks: the main board, the drivers, and the DC-DC converters.

Figure 2. STDES-SICGP4 block diagram



1.2.1 Main board

The main board features two SCTWA70N120G2V-4 power SiC MOSFETs (Q1 and Q2), connected respectively, at the high and low side of a HB configuration. C_{IN} and C_{OUT} DC-Link foil capacitors work both as input and output capacitors, depending on the board usage in a Buck or a Boost topology. An external inductor (L) is connected between the HB center point and the C_{OUT} capacitor.

The maximum voltage allowed on the power side is limited by both the MOSFETs and the capacitors rating. Normally the system embeds two SCTWA70N120G2V-4 SiC MOSFETs, able to withstand 1.2 kV, and two 1.2 kV foil capacitors, therefore the voltage must not exceed 1.0 kV.

The main board contains connectors to supply the signal side of the gate drivers and connections for PWM signals. The PWM signals have to be generated externally, for the high side and the low side separately.

The board can be controlled through PWM signals for double pulse test. Consequently, the drain-source voltage drop and source current can be simply measured on the low side (Q2) MOSFET and used for switching energy calculation.

1.2.2 Driver boards

The MOSFETs are controlled via gate drivers assembled on the separated subboards soldered to the main board.

The STGAP2 rectangle in Figure 2 identifies the subboards. They embed a galvanic isolated gate driver STGAP2HS and the passive components around.

1.2.3 Isolated DC-DC converter

The power part of the gate drivers is supplied through additional subboards stacked onto the driver board. These subboards contain an isolated SMPS that generates the supply voltage (positive and negative) for the gate driver.

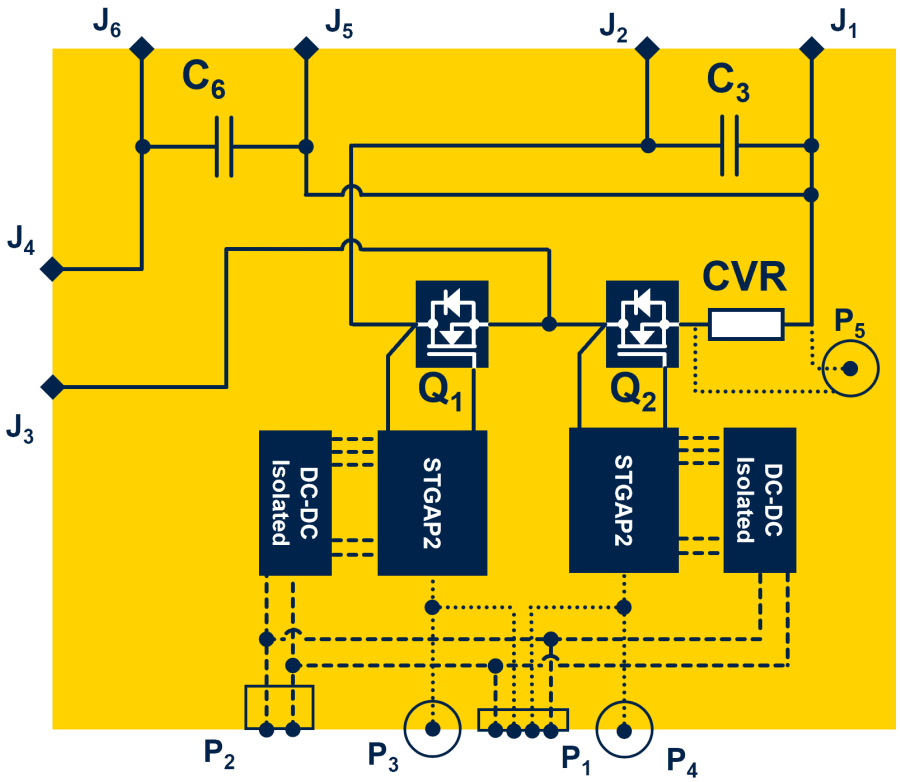
The DC-DC converter is based on the fly-buck topology. The primary side converter is L6986I.

The converter generates two output voltages. There is a discrete linear regulator behind each transformer winding. You can set the output voltage of the linear regulator through a resistor divider. This divider allows setting a custom gate voltage supply, depending on the tested MOSFETs.

1.3 Board connection

1.3.1 Power terminals (J1-J6)

Figure 3. Position of connectors



There are the following power terminal connections:

- the DC bus between the high-side drain and the low-side source is connected to the J1 and J2 terminals (to the C3 capacitor)
- the J1 terminal is connected to the GND common power (PGND)
- the J2 terminal is connected to the HV bus line
- the J5 and J6 terminals are connected to the C6 capacitor
- the J5 terminal is connected to the GND power (PGND in the block diagram) and the J6 terminal is connected to the HV BUS line.

If the board works in buck mode, the voltage source is connected between the J2–J1 pins (J2 is connected to the positive source terminal and J1 is connected to the negative source terminal) and the J6–J5 terminals are connected to the load.

If the board is used in a boost mode, the J6–J5 terminals are connected to the voltage source (J6 is connected to the positive source and J5 is connected to the negative source terminal), while J2 and J1 terminals are connected to the load.

The J3–J4 terminals are dedicated to the connection of the power inductor.

1.3.2 Signal terminals (P1-P5)

The signal side is dedicated to the connection of the auxiliary voltage (input), two PWM signals for MOSFET drivers (input), and shunt resistor sensing (output).

The auxiliary voltage and PWM signals can be connected to the board through the P1 header. The auxiliary voltage can be alternatively connected through P2 screw terminals. The PWM signals can be alternatively connected through the P3 and P4 SMA connectors.

The PWM signals can be generated through an oscillator or the MCU.

Important: *Avoid that both signals are set high at the same time.*

If the constant frequency is applied, both signals have to be complementary with the dead time.

You can apply a sense resistor between the source of the low-side MOSFET (Q2) and the power GND. There are two possible assembling options:

- a low inductance shunt, connected through the P5 connector MMCX
- a coaxial shunt, which is the BNC output

The shunt can be also shorted and not used. If a coaxial shunt is assembled, disassemble the low inductance shunt.

1.3.3 Connection summary

Table 1. Connectors and terminals

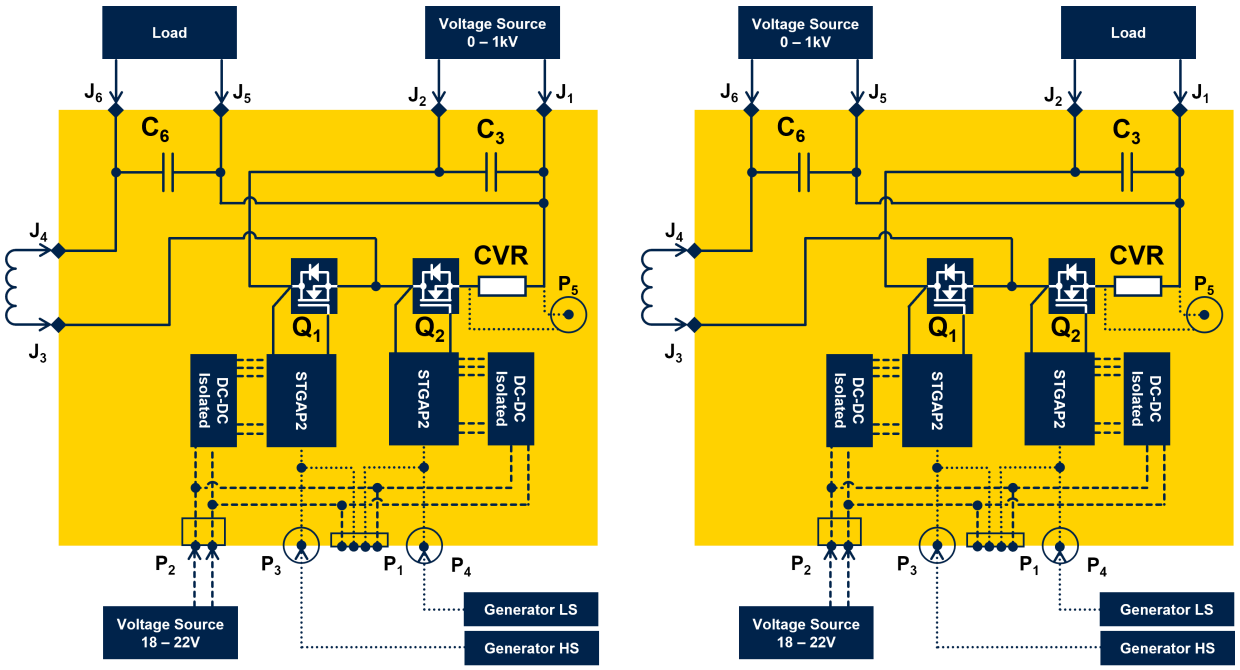
Name	Pin	Label	Description
J1	1	J1	Source voltage or load. Use the source if the buck converter mode operation is used. Use the load if the boost mode operation is used. J2 positive, J1 negative terminal.
J2	1	J2	
J3	1	J3	Inductor terminal
J4	1	J4	
J5	1	J5	Source voltage or load. Use the load if the buck converter mode operation is used. Use the source if the boost mode operation is used. J6 positive, J5 negative terminal.
J6	1	J6	
P1	1	P1	Auxiliary supply positive terminal
	2	P1	PWM digital input for the high-side MOSFET driver
	3	P1	PWM digital input for the low-side MOSFET driver
	4	P1	GND for the auxiliary supply and PWM signals
P2	1	P2	GND for the auxiliary supply

Name	Pin	Label	Description
	2	P2	Auxiliary supply positive terminal
P3	1	P3	PWM digital input for the high-side MOSFET driver, SMA coaxial connector
P4	1	P4	PWM digital input for the low-side MOSFET driver, SMA coaxial connector
P5	1	P5	Power shunt (R22) connection, MMCX coaxial connector

1.3.4 Typical connections

The following figure shows the typical connection when the board is used in a buck converter mode (left side) or in a boost mode (right side).

Figure 4. Typical connection in buck (on the left) or boost mode (on the right)



1.4 Maximum and minimum operating values

For a safe operation, keep the voltages present on the terminals within the defined limits. The crossing of maximum values can damage the parts assembled on the PCB.

Using signal and auxiliary supply values out of the defined range can damage the board or cause it not to work properly.

Set the PWM logic level signals as defined in the table below.

Table 2. Maximum and minimum values

Connector	Description	Min	Max
J2 - J1	DC bus over HB (input in buck mode)	0	1000 V
J6 - J5	Inductor to GND (output in buck mode)	0	1000 V
J2 - J1	Input current level peak (duration up to 100 µs)	-69 A	69 A
J2 - J1	Input current level peak	-1 A	1 A
J6 - J5	Input current level peak (duration up to 100 µs)	-69 A	69 A
J6 - J5	Input current level peak	-1 A	1 A
P2, P1–pins (1–4)	Auxiliary supply voltage range	22 V	26 V

Connector	Description	Min	Max
P2, P1–pins (1–4)	Auxiliary supply input current	0	100 mA
P3, P4, P1 - pins (3–4), P1 - pins (2–4)	PWM–voltage range	0	3.3 V
-	Ambient temperature	10°C	30°C

The maximum and minimum operating values refer to the original board MOSFETs. If you assemble MOSFETs with a lower V_{BDS}, adapt the limits for the J1, J2, J5, and J6 connectors.

Important: *Consider that the maximum value is valid also for the load. For instance, if the board works in the boost mode, the output voltage could reach the maximum value. Thus, you have to build an external limitation.*

Table 3. PWM high and low levels: voltage ranges

PWM	Min.	Max.
PWM high level	2.2 V	3.3 V
PWM low level	0.0 V	1.1 V

Warning:
- *The DC supply has to be connected by respecting the signs applied on the board. The connection of a negative voltage can damage the board or parts of it.*
- *The specification visible in Table 2 is valid for the original board. If the tested MOSFET is replaced with another device with a lower voltage, reduce the current or thermal rating maximum values of the original device (SCTWA70N120G2V-4) accordingly.*

2 Testing the kit

2.1 Test setup

To use the board, connect the external parts as shown in Figure 4.

Turn the power supplies off when they are connected to the board. Turn the first auxiliary supply on. Then, activate the PWM signal. Finally, turn on the power supply connected to the power connectors (J1 and J2 or J5 and J6).

Warning:

- *Apply a cover to the board to protect it*
- *Do not touch the power board when the power supply is applied*
- *Use an isolated connection between the power source and the board*
- *Use the DC power source with built-in protections against overvoltage and overcurrent or use external protections on the input path*
- *Use the DC load with built-in protections against overvoltage and overcurrent or use external protections on the input path*
- *This device is classified as ES3. There is no isolation. Connect the device to an external DC voltage only if the board and the external equipment are in a protected area (for instance, a closed box), to avoid any electrical risk.*

2.2 Test equipment

The auxiliary supply connected to P1 and P2 has to satisfy the following requirements:

- the supply voltage has to be within the specification defined in Table 2
- an internal or external current limitation has to be implemented as per the level defined in Table 2

The DC source that supplies the board input in buck or boost mode has to satisfy the following requirements:

- The requirements of the maximum voltage for J1 and J2 or J5 and J6 connectors specified in Table 2. The maximum voltage must not be crossed. Thus, if the DC source has a tolerance, the output voltage has to be set to the value lower or equal to the maximum value specified in Table 2
- The maximum input current must not cross the values specified in Table 2. The current limitation has to be applied to limit the applied current. The current limiter can be implemented in the DC source or it can be an external component. If the current crosses the limit, turn off the DC source output.
- Reduce the current limit if the IRMSmax (see Section 6) is lower than the maximum input current value defined in Table 2.
- Protect the DC source output against overvoltage. If the DC source cannot guarantee this operation, apply an external surge suppressor to the input DC bus. If the protection allows any overvoltage spike, the total maximum DC voltage applied on the DC input must be set as the maximum DC voltage defined in Table 2, reduced about the DC source voltage tolerance, and reduced about the possible voltage spike that the surge can generate.

Test the output electrical values. The load must integrate the protections listed below. Otherwise, implement these protections externally:

- The voltage on the output voltage must not cross the voltage value defined in Table 2 for J1 and J2 or J5 and J6 connectors. If the output voltage crosses the value specified in Table 2, the in-built circuit or the externally applied circuit must sense the voltage and disconnect the input voltage DC source.
- Measure the output current through the load or through an external sensing circuit. If the output current crosses the limitation specified in Table 2, disconnect the input DC voltage.

2.3 Test conditions

While testing the board, the ambient temperature has to be within the thermal range specified in Table 2.

Use a cover to protect the board in order to:

- avoid accidentally touching the board or the unisolated wires connected to the input, output, or inductor
- avoid accidentally touching the inductor
- protect against possible fire on the board
- protect against possible explosion of any components on the board

2.4 Test inductor

The inductor parameters applied to the J3 and J4 pins can be calculated by following the indications of Section 6 .

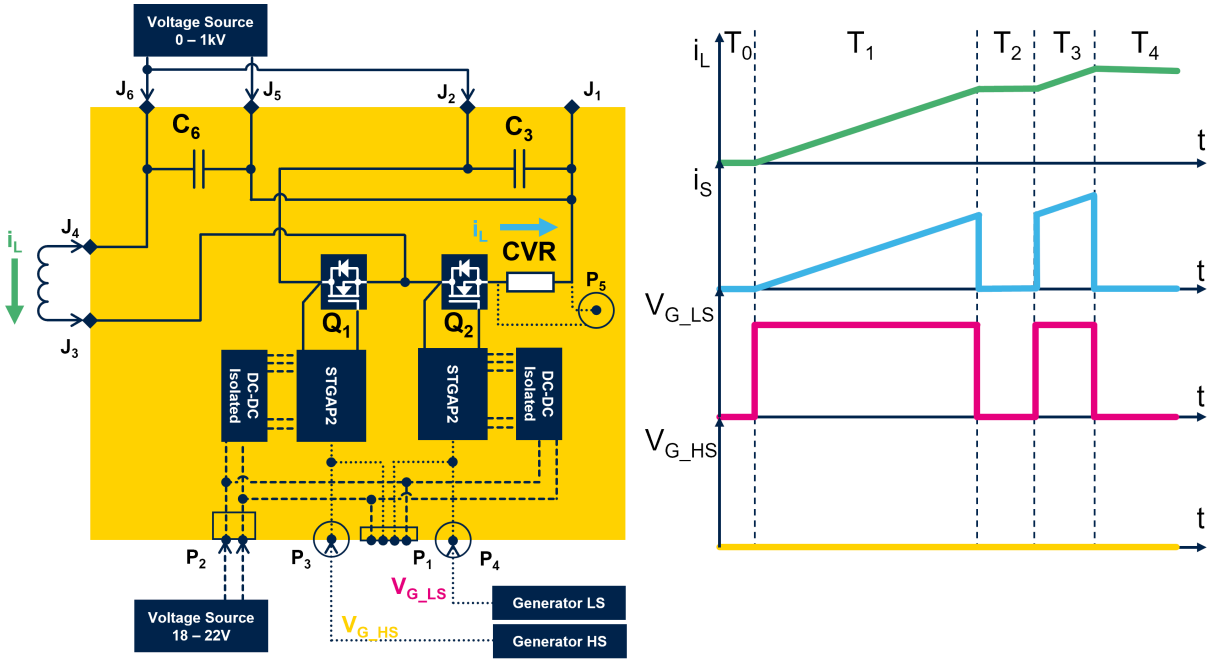
3 DPT operation

The double pulse test (DPT) allows measuring the turn on and off energy of the on-board low-side MOSFET. The simplest way is to connect input and output. It means the J6 and J2 connectors are connected through a short and low resistive wire. The test is provided on the low-side MOSFET (Q2).

The DPT operation requires the proper setting of the gate signal timing.

The signal for the high-side MOSFET is set to low. The low-side signal has to follow the timing shown in the following figure.

Figure 5. DPT timing steps



1. T_0 period: both MOSFETs are turned off. The auxiliary and high power sources are connected.
2. T_1 period: low-side MSOFET is turned on. The high-side MOSFET is kept off. The inductor current rises up. At the end of the T_1 period, the MOSFET current reaches the level used to test the MOSFET. The T_1 duration allows programming the test current level.
3. T_2 period: if the current reaches the dedicated value, the T_2 period starts from the low-side MOSFET turning off. The V_{DS} and I_S are measured during the transient for measurement of the E_{OFF} energy. The inductor current closes the loop through the high-side MOSFET. As the gate voltage of the high-side MOSFET is turned off, the current flows through the MOSFET body diode.
4. T_3 period: at the beginning of the period, the low-side MOSFET is turned on. The V_{DS} and I_S are measured during the transient for measurement of the E_{ON} energy. This period finishes after the on energy inputs are collected.
5. T_4 period: both MOSFETs are turned off. The inductor current flows through the high-side MOSFET body diode. The inductor slowly discharges. The period finished after the inductor current is 0 A.

4 Shunt

There are two options for the low-side MOSFET current measurement:

- Use the R22 resistor that is a low inductance shunt. The signal from this resistor is connected to the MMCX connector. It is referred to the source of the low-side MOSFET
- Use a coaxial shunt on the R13 position. In this case, disassemble R22

4.1 Coaxial shunt

The coaxial shunt is not assembled in the original board. However, the PCB layout supports the use of this type of resistor.

The layout supports the version with a threaded case body with low-profile panel nuts (see R13 in Section 8 Bill of materials).

This type of sense resistor is applicable to sense a fast transient signal that requires a bandwidth in the range of a hundred MHz. This is possible thanks to the coaxial shunt that has a marginal stray inductance.

To assemble a coaxial shunt, consider the following points:

- The board is originally assembled with the R22 resistor (low inductive SMD shunt). R22 is parallel to R13. The proper current sensing is possible only using one of these shunts. Therefore, if R13 is assembled, disassemble R22.
- The proper measurement considering the voltage sensing (V_{D-S} and V_{G-S}) is referred to the source point of the transistor. Therefore, the coaxial shunt body, which is the grounding point, is connected to the source of the low-side MOSFET source. The middle point of the coaxial shunt is connected to the power GND of the board (power GND means that the GND is connected to the input and output capacitors and to the heat-sink). Connecting the coaxial shunt to the scope and connecting the voltage probe reference to the power GND at the same time cause the shorting of the coaxial shunt through the scope GND. Connect the voltage probe reference only to the source point of the low-side MOSFET.
- The connection of the coaxial shunt described in the previous point also causes the signal visible in the scope to be negative.
- The coaxial shunt body is close to the heat-sink. As the heat-sink is connected to the power GND, ensure that the GND of the coaxial cable connected to the coaxial shunt does not touch the heat-sink.
- When selecting the operating conditions, consider that the coaxial shunt has a limited average power dissipation.

5 Gate driver supply voltage setting

The driver isolated part is supplied via the isolated DC-DC converter. It is based on the fly-buck topology controlled through the L6986I.

The converter generates two output voltages by two secondary windings. There is a discrete linear regulator behind each winding. You can set the output voltage of the linear regulator through a resistor divider.

The voltage level connected to the VH pin of STGAP2HS is set through the R2 and R3 resistors.

The negative voltage connected to the VL pin of the gate driver is set through the R6 and R9 resistors.

The middle point of each divider is regulated to 2.5 V. The nominal setting of the gate voltage is +18 V/-3 V.

6 Inductor

The inductor is not embedded in the testing board. In the applied inductor:

- The inductance value has to be in the appropriate range
- The inductance value has not to drop below a certain level due to the operating current: that is, the inductor saturation current has to be high enough to avoid that the inductance drops below the minimum limit during the operation
- The inductor winding has to be rated to the applied voltages. It means it is rated to the voltage applied as the input and output protection.

The inductor value is defined through the following parameters:

- Inductance L (inductor inductance)
  - Saturation current I_{sat}: the current that makes the inductor to drop of about 20%
  - Maximum operating temperature
  - Maximum RMS current (I_{RMSmax}): the current that causes the inductor thermal increase below the allowed operating temperature of the inductor for the maximum ambient temperature specified in Table 2

6.1 Inductor value

The inductor value has to guarantee that the pulse current does not saturate the inductor. The expected shortest duration of the MOSFET turn-on is considered 1 µs. The inductor minimum value can be defined as:

$$L_{\min} \geq \frac{t_{ON} V_{IN\_MAX}}{I_{MAX}}$$

Where

L_{min} is the inductance minimum value.

t_{ON} is the MOSFET turn on time. It is considered 1 µs.

V_{IN_MAX} is the maximum input or output voltage (see Table 2).

I_{MAX} is the maximum pulse inductor current. It is the lowest value among the pulse current defined for the input and for the output in Table 2 or I_{sat}.

The maximum value of inductance is not limited.

7 Schematic diagrams

Figure 6. **STDES-SICGP4 main board circuit schematic - power section**

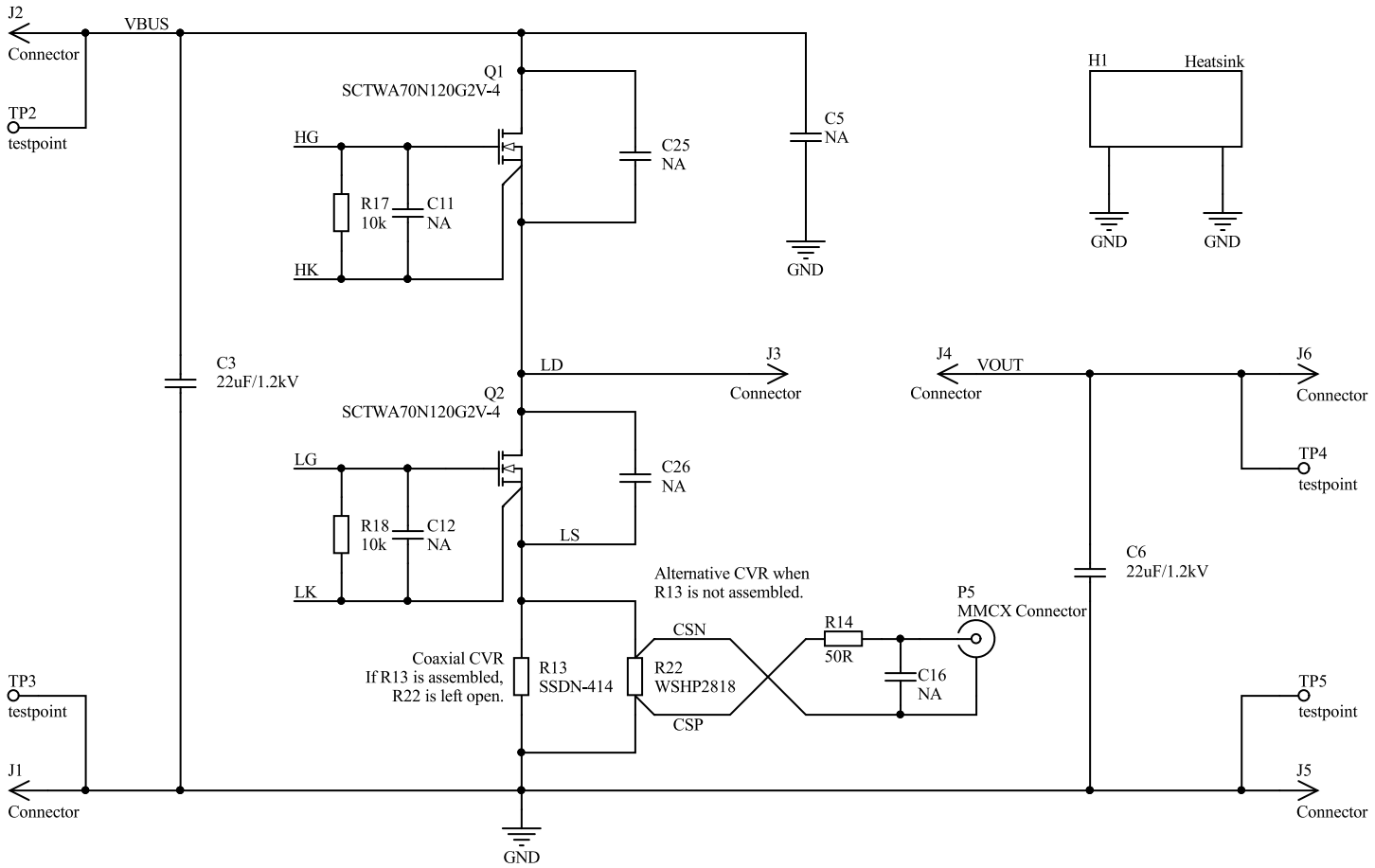


Figure 7. **STDES-SICGP4 main board circuit schematic - signal section**

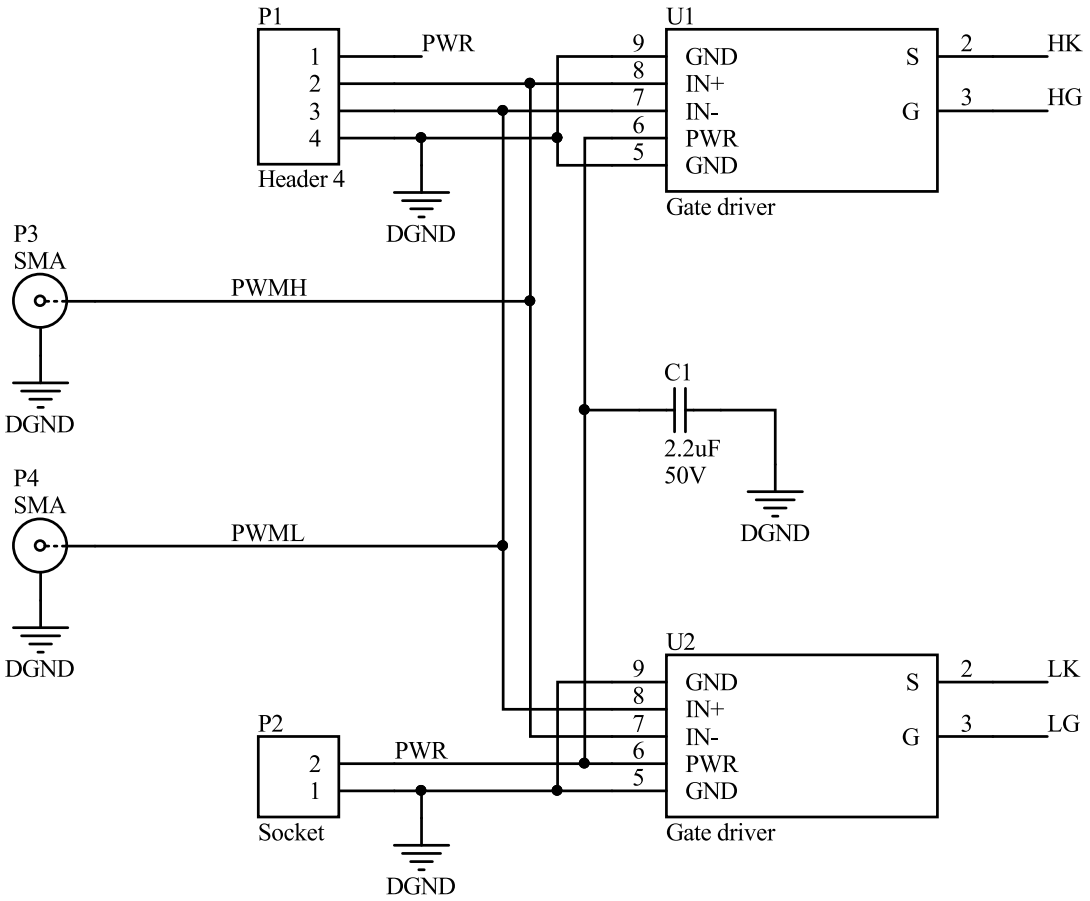


Figure 8. STDES-SICGP4 driver circuit schematic

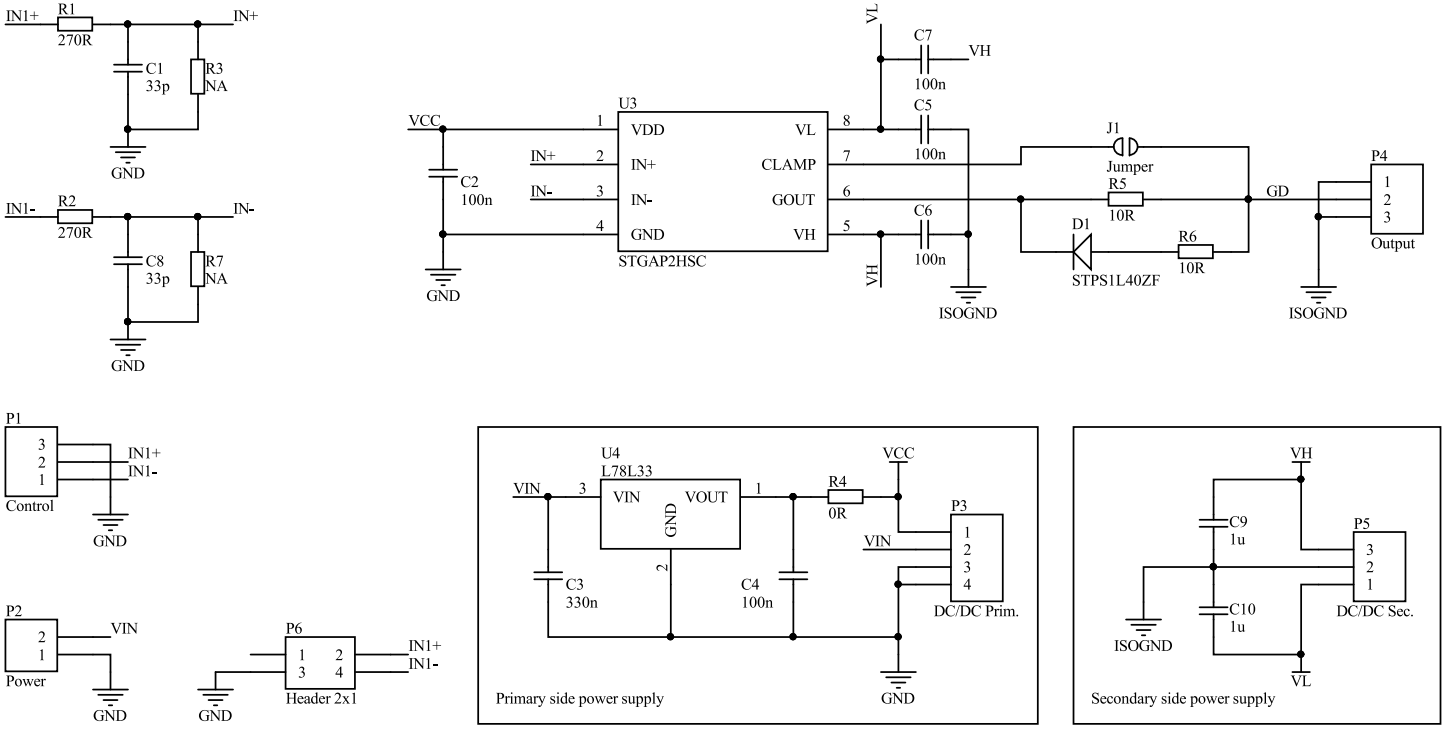
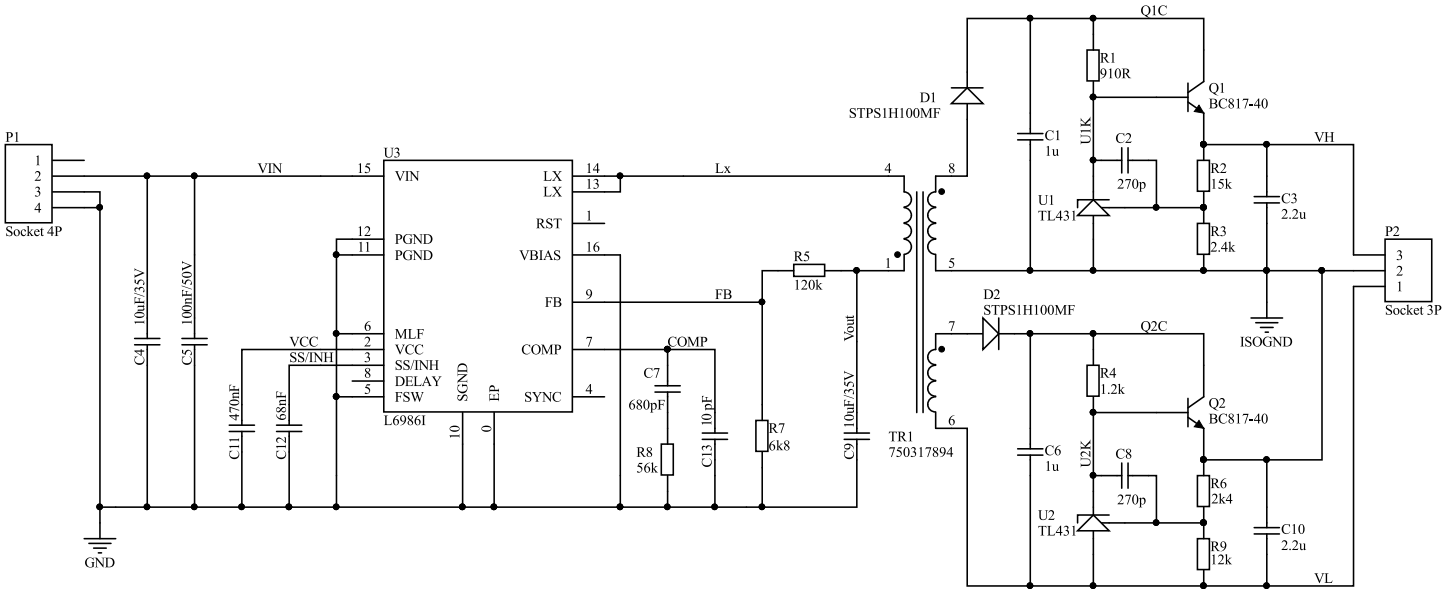


Figure 9. STDES-SICGP4 DC-DC isolated converter circuit schematic



8 Bill of materials

Table 4. STDES-SICGP4 bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	Table 5. Main board bill of materials	-	Main board	ST	Not available for separate sale
2	1	Table 6. Driver bill of materials	-	Driver	ST	Not available for separate sale
3	1	Table 7. DC-DC converter bill of materials	-	DC-DC converter	ST	Not available for separate sale

Table 5. Main board bill of materials

Item	Q.ty	Ref.	Value	Description	Manufacturer	Order code
1	1	C1	CAP CER 1206 2.2uF 50V X7R 20%, 1206	Ceramic capacitor	Any	Any
2	2	C3, C6	CAP FOIL RBOX 22uF 1.2kV PP 5%	Foil capacitor	Vishay	MKP1848H62212JY5
3	1	C5 Not Assembled	CAP 22.5-26x13	Foil capacitor	Any	Any
4	2	C11, C12	CAP CER 0805 50V, 0805	Ceramic capacitor	Any	Any
5	1	C16	CAP CER 0603 X7R, 0603	Ceramic capacitor	Any	Any
6	2	C25, C26 Not Assembled	CAP CER 2220 C0G, 2220	Ceramic capacitor	Any	Any
7	1	H1	SK 575 84 SA	Heatsink	Fischer Elektronik	SK 575 84 SA
8	6	J1, J2, J3, J4, J5, J6	CONN WP-THRBU, M4, 8p, 10x10mm	Connector	Wurth Elektronik	74650094R
9	1	P1	CON HDR 2.54mm 4pin 1row	Header 4	Any	Any
10	1	P2	CON PCB TERMINAL 2-pole 5mm	Socket	Wurth Elektronik	691213710002
11	2	P3, P4	CON SMA THR ANGLE PLUG	SMA	Wurth Elektronik	60311002111526
12	1	P5	CON MMCX SMD STRAIGHT PLUG	MMCX Connector	Amphenol	908-NM22109
13	2	Q1, Q2	SCTWA70N120G2V-4, HiP-247-4	Silicon carbide power MOSFET	ST	SCTWA70N120G2V-4
14	1	R13 Not Assembled	SSDN-414 Coaxial CVR	Coaxial shunt	Billmann Engineering	-
15	1	R14	RES 0603 50R 1% 125mW, 0603	Resistor	Any	Any
16	2	R17, R18	RES 0805 10k 250mW 1%, 0805	Resistor	Any	Any
17	1	R22	RES 2818 20mR 10W 1%, 2818	Resistor	Vishay	WSHP2818R0200FEB
18	4	TP2, TP3, TP4, TP5	TP THR 1.6mm	Test point	Keystone Electronics	5011
19	2	U1, U2	Gate driver module	Sub board	Any	Any
20	2	-	Retaining springs for transistors	Spring	Fischer Elektronik	THFU 4

Item	Q.ty	Ref.	Value	Description	Manufacturer	Order code
21	2	-	Insulation foil for transistors	Isolation foil	Fischer Elektronik	WS 247 1

Table 6. Driver bill of materials

Item	Q.ty	Ref.	Value	Description	Manufacturer	Order code
1	2	C1, C8	33p, 0603	Ceramic capacitor	Any	Any
2	4	C2, C5, C6, C7	100n, 0603	Ceramic capacitor	Any	Any
3	1	C3	330n, 0805	Ceramic capacitor	Any	Any
4	1	C4	100n, 0805	Ceramic capacitor	Any	Any
5	2	C9, C10	1u, 0805	Ceramic capacitor	Any	Any
6	1	D1	STPS1L40ZF, SOD123 Flat	40 V, 1 A low drop power Schottky rectifier	ST	STPS1L40ZF
7	1	J1	Jumper	PCB Jumper	Any	Any
8	1	P1	Control	PCB connector	Any	Any
9	1	P2	Power	PCB connector	Any	Any
10	1	P3	DC/DC Prim., 4 pin x 1	Header 2.54 4pin x 1	Any	Any
11	1	P4	Output	PCB connector	Any	Any
12	1	P5	DC/DC Sec., 3 pin x 1	Header 2.54 3pin x 1	Any	Any
13	1	P6	Header 2x1, 2 pin x 2	Header 2.54 2pin x 2	Any	Any
14	2	R1, R2	270R, 0603	Resistor	Any	Any
15	2	R3, R7 Not Assembled	NA, 0603	Resistor	Any	Any
16	1	R4	0R, 0805	Resistor	Any	Any
17	2	R5, R6	10R, 1210	Resistor	Any	Any
18	1	U3	STGAP2HSCMTR, SO 8 WIDE 300	Galvanically isolated 4 A single gate driver	ST	STGAP2HSCMTR
19	1	U4	L78L33ABUTR, SOT-89	Positive voltage regulator	ST	L78L33ABUTR

Table 7. DC-DC converter bill of materials

Item	Q.ty	Ref.	Value	Description	Manufacturer	Order code
1	2	C1, C6	CAP CER 0805 1uF 50V X7R 10%, 0805	Ceramic capacitor	Any	Any
2	2	C2, C8	CAP CER 270p 0603 50V C0G 10%, 0603	Ceramic capacitor	Any	Any
3	2	C3, C10	CAP CER 0805 2.2uF 50V X7R 10%, 0805	Ceramic capacitor	Any	Any
4	2	C4, C9	CAP CER 10uF 35V 1206 X7R 10%, 1206	Ceramic capacitor	Any	Any
5	1	C5	CAP CER 100nF 50V 1206 X7R 10%, 1206	Ceramic capacitor	Any	Any
6	1	C7	CAP CER 680pF 50V 0603 C0G 10%, 0603	Ceramic capacitor	Any	Any
7	1	C11	CAP CER 470nF 50V 0603 X7R 10%, 0603	Ceramic capacitor	Any	Any
8	1	C12	CAP CER 68nF 50V 0603 X7R 10%, 0603	Ceramic capacitor	Any	Any

Item	Q.ty	Ref.	Value	Description	Manufacturer	Order code
9	1	C13	CAP CER 10pF 50V 0603 C0G 10%, 0603	Ceramic capacitor	Any	Any
10	2	D1, D2	STPS1H100MF, STmiteFLAT	00 V, 1 A STmite flat power Schottky rectifier	ST	STPS1H100MF
11	1	P1	CON SOCK 2.54mm 4pin 1row	Header Receptacle 4 pins 1 row	Any	Any
12	1	P2	CON SOCK 2.54mm 3pin 1row	Header Receptacle 3 pins 1 row	Any	Any
13	2	Q1, Q2	BC817-40, SOT23	NPN Transistor	Any	Any
14	1	R1	RES 910R 0805 125mW 1%, 0805	Resistor	Any	Any
15	1	R2	RES 15k 0603 100mW 1%, 0603	Resistor	Any	Any
16	1	R3	RES 2.4k 0805 125mW 1%, 0805	Resistor	Any	Any
17	1	R4	RES 1.2k 0805 125mW 1%, 0805	Resistor	Any	Any
18	1	R5	RES 120k 0603 100mW 1%, 0603	Resistor	Any	Any
19	1	R6	RES 2k4 0603 100mW 1%, 0603	Resistor	Any	Any
20	1	R7	RES 6k8 0603 100mW 1%, 0603	Resistor	Any	Any
21	2	R8, R9	RES 12k 0603 100mW 1%, 0603	Resistor	Any	Any
22	1	TR1	WE-AGDT gate drive transformer, SMD	Transformer	Wurth Elektronik	750317894
23	2	U1, U2	TL431ACL3T, SOT23	Adjustable micropower shunt voltage reference	ST	TL431ACL3T
24	1	U3	L6986ITR, HTSSOP16	38 V, 5 W synchronous iso-buck converter	ST	L6986ITR

Revision history

Table 8. **Document revision history**

Date	Revision	Changes
24-Nov-2022	1	Initial release.

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