User Manual

SCS25BD400

(Bi-Directional Power Converter)

Prepared By: SCS

www.scspower.in info@scspower.in

Jan, 2025. Rev. – 1.1

This document serves as a user guide for the installation and operation of SCS hardware**.** It has been written in English. All cautionary information is also provided in English. If the final user of this hardware is not proficient in English, it is the responsibility of the provider or intermediary to ensure that the user fully comprehends the information outlined in this document, particularly the terms, conditions, safety warnings, and operational hazards associated with the hardware.

Note: This hardware, developed by SCS, is a delicate, high-voltage, and high-temperature power electronics system. It is intended strictly for handling and operation by qualified professionals, such as experienced engineers or certified technicians.

When not in use, the hardware must be stored in an environment with a temperature range between -10°C and 70°C. During transportation, appropriate precautions must be taken to prevent mechanical or electrostatic damage. The device should be securely packaged, ideally in an ESD-safe bag or enclosure, equivalent to what SCS uses for safe shipment. For any queries regarding transportation safety, please reach out to info@scspower.in.

⚠ CAUTION

PLEASE CAREFULLY REVIEW THE FOLLOWING PAGES, AS THEY CONTAIN IMPORTANT INFORMATION REGARDING THE HAZARDS AND SAFE OPERATING REQUIREMENTS RELATED TO THE HANDLING AND USE OF THIS BOARD. DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD. THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS EVALUATION BOARD WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS BOARD CAN REACH TEMPERATURES ABOVE 50˚ CELSIUS. FURTHER, THESE CONDITIONS WILL CONTINUE FOR A SHORT TIME AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED.

Please ensure that appropriate safety procedures are followed when operating this board, as any of the following can occur if you handle or use this board without following proper safety precautions:

DEATH ▲ SERIOUS INJURY ▲ ELECTROCUTION ▲ ELECTRICAL SHOCK ▲ ELECTRICAL BURNS ▲ SEVERE HEAT BURNS

You must read this document in its entirety before operating this board. It is not necessary for you to touch the board while it is energized. All test and measurement probes or attachments must be attached before the board is energized. You must never leave this board unattended or handle it when energized, and you must always ensure that all bulk capacitors have completely discharged prior to handling the board. Do not change the devices to be tested until the board is disconnected from the electrical source and the bulk capacitors have fully discharged.

Contents

List of Figures

List of Tables

1. Introduction

The SCS25BD400 Bi-Directional Power Converter is a compact modular unit designed for DC–DC bidirectional conversion. It is ideally suited for battery charging/discharging, energy storage systems, and renewable energy integration, supporting both Silicon (Si) and Silicon Carbide (SiC) power devices. The system is designed for external control via microcontrollers (MCUs) or digital signal processors (DSPs), offering flexibility for rapid development and prototyping.

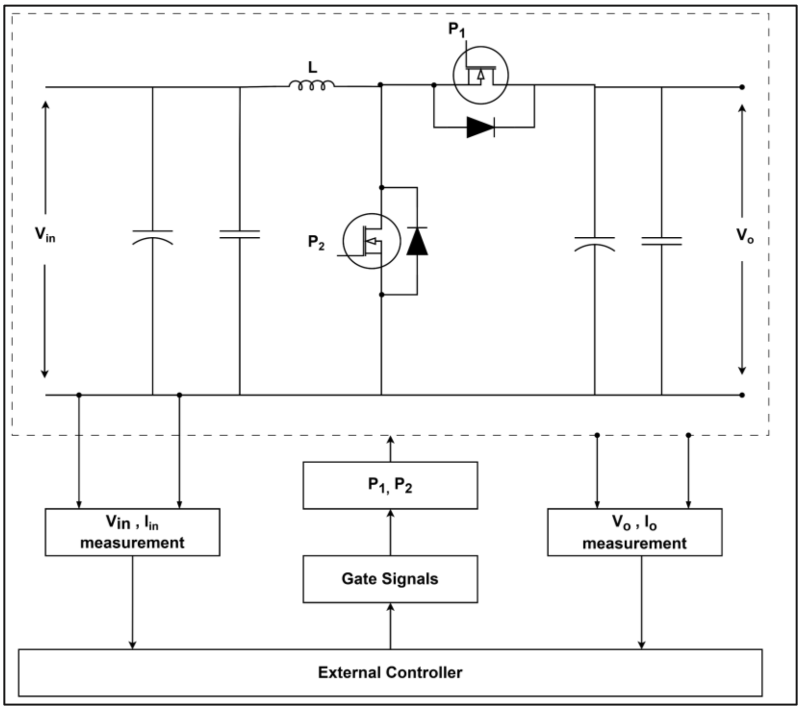


Figure 1: SCS25BD400 Block Diagram

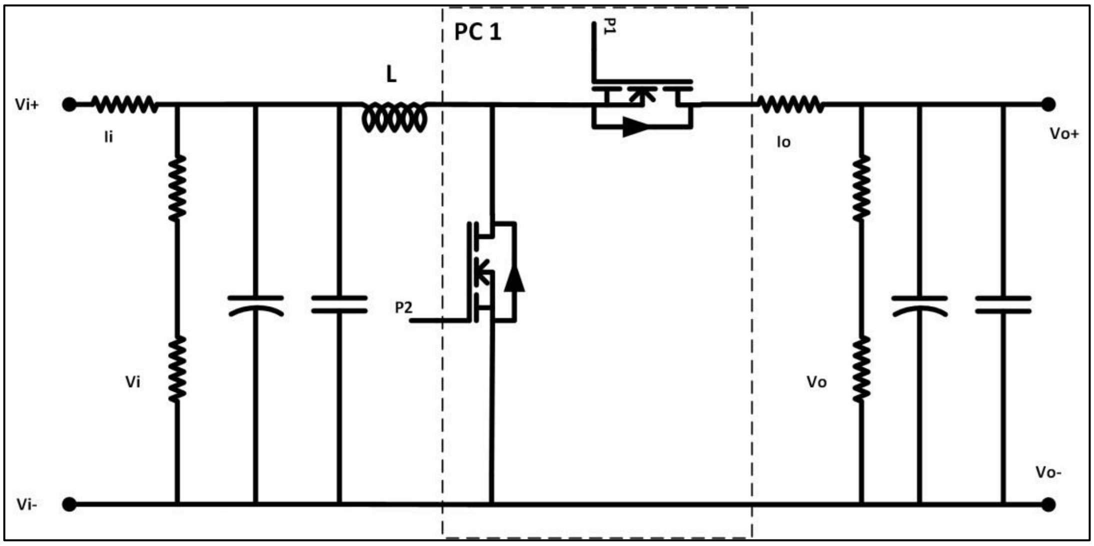


Figure 2: SCS25BD400 Circuit Diagram

As illustrated in the figure above, the Bi-Directional converter driven by two power switches (P_1–P_2). A regulated DC input (Vi) is applied to the converter, which converts it into a modulated DC output (Vo) through controlled switching. allowing precise control over voltage and frequency.

The system integrates bus and phase measurement circuits, which monitor key parameters such as V_{IDC}, I_{IDC} ,V_{ODC}, I_{ODC}. These signals are fed back to the external controller, enabling real-time adjustments to gate signals for optimized performance and protection. This converter architecture supports safe operation under high power conditions, with provisions for thermal and electrical feedback control, ensuring reliability and efficiency in demanding applications.

2. Design Features

2.1 Key System Specifications

- Reinforced isolated converter suited for up to 400-V DC drives rated up to 10 kW.
- Simple yet effective high-speed gate driver up to 250kHz switching frequency, 8-A sink/source current capability.
- Reinforced isolated amplifier with high bandwidth (>250 kHz) for sensing input dc voltage and current, output DC bus voltage and current, and temperature; enables direct interface with MCU.
- Calibrated current and voltage measurements with accuracy of ±1%.
- Protection against DC bus overvoltage, overload, short circuit, open circuit, shoot through, ground fault, and overtemperature.
- All low and isolated power requirements fulfilled with the single DC power source of 24V.

Applications

- DC-DC Power Converter
- Industrial DC Power Supplies
- EV Chargers
- Renewable Energy

Table 1: SCS25BD400 Ratings

Symbol	Parameter	Min.	Typ.	Max.	Unit
P_{OUT}	Output Power	-	-	10	kW
V_{DC}	DC Bus Voltage	-	350	400	V
V_{AUX}	Auxiliary Voltage	22	24	25	V
I_{AUX}	Auxiliary Current	-	-	2	A
I_{OUT}	Output Current	-	-	25	A
f_s	Switching Frequency	-	-	150	kHz

Note: For switching frequency above 100kHz, change in snubber components required for smooth switching voltages

2.2 Subsystem Functional Groups

The figures below show the subsystem functional groups of the evaluation board from top and side profile views, with descriptions of each labelled subsystem provided in Table 2.

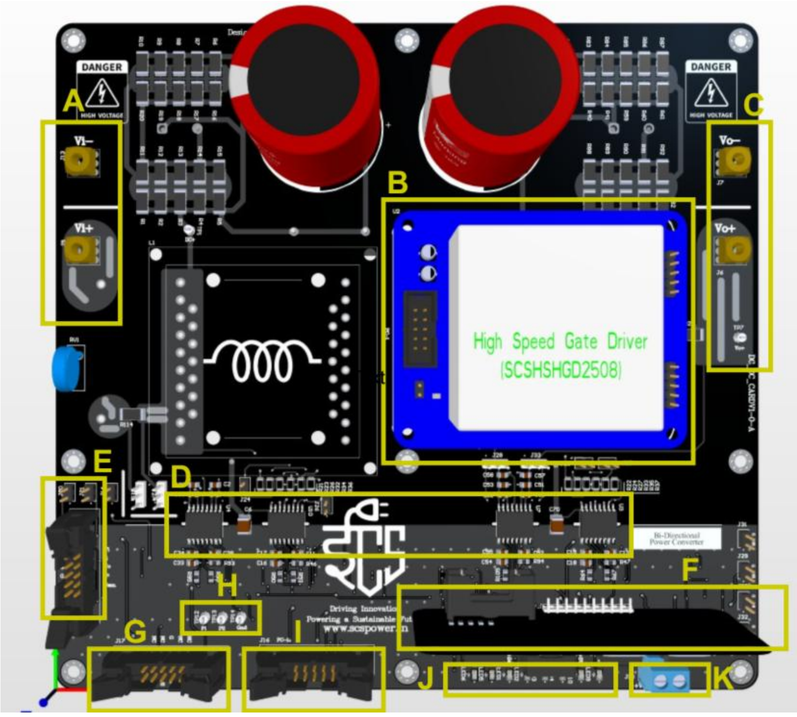


Figure 3: SCS25BD400 Top View Layout

Table 2: Subsystem Functional Group Descriptions

Label	Description
A	Input DC Voltage Terminals
B	High Speed Gate Driver
C	Output DC Voltage Terminals
D	Voltage and Current Sensors
E	Sensor Output
F	Auxiliary Power Supply
G	Gate Driver I/O
H	Fault Indicators for Gate Pulse
I	Gate Driver Terminals
J	LED Indicators
K	24V I/P

2.2.1 Input DC Voltage Terminals

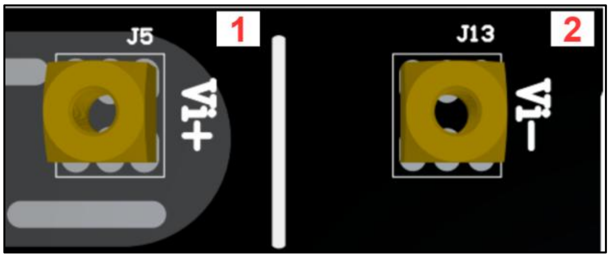


Figure 4: Input DC Voltage Terminals

These terminals accept the main DC input power for the converter. Ensure correct polarity and that the voltage range is within the specified limit (maximum DC voltage: 400 V) during connection. Below is the pinout and corresponding table for reference

Table 3: Input Terminals pinout

Pin No.	Indicator	Description
1	Vi+	Input DC positive Voltage
2	Vi-	Input DC negative Voltage

2.2.2 High Speed Gate Driver

SCSHSHGD2508 is a compact yet powerful half-bridge (two output channels) gate driver for all types of power semiconductor switches (Si, SiC, and GaN) and can operate at switching frequencies of up to 250 kHz, making it particularly suitable for new generation SiC and GaN power switches that require high-speed operation. It features several protection mechanisms with onboard isolated supplies, ensuring reliability and efficient switching performance.

Features

- Up to 250 kHz switching frequency
- Standard +15/-5 volts drive (can be provided with other preferable options)
- Direct 3.3V and 5V pulse support, no need for additional interfacing circuit
- 8A peak current drive capability
- On board isolated supplies
- Half-bridge drive with inbuilt dead band option available
- Buffered inputs for low noise
- Under-voltage lockout protection
- Short-circuit protection using VCESAT and Fault feedback
- Up to 1000 volts DC link support
- Power and fault indication LED

2.2.3 Connection Schematic & Characteristics

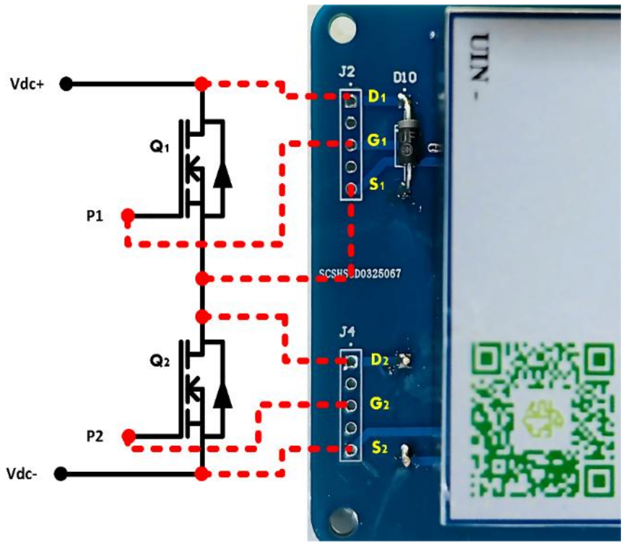


Figure 5: Connection of gate driver points with semiconductor switch

Indications

- **Green LED:** Power ON
- **Red LED:** Fault Condition

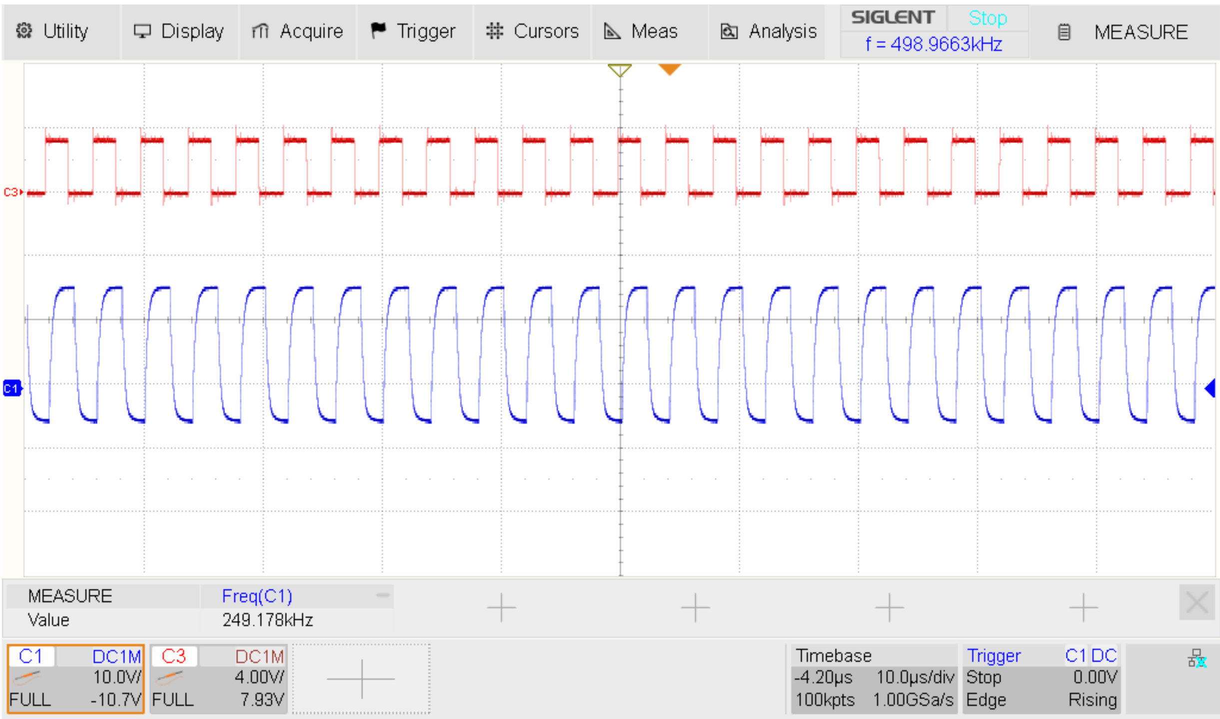


Figure 6 : 250kHz Operation

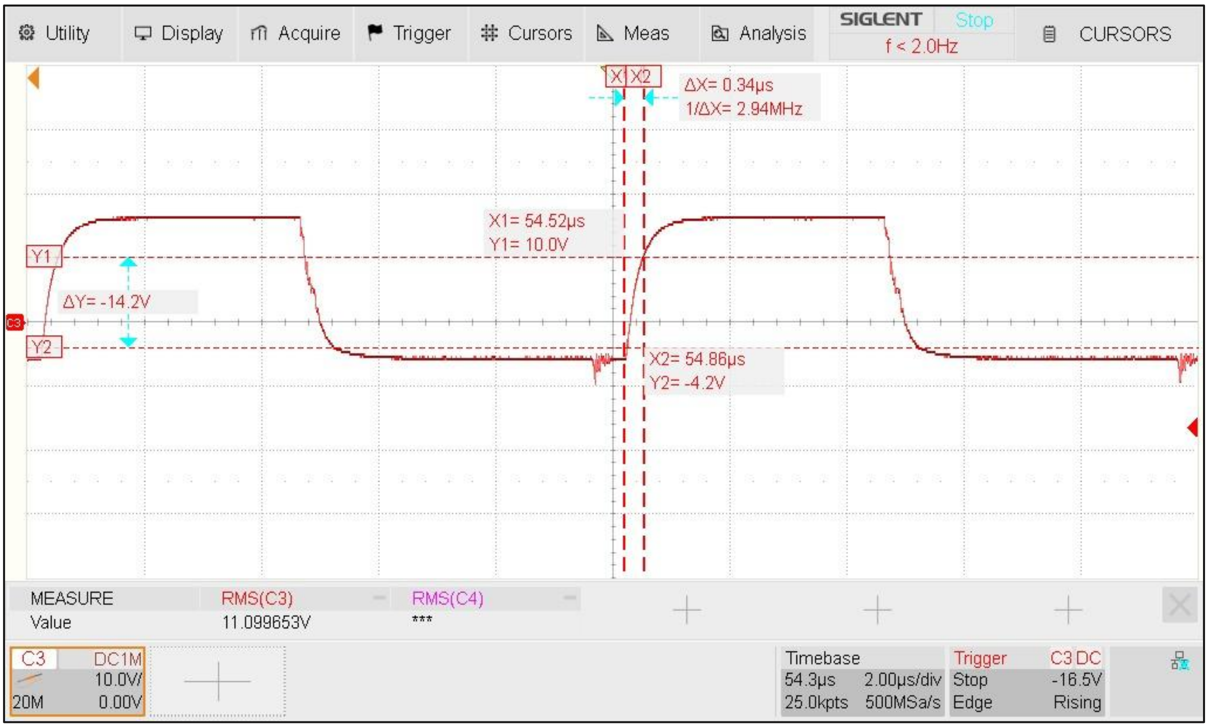


Figure 7 : Switch rise time = 0.34 µs

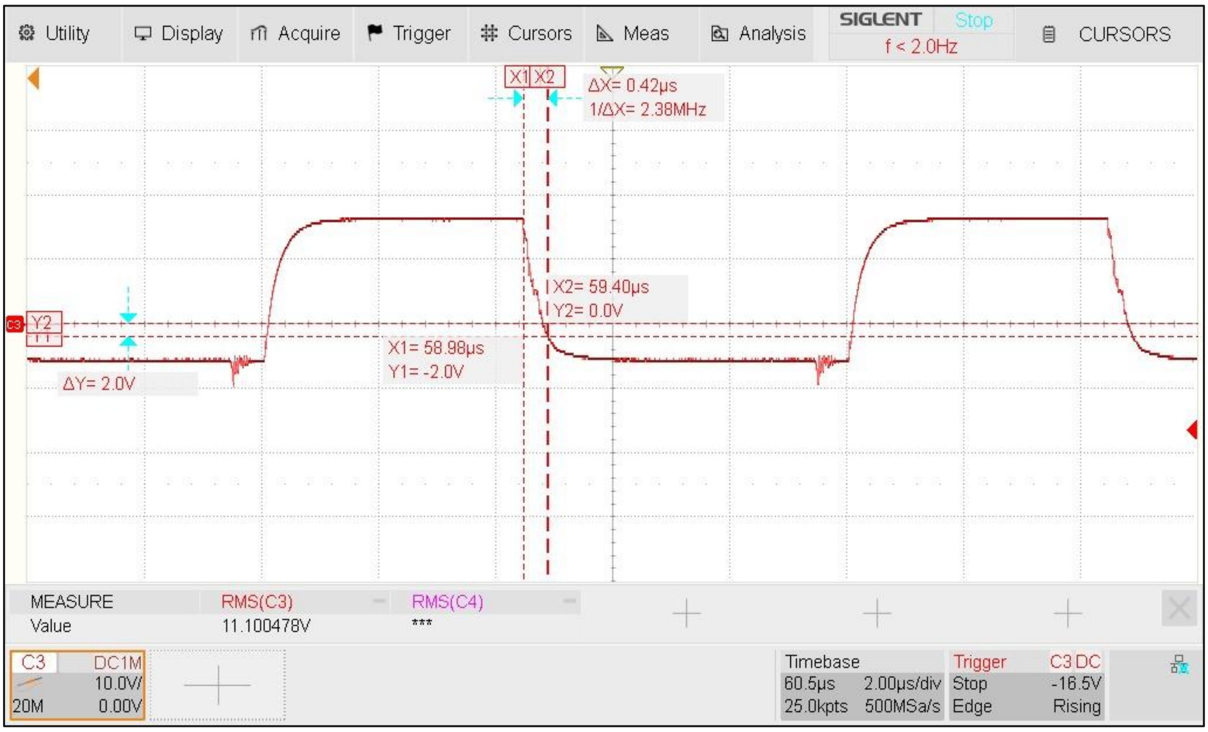


Figure 8 : Gate pulse fall time = 0.42 µs

2.2.4 Output DC Voltage Terminals

The output DC voltage terminals provide the modulated DC waveform generated from the converter. These terminals are typically connected to the load or the next stage in the power conversion chain. Proper insulation and connection with protective devices are necessary to ensure safety and performance.

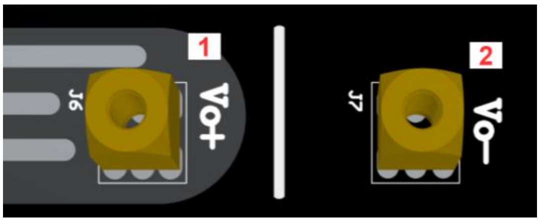


Figure 9 : Output AC terminals

Table 4: Pinouts of Output Terminals

Pin No.	Indicator	Description
1	Vo+	Positive terminal of DC output
2	Vo-	Negative terminal of DC output

2.2.5 Voltage and Current Sensors

Voltage and current are sensed using isolation amplifiers, with their respective gains shown in the blocks below. These amplifiers provide electrical isolation between high-power circuits and the control system, enhancing safety and ensuring accurate signal measurement for real-time monitoring and control.

Each 3-pin header (J19, J27, J28, J33) in the sensing circuit is provided for selecting the required operating mode:

- Buck Mode: Install the jumper between the 2-3 pins.
- boost Mode: Install the jumper between the 1-2 pins.

Ensure the correct jumper placement on all four headers.

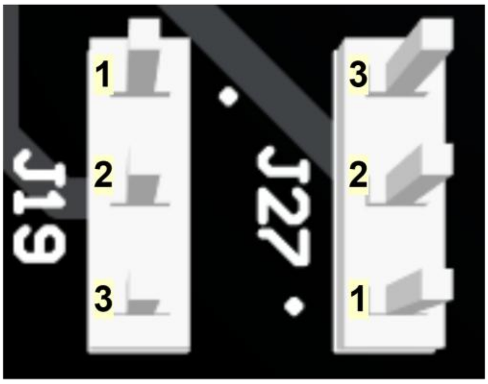


Table 5 :Sensor IC Identification

Sr. No.	Indicator	Description
1	U4	Input DC Current sensor
2	U10	Input DC voltage sensor
3	U7	Output DC current sensor
4	U3	Input DC Voltage sensor

Figure 10 : Top View of Voltage and Current Sensors

2.2.6 Sensors Output

The sensor output section aggregates the analog sensing signals, including DC input voltage, DC input current, DC output voltage, DC output current, and temperature. These outputs are designed to be interfaced with the microcontroller's ADC channels, enabling real-time monitoring, protection, and feedback control. All signals are referenced to isolated grounds to maintain system safety.

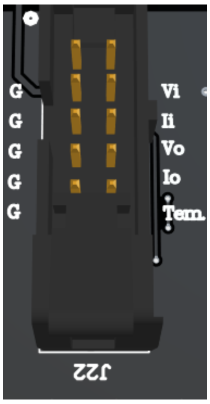


Figure 11 : Top view layout of Sensor Output

Table 6: Pinout of Sensor terminals

Pin No.	Indicator	Description
1	G	Ground
2	Vi	Sensing Input DC Voltage
3	G	Ground
4	Ii	Sensing Input DC Current
5	G	Ground
6	Vo	Sensing output DC Voltage
7	G	Ground
8	Io	Sensing output DC current
9	G	Ground
10	Temp.	Sensing RTD Temp.

2.2.7 Gate Driver I/O

This section provides the pulse and fault signal connections between the microcontroller/DSP and the gate drivers. It facilitates the transmission of high-speed switching signals (EPWM) and also receives feedback to monitor switch faults in real-time, enabling safe operation of power devices.

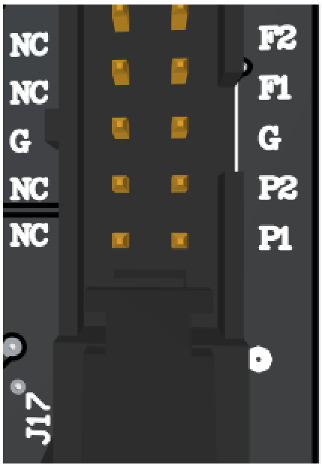


Figure 12 : Top View of Gate Driver I/O

Table 7: Pinouts of Gate Driver I/O

Pin No.	Indicator	Description
1	P1	Gate Pulse for Switch 1
2	NC	-
3	P2	Gate Pulse for Switch 2
4	NC	-
5	G	Ground
6	G	Ground
7	F1	Fault o/p of switch 1, Normal operation gives 5V
8	NC	-
9	F2	Fault o/p of switch 2, Normal operation gives 5V
10	NC	-

2.2.8 Test points for Gate Pulse

Test points are provided for debugging and verification of PWM signals. These allow engineers to probe and validate gate signals (P1 and P2) during system testing using an oscilloscope or logic analyser. Proper test point grounding is critical for accurate measurement.

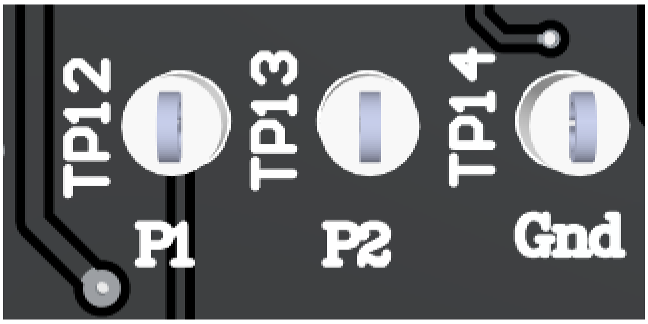


Figure 13 : Top View of Test Point

Table 8: Pinouts of Test Points

Pin No.	Indicator	Description
1	TP12/P1	Test Point for P1
2	TP13/P2	Test Point for P2
3	TP14/G	Ground

2.2.9 Gate Driver Terminals

The gate driver terminals provide direct connection to gate driver input interfaces, enabling modular interfacing and replacement. These terminals are typically routed to control boards or pulse generation units for streamlined system integration.

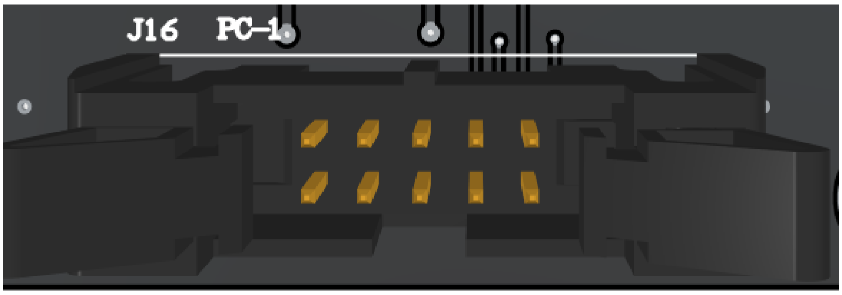


Figure 14 : Top View of Gate Driver Terminals

Table 8: Pinouts of Gate Driver Terminals

Pin No.	Indicator	Description
1	PC1	Pulses of Gate Driver 1

2.2.10 Fault Indicator

The fault indicator section uses dedicated LEDs to show the fault status of each power switch. This immediate visual feedback helps the user quickly identify faults such as short-circuit or undervoltage lockout in any leg of the converter.

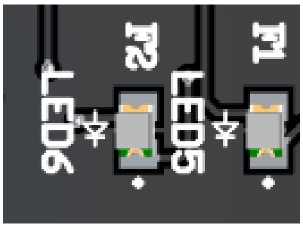


Figure 15 : Top View of Fault Indicator for Switches

Table 9: Pinouts of Fault Indicator

Pin No.	Indicator	Description
1	F1/LED5	Fault Indicator for Switch Q1
2	F2/LED6	Fault Indicator for Switch Q2

2.2.11 LED Indicators

This section shows the status of auxiliary power supplies (+24V, +15V, +12V, +5V, +3.3V, +1.5V). The corresponding LEDs indicate whether the voltage rails are active and functioning, aiding in system diagnostics and ensuring safe startup.

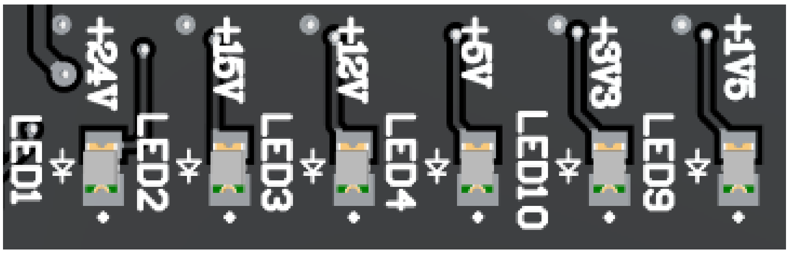


Figure 16 : Top view of LED Indicators for Aux. supply

Table 10: Pinouts of LED Indicators

Pin No.	Indicator	Description
1	+24V/LED1	+24 V Supply is ON
2	+15V/LED2	+15 V Supply is ON
3	+12V/LED3	+12 V Supply is ON
4	5V/LED4	+5 V Supply is ON
5	3V3/LED10	+3.3 V Supply is ON
6	1V5/LED9	+1.5 V Supply is ON

2.2.12 24V I/P

The 24V input terminal supplies power to all auxiliary circuits, including gate drivers, sensors, and control boards.

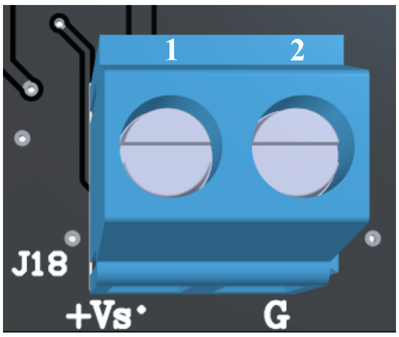


Figure 17 : Top view of 24 I/P

Table 11: Pinouts of 24V supply

Pin No.	Indicator	Description
1	+Vs	Positive Terminal of 24V I/P
2	G	Ground

2.2.13Auxiliary Power Supply

The auxiliary power supply module provides regulated low-voltage DC rails (such as +24V, +15V, +12V, +5V, etc.) necessary for gate drivers, sensors, and control circuits. It ensures stable and isolated power delivery, which is critical for the reliable and safe operation of the system. Refer to the figures below for the physical layout and structure.

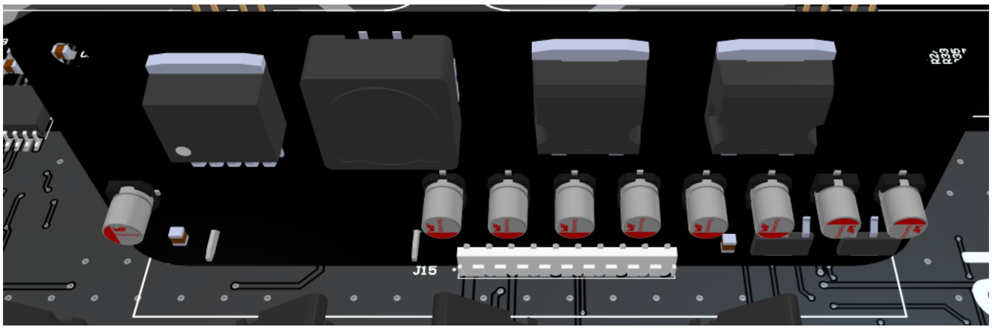


Figure 18 : Auxiliary supply picture

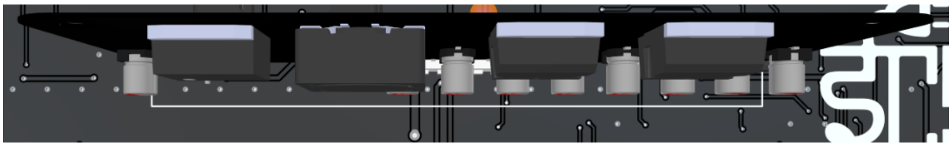


Figure 19 : Top View of Auxiliary Supply

3. Add-on devices

The F28379D plugin board is designed for seamless interfacing with the TI Delfino Launchpad. It features a ZIF socket for easy IC insertion (e.g., TMS320F2800133), GPIO header breakouts for signal access, and a Booster Pack-compatible connector for plug-and-play use. Ideal for prototyping, in-circuit testing, and programming of low-pin-count DSPs.

The F28379D plugin board is designed to interface with the TI Delfino Launchpad, enabling easy prototyping and testing of low-pin-count DSPs such as the TMS320F2800133. It features a ZIF socket for secure IC mounting, GPIO breakout headers for signal access, and ensures reliable connectivity through the Booster Pack-compatible interface. This setup facilitates efficient development, debugging, and programming of custom embedded control applications.

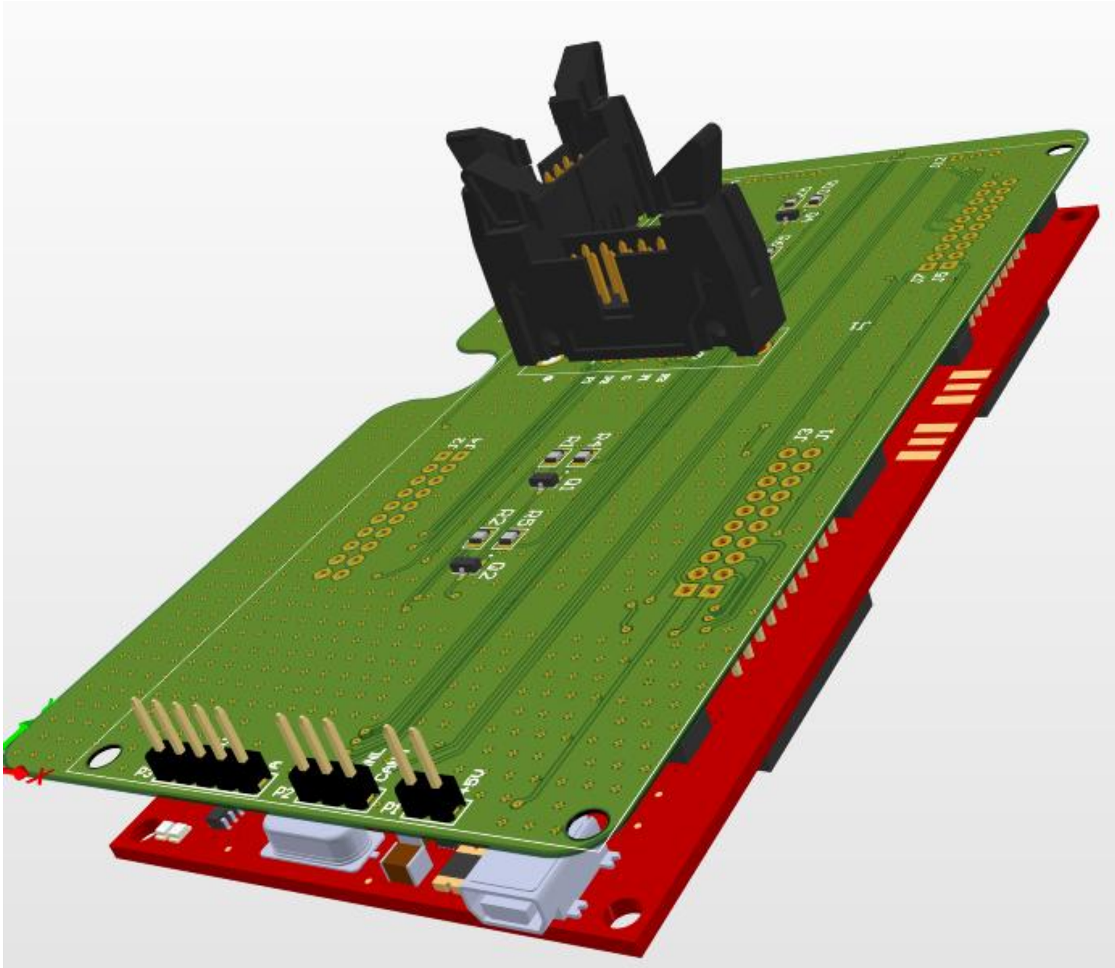


Figure 20 : F28379D Mounting Base

The following guide covers the mapping pin connection of the Development board with 1 1-phase inverter & Bi bi-directional inverter.

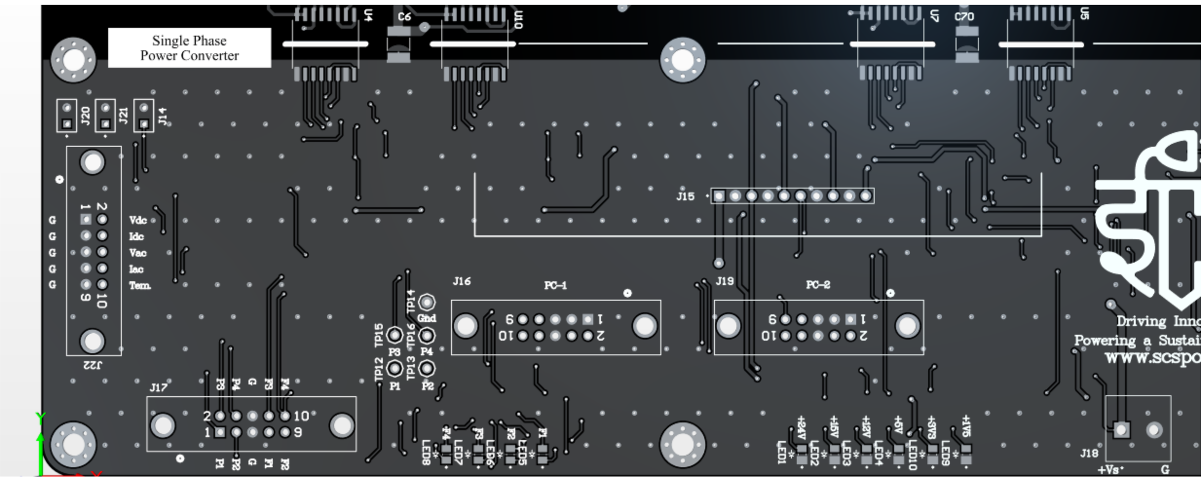


Figure 21 : Schematic of F28379D Mounting Base

Gate Drivers I/O

Table 12: Pinouts of Gate Driver I/O

Inverter Pin	F28379D Pin	Pin's name	Inverter Pin	F28379D Pin	Pin's name
P1	J4-10	EPWM1A	F1	J1-4	GPIO18
P2	J4-9	EPWM1B	F2	J1-3	GPIO19

Sensor Inputs

Table 13: Pin Description of Sensor Inputs

Inverter Pin	DCDC Conv Pin	F28379D Pin	Pin's name
Idc	Ii	J7-5	ADCINB5
Vdc	Vi	J7-8	ADCINB4
Iac	Io	J7-10	ADCINA1
Vac	Vo	J3-9	ADCINA2
Temp	Temp	J7-6	ADCINA5

4. Experimental Validation

4.1 Setup

The system was tested using a R load. Input power was supplied by a stiff DC power source .A Siglent SDS824 oscilloscope was used to monitor the output current, load voltage, input voltage, input current and gate drive signals. The overall experimental setup is shown below. Micsig isolated current probes and differential voltage probes are used to capture the signals. The overall experimental setup is shown below

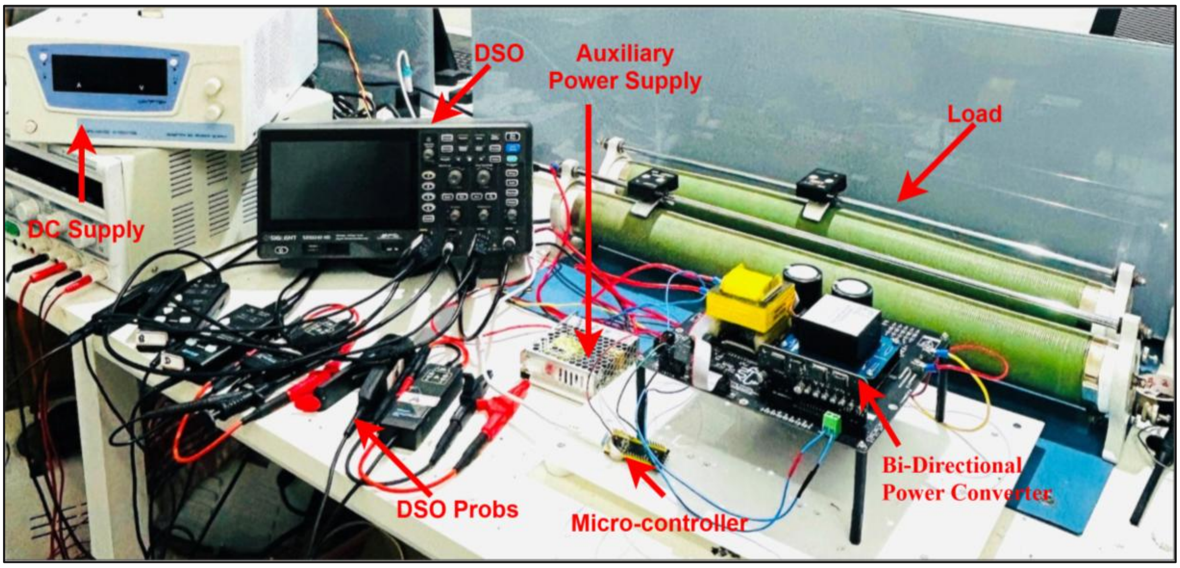


Figure 22 : Experimental Setup

4.2 Experimental Results

The system was tested with a square gate pulse having switching frequency of 100kHz and 60% duty cycle. The experimental waveforms of the key parameters are shown in Figure 25. The first trace waveform corresponds to the DC supply voltage, which remained constant at around 150V, confirming a stable input bus condition. The second waveform represents the DC supply current, measured at approximately 12A, demonstrating steady current draw from the DC source under load. The third waveform shows the DC output voltage of the Converter. The value was measured as 90V. The fourth waveform illustrates the DC load current, with a magnitude of about 19.2 A.

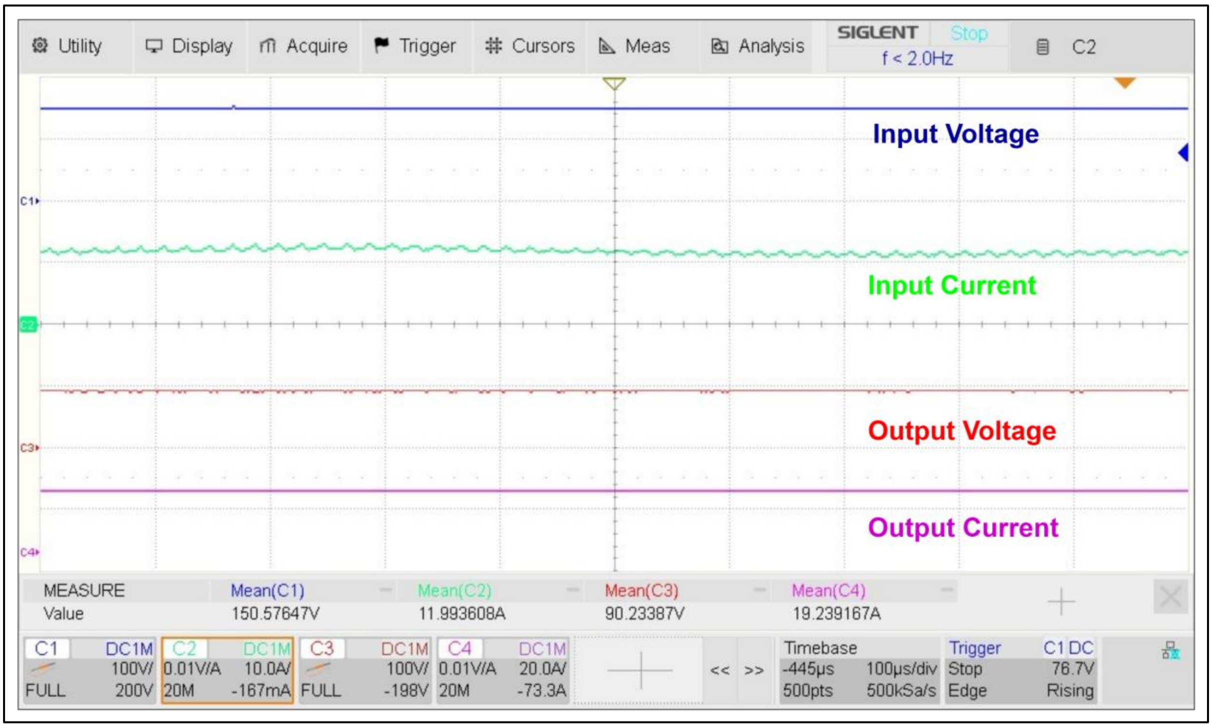


Figure 23 : Experimental measurements at V_{DC}=150V, I_{DC}=12A and f_{SW}=50 kHz

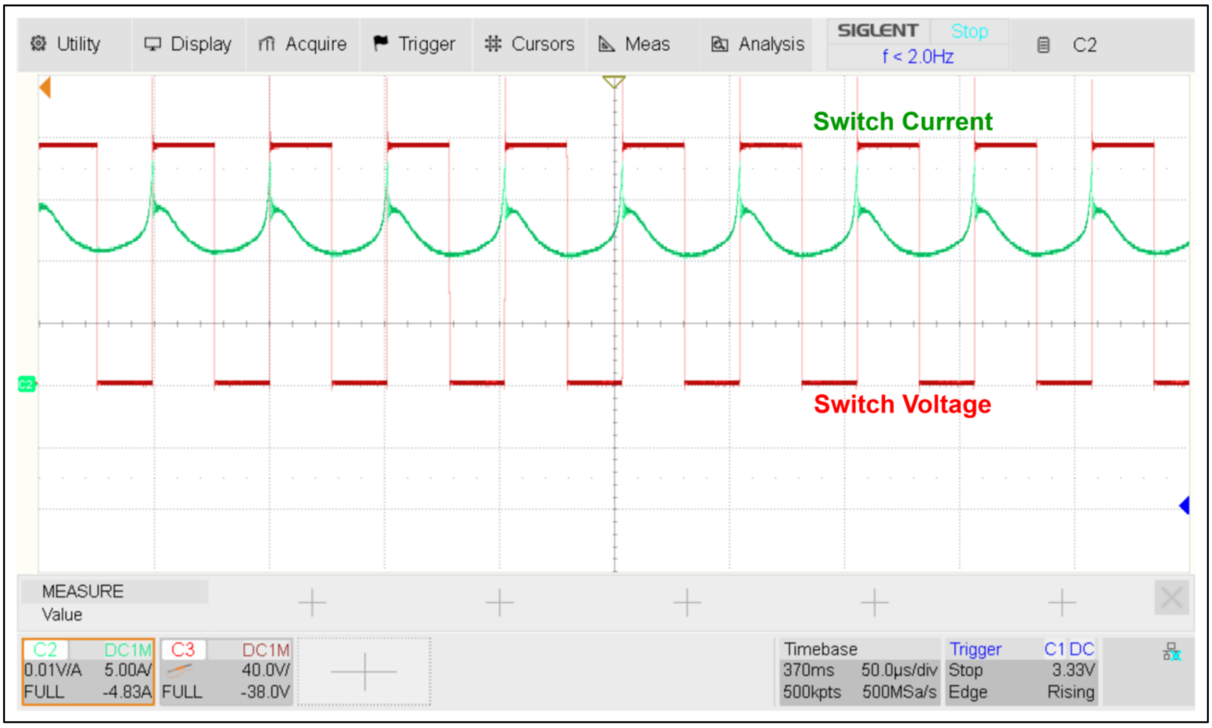


Figure 24 : Switch across voltage and current

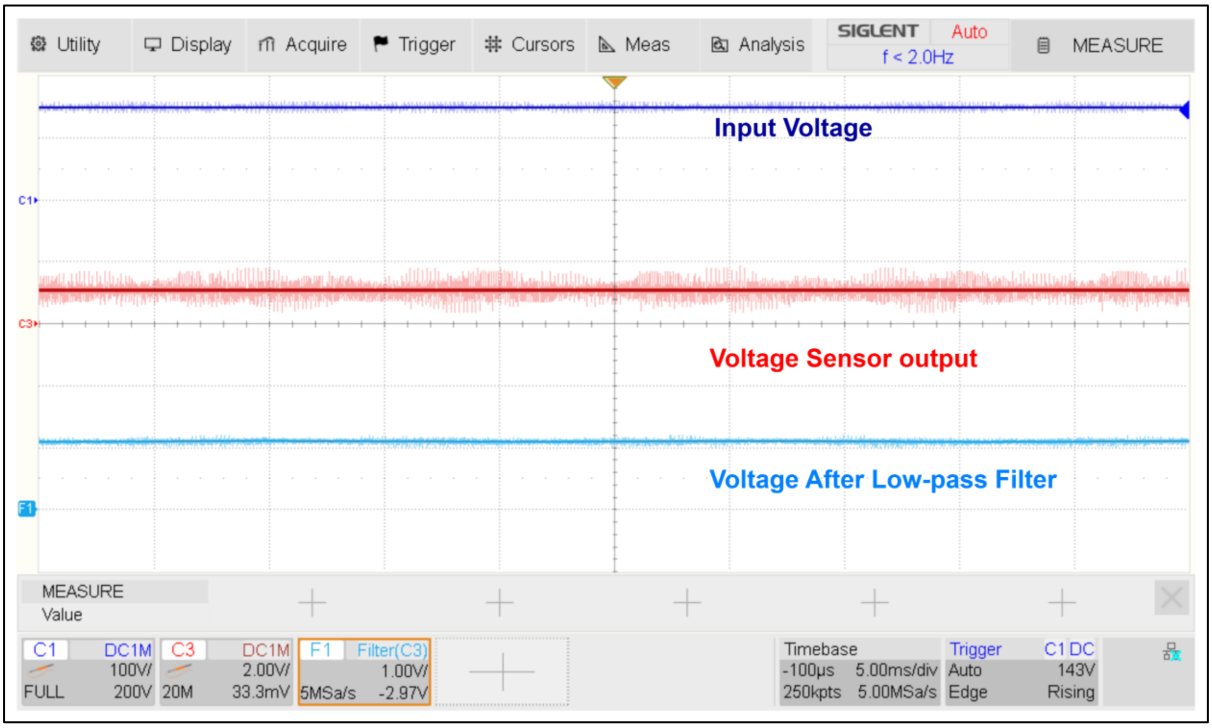


Figure 25 : Measured Input DC voltage waveforms: Actual voltage, sensor output with high-frequency interference, and filtered response after applying 1MHz low-pass

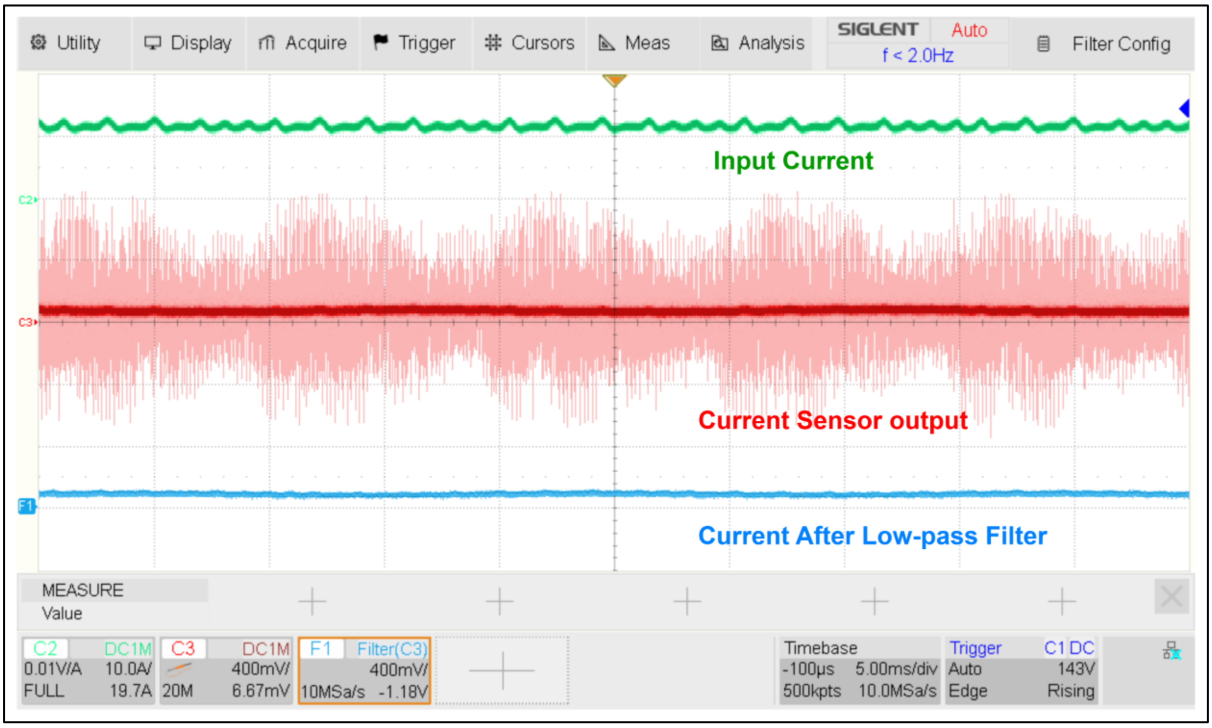


Figure 26 : Measured Input DC current waveforms: Actual current, sensor output with high-frequency interference, and filtered response after applying 1MHz low-pass

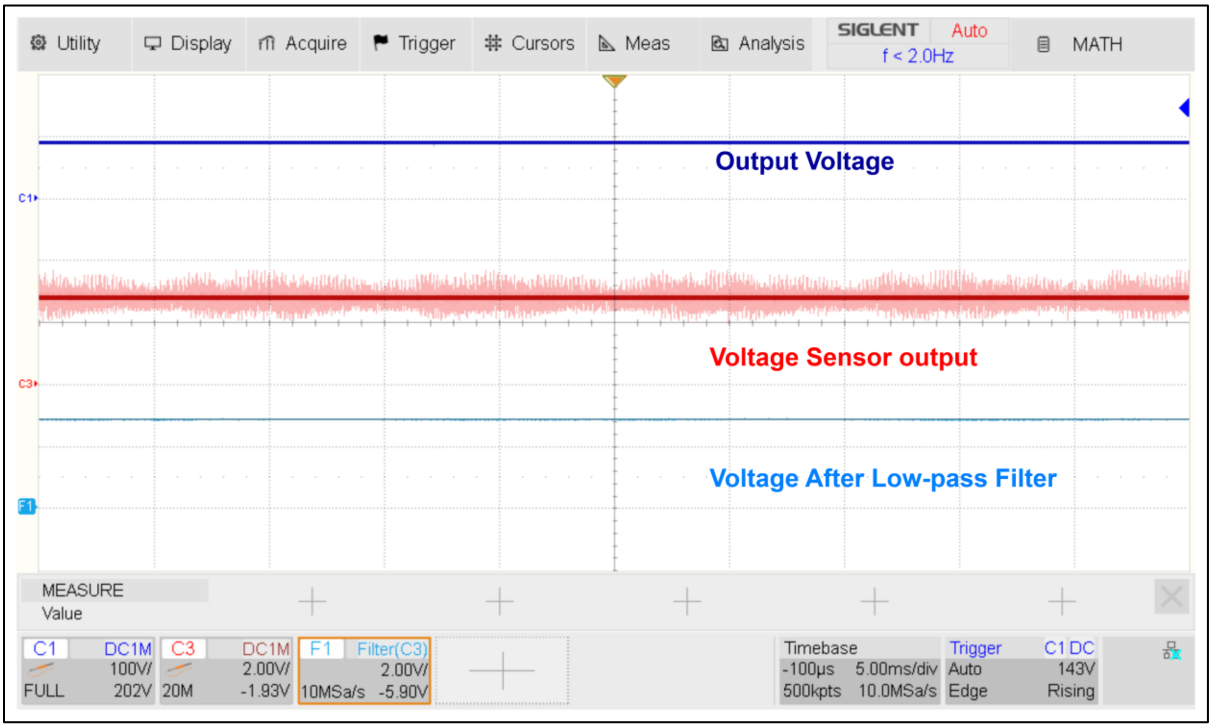


Figure 27 : Measured Output DC voltage waveforms: Actual voltage, sensor output with high-frequency interference, and filtered response after applying 1MHz low-pass

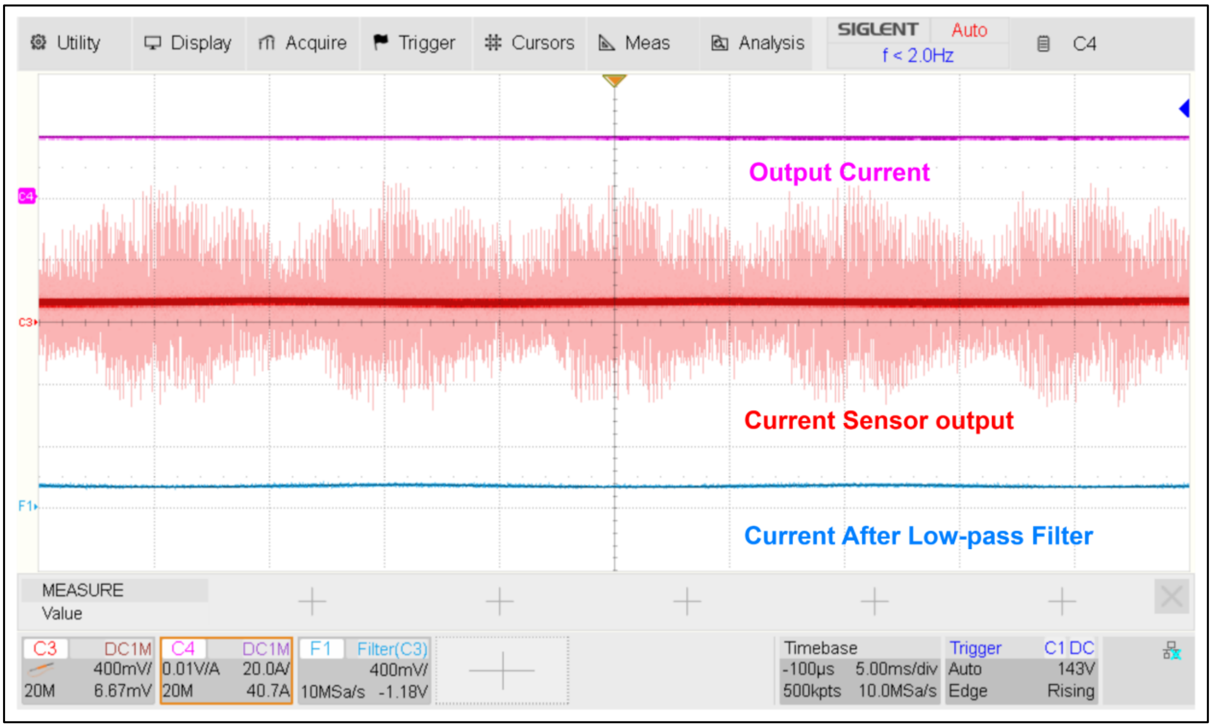
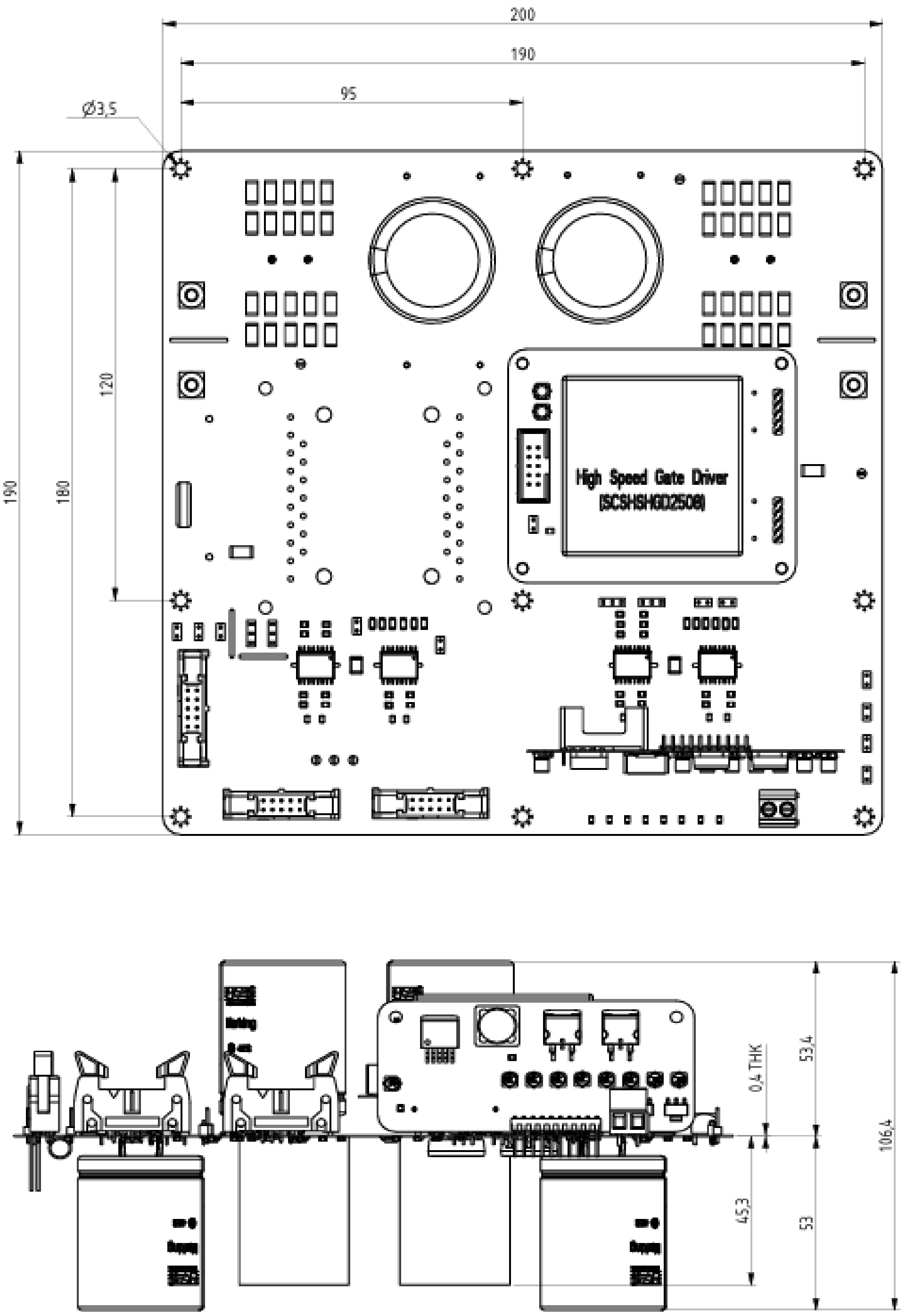


Figure 28 : Measured Output DC current waveforms: Actual current, sensor output with high-frequency interference, and filtered response after applying 1MHz low-pass

5. Mechanical Assembly



All dimensions in mm