Integrated Actuation Solution

CD-MSCGLQ75X120CTYZBNMG (15KVA/540 VDC) Fast IGBT + SiC Diode

Product Family Overview

Microchip's Integrated Actuation Solution is a highly integrated, scalable, reliable, cost-effective, compact, and easy to use solution targeting electric motor drives and solenoids on actuator systems in aviation applications and designed in accordance with aviation standards. It is designed to be driven with external PWM signals.

This solution consists of a combination of Hybrid Power Drive (SP6HPD) and companion driver board to provide unparalleled integration with simplicity.

The SP6HPD module is comprised of a three-phase inverter bridge and optional functions such as brake chopper, solenoid drive, and soft-start with Si IGBT or SiC MOSFET switches. The driver board provides a galvanically isolated interface to the semiconductor switches and their local feedback signals. The driver board is factory configurable, allowing it to drive both SiC MOSFETs and Si IGBTs at a higher switching frequency.

The integration of the gate driver board together with the SP6HPD gives direct access to a fully validated and optimized solution in terms of switching speed and losses, robustness against dV/dt, telemetry outputs and multiple protection such as short-circuit, Under Voltage Lock Out (UVLO), shoot-through, and Active Miller Clamping.

The solution ranges from 5KVA to 20KVA with the same footprints.

Figure 1. View of Integrated Actuation Solution

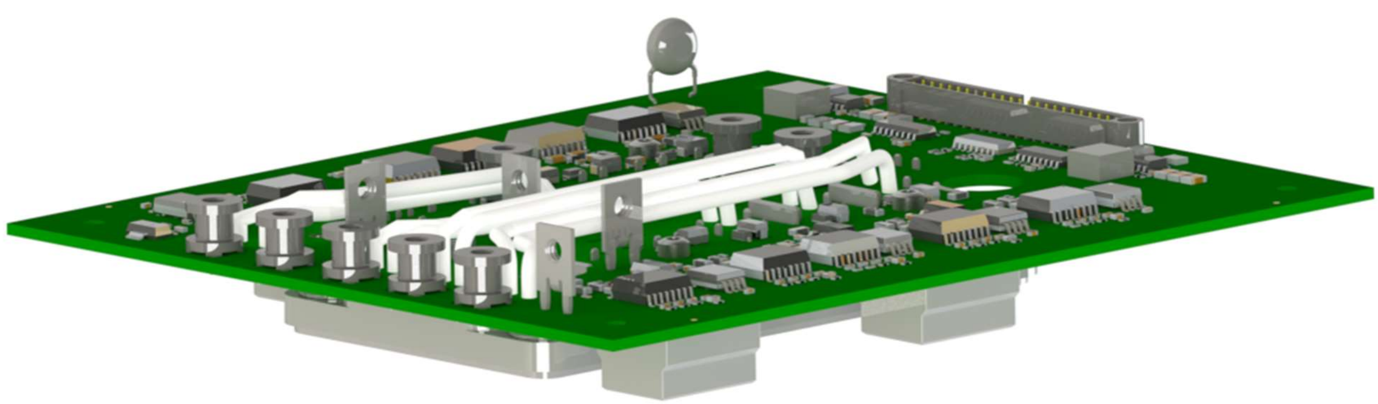
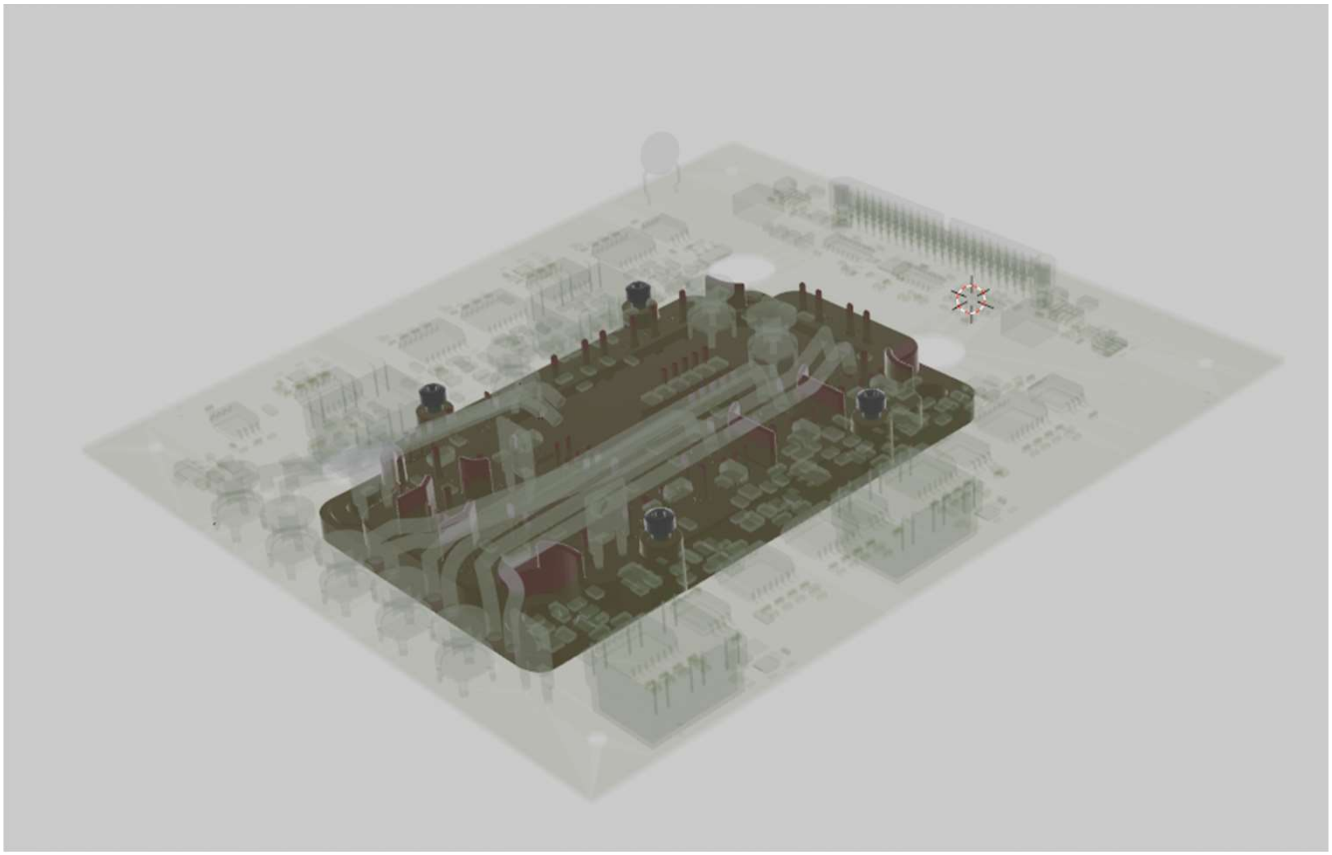


Figure 2. Transparent Image



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1. Product Family Key Features

1.1 Power Stage – SP6HPD Power Module

- SiC MOSFET/Si IGBT switches with rating up to 1200V
- Three-phase inverter bridge with integrated shunt for phase current measurement
- Solenoid drive with Si IGBT, SiC Diode, and integrated shunt for current measurement
- Soft-start switch, brake switch
- Options available without integrating Solenoid, soft-start, or brake switch
- Integrated shunt for DC bus current measurement
- Two PT1000 temperature sensors
- Maximum 175 °C operating junction temperature

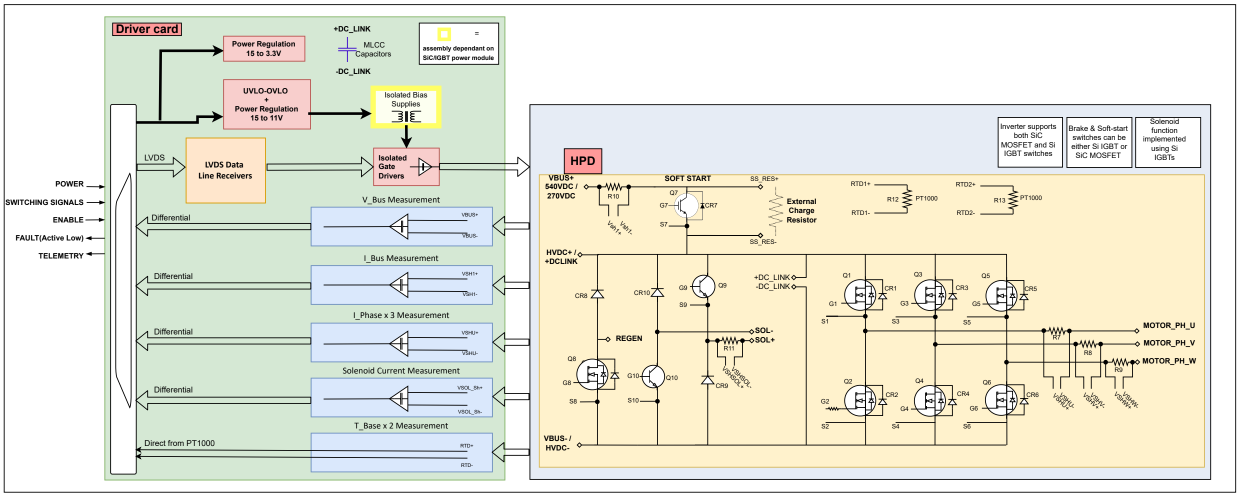
1.2 Companion Driver Board

- Compatible to Microchip SP6HPD power module
  - SP6HPD soldered directly on the driver board.
  - Drives three-phase inverter bridge and switches for solenoid, brake, and soft start.
  - Compatible to Si IGBT/SiC MOSFET up to 1200V.
  - Direct temperature sensor output (from SP6HPD)
- Environment
  - Maximum 110 °C operating ambient temperature (gate driver)
  - Altitudes up to 50,000 feet
  - RoHS compliant
  - Conformal coated for environmental protection
- Galvanically isolated gate drive – 1500 VAC, 50 Hz, 1 minute
- Partial discharge across isolation barrier <10 pC at V_{inc} = 1327 VAC, V_{ext} = 1062 VAC
- Single power supply (V_{CC}): +15V (typ.)
- UVLO on input V_{CC} and internal bias supply
- LVDS control inputs from higher level system–PWM input and enable input for gate drive.
- Switching frequency up to 20 kHz
- Negative gate drive: –4.3V (SiC Mosfet) and –8.2V (IGBT)
- Differential outputs for current and voltage telemetry–phase current, DC bus current, solenoid current, and DC Link bus voltage
- Desaturation protection
- Soft shutdown turn-off
- Active low fault reporting for all switches together
- Active Miller Clamping
- Shoot–through protection for inverter switches.

2. Product Family Functional Overview

Integrated Actuation Solution is an integration of the SP6HPD power module and its companion gate driver board that is used for motor drive applications. The functional block diagram of the Integrated Actuation Solution is shown in the following figure.

Figure 2-1. Block Diagram



The driver board receives PWM inputs from a higher–level system and provides the gate–drive signals to the SP6HPD power switches (Si IGBT/SiC MOSFET), that is, three-phase inverter bridge switch, optional switches such as solenoid switch, soft–start switch, and brake switch. The driver board measures the voltage across the shunts in SP6HPD and provides current measurement signals as isolated differential output for phase current, bus current, and solenoid current (if equipped). The driver board also measures the DC link bus voltage and provides an isolated differential voltage output. Internal floating bias power supplies generate the bias voltages for the logic–side gate drivers and other telemetry circuits. The floating bias supplies, gate drivers, and measurement amplifiers within the driver PCB provide the required isolation to allow reliable interface with a higher–level system. Two platinum resistive temperature transducers (PT1000) on the SP6HPD are directly wired to the low–voltage connector through driver PCB. These temperature sensors monitor the SP6HPD temperature. A 2x23 pin connector is mounted on the driver board to interface the low–voltage power supply, PWM inputs, and monitoring signals to the system.

The power stage is the Microchip SP6HPD power module containing Si IGBT/SiC MOSFET switches with ratings up to 1200V to generate the three-phase switching outputs. The SP6HPD power module also has optional switches for functionalities like solenoid, brake, and soft start. Power and low–voltage signal routing are provided through pin terminals of SP6HPD soldered on to the driver board.

3. Part Number

The following table shows the ordering part number of Integrated Actuation Solution (SP6HPD integrated with a companion driver board) and the respective SP6HPD power module used in the solution.

Table 3-1. Part Numbering - Integrated Actuation Solution

DC Bus Voltage (V)	Power Level (kVA)	Inverter Switch Technology	Ordering Part Number of Integrated Actuation Solution	Corresponding Standard Part Number of SP6HPD
540	15	IGBT + SiC Diode	CD-MSCGLQ75X120CTYZBNMG	MSCGLQ75X120CTYZBNMG

The following table shows the standard part number of SP6HPD along with its internal configuration.

Table 3-2. SP6HPD and Its Internal Configuration

DC Link Bus Input	Power Rating	Ordering Standard Part Numbers of SP6HPD	Inverter		Solenoid		Soft-Start		Brake	
			Switch Type	Switch Voltage	Switch Type	Switch Voltage	Switch Type	Switch Voltage	Switch Type	Switch Voltage
540V	15KVA	MSCGLQ75X120CTYZBNMG	IGBT + SiC Diode	1200V	IGBT	1200V	IGBT	1200V	IGBT	1200V

Note: Two PT1000 temperature sensors are present in SP6HPD power module.

4. Electrical Specifications

This section details the electrical specifications for the Integrated Actuation Solution and the driver board.

Absolute Maximum Ratings

This section shows the absolute maximum ratings of the Integrated Actuation Solution.

Table 4-1. Absolute Maximum Ratings

Parameter	Symbol	Condition	Max	Units
Input Low Voltage Supply	V_{CC}	—	18	V
Input Low Voltage Supply Current	I_{CC}	Fsw = 20 kHz	0.8	A
DC Link Bus Voltage	V_{BUS}	VDC Link = 540 VDC	940	V
Maximum power semiconductor junction temperature	T_J	—	175	°C

Typical Electrical Performance

The following table shows the DC Link Bus input electrical characteristics at ambient temperature T_A = 25 °C unless otherwise specified.

Table 4-2. DCLink Bus Input Electrical Characteristics

Parameters / Functions	Symbol	Conditions	Min	Typ	Max	Units
Steady State DC Link Bus Voltage Range	V_{BUS}	—	470	540	650	V
Maximum Allowed Ripple Amplitude	V_{BUSR}	—	—	—	32	V
Voltage Transients	V_{BUSTR}	—	400	—	940	V
Internal Capacitance – DC Link (MLCC Capacitors)	$C_{BUSINT\ (MLCC)}$	—	—	0.132	—	µF

The following table shows the typical power output electrical characteristics at ambient temperature T_A = 25 °C unless otherwise specified.

Table 4-3. Power Output Characteristics

Parameters/ Functions	Symbol	Conditions	Value	Units
Inverter				
Power Output	P_O	V_{BUS} = 540VDC	15	KVA
RMS Phase Current	$I_{PH95\text{-}RMS}$	T_{CASE}=95 °C, F_{SWINV} = 10 kHz	28	A
RMS Phase Current	$I_{PH105\text{-}RMS}$	T_{CASE} = 110 °C, F_{SWINV} = 10 kHz	14	A
Solenoid				
Max RMS Pull–in Current	I_{SOLP}	t<100 ms	5	A
Max Holding Current	I_{SOLH}	Continuous	1	A
Brake Function				

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Parameters/ Functions	Symbol	Conditions	Value	Units
Switch Rated Current	I_{BRAKE}	T_{CASE} = 80 °C	95	A
Soft-start external resistor				
Maximum Current	I_{SSMAX}	Restricted by terminal rating	15	A

The following table shows typical switching characteristics of SP6HPD + driver board at ambient temperature T_A = 25 °C unless otherwise specified.

Table 4-4. SP6HPD + Driver Board Switching Characteristics

Parameters/ Functions	Symbol	Conditions	Typ.	Units
Inverter				
Switching Voltage Transient Rate	dV/dt	V_{BUS}=540VDC, $I_{PH95\text{-}Peak}$ = 40A, T_{CASE} = 25 °C	5	kV/µs
Turn–On Energy	$E_{ON\text{-}INV}$	V_{BUS} = 540VDC, $I_{PH95\text{-}Peak}$ = 40A, T_{CASE} = 25 °C	2.11	mJ
Turn–Off Energy	$E_{OFF\text{-}INV}$	V_{BUS} = 540VDC, $I_{PH95\text{-}Peak}$ = 40A, T_{CASE} = 25 °C	1.8	mJ
Solenoid				
Switching Voltage Transient Rate	dV/dt	V_{BUS} = 540VDC, I_{SOLP} = 5A, T_{CASE} = 25 °C	5	kV/µs
Turn–On Energy	$E_{ON\text{-}SOL}$	V_{BUS} = 540VDC, I_{SOLP} = 5A, T_{CASE} = 25 °C	0.128	mJ
Turn–Off Energy	$E_{OFF\text{-}SOL}$	V_{BUS} = 540VDC, I_{SOLP} = 5A, T_{CASE} = 25 °C	0.313	mJ
Brake				
Switching Voltage Transient Rate	dV/dt	V_{BUS} = 750VDC, I_{BRAKE} = 95A, T_{CASE} = 25 °C	5	kV/µs
Turn–On Energy	$E_{ON\text{-}B}$	V_{BUS} = 750VDC, I_{BRAKE} = 95A, T_{CASE} = 25 °C	5.13	mJ
Turn–Off Energy	$E_{OFF\text{-}B}$	V_{BUS} = 750VDC, I_{BRAKE} = 95A, T_{CASE} = 25 °C	2.49	mJ

Note: In the application, the soft start switch is meant to turn on and turn off at almost zero current, hence switching energy of soft start switch is not provided.

The following table shows the gate drive electrical characteristics at ambient temperatures –55 °C to +110 °C unless otherwise specified.

Table 4-5. Gate Drive Characteristics

Parameter	Symbol	Condition	Min	Typ.	Max	Units
Driver Board Power Supply						
Input Voltage	V_{CC}	—	14.5	15	15.5	V
Input Voltage Ripple Amplitude	$V_{CCR(P\text{-}P)}$	—	—	—	50	mV (P-P)
Under–Voltage Lock–Out	V_{CCUVLO}	Threshold Rising	—	14	14.42	V
		Threshold Falling	13.58	—	—	V
Over–Voltage Lock–Out	V_{CCOVLO}	Threshold Rising	—	16	16.48	V
		Threshold Falling	15.52	—	—	V

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Parameter	Symbol	Condition	Min	Typ.	Max	Units
Supply Current	I_{CC}	PWM = OFF, V_{IN} = 15V, T_A = 25 °C	—	310	—	mA
LVDS PWM Inputs—All Switches						
Magnitude of Differential Input Voltage	V_{IDPWM}	—	0.1	—	3	V
Switching Frequency	F_{sw}	—	—	10	20	kHz
Duty Cycle	D_C	—	0	—	100	%
Voltage at any input (Separately or common mode)	V_I or V_{IC}	—	–4	—	5	V
PWM non– overlapping dead–time	DT_{PWM}	—	—	750	—	ns
Positive–going differential input voltage threshold	V_{IPPWM}	—	—	—	+50	mV
Negative–going differential input voltage threshold	V_{INPWM}	—	–50	—	—	mV
Differential input failsafe voltage threshold	V_{IDPWM}	—	–32	—	–100	mV
Drive Enable/Disable – LVDS						
Positive-going differential input voltage threshold	V_{IPEN}	—	-—	—	+50	mV
Negative–going differential input voltage threshold	V_{INEN}	—	–50	—	—	mV
Differential input failsafe voltage threshold	$V_{IDEN(fs-th)}$	—	–32	—	–100	mV
Magnitude of Differential input voltage	V_{IDEN}	—	0.1	—	3	V
Voltage at any input (Separately or common mode)	V_I or V_{IC}	—	–4	—	5	V
Minimum Pulse Width	t_{enable}	—	800	—	—	ns
Gate Drive						
Turn–On Output Voltage	$V_{g(on)}$	F_{SW} = up to 20kHz	13.5	—	15.5	V
Turn–Off Output Voltage	$V_{g(off)}$	—	–8.61	–8.2	–7.79	V
UVLO internal bias – Positive Going Threshold	V_{ibuvlo}	Internal Gate Drive Supply, T_A = 25 °C	—	12	13	V
UVLO Internal Bias – Negative Going Threshold	$V_{ibuvlohys}$	Internal Gate Drive Supply, T_A = 25 °C	9.5	11	—	V
Turn–On Propagation Delay	$t_{d(on)io}$	PWM Input to Gate Output, T_A = 25 °C	—	150	—	ns
Turn–Off Propagation Delay	$t_{d(off)io}$	PWM Input to Gate Output, T_A = 25 °C	—	150	—	ns
Active Miller Clamp Threshold Voltage	V_{CLTH}	T_A = 25 °C	1.6	2.1	2.5	V
Desaturation Threshold – W.R.T. Power Switch Source	V_{DSTH}	T_A = 25 °C	—	7.8	—	V

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Parameter	Symbol	Condition	Min	Typ.	Max	Units
Desaturation Blanking Time	$t_{ds(BL)}$	T_A = 25 °C	—	3.832	—	µs
Desaturation Detection to FAULT in Fault State	$t_{ds(FLT)}$)	T_A = 25 °C	—	—	1.4	µs
Soft Turn-Off at Short-Circuit – Desat sense to 10% gate voltage.	t_{ssd}	V_{BUS} = 540VDC, T_{CASE} = 25 °C	—	1.1	—	µs
Fault Output – Active Low						
Output Voltage–High	V_{FLTH}	w.r.t GND of input supply, T_A = 25 °C	—	3.3	—	V
Output Voltage–Low	V_{FLTL}	w.r.t GND of input supply	—	0.1	—	V

The following table shows the telemetry characteristics of the gate drive board at ambient temperatures –55 °C to +110 °C unless otherwise specified.

Table 4-6. Telemetry Characteristics

Parameter	Symbol	Condition	Min	Typ	Max	Units
DC Link Bus Voltage Monitoring–Analog Output						
Monitoring Range	V_{BUS}	—	0	—	1000	V
Output Differential Voltage	V_{BUSD}	—	0	VBUS* 0.002	—	V
Accuracy	—	Full Scale	—	—	3	%
Bandwidth	—	At –3 dB	200	—	—	kHz
Withstand Isolation Voltage	—	AC, 50 Hz, 1 minute	1500	—	—	V
DC Bus Current Monitoring - Analog Output						
Monitoring Range	I_{BUS}	—	0	—	100	A
Output Differential Voltage	V_{IBD}	Full Scale Current	—	2.05	—	V
Accuracy	—	Full Scale	—	—	3	%
Bandwidth	—	At –3 dB	200	—	—	kHz
Withstand Isolation Voltage	—	AC, 50 Hz, 1 minute	1500	—	—	V
Phase Current Monitoring — Analog Output						
Monitoring Range	I_{PH}	—	—	—	—	A
		—	–71.43	—	71.43	
Output Differential Voltage	V_{IPHD}	1. Full Scale Current 2. Polarity depends on measured current polarity.	—	±2.05	—	V
Accuracy	—	Full Scale	—	—	3	%
Bandwidth	—	At –3dB	200	—	—	kHz
Withstand Isolation Voltage	—	AC, 50 Hz, 1 minute	1500	—	—	V
Solenoid Current Monitoring — Analog Output						

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Parameter	Symbol	Condition	Min	Typ	Max	Units
Monitoring Range	I_{SOL}	—	–16.7	—	16.7	A
Output Differential Voltage	V_{ISOLD}	1. Full scale current 2. Polarity depends on measured current polarity.	—	±2.05	—	V
Accuracy	—	Full Scale	—	—	3	%
Bandwidth	—	At –3dB	200	—	—	kHz
Withstand Isolation Voltage	—	AC, 50 Hz, 1 minute	1500	—	—	V
Temperature Monitoring — RTD Output						
Resistance at 0deg cent	RTD 1, RTD2	1. PT1000 Type a. Two sensors part of SP6HPD 2. Directly routed to J11 connector	—	1000	—	Ω
Accuracy	—	—	—	±2	—	°C
Difference between two sensors	—	—	—	—	4	°C
Measurement Range	—	—	–60	—	+150	°C

The following table shows the isolation characteristics at ambient temperature 25 °C unless otherwise specified.

Table 4-7. Isolation Characteristics

Parameter	Symbol	Condition	Min	Typ.	Max	Units
Dielectric strength between power terminals and low–voltage connector	V_{ISOL1}	AC RMS, 50 Hz, 1 minute	1500	—	—	V
Insulation resistance between power terminals and low–voltage connector	R_{ISOL2}	V_{ISOL2} = 500 VDC	100	—	—	MΩ
Dielectric Strength between any terminal to case	V_{ISOL3}	AC RMS, 50/60 Hz, 1 minute	1500	—	—	V
Insulation resistance between the SP6HPD power part and the temperature sensors	R_{ISOL4}	V_{ISOL4} = 500 VDC	100	—	—	MΩ
Insulation resistance between temperature sensors	R_{ISOL5}	V_{ISOL5} = 45VDC	100	—	—	MΩ
Partial Discharge between isolation barrier	PD	T_A = –55 °C to +110 °C Altitude up to 50000 ft V_{Inc} = 1327 Vrms V_{ext} = 1062 Vrms	—	—	<10	pC
Parasitic Capacitance	C_p	Between High Side and Primary (per switch)	—	10	—	pF
Gate Driver Common-Mode Transient Immunity (CMTI)	dV_{ISO}/dt	VCM=1KV	100	—	—	kV/µs

The following table shows the operating environment.

Table 4-8. Operating Environment

Parameter	Symbol	Condition	Min	Typ.	Max	Units
SP6HPD Case Temperature	T_C	—	–55	—	+110	°C
Driver Board Operating Ambient Temperature	T_{AD}	—	–55	—	+110	°C
Storage Temperature	T_S	—	–55	—	+125	°C
Pressure Range	—	—	11.6	—	190	kPa

Note: Testing at maximum pressure 190kPa can be performed on demand.

5. Mechanical Specifications

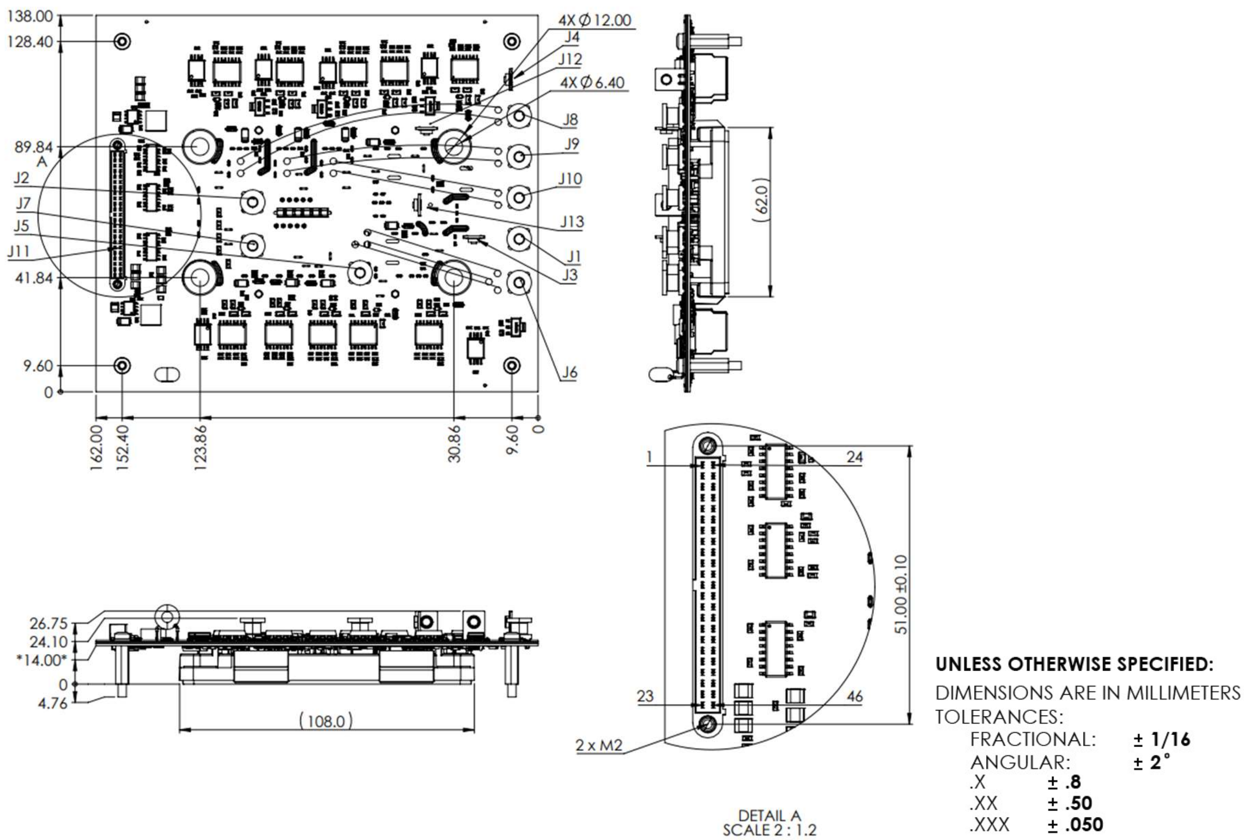
The following table provides mechanical characteristics.

Table 5-1. Mechanical Characteristics

Parameter	Conditions	Typ.	Unit
Size	—	162 x 138 x 29.35	mm
Mass	Without mounting hardware	380	g

The following figure shows the power terminal and signal connector locations.

Figure 5-1. Power Terminal and Signal Connector Locations



The following table provides the power terminal references and torque values.

Table 5-2. Power Terminals Reference and Torque

Connector	Reference	Torque Reference	Maker	Type No.
J1	HV_IN+	1.7 Nm	BROXING	SN09R4M-H8
J2	BUS+	1.7 Nm	BROXING	SN09R4M-H8
J3	SSRES+	—	KEYSTONE ELECTRONICS	9-7837-M3
J4	SOL+	—	KEYSTONE ELECTRONICS	9-7837-M3
J5	REGEN	1.7 Nm	BROXING	SN09R4M-H8

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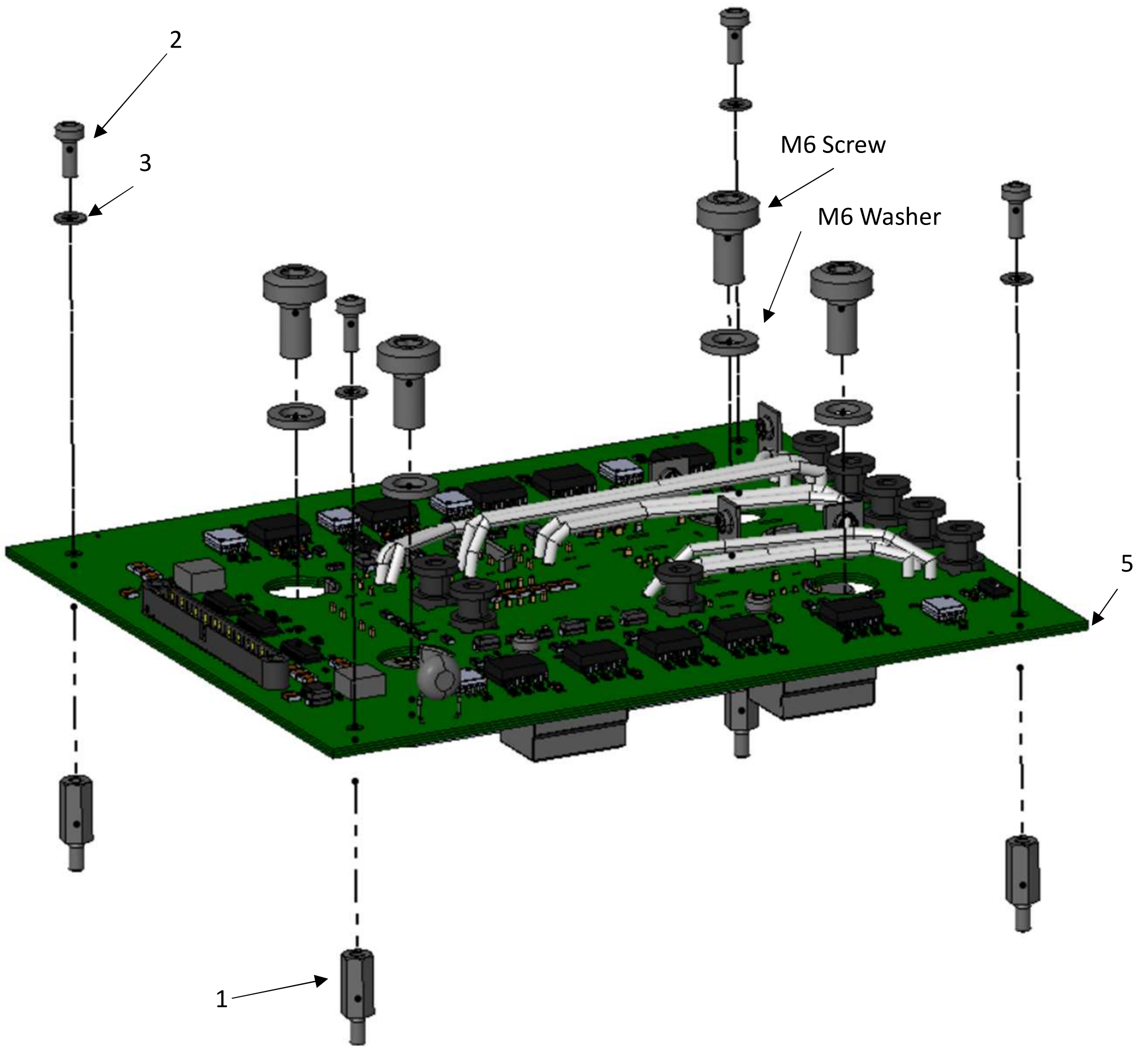
Connector	Reference	Torque Reference	Maker	Type No.
J6	HV_IN-	1.7 Nm	BROXING	SN09R4M-H8
J7	BUS-	1.7 Nm	BROXING	SN09R4M-H8
J8	PHU	1.7 Nm	BROXING	SN09R4M-H8
J9	PHV	1.7 Nm	BROXING	SN09R4M-H8
J10	PHW	1.7 Nm	BROXING	SN09R4M-H8
J11	LV CONNECTOR	—	NICOMATIC	221Y46F22HW
J12	SOL-	—	KEYSTONE ELECTRONICS	9-7837-M3
J13	SSRES-	—	KEYSTONE ELECTRONICS	9-7837-M3

FASTENER	TORQUE
M2.5	0.30 Nm MAX
M3	0.65 Nm MAX
M6	4.0 Nm ± 1Nm

The following figure shows the mechanism to mount to the customer interface.

Figure 5-2. Mounting to Customer Interface



Note: Install item 1 to user's interface plate, then use four stainless steel M6 washers and four stainless steel M6 screws with suitable length to fix the power module. Finally, screw item 2 with item 3. Refer to the suggested torque in the table above. Apply the proper thread lock compound to all screws and standoffs before assembly.

The following table provides the components supplied as part of deliverables.

Table 5-3. Deliverables[1]

Item No.	Description	Qty	Unit
1	Male-Female Threaded Hex Standoff, Stainless Steel, 4.5 mm Hex, 14 mm Long, M3 x 0.50 mm Thread	4	PC
2	ISO 14583 M3 x 8, Stainless Steel A2: Hexalobular socket pan head screw	4	PC
3	M3 DIN 433 Stainless Steel A2 Washer	4	PC
5	SP6HPD + Driver Board	1	PC

Note:

1. In addition, 4x M6 screws as per required length are to be used for screwing the SP6HPD power module to the customer interface. These screws as well as 4x M6 washers are not provided as part of the deliverables.

6. Qualifications

The following table provides the details of the qualification plan. The qualification tests are ongoing, but engineering tests have been successfully completed for all the demanding mechanical and environmental conditions.

Table 6-1. Qualification Tests

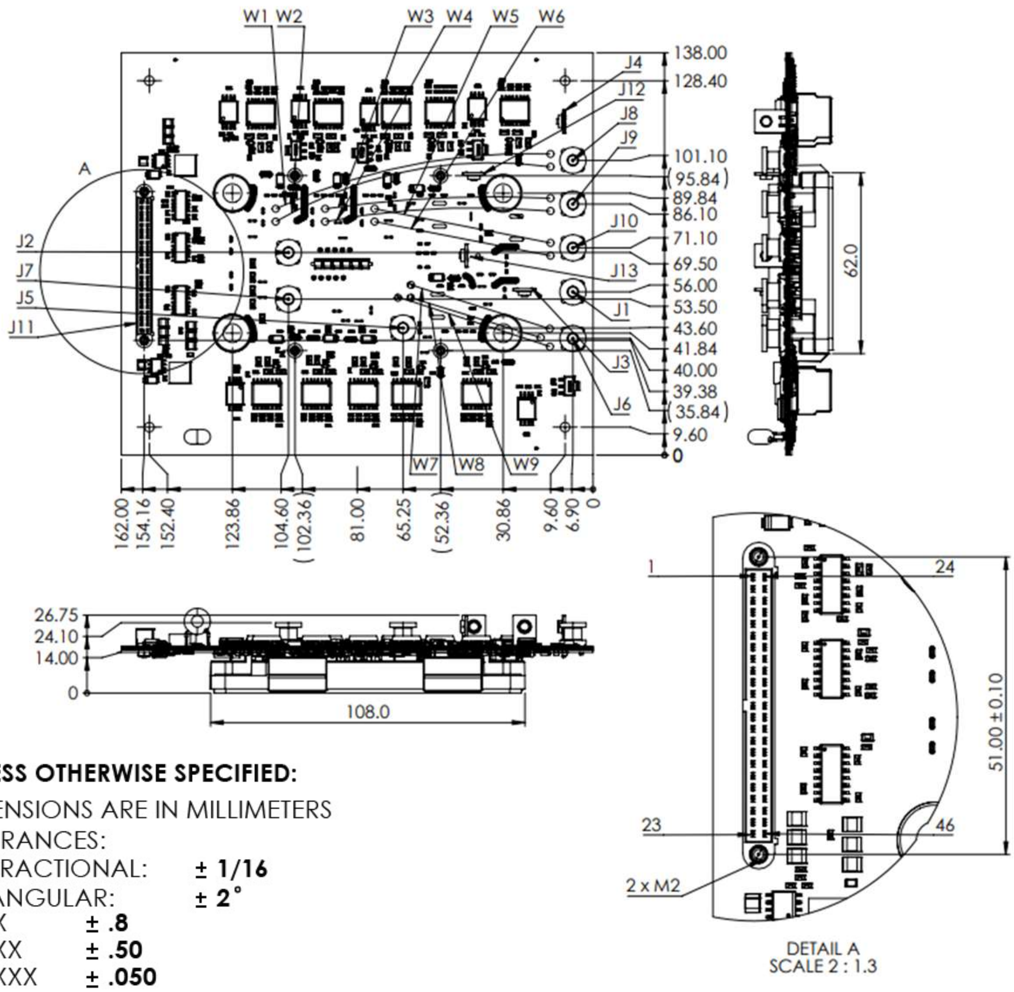
Test	Conditions
High Temperature Cycle	DO–160G, Section 4, Cat. D2 (100 °C)
Low Temperature Cycle	DO–160G, Section 4, Cat. D2 (–55 °C)
Cold Temperature Start–up	10 starts, –55 °C
Temperature Variation	DO–160G, Section 5, Cat. A (>10 °C/minute)
Altitude	DO–160G, Section 4, Cat. D2 (Unpressurized area) (50,000 feet)
Humidity	DO–160G, Section 6, Cat. C (55 °C, 95% RH)
Operational Vibration	DO–160G, Section 8, Cat. R, Curve E1 (11g)
Operational Shock and Crash Safety	DO–160G, Section 7, Cat. D (20g, 11 ms, saw–tooth)

Note: Partial discharge testing performed before and after the qualification tests.

7. Package Outline

The following figure shows the package outline of the integrated solution of the SP6HPD and driver board.

Figure 7-1. Package Outline



Note: The detailed dimensions can be referred to the 3D file which is available on request.

8. Interface Description

8.1 Signal Connector (J11): 2x23 Straight Male Connector

Nicomatic Make, Type No. 221Y46F22HW

Figure 8-1. J11 Signal Connector Interface Pin-Outs

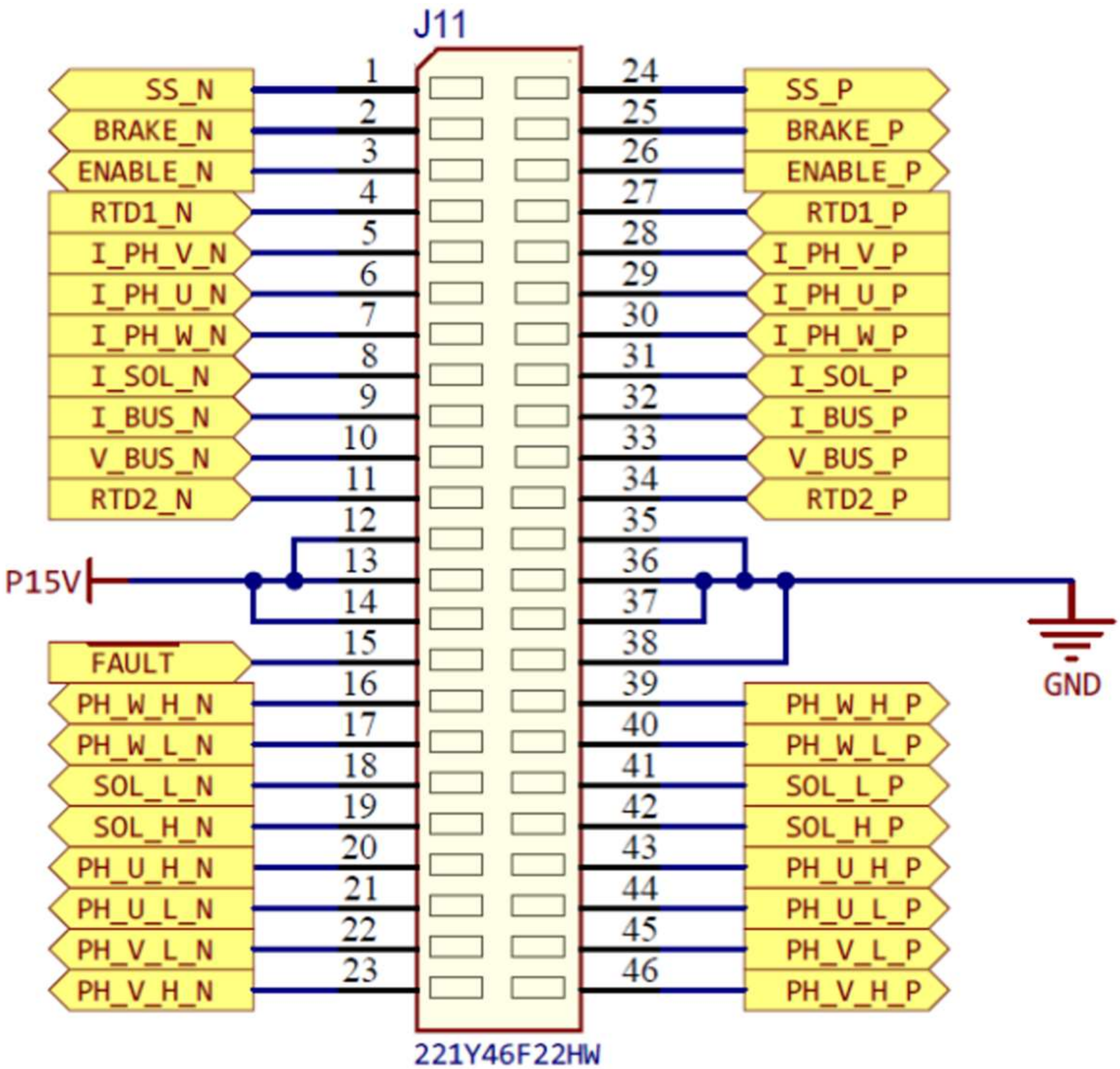


Table 8-1. J11 Signal Connector Pin Descriptions

Pin No.	Signal	Input/ Output	Description	Definition
1	PWM_SS_N	Input	PWM Input Soft Start – Differential (LVDS) Inverting Input	PWM input from higher level system for soft–start switch
2	PWM_BRAKE_N	Input	PWM Input Brake – Differential (LVDS) Inverting Input	PWM input from higher level system for brake switch
3	ENABLE_N	Input	Enable Input – Differential (LVDS) Inverting Input	Enable input for enabling all drive functionalities of the gate driver board
4	RTD1_N	Output	Temperature Sensor 1 (-)	Sensor 1 PT1000 directly wired output (-)
5	I_PH_V_N	Output	V Phase Current – Differential Inverting Output	Phase V current output as differential voltage – Inverting
6	I_PH_U_N	Output	U Phase Current – Differential Inverting Output	Phase U current output as differential voltage – Inverting
7	I_PH_W_N	Output	W Phase Current – Differential Inverting Output	Phase W current output as differential voltage – Inverting
8	I_SOL_N	Output	Solenoid Current – Differential Inverting Output	Solenoid current output as differential voltage – Inverting
9	I_BUS_N	Output	DC Bus Current – Differential Inverting Output	DC Bus Current output as differential voltage – Inverting
10	V_BUS_N	Output	DC Bus Voltage – Differential Inverting Output	DC Bus Voltage output as differential voltage – Inverting
11	RTD2_N	Output	Temperature Sensor 2 (-)	Sensor 2 PT1000 directly wired output (-)
12	P15V	Input	+15V Power Supply	Input power supply 15V to gate drive board
13	P15V	Input	+15V Power Supply	Input power supply 15V to gate drive board
14	P15V	Input	+15V Power Supply	Input power supply 15V to gate drive board
15	$\overline{FAULT}$	Output	Active Low Fault Output	Active low Fault output for Desat condition in any of the power module switches
16	PWM_PH_W_H_N	Input	PWM Input Phase W Top Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for phase W top switch (Inverting)
17	PWM_PH_W_L_N	Input	PWM Input Phase W Bottom Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for phase W bottom switch (Inverting)
18	PWM_SOL_L_N	Input	PWM Input Solenoid Bottom Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for Solenoid bottom switch (Inverting)
19	PWM_SOL_H_N	Input	PWM Input Solenoid Top Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for Solenoid top switch (Inverting)
20	PWM_PH_U_H_N	Input	PWM Input Phase U Top Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for phase U top switch (Inverting)
21	PWM_PH_U_L_N	Input	PWM Input Phase U Bottom Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for phase U bottom switch (Inverting)
22	PWM_PH_V_L_N	Input	PWM Input Phase V Bottom Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for phase V Bottom switch (Inverting)
23	PWM_PH_V_H_N	Input	PWM Input Phase V Top Switch – Differential (LVDS) Inverting Input	PWM input from higher level system for phase V top switch (Inverting)
24	PWM_SS_P	Input	PWM Input Soft-Start – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for Soft–Start switch (Inverting)
25	PWM_BRAKE_N	Input	PWM Input Brake – Differential (LVDS) No–-Inverting Input	PWM input from higher level system for Brake switch (Inverting)

...........continued

Pin No.	Signal	Input/ Output	Description	Definition
26	ENABLE_P	Input	Enable Input – Differential (LVDS) No-–Inverting Input	Enable input from higher level system for enabling all gate drive channels
27	RTD1_P	Output	Temperature Sensor 1 (+)	Sensor 1 PT1000 directly wired output (+)
28	I_PH_V_P	Output	V Phase Current – Differential Non– Inverting Output	Phase V current output as differential voltage – Non–Inverting
29	I_PH_U_P	Output	U Phase Current – Differential Non–Inverting Output	Phase U current output as differential voltage – Non–Inverting
30	I_PH_W_P	Output	W Phase Current – Differential Non–Inverting Output	Phase W current output as differential voltage – Non–Inverting
31	I_SOL_P	Output	Solenoid Current – Differential Non–Inverting Output	Solenoid current output as differential voltage – Non–Inverting
32	I_BUS_P	Output	DC Bus Current – Differential Non–Inverting Output	DC Bus Current output as differential voltage – Non–Inverting
33	V_BUS_P	Output	DC Bus Voltage – Differential Non–Inverting Output	DC Bus Voltage output as differential voltage – Non–Inverting
34	RTD2_P	Output	Temperature Sensor 2 (+)	Sensor 2 PT1000 directly wired output (+)
35	GND	Input	GND Power Supply	Input power supply Ground to gate drive board
36	GND	Input	GND Power Supply	Input power supply Ground to gate drive board
37	GND	Input	GND Power Supply	Input power supply Ground to gate drive board
38	GND	Input	GND Power Supply	Input power supply Ground to gate drive board
39	PWM_PH_W_H_P	Input	PWM Input Phase W Top Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for phase W top switch – Non–Inverting
40	PWM_PH_W_L_P	Input	PWM Input Phase W Bottom Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for phase W bottom switch – Non–Inverting
41	PWM_SOL_L_P	Input	PWM Input Solenoid Bottom Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for Solenoid bottom switch – Non–Inverting
42	PWM_SOL_H_P	Input	PWM Input Solenoid Top Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for Solenoid top switch – Non–Inverting
43	PWM_PH_U_H_P	Input	PWM Input Phase U Top Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for phase U top switch – Non–Inverting
44	PWM_PH_U_L_P	Input	PWM Input Phase U Bottom Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for phase U bottom switch – Non–Inverting
45	PWM_PH_V_L_P	Input	PWM Input Phase V Bottom Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for phase V Bottom switch – Non–Inverting
46	PWM_PH_V_H_P	Input	PWM Input Phase V Top Switch – Differential (LVDS) Non–Inverting Input	PWM input from higher level system for phase V top switch – Non–Inverting

8.2 Power Interface

Table 8-2. Power Terminals Description

Pin	Reference	Description	Type of Terminal
J1	HV_IN+	HV DC Input +	M4 Screw Terminal
J2	BUS+	External DC Bus Capacitor +	M4 Screw Terminal
J3	SSRES+	Soft–Start Resistor Terminal +	M3 Screw Terminal VERT
J4	SOL+	Solenoid Terminal +	M3 Screw Terminal VERT
J5	REGEN	Brake Resistor +	M4 Screw Terminal
J6	HV_IN-	HV DC Input –	M4 Screw Terminal
J7	BUS-	External DC Bus Capacitor –	M4 Screw Terminal
J8	PHU	Phase U Output Terminal	M4 Screw Terminal
J9	PHV	Phase V Output Terminal	M4 Screw Terminal
J10	PHW	Phase W Output Terminal	M4 Screw Terminal
J12	SOL-	Solenoid Terminal –	M3 Screw Terminal VERT
J13	SSRES-	Soft–Start Resistor Terminal –	M3 Screw Terminal VERT

9. Power Functionality (SP6HPD + Companion Driver Board) – Product Family

Input

The input to the power stage is the DC voltage through J1 and J6 terminals. External DC link capacitor must be connected to terminals J2 and J7 through low inductive path to have clean switching power modules and to avoid overheating of MLCC DC-link capacitors present on the PCB board.

Soft Start

The soft start function is used to avoid a sudden in-rush current drawn by DC link capacitor when DC input is turned on. If SP6HPD is equipped with the soft start switch, terminals J3 and J13 are used for connecting the soft start resistor. When the DC input is switched ON, the external DC link capacitor is first charged through the soft start resistor and then the soft-start switch can be turned on by the higher-level system to bypass the soft start resistor. The external PWM input to the soft start switch is provided to the signal connector J11.

Three-Phase Output

The electrical power coming from the DC power supply is modulated according to the received PWM inputs and a three-phase output is available in terminals J8, J9, and J10. The external PWM inputs from a higher level system are provided to the signal connector J11.

Solenoid Drive

The electrical power coming from the DC power supply is modulated according to the received PWM inputs and the solenoid is driven. If SP6HPD is equipped with Solenoid switch, terminals J4 and J12 are used to connect the solenoid load. The external PWM inputs from a higher-level system are provided to the signal connector J11.

Brake

Whenever braking action is required to be taken by the higher-level system, the PWM inputs are provided to the brake switch to dissipate the energy across the brake resistor. If SP6HPD is equipped with the brake switch, terminal J5 is used to connect the brake resistor. The external PWM inputs from a higher-level system are provided to the signal connector J11.

10. Gate Drive Board Functionality – Product Family

Input

The input to gate drive supply is 15V through signal connector J11.

Under Voltage Lock Out (UVLO)

The readiness for the gate driver to be operated is under the control of two UVLO circuits monitoring the input side and internal bias voltage.

The gate driver board constantly monitors the input 15V supply. UVLO feature is present for the input supply, the gate driver board powers ON only when the input voltage crosses the UVLO limits. Hysteresis is provided to avoid oscillations when the input voltage is close to the UVLO threshold.

UVLO is also present for internal bias supply. If the positive going gate voltage is less than the threshold limits the gate drive outputs are pulled to negative until the voltage levels are as per requirement. Hysteresis is provided to avoid oscillations when the input voltage is close to the UVLO threshold.

On-Board Power Supplies

The gate driver board receives the 15V input and derives 3.3V and 11V using DC/DC buck converter for internal use.

On-Board Floating Bias Supplies

The on-board isolated bias power supply is push-pull DC/DC converter with primary side pre-regulated input. There are four push-pull DC/DC converters onboard to provide high-side and low-side channels with the positive and negative supply voltages required to drive the switches. The bias supplies are also used to provide power to the isolation amplifier used for telemetry purposes.

Drive Enable

The Drive Enable input interface from higher-level systems is based on low-voltage differential signaling (LVDS). These are provided to signal connector J11. This is used to enable/disable all gate drives by the higher-level system irrespective of the PWM inputs.

PWM Inputs

The PWM input interface from higher-level systems is based on LVDS. These are provided to signal connector J11. The received PWM inputs are provided to the power switches through the isolated gate drive circuitry. All power switches on the SP6HPD are normally off when there are no PWM inputs.

Shoot-Through Protection

Shoot-through protection is present in the gate drive for the three-phase inverter bridge. This prevents the high-side and low-side switches of the inverter from being active at the same time.

Short-circuit Protection, Soft Turn Off

An internal desaturation (DESAT) fault detection recognizes when the Si IGBT/SiC MOSFET is in an overcurrent/short-circuit condition. Upon a DESAT detection, a mute logic immediately blocks the output of the isolator and initiates a soft turnoff procedure turning the IGBT off immediately. A fault signal is sent across the isolation barrier and blocks the isolator input. The fault output condition is latched and can be reset only by the Disable/Enable gate drive or 15V power OFF/ON. When the DESAT fault is detected, the power module gate is discharged by means of soft-shutdown circuit to avoid high di/dt at power module turn off.

Fault

All fault signals of individual gate channels are combined internally and are provided as one single

FAULT signal to the higher-level system through J11 connector. The FAULT is active low output. The FAULT signal is permanently active following a DESAT event. It is also active if the power supply to internal gate drivers is not healthy.

Active Miller Clamping

In case of high positive dV/dt and despite the negative drive of the power module gate, a parasitic turn on of the gate could take place, inducing shoot through current on the power arm.

To prevent this, the gate driver board has Active Miller Clamping function.

Telemetry

The driver board internally monitors the DC bus currents, phase currents, and solenoid currents from the respective shunt present in the SP6HPD power module. The driver board also internally monitors the DC bus voltage. Isolation amplifiers present in the driver board take these monitored signals, amplifies, and provides isolated differential output for each of these measurements. These outputs are available in the J11 connector.

The temperature sensors output from SP6HPD are taken directly and given to the J11 connector for higher-level system monitoring. No processing is done inside the driver board circuitry.

11. Revision History

Revision	Date	Description
A	02/2024	Initial version

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