MAIPDMC40X120A Hybrid Power Drive with SiC Power Stage Datasheet

1 Product Overview

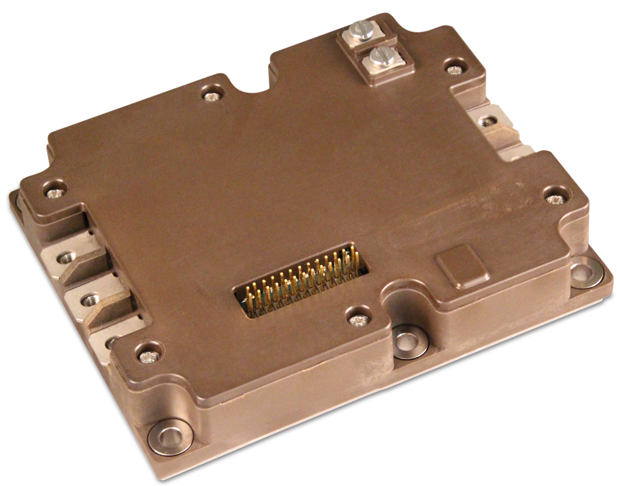
The Hybrid Power Drive (HPD) is an intelligent, cost-effective module that is built on Microsemi's legacy of flight heritage and design excellence. The HPD is targeted at electric motor drives and solenoids on aircraft actuator systems up to 5 kVA. It is designed to be driven with external PWM signals.

The HPD module is comprised of a power stage substrate and a driver circuit sub-assembly. The power stage of the HPD is comprised of a three-phase inverter bridge with embedded SiC MOSFETs and SiC Schottky antiparallel diodes. The driver circuit sub-assembly provides a galvanically isolated interface to the power MOSFETs and their local feedback signals. It also features the SiC MOSFETs and SiC Schottky freewheel diode that form the solenoid driver.

The HPD design features screw-on M3 terminals for power connections and a standard connector interface for low-voltage signals. The module is offered in a plastic package with an AlSiC baseplate and dimensions of 105.5 mm × 85.5 mm × 25 mm. The power substrate is potted with silicone gel and the driver printed wiring board (PWB) is Parylene coated, providing best possible environmental protection in a cost-effective, non-hermetic package.

Documentation support includes qualification and reliability data (reliability is based on FIDES guidelines).

Figure 1 • MAIPDMC40X120A



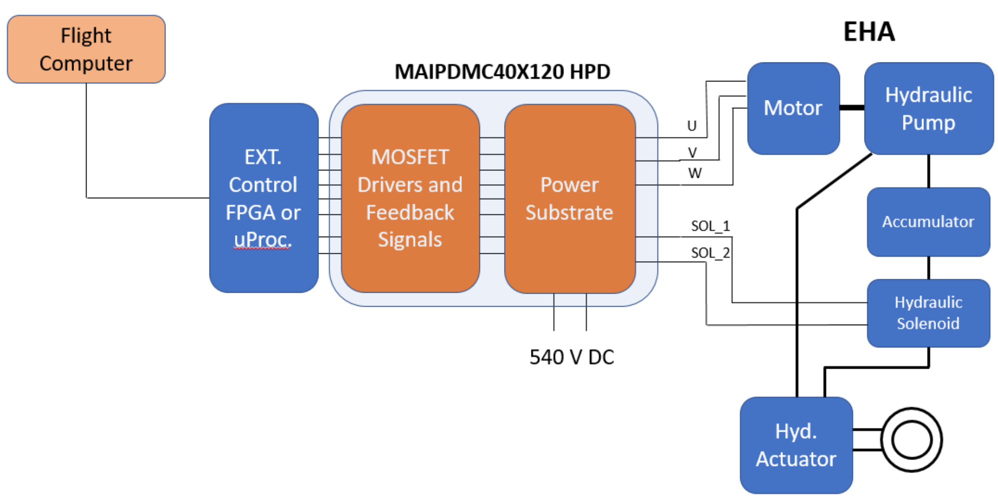
1.1 Features

The MAIPDMC40X120A Hybrid Power Drive module provides a fully engineered solution, offering excellent performance and reliability in electrohydrostatic actuator (EHA), electrical back-up hydraulic actuator (EBHA), and electromechanical actuator (EMA) aviation applications. The following are the key features of the MAIPDMC40X120A Hybrid Power Drive:

- **Power Stage**
  - SiC MOSFETs for power conversion
    - Low $R_{DS(on)}$
    - High-speed switching
    - High power efficiency
  - SiC Schottky diodes for freewheeling
    - Zero-reverse recovery
    - Temperature-independent switching behavior
- **Driver Circuit Sub-Assembly**
  - Integrated galvanically isolated gate drive circuitry
  - Circuitry for three-phase current sense, DC bus voltage sense, solenoid current sense, and temperature sense
  - SiC MOSFETs and SiC Schottky freewheel diode for solenoid driver
- **Package**
  - AlSiC base plate for extended reliability and reduced weight
  - Si_3N_4 substrate for improved thermal performance and extended reliability
  - Direct mounting to heat sink (isolated package)
  - Designed for multi-sourced SiC devices, easily expandable to higher currents and technology platforms
  - Custom variants are available; contact your Microsemi sales representative for more details

The following illustration shows the application of an HPD within the power drive electronics system.

Figure 2 • Intelligent Power Electrical Control System (in Electrohydrostatic Actuator (EHA))



1.2 Part Numbering

The following table shows the naming methodology for the MAIPDMC40X120A Hybrid Power Drive.

Table 1 • Module Naming Methodology

M	Microsemi	
A	Screening level	A = Aviation
I	Intelligent power solutions	
PD	Type	PD = Hybrid Power Drive
MC	Technology	MC = SiC MOSFET
40	Maximum current rating in amps that MOSFETs can handle	
X	Topology	X = three-phase bridge
120	Voltage rating	120 = 1200 V
A	Standard package	

2 Functional Description

The HPD architecture has evolved from Microsemi's standard module design, providing gate drive, monitoring, and power stages for motor control applications. The HPD has two parts—the substrate power devices and the isolated gate driver/signal board. A functional block diagram of the HPD with the subassembly architecture is shown in Figure 3 below.

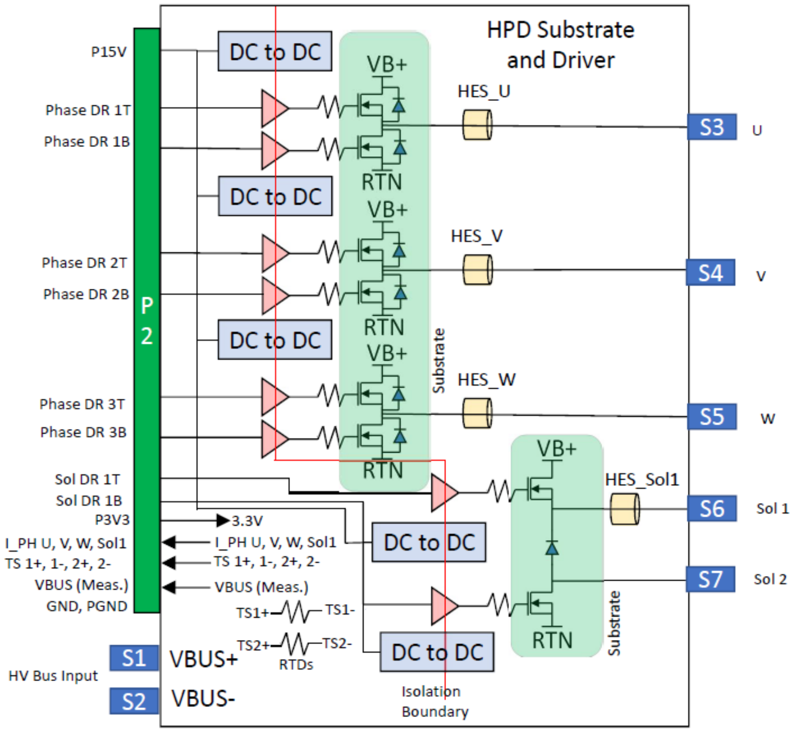
The driver circuit subassembly within the HPD provides the gate-drive signals to the MOSFETs in the three-phase bridge and solenoid driver. There are five sets of gate-drive signals to control the SiC MOSFETs. Four floating bias power supplies generate the bias voltages for the logic side gate drivers and other telemetry circuits are supplied by the input connector. The solenoid driver SiC MOSFETs and SiC Schottky freewheel diode are located on the driver circuit subassembly along with Hall Effect Sensors (HES) to monitor the motor and solenoid output currents. The driver PWB also measures the HVDC bus voltage and provides an isolated DC voltage output signal. The gate drivers, HES, and the voltage amplifier within the driver PWB provide the voltage isolation to allow reliable interface with next-level circuitry. Two platinum resistive temperature transducers (PT1000) on the driver PWB monitor the HPD temperature.

A 26-pin external connector is mounted on the driver circuit subassembly to interface the LV power supply, drive, and monitoring signals to the system.

The substrate contains 1200 V–rated, high-speed SiC MOSFETs and SiC Schottky antiparallel diodes to generate the three-phase switching outputs. Power and low-level signal routing are provided through pin terminals from the driver PWB to the substrate.

The following illustration shows the functional blocks of the MAIPDMC40X120A Hybrid Power Drive.

Figure 3 • Functional Block Diagram



3 Electrical Specifications

This section details the electrical specifications for the MAIPDMC40X120A Hybrid Power Drive device.

3.1 Absolute Maximum Ratings

This section shows the absolute maximum ratings of the MAIPDMC40X120A Hybrid Power Drive device.

Table 2 • Absolute Maximum Ratings

Symbol	Parameter		Ratings	Unit
V_{DSS}	Drain-source breakdown voltage		1200	V
I_D	Continuous switch drain current	T_C = 25 °C	63	A
		T_C = 100 °C	46	A
I_{DM}	Pulsed drain current		160	A
I_F	Antiparallel diode maximum DC forward current	T_J = 25 °C	43	A
P15V	Input bias1 supply voltage		18	V
P3.3V				
I_{CC}	Input bias1 supply current (at 12 V)		250	mA
V_{DISC}	Discrete signal input voltage		3.6	V
T_J	Maximum power semiconductor junction temperature		175	°C

3.2 Typical Electrical Performance

The following table shows the input electrical characteristics of the MAIPDMC40X120A Hybrid Power Drive at 25 °C unless otherwise specified.

Table 3 • Input Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Steady-state HVDC input voltage	VBUS		540	750	V	
Bias1 power supply voltage	P15V	12	15	18	V	
Bias1 supply current	ICC		140		mA	F_{SW}[1] = 10 kHz
Bias2 power supply voltage	P3V3	0.0	3.3	3.6	V	
Bias2 supply current	P3V3		50		mA	

Note:

1. F_{SW} corresponds to the switching frequency.

The following table shows the output electrical characteristics of the MAIPDMC40X120A Hybrid Power Drive at 25 °C unless otherwise specified.

Table 4 • Output Electrical Characteristics

Parameter		Symbol	Min	Typ	Max	Unit	Notes
Phase current	Peak amplitude	I_{ph}			12.5	A	F_{SW} = 10 kHz T_C = 110 °C HVDC = 540 VDC
					25		F_{SW} = 10 kHz T_C = 95 °C HVDC = 540 VDC
Solenoid current	Steady state	SOL_SW-SS		1		A	F_{SW} = 10 kHz T_C = 110 °C HVDC = 540 VDC
	Transient	SOL_SW-T		5			F_{SW} = 10 kHz T_C = 110 °C HVDC = 540 VDC For <100 ms
Power rating		P_{OUT}		5		kVA	
Switching voltage transient rate		dV_{DS}/dt		16		kV /µs	F_{SW} = 10 kHz HVDC = 540 VDC I_D = 12.5 A
Power efficiency		η		99.5		%	F_{SW} = 10 kHz T_C = 20 °C HVDC = 540 VDC I_D = 12.5 A MI = 0.98 CosΦ = 0.87
Phase current sense range		I_{PR}	–40		40	A	
Solenoid current sense range		I_{SR}	–10		10	A	
Full-scale current sense accuracy		I_{TOT}		Motor current	12.8	%	T_A = –55 °C to 110 °C
				Solenoid	10.6		T_A = –55 °C to 110 °C
Full-scale HVDC sense accuracy accuracy					3.0	%	T_A = –55 °C to 110 °C

The following table shows the SiC MOSFET characteristics of the MAIPDMC40X120A Hybrid Power Drive at 25 °C unless otherwise specified. The SiC MOSFET characteristics listed in Table 6 are bare die measurements. This data is for analysis only and has not been validated in the HPD package.

Table 5 • SiC MOSFET Die Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Drain-source on resistance	$R_{DS(on)}$		40	52	mΩ	V_{GS} = 20 V T_C = 25 °C I_D = 40 A
Turn-on delay time	$T_{d(on)}$		15		ns	V_{GS} = 20/–5 V V_{Bus} = 800 V I_D = 40 A R_G = 2.5 Ω Inductive switching
Turn-off delay time	$T_{d(off)}$		26			
Rise time	T_r		52			
Fall time	T_f		34			
Turn-on energy	E_{on}		1		mJ	
Turn-off energy	E_{off}		0.4			

The following table shows the body diode and SiC freewheeling diode characteristics of the MAIPDMC40X120A Hybrid Power Drive at 25 °C unless otherwise specified. The SiC diode characteristics listed in Table 6 are bare die measurements. This data is for analysis only and has not been validated in the HPD package.

Table 6 • Body Diode and SiC Freewheeling Diode Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Body diode forward voltage	VSD		4.1		V	V_{GS} = –5 V I_{SD} = 20 A T_J = 25 °C
Body diode reverse recovery time	t_{rr}		54		ns	ISD = 40 A VGS = –5 V VR = 800 V diF/dt = 1000 A/µs T_J = 25 °C
Body diode reverse recovery charge	Q_{rr}		283		nC	
Body diode reverse recovery current	I_{rr}		15		A	
Peak repetitive reverse voltage	V_{RRM}			1200	V	
Freewheeling diode forward voltage	V_F		1.5	1.8	V	I_F = 10 A T_J = 25 C
			2.3		V	I_F = 10 A T_J = 175 C

The following table shows the isolation characteristics of the MAIPDMC40X120A Hybrid Power Drive at 25 °C unless otherwise specified.

Table 7 • Isolation Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Gate driver common-mode transient immunity (CMTI)	$\|dV_{ISO}/dt\|$			100	kV/µs	V_{CM} = 1 kV
RMS isolation voltage, any terminal to case t = 1 min, 50 Hz/60 Hz	V_{ISOL1}	1500			V_{RMS}	
Isolation dielectric between power and control stage under DC voltage	V_{ISOL2}	2120			V_{DC}	
Isolation resistance between power and control stage under 500 VDC	V_{ISOL3}	100			MΩ	

The following table shows the temperature sensor PTC characteristics of the MAIPDMC40X120A Hybrid Power Drive at 25 °C unless otherwise specified. Use the values in the following table to calculate the thermistor value (R_T):

$R_T = R_0(1 + A \cdot T + B \cdot T^2)$ for the temperature range from 0 °C to 250 °C

$R_T = R_0(1 + A \cdot T + B \cdot T^2 + C(T - 100)T^3)$ for the temperature range from –55 °C to 0 °C

Table 8 • Temperature Sensor PTC Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Temperature sense range	T_R	–55		250	°C	
RTD nominal value	R_0		1000		Ω	At 0 °C
Temperature sense accuracy	T_{TOT}	–2		2	°C	
	A		3.9083×10^{-3}		$°C^{-1}$	
	B		-5.775×10^{-7}		$°C^{-2}$	
	C		-4.183×10^{-12}		$°C^{-4}$	
	ΔT					As per IEC60751 Class A

4 Thermal Characteristics

The following table shows the thermal characteristics of the MAIPDMC40X120A Hybrid Power Drive.

Table 9 • Thermal Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Case temperature	T_C	–55		110	°C	Refer to derating curves in Characteristic Curves (see page 9)
Storage	T_S	–55		125	°C	
Pressure range		11.6		190	kPa	
Thermal resistance (junction-case)	$\Theta_{JC\ MOSFET}$			0.77	°C/W	
	$\Theta_{JC\ DIODE}$			0.67		

Parameter	Symbol	Min	Typ	Max	Unit	Notes
Power dissipation			25		W	F_{SW} = 10 kHz T_C = 20 °C CosΦ = 0.97 V_{BUS} = 540 V I_D = 12.5 A

5 Mechanical Characteristics

The following table shows the mechanical characteristics of the MAIPDMC40X120A Hybrid Power Drive. Use caution as these devices are sensitive to electrostatic discharge. Be sure to follow proper handling procedures.

Table 10 • Mechanical Characteristics

Parameter	Max	Unit
Size: MAIPDMC40X120A	105.5 × 85.5 × 25	mm
Mass	270	g
Mounting: fastener	4.4 Ø (×6) (through-hole)	mm
Mounting: washer	9.0 Ø (×6) (surface)	mm
Mounting torque: M4 (to heat sink)	1.2–3.5	Nm
Power connector	M3 screw terminals (×7)	
Mounting torque: power connector[1]	0.9–1	Nm
Signal connector pin pitch	2.00	mm
Signal connector pin dimension	0.5 × 0.5	mm
Baseplate information	AlSiC material with thickness: 4 mm	

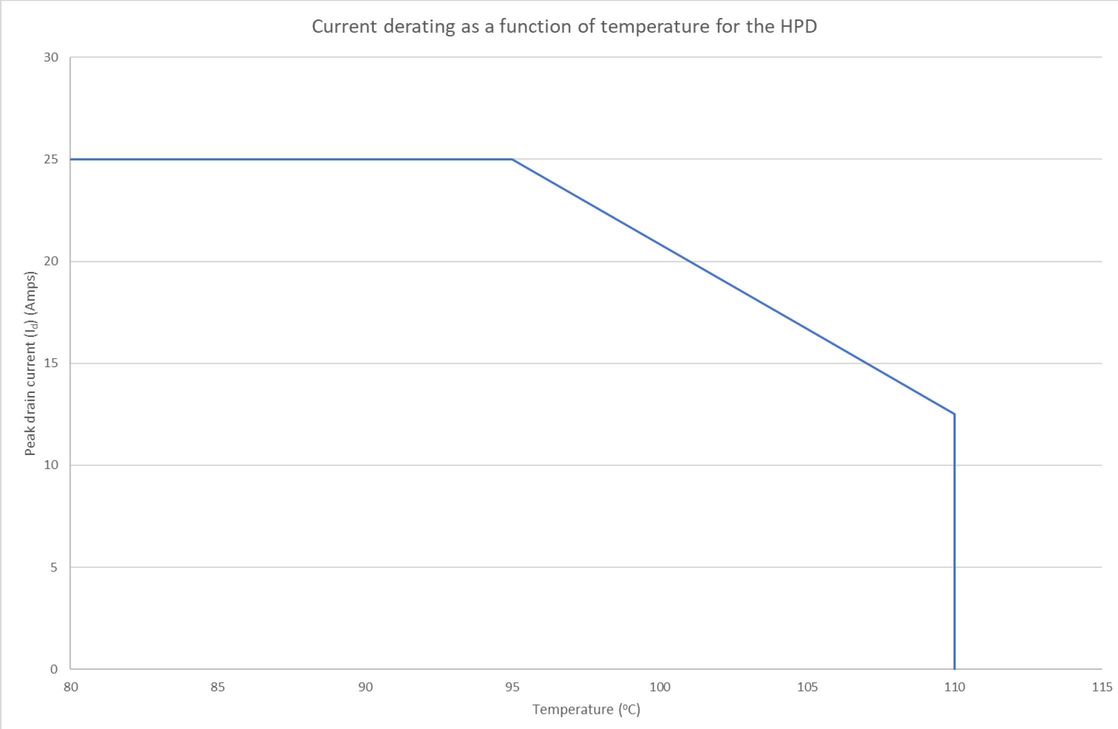
Note:

1. Hole call-outs in Figure 6 indicate threaded depth only. Copper terminals are an additional 0.7 mm to the indicated value.

6 Characteristic Curves

The following illustration shows the thermal derating curve of the MAIPDMC40X120A Hybrid Power Drive.

Figure 4 • Thermal Derating Curve



7 Pin Descriptions

The following table shows the power pin descriptions for the MAIPDMC40X120A Hybrid Power Drive.

Table 11 • Power Pin Descriptions

Power pin	Description	Reference	I/O Type	Connector Type
S1	HVDC bus input	V_BUS +	Input	M3 screw terminal
S2	HVDC bus input return	V_BUS –	Input	M3 screw terminal
S3	Output current for phase	Phase_U	Output	M3 screw terminal
S4	Output current for phase	Phase_V	Output	M3 screw terminal
S5	Output current for phase	Phase_W	Output	M3 screw terminal
S6	Solenoid output current	Sol_1	Output	M3 screw terminal
S7	Solenoid output current return	Sol_2	Output	M3 screw terminal

The following table shows the signal pin descriptions for the MAIPDMC40X120A Hybrid Power Drive.

Table 12 • MAIPDMC40X120 Signal Pin Descriptions

P2 Signal Pin	Description	Designator	I/O Type	Signal Definition
1	Ground reference	GND_REF	Output	
2	Logic ground	GND	Input	
3	Phase 3 sense current	IPHASE_3	Output	Single-ended voltage proportional to the motor phase current 3 Current range: –25 A to 25 A Zero current output range: $V_{CC}/2$ Sensitivity: 33 mV/A
4	3.3 V	V_{CC}[1,2]	Input	Low-voltage DC power source
5	Phase 2 sense current	IPHASE_2	Output	Single-ended voltage proportional to the motor phase current 2 Zero current output range: $V_{CC}/2$ Sensitivity: 33 mV/A
6	Temperature sensor (1) +	RT1+	Output	Refer to Temperature Sensor (see page 7)
7	Phase 1 sense current	IPHASE_1	Output	Single-ended voltage proportional to the motor phase current 1 Zero current output range: $V_{CC}/2$ Sensitivity: 33 mV/A
8	Temperature sensor (1) –	RT1–	Output	Return for RT1+
9	Phase 3 gate drive signal – bottom MOSFET	PHASE_DR_3B	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
10	Temperature sensor (2) +	RT2+	Output	Refer to Temperature Sensor (see page 7)
11	Phase 2 gate drive signal – bottom MOSFET	PHASE_DR_2B	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
12	Temperature sensor (2) –	RT2–	Output	Return for RT2+
13	Phase 1 gate drive signal – bottom MOSFET	PHASE_DR_1B	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
14	Scaled HVDC voltage (+)	TM_VBUS+	Output	Differential voltage proportional to the bus voltage Voltage range: 0 V to 1000 V Zero voltage output voltage: 0 V Sensitivity: 2 mV/V
15	Phase 3 gate drive signal – top MOSFET	PHASE_DR_3T	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
16	Scaled HVDC voltage (–)	TM_VBUS–	Output	Return for TM_VBUS+
17	Phase 2 gate drive signal – top MOSFET	PHASE_DR_2T	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
18	Bus current sense signal	IBUS	Output	Single-ended voltage proportional to the bus current Current range: –25 A to 25 A Zero current output range: $V_{CC}/2$ Sensitivity: 33 mV/A
19	Phase 1 gate drive signal – top MOSFET	PHASE_DR_1T	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
20	Solenoid sense current	ISOL	Output	Single-ended voltage proportional to the solenoid current Current range: –10 A to 10 A Zero current output range: $V_{CC}/2$ Sensitivity: 132 mV/A
21		SOL_DR_1B	Input	

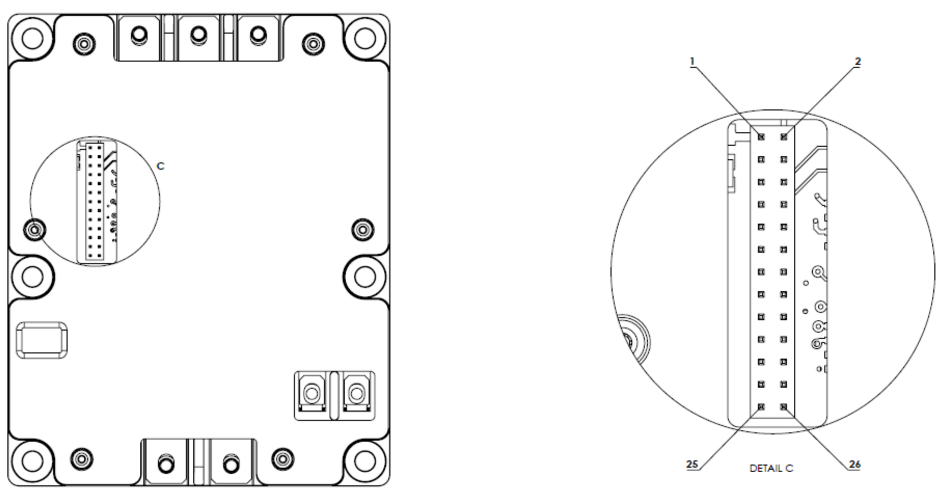
P2 Signal Pin	Description	Designator	I/O Type	Signal Definition
	Solenoid gate drive signal – bottom MOSFET			High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
22	Solenoid gate drive signal – top MOSFET	SOL_DR_1T	Input	High level = 0.7 * V_{CC} to + V_{CC} Low level = GND to 0.3 * V_{CC}
23	15 V	P15V	Input	15 V power source
24	Power ground	PGND	Input	
25	15 V	P15V	Input	15 V power source
26	Power ground	PGND	Input	

Notes:

1. Voltage range levels are calculated based on V_{CC} = 3.3 V.
2. The HPD module is designed to accept 3.3 V or 5 V bias input. Standard design uses 3.3 V.

The following image shows the P1 signal pin locations for the MAIPDMC40X120A Hybrid Power Drive.

Figure 5 • P2 Signal Pin Locations



8 Package Outlines

The following illustrations show the package outlines for the MAIPDMC40X120A Hybrid Power Drive.

Figure 6 • Package Outline

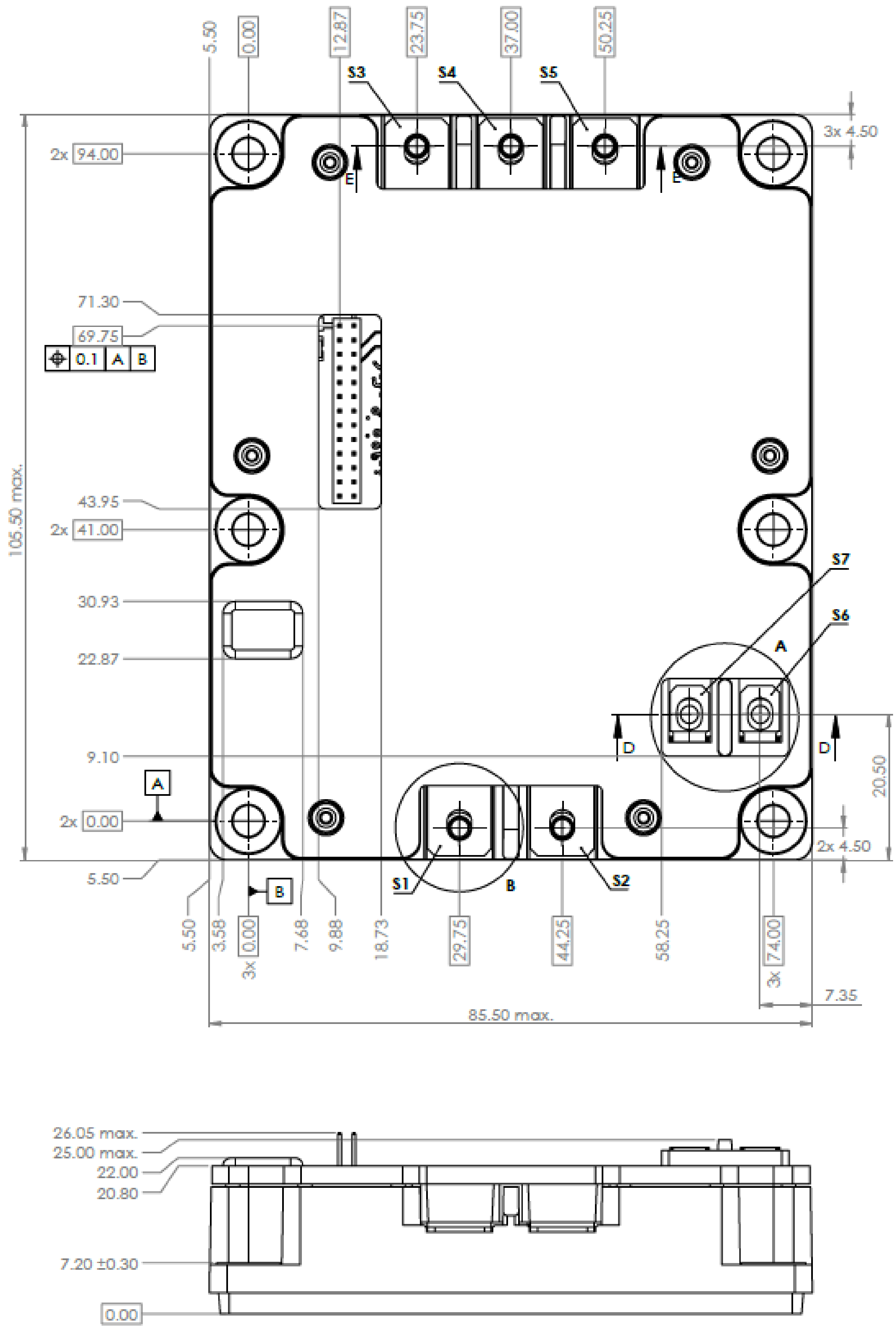
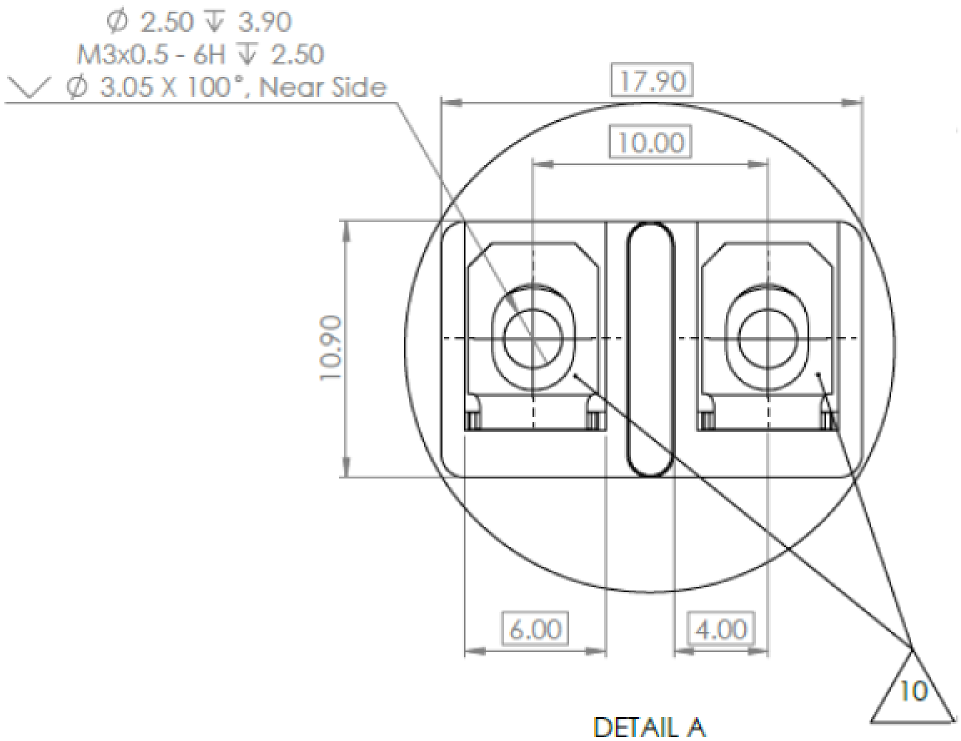


Figure 7 • Terminals Detailed View



DETAIL A
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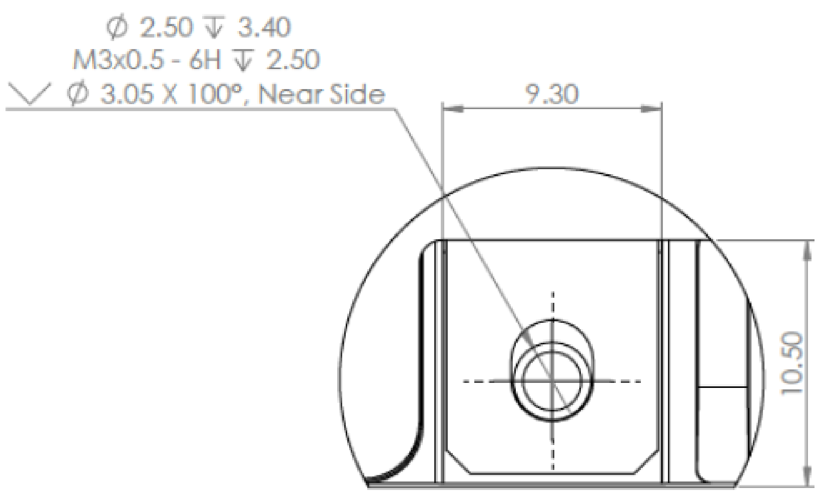

DETAIL B
SCALE 4 : 1

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