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SOLO PRO 400-160 — HARDWARE USER MANUAL

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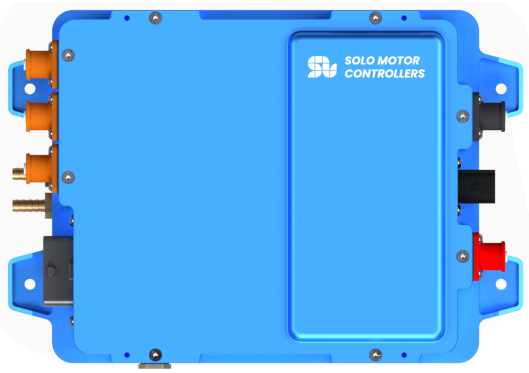
Control Module: SOLO SOM — dual-core TMS320F28388D DSP



EtherCAT CANopen

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TABLE OF CONTENTS

1. About This Document 5
- 1.1 Purpose and Scope 5
- 1.2 Safety Symbols 6
- 1.3 Abbreviations 6
- 1.4 Revision History 8
- 1.5 Further Information 8
- 1.6 Trademarks 8

2. Product Safety 9
- 2.1 General Safety Precautions 9
- 2.2 Intended Use 10
- 2.3 Prohibited Use 10

3. Product Overview 11
- 3.1 What the Drive Provides 11
- 3.2 Key Features 12
- 3.3 Applications 13
- 3.4 Functional Block Diagram 13
- 3.5 Architecture 14
- 3.6 Control Principle 16
- 3.7 Ordering Information 18

4. Dual-Core Architecture and the User Core 19

5. Technical Specifications 20
- 5.1 Power 20
- 5.2 Control and Timing 22
- 5.3 Thermal & Environmental 23
- 5.4 Mechanical 24
- 5.5 Hardware Protections 24
- 5.6 Absolute Maximum Voltage Ratings 25

6. Mechanical Integration and Cooling 27
- 6.1 Dimensions and Mounting 27
- 6.2 Liquid Cooling 30
- 6.3 Thermal Considerations 31

7. Connectors, Sections & Pinout 33
- 7.1 Connector Organization 33
- 7.2 Front Face — Sections [1] and [2] 33

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7.3 Back Face — Sections [3] and [4] 35
7.4 Right Face — Section [5] 36
7.5 Section [1] J4, J5, J6 — Motor Outputs 37
7.6 Section [2] J3 — I/O Connector 38
7.7 Section [3] — DC Bus Input 42
7.8 Section [4] J13 — Motor PT1000 Connector 43
7.9 Section [5] — USB 2.0 Type-C 45
7.10 Mating Connector Part Numbers 46
8. Networking & Communications 47
8.1 EtherCAT 47
8.2 CANopen (DS402) 48
8.3 USB 49
9. Position and Temperature Sensing 51
9.1 Digital Hall Sensors 51
9.2 Incremental Encoder — Differential 52
9.3 BiSS-C Absolute Encoder 53
9.4 Sin/Cos Encoder 54
9.5 Temperature Sensors 55
10. Analogue and Digital Control 60
10.1 Analogue versus Digital Control 60
10.2 Analogue Command Inputs AI1_IN and AI2_IN 60
10.3 Analogue Wiring — Controller with NPN Outputs 60
10.4 Analogue Wiring — Embedded MCU Boards 61
10.5 General-Purpose Input Wiring 62
10.6 General-Purpose Output Wiring 62
10.7 Digital Mode 63
11. Safe Torque Off (STO) 64
11.1 Function 64
11.2 Electrical Characteristics 65
11.3 Wiring the STO Inputs 65
11.4 Timing 67
12. Firmware Update (DFU Mode) 69
13. Complete Wiring Examples 72
13.1 Wiring Legend 72
13.2 Standalone Wiring — No External Modules 72
13.3 Embedded MCU Board Using Analogue/PWM 74
13.4 Embedded MCU Board Using CANopen 74
13.5 Embedded MCU Board Using EtherCAT 75
13.6 General Wiring Considerations 76

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14. Getting Started / Initial Setup 79
14.1 Required Equipment 79
14.2 First Power-Up 79
14.3 SOLO Motion Terminal — Initial Configuration 80
15. Regulatory Compliance & Approvals 82
16. Revision History 83

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1. ABOUT THIS DOCUMENT

1.1 PURPOSE AND SCOPE

The SOLO PRO 400-160 is a complete, ready-to-use high-voltage motor drive for 150–450 VDC systems, delivering up to 160 A DC (100 Arms) of continuous output current and up to 45 kW of continuous output power. It drives DC brushed, BLDC, PMSM and EC coreless motors in closed loop, with torque, speed and position control, and it requires neither firmware development nor any power-electronics design: the inverter, the gate drivers, the current and voltage sensing, the DC-bus capacitance, the liquid-cooled base plate and the isolated Safe Torque Off circuit are all built in and pre-qualified.

The unit is housed in a sealed, liquid-cooled enclosure rated **IP67**, which allows it to be installed in wet, dusty or wash-down surroundings where an air-cooled drive could not be used. Every external connection is made through a sealed connector. There is no ventilation opening and no exposed heatsink.

The user connects the DC bus, the logic supply, the motor, the position sensor and the command interface, configures the drive through the SOLO Motion Terminal, and the unit performs Field Oriented Control of the motor. Commands can arrive as analogue voltages or PWM pulses, or as data packets over USB, CANopen or EtherCAT.

The drive is built around the **SOLO SOM**, SOLO's dual-core System-on-Module, which forms its digital control section. Two independent processors work in parallel inside the drive. Section 4 describes what each of them does.

This manual specifies the electrical and mechanical characteristics of the drive, the function and pinout of every connector, the communication interfaces, the supported position sensors, the Safe Torque Off function, the liquid-cooling interface, and the wiring required to commission a system. It provides the information needed to integrate the SOLO PRO 400-160 into a machine.

The reader is assumed to be familiar with electrical drives, high-voltage working practice and industrial wiring. No prior experience with this specific product is assumed. Where a design constraint is not self-evident, the text states the underlying reason so that it can be applied correctly to a given system.

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1.2 SAFETY SYMBOLS

Four callout types appear throughout this manual. They follow the ANSI Z535 convention, in which the severity of the potential consequence determines the label:

Symbol	Meaning
i NOTE	Additional information or guidance. No risk of damage.
⚠ CAUTION	Possible minor equipment damage or data loss if disregarded.
⚠ WARNING	Possible personal injury or significant equipment damage.
⛔ DANGER	Immediate risk of serious injury or death.

⛔ **DANGER:** The DC bus of this drive operates at up to 450 VDC, a lethal voltage. Do not connect or disconnect any connector, motor lead or supply cable while the drive is powered. Isolate the supply, wait for the 330 µF of bus capacitance to discharge, and verify with a meter that the bus has fallen to a safe level before touching any terminal.

⛔ **DANGER:** Installation, commissioning and servicing of this drive must be carried out only by personnel qualified to work on high-voltage equipment.

⛔ **DANGER:** The 11–28 VDC logic-side supply must be **galvanically isolated from the DC bus**. Its 0 V must never be connected to DC−, to DC+, or to any conductor galvanically connected to the bus. Bonding the two places the full bus potential on GND_ISO, and therefore on every signal of the I/O connector, on the USB port, and on anything plugged into them. Section 5.1 gives the requirement in full.

⚠ **WARNING:** Confirm the polarity of the DC bus at the **DC+** and **DC−** terminals before switching it on. The unit has no reverse-polarity protection. Treat a reversed supply as capable of destroying it.

⚠ **CAUTION:** The drive contains ESD-sensitive components. Handle it at a grounded workstation and retain it in its packaging until installation.

1.3 ABBREVIATIONS

Abbreviation	Definition
ADC	Analog-to-Digital Converter
AGV	Automated Guided Vehicle
AI	Analogue Input
BiSS-C	Bidirectional Serial Synchronous, protocol C (an open absolute-encoder standard)

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Abbreviation	Definition
BLDC	Brushless DC motor
CAN	Controller Area Network
CLA	Control Law Accelerator (a co-processor within the TI DSP)
DFU	Device Firmware Upgrade
DSP	Digital Signal Processor
DVC	Decisive Voltage Class (UL 61800-5-1 circuit classification)
EMI	Electromagnetic Interference
FOC	Field Oriented Control
GND_ISO	Isolated ground — the reference of the control and I/O side; isolated from the DC bus only while the logic-side supply is (Section 5.1)
GPI/O	General-Purpose Input / Output
INC	Incremental (encoder type)
IP67	Ingress protection — dust-tight, protected against temporary immersion
LSS	Layer Setting Services (CANopen — sets node ID and bit rate)
NTC	Negative Temperature Coefficient thermistor (here, the internal base-plate sensor)
OCP	Over-Current Protection
OTP	Over-Temperature Protection
OVP	Over-Voltage Protection
PHY	Ethernet physical-layer transceiver
PMSM	Permanent Magnet Synchronous Motor
PTC	Positive Temperature Coefficient (here, the PT1000 sensor inputs)
PWM	Pulse-Width Modulation
RTD	Resistance Temperature Detector (e.g. PT1000)
SOM	System-on-Module
STO	Safe Torque Off
SVM	Space Vector Modulation
UVP	Under-Voltage Protection
VCP	Virtual COM Port

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1.4 REVISION HISTORY

Rev	Date	Firmware	Author	Summary of Changes
V1.0.0	31/05/2023	0x0000B00F	SOLO Motor Controllers	First release
V1.0.1	2024-05	—	SOLO Motor Controllers	Preliminary user manual issued
01	2026-09-14	—	SOLO Motor Controllers	Restructured hardware user manual

1.5 FURTHER INFORMATION

This manual covers the **hardware** of the SOLO PRO 400-160. Everything beyond it is documented separately on the SOLO website, **solomotorcontrollers.com**: configuring and tuning the drive with the **SOLO Motion Terminal**, the **CANopen (DS402)** and **EtherCAT** communication profiles and their object dictionaries, and application notes.

1.6 TRADEMARKS

EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

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2. PRODUCT SAFETY

2.1 GENERAL SAFETY PRECAUTIONS

The SOLO PRO 400-160 is a power converter capable of delivering 45 kW into a motor from a bus of up to 450 VDC. It can produce sufficient energy to cause death, fire, or violent unintended motion of a machine if misapplied. Review this section before applying power.

Two supplies are required, and they are not interchangeable. The **DC bus** input accepts 150 to 450 VDC and feeds the inverter. The **logic-side supply** accepts 11 to 28 VDC and powers the control electronics. It sits on the isolated side of the drive and must be present for the unit to operate at all. Applying the DC bus to the logic input, or the reverse, will destroy the drive.

The logic-side supply must also be **galvanically isolated from the DC bus**. The drive separates its control and I/O side from the power stage internally (Section 3.5), but that barrier closes through the supply feeding it: connect the logic 0 V to the bus return and the barrier is bridged from outside the unit, where the drive can neither detect it nor protect against it. Section 5.1 states the requirement and what it costs to ignore it.

The signal-level pins are not all rated alike: the analogue inputs, the general-purpose I/O, the Hall inputs and the DFU input tolerate up to 5 V, the differential encoder and BiSS-C inputs up to 12 V, and the PT1000 input only 3.3 V. Confirm the rating of each pin group against the absolute-maximum table in Section 5.6 before connecting it. Do not assume a common level.

⛔ **DANGER:** The motor output terminals **A**, **B** and **C** carry the switched bus voltage whenever the drive is enabled. Never connect a power supply to the motor outputs, and never touch them while the unit is powered.

⛔ **DANGER:** Never derive the logic-side supply from the DC bus through a non-isolated converter, and never bond its 0 V to the bus return. Every I/O signal, the USB port and any PLC, MCU board or PC attached to them would then sit at bus potential.

⚠ **WARNING:** The 3.3 V pins are not 5 V tolerant. Applying more than 3.3 V to PTC+ or PTC– can permanently damage the device.

⚠ **WARNING:** Providing the STO wiring is mandatory for the drive to operate. Do not defeat the STO function in a production machine. The bypass wiring of Section 11.3.3 is for bench commissioning only.

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> ⚠ **CAUTION:** The +5V_Ext. output is intended to supply position sensors and small external logic, and is protected by a 2 A e-fuse. Do not use it as a general-purpose power source. Overloading it will trip the fuse or brown out the position feedback during operation.
>
> ⚠ **CAUTION:** The drive is liquid cooled. Do not operate it without coolant flowing through the base plate, not even briefly at low load. The enclosure is sealed, so there is no air path and nothing else to carry the heat away.

2.2 INTENDED USE

The drive is intended for installation in an industrial machine or a vehicle, as the power and control stage of an electric drive axis. It is a component, not a finished machine: responsibility for the safety of the complete installation lies with the machine builder: the risk assessment, the safety function that commands the STO inputs, the emergency-stop circuit and the guarding of the driven mechanism.

Because the enclosure is sealed to IP67 and liquid cooled, the unit may be installed in wet or dusty surroundings. It still requires a coolant circuit sized for the dissipation of the application (Section 6.3).

2.3 PROHIBITED USE

Do not use the drive:

- outside the electrical, thermal and mechanical limits of Section 5;
- without a coolant circuit in operation;
- as the sole means of achieving a safety function, other than through the STO inputs wired as described in Section 11 and assessed at the machine level;
- in an application where the coasting stop that follows an STO request is itself hazardous, unless an independent mechanical brake is fitted;
- with the DC bus connected to the logic supply input, the motor outputs connected to a supply, or either polarity reversed;
- with the logic-side supply referenced to the DC bus, its 0 V bonded to DC–, to DC+, or to any bus-connected conductor, or the supply itself derived from the bus without a galvanic barrier;
- with any connector unmated in a wet environment, since an unmated connector has no IP rating.

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3. PRODUCT OVERVIEW

3.1 WHAT THE DRIVE PROVIDES

The SOLO PRO 400-160 packs a complete high-voltage, high-current motor drive (power stage, digital control, position sensing, industrial communications and an isolated functional-safety input) into a sealed 316 × 220.5 × 107 mm (W × D × H) liquid-cooled housing. The user supplies the DC bus, the logic supply, the coolant, the motor and the command source.

Figure 1. The SOLO PRO 400-160 — a complete 150–450 VDC, 160 A liquid-cooled motor drive. The front face carries the three motor outputs A, B and C, the 48-pin I/O connector and the coolant inlet and outlet. The sealed USB port is on the right face.

The unit is complete in itself. The inverter, gate drivers, current and voltage measurement, bus capacitance and isolated safety inputs are all inside it, so there is no power-electronics design work and no firmware to write. It is built for hostile surroundings: 45 kW continuous and 160 A DC from a 450 V bus, with EtherCAT, CANopen, USB, four position-sensor interfaces and an isolated safety function, inside an IP67 enclosure cooled by liquid rather than by air. Commands reach it as an analogue voltage, as PWM, or over USB, CANopen or EtherCAT, and the interface is chosen in configuration rather than by ordering a different part.

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3.2 KEY FEATURES

Power and control

- Wide DC bus range, 150 to 450 VDC, with a separate 11–28 VDC logic supply
- 160 A DC / 100 Arms continuous output current, 45 kW continuous output power
- Drives DC brushed, BLDC, PMSM and EC coreless motors
- Closed-loop torque, speed and position control with Field Oriented Control and nested loops
- Field Oriented Control loop rate up to approximately 140 kHz (7 µs complete execution time)
- Space Vector Modulation (SVM) and an embedded S-curve motion profile for position and speed
- Selectable output PWM switching frequency from 8 kHz to 80 kHz
- Four-quadrant regenerative operation
- Automatic identification of motor parameters and self-tuning

Protection and safety

- Bus over-voltage, bus under-voltage, bus over-current, motor-phase over-current and over-temperature protections, all acting in hardware
- Isolated **Safe Torque Off (STO)**, dual channel, with an isolated feedback output
- Galvanic isolation between the complete control and I/O side and the 150–450 V power stage, requiring an isolated logic-side supply (Section 5.1)

Interfaces

- USB 2.0 Type-C, CAN bus with CANopen (DS402), and EtherCAT with two on-board PHYs
- Analogue command inputs AI1_IN and AI2_IN (0–5 V or PWM above 5 kHz)
- Two general-purpose I/O, GPI/O1 and GPI/O2
- Position sensing: digital Hall, differential incremental, primary BiSS-C absolute, and Sin/Cos
- Two PT1000 temperature-sensor inputs, one for a user sensor and one isolated for a motor sensor, plus an internal NTC on the cooled base plate
- +5 V / 1 A (5 W) auxiliary output for external modules and sensors
- All external connections through sealed IP67 connectors

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3.3 APPLICATIONS

The combination of a high-voltage bus, a large continuous current and a sealed, liquid-cooled enclosure suits the drive to traction and to heavy industrial machinery:

- Industrial automation
- Robotics and traction units
- Drones
- Automotive
- Household appliances
- Medical devices
- Aerospace
- Textile machinery
- Automated guided vehicles (AGVs)
- Heating, ventilation and air-conditioning (HVAC)

3.4 FUNCTIONAL BLOCK DIAGRAM

Figure 2 shows the functional block diagram of the drive: the interfaces it presents to the machine, the three-phase inverter and the DC bus terminals, and the galvanic isolation barrier that separates the entire control and I/O side from the power stage.

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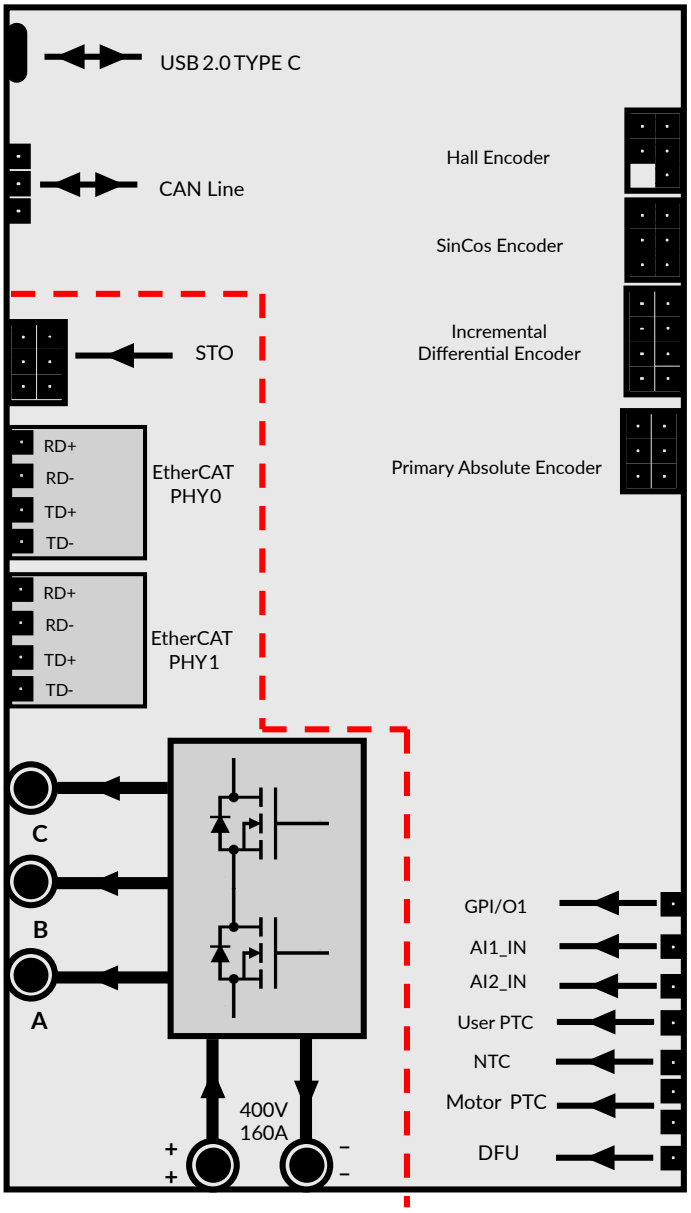

Figure 2. Functional block diagram of the SOLO PRO 400-160.

3.5 ARCHITECTURE

Figure 3 shows the internal architecture. The **SOLO SOM** control module sits at the centre and performs all digital control. Around it are the gate drivers and power MOSFETs, the phase current and voltage measurement chain, the 330 µF bus capacitance, the pre-charge circuit, the switched +5V_OUT_P encoder supply, the two EtherCAT PHYs with their magnetics, and the optically isolated STO front end.

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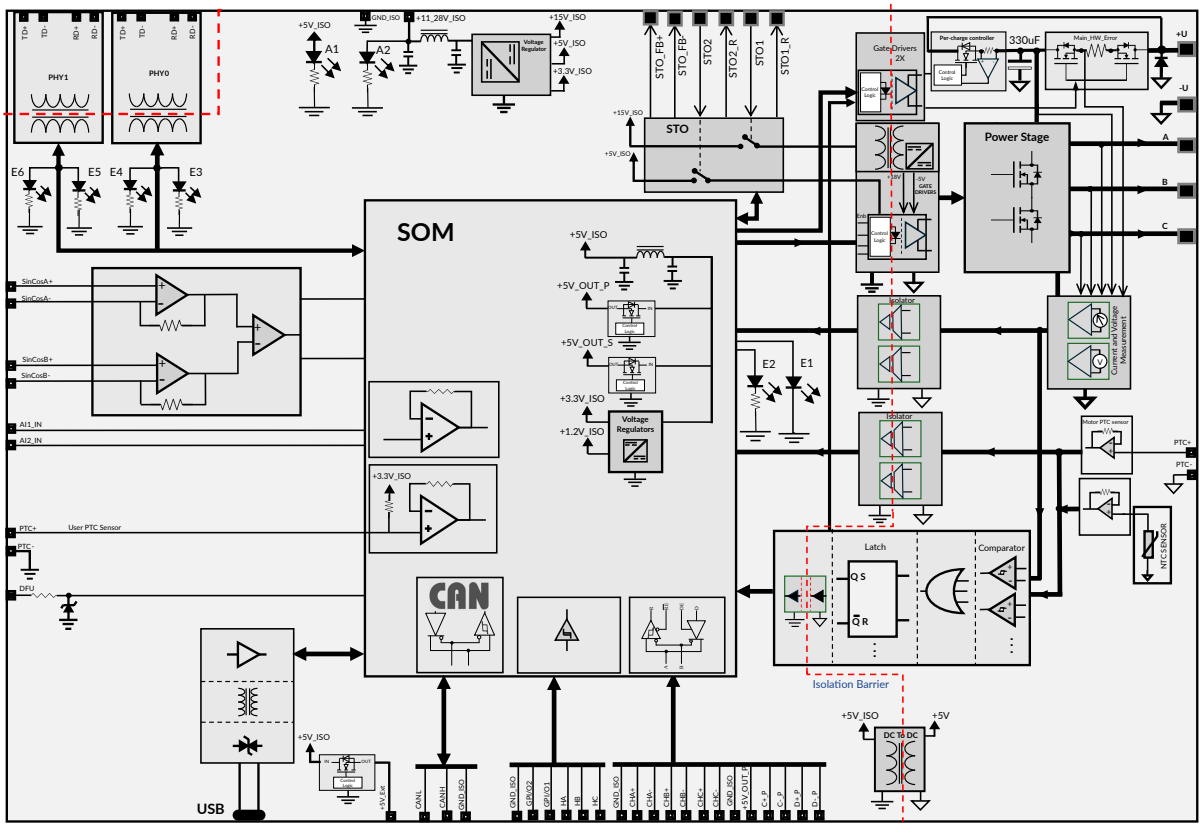

Figure 3. Architecture of the SOLO PRO 400-160.

Three features of the diagram bear directly on the wiring:

- **There are two isolation barriers, not one.** The main barrier separates the whole control and I/O side (the communication interfaces, the encoders, the analogue and general-purpose I/O, the temperature inputs and their regulators) from the 150–450 V power stage and its gate drivers. Everything the machine wires to the 48-pin I/O connector is therefore referenced to **GND_ISO**, the isolated ground, and never to the DC bus, provided the logic supply that feeds GND_ISO is itself isolated from the bus (Section 5.1). A second, optical barrier sits at the STO inputs themselves, so the safety command device is isolated even from the control side.
- **The logic side has its own supply, and it must be an isolated one.** The 11–28 VDC input feeds a regulator chain that produces +15 V_ISO, +5 V_ISO and +3.3 V_ISO for the control electronics. The drive draws no control power from the DC bus, which is why the logic supply must be present before the unit will communicate or respond at all, and why that supply has to be **galvanically isolated from the bus**. The barrier is drawn inside the drive, but it closes outside it: the isolated side has exactly the isolation its supply has, and no more.

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- **The protection chain is in hardware.** The comparator and latch block combines the over-current trips with the over- and under-voltage detectors into a single hardware fault line, `Main_HW_Error`, and takes it to the gate drivers, so the output is disabled without waiting for firmware.

3.6 CONTROL PRINCIPLE

This section describes the control function performed by the drive. The function is built in and requires no user programming, but an understanding of it supports sensor selection, tuning, and interpretation of the feedback signals.

The drive operates in closed loop with cascaded torque, speed and position control loops. Each loop encloses the next and executes at a faster rate, which allows torque, speed and position to be controlled independently and gives robust, smooth performance under variable load. For three-phase motors this cascade is implemented as Field Oriented Control (FOC), also termed vector control.

3.6.1 THREE-PHASE MOTORS AND FIELD ORIENTED CONTROL

A three-phase motor (BLDC or PMSM) produces torque through the interaction between the rotating stator field and the rotor magnets. Smooth, efficient torque requires that stator current be injected at the correct angle relative to the rotor; Field Oriented Control performs this function. It consists of three nested loops:

1. **Torque (current) loop.** The innermost and fastest loop, executing in step with the PWM switching and completing in 7 µs. Motor torque is proportional to winding current, so torque control is implemented as current control: the loop measures the phase currents, compares them with the demand, and adjusts the PWM duty cycles.
2. **Speed loop.** Enclosing the torque loop and executing every 500 µs, this loop compares measured shaft speed with the demand and sets the torque reference. When the load increases and the motor decelerates, the speed loop commands additional torque. Speed is therefore regulated through torque rather than directly, because a motor is fundamentally a torque-producing device and speed is the result of applied torque acting against the load.
3. **Position loop.** The outermost loop, also executing every 500 µs. It compares commanded shaft position with measured position and sets a speed reference that reduces the error. This loop requires the torque and speed loops beneath it to be tuned first.

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Figure 4 shows the complete structure, including the Park and inverse-Park transforms that convert between the three motor phases and the rotating d–q frame in which the two current controllers operate.

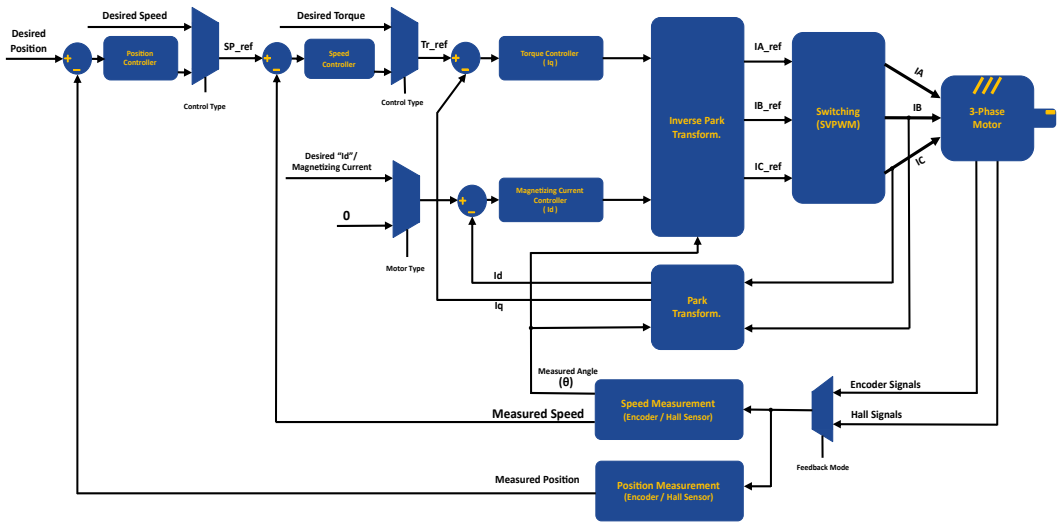

Figure 4. Field Oriented Control architecture of the SOLO PRO 400-160 for three-phase motors.

Closed-loop FOC requires four feedback quantities:

- **Phase current**, measured inside the drive. Used by the torque loop.
- **Speed**, derived from the position sensor. Used by the speed loop.
- **Position**, from an encoder. This enables servo operation.
- **Rotor electrical angle**, computed inside the drive. Closed-loop control is not possible without it, because the controller would not know the correct direction in which to inject current.

3.6.2 DC BRUSHED MOTORS

A DC brushed motor is electrically simpler: commutation occurs mechanically through the brushes, so no rotor-angle computation or three-phase management is required. The drive applies the same nested torque-speed-position structure with a single control channel rather than three, as shown in Figure 5. Only the **B** and **C** motor terminals are used. As with three-phase motors, adding an incremental encoder enables closed-loop position (servo) control, and the tuning procedure is identical apart from the internal processing.

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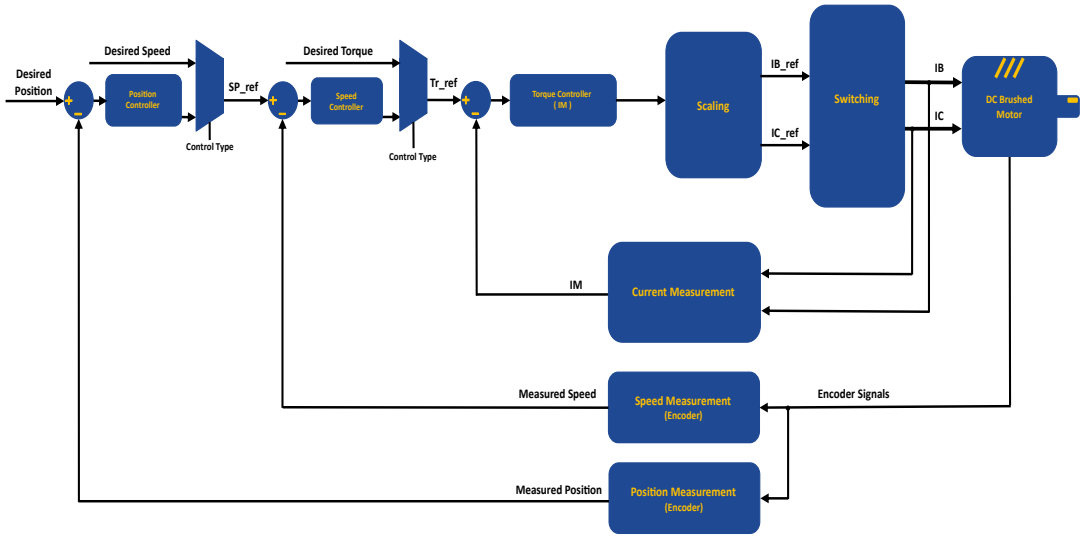

Figure 5. Cascade control architecture of the SOLO PRO 400-160 for DC brushed motors.

3.7 ORDERING INFORMATION

Field	Value
Product name	SOLO PRO 400-160
Part number	SLSG2_0126_400160
DC bus voltage range	150–450 VDC
Logic-side supply	11–28 VDC
Continuous output current	160 ADC / 100 Arms
Continuous output power	45 kW
Control module	SOLO SOM (TMS320F28388D)
Cooling	Liquid, through the integrated base plate
Ingress protection	IP67
Form factor	316 × 220.5 × 107 mm (W × D × H), four-point wall or frame mount

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4. DUAL-CORE ARCHITECTURE AND THE USER CORE

The digital control section of the drive is the **SOLO SOM**, which carries the Texas Instruments TMS320F28388D dual-core DSP: two independent CPUs, each with its own Control Law Accelerator, running in parallel. The two cores are assigned distinct roles.

Core	Function	Firmware
Motion Core	Motor control, position sensing, protections, EtherCAT, CANopen and USB	Programmed and maintained by SOLO; not user-modifiable
User Core	Reserved for a user application running inside the drive	Programmed by SOLO on request

For the applications this product is built for, only the Motion Core matters: it is configured through the SOLO Motion Terminal and commanded over the analogue inputs or the communication interfaces. The drive is complete and fully functional in that configuration.

Because the two run in parallel, the drive can hold a 140 kHz control loop while servicing an EtherCAT cycle, a CANopen exchange and the USB link, without any of them disturbing the motor control.

> ℹ **NOTE:** Unlike the panel-mounted drives in the SOLO PRO range, this unit is sealed to IP67 and brings out no JTAG connector, so the User Core cannot be programmed in the field. Contact SOLO if an application requires custom code running inside the drive.
>
> ℹ **NOTE:** The Motion Core firmware is supplied and supported by SOLO. It is not accessible to the user and cannot be modified. No access to it is required, since the user interacts with it through the SOLO Motion Terminal and the communication interfaces.

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5. TECHNICAL SPECIFICATIONS

The following tables specify the values required to design a system around the drive and to verify operation within the rated limits. Where additional explanation is warranted, it is given in the accompanying text.

5.1 POWER

Description	Units	Value
DC bus supply voltage range (continuous)	VDC	150 to 450
Logic-side supply voltage range	VDC	11 to 28
Logic-side supply isolation	—	Galvanically isolated from the DC bus — mandatory
Hardware over-voltage activation voltage (DC bus)	VDC	450
DC bus under-voltage limit	VDC	150
Maximum continuous output current	ADC	160
Maximum continuous output current	Arms	100
Maximum continuous output power	kW	45
Internal bus capacitance	µF	330
Switching frequency (output PWM frequency)	kHz	8 to 80
+5V_Ext. auxiliary output	—	+5 V, 1 A (5 W), 2 A e-fuse protected
+5V_OUT_P absolute-encoder supply	—	+5 V, 200 mA, switched

The drive needs **both** supplies. The DC bus feeds the inverter only. The 11–28 VDC logic supply powers the control electronics, the communication interfaces and the sensor supplies, on the isolated side of the barrier. A unit with bus voltage but no logic supply is dead, and a unit with logic supply but no bus voltage communicates normally but cannot produce torque.

The logic-side supply must be galvanically isolated from the DC bus. This is a requirement on the supply the integrator provides. It is not something the drive can enforce or detect. Use an isolated DC/DC converter, or a supply drawn from a source with no galvanic connection to

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the bus, and rate its barrier for the full bus voltage, 450 V continuous, with the creepage and clearance the installation demands. The 0 V of that supply becomes **GND_ISO** inside the drive, and it must float with respect to both DC+ and DC–.

Every statement in this manual that a signal is *referenced to GND_ISO* rests on this. The drive separates its whole control and I/O side from the power stage internally (Section 3.5), and that is what lets a PLC, an MCU board or a laptop be wired to the 48-pin connector while the inverter switches 450 V. The separation closes through the logic supply: bond the logic 0 V to the bus return anywhere in the installation and the barrier is bridged from outside, so every signal on J3, together with the USB port and whatever is connected to it, rises to bus potential. Nothing in the drive will report the fault, and nothing in the drive can protect against it.

> ⛔ **DANGER:** Never connect the 0 V of the logic-side supply to **DC–**, to **DC+**, or to any conductor galvanically connected to the bus. Doing so places up to 450 V on GND_ISO and on every I/O and USB connection, where an operator or a service engineer can reach it.
>
> ⚠ **WARNING:** A non-isolated step-down converter fed from the DC bus is **not** an acceptable source for the logic supply, however convenient it looks on a schematic. Use a supply with a genuine galvanic barrier rated for the bus voltage.
>
> ⚠ **CAUTION:** Design the installation so that the DC bus stays at or below the **+400 V Typical Max** of Section 5.6. The hardware over-voltage protection trips at 450 V, which is the limit of the rated range, not a working point. There is no margin above it.

The internal bus capacitance is 330 µF, charged through an internal pre-charge circuit at power-up. This gives the unit some capacity to absorb short regeneration transients, but it is small relative to the 45 kW rating: where the load returns energy for any length of time, as a descending vertical axis, a decelerating flywheel or a braking vehicle does, the returned energy must be taken by the supply, by a battery, or by a brake resistor and chopper external to this drive. There is no brake chopper inside the unit.

> ⚠ **WARNING:** Where the load can regenerate, provide an external means of absorbing the returned energy. Without one, regeneration raises the DC bus into over-voltage, the drive trips, and the bus can be driven beyond its rated limit by the energy still in the load.

The switching frequency is selectable from 8 kHz to 80 kHz. A higher frequency reduces current ripple and audible noise but increases switching losses in the power stage. Choose it from the motor's electrical time constant and from the thermal budget the coolant circuit can carry.

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5.2 CONTROL AND TIMING

Description	Units	Value
Analogue speed / torque command	VDC	0–5 V analogue, or a PWM input above 5 kHz
Digital direction control (GPI/O)	VDC	0–3.3 / 5
Modes of operation	—	Torque, speed, position
Motors supported	—	DC brushed, BLDC, PMSM, EC coreless
Protections	—	Bus over-voltage, bus under-voltage, bus over-current, motor-phase over-current, over-temperature
Current (torque) loop sampling time	µs	Synchronized to PWM frequency (7 µs minimum)
Current (torque) loop execution time	µs	7
Speed loop sampling time	µs	500
Speed loop execution time	µs	75
Position loop sampling time	µs	500
Position loop execution time	µs	75
Maximum encoder frequency (pre-quadrature)	MHz	2
Current measurement resolution	mA	To be confirmed
Modulation	—	Space Vector Modulation (SVM)
Motion profiling	—	Embedded S-curve for position and speed

The loop timing reflects the cascade of Section 3.6: the torque loop samples in step with the PWM and completes in 7 µs, giving an FOC loop rate up to approximately 140 kHz, while the speed and position loops run every 500 µs (2 kHz) and each execute in 75 µs.

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5.3 THERMAL & ENVIRONMENTAL

Description	Units	Value
Board temperature range	°C	-20 to +120
Base-plate temperature range	°C	-20 to +85
Cooling system	—	Liquid cooled, through the integrated base plate
Ingress protection	—	IP67
Base-plate over-temperature trip (internal NTC)	°C	85
Motor over-temperature trip (PT1000 on J13)	°C	120

The drive is cooled by liquid flowing through a serpentine channel cast into the base plate (Section 6.2). The two temperature ratings above are the limits at the board and at the base plate respectively, and they are not interchangeable: the board tolerates up to 120 °C, but the base plate must remain at or below 85 °C, and it is the base-plate temperature that governs how much continuous current the unit can deliver at a given coolant temperature and flow rate.

The internal NTC measures the base plate directly and trips the drive at 85 °C, so a coolant circuit that is undersized, blocked or not running will shut the unit down rather than damage it, but the trip is a protection, not a design margin.

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5.4 MECHANICAL

Description	Units	Value
Overall size (W × D × H)	mm	316 × 220.5 × 107
Body size, excluding the mounting tabs (W × D)	mm	262 × 217
Mounting holes	—	4 × Ø6.5 mm through holes, one in each corner tab
Mounting hole pattern	mm	289 × 120
Mounting hole height above the base plane	mm	24
Weight (with base plate)	g	To be confirmed
Form factor	—	Four-point wall or frame mount

5.5 HARDWARE PROTECTIONS

Every protection listed here acts in hardware, through the comparator and latch chain of Figure 3, and disables the inverter without waiting for firmware.

Protection	Description	Value
Phases_OCP	Motor-phase over-current protection	250 A
Bus_OCP	DC bus over-current protection	125 A
OVP	DC bus over-voltage protection	450 V
UVP	DC bus under-voltage protection	150 V
PT1000_OTP	Over-temperature protection, motor PT1000 sensor (J13)	120 °C
NTC_OTP	Over-temperature protection, internal base-plate NTC	85 °C

The two current trips watch different currents. **Phases_OCP** at 250 A is the instantaneous limit in a motor phase and protects the inverter against a short circuit or a stalled rotor. **Bus_OCP** at 125 A is the limit on the current drawn from the DC bus. Because the bus current and the motor current differ with modulation depth, the two are not directly comparable, and the bus trip is the one that sets the useful continuous power at a given bus voltage.

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5.6 ABSOLUTE MAXIMUM VOLTAGE RATINGS

This table specifies, for each section and pin group, the maximum voltage that may be applied. The section numbers are those of the face figures in Section 7, Figures 12 and 14.

Two columns require careful interpretation. **Typical Max** is the maximum continuous voltage permitted at the pin in normal operation. Design to this value. **Absolute Max** is a short-transient limit that bounds voltage spikes and switching noise lasting microseconds. It is not a level to be applied intentionally. Designing to the Absolute Max value will result in eventual damage to the drive.

> ⚠ **WARNING:** Design the installation against the **Typical Max** column. The **Absolute Max** column bounds brief transients only. Continuously exceeding Typical Max will permanently damage the unit.

Section	Pin / Signal	Dir	Units	Min	Typical Max	Absolute Max
[2]	+11_28V_ISO (logic-side supply)	Input	VDC	+11	+28	+30
[3]	DC+ / DC- (DC bus input)	Input	VDC	+155	+400	+445
[2]	SinCOS A±, SinCOS B±	Input	VDC	0	+4.5	+5
[2], [4]	PTC+ / PTC- (PT1000 and NTC sensing)	Input	VDC	0	+3.3	+3.75
[2]	DFU	Input	VDC	0	+5	+5.25
[2]	AI1_IN, AI2_IN	Input	VDC	0	+5	+5.25
[2]	STO1, STO2 (Safe Torque Off inputs)	Input	VDC	0	+5	+5.25
[2]	+5V_Ext. (auxiliary supply)	Output	VDC	+4.95	+5.0	+5.05
[2]	HA, HB, HC	Input	VDC	0	+5	+5.5
[2]	C+_P, C-_P, D+_P, D-_P (primary BiSS-C)	Input	VDC	0	+12	+12.25
[2]	CHA±, CHB±, CHC± (differential incremental)	Input	VDC	0	+12	+12.25
[2]	CANH, CANL	—	VDC	-2	—	+7
[2]	GPI/O1, GPI/O2	In/Out	VDC	0	+5	+5.5

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Read the DC bus row carefully. Its **Typical Max of +400 V** is the design target, below the 450 V top of the rated range in Section 5.1 and below the hardware over-voltage trip. Size the supply, and the regeneration path, so that the bus operates at or under 400 V.

The **+11_28V_ISO** row is measured against GND_ISO, the input's own return, and so says nothing about the potential between that pair and the bus. That pair must float relative to the bus, behind isolation rated for the full bus voltage (Section 5.1). The same applies to every other row in this table: each limit is referred to GND_ISO, and all of them are meaningless if GND_ISO is not clear of the bus.

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6. MECHANICAL INTEGRATION AND COOLING

6.1 DIMENSIONS AND MOUNTING

The SOLO PRO 400-160 measures 316 × 220.5 × 107 mm (W × D × H) overall. The fully dimensioned drawing is given in Figure 6. All dimensions are in millimetres. Use it to lay out the mounting points, the cable entries, the coolant pipework and the keep-out zones in the machine.

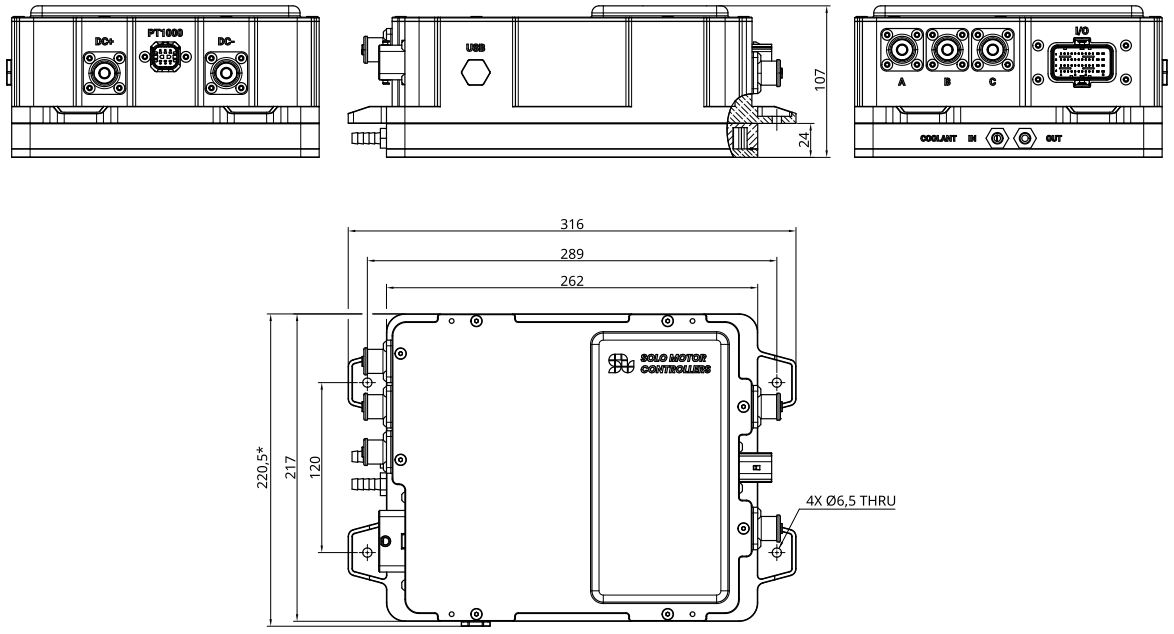

Figure 6. SOLO PRO 400-160 assembly drawing — all dimensions in millimetres.

Figure 7 shows the same assembly as an isometric view, with the front connector face and the coolant ports towards the viewer.

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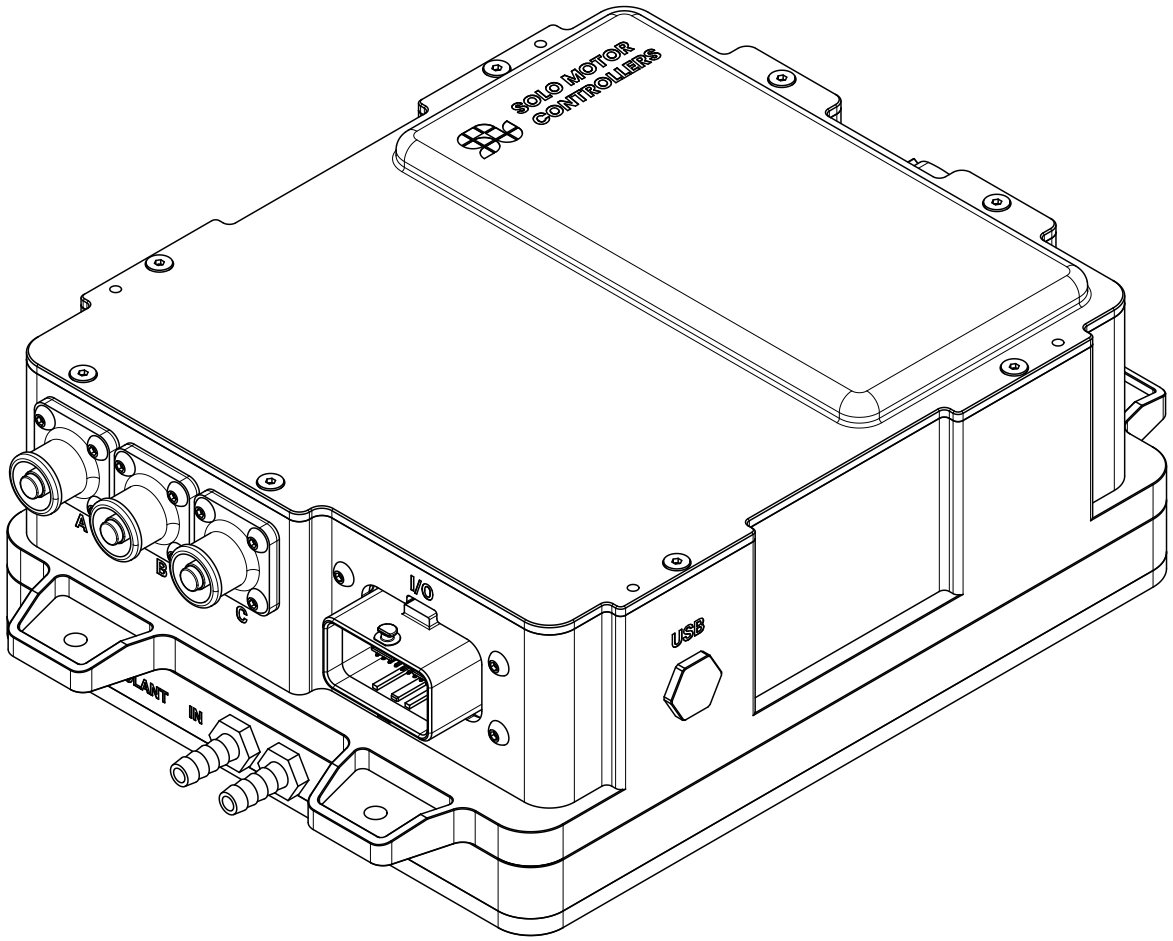

Figure 7. Isometric view of the enclosure, showing the front face — motor outputs A, B and C, the I/O connector, and the coolant inlet and outlet — with the sealed USB port on the right face.

The unit is mounted through **four Ø6.5 mm through holes**, one in each of the four cast corner tabs, on a **289 × 120 mm** pattern. Figure 8 is the plan view that gives the footprint and the position of those tabs, and Figure 9 shows the same view of the manufactured unit.

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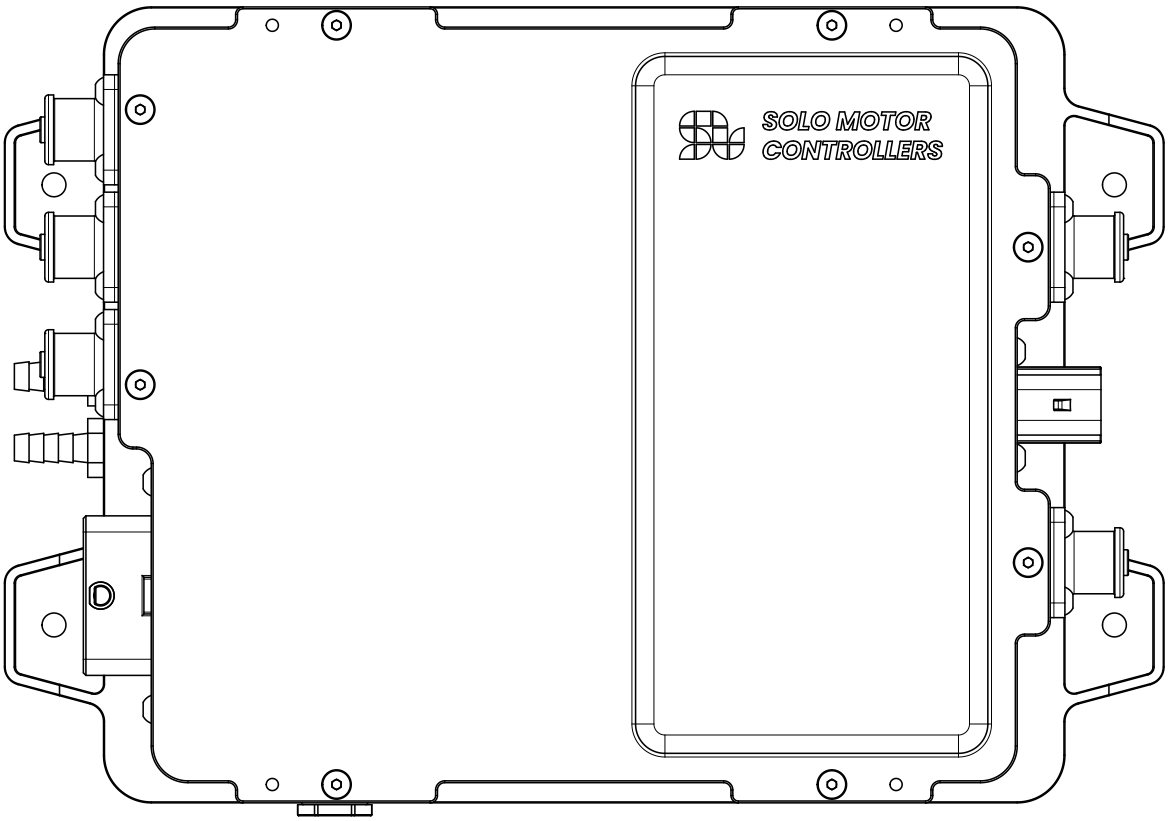

Figure 8. Plan view of the enclosure, showing the footprint and the four corner mounting tabs.

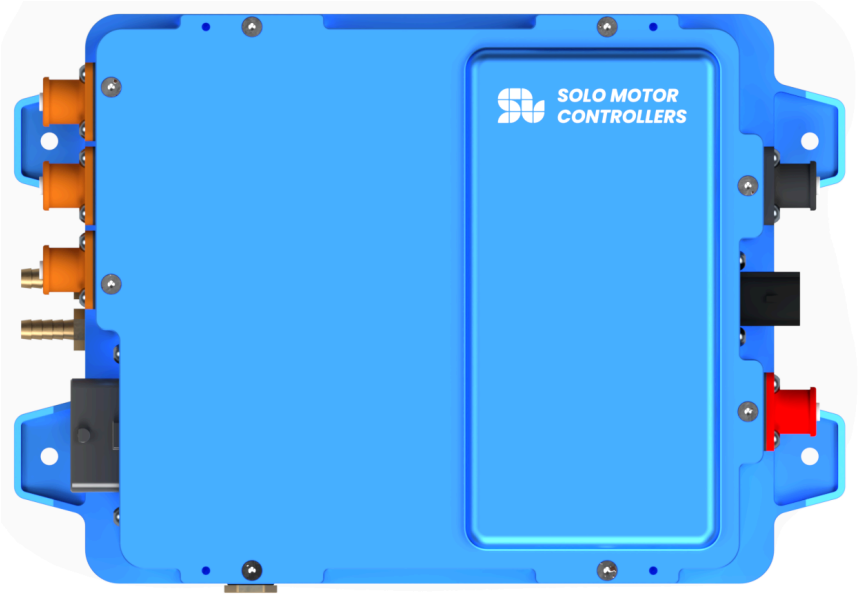

Figure 9. Plan view of the manufactured unit. The motor outputs and coolant fittings are on the left, the DC bus terminals and the motor PT1000 connector on the right.

When laying out the installation:

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- **Mount on a flat surface, through all four tabs.** The hole centres stand 24 mm above the base plane of the unit, so the mounting surface must clear the base plate itself. Use all four fixings. A three-point mount will load the cast tabs unevenly.
- **Allow clearance at both connector faces.** The front face and the back face each carry high-current terminals whose mating connectors need room for the cable and its bend radius. The right face carries the USB port.
- **Do not obstruct the coolant fittings.** They project from the front face, below the connector plane, and need room for the hose and its clamp.
- **Bond the enclosure to the machine ground** through the mounting hardware, and keep that path short. It is the reference for the EMI filtering and for the cable shields.

6.2 LIQUID COOLING

The drive is cooled by liquid, not by air. Coolant enters and leaves through two barbed fittings on the front face, marked **COOLANT IN** and **COOLANT OUT**, section [6] in Figure 10, and passes through a serpentine channel that runs the full area of the base plate directly beneath the power stage. Figure 11 shows that channel on the underside of the unit.

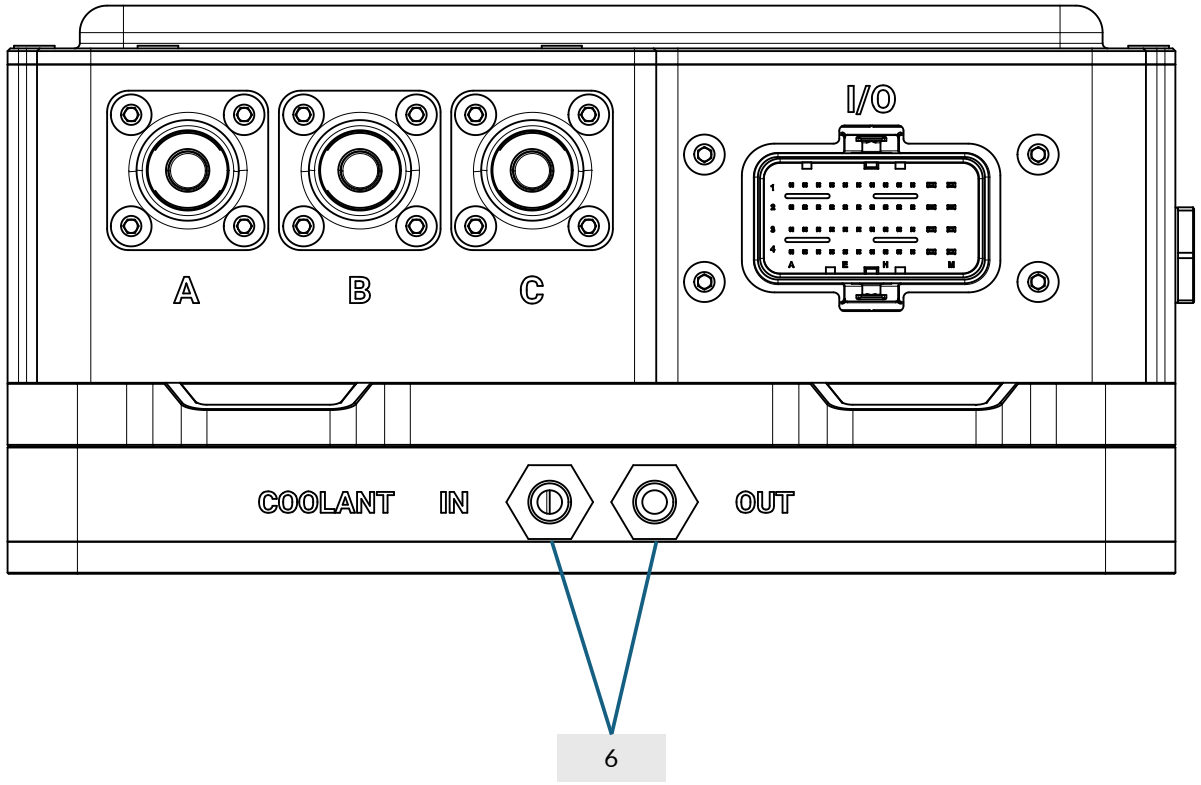

Figure 10. Section [6] — the coolant inlet and outlet on the front face, below the connector plane.

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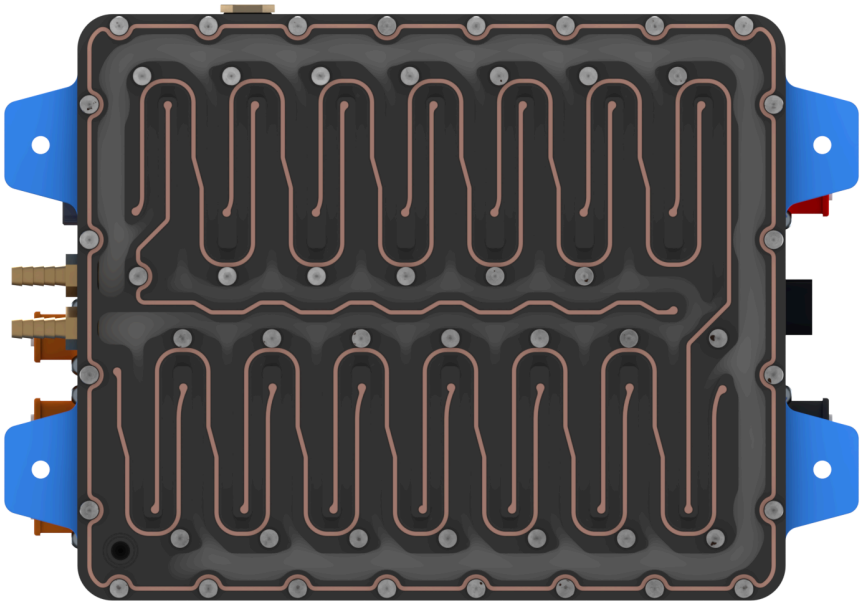

Figure 11. The cooled base plate seen from beneath: the coolant follows a serpentine path across the full area under the power stage, entering and leaving at the fittings on the left.

Observe the flow direction marked on the casting: **IN** is the inlet. Reversing it does not damage the unit, but it puts the coolest liquid at the wrong end of the channel and reduces the heat the plate can carry.

> ⚠ **CAUTION:** Never run the drive without coolant flow. The enclosure is sealed, so there is no convection path; at any appreciable load the base plate reaches its 85 °C trip within seconds and, above the trip, the power stage is at risk.
>
> ℹ **NOTE:** Connect the hoses before filling and bleed the circuit of air. An air pocket over the power stage behaves exactly like a blocked channel.

6.3 THERMAL CONSIDERATIONS

The continuous current the drive can deliver in a given installation is limited by the base-plate temperature, not by the board rating. Keep the plate at or below 85 °C at the intended duty cycle, which in practice means choosing the coolant temperature and the flow rate together:

- **Coolant inlet temperature** sets the floor. Every degree at the inlet is a degree less headroom at the plate.
- **Flow rate** sets the rise across the plate. Too low a flow and the coolant leaves much hotter than it entered, so the far end of the channel, and the power stage above it, runs hot.

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- **Switching frequency** sets the load on the circuit. Losses in the power stage rise with switching frequency, so a design running at 80 kHz needs appreciably more cooling than the same design at 8 kHz.

Size the circuit for the worst-case continuous dissipation of the application, not for its average, and verify the base-plate temperature over a full duty cycle during commissioning. The drive reports it over any of the communication interfaces.

> ⚠ **CAUTION:** The base plate and the coolant reach temperatures that can cause burns. Allow the unit and the circuit to cool before handling or opening them after operation.

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7. CONNECTORS, SECTIONS & PINOUT

7.1 CONNECTOR ORGANIZATION

This chapter is the primary reference for wiring the drive. The unit is described as **six numbered sections** distributed over three faces. Each section is a connector, a terminal pair or the coolant interface. Figure 1 shows the unit as a whole. The sections are then numbered on the individual face figures that open Sections 7.2 to 7.4, and each multi-pin connector is given its own pinout.

Section	Designator	Face	Content
[1]	J4, J5, J6	Front	Motor outputs A, B, C
[2]	J3	Front	I/O connector — EtherCAT, CAN, analogue, encoders, STO, DFU, logic supply — 48-pin
[3]	—	Back	DC bus input, DC+ and DC-
[4]	J13	Back	Motor PT1000 temperature sensor — 2-pin
[5]	—	Right	USB 2.0 Type-C, behind a sealed cap
[6]	—	Front	Coolant inlet and outlet (Section 6.2)

In the pin tables that follow, the **Dir** column is given from the point of view of the drive: **I** is an input to the drive, **O** an output from it.

Every signal on the I/O connector is referenced to **GND_ISO**, the isolated ground of the control side, and none of them is referenced to the DC bus. That is what lets a PLC, an MCU board or a laptop be wired directly to the drive while the power stage runs at 450 V, and it holds only while the logic-side supply that feeds GND_ISO is itself galvanically isolated from the bus (Section 5.1). Establish that before wiring anything to this connector.

7.2 FRONT FACE — SECTIONS [1] AND [2]

The front face carries the power output and the signal connector: the three motor terminals at one end, the 48-pin I/O connector at the other, and the coolant fittings in the plinth below them. Figure 12 numbers its two connector sections and Figure 13 gives the same face as a scale layout drawing.

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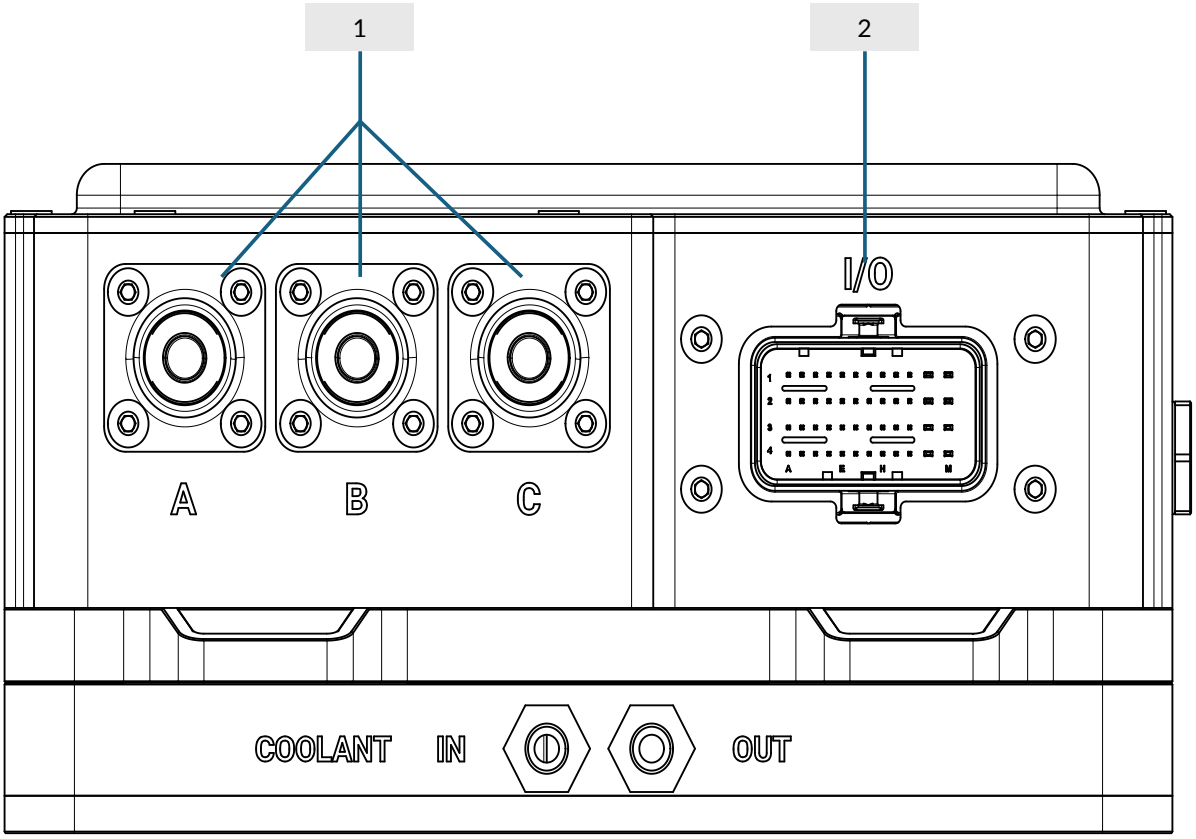

Figure 12. Front face — section [1], the motor outputs A, B and C, and section [2], the I/O connector.

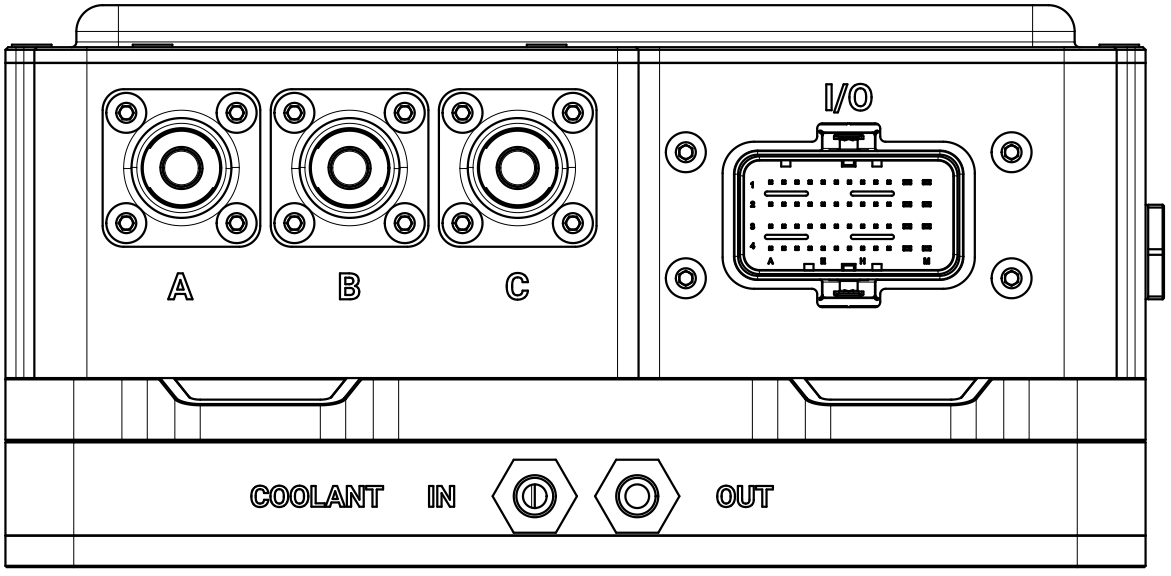

Figure 13. Front face layout drawing, showing the three motor terminals, the I/O connector and the coolant inlet and outlet.

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Keeping the motor terminals and the signal connector on the same face but at opposite ends of it is deliberate: it lets the motor cable and the control cable leave the machine in the same direction while staying physically separated, as Section 13.6 asks.

7.3 BACK FACE — SECTIONS [3] AND [4]

The back face carries the DC bus input and the motor temperature-sensor connector. Figure 14 numbers its two sections, and Figure 15 shows the same face on the manufactured unit.

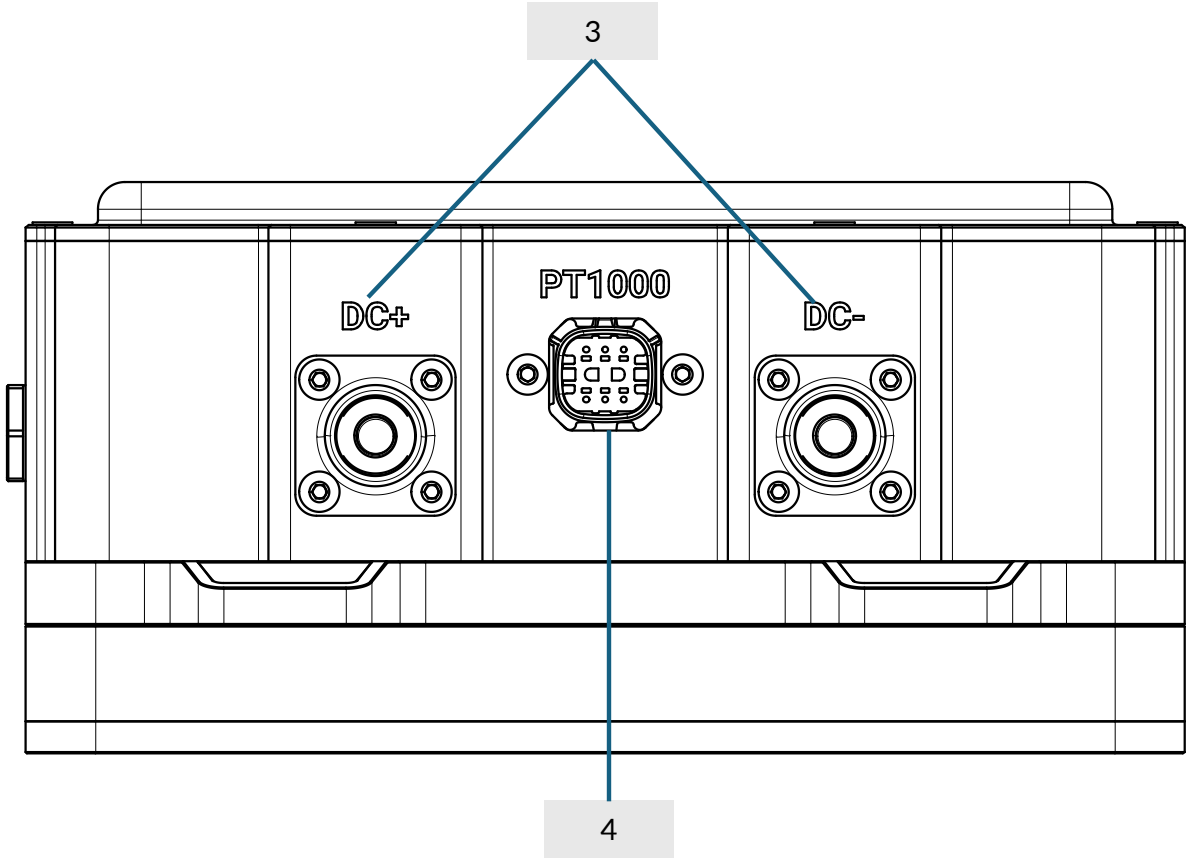

Figure 14. Back face — section [3], the DC+ and DC- bus terminals, and section [4], connector J13 for the motor PT1000.

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Figure 15. The manufactured unit seen from the back face: DC+ (red), the PT1000 connector (black, centre) and DC- (black).

Putting the bus terminals on the opposite face from the motor terminals keeps the incoming and the outgoing high-current wiring apart over the whole length of the unit.

7.4 RIGHT FACE — SECTION [5]

The right face carries only the USB port, section [5], closed by a sealed cap that preserves the IP67 rating when the port is not in use. Figure 16 identifies it.

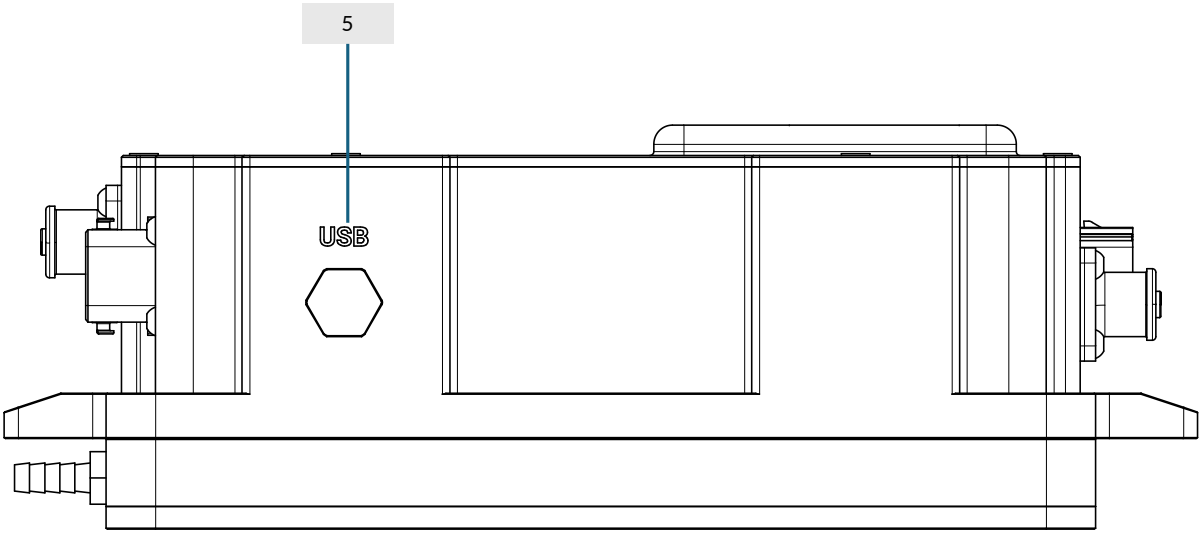

Figure 16. Right face — section [5], the USB 2.0 Type-C port behind its sealed cap.

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> ⚠ **CAUTION:** Refit and tighten the cap after using the USB port. With the cap removed the enclosure is no longer sealed and the IP67 rating does not apply.

7.5 SECTION [1] J4, J5, J6 — MOTOR OUTPUTS

The three motor terminals are separate sealed connectors, marked **A**, **B** and **C** on the casting, shown in Figure 17.

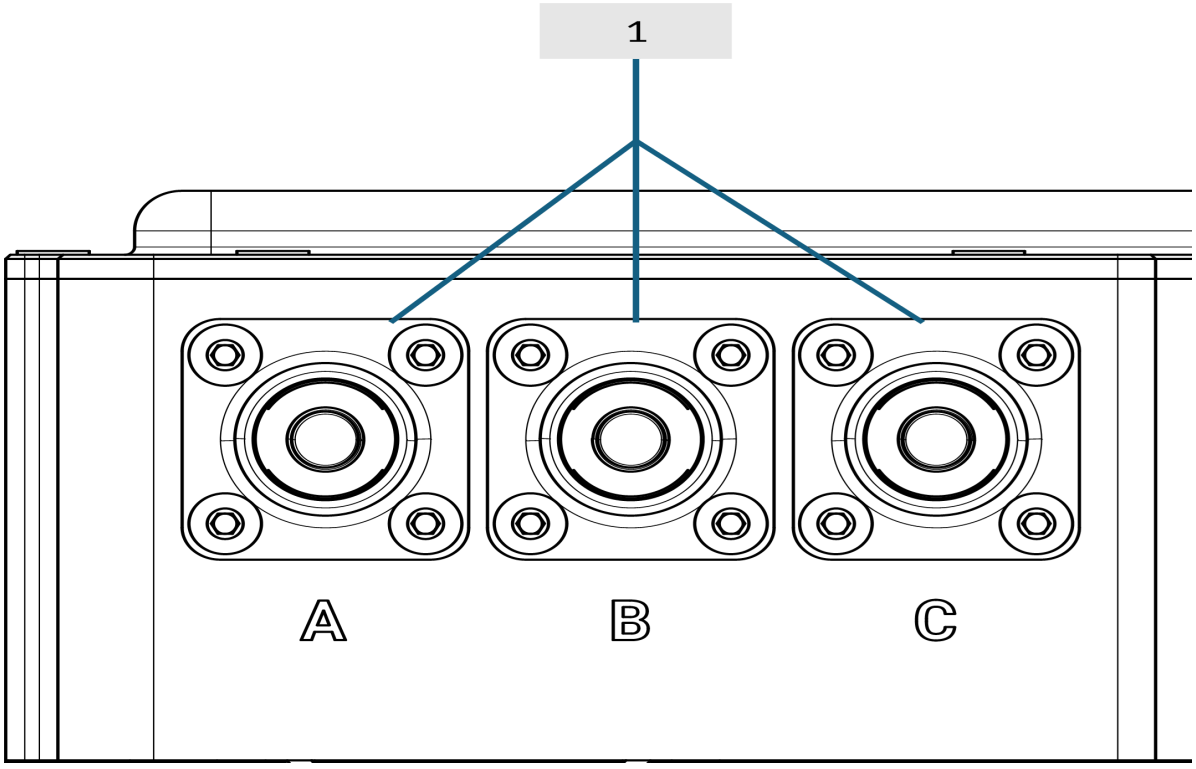

Figure 17. Section [1], connectors J4, J5 and J6 — the motor output terminals A, B and C.

Terminal	Name	Description / Notes	Dir
J4	A	Motor output 1 — phase A	O
J5	B	Motor output 2 — phase B	O
J6	C	Motor output 3 — phase C	O

For a three-phase motor, whether BLDC, PMSM or EC coreless, connect the three motor leads to A, B and C. For a DC brushed motor connect the two motor leads to **B** and **C** only, and leave A unused.

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The phase over-current protection acts at **250 A** instantaneous, which protects the inverter against a phase-to-phase short or a stalled rotor.

> ⛔ **DANGER:** Never connect a power supply to the motor outputs. These terminals carry the switched bus voltage and are driven from the inverter; applying an external supply to them will destroy the unit and may cause an arc flash.
>
> ⚠ **CAUTION:** Size the motor cable for 160 A continuous and terminate it properly at the drive. A loose or undersized motor connection at this current heats, and the heat is inside a sealed enclosure.

7.6 SECTION [2] J3 — I/O CONNECTOR

This single 48-pin sealed connector carries everything the machine needs apart from the motor, the bus and the coolant: the logic-side supply, both EtherCAT ports, the CAN bus, the analogue inputs, the general-purpose I/O, every position-sensor interface, the user PT1000 input, the STO inputs with their feedback, and the DFU forced-boot input. Figure 18 gives the pin numbering as seen on the connector: four rows numbered **1** to **4**, each with twelve positions lettered **A** to **J**, then **N** and **M**.

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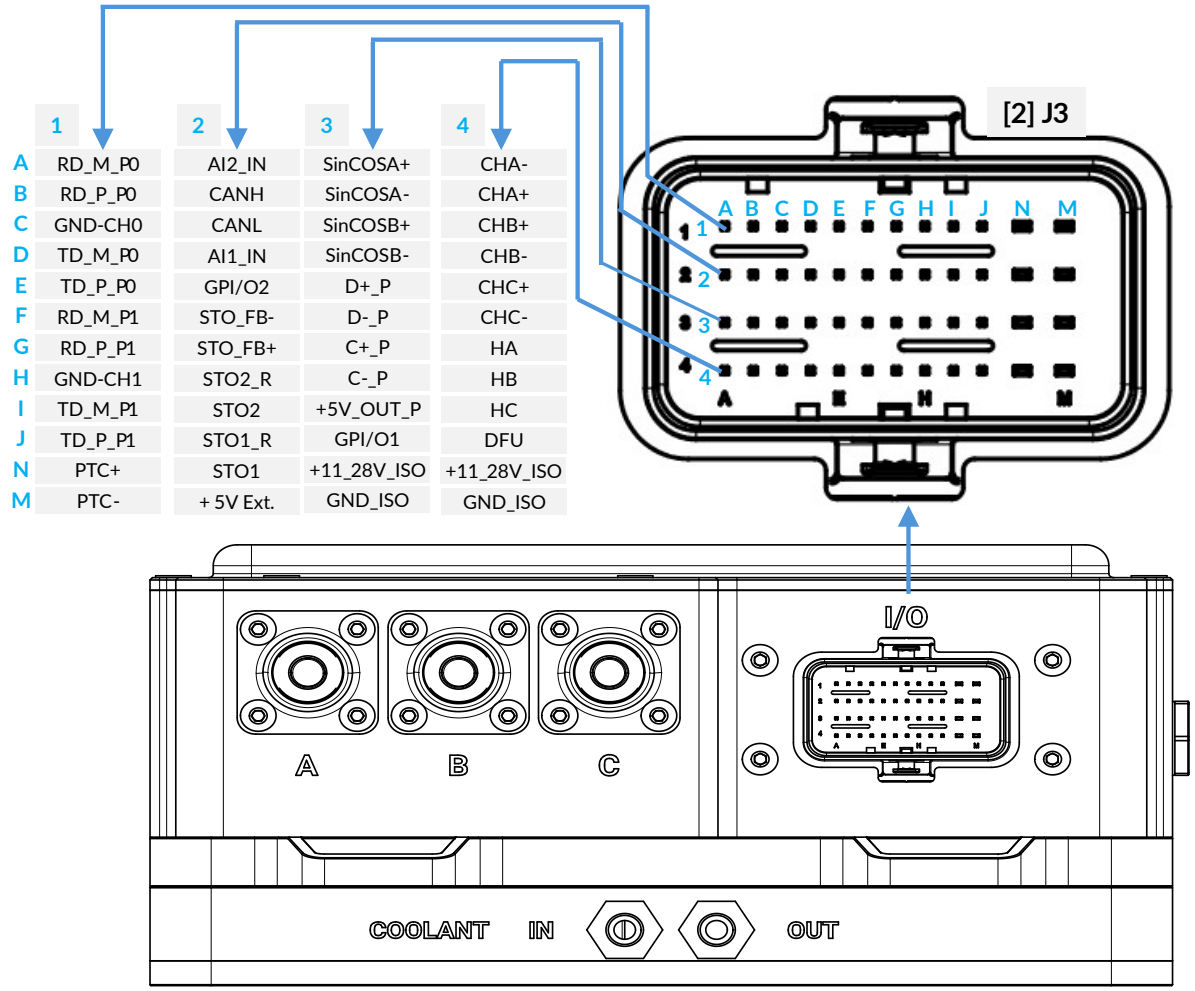

Figure 18. Section [2], connector J3 — the 48-pin I/O connector, with the pin map for rows 1 to 4.

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Pin	Name	Description / Notes	Dir
1A	RD_M_P0	EtherCAT receive data –, PHY0	I
1B	RD_P_P0	EtherCAT receive data +, PHY0	I
1C	GND-CH0	EtherCAT ground, channel 0	—
1D	TD_M_P0	EtherCAT transmit data –, PHY0	O
1E	TD_P_P0	EtherCAT transmit data +, PHY0	O
1F	RD_M_P1	EtherCAT receive data –, PHY1	I
1G	RD_P_P1	EtherCAT receive data +, PHY1	I
1H	GND-CH1	EtherCAT ground, channel 1	—
1I	TD_M_P1	EtherCAT transmit data –, PHY1	O
1J	TD_P_P1	EtherCAT transmit data +, PHY1	O
1N	PTC+	PT1000 sensor + (user sensor)	I
1M	PTC–	PT1000 sensor – — internally connected to GND_ISO	—
2A	AI2_IN	Analogue input 2 (0–5 V or PWM)	I
2B	CANH	CAN bus high	I/O
2C	CANL	CAN bus low	I/O
2D	AI1_IN	Analogue input 1 (0–5 V or PWM)	I
2E	GPI/O2	General-purpose I/O 2	I/O
2F	STO_FB–	STO feedback –	O
2G	STO_FB+	STO feedback +	O
2H	STO2_R	STO channel 2 negative input (optically isolated)	I
2I	STO2	STO channel 2 positive input (optically isolated)	I
2J	STO1_R	STO channel 1 negative input (optically isolated)	I
2N	STO1	STO channel 1 positive input (optically isolated)	I
2M	+5V Ext.	+5 V output, 1 A (2 A e-fuse)	O
3A	SinCOS A+	Sin/Cos encoder, Sin+	I
3B	SinCOS A–	Sin/Cos encoder, Sin–	I
3C	SinCOS B+	Sin/Cos encoder, Cos+	I

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Pin	Name	Description / Notes	Dir
3D	SinCOS B-	Sin/Cos encoder, Cos-	I
3E	D+_P	Primary BiSS-C data +	I/O
3F	D-_P	Primary BiSS-C data -	I/O
3G	C+_P	Primary BiSS-C clock +	O
3H	C-_P	Primary BiSS-C clock -	O
3I	+5V_OUT_P	Switched +5 V / 200 mA for the primary absolute encoder	O
3J	GPI/O1	General-purpose I/O 1	I/O
3N	+11_28V_ISO	Logic-side power supply input	I
3M	GND_ISO	Isolated ground	—
4A	CHA-	Differential incremental encoder, channel A -	I
4B	CHA+	Differential incremental encoder, channel A +	I
4C	CHB+	Differential incremental encoder, channel B +	I
4D	CHB-	Differential incremental encoder, channel B -	I
4E	CHC+	Differential incremental encoder, index C +	I
4F	CHC-	Differential incremental encoder, index C -	I
4G	HA	Hall sensor A	I
4H	HB	Hall sensor B	I
4I	HC	Hall sensor C	I
4J	DFU	Forced-boot input — hold at +5 V to force the bootloader	I
4N	+11_28V_ISO	Logic-side power supply input	I
4M	GND_ISO	Isolated ground	—

Four groups of pins on this connector need a word of explanation:

- **The logic supply.** +11_28V_ISO appears on **3N and 4N**, and GND_ISO on **3M and 4M**, two contacts each, so the supply current is shared across two crimps. Connect both. This supply must be present for the drive to run, it must be fused externally (Section 14.1), and it must be **galvanically isolated from the DC bus** (Section 5.1). GND_ISO on 3M and 4M is the reference for every other signal on this connector: whatever potential is put on it is put on all of them.

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- **The two +5 V outputs are different. +5V Ext.** (2M) is the general auxiliary rail, 5 V at 1 A behind a 2 A e-fuse, for Hall sensors, incremental encoders, a potentiometer or a small external board. **+5V_OUT_P** (3I) is a switched 200 mA output dedicated to the primary absolute encoder; because it is switched, the firmware can power-cycle that encoder to recover it from a fault. Do not load either with anything else.
- **The EtherCAT pairs are transmission lines,** not general signals. Section 8.1 gives the routing, isolation and impedance requirements; ignoring them corrupts the data.
- **The STO pins are the safety function.** STO1 (2N), STO1_R (2J), STO2 (2I) and STO2_R (2H) are the two isolated channels, and STO_FB+ / STO_FB- (2G, 2F) report the state of the function back to the machine controller. Section 11 covers them in full.

> ⚠ **CAUTION:** The pins on this connector do not share one voltage rating. The analogue, Hall, GPI/O, DFU and STO pins are rated to +5 V. The BiSS-C and differential encoder pins to +12 V. The PT1000 pins to +3.3 V only. Check Section 5.6 before connecting any of them.
>
> ⛔ **DANGER:** GND_ISO (pins 3M and 4M) must float with respect to the DC bus. If the logic supply's 0 V is bonded to DC- anywhere in the installation, every pin in the table above is at bus potential, including the ones a commissioning engineer probes with a meter.

7.7 SECTION [3] — DC BUS INPUT

The DC bus enters through the two sealed high-current terminals marked **DC+** and **DC–** on the back face, shown to scale in Figure 19.

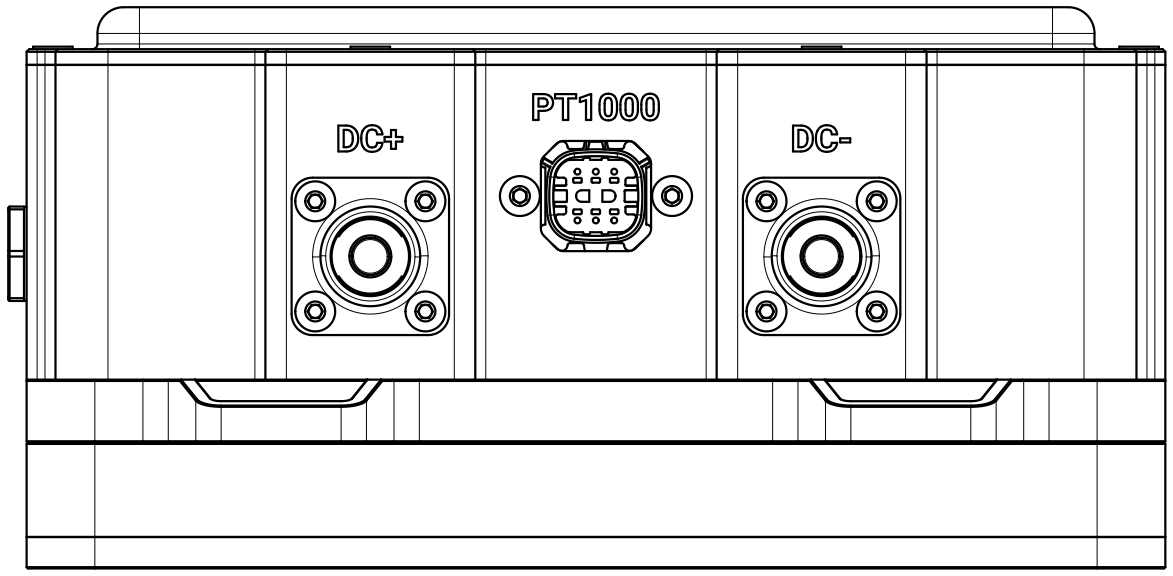

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Figure 19. Back face layout drawing — the DC+ and DC- bus terminals with the PT1000 connector between them.

Terminal	Name	Description / Notes	Dir
DC+	DC+	Positive DC bus input	I
DC–	DC–	Negative DC bus input (bus return)	I

The drive accepts any DC bus voltage from **150 to 450 V** continuously, chosen to suit the motor connected at the output. The relevant trips are **OVP at 450 V**, **UVP at 150 V** and **Bus_OCP at 125 A**. Section 5.5 lists them together. A bus that rises above the over-voltage threshold puts the drive into protection and disables the output.

⛔ **DANGER:** These terminals sit at bus potential, up to 450 V, and the 330 µF of bus capacitance holds that charge after the supply is removed. Isolate the supply and verify with a meter that the bus has discharged before working on the terminals.

⚠ **WARNING:** The drive has **no reverse-polarity protection**. Confirm the polarity at DC+ and DC– before switching the bus on. A reversed supply can destroy the unit.

⛔ **DANGER:** The **DC–** terminal is the return of the power stage, not a signal ground. **GND_ISO** on the I/O connector is a separate, isolated node and must never be bonded to DC–: not at the drive, not at the supply, and not anywhere else in the machine. The logic-side supply must be galvanically isolated from the bus for that separation to exist at all (Section 5.1). Bond the two and the full bus voltage appears on every I/O and USB connection.

7.8 SECTION [4] J13 — MOTOR PT1000 CONNECTOR

A second, fully isolated PT1000 input is brought out on its own 2-pin sealed connector, J13, between the two bus terminals on the back face. It is intended for a sensor embedded in the motor windings, which is why it is isolated: the motor end of that sensor sits in a winding at bus potential. Figure 20 gives its pinout.

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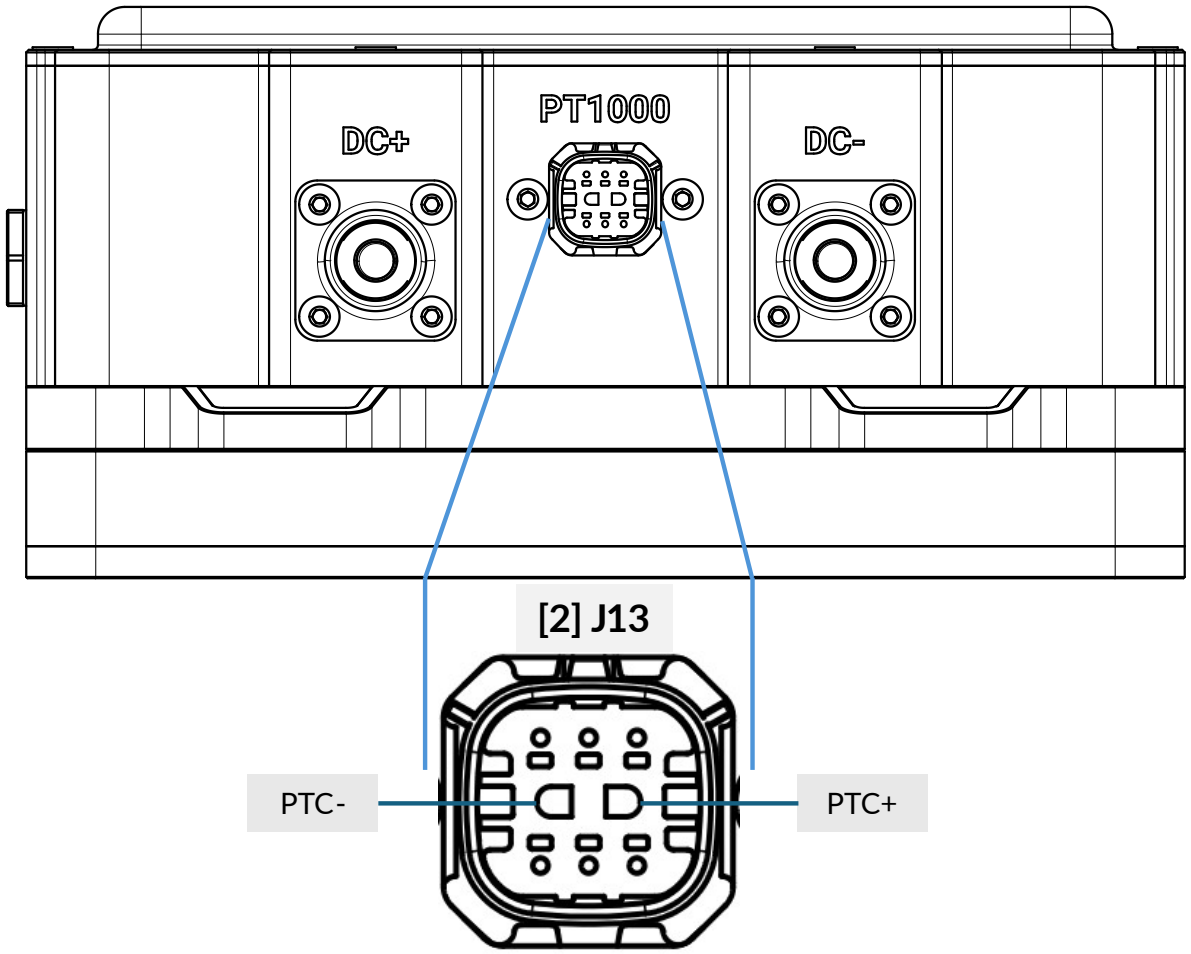

Figure 20. Section [4], connector J13 — the isolated motor PT1000 input, PTC+ and PTC–.

Pin	Name	Description / Notes	Dir
1	PTC+	PT1000 sensor + (motor sensor)	I
2	PTC–	PT1000 sensor –	I

The over-temperature protection on this input trips at **120 °C**: the drive goes into protection as soon as the sensed temperature rises above that, in hardware, whatever the firmware or the machine controller is doing. Section 9.5.2 covers the wiring and the conversion from the reported voltage to a temperature.

> ⚠ **WARNING: Never leave this input open or unconnected.** The sensor forms the lower leg of a divider from +3.3 V_ISO, so an open input reads as the highest possible temperature and the drive sits permanently in over-temperature protection. A PT1000 must always be present across pins 1 and 2. Section 9.5.2 covers what to fit when the motor has no embedded sensor.

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> ⚠ **CAUTION:** The PT1000 input is limited to +3.3 V continuous, with a +3.75 V absolute maximum. It is **not** 5 V tolerant. Exceeding the rating will permanently damage the drive.

7.9 SECTION [5] — USB 2.0 TYPE-C

The USB port sits in the centre of the right face, under a threaded sealing cap. Figure 21 gives that face as a scale layout drawing.

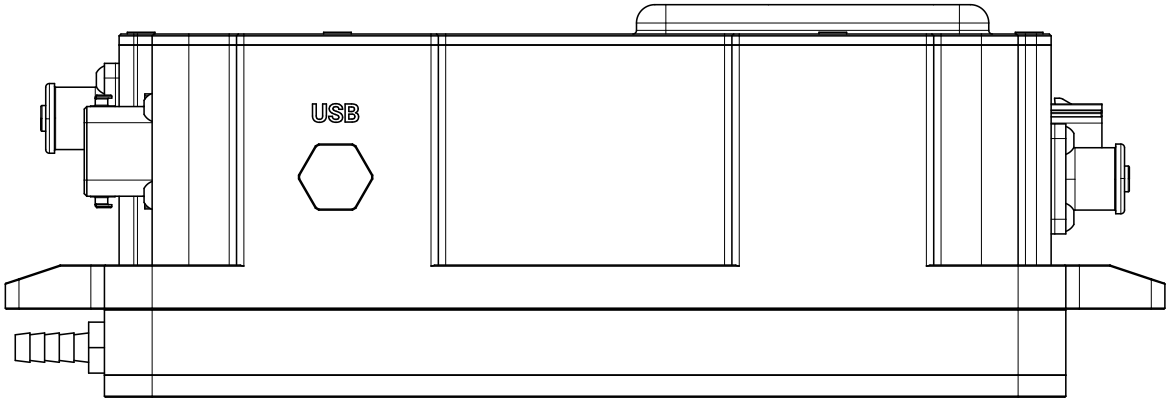

Figure 21. Right face layout drawing — the sealed USB port, with the coolant fittings visible at the left of the plinth.

Port	Name	Description / Notes	Dir
—	USB	USB 2.0 Type-C — virtual COM port and firmware update	I/O

In digital mode the port enumerates as a Virtual COM Port, giving a host PC full access to every function of the drive over a single cable. It is also the interface the SOLO Motion Terminal uses, and the path for a firmware update (Section 12). Section 8.3 covers it in detail.

> ⚠ **CAUTION:** The USB cable does not power the drive. The 11–28 VDC logic supply must be connected for the unit to enumerate.

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7.10 MATING CONNECTOR PART NUMBERS

Section	Connector	Manufacturer	Mating part number	Mating terminals
[1]	J4, J5, J6 — motor outputs	—	To be confirmed	To be confirmed
[2]	J3 — I/O connector	Molex	5007621001	643201311
[3]	DC+ / DC- — bus terminals	—	To be confirmed	To be confirmed
[4]	J13 — motor PT1000	—	To be confirmed	To be confirmed

i NOTE: Use the specified mating parts and their sealing grommets, and crimp the terminals with the manufacturer's tool. The IP67 rating of the installation depends on the mating connector and its seal, not on the drive alone.

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8. NETWORKING & COMMUNICATIONS

The drive can be commanded over three digital interfaces, all built in: two EtherCAT PHYs, a CAN transceiver and a USB 2.0 Type-C port. EtherCAT and CAN are brought out on the 48-pin I/O connector, section [2]; USB has its own sealed port on the right face, section [5].

8.1 ETHERCAT

EtherCAT is a high-speed industrial bus used to connect a controller, usually a PLC or an industrial PC acting as the master, to a series of drives. Its principal characteristic is deterministic timing: every node is updated within the same cycle, which keeps multiple axes synchronized.

The drive carries two **DP83822IRHBR** 100BASE-TX PHYs connected to the EtherCAT Slave Controller inside the DSP, brought out as **PHY0** (J3 pins 1A to 1E) and **PHY1** (pins 1F to 1J). Two ports allow drives to be daisy-chained without an external switch: data enters one port, passes through the node and leaves by the other.

Each port presents one transmit pair, one receive pair and its own EtherCAT ground:

Port	Transmit pair	Receive pair	Ground	J3 pins
PHY0	TD_P_P0 / TD_M_P0	RD_P_P0 / RD_M_P0	GND-CH0	1A–1E
PHY1	TD_P_P1 / TD_M_P1	RD_P_P1 / RD_M_P1	GND-CH1	1F–1J

The Ethernet signals are high-speed differential pairs and must be treated as controlled-impedance transmission lines. Otherwise the data is corrupted between the drive and the network. Because this enclosure has no RJ45 socket, the magnetics and the jack are on the machine side of the cable, which makes the following the integrator's responsibility rather than the drive's:

- Route each transmit and receive pair as a **100 Ω differential** pair, with each conductor **50 Ω single-ended** to ground.
- Provide galvanic isolation between the EtherCAT cabling and the drive by placing an **isolating LAN transformer** in each port's signal path: an RJ45 connector with integrated

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magnetics, or a discrete transformer between the port and the jack. Figure 22 shows that arrangement.

- Reference each pair's shield to the matching **GND-CHx** pin, and bond the cable shielding to ground to improve immunity against external EMI.
- Keep each EtherCAT segment within the 100 m limit of 100BASE-TX.

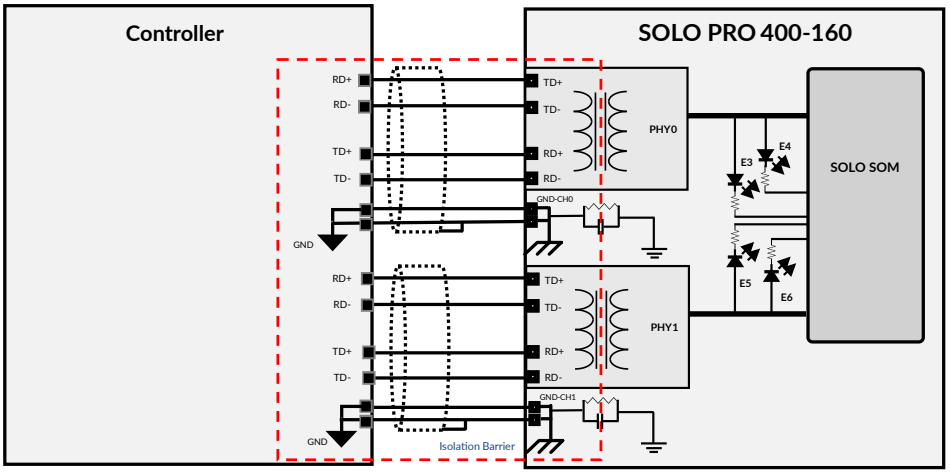

Figure 22. EtherCAT wiring between the controller and the SOLO PRO 400-160, through the isolating LAN transformers of the two PHYs.

8.2 CANOPEN (DS402)

CAN is a robust, lower-speed bus common in vehicles and in industrial systems, which makes it a natural fit for a traction drive. The unit implements CANopen with the DS402 motion profile, the standard method for commanding a drive over CAN. The transceiver is on board, so only **CANH** (J3 pin 2B) and **CANL** (pin 2C) are routed to the machine, as shown in Figure 23.

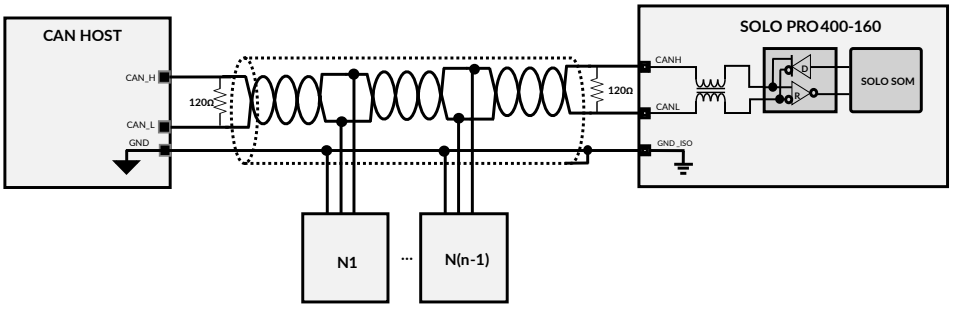

Figure 23. CAN bus wiring — CANH and CANL to the network, referenced to GND_ISO.

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Design considerations:

- The firmware uses classical CAN at up to 1 Mbit/s with the CANopen layer.
- A CAN bus must be terminated with a **120 Ω** resistor at each of its two physical ends, and nowhere else. Fit a terminator at the drive only if it is the last node on the bus.
- Set the node address and bit rate from the SOLO Motion Terminal, or over the bus using CANopen LSS.
- The transceiver sits on the isolated control side and is referenced to GND_ISO, which separates it from the DC bus as long as the logic supply is itself isolated from the bus (Section 5.1). If it is not, the CAN network is referenced to the bus, and every node on it with it. The transceiver is not isolated from the rest of the control side. Where the CAN network must also be isolated from the drive's logic supply, as it must when nodes sit at different ground potentials, add an isolated transceiver externally.
- Bond the cable shielding to ground, or to the CAN host ground, at one end only.
- Connect **GND_ISO** to the CAN host ground. Two CAN nodes with no common reference cannot communicate reliably however good the differential pair is.

Through CANopen, every function of the drive can be accessed and controlled digitally. For the object dictionary and the profile detail, refer to the CANopen user manual on the SOLO website.

8.3 USB

The USB 2.0 Type-C port, section [5], is the simplest way to reach the drive: a single cable to a PC or a host controller, as shown in Figure 24, over which the unit enumerates as a Virtual COM Port and exposes its full digital feature set. It is also the path for firmware updates (Section 12), and it is the interface the SOLO Motion Terminal uses to configure the drive, tune the loops and monitor live signals.

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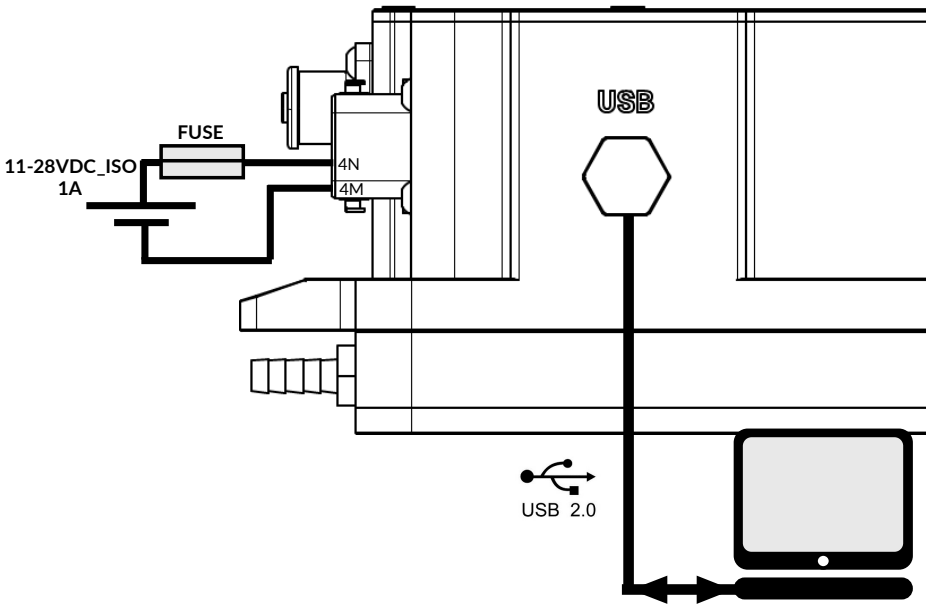

Figure 24. USB 2.0 Type-C wiring, with the drive powered from its own 11–28 VDC logic supply through a 1 A fuse.

The Type-C connector is reversible, with no up or down orientation, which makes it robust in an industrial setting; behind its sealed cap it also keeps the IP67 rating when unused.

> ⚠ **CAUTION:** The drive must be powered from its external 11–28 VDC logic supply when connected to a host over USB. The USB cable does not power the unit.
>
> ⛔ **DANGER:** The USB port is referenced to GND_ISO. A PC connected to it sits at the logic supply's potential, which is safe only because that supply is isolated from the bus (Section 5.1). If the logic 0 V has been bonded to the bus return, the laptop, the person holding it and everything else on its ground are at bus potential.
>
> ℹ **NOTE:** The maximum recommended USB cable length is 5 m. USB is well suited to configuration, commissioning and monitoring. For multi-axis or hard real-time control, use EtherCAT or CANopen.

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9. POSITION AND TEMPERATURE SENSING

Accurate control of motor position or speed requires knowledge of the rotor position, provided by a sensor mounted on the motor. The drive supports four sensor families, all on the single J3 connector (Section 7.6), so the sensor can be matched to the accuracy, cost and robustness the application requires. The same connector carries a PT1000 input for a user temperature sensor, and a second, isolated PT1000 input is provided on J13 for a sensor inside the motor.

Every sensor type shares three wiring rules, and most feedback problems come from breaking one of them:

- Keep the sensor cable to **3 m or less**.
- Bond the cable shield to ground **at one end only**. Grounding both ends creates a ground loop that injects switching noise straight into the feedback.
- Connect the sensor ground to **GND_ISO**, and keep the sensor cable away from the motor and bus cables (Section 13.6). On a 450 V, 160 A drive the motor cable is an aggressive noise source and the separation matters more than on a low-voltage unit.
- Remember that a sensor body is usually bolted to the motor frame, at machine-earth potential, while its signal return goes to GND_ISO. This is a further reason the logic supply must be isolated from the bus (Section 5.1): were GND_ISO tied to the bus, the sensor cable would carry bus potential into an earthed housing.

> **i NOTE:** Every sensor type requires a one-time setup and calibration before the motor is run, performed with the SOLO Motion Terminal. The procedure is maintained online at solomotorcontrollers.com.

9.1 DIGITAL HALL SENSORS

Hall sensors provide coarse position feedback through three digital signals that change state as the rotor magnets pass them. This is sufficient for commutation and a coarse speed estimate, and it is the lowest-cost way to run a BLDC or PMSM motor in closed loop. As shown in Figure 25, connect the motor's HALL A, HALL B and HALL C outputs to **HA, HB and HC** (J3 pins 4G, 4H and 4I) and supply the sensors from **+5V Ext.** (pin 2M), returning them to GND_ISO.

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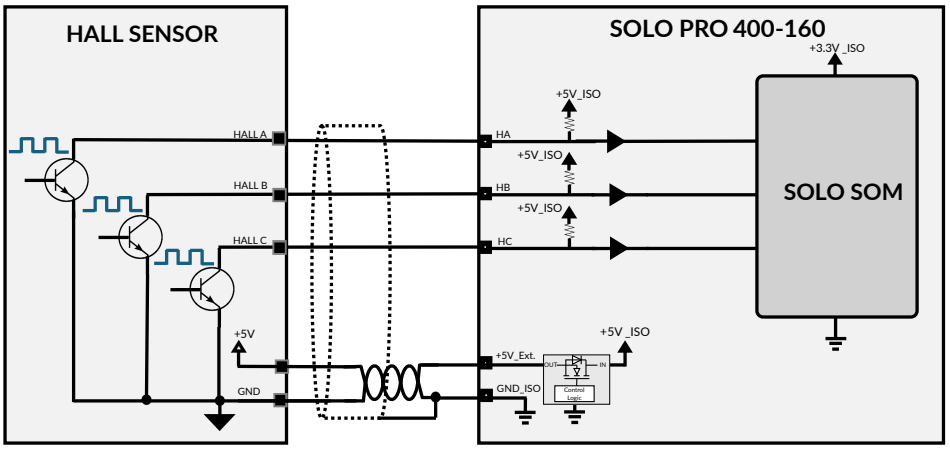

Figure 25. Digital Hall sensor wiring (HA / HB / HC), supplied from +5V Ext.

9.2 INCREMENTAL ENCODER — DIFFERENTIAL

A differential incremental encoder transmits each channel as a balanced pair, which gives far better noise immunity than a single-ended type over long or electrically noisy cable runs, which is the normal case on a drive of this size. Connect the encoder's positive outputs to **CHA+, CHB+ and CHC+** (J3 pins 4B, 4C, 4E) and its negative outputs to **CHA–, CHB– and CHC–** (pins 4A, 4D, 4F).

Wire each pair as a **twisted pair**, as shown in Figure 26. Twisting matters here. Interference coupled into the cable affects both conductors nearly equally, and the receiver, responding only to the difference between them, cancels it. Terminate each pair with the 120 Ω resistor shown in the figure.

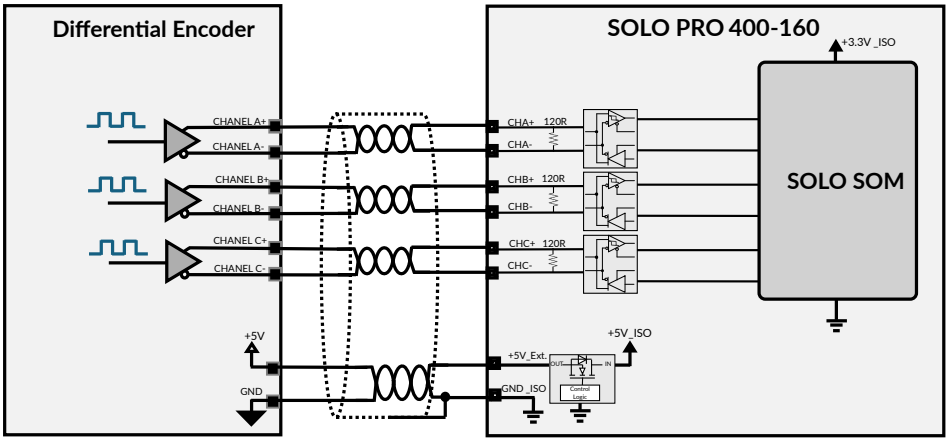

Figure 26. Differential incremental encoder wiring (CHA± / CHB± / CHC± as terminated twisted pairs).

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> **i NOTE:** For a three-phase motor the index signal (channel C) is **mandatory**, because the firmware uses it during the one-time encoder calibration that aligns the encoder count with the rotor magnetic position. A DC brushed motor does not require the index pulse.

9.3 BISS-C ABSOLUTE ENCODER

An absolute encoder reports the exact shaft angle at power-up, with no requirement to move the motor to a reference position first. On a traction axis or a vertical axis, that removes the homing move entirely. BiSS-C is an open digital standard for absolute encoders; on its primary channel the drive operates as a full BiSS-C master. It generates the clock, reads back the position data, and can both read from and write to the encoder's internal registers, which supports operations such as configuring the encoder or clearing its error and warning flags.

The clock and data each use a differential pair, wired as shown in Figure 27:

Signal	Function	J3 pin
C+_P / C-_P	Clock, drive to encoder	3G / 3H
D+_P / D-_P	Data, encoder to drive	3E / 3F
+5V_OUT_P	Switched +5 V / 200 mA encoder supply	3I
GND_ISO	Encoder ground	3M / 4M

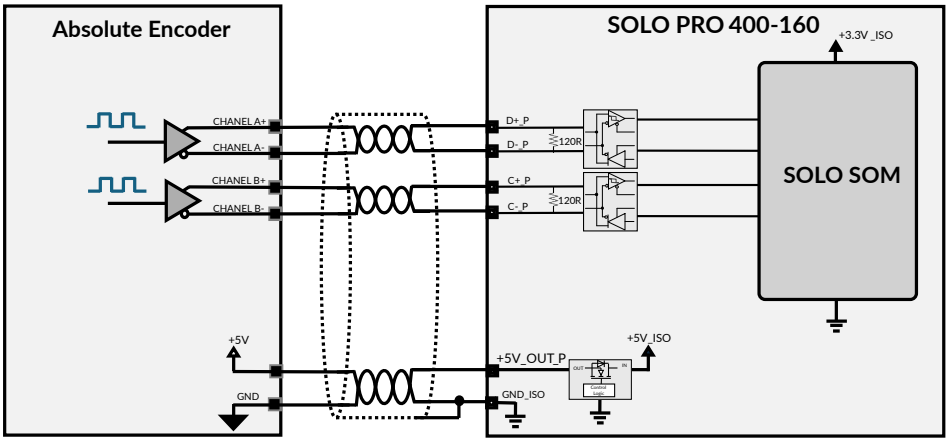

Figure 27. BiSS-C absolute encoder wiring — clock and data as terminated twisted pairs, with the switched +5 V supply.

Wire each pair as a twisted pair and bond the shield at one end only. The switched supply provides 200 mA, which is enough for a typical absolute encoder and no more, so do not load it with anything else.

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9.4 SIN/COS ENCODER

A Sin/Cos encoder outputs two analogue signals, a sine and a cosine, as the shaft rotates. Measuring both allows the drive to interpolate the angle finely between the coarse counts, which gives a much higher effective resolution than the raw count alone. Connect the encoder to **SinCOS A+/A–** and **SinCOS B+/B–** (J3 pins 3A, 3B, 3C and 3D) as shown in Figure 28.

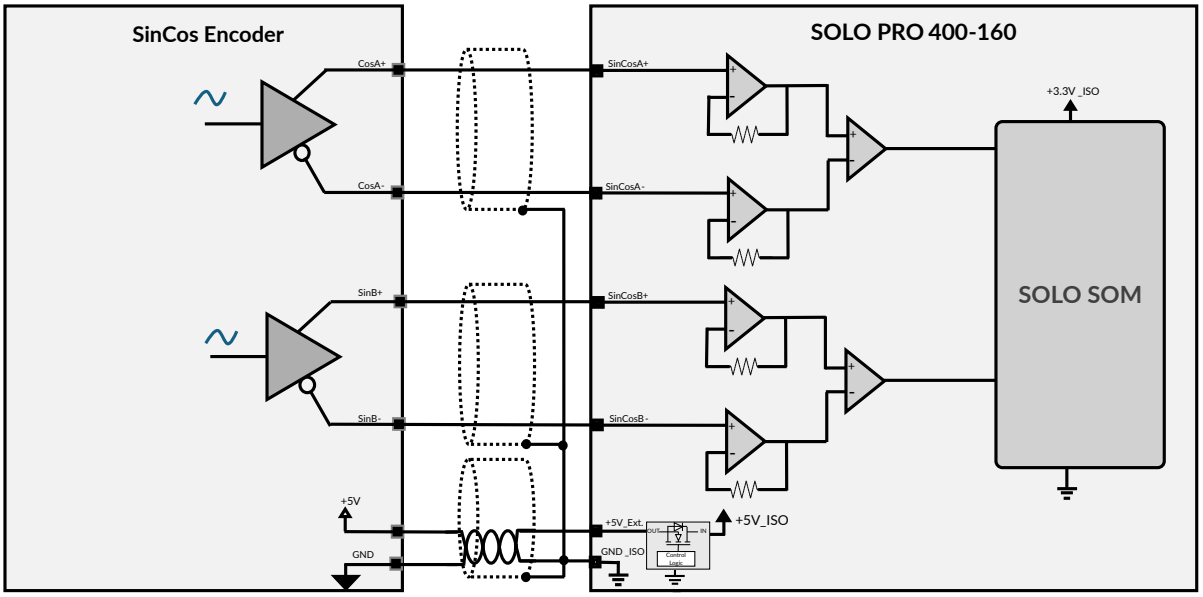

Figure 28. Sin/Cos encoder wiring, with the interface board scaling and biasing both channels into the drive's analogue input window.

Because these signals drive the drive's analogue inputs directly, their amplitude and offset matter, and an interface board is normally required between the encoder and the drive to scale and bias them. Figure 29 gives the two constraints that board has to satisfy:

- **Offset.** The centre voltage of each channel must lie between **1.25 V and 3.75 V**, nominally on the 2.5 V mid-rail.
- **Amplitude.** The peak-to-peak swing of each channel must be **less than 2.5 V**, and the waveform must stay inside the 0–5 V input window at all times.

A larger amplitude gives the angle interpolation more resolution, so use as much of the permitted swing as the signal chain allows for the best position accuracy, stopping short of clipping.

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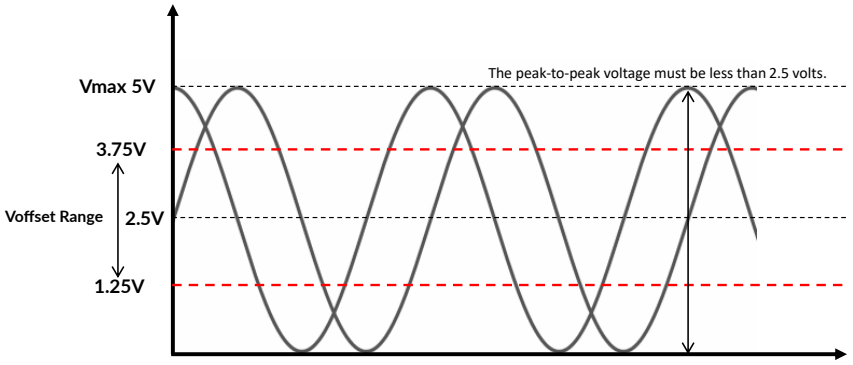

Figure 29. Sin/Cos input range: the permitted offset band and the peak-to-peak limit.

> ⚠ **CAUTION:** The Sin/Cos inputs are rated to +4.5 V continuous and +5 V absolute maximum (Section 5.6). Scale the encoder signals before connecting them.

9.5 TEMPERATURE SENSORS

The drive measures temperature at three points, and the three are not interchangeable:

Sensor	Location	Connector	Isolated	Trip
User PT1000	Wherever the integrator fits it	J3, pins 1N / 1M	No — referenced to GND_ISO	—
Motor PT1000	Motor windings	J13, pins 1 / 2	Yes	120 °C
NTC	Internal, on the cooled base plate	— (built in)	Yes	85 °C

9.5.1 USER PT1000 (J3)

A PT1000 is a platinum resistance thermometer whose resistance rises predictably with temperature, reaching 1000 Ω at 0 °C. Connect one across **PTC+** (J3 pin 1N) and **PTC–** (pin 1M), as shown in Figure 30. PTC– is internally connected to GND_ISO. This input is the general-purpose one: use it for a sensor on a gearbox, a bearing housing, a cabinet or anywhere else in the machine that matters.

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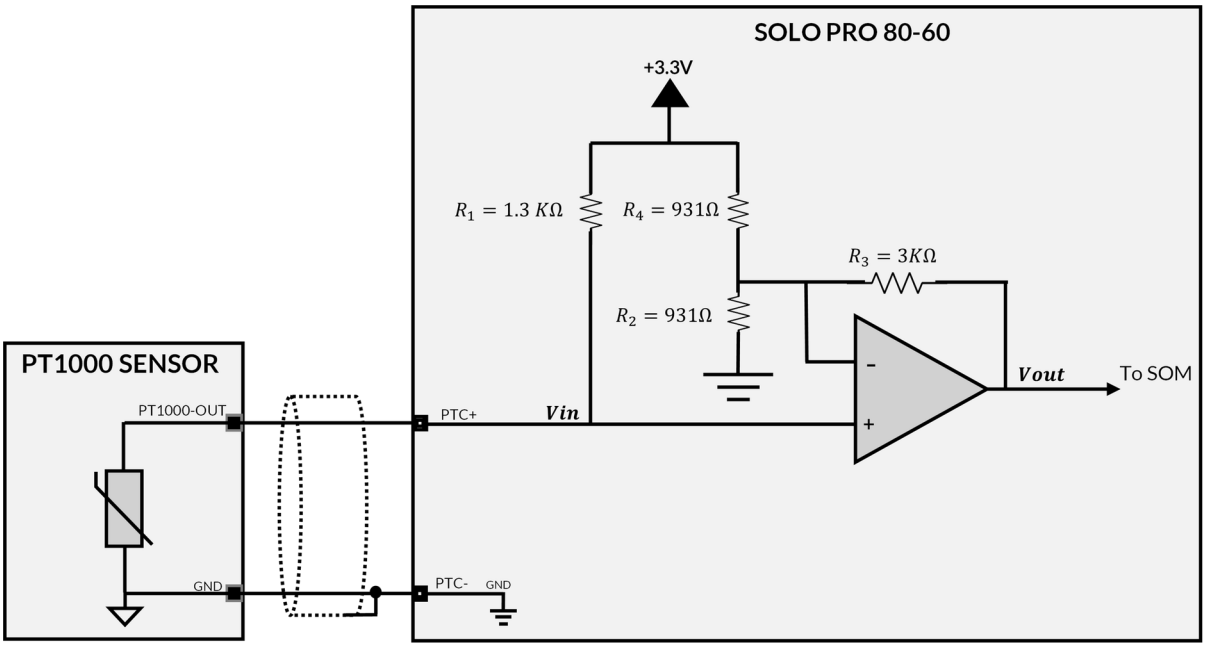

Figure 30. User PT1000 temperature-sensor wiring on J3 (PTC+ / PTC–), with the internal divider and amplifier that condition it.

> ⚠ **CAUTION:** The PT1000 input is limited to +3.3 V continuous, with a +3.75 V absolute maximum. It is **not** 5 V tolerant. Exceeding the rating will permanently damage the drive.

Converting the reading to a temperature. The drive reports the measurement as a voltage, V_{out}, over USB or the CAN bus. Convert it in four steps:

1. Read V_{out} over one of the communication interfaces.
2. Compute the sensor node voltage:

```
V_in = (10.64 + V_out) / 7.45
```

1. Compute the PT1000 resistance from the divider it forms with the internal 1.3 kΩ resistor:

```
R_ptc = (1300 × V_in) / (3.3 – V_in)
```

1. Convert the resistance to a temperature using the characteristic curve or table from the PT1000 datasheet. For a standard PT1000 the linear approximation is `R = 3.85 × T + 1000`, with R in ohms and T in °C.

Figure 31 shows a sample PT1000 characteristic curve. Always use the curve or table from the datasheet of the sensor actually fitted, since the linear approximation above loses accuracy at the ends of the range.

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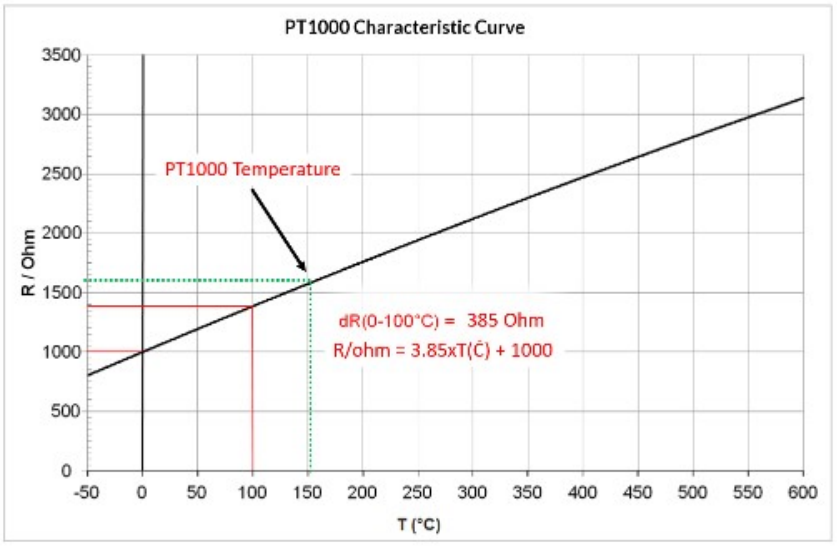

Figure 31. A sample PT1000 temperature-sensor characteristic curve.

Worked example. The drive reports V_{out} = 2.9 V:

Step	Calculation	Result
Node voltage	V_{in} = (10.64 + 2.9) / 7.45	1.82 V
Resistance	R = (1300 × 1.82) / (3.3 – 1.82)	1598 Ω
Temperature	T = (1598 – 1000) / 3.85	≈ 155.5 °C

9.5.2 MOTOR PT1000 (J13)

The motor temperature input on J13 is **galvanically isolated**, because the sensor it reads is embedded in a winding that sits at bus potential. Connect the motor's PT1000 across **PTC+** (pin 1) and **PTC–** (pin 2), as shown in Figure 32. The drive pulls the sensor up through an internal 1.4 kΩ resistor against +3.3 V_ISO, measures the node through an isolation amplifier, and compares it against a hardware threshold.

The drive goes into protection as soon as the sensed temperature rises above 120 °C. The comparison is made in hardware, on the isolated side, and it disables the output without waiting for the firmware or for anything the machine controller does. There is no configuration setting that raises the threshold or turns the trip off.

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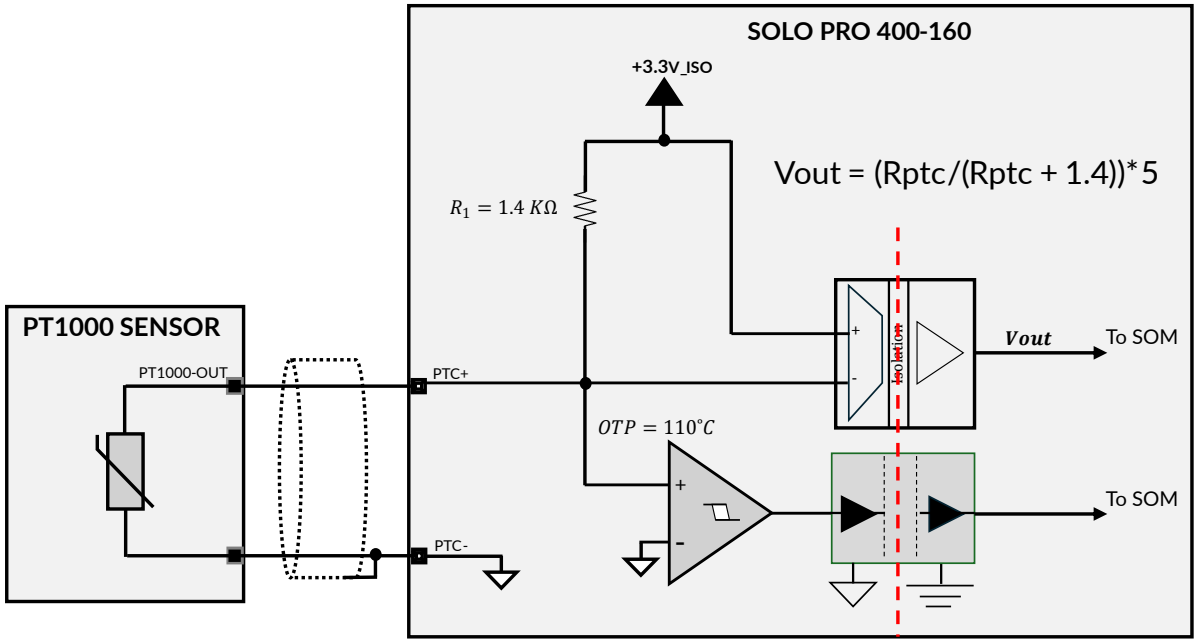

Figure 32. Isolated motor PT1000 wiring on J13, with the hardware over-temperature comparator.

The reported voltage follows the relation given on the drawing, with the resistances in kΩ:

```
V_out = ( R_ptc / ( R_ptc + 1.4 ) ) × 5
```

Solve it for R_{ptc} and apply the same characteristic curve as in Section 9.5.1 to obtain the winding temperature.

The input must never be left open or unconnected. The PT1000 is the lower leg of the divider, so removing it is electrically identical to a sensor of infinite resistance: the node rises to the rail and the drive reads the maximum possible temperature. An open J13 therefore holds the unit in over-temperature protection and it will not produce torque. A broken sensor wire does the same thing, which is the intended fail-safe behaviour: the trip is on the side of stopping the machine.

> ⛔ **DANGER:** Never defeat this input by fitting a fixed resistor, a link, or anything else that is not a temperature sensor. Doing so removes the motor's thermal protection entirely and the drive will keep driving a winding that is burning.

Where the motor has no embedded PT1000. The protection cannot be switched off, so the sensor has to measure something real. Fit an external PT1000 in the machine, on the motor housing, on the terminal box, or sensing the air around the drive and motor, and wire it to J13. The trip then guards the temperature of whatever the sensor is mounted on rather than the

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winding itself. That is less direct, but it is still a real protection, and it keeps the input inside its measuring range. Choose the mounting point so that 120 °C at the sensor still means something has gone wrong.

> ⚠ **WARNING:** An externally mounted sensor protects only what it is mounted on. A PT1000 sensing ambient air will not detect a stalled rotor cooking a winding. Where the motor can be thermally overloaded, use a sensor embedded in the winding and size the drive's current limit to the motor.

9.5.3 BASE-PLATE NTC

A negative-temperature-coefficient thermistor is built into the cooled base plate, beneath the power stage. It needs no wiring, and there is nothing on the enclosure to connect to it: it is read internally through an isolation amplifier, exactly as the motor PT1000 is, and it drives a hardware over-temperature trip at **85 °C**. Figure 33 shows the arrangement.

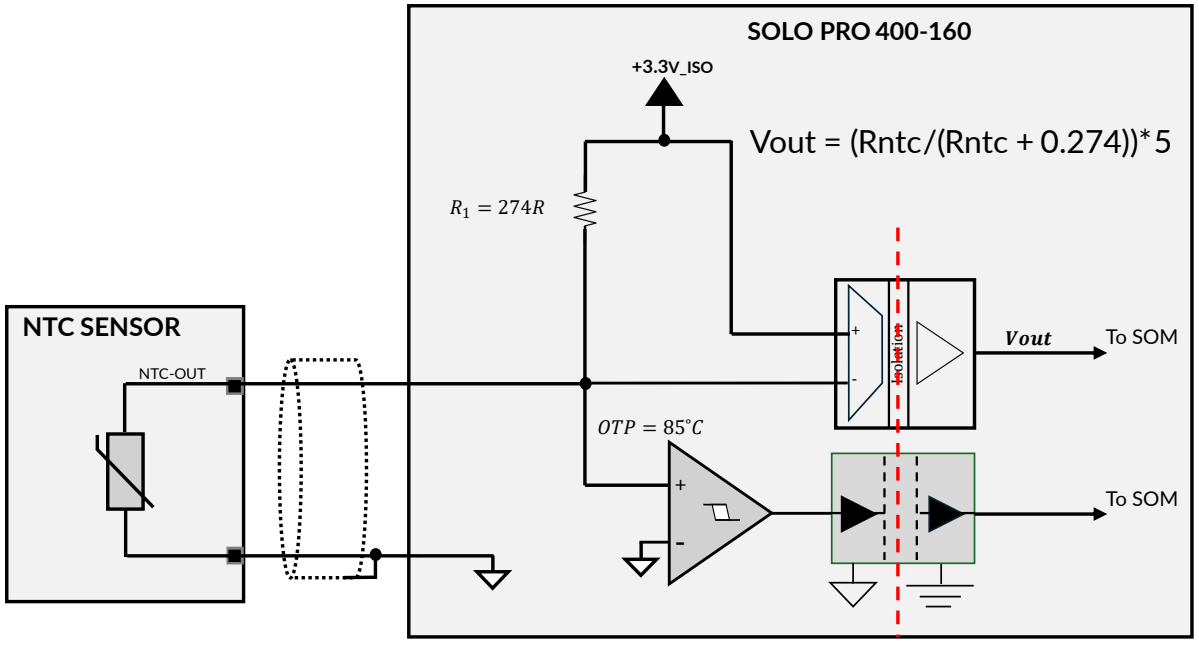

Figure 33. The internal base-plate NTC, with its hardware over-temperature comparator set at 85 °C.

The reported voltage follows the relation given on the drawing, with the resistances in kΩ:

```
V_out = ( R_ntc / ( R_ntc + 0.274 ) ) × 5
```

This is the sensor that reports whether the coolant circuit is doing its job. Log it over a full duty cycle during commissioning (Section 6.3): if the plate approaches 85 °C, the circuit is undersized for the application, and the trip will eventually stop the machine in service.

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10. ANALOGUE AND DIGITAL CONTROL

10.1 ANALOGUE VERSUS DIGITAL CONTROL

The drive accepts commands in two distinct modes, selected by configuration:

- **Analogue mode.** Torque or speed references, the current limit and the direction of rotation arrive as analogue voltages or PWM pulses on the AI and GPI/O pins. This suits a PLC with analogue outputs, a potentiometer, or an MCU board with a DAC or PWM output.
- **Digital mode.** All commands and all feedback are exchanged as data packets over USB, CANopen or EtherCAT. This gives access to every function of the drive, including those with no analogue equivalent.

The two are not exclusive over the life of a machine: a unit commissioned over USB can run in analogue mode afterwards.

10.2 ANALOGUE COMMAND INPUTS AI1_IN AND AI2_IN

AI1_IN (J3 pin 2D) and **AI2_IN** (pin 2A) accept either a pure analogue voltage of 0 to 5 V or a PWM signal. When a PWM output is used, its frequency must be **at least 5 kHz**. Below that the input filter no longer averages the pulse train into a stable reference, and the command becomes noisy.

Both inputs are rated to +5 V continuous and +5.25 V absolute maximum. The ground of the commanding device must be connected to **GND_ISO** (J3 pin 3M or 4M). An analogue voltage has no meaning without a shared reference.

10.3 ANALOGUE WIRING — CONTROLLER WITH NPN OUTPUTS

PLC outputs fall into two families. In an **NPN (sinking)** configuration, an activated output pulls its pin to ground; in a **PNP (sourcing)** configuration, an activated output pulls its pin up to the PLC supply. Figure 34 shows a controller with NPN outputs: the GPI/O1 pin is driven by an NPN output, and the controller's 0–5 V analogue outputs feed AI1_IN and AI2_IN.

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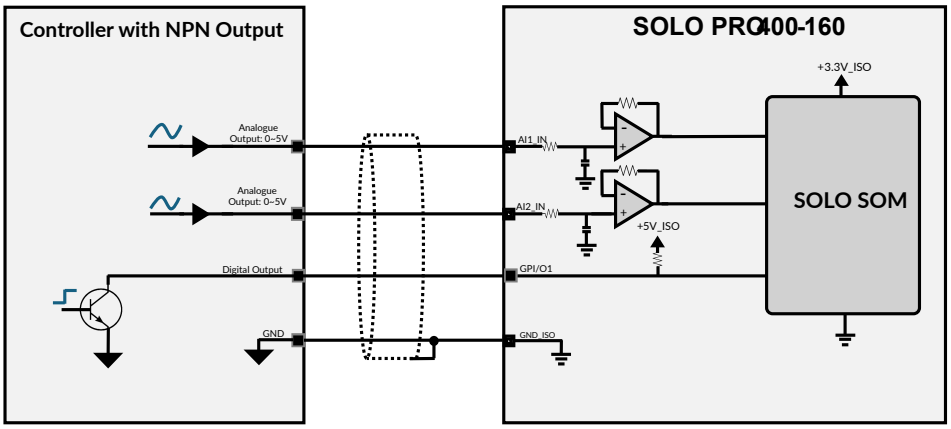

Figure 34. Analogue wiring with a controller having NPN (sinking) outputs.

- Connect GND_ISO to the controller ground.
- Bond the cable shielding to ground at one end only.

10.4 ANALOGUE WIRING — EMBEDDED MCU BOARDS

The drive works with any embedded MCU board using 3.3 V or 5 V logic, such as an Arduino or a Raspberry Pi. As shown in Figure 35, GPI/O1 connects to any digital output of the board, and AI1_IN or AI2_IN to an analogue or PWM output.

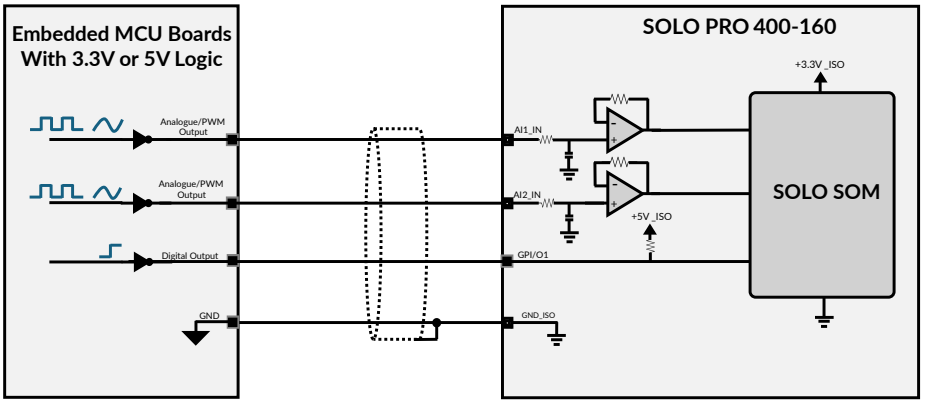

Figure 35. Analogue wiring with an embedded MCU board.

- GND_ISO must be connected to the MCU board ground.
- The GPI/O pins accept input voltages up to +5 V.
- When a PWM output drives AI1_IN or AI2_IN, the PWM frequency must be at least 5 kHz.
- Bond the cable shielding to GND_ISO or to the controller ground at one side only.

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10.5 GENERAL-PURPOSE INPUT WIRING

A general-purpose I/O configured as an input accepts an on/off logic signal such as a direction command, an enable or a limit switch. Figure 36 shows a switch wired to GPI/O1 and fed from the drive's own +5V Ext. rail.

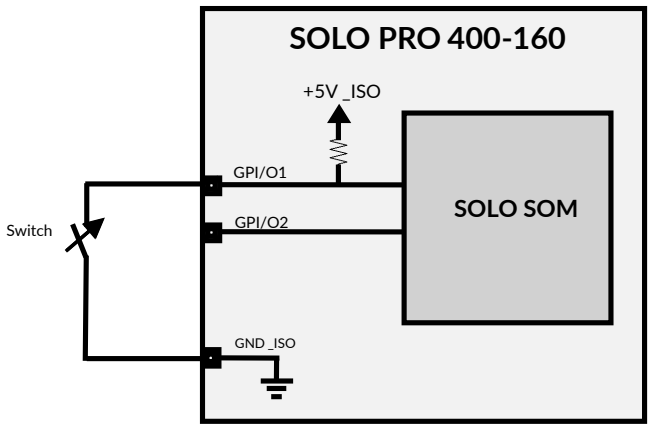

Figure 36. General-purpose input wiring (GPI/O1).

> ⚠ **CAUTION:** The general-purpose inputs are 5 V inputs. Exceeding +5 V will damage the unit.

10.6 GENERAL-PURPOSE OUTPUT WIRING

A general-purpose I/O configured as an output can control an external circuit: an electrical valve, a solenoid, a contactor, a small pump. Because the pin sources only a small current, drive anything larger through a transistor and a relay, as shown in Figure 37.

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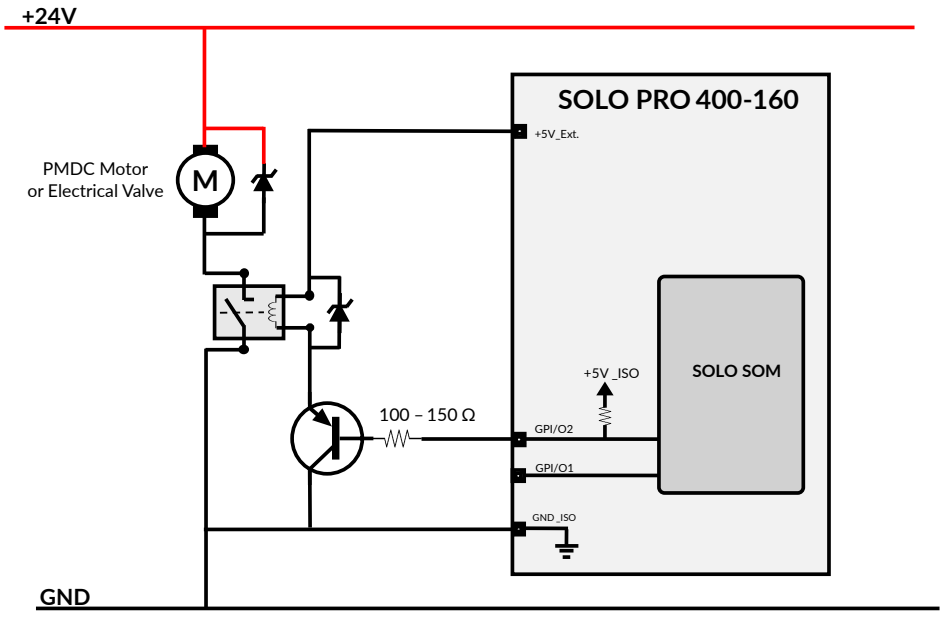

Figure 37. General-purpose output wiring (GPI/O2) driving a relay through a transistor.

> ⚠ **CAUTION:** The maximum current available from a general-purpose output is **10 mA**. Drawing more will damage the unit. Use the output to switch a transistor rather than driving a load directly.

10.7 DIGITAL MODE

In digital mode, every function of the drive is reachable by sending data packets over USB, the CAN bus (using the CANopen protocol) or EtherCAT. Section 8 covers each interface and its wiring, and Section 13 gives complete wiring examples for the common host arrangements.

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11. SAFE TORQUE OFF (STO)

11.1 FUNCTION

Safe Torque Off is a hardware-level safety function that reliably removes the torque-producing power from the motor. When STO is requested, the drive interrupts the path to the gate drivers and the motor coasts to a stop according to its own time constant, while the rest of the system may remain powered.

The function is **energise-to-enable**: the STO inputs must be actively driven for the drive to produce torque.

- **Enabled.** With the STO inputs driven to their high state (+5 V), the power electronics driving the motor are active.
- **Disabled (safe state).** With the STO pins open-circuit or at 0 V, the drive immediately interrupts power to the motor.

The polarity is not arbitrary: a broken wire, a lost supply or a disconnected connector all produce the safe state rather than an enabled drive.

The drive provides **two independent STO channels**, STO1 and STO2, for redundancy, plus an isolated **feedback pair** (STO_FB+ / STO_FB–) through which the machine controller can read back the state of the function. All of these are optically isolated, both from the power stage and from the rest of the control side.

Signal	Function	J3 pin
STO1	Channel 1, positive input	2N
STO1_R	Channel 1, negative input	2J
STO2	Channel 2, positive input	2I
STO2_R	Channel 2, negative input	2H
STO_FB+	Isolated feedback, positive	2G
STO_FB-	Isolated feedback, negative	2F

> ⚠ **WARNING:** Providing the STO wiring is mandatory for the drive to operate.

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> ⚠ **WARNING:** When STO is requested, the motor coasts to a stop under its own inertia. On a vehicle, a vertical axis or an overhauling load this coasting may continue or even accelerate. Where the application cannot tolerate coasting, add an independent mechanical brake commanded by the machine's safety system.

11.2 ELECTRICAL CHARACTERISTICS

Parameter	Description	Value
Type of input	STO1, STO1_R, STO2 and STO2_R	Optically isolated
Voltage range	Acceptable voltage applied to the STO inputs	+3.3 V to +5 V
Input current	STO1 and STO2 channel input current	2.1 mA to 3.3 mA
Low-level input threshold	For +3.3 V and +5 V logic	To be confirmed
High-level input threshold	For +3.3 V and +5 V logic	To be confirmed
Pulse time	Maximum width of a pulse that the STO unit ignores	< 1 ms
Deactivation time	Minimum time to deactivate the STO unit	> 13 ms
Activation time	Minimum time to activate the STO unit	> 7 ms

Where the safety relay switches a supply higher than +5 V, a **series resistor of 2.2 kΩ** is required in each channel to set the input current. The wiring of Section 11.3.1 shows it. No series resistor is needed for a 5 V supply.

11.3 WIRING THE STO INPUTS

There are three ways to wire the STO inputs. Only the first is suitable for a production machine.

11.3.1 SAFETY RELAY WITH AN EXTERNAL SUPPLY

The correct arrangement for production: a safety relay, driven by the machine's safety system, energises the STO inputs from a **separate external supply** of +5 to +24 VDC, as shown in Figure 38. The optical isolation of the STO inputs is preserved, and the drive can be tripped by the safety system independently of its own supply and firmware.

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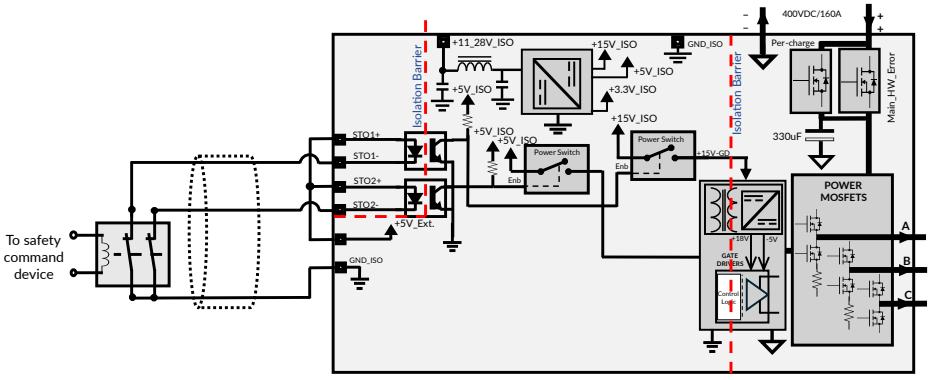

Figure 38. STO wiring to an external safety relay using an external +5 to +24 VDC supply, with the 2.2 kΩ series resistors required above 5 V.

> **NOTE:** The 2.2 kΩ series resistors shown in each channel are required for a 12 V or 24 V command supply. Omit them only if the supply is +5 V.
>
> **NOTE:** Bond the cable shield to the external ground to minimise interference from external EMI sources.

11.3.2 SAFETY RELAY WITH THE INTERNAL +5 V SUPPLY

The same relay arrangement, but the STO inputs are energised from the drive's own **+5V Ext.** rail (J3 pin 2M) and returned to GND_ISO, as shown in Figure 39. This simplifies bring-up, but it defeats the isolation of the STO inputs and makes the safety function dependent on the drive's own logic supply.

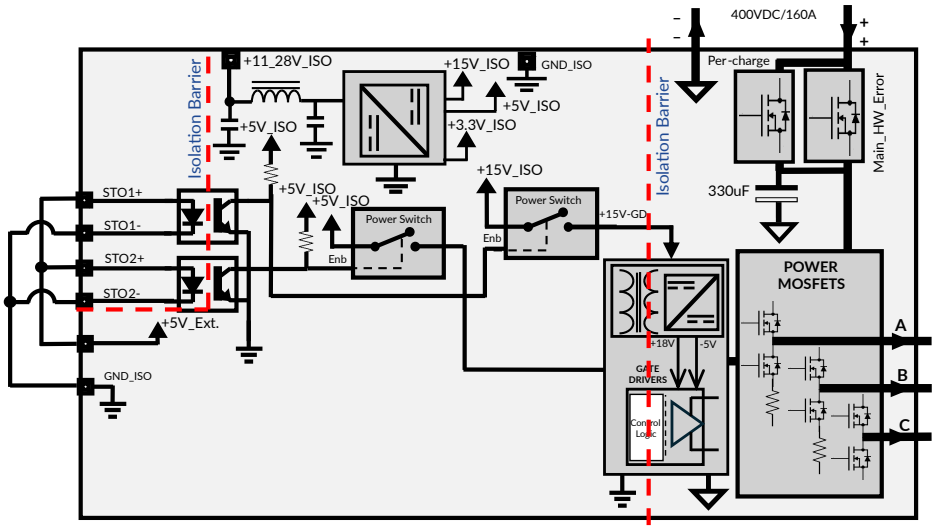

Figure 39. STO wiring to an external safety relay using the internal +5 V supply.

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> ⚠ **WARNING:** This configuration is for initial testing and commissioning only. Do not use it in production.

11.3.3 BYPASS — NO EXTERNAL COMMANDING DEVICE

The STO inputs are tied directly to **+5V Ext.** so that the drive runs with no safety device connected at all, as shown in Figure 40. This exists purely so that a motor can be turned for the first time on a bench.

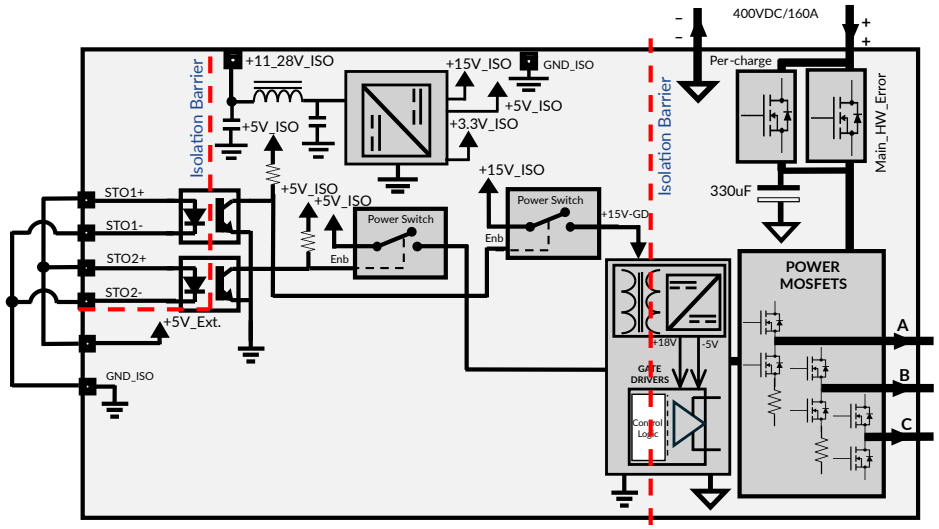

Figure 40. STO bypass wiring via the internal +5 V supply, with no external commanding device.

> ⛔ **DANGER:** This wiring removes the Safe Torque Off protection entirely. Use it only on a bench, with the motor uncoupled from the machine, and never in an installation where a person can reach the driven mechanism.

11.4 TIMING

The STO inputs are deliberately slow to respond to short disturbances, so that electrical noise on a long safety cable cannot trip or release the function. Figure 41 shows the three characteristic times, together with the internal STO-ACTIVE state and the PWM output that follows it.

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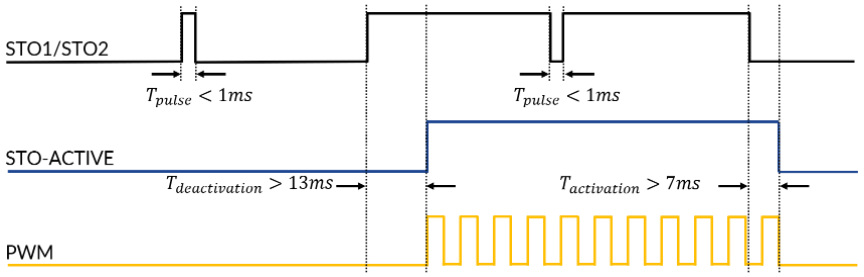

Figure 41. STO activation, deactivation and pulse timing, with the resulting PWM output.

- **Pulse time, < 1 ms.** A pulse shorter than 1 millisecond applied to the STO inputs has no effect on the function, in either direction. Noise on a long safety cable therefore cannot trip or release the function.
- **Deactivation time, > 13 ms.** The controller must hold both STO1 and STO2 in the requested state for at least 13 milliseconds for the STO unit to deactivate.
- **Activation time, > 7 ms.** The controller must hold the inputs for at least 7 milliseconds to activate the unit.

Design the safety circuit so that both channels are commanded together and held for longer than these minimums. A safety relay with a contact bounce comparable to the pulse time will produce an indeterminate result.

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12. FIRMWARE UPDATE (DFU MODE)

The drive's firmware is updated over the USB port. To make the unit start its bootloader instead of the application firmware, the **DFU** input (J3 pin 4J) is held at **+5 V Ext.** (pin 2M) while the drive powers up. Figure 42 shows the switch, and Figure 43 shows which two contacts of the connector it bridges.

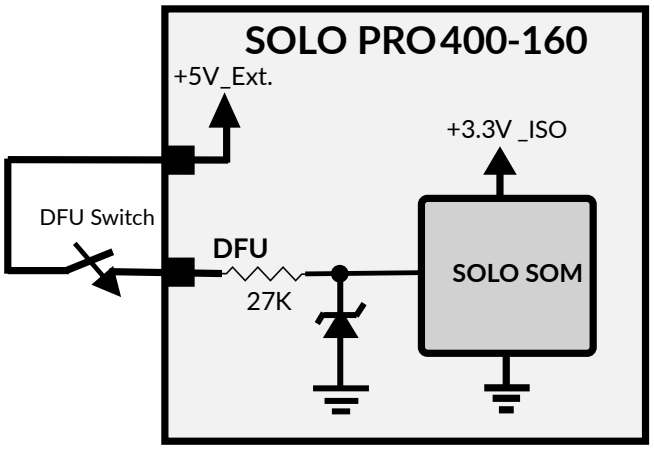

Figure 42. DFU mode wiring — a switch between the DFU input and +5V Ext.

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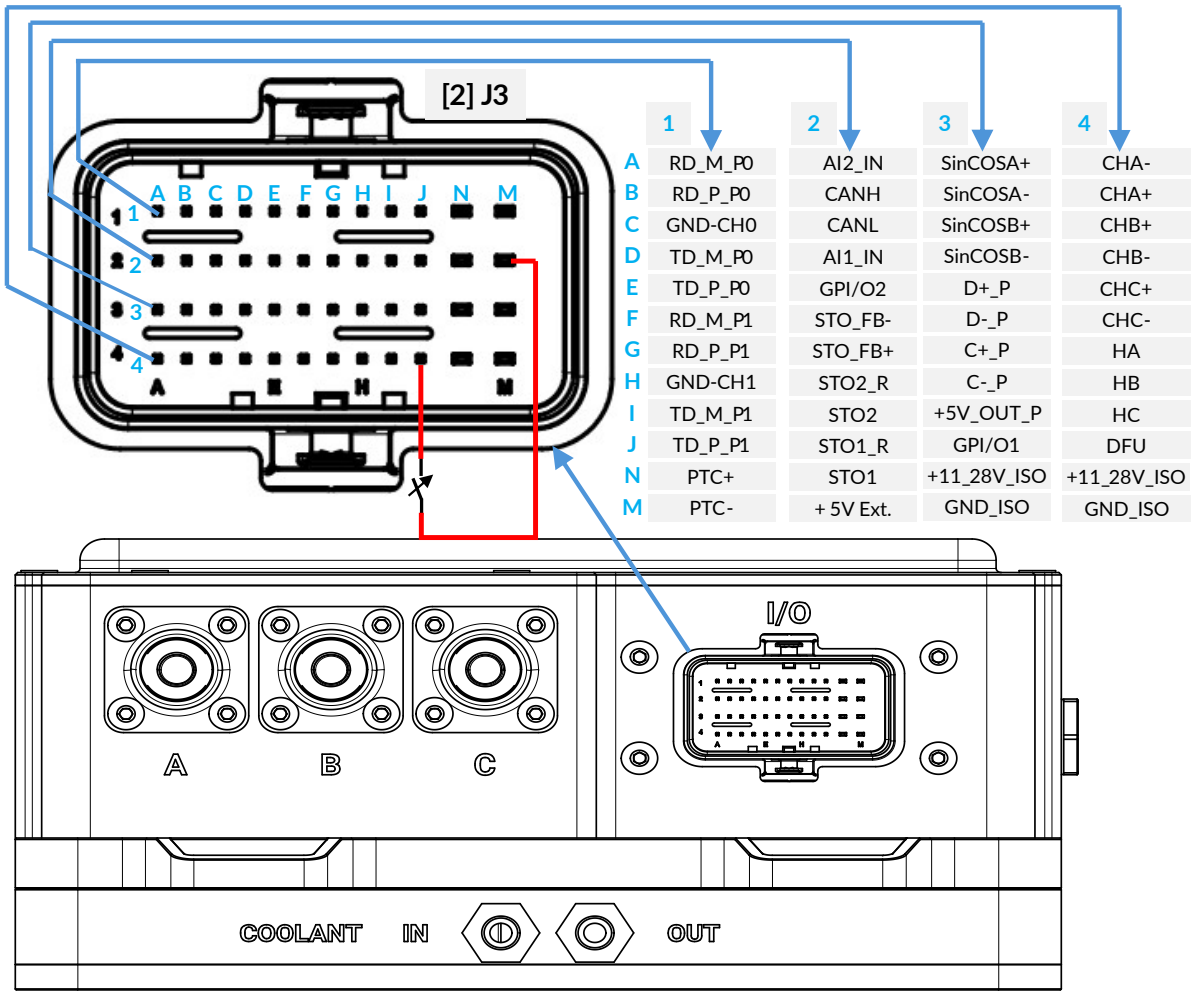

Figure 43. The DFU link on connector J3: pin 4J (DFU) to pin 2M (+5V Ext.).

The procedure is:

1. Remove the sealing cap from the USB port (section [5]) and connect the drive to the PC.
2. Close the DFU link between J3 pin **4J** and pin **2M**.
3. Power the logic supply. The drive enumerates in DFU mode rather than as a virtual COM port.
4. Load the firmware image with the SOLO Motion Terminal.
5. Remove the power, open the DFU link, and power up again for the drive to run the new firmware.
6. Refit and tighten the USB cap.

> **i NOTE:** The DFU pin is read only at power-up. Closing the link while the drive is running has no effect.

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> ⚠ **CAUTION:** The DFU input is rated to +5 V (Section 5.6). Drive it only from +5V Ext.. Do not connect it to the logic supply.

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13. COMPLETE WIRING EXAMPLES

13.1 WIRING LEGEND

The wiring diagrams in this manual use the following conventions.

Symbol	Meaning
Ground symbol	GND_ISO — the isolated ground of the SOLO PRO 400-160, which is **not** the DC bus return
External ground symbol	External ground — peripheral, PLC, embedded MCU board, or external supply ground
Fuse symbol	Fuse; the rating must be selected from the requirements of the system
Pulse line	Line carrying PWM pulses (fixed frequency above 5 kHz)
Analogue line	Line carrying a pure analogue voltage
On/off line	Line carrying on/off signals (low frequency)
Filled pin	Input/output pin of the SOLO PRO 400-160
Open pin	Input/output pin of the external controller
Dashed red line	Galvanic isolation barrier

13.2 STANDALONE WIRING — NO EXTERNAL MODULES

The drive can be operated with no external modules at all, using only a potentiometer and a switch. Figure 44 shows the complete wiring for closed-loop operation of a BLDC or PMSM motor: the 400 V bus through its fuse, the 11–28 V logic supply, the motor, the position sensor, the safety relay on the STO inputs, and two potentiometers with a direction switch on the analogue inputs.

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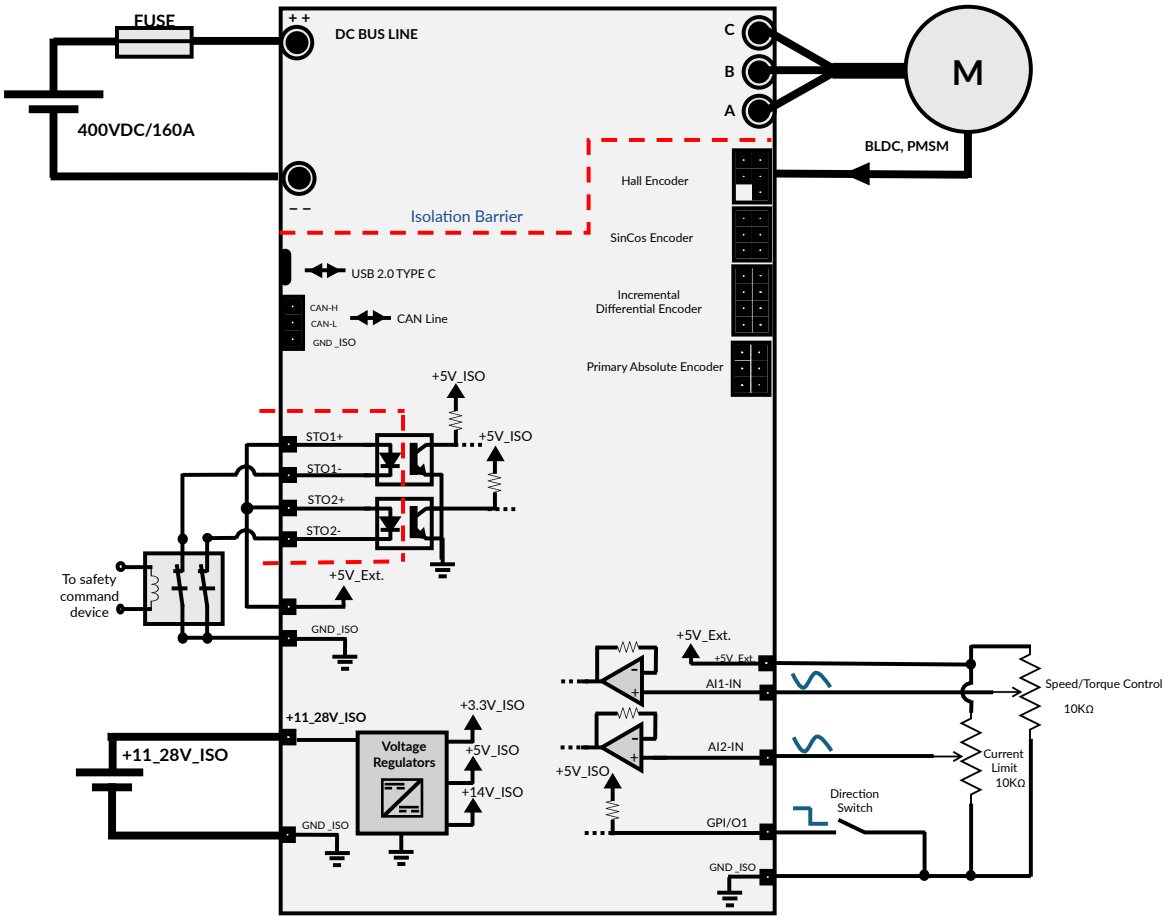

Figure 44. Standalone wiring — closed-loop control from potentiometers, with no external modules.

⚠ **CAUTION:** To avoid short-circuiting the internal +5 V source of the drive, the resistance of each potentiometer must not fall below **1 kΩ at any position**. Check this against the potentiometer datasheet before use.

ℹ **NOTE:** Fuse the DC bus in the positive line, close to the supply, and rate the fuse for the application rather than for the drive's 160 A maximum.

⛔ **DANGER:** The 11–28 V logic supply in this diagram, and in every other wiring example in this section, must be **galvanically isolated from the 400 V bus** (Section 5.1). The isolation barrier is drawn in each figure as a dashed red line; wiring the two supplies to a common return defeats it, whatever the figure shows.

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13.3 EMBEDDED MCU BOARD USING ANALOGUE/PWM

Figure 45 shows the drive commanded by an embedded MCU board such as an Arduino or a Raspberry Pi, using an analogue voltage or a PWM output for the reference and a digital output for direction.

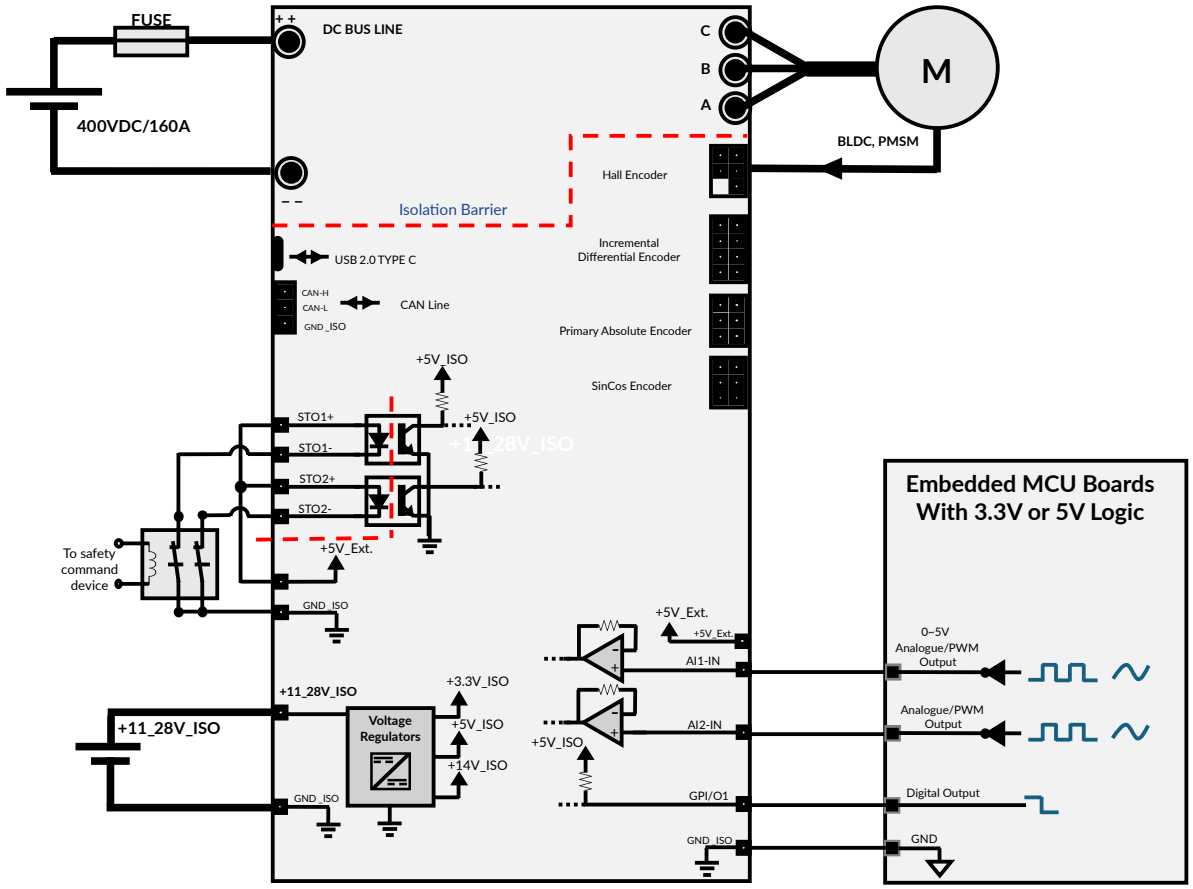

Figure 45. Complete wiring with an embedded MCU board commanding the drive over analogue/PWM.

- **GND_ISO** must be connected to the ground of the MCU board at least at one common point. Without a shared reference the analogue command has no defined value, so make this connection before any other.
- The GPI/O pins accept input voltages up to +5 V.
- When using a PWM output to drive AI1_IN or AI2_IN, the PWM frequency must be at least **5 kHz**.

13.4 EMBEDDED MCU BOARD USING CANOPEN

Figure 46 shows the drive commanded digitally over CANopen from an embedded MCU board.

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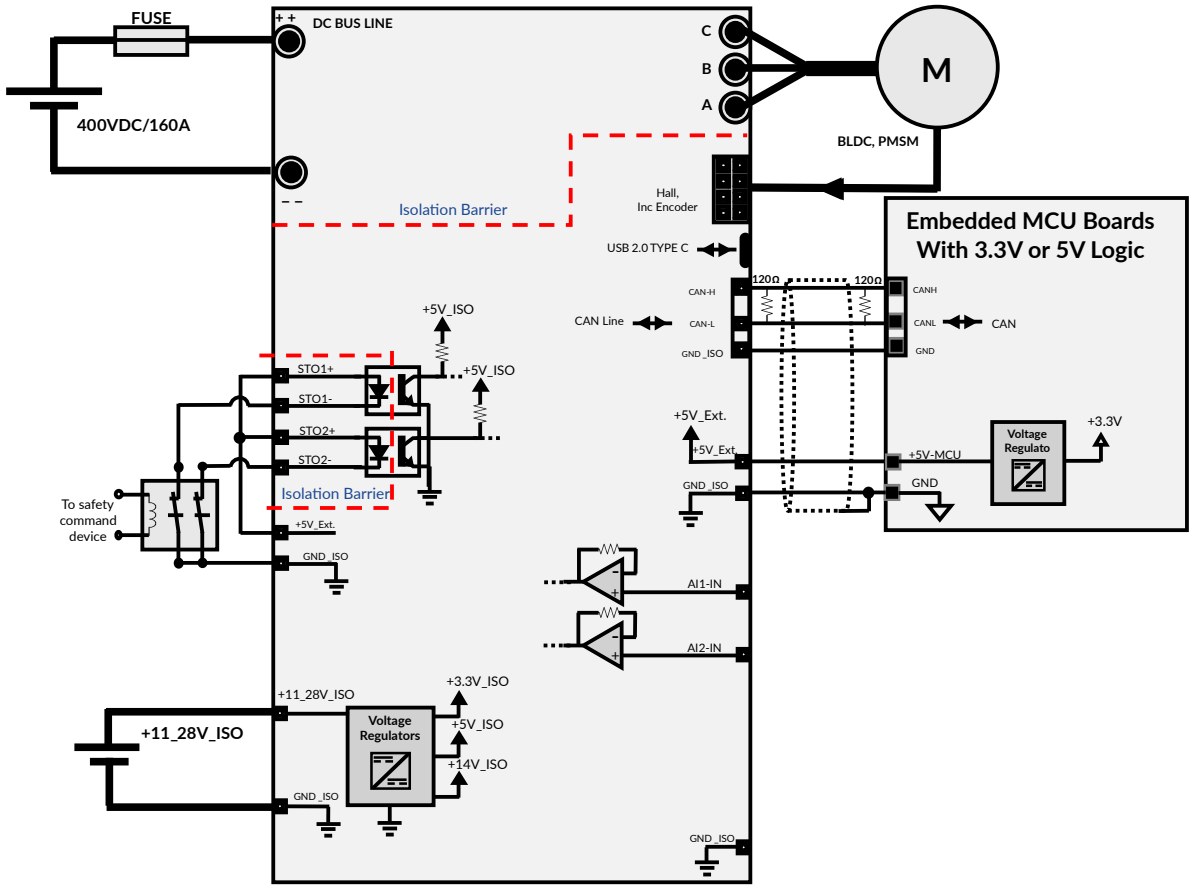

Figure 46. Complete wiring with an embedded MCU board commanding the drive over CANopen.

> **NOTE:** For reliable CAN communication, power the embedded MCU board from the drive's +5V Ext. supply and establish a single common ground, so that no ground loop is formed between the two boards. Bond the cable shield to ground, or to the MCU board ground, at one side only.

13.5 EMBEDDED MCU BOARD USING ETHERCAT

Figure 47 shows how the EtherCAT signals of section [2] are wired from an external board to the drive. Observe the routing and isolation requirements of Section 8.1: 100 Ω differential pairs and an isolating LAN transformer in each port's path.

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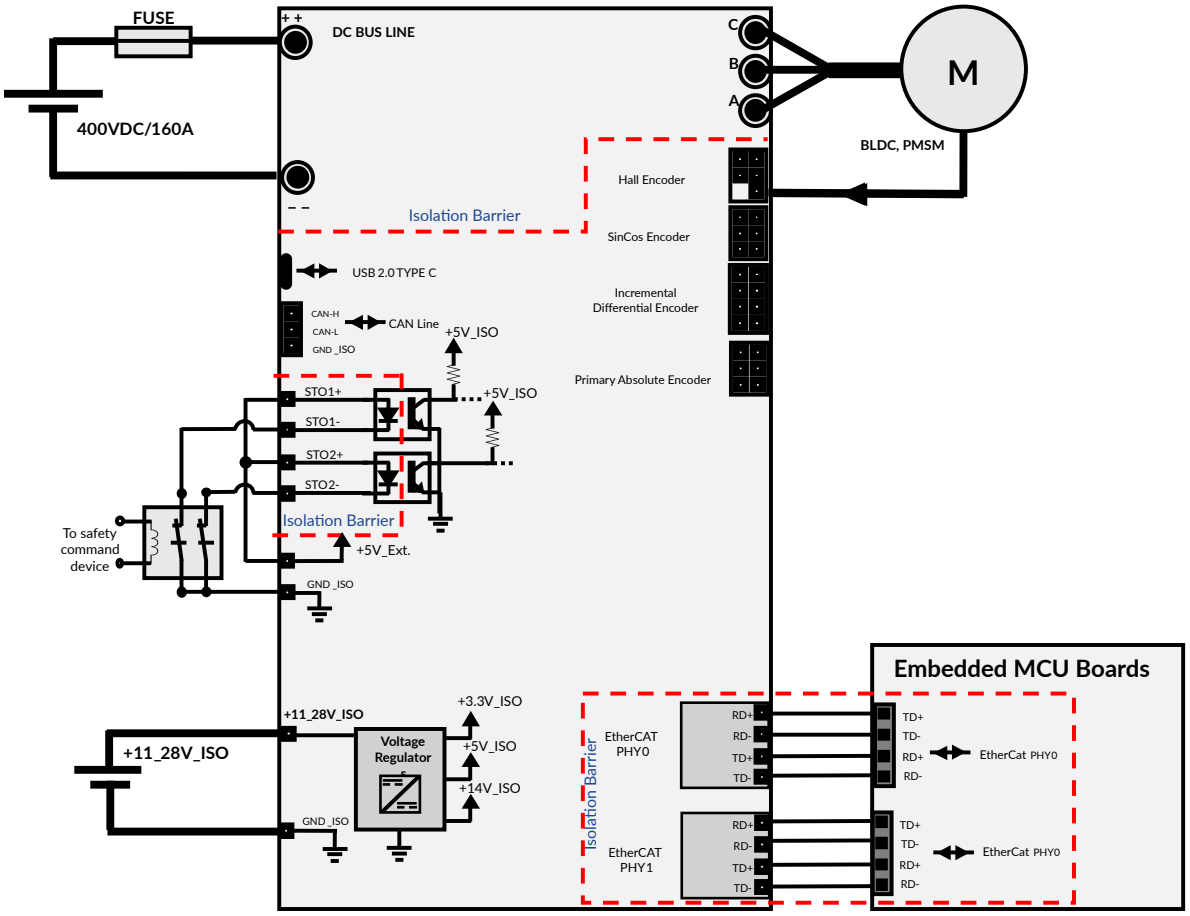

Figure 47. Complete wiring with an embedded board commanding the SOLO PRO 400-160 over EtherCAT.

13.6 GENERAL WIRING CONSIDERATIONS

Most of the noise problems seen in drive installations come down to two wiring mistakes, and both matter more here than on a small drive, because the motor and bus cables carry up to 160 A switched from 450 V.

Do not run feedback and power wiring together. Encoder, Hall and analogue signals are low-level. Motor phase and bus cables carry switched currents with fast edges. Running them in the same bundle, or parallel over any distance, couples that switching noise into the feedback and degrades both position and current measurement. Separate them, and cross at right angles where a crossing is unavoidable (Figure 48).

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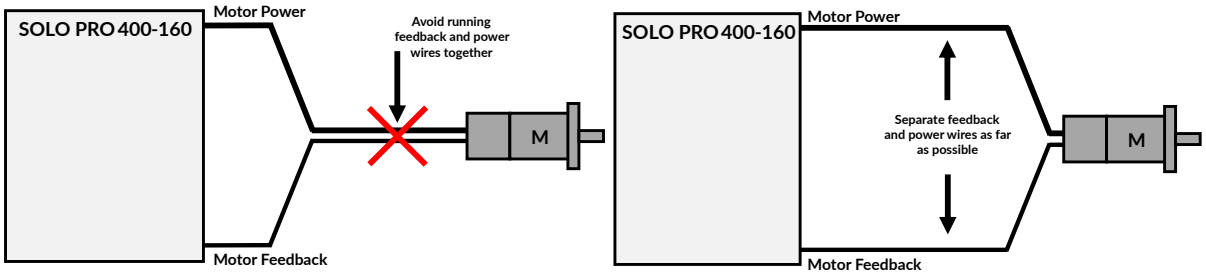

Figure 48. Keep feedback wiring away from power wiring.

Do not create ground loops. Connect GND_ISO to the ground of the external board in a **star** configuration, so that signal and power returns share a single reference point rather than several parallel paths (Figure 49). Where two ground paths exist between the same two units, the loop they enclose carries circulating current and injects switching noise directly into the feedback.

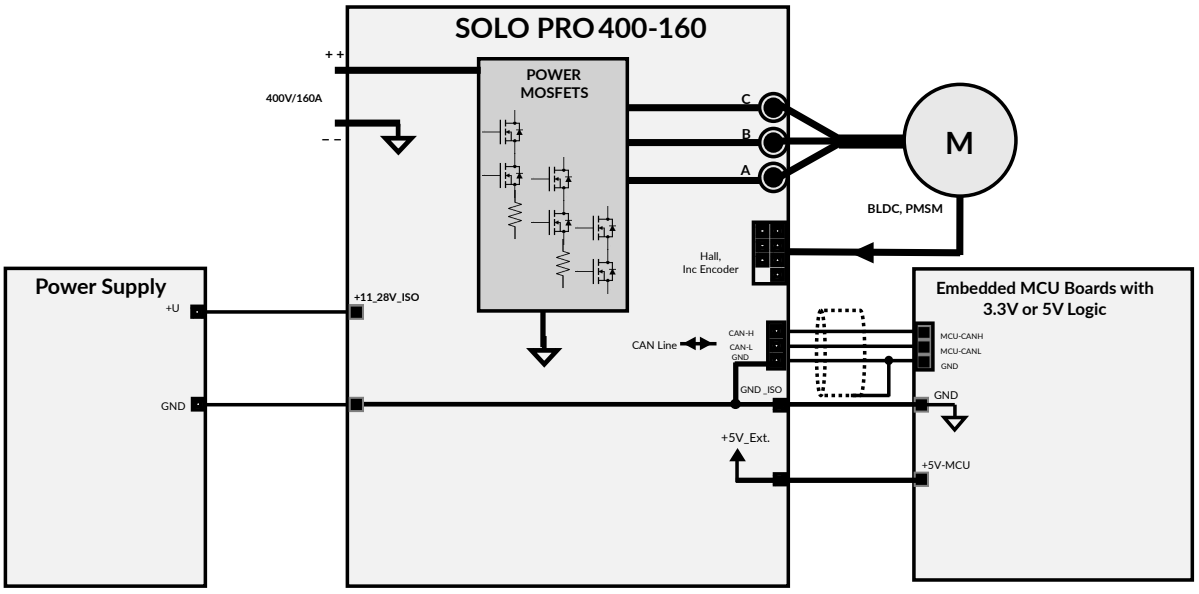

Figure 49. Improper ground wiring: parallel ground paths form a ground loop. Use a single star point instead.

The isolation barrier helps here but does not remove the problem. It keeps the DC bus out of the signal wiring entirely, which is why a laptop can be plugged into the USB port of a drive running at 450 V. It does nothing about a loop formed on the control side between the drive, a PLC and an MCU board that share more than one ground path.

Do not reference the logic supply to the bus. The star ground of the paragraph above is a ground on the *control* side: GND_ISO, the MCU board, the PLC, the sensor returns. It must stop there. Keep the 11–28 V logic supply galvanically isolated from the 150–450 V bus, and keep its

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0 V clear of DC– everywhere in the machine: at the drive, at the supply, and at any shared earth bar or cabinet stud where the two could meet unintentionally. Of the three rules in this section this is the one whose consequence is a hazard rather than a noise problem. The other two cost measurement quality. This one puts 450 V on the I/O connector, on the USB port and on everything wired to them (Section 5.1).

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14. GETTING STARTED / INITIAL SETUP

14.1 REQUIRED EQUIPMENT

Commissioning the drive for the first time requires:

1. The SOLO PRO 400-160.
2. A DC bus supply between 150 V and 450 V, sized for the intended motor current, with a fuse in the positive line and a means of isolating it.
3. A logic-side supply between 11 V and 28 VDC, **galvanically isolated from the DC bus** and with its barrier rated for the full bus voltage, with a 1 A fuse (Section 5.1).
4. A coolant circuit (pump, reservoir and heat exchanger) connected to the base plate and filled, with the air bled out (Section 6.2).
5. The STO wiring: a safety relay for production use, or the bypass of Section 11.3.3 for bench testing only.
6. A PT1000 sensor for J13: the motor's embedded sensor, or an external one mounted in the machine. The input cannot be left open (Section 9.5.2).
7. A USB Type-C cable, up to 5 m.
8. A PC running Windows 10/11 or Linux.
9. The SOLO Motion Terminal software, available from solomotorcontrollers.com.
10. Appropriate personal protective equipment and a meter rated for the bus voltage.

14.2 FIRST POWER-UP

Perform these steps in order, with the motor uncoupled from the machine, to confirm that the drive is operating correctly before it is committed to a load.

1. Confirm that the coolant circuit is connected, filled, bled and running.
2. Verify that the DC bus supply is between 150 and 450 VDC, and confirm its polarity at DC+ and DC− before connecting it. There is no reverse-polarity protection.
3. Confirm that every ground connection is secure.
4. **Verify the isolation between the logic supply and the bus before energising either.** With both supplies switched off and disconnected from the drive, measure between the logic supply's 0 V and each bus conductor in turn: both readings must be open circuit. Then

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measure between GND_ISO at the drive end of the loom (J3 pin 3M or 4M) and DC−. That must be open circuit too. Any continuity means the barrier is bridged somewhere in the installation. Find it and remove it before going further. The check takes a minute, and it is what keeps 450 V off the I/O connector (Section 5.1).

5. Wire the STO inputs (Section 11.3). The drive will not produce torque until they are energised.
6. Connect the motor to A, B and C for a three-phase motor, or to B and C for a DC brushed motor.
7. Connect the position sensor to J3 (Section 9), if one is used.
8. Connect a PT1000 to J13 (Section 9.5.2): the motor's embedded sensor if it has one, otherwise an external sensor mounted in the machine. **This input must not be left open**, or the drive stays in over-temperature protection and will not run.
9. Remove the USB cap and connect the cable between the drive and the PC.
10. Apply the **logic supply first**, with the DC bus still isolated. The drive boots and enumerates as a virtual COM port. The SOLO Motion Terminal can now reach it.
11. Open the SOLO Motion Terminal, connect to the drive, and confirm that the base-plate temperature reads a plausible ambient value. If it does not, stop and check the cooling circuit before energising the bus.
12. Apply the DC bus. Confirm in the Motion Terminal that the measured bus voltage matches the supply and that no fault is reported.
13. If a fault is reported, isolate the bus and check the supply voltage, the encoder wiring, the STO wiring and the motor connections before proceeding.

14.3 SOLO MOTION TERMINAL — INITIAL CONFIGURATION

The Motion Terminal is used to configure the drive for the connected motor and to tune it. It communicates with the drive over USB, and optionally over CANopen.

1. Download and install the software from solomotorcontrollers.com/SOLO-motion-terminal.
2. With the logic supply on and the USB cable connected, open the software.
3. Select the drive's COM port from the list and click **Connect**.
4. Open **Motor Setup** and enter the motor parameters: type, pole-pair count and rated current.
5. Run the automatic parameter identification and self-tuning routine.
6. Configure the position sensor and run its one-time calibration (Section 9).

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7. Log the base-plate temperature through a representative duty cycle and confirm it stays well below the 85 °C trip (Section 6.3).

From this point, follow the online guides at solomotorcontrollers.com to tune and calibrate the motor. The full tuning and calibration procedure is maintained online and is outside the scope of this manual.

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15. REGULATORY COMPLIANCE & APPROVALS

The compliance status below applies to the SOLO PRO 400-160. Compliance of the complete machine depends on the installation, the wiring and the enclosure. System-level certification is the responsibility of the machine builder.

Standard	Code	Class
UL 61800-5-1 / CSA C22.2 No. 274	File number E535351	See note below
Radiated emissions — enclosure port	CISPR 16-2-3, EN 55016-2-3	B*
Enclosure ports — electrostatic discharge	IEC / EN 61000-4-2	B*
Enclosure ports — radio-frequency electromagnetic field (AM)	IEC / EN 61000-4-3	B*
I/O and DC power ports — fast transients	IEC / EN 61000-4-4	B*
I/O and DC power ports — surges	IEC / EN 61000-4-5	B*
I/O and DC power ports — radio-frequency common mode	IEC / EN 61000-4-6	B*
Enclosure ports — power-frequency magnetic field	IEC / EN 61000-4-8	B*
Ingress protection	IEC / EN 60529	IP67
RoHS	2011/65/EU	—

* Achieved without any external filters.

> **NOTE:** The Decisive Voltage Class of the DC bus circuit under UL 61800-5-1 is stated as pending. Treat the bus terminals, the motor terminals and everything galvanically connected to them as hazardous live at all times, and rely on the galvanic isolation of the control side, not on a voltage-class claim, when designing the operator interface. That reliance is valid only while the logic-side supply is itself isolated from the bus (Section 5.1). The drive's internal barrier and the supply's barrier are in series, and the installation has whichever is weaker.

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16. REVISION HISTORY

Rev	Date	Firmware	Author	Change Description
V1.0.0	31/05/2023	0x0000B00F	SOLO Motor Controllers	First release
V1.0.1	2024-05	—	SOLO Motor Controllers	Preliminary user manual issued
01	2026-09-14	—	SOLO Motor Controllers	Restructured hardware user manual

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