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SOLO PRO 60-40 CUBE — HARDWARE USER MANUAL

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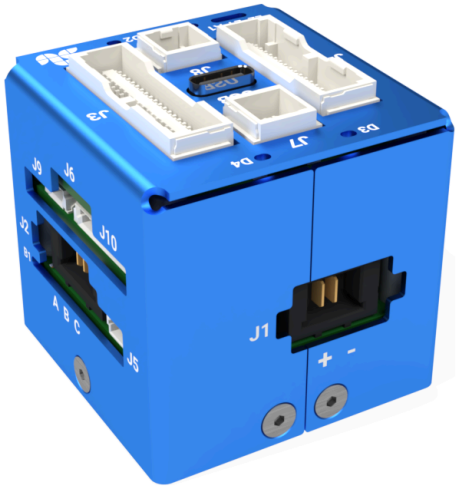
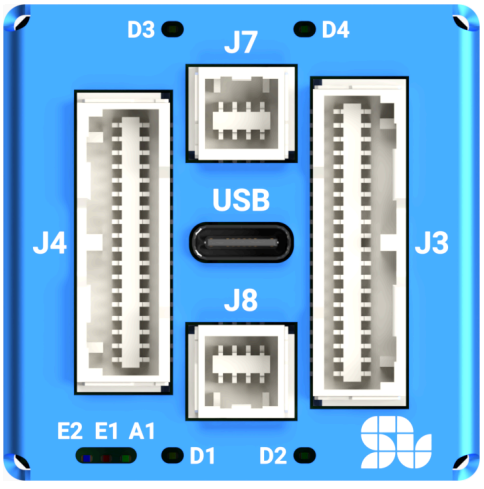
Control Module: SOLO SOM — dual-core C2000 DSP





EtherCAT CANopen

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1. ABOUT THIS DOCUMENT

1.1 PURPOSE AND SCOPE

The SOLO PRO 60-40 CUBE is a complete, ready-to-use motor drive for 8–60 VDC systems, delivering up to 40 A DC (25 Arms) of continuous output current and up to 1200 W of continuous output power from a 43.2 mm cube. 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 active brake chopper and the isolated Safe Torque Off and Safe Brake Off circuits are all built in and pre-qualified.

The user connects the 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, UART, CANopen or EtherCAT.

The drive is built around the **SOLO SOM**, SOLO's dual-core System-on-Module, which forms its digital control section. Practically, this means two independent processors work in parallel inside the drive:

- **Motion Core.** Programmed and maintained by SOLO, this core runs the production motor-control firmware: Field Oriented Control of the motor, the position-sensing interfaces, the protections, and the EtherCAT and CANopen communication stacks. It requires no firmware development. The user configures it through the SOLO Motion Terminal and commands it over the communication interfaces or the analogue inputs. For most users this is the whole drive.
- **User Core.** A second, fully open processor, programmed through the on-board JTAG connector and reachable from outside the drive over the SPI port on J4, available to run the user's own application inside the drive. It is optional: the drive is complete without it. Section 4 covers it.

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, Safe Brake Off and active brake chopper functions, and the wiring required to commission a system. It provides the information needed to integrate the SOLO PRO 60-40 CUBE into a machine.

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The reader is assumed to be familiar with electrical drives and industrial wiring practice. 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.

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:** Do not connect or disconnect any connector, motor lead or supply cable while the drive is powered. Wait until the DC bus has discharged and the **A1** LED has gone out before touching any terminal.

⚠ **WARNING:** Confirm the polarity of the DC supply at section [13] before switching it on. Do not rely on reverse-polarity protection: treat a reversed supply as capable of destroying the unit.

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

1.3 ABBREVIATIONS

Abbreviation	Definition
ADC	Analog-to-Digital Converter
AI / AO	Analogue Input / Analogue Output
BiSS-C	Bidirectional Serial Synchronous, protocol C (an open absolute-encoder standard)
BLDC	Brushless DC motor
BRKA / BRKB	Brake activation resistor inputs (external resistor sets the chopper threshold)
CAN	Controller Area Network

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Abbreviation	Definition
CLA	Control Law Accelerator (a co-processor within the TI DSP)
CLK	SPI clock input
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	Ground
GPI/O	General-Purpose Input / Output
INC	Incremental (encoder type)
JTAG	Joint Test Action Group (standard debug interface)
LSS	Layer Setting Services (CANopen — sets node ID and bit rate)
PMSM	Permanent Magnet Synchronous Motor
PTC	Positive Temperature Coefficient (here, the PT1000 sensor input)
PWM	Pulse-Width Modulation
RB1 / RB2	Brake resistor output terminals
RTD	Resistance Temperature Detector (e.g. PT1000)
SBO	Safe Brake Off
SIMO / SOMI	SPI serial data lines (Section 8.5 gives the direction of each)
SOM	System-on-Module
SPI	Serial Peripheral Interface
SPID	The SPI-D port of the dual-core DSP, brought out on J4 and belonging to the User Core
STEn	SPI chip-select (enable) input, active low
STO	Safe Torque Off
SVM	Space Vector Modulation
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	10/05/2024	0x0000B020	SOLO Motor Controllers	P/F pin description changed; certification table updated; temperature ratings updated per UL 61800-5-1; PT1000 formulas changed
01	2026-08-16	—	SOLO Motor Controllers	Restructured hardware user manual
02	2026-09-18	—	SOLO Motor Controllers	SPI port added on J4 as the User Core's external interface, and J4 becomes a 36-pin connector; J4 pinout, mating connector and absolute maximum ratings updated; SPI wiring examples added
03	2026-09-25	—	SOLO Motor Controllers	Encoder frequency specification corrected to the control module's ratings: 10 MHz for incremental encoders, and a 2–8 MHz clock range for BiSS-C

1.5 FURTHER INFORMATION

This manual covers the **hardware** of the SOLO PRO 60-40 CUBE. 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, **User Core** programming, 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 60-40 CUBE is a power converter capable of delivering 1200 W into a motor. It can produce sufficient energy to cause injury, fire, or violent unintended motion of a machine if misapplied. Review this section before applying power.

The supply input accepts 8 to 60 VDC. The signal-level pins are not all rated alike: the analogue and general-purpose I/O 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 5.5 before connecting it. Do not assume a common level.

> ⚠ **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.
>
> ⚠ **CAUTION:** Confirm the rating of a pin group in Section 5.5 before connecting it to 5 V or 12 V logic.
>
> ⚠ **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.
>
> ⚠ **CAUTION:** The +5V outputs are intended to supply position sensors and small external logic. Each is protected by a 2 A e-fuse. Do not use them as a general-purpose power source. Overloading them will trip the fuse or brown out the position feedback during operation.
>
> ⚠ **CAUTION:** Where the load can regenerate, as a high-inertia load, an overhauling axis or a rapid deceleration will, an external brake resistor on the active brake chopper is mandatory (Section 13). Without it, excessive regeneration raises the DC bus into over-voltage and can damage the drive or the power supply.
>
> ℹ **NOTE:** Limit encoder and Hall sensor cables to 3 m, and bond the cable shield to ground at one end only. Grounding a shield at both ends forms a ground loop that injects noise into the feedback signals.

The drive is a component intended for integration into a machine, not a finished product. The complete system must comply with the standards applicable to its market and application. Section 18 lists the standards to which the unit itself has been assessed.

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2.2 INTENDED USE

The SOLO PRO 60-40 CUBE is intended to drive and control DC brushed, BLDC, PMSM and EC coreless motors within its rated supply voltage, current and power, mounted inside a machine or an enclosure that provides the environmental and contact protection the application requires.

2.3 PROHIBITED USE

Do not use the SOLO PRO 60-40 CUBE in any of the following ways:

- Outside the rated supply voltage range of 8 to 60 VDC.
- Above the rated continuous output current or output power.
- With the STO function defeated in a production machine.
- In a safety-critical application without an independent, validated safety system.
- Outside the specified temperature range, or with the heatsink obstructed.
- In an environment subject to condensation or to conductive dust and contamination.
- As a general-purpose 5 V or 12–48 V supply. The auxiliary outputs are for sensors and the brake circuit only.

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3. PRODUCT OVERVIEW

3.1 WHAT THE DRIVE PROVIDES

The SOLO PRO 60-40 CUBE packs a complete motor drive (power stage, digital control, position sensing, industrial communications and functional-safety inputs) into a 43.2 × 43.2 × 43.6 mm cube with an integrated heatsink. The user supplies only the DC power, the motor and the command source.

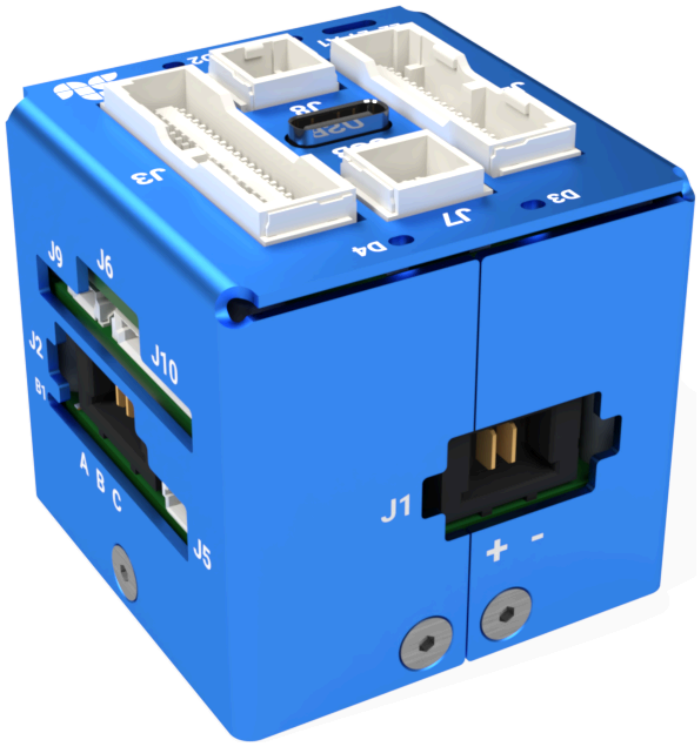

Figure 1. The SOLO PRO 60-40 CUBE — a complete 8–60 VDC, 40 A motor drive in a 43.2 mm cube, with all three connector faces in view: the top face (J3, J4, J7, J8 and the USB port), the right face (J2, J5, J6, J9, J10) and the left face (J1, the DC supply input).

The unit is complete in itself. The inverter, gate drivers, current and voltage measurement, bus capacitance, brake chopper and isolated safety inputs are all inside it, so there is no power-electronics design work and no firmware to write. It is also unusually dense: a 1200 W drive with EtherCAT, CANopen, USB, UART, SPI, six position-sensor interfaces and two isolated safety functions in 81 cm^3, small enough to mount at the motor rather than in a cabinet.

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Finally, it accepts commands in whatever form the machine offers, as an analogue voltage or PWM, or over USB, UART, CANopen or EtherCAT. Which one is used is set in configuration, not by ordering a different part.

3.2 KEY FEATURES

Power and control

- Wide supply range, 8 to 60 VDC
- 40 A DC / 25 Arms continuous output current, 1200 W 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, over-current and over-temperature protections
- Active brake chopper with an activation voltage set by an external resistor
- Isolated **Safe Torque Off (STO)**, dual channel, with a feedback output
- Isolated **Safe Brake Off (SBO)** for a mechanical holding brake

Interfaces

- USB 2.0 Type-C, UART, CAN bus with CANopen (DS402), and EtherCAT with two on-board PHYs
- Analogue command inputs AI1 and AI2 (0–5 V or PWM above 5 kHz) and three analogue outputs
- Eight general-purpose I/O (GPI/O1–8) and three general-purpose inputs (GPI1–3)
- Position sensing: digital Hall, single-ended incremental (two channels), differential incremental, primary and secondary BiSS-C absolute, and Sin/Cos
- PT1000 temperature-sensor input

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- +5 V / 1 A auxiliary output for external modules and sensors
- On-board JTAG connector for User Core debugging, and an SPI port on J4 that reaches the User Core from outside the drive
- Sleep mode with a consumption of approximately 2.6 mA

3.3 FUNCTIONAL BLOCK DIAGRAM

Figure 2 shows the functional block diagram of the drive: the interfaces it presents to the machine on the left and right, the three-phase inverter and supply terminals at the bottom, and the galvanic isolation barrier (dashed) that separates the EtherCAT ports and the STO/SBO inputs from the rest of the unit.

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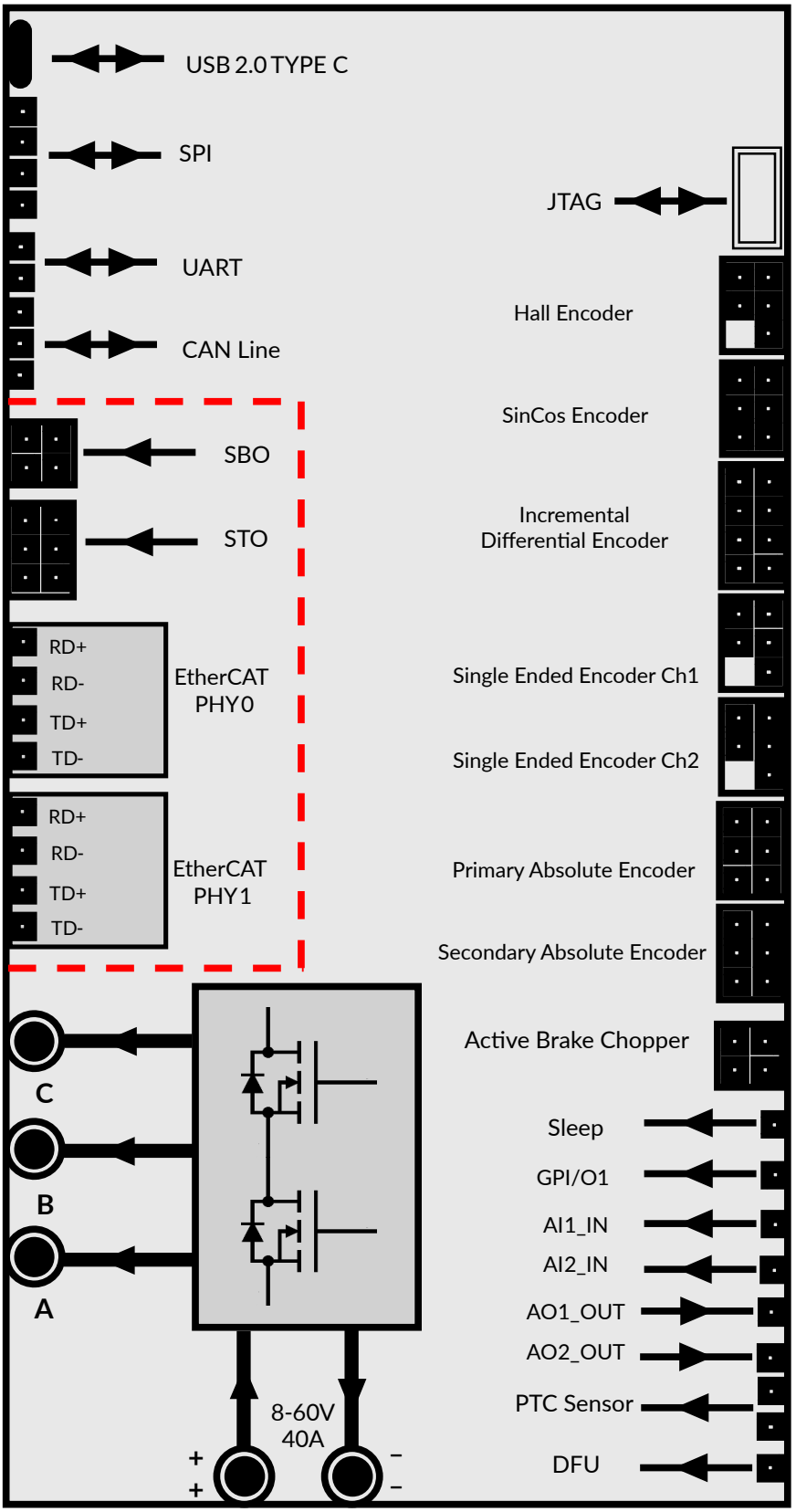

Figure 2. Functional block diagram of the SOLO PRO 60-40 CUBE.

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3.4 ARCHITECTURE

Figure 3 shows the internal architecture. The **SOLO SOM** control module sits at the centre and performs all digital control, with its Motion Core and User Core running side by side and exchanging data over the inter-processor link (IPC). Around it are the gate drivers and power MOSFETs, the phase current and voltage measurement chain, the bus capacitance, the brake chopper, the switched +5V_OUT_P and +5V_OUT_S encoder supplies, the two EtherCAT PHYs with their magnetics, and the optically isolated STO and SBO front end with its own regulators on the isolated side of the barrier.

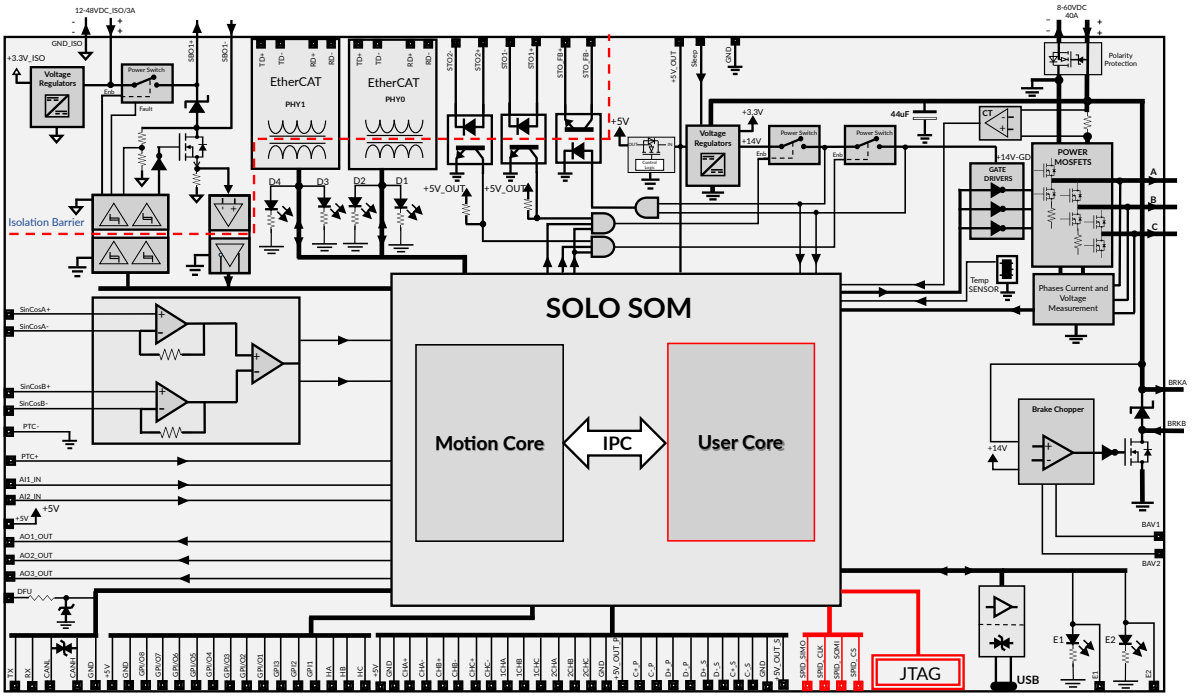

Figure 3. Architecture of the SOLO PRO 60-40 CUBE. The User Core and the resources assigned to it are drawn in red.

Two details in the diagram govern how the unit is wired:

- **The isolation barrier** (dashed) encloses the EtherCAT ports and the STO/SBO section. Everything else, from the supply and the motor to the encoders, CAN, UART, SPI, USB and the analogue and general-purpose I/O, shares the drive's single non-isolated ground.
- **The encoder supplies are switched.** +5V_OUT_P and +5V_OUT_S are fed through controlled power switches, which allows the firmware to power-cycle a position sensor and protects the drive against a sensor fault.

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3.5 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.

3.5.1 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. The current measurement resolution of this drive is 80 mA.
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.

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.

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- **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.

3.5.2 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 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.

3.6 ORDERING INFORMATION

Field	Value
Product name	SOLO PRO 60-40 CUBE
Supply voltage range	8–60 VDC
Continuous output current	40 ADC / 25 Arms
Continuous output power	1200 W
Control module	SOLO SOM
Form factor	Cube, 43.2 × 43.2 × 43.6 mm, wall 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 a 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, USB and UART	Programmed and maintained by SOLO; not user-modifiable
User Core	The user's own application, running inside the drive, and the SPI port on J4	Fully open; programmed through the JTAG connector

For the majority of applications only the Motion Core matters: it is configured through the SOLO Motion Terminal and commanded over the analogue inputs or the communication interfaces, and the User Core is left unused. The drive is complete and fully functional in that configuration.

Where an application needs custom logic close to the motor (a machine-specific state machine, a bespoke command interpretation, supervisory logic that must survive a communication dropout) the User Core allows it to run inside the drive rather than on an external microcontroller. The two cores exchange data over an on-chip inter-processor link, so user code runs without interrupting the motor-control loops. Access is through the **JTAG connector, section [14] J6** (Section 7.11), using Code Composer Studio and a standard TI XDS-class debug probe, or the general-purpose JTAG programmer offered by SOLO.

The User Core is not sealed inside the drive. The **SPI port on J4** is the DSP's SPID module, and it is wired to the User Core rather than to the Motion Core, so an external controller has explicit access to the application the user has programmed. What travels over it is whatever that application defines; the User Core in turn exchanges data with the Motion Core over the on-chip link, so motor functions can be reached through the user's own code where an application calls for it.

Because each unit on an SPI bus is selected by its own chip-select line, several drives can share one bus. That makes an SPI network of User Cores possible: the drives in a machine can pass data between themselves and the host over a single set of wires, independently of the

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fieldbus that commands the motion side. Section 8.5 covers the port and its wiring.

> 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 supply voltage range (continuous)	VDC	8 to 60
Active brake chopper activation voltage (default)	VDC	61
Software over-voltage activation voltage	VDC	63
DC bus under-voltage limit	VDC	7
Maximum continuous output current	ADC	40
Maximum continuous output current	Arms	25
Maximum continuous output power	W	1200
Internal bus capacitance	µF	44
Switching frequency (output PWM frequency)	kHz	8 to 80
+5V auxiliary output (J4, J3)	—	+5 V, 1 A, 2 A e-fuse protected
+5V_OUT_P / +5V_OUT_S absolute-encoder supplies	—	+5 V, 200 mA each
SBO supply input (J9)	—	12–48 VDC isolated, 3 A
Sleep-mode current consumption	mA	≈ 2.6

The three voltage thresholds above form a graded response to a rising DC bus. The **brake chopper** engages first, at approximately 61 V by default, and dissipates returned energy in the external brake resistor. If the bus keeps rising, the **software** over-voltage protection trips at 63 V and the firmware disables the output and reports the fault. The **absolute maximum** at the supply terminals is +66 V (Section 5.5). Because the margin between the nominal 60 V maximum supply and these thresholds is narrow, size the brake resistor for the worst-case regeneration of the application (Section 13).

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The internal bus capacitance is 44 µF. That is deliberately small for a drive of this rating, since it is what lets the unit fit in a 43.2 mm cube, and it leaves very little capacity to absorb regenerated energy. Where the load can return energy, the bus is protected by the brake chopper and its external resistor, not by the bus capacitor.

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 the thermal budget of the installation.

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, 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 — incremental	MHz	10
Encoder clock frequency — absolute (BiSS-C)	MHz	2 (min) to 8 (max)
Current measurement resolution	mA	80
Modulation	—	Space Vector Modulation (SVM)
Motion profiling	—	Embedded S-curve for position and speed

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The loop timing reflects the cascade of Section 3.5: 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.

5.3 THERMAL & ENVIRONMENTAL

Description	Units	Value
Board temperature range	°C	-20 to +120
Heatsink (base) temperature range	°C	-20 to +85
Cooling system	—	Natural convection
Ingress protection (IP)	—	None — open board-level assembly with heatsink

The drive is cooled by natural convection through its integrated heatsink. The two ratings above are the limits at the board and at the heatsink base respectively. They are not interchangeable: the board tolerates up to 120 °C, but the heatsink base must remain at or below 85 °C, and it is the heatsink temperature that governs how much continuous current the unit can deliver in a given enclosure. Provide sufficient free air around the heatsink, or add forced-air cooling, so that the base temperature stays within range at the intended duty. The unit has no ingress protection, so provide environmental protection at the enclosure level as the application requires.

5.4 MECHANICAL

Description	Units	Value
Size (H × W × D)	mm	43.2 × 43.2 × 43.6
Weight	g	Contact SOLO
Mounting	—	4 × M2.5, 6 mm deep, on a 34 × 34 mm pattern
Form factor	—	Wall mount

5.5 ABSOLUTE MAXIMUM VOLTAGE RATINGS

This table specifies, for each section and pin group, the maximum voltage that may be applied. The section numbers refer to Figures 5, 6 and 7.

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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.

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Section	Pin / Signal	Dir	Units	Min	Typical Max	Absolute Max
[13]	Supply input	Input	VDC	+8	+60	+66
[16]	Sleep	Input	VDC	0	+60	+60
[5]	SinCOS A±, SinCOS B±	Input	VDC	0	+4.5	+5
[5]	PTC+ / PTC-	Input	VDC	0	+3.3	+3.75
[1]	DFU	Input	VDC	0	+5	+5.25
[1]	AI1, AI2	Input	VDC	0	+5	+5.25
[15]	STO1 / STO2 (Safe Torque Off inputs)	Input	VDC	0	+5 / +12	+5.25 / +26
[1], [5]	+5V_OUT (auxiliary supply)	Output	VDC	+4.95	+5.0	+5.05
[5]	HA, HB, HC	Input	VDC	0	+5	+5.5
[5]	GPI1, GPI2, GPI3	Input	VDC	0	+5	+5.05
[5]	C+_S, C-_S, D+_S, D-_S (secondary BiSS-C)	Input	VDC	0	+12	+12.25
[5]	C+_P, C-_P, D+_P, D-_P (primary BiSS-C)	Input	VDC	0	+12	+12.25
[5]	CHA±, CHB±, CHC± (differential incremental)	Input	VDC	0	+12	+12.25
[5]	1CHA, 1CHB, 1CHC (single-ended encoder 1)	Input	VDC	0	+5	+5.5
[5]	2CHA, 2CHB, 2CHC (single-ended encoder 2)	Input	VDC	0	+5	+5.5
[1]	CANH, CANL	—	VDC	-2	—	+7
[1]	RX (UART); CLK, STEn, SOMI (SPI)	Input	VDC	0	+5	+5.5
[1]	TX (UART); SIMO (SPI)	Output	VDC	0	+5	+5.5
[1]	GPI/O1-GPI/O4	In/Out	VDC	0	+5	+5.5
[1]	GPI/O5-GPI/O8	In/Out	VDC	0	+5	+5.5

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6. MECHANICAL INTEGRATION

6.1 DIMENSIONS AND MOUNTING

The SOLO PRO 60-40 CUBE is a wall-mount cube measuring 43.2 × 43.2 × 43.6 mm. The fully dimensioned drawing is given in Figure 4. All dimensions are in millimetres. Use it to lay out the mounting points, the cable entries and the keep-out zones in the enclosure.

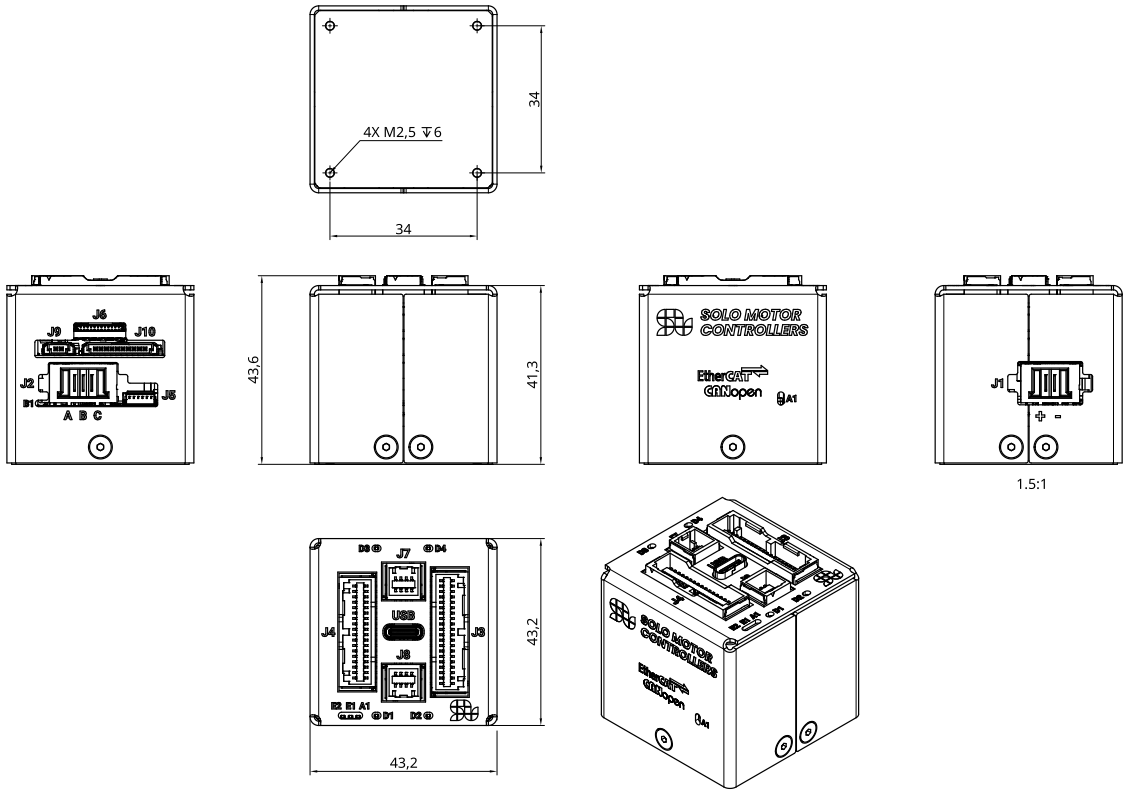

Figure 4. SOLO PRO 60-40 CUBE mechanical drawing — all dimensions in millimetres.

The unit is fixed through **four M2.5 threaded holes, 6 mm deep, on a 34 × 34 mm square pattern** in the mounting face. Use all four, and take the thread depth into account when selecting screw length: a screw that bottoms out will not clamp, and one that is too long can damage the assembly.

Three of the six faces carry connectors: the top, the right and the left (Sections 7.2 to 7.4). Allow clearance on all three for the mating connectors and their cable bends, and route the cables so that they do not press on the housings.

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6.2 THERMAL CONSIDERATIONS

The continuous current the drive can deliver in a given installation is limited by the heatsink base temperature, not by the board rating. Keep the base at or below 85 °C at the intended duty cycle and ambient temperature, allowing for the switching frequency in use. Losses in the power stage rise with switching frequency, so a design running at 80 kHz needs more thermal headroom than the same design at 8 kHz.

Because the unit is a compact cube cooled by natural convection, mounting it against a thermally conductive surface materially increases the current it can sustain. Where the enclosure allows, bolt the mounting face to a metal panel and treat that panel as part of the cooling path.

> ⚠ **CAUTION:** The heatsink reaches temperatures that can cause burns. Allow the unit to cool before handling it 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 **20 numbered sections**. Each section is a connector, a terminal or an indicator. Nineteen of them are spread over the three connector faces, which Figure 1 shows at once. They are numbered on the individual face figures that open Sections 7.2 to 7.4, and each multi-pin connector is given its own pinout. The twentieth, section [20], is the power LED of the SOLO SOM, which shows through the face carrying the SOLO logo.

Section(s)	Designator	Face	Content
[1]	J4	Top	GPI/O, analogue I/O, CAN, UART, SPI, DFU, E1/E2 outputs — 36-pin
[2], [4], [7], [9]	D3, D4, D2, D1	Top	EtherCAT link and activity LEDs
[3]	J7	Top	EtherCAT port — 8-pin
[5]	J3	Top	Encoders, Hall, Sin/Cos, GPI1-3, PT1000 — 40-pin
[6]	—	Top	USB 2.0 Type-C
[8]	J8	Top	EtherCAT port — 8-pin
[10], [11], [12]	A1, E1, E2	Top	Power, error and heartbeat LEDs
[13]	J1	Left	DC supply input, + and -
[14]	J6	Right	JTAG connector — 12-pin
[15]	J10	Right	STO and SBO connector — 10-pin
[16]	J5	Right	Active brake chopper and Sleep — 6-pin
[17]	B1	Right	Brake activation LED
[18]	J2	Right	Motor outputs A, B, C
[19]	J9	Right	SBO supply input — 2-pin
[20]	A1	Logo face	SOLO SOM power LED

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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.

7.2 TOP SIDE — SECTIONS [1] TO [12]

The top face carries the signal and communication connectors, the USB port and all of the indicator LEDs. Figure 5 shows its twelve sections.

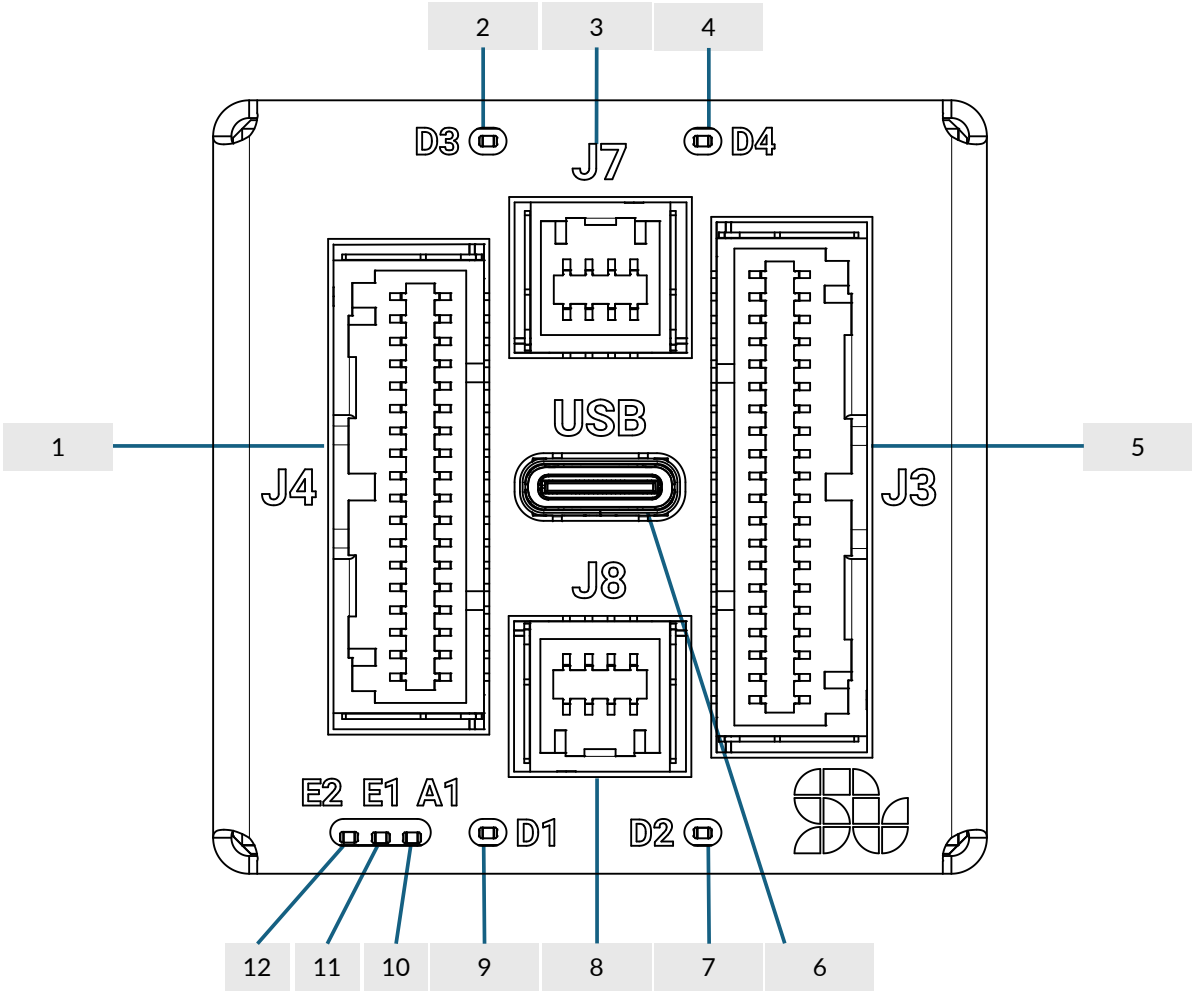

Figure 5. Top face — sections [1] to [12].

The two large connectors dominate the face: **J4** on one side carries the general-purpose, analogue and serial-communication signals, and **J3** on the other carries every position-sensor interface. Between them sit the USB Type-C port and the two EtherCAT connectors J7 and J8, each flanked by its pair of status LEDs.

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7.3 RIGHT SIDE — SECTIONS [14] TO [19]

The right face carries the motor output, the safety connectors, the brake chopper and the debug connector. Figure 6 shows its six sections.

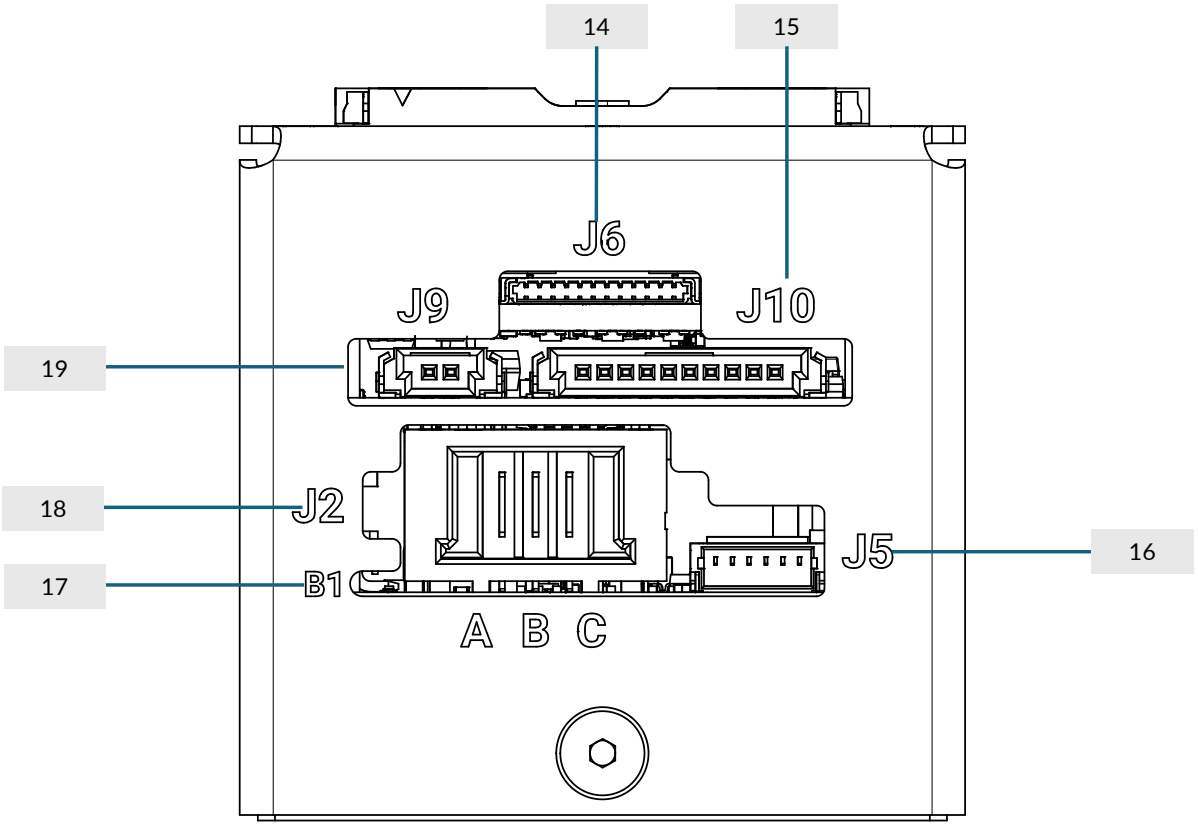

Figure 6. Right face — sections [14] to [19].

7.4 LEFT SIDE — SECTION [13]

The left face carries only the DC supply input, J1. Keeping the supply on its own face separates the high-current wiring from the signal wiring, which is the single most effective step in keeping switching noise out of the feedback. Figure 7 shows the section.

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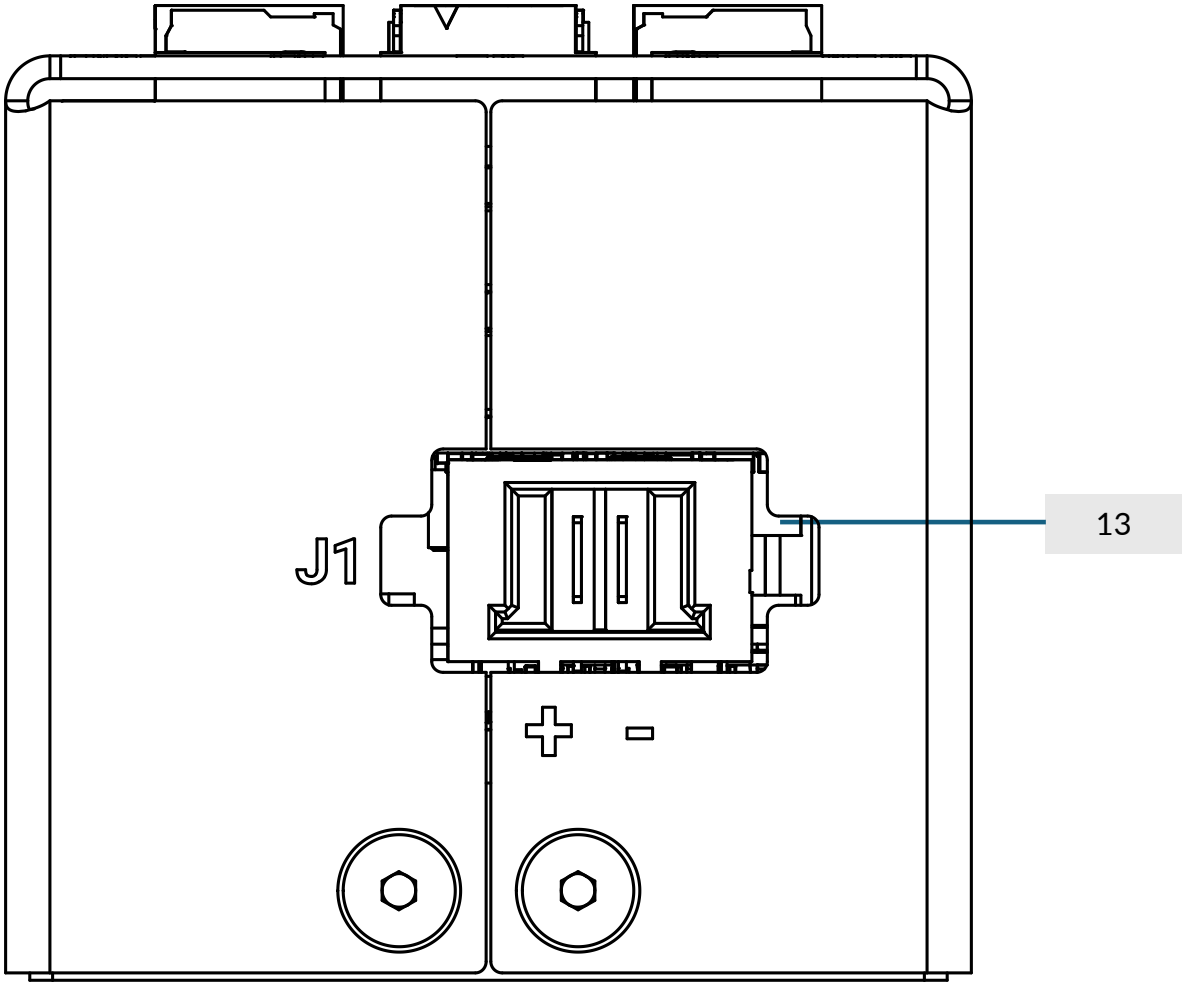

Figure 7. Left face — section [13], the DC supply input J1.

7.5 SECTION [1] J4 — GPIO, ANALOGUE, CAN, UART AND SPI CONNECTOR

This 36-pin connector carries everything the machine needs for analogue and digital interfacing: the eight general-purpose I/O, the CAN bus, the UART and SPI serial ports, the analogue inputs and outputs, the E1/E2 indicator outputs, the DFU forced-boot input, and seven +5 V auxiliary supply pins with their grounds. Figure 8 gives the pin numbering as seen on the connector.

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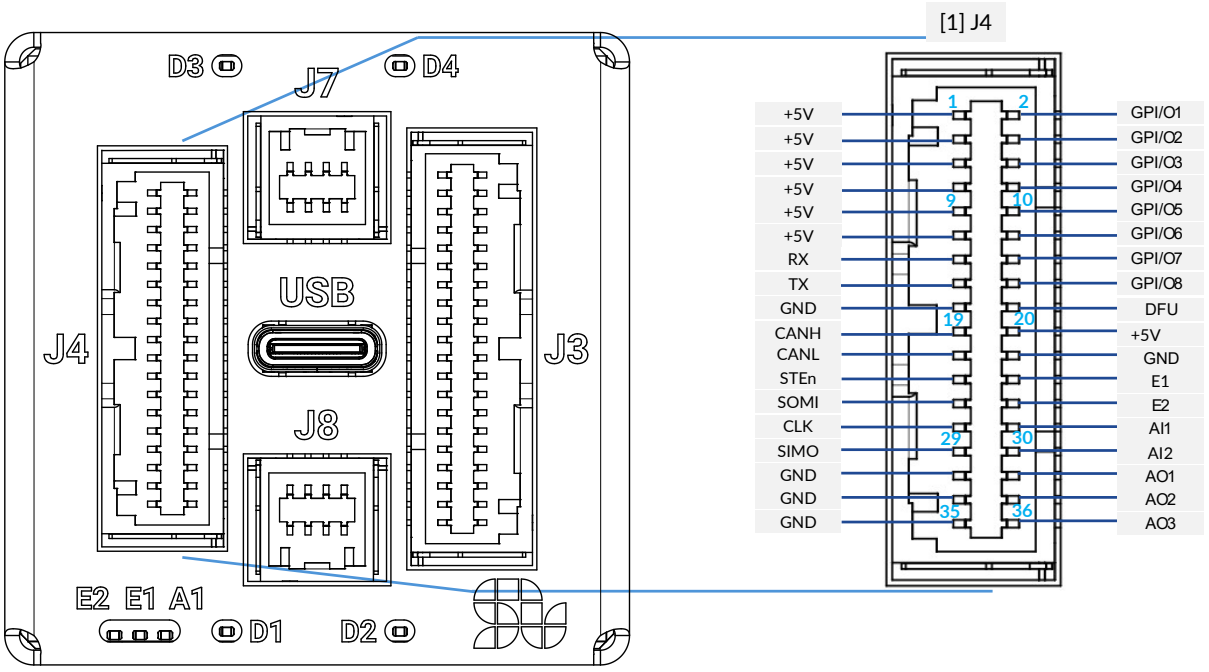

Figure 8. Section [1], connector J4 — GPIO, analogue, CAN, UART and SPI connector.

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Pin	Name	Description / Notes	Dir
1	+5V	+5 V output (2 A e-fuse)	O
2	GPI/O1	General-purpose I/O 1	I/O
3	+5V	+5 V output (2 A e-fuse)	O
4	GPI/O2	General-purpose I/O 2	I/O
5	+5V	+5 V output (2 A e-fuse)	O
6	GPI/O3	General-purpose I/O 3	I/O
7	+5V	+5 V output (2 A e-fuse)	O
8	GPI/O4	General-purpose I/O 4	I/O
9	+5V	+5 V output (2 A e-fuse)	O
10	GPI/O5	General-purpose I/O 5	I/O
11	+5V	+5 V output (2 A e-fuse)	O
12	GPI/O6	General-purpose I/O 6	I/O
13	RX	UART receive	I
14	GPI/O7	General-purpose I/O 7	I/O
15	TX	UART transmit	O
16	GPI/O8	General-purpose I/O 8	I/O
17	GND	Ground	—
18	DFU	Forced-boot input — hold at +5 V to force the bootloader	I
19	CANH	CAN bus high	I/O
20	+5V	+5 V output (2 A e-fuse)	O
21	CANL	CAN bus low	I/O
22	GND	Ground	—
23	STEn	SPI chip-select input, active low	I
24	E1	Error indicator output	O
25	SOMI	SPI serial data input	I
26	E2	Heartbeat indicator output	O
27	CLK	SPI clock input, up to 50 MHz	I

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Pin	Name	Description / Notes	Dir
28	AI1	Analogue input 1 (0–5 V or PWM)	I
29	SIMO	SPI serial data output	O
30	AI2	Analogue input 2 (0–5 V or PWM)	I
31	GND	Ground	—
32	AO1	Analogue output 1 (0–5 V)	O
33	GND	Ground	—
34	AO2	Analogue output 2 (0–5 V)	O
35	GND	Ground	—
36	AO3	Analogue output 3 (0–5 V)	O

The GND pins are the ground and analogue return reference of the drive. When sending analogue commands, the ground of the commanding device (PLC, Arduino, Raspberry Pi or similar) must be connected to one of these pins, so that both ends share a reference for the analogue voltage. Without it the analogue command has no defined value.

The +5V pins are a single +5 V / 1 A rail brought out on several contacts, protected by a 2 A e-fuse. Use it to supply sensors, a potentiometer or a small external board. Do not draw a general load from it.

The SPI pins, STEn, SOMI, CLK and SIMO (pins 23, 25, 27 and 29), are the DSP's SPID port, which belongs to the **User Core** and not to the Motion Core: they carry whatever the user's own application defines. Section 4 explains the division between the two cores and Section 8.5 describes the port and how to wire it.

> ⚠ **CAUTION:** Every signal on this connector is rated to +5 V maximum (Section 5.5). Do not drive any of these pins from 12 V logic.

7.6 SECTION [5] J3 — ENCODER CONNECTOR

This 40-pin connector accepts every position-sensor family the drive supports, on one housing, together with the PT1000 temperature input and three general-purpose digital inputs. Figure 9 gives the pin numbering as seen on the connector.

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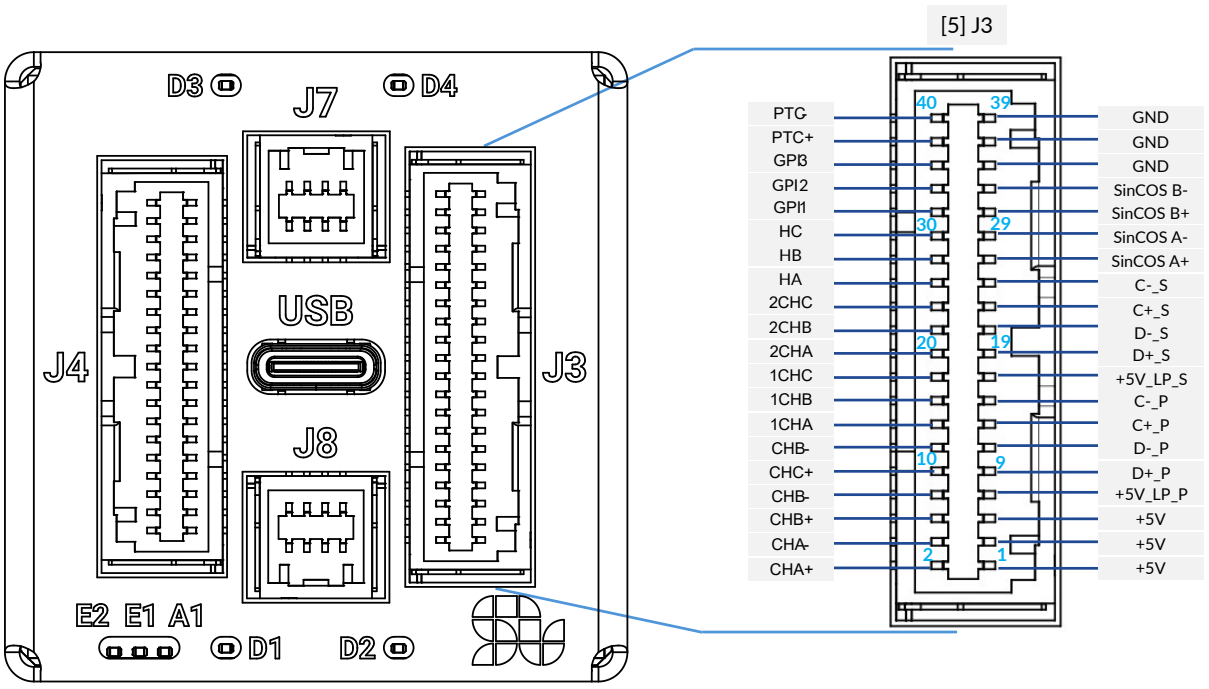

Figure 9. Section [5], connector J3 — encoder connector.

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Pin	Name	Description / Notes	Dir
1	+5V	+5 V output (2 A e-fuse)	O
2	CHA+	Differential incremental encoder, channel A+	I
3	+5V	+5 V output (2 A e-fuse)	O
4	CHA–	Differential incremental encoder, channel A–	I
5	+5V	+5 V output (2 A e-fuse)	O
6	CHB+	Differential incremental encoder, channel B+	I
7	+5V_OUT_P	Switched +5 V / 200 mA for the primary absolute encoder	O
8	CHB–	Differential incremental encoder, channel B–	I
9	D+_P	Primary BiSS-C data +	I/O
10	CHC+	Differential incremental encoder, index C+	I
11	D–_P	Primary BiSS-C data –	I/O
12	CHC–	Differential incremental encoder, index C–	I
13	C+_P	Primary BiSS-C clock +	O
14	1CHA	Single-ended encoder 1, channel A	I
15	C–_P	Primary BiSS-C clock –	O
16	1CHB	Single-ended encoder 1, channel B	I
17	+5V_OUT_S	Switched +5 V / 200 mA for the secondary absolute encoder	O
18	1CHC	Single-ended encoder 1, index C	I
19	D+_S	Secondary BiSS-C data +	I
20	2CHA	Single-ended encoder 2, channel A	I
21	D–_S	Secondary BiSS-C data –	I
22	2CHB	Single-ended encoder 2, channel B	I
23	C+_S	Secondary BiSS-C clock +	O
24	2CHC	Single-ended encoder 2, index C	I
25	C–_S	Secondary BiSS-C clock –	O
26	HA	Hall sensor A	I
27	SinCOS A+	Sin/Cos encoder, Sin+	I

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Pin	Name	Description / Notes	Dir
28	HB	Hall sensor B	I
29	SinCOS A-	Sin/Cos encoder, Sin-	I
30	HC	Hall sensor C	I
31	SinCOS B+	Sin/Cos encoder, Cos+	I
32	GPI1	General-purpose digital input 1	I
33	SinCOS B-	Sin/Cos encoder, Cos-	I
34	GPI2	General-purpose digital input 2	I
35	GND	Ground	—
36	GPI3	General-purpose digital input 3	I
37	GND	Ground	—
38	PTC+	PT1000 sensor +	I
39	GND	Ground	—
40	PTC-	PT1000 sensor - (internally connected to ground)	—

Three separate +5 V supplies appear on this connector, and they are not interchangeable:

- **+5V** (pins 1, 3, 5) is the general auxiliary rail, +5 V / 1 A behind a 2 A e-fuse. Use it for Hall sensors, incremental encoders and other logic-level sensors.
- **+5V_OUT_P** (pin 7) and **+5V_OUT_S** (pin 17) are switched outputs of 200 mA each, dedicated to the primary and secondary absolute encoders. Because they are switched, the firmware can power-cycle an absolute encoder to recover it from a fault.

Use these outputs only to supply position sensors. The maximum encoder or Hall-sensor cable length is 3 m. Bond the cable shield to ground at one end only to improve immunity against external EMI.

> **i NOTE:** The mechanical drawings label the two switched encoder supplies **+5V_LP_P** and **+5V_LP_S**. They are the same two pins as **+5V_OUT_P** and **+5V_OUT_S** used throughout this manual and in the architecture diagram.

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7.7 SECTIONS [3], [8] J7 AND J8 — ETHERCAT PORTS

The two EtherCAT ports are identical 8-pin connectors. Each carries one transmit pair and one receive pair, with the remaining four contacts tied to the port's EtherCAT ground. Figure 10 gives the pin numbering as seen on the connector.

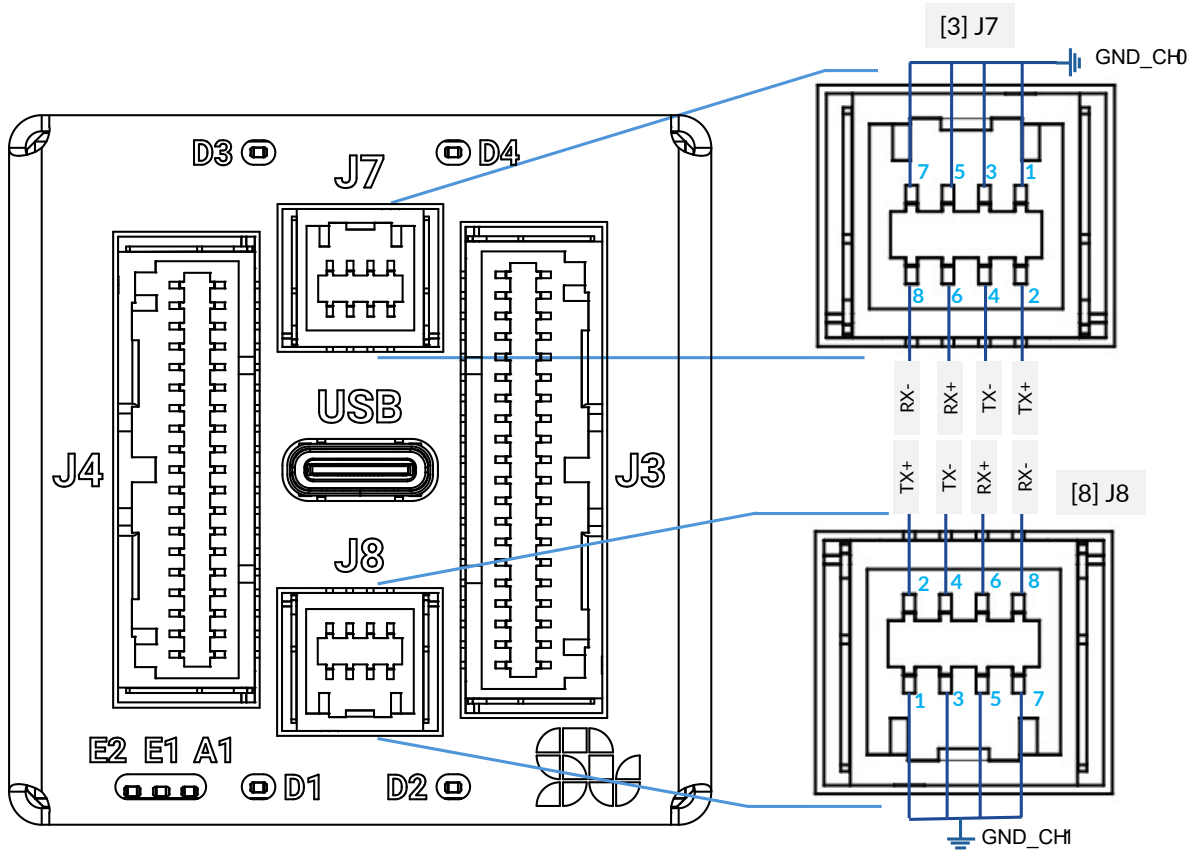

Figure 10. Sections [3] and [8], connectors J7 and J8 — the two EtherCAT ports.

Pin	Name	Description / Notes	Dir
1	GND_CH	EtherCAT ground for this port	—
2	TX+	Transmit data +	O
3	GND_CH	EtherCAT ground for this port	—
4	TX-	Transmit data -	O
5	GND_CH	EtherCAT ground for this port	—
6	RX+	Receive data +	I
7	GND_CH	EtherCAT ground for this port	—
8	RX-	Receive data -	I

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Two ports allow drives to be daisy-chained: data enters one port, passes through the node and leaves by the other, with no external switch. Section 8.1 gives the routing and isolation requirements.

7.8 SECTION [6] — USB 2.0 TYPE-C

Name	Description / Notes	Dir
USB	Virtual COM Port, or device firmware upgrade	I/O

Parameter	Value
USB standard	USB 2.0 Full-Speed
Connector	USB Type-C (reversible orientation)
Modes	Virtual COM Port for the SOLO Motion Terminal; DFU for firmware updates
Maximum recommended cable length	3 m
Power	The USB cable does not power the drive; the external 8–60 VDC supply is always required

In digital mode the port presents itself to the host as a Virtual COM Port, which allows the drive to be operated in standalone digital control mode over a single USB cable, with only the motor connected to the output. The Type-C connector is reversible, which makes it robust for industrial use.

> ⚠ **CAUTION:** The drive must be powered from its external DC supply (8–60 V) whenever it is connected to a host over USB. The USB cable supplies no power to the unit.

7.9 SECTION [13] J1 — SUPPLY INPUT

Name	Description / Notes	Dir
+	Positive voltage input	—
-	Negative voltage input (ground)	—

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This is the DC supply input of the drive, on the left face (Figure 7). It accepts any DC voltage from 8 to 60 V continuously, chosen to suit the voltage rating of the connected motor. The maximum rated input is 60 V. The drive enters over-voltage protection above approximately 61 V, which is also where the brake chopper engages by default. To move that threshold, see Section 13.3.

Fit a fuse in the positive supply line, rated for the current the application draws and for the prospective fault current of the supply. Every complete wiring example in Section 16 shows this fuse.

> ⚠ **WARNING:** Verify the polarity of the supply before switching it on. Do not rely on reverse-polarity protection; a reversed supply must be assumed to destroy the unit.

7.10 SECTION [18] J2 — MOTOR OUTPUTS

Name	Description / Notes	Dir
A	Motor output 1	O
B	Motor output 2	O
C	Motor output 3	O

These terminals connect to the motor windings:

- **Three-phase motors (BLDC, PMSM, EC coreless).** Connect A, B and C to the three motor phase wires.
- **DC brushed motors.** Only B and C are used. Connect them to the two motor leads.

> ⚠ **WARNING:** Never connect a power supply cable to a motor output. This will cause serious damage to the unit.

7.11 SECTION [14] J6 — JTAG CONNECTOR

This 12-pin single-row connector gives a standard TI debug probe direct access to the DSP for loading and debugging User Core code (Section 4). Figure 11 gives the pin numbering as seen on the connector.

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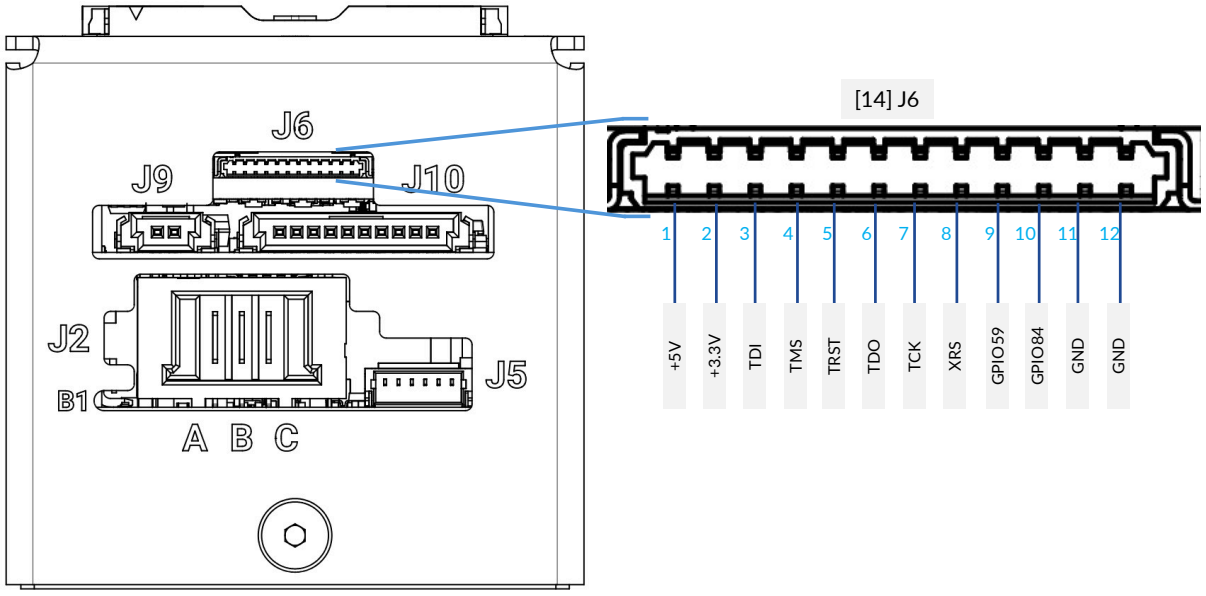

Figure 11. Section [14], connector J6 — the JTAG connector.

Pin	Name	Description / Notes	Dir
1	+5V	+5 V reference	O
2	+3.3V	+3.3 V reference	O
3	TDI	Test data in	I
4	TMS	Test mode select	I
5	TRST	Test reset (active low)	I
6	TDO	Test data out	O
7	TCK	Test clock	I
8	XRS	External DSP reset	I
9	GPIO59	DSP GPIO59	I/O
10	GPIO84	DSP GPIO84	I/O
11	GND	Ground	—
12	GND	Ground	—

The five core JTAG signals (TDI, TDO, TMS, TCK, TRST) plus the device reset XRS come directly from the corresponding DSP pins, so the port is a standard IEEE 1149.1 interface. It is compatible with the TI XDS100V2, XDS110 and XDS200 debug probes; SOLO also offers a

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general-purpose JTAG programmer for faster bring-up. A minimal connection needs only TDI, TDO, TMS, TCK, GND and the 3.3 V reference, with TRST and XRS recommended for reliable reset control. Figure 12 shows the port wired out to an external probe.

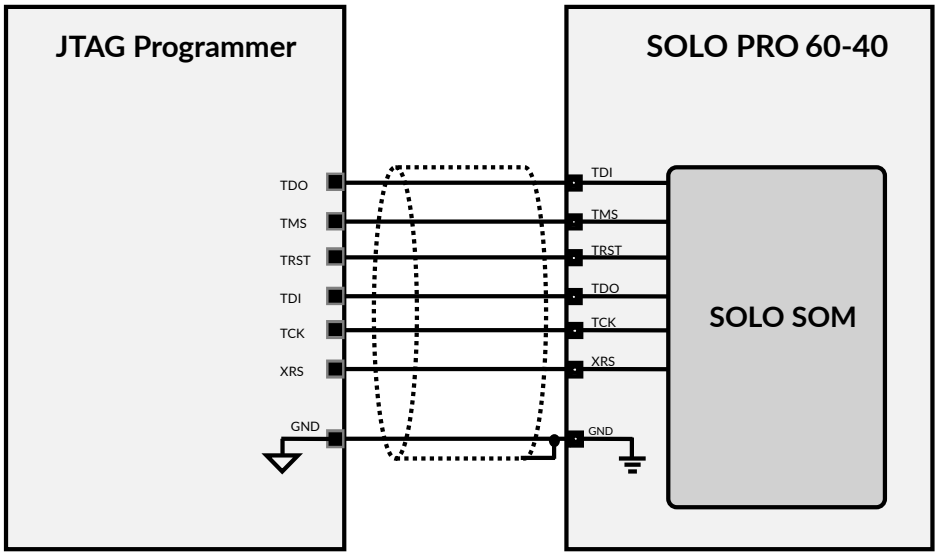

Figure 12. Wiring the JTAG port to an external debug probe.

> **NOTE:** Pins 1 (+5 V) and 2 (+3.3 V) are voltage references for the probe's level detection, not power inputs to the drive. Use the 3.3 V reference to set the probe's I/O voltage. Do not back-feed the unit from the probe.

7.12 SECTION [15] J10 — STO AND SBO CONNECTOR

This 10-pin connector carries both isolated safety functions: the two Safe Torque Off request channels with their feedback pair, and the two Safe Brake Off control lines. Figure 13 gives the pin numbering as seen on the connector.

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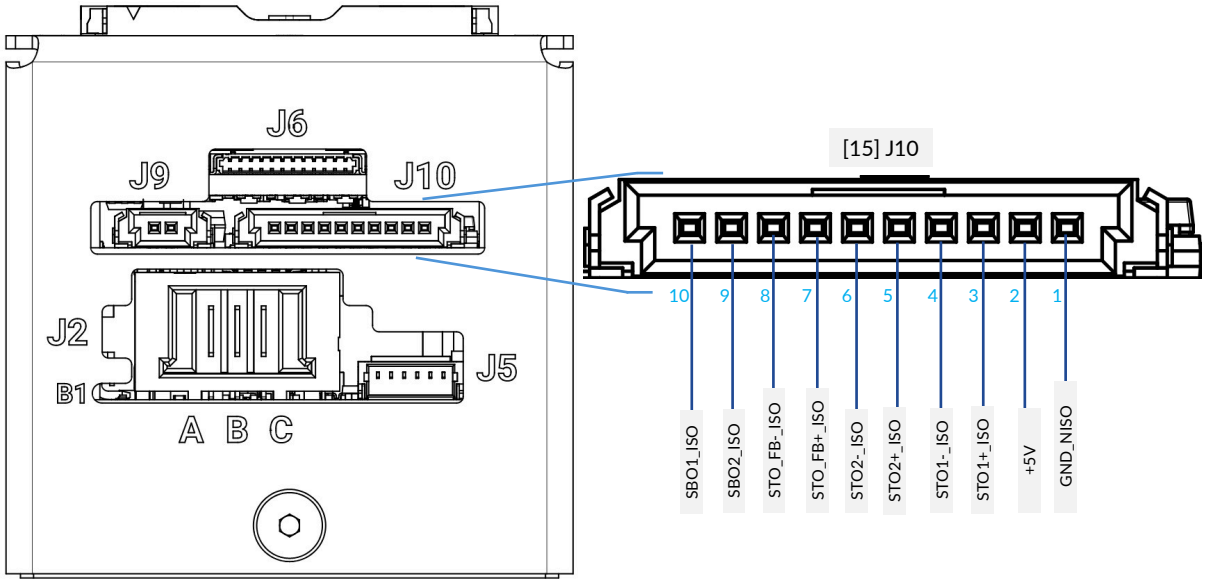

Figure 13. Section [15], connector J10 — the STO and SBO connector.

Pin	Name	Description / Notes	Dir
1	GND_NISO	Ground of the drive (non-isolated)	—
2	+5V	+5 V output, non-isolated — for commissioning only	O
3	STO1+_ISO	STO channel 1 positive input (optically isolated)	I
4	STO1-_ISO	STO channel 1 negative input (optically isolated)	I
5	STO2+_ISO	STO channel 2 positive input (optically isolated)	I
6	STO2-_ISO	STO channel 2 negative input (optically isolated)	I
7	STO_FB+_ISO	STO feedback +	O
8	STO_FB-_ISO	STO feedback -	O
9	SBO2_ISO	SBO negative input (optically isolated)	I
10	SBO1_ISO	SBO positive input (optically isolated)	I

Pins 3 to 10 are optically isolated from the rest of the drive; pins 1 and 2 are not, and exist so that the STO inputs can be energised from the drive itself during bench commissioning. Section 11 covers the STO function and its three wiring options. Section 12 covers SBO.

> ⚠ **WARNING:** Using the non-isolated +5 V on pin 2 to feed the STO inputs defeats the isolation and the safety function. It is for testing and initial commissioning only, never for production.

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7.13 SECTION [16] J5 — BRAKE CHOPPER AND SLEEP CONNECTOR

This 6-pin connector carries the active brake chopper terminals, the external resistor that sets the chopper's activation voltage, and the Sleep input. Figure 14 gives the pin numbering as seen on the connector.

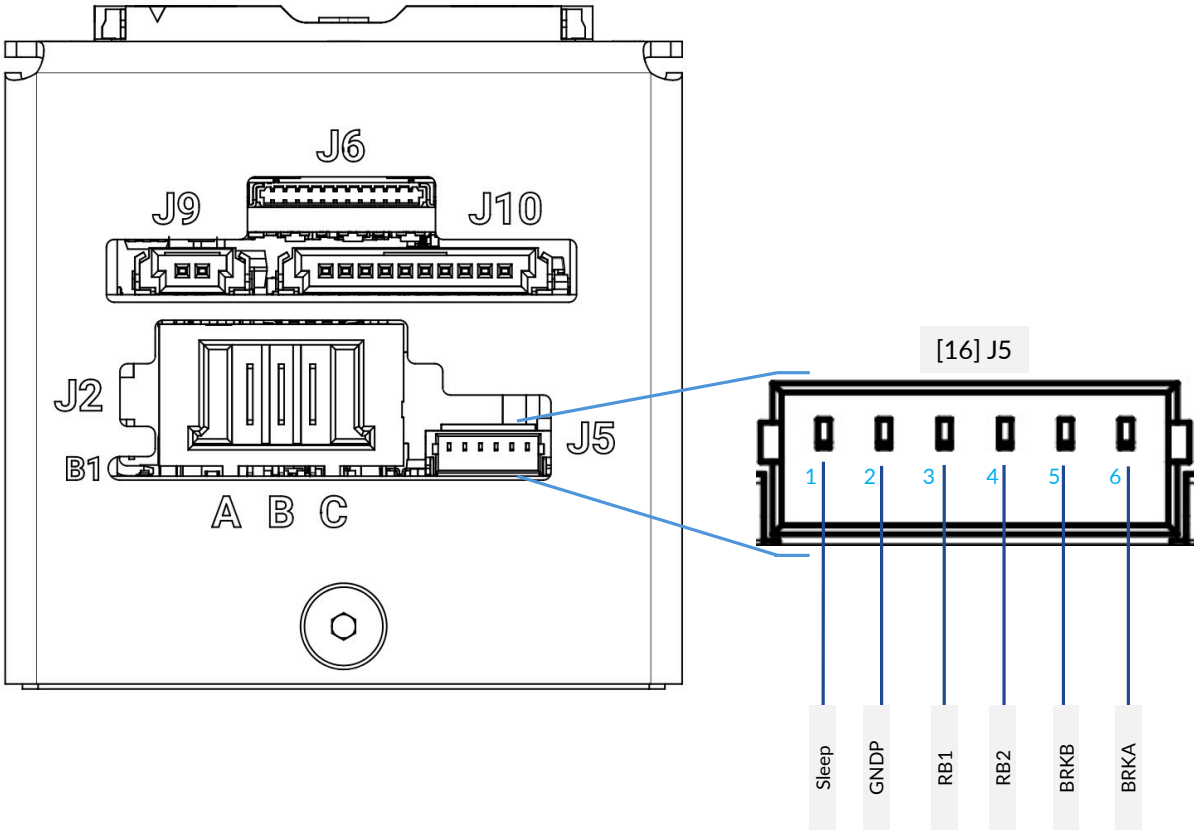

Figure 14. Section [16], connector J5 — the active brake chopper and Sleep connector.

Pin	Name	Description / Notes	Dir
1	Sleep	Sleep-mode input — pull to ground to enter sleep	I
2	GNDP	Ground (power)	—
3	RB1	Brake chopper output, positive	O
4	RB2	Brake chopper output, negative	O
5	BRKB	Brake activation voltage — external resistor input 2	I
6	BRKA	Brake activation voltage — external resistor input 1	I

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The brake resistor connects across RB1 and RB2. The resistor that sets the activation threshold connects across BRKA and BRKB. Section 13 covers both, including the formula for the threshold-setting resistor. The Sleep input is covered in Section 14.1.

7.14 SECTION [19] J9 — SBO SUPPLY INPUT

This 2-pin connector is a separate, galvanically isolated supply input for the mechanical holding brake, rated 12 to 48 VDC at up to 3 A. It powers only the brake through the SBO switch. It does not supply the drive. Section 12 covers the function. Figure 15 gives the pin numbering as seen on the connector.

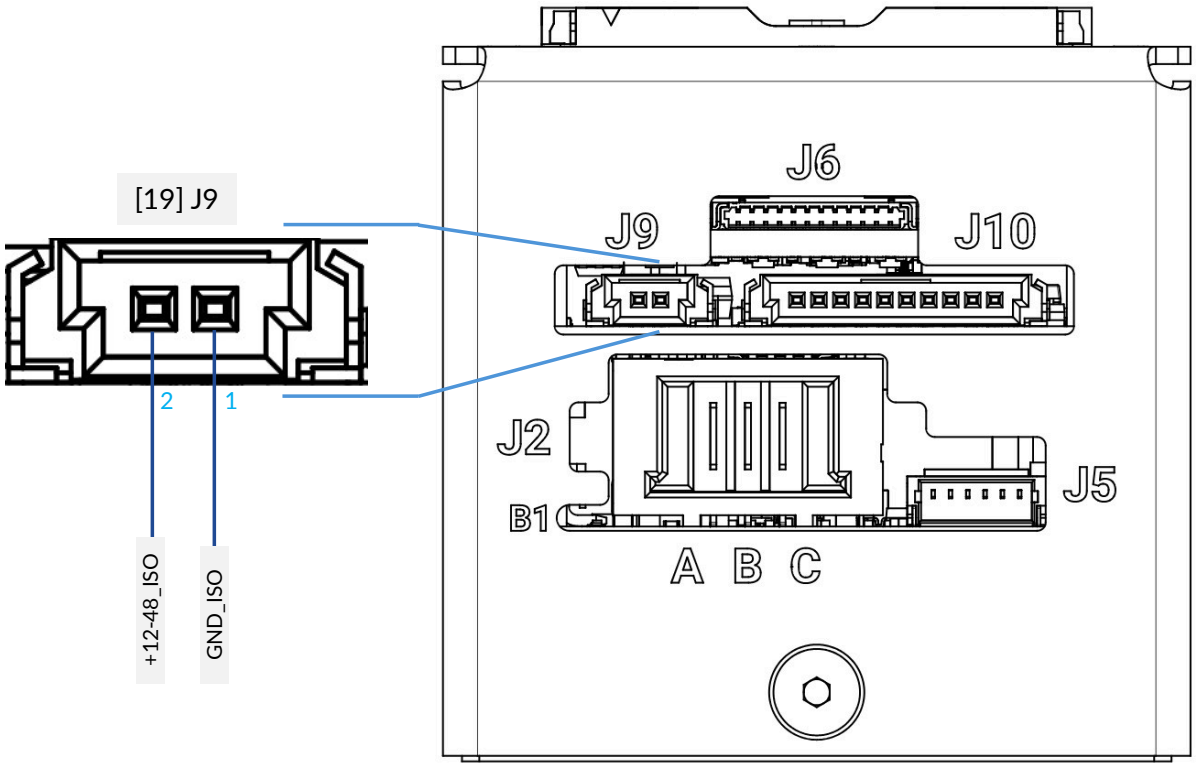

Figure 15. Section [19], connector J9 — the isolated supply input for the Safe Brake Off circuit.

Pin	Name	Description / Notes	Dir
1	GND_ISO	Isolated ground of the brake supply	—
2	+12-48V_ISO	Isolated 12–48 VDC supply for the mechanical brake	I

> ⚠ **WARNING:** The SBO supply input has no reverse-polarity protection. Verify the polarity before switching it on.

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7.15 MATING CONNECTOR PART NUMBERS

Section	Connector	Manufacturer	Connector on the drive	Mating connector
[1]	J4 (36-pin)	Molex	5054333681	5054323601
[5]	J3 (40-pin)	Molex	5054334081	5054324001
[3], [8]	J7, J8 (8-pin)	Molex	5054330881	5054320801
[13]	J1 (supply)	Samtec	UMPT-02-01-X-RA-WT-XX	UMPS-02-05.5-G-V-S-W-TR
[18]	J2 (motor)	Samtec	UMPT-03-01-X-RA-WT-X	UMPS-03-05.5-G-V-S-W-TR
[16]	J5 (6-pin)	TE Connectivity	2367196-6	2367198-6

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8. NETWORKING & COMMUNICATIONS

The drive can be commanded over four digital interfaces. All of them are built in: two EtherCAT PHYs, a CAN transceiver, a USB 2.0 Type-C port and a UART, with no external transceiver circuitry required. A fifth serial port, SPI, is brought out on the same connector as the UART, but it reaches the User Core rather than the Motion Core, and Section 8.5 covers it on that footing.

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 **DP83822** 100BASE-TX PHYs connected to the EtherCAT Slave Controller inside the DSP, brought out at sections [3] J7 and [8] J8. Two ports allow drives to be daisy-chained without an external switch, and both ports sit on the isolated side of the barrier shown in Figure 3.

Four LEDs report the state of the two ports. Figure 16 shows where they sit on the top face, next to the connector each pair belongs to.

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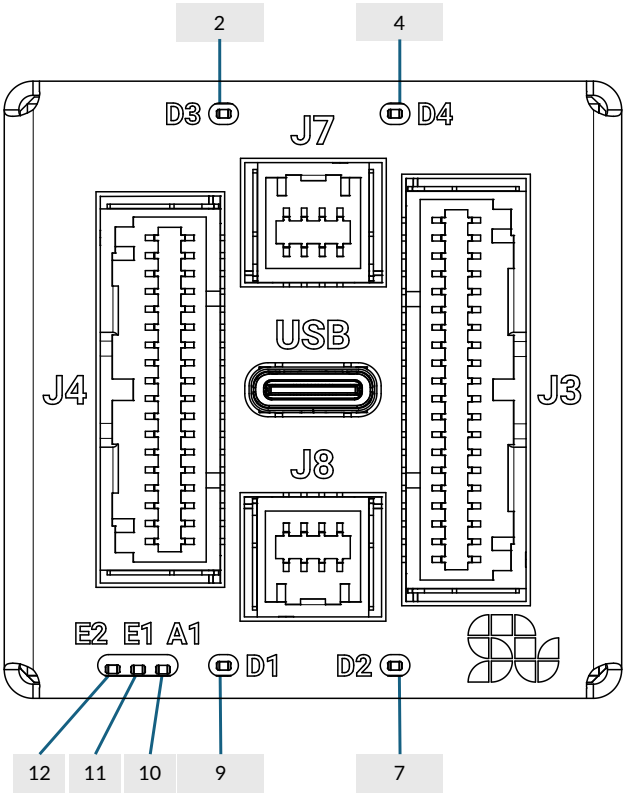

Figure 16. Sections [2], [4], [7] and [9] — the EtherCAT link and activity LEDs.

Section	LED	Function
[2]	D3	LED_0_P1 — link status, port near J7
[4]	D4	LED_1 / GPIO1_P1 — activity, port near J7
[9]	D1	LED_0_P0 — link status, port near J8
[7]	D2	LED_1 / GPIO1_P0 — activity, port near J8

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. When wiring them:

- Route each transmit and receive pair (TX+/TX–, RX+/RX–) 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. Use an RJ45 connector with integrated magnetics, or a discrete LAN transformer between the port and the jack.
- Bond the cable shielding to ground to improve immunity against external EMI.
- Keep each EtherCAT segment within the 100 m limit of 100BASE-TX.

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Figure 17 shows the wiring from an EtherCAT controller to the drive through the isolating magnetics.

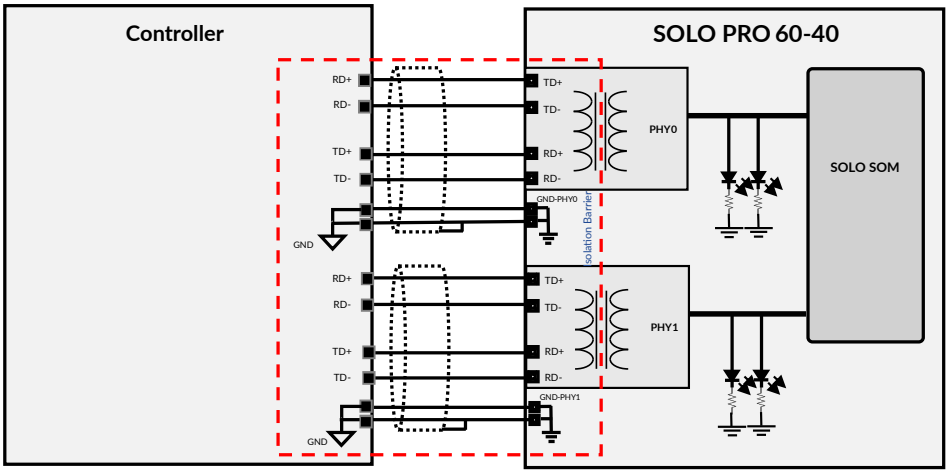

Figure 17. EtherCAT wiring between the controller and the SOLO PRO 60-40 CUBE.

8.2 CANOPEN (DS402)

CAN is a robust, lower-speed bus common in vehicles and in industrial systems. The drive implements CANopen with the DS402 motion profile, which is the standard method for commanding a drive over CAN. The transceiver is on board, so only CANH and CANL, J4 pins 19 and 21, are routed to a connector.

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 is not isolated. Where galvanic isolation between the drive and the CAN network is required, as it commonly is when nodes sit at different ground potentials, add an isolated transceiver such as the ISO1042 externally.
- Bond the cable shielding to ground, or to the CAN host ground, at one end only.

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Through CANopen, every function of the drive can be accessed and controlled digitally, over the two-wire connection of Figure 18. For the object dictionary and the profile detail, refer to the CANopen user manual on the SOLO website.

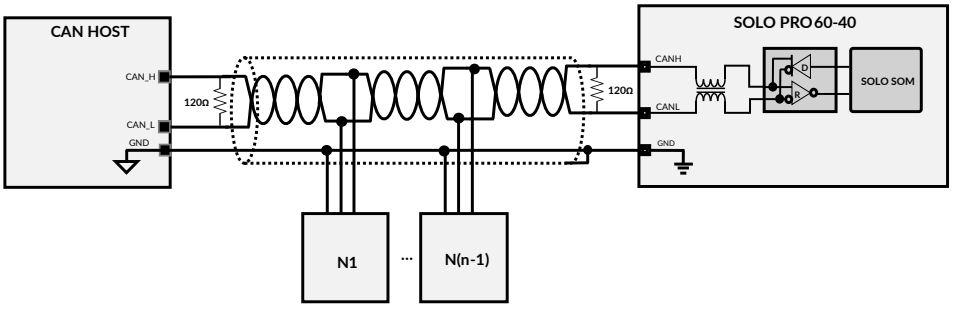

Figure 18. CAN bus wiring (CANH / CANL to the network connector).

8.3 USB

The USB 2.0 Type-C port, section [6], is the simplest way to control the drive: a single cable to a PC or a host controller, as shown in Figure 19, 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 14.2), and it is the interface the SOLO Motion Terminal uses to configure the drive, tune the loops and monitor live signals.

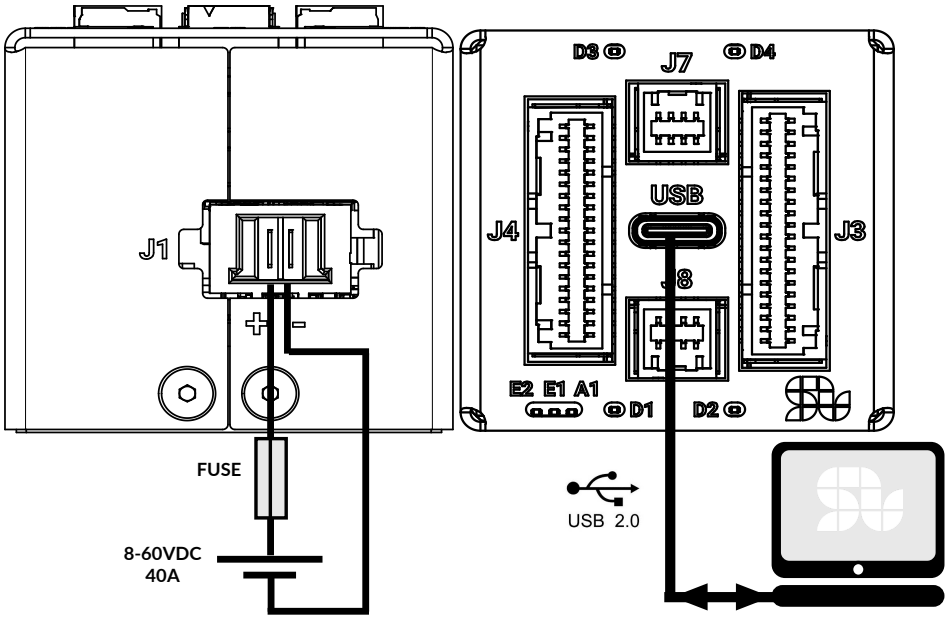

Figure 19. USB 2.0 Type-C wiring.

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> ⚠ **CAUTION:** The drive must be powered from its external 8–60 VDC supply when connected to a host over USB. The USB cable does not power the unit.
>
> **i NOTE:** The maximum recommended USB cable length is 3 m. USB is well suited to configuration, commissioning and monitoring. For multi-axis or hard real-time control, use EtherCAT or CANopen.

8.4 UART

An asynchronous serial port is available on J4 pins 13 (RX) and 15 (TX). It provides a simple link to another microcontroller or to a host that does not support EtherCAT or CAN. Both lines are +5 V tolerant and accept signals at either +3.3 V or +5 V levels.

Wire the host's TX to the drive's RX and the host's RX to the drive's TX, and connect the two grounds, as shown in Figure 20. Bond the cable shield to the isolated ground or to the host board's ground at one end only.

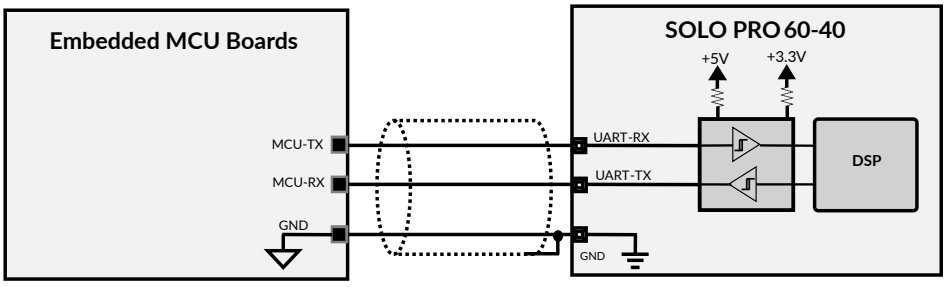

Figure 20. UART wiring (TX / RX to an external host).

8.5 SPI

The SPI port is different in kind from the four interfaces above. It is the DSP's **SPID** module, wired to the **User Core** — the processor the user programs — and not to the Motion Core that runs the motor. Nothing sent to it commands the drive by itself: it carries the protocol the user's own application implements, and that application exchanges whatever it needs with the Motion Core over the on-chip link between the two cores. The port exists so that a machine controller can reach the code running inside the drive directly, and so that several drives can be linked into one SPI network in which their User Cores talk to each other and to the host.

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The drive is the subordinate on the bus: the host generates the clock on **CLK** (pin 27), at up to 50 MHz, and selects the drive by pulling **STEn** (pin 23) low. Each unit on the bus takes its own chip-select, which is what allows several of them to share one set of data lines. Data travels on **SOMI** (pin 25), the drive's data input, and **SIMO** (pin 29), its data output. All four lines are rated to **+5 V** and accept signals at either +3.3 V or +5 V levels.

Wire the host's data output (MOSI) to SOMI, the host's data input (MISO) to SIMO, the host's clock to CLK and its chip-select output to STEn, and connect the two grounds, as shown in Figure 21. To keep noise from other EMI sources off the lines, bond the cable shield to ground at one end only, either to the drive ground or to the host board's ground.

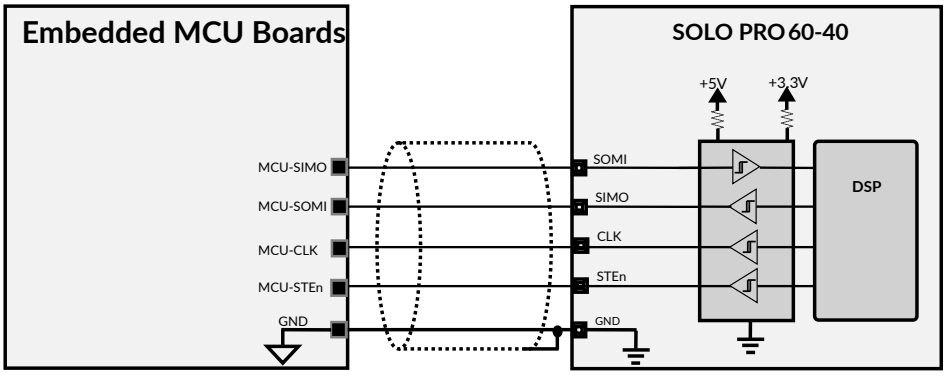

Figure 21. SPI wiring (SOMI / SIMO / CLK / STEn to an embedded MCU board).

> ℹ **NOTE:** The port carries nothing until the User Core has been programmed. On a drive whose User Core is unused, the SPI pins can be left unconnected and the drive is commanded over the interfaces of Sections 8.1 to 8.4.
>
> ⚠ **CAUTION:** On the drive, SOMI is an input and SIMO an output. Connect each to the opposite data line of the host, as shown in Figure 21, never to the host pin of the same name.

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9. POSITION 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 six sensor arrangements on the single J3 connector (Section 7.6), so the sensor can be matched to the accuracy, cost and robustness the application requires.

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 the drive ground, and keep the sensor cable away from the motor and supply cables (Section 16.9).

> 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 22, connect the motor's HALL A, HALL B and HALL C outputs to **HA, HB and HC** (J3 pins 26, 28 and 30) and supply the sensors from the +5 V pins of the same connector.

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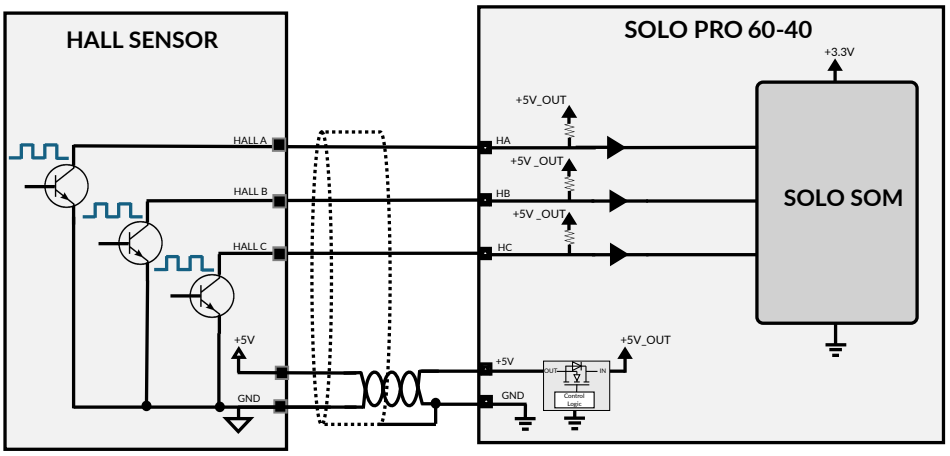

Figure 22. Digital Hall sensor wiring (HA / HB / HC).

9.2 INCREMENTAL ENCODER — SINGLE-ENDED

A single-ended incremental encoder transmits each channel on a single conductor referenced to ground. It is lower in cost than a differential type but more susceptible to noise, and is therefore suited to short cable runs in electrically quiet installations. Connect channels A, B and C to **1CHA, 1CHB and 1CHC** (J3 pins 14, 16 and 18) as shown in Figure 23.

A **second** single-ended channel set, **2CHA, 2CHB and 2CHC** (pins 20, 22 and 24), is available for a second encoder: a load-side encoder read alongside the motor-side one, for instance, so that a slipped coupling or a broken belt can be detected.

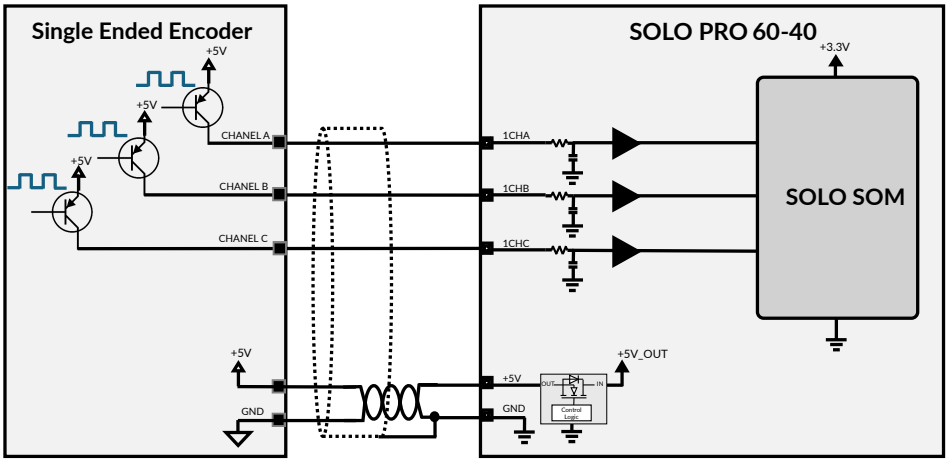

Figure 23. Single-ended incremental encoder wiring (1CHA / 1CHB / 1CHC).

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9.3 INCREMENTAL ENCODER — DIFFERENTIAL

The differential version transmits each channel as a balanced pair, which provides far better noise immunity over long or electrically noisy cable runs. Connect the encoder's positive outputs to **CHA+, CHB+ and CHC+** and its negative outputs to **CHA–, CHB– and CHC–**, J3 pins 2 to 12.

Wire each pair as a **twisted pair**, as shown in Figure 24. Without the twist the differential scheme gains nothing. Interference coupled into the cable affects both conductors nearly equally, and the receiver, responding only to the difference between them, cancels it.

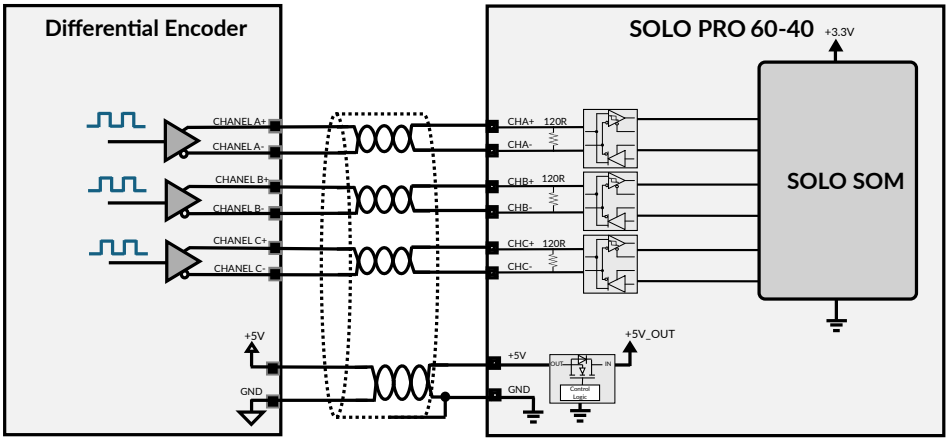

Figure 24. Differential incremental encoder wiring (CHA± / CHB± / CHC± as twisted pairs).

> **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.

9.4 BISS-C ABSOLUTE ENCODERS — PRIMARY AND SECONDARY

An absolute encoder reports the exact shaft angle at power-up, with no requirement to move the motor to a reference position first. BiSS-C is an open digital standard for absolute encoders. On the **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 drive provides two channels, each with its own clock pair, data pair and switched supply:

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Channel	Clock	Data	Supply	J3 pins
Primary	C+_P / C-_P	D+_P / D-_P	+5V_OUT_P	13, 15, 9, 11, 7
Secondary	C+_S / C-_S	D+_S / D-_S	+5V_OUT_S	23, 25, 19, 21, 17

The clock and data each use a differential pair, wired as shown in Figure 25. Wire each as a twisted pair and bond the shield at one end only. Each switched supply provides 200 mA, which is enough for a typical absolute encoder and no more, so do not load it with anything else.

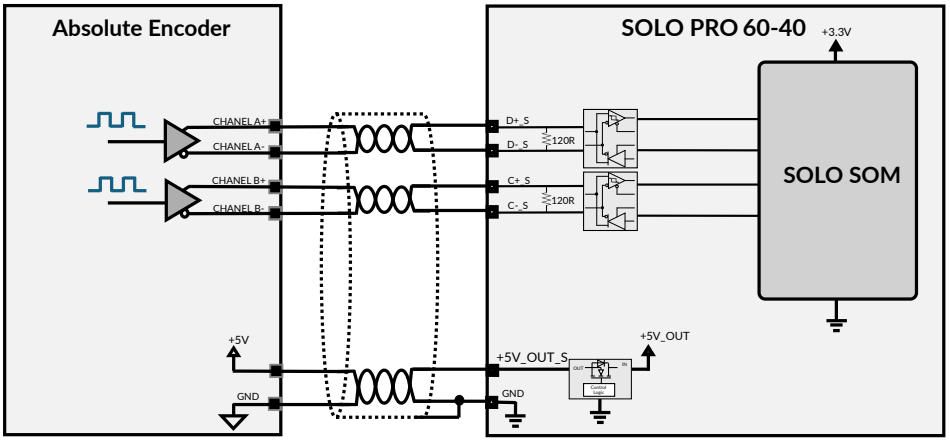

Figure 25. BiSS-C absolute encoder wiring (clock and data differential pairs with the switched 5 V supply).

9.5 SIN/COS ABSOLUTE 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 27, 29, 31 and 33) as shown in Figure 26.

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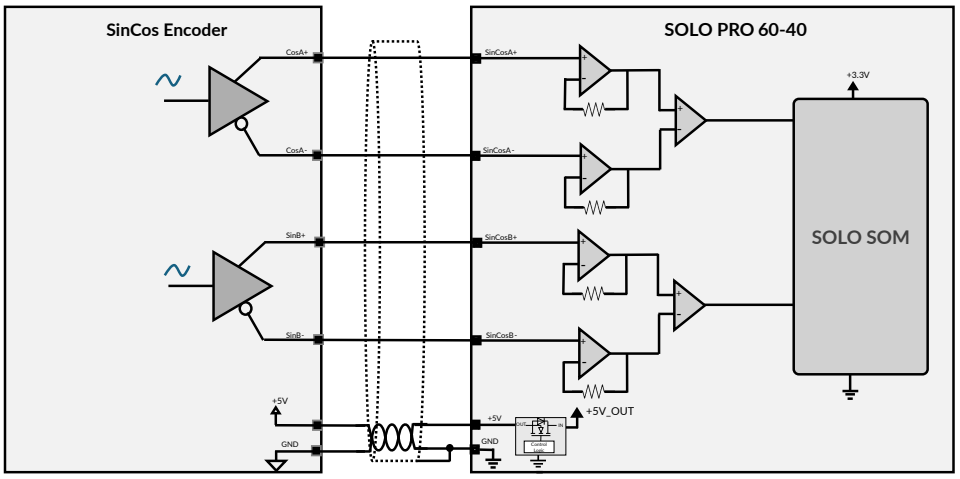

Figure 26. Sin/Cos encoder wiring.

Because these signals drive the drive's analogue inputs directly, their amplitude and offset matter. Present each channel as a clean sine and cosine **centred on the 2.5 V mid-rail**, with the minimum and maximum kept inside the **0–5 V** input window (Figure 27). The waveform does not have to use the full 0–5 V span: any swing that stays within those rails is acceptable, a reduced range such as 0.3 V to 4.8 V included, provided it stays centred. The acceptable centre voltage is **1.125 V to 3.75 V**.

A larger amplitude gives the angle interpolation more resolution, so use as much of the 0–5 V range as the signal chain allows for the best position accuracy.

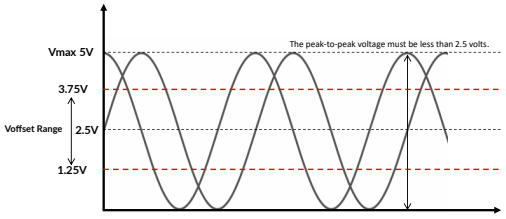

Figure 27. Sin/Cos input range: sine and cosine centred on 2.5 V with the swing kept inside the 0–5 V window.

> ⚠ **CAUTION:** The Sin/Cos inputs are rated to +4.5 V continuous and +5 V absolute maximum (Section 5.5). Scale the encoder signals before connecting them.

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9.6 PT1000 TEMPERATURE SENSOR

A PT1000 is a platinum resistance thermometer whose resistance rises predictably with temperature (1000 Ω at 0 °C). Mounting one on the motor windings or on a heatsink allows the drive to monitor for over-temperature and reduce output before damage occurs. Connect it across **PTC+** (J3 pin 38) and **PTC–** (J3 pin 40), as shown in Figure 28.

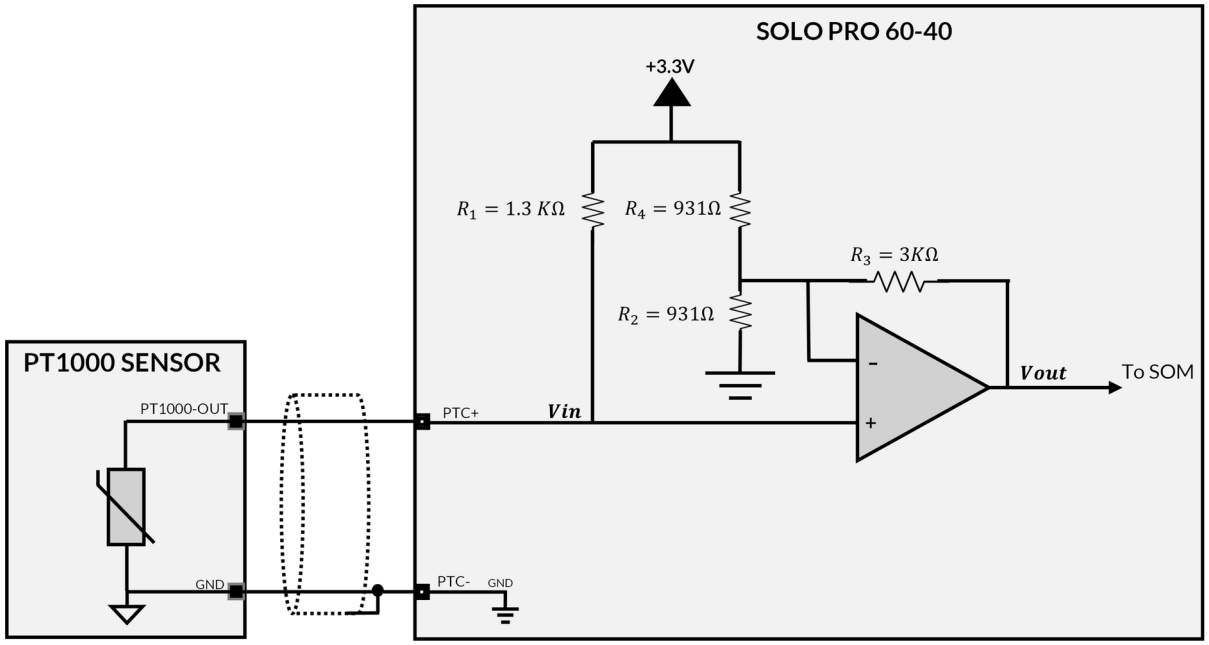

Figure 28. PT1000 temperature-sensor wiring (PTC+ / PTC–).

> ⚠ **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 PT1000 measurement as a voltage, V_{out}, over USB or the CAN bus. Convert it in three 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 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.

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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

Figure 29 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.

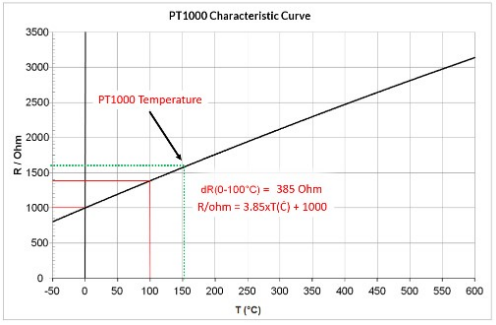

Figure 29. A sample PT1000 temperature-sensor characteristic curve.

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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, UART, 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 AND AI2

AI1 (J4 pin 28) and **AI2** (J4 pin 30) 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 a GND pin of J4. 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 30 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 and AI2.

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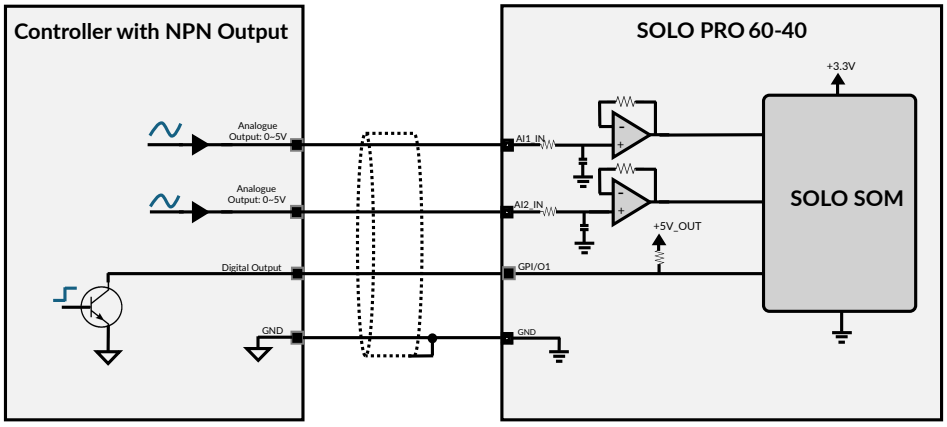

Figure 30. Analogue wiring with a controller having NPN (sinking) outputs.

- Connect the ground of the drive 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 31, GPI/O1 connects to any digital output of the board, and AI1 or AI2 to an analogue or PWM output.

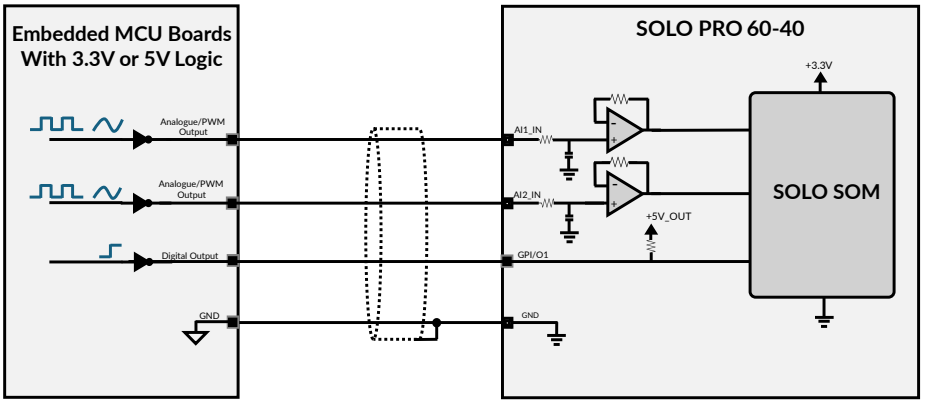

Figure 31. Analogue wiring with an embedded MCU board.

- The ground of the drive 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 or AI2, the PWM frequency must be at least 5 kHz.
- Bond the cable shielding to the drive ground or the controller ground at one side only.

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10.5 GENERAL-PURPOSE INPUT WIRING

The general-purpose I/O pins, and the dedicated inputs GPI1–GPI3 on J3, accept on/off logic signals such as a direction command, an enable or a limit switch. Figure 32 shows a switch wired to GPI/O1 and fed from the drive's own +5 V rail.

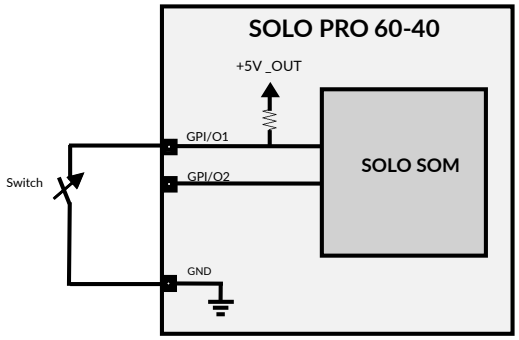

Figure 32. General-purpose input wiring (GPI/O1).

> ⚠ **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. Because the pin sources only a small current, drive anything larger through a transistor and a relay, as shown in Figure 33.

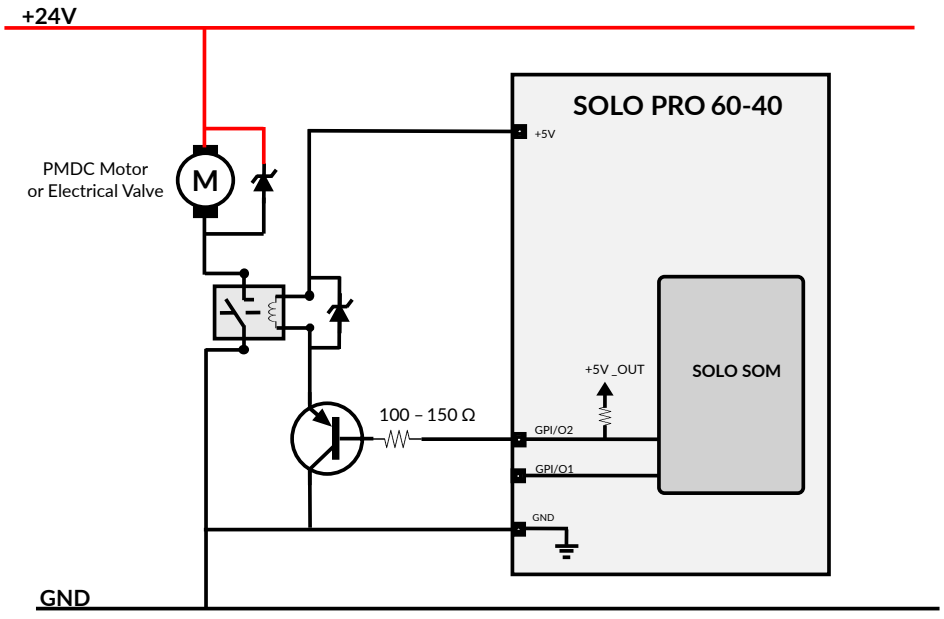

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Figure 33. General-purpose output wiring (GPI/O2) driving a relay through a transistor.

> ⚠ **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 ANALOGUE OUTPUTS AO1–AO3

Three analogue outputs, **AO1**, **AO2** and **AO3** (J4 pins 32, 34 and 36), each deliver 0 to 5 V. They transmit a measured quantity, torque or speed for example, to an external controller or instrument, so that the machine controller can read the drive's state without a digital link. As with the analogue inputs, the receiving device must share the drive's ground.

10.8 DIGITAL MODE

In digital mode, every function of the drive is reachable by sending data packets over USB, UART, CAN bus (using the CANopen protocol) or EtherCAT. Section 8 covers each interface and its wiring, and Section 16 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 power path to the motor 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, 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 deliberate: 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 from the rest of the drive.

> ⚠ **WARNING:** Providing the STO wiring is mandatory for the drive to operate.
>
> ⚠ **WARNING:** When STO is requested, the motor coasts to a stop under its own inertia. This coasting motion can be hazardous. On a vertical axis or an overhauling load the motor may accelerate rather than stop. Where the application cannot tolerate coasting, add an external measure such as a mechanical brake (Section 12).

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11.2 ELECTRICAL CHARACTERISTICS

Parameter	Description	Value
Type of input	STO1+, STO1–, STO2+ and STO2–	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	Contact SOLO
High-level input threshold	For +3.3 V and +5 V logic	Contact SOLO
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

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**, as shown in Figure 34. The isolation of the STO inputs is preserved, and the drive can be tripped by the safety system independently of its own supply and firmware.

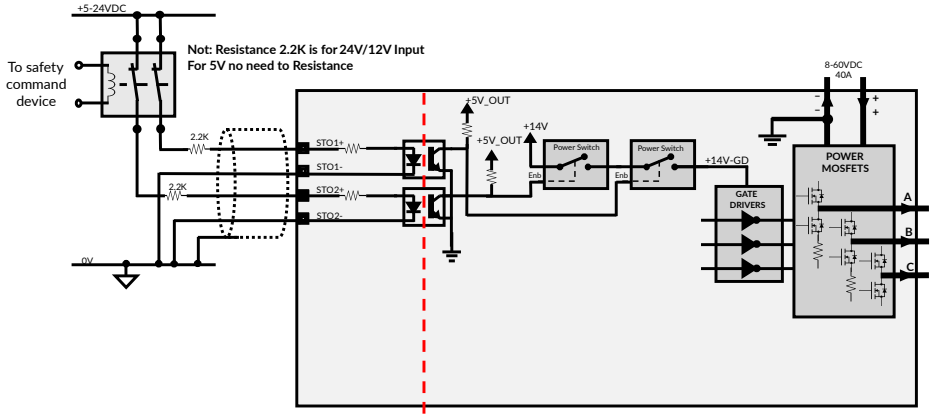

Figure 34. STO wiring to an external safety relay using an external supply voltage.

> **i NOTE:** Bond the cable shield to the external ground to minimise interference from external EMI

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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 non-isolated +5 V (J10 pin 2), as shown in Figure 35. This simplifies bring-up, but it defeats the galvanic isolation of the STO inputs and makes the safety function dependent on the drive's own supply.

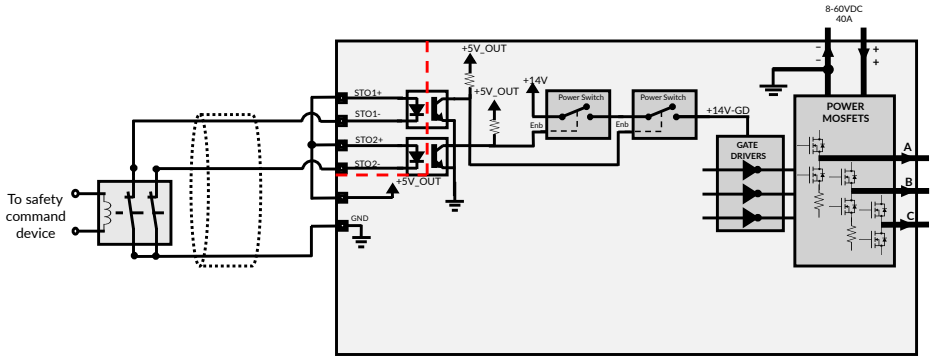

Figure 35. STO wiring to an external safety relay using the internal +5 V supply.

⚠ **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 to the internal +5 V so that the drive runs with no safety device connected at all, as shown in Figure 36. This exists purely so that a motor can be turned for the first time on a bench.

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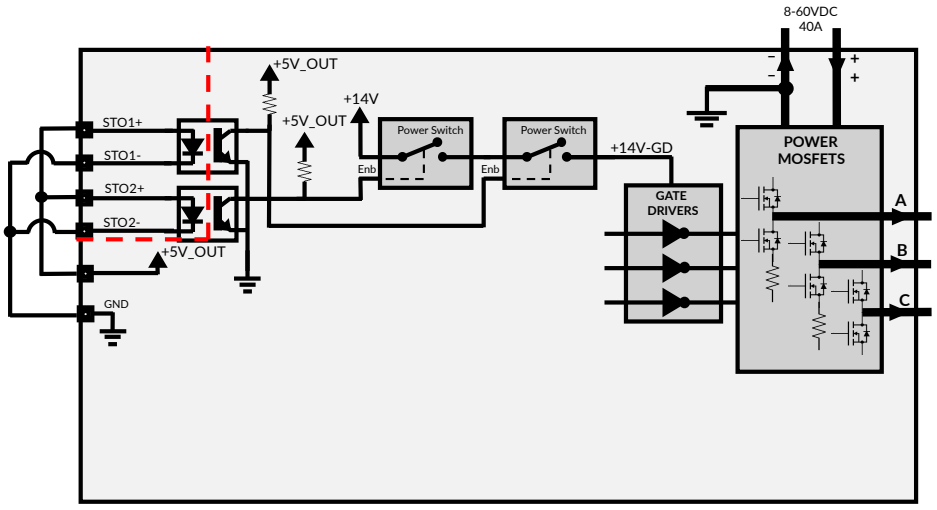

Figure 36. STO bypass wiring via the internal +5 V supply, with no external commanding device.

> ⛔ **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 37 shows the three characteristic times.

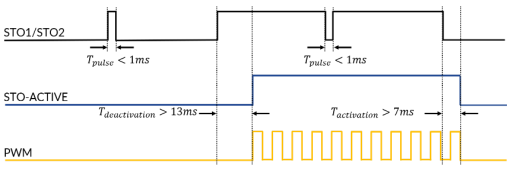

Figure 37. STO activation, deactivation and pulse timing.

- **Pulse time, < 1 ms.** A pulse shorter than 1 millisecond applied to the STO inputs has no effect on the function, in either direction.
- **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.

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12. SAFE BRAKE OFF (SBO)

12.1 FUNCTION

Safe Brake Off is the mechanical counterpart of STO. Where STO removes the torque and leaves the motor to coast, SBO controls an **electromagnetic holding brake**, so that the load is brought to rest and held mechanically. It is the answer to the coasting hazard of Section 11.1, and it is what a vertical or overhauling axis needs to be safe.

Like STO, the SBO control inputs (**SBO1_ISO** and **SBO2_ISO** on J10 pins 10 and 9) are optically isolated. They drive an internal power switch that connects the brake to its supply, and that switch reports a fault condition back to the drive.

The brake itself is powered from its own **isolated supply**, 12 to 48 VDC at up to 3 A, on section [19] J9 (Section 7.14). Keeping the brake supply separate means the holding brake is not affected by anything happening on the drive's own 8–60 V rail.

12.2 SUPPLY AND WIRING

Figure 38 shows the SBO connection, and Figure 39 the same function in the context of the complete drive.

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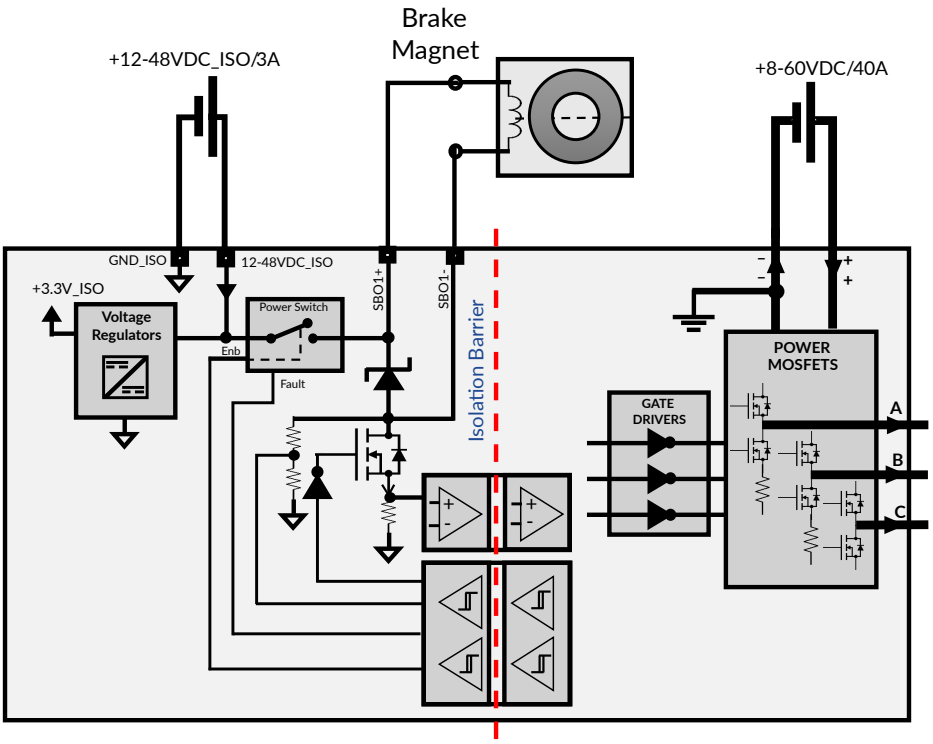

Figure 38. Safe Brake Off wiring.

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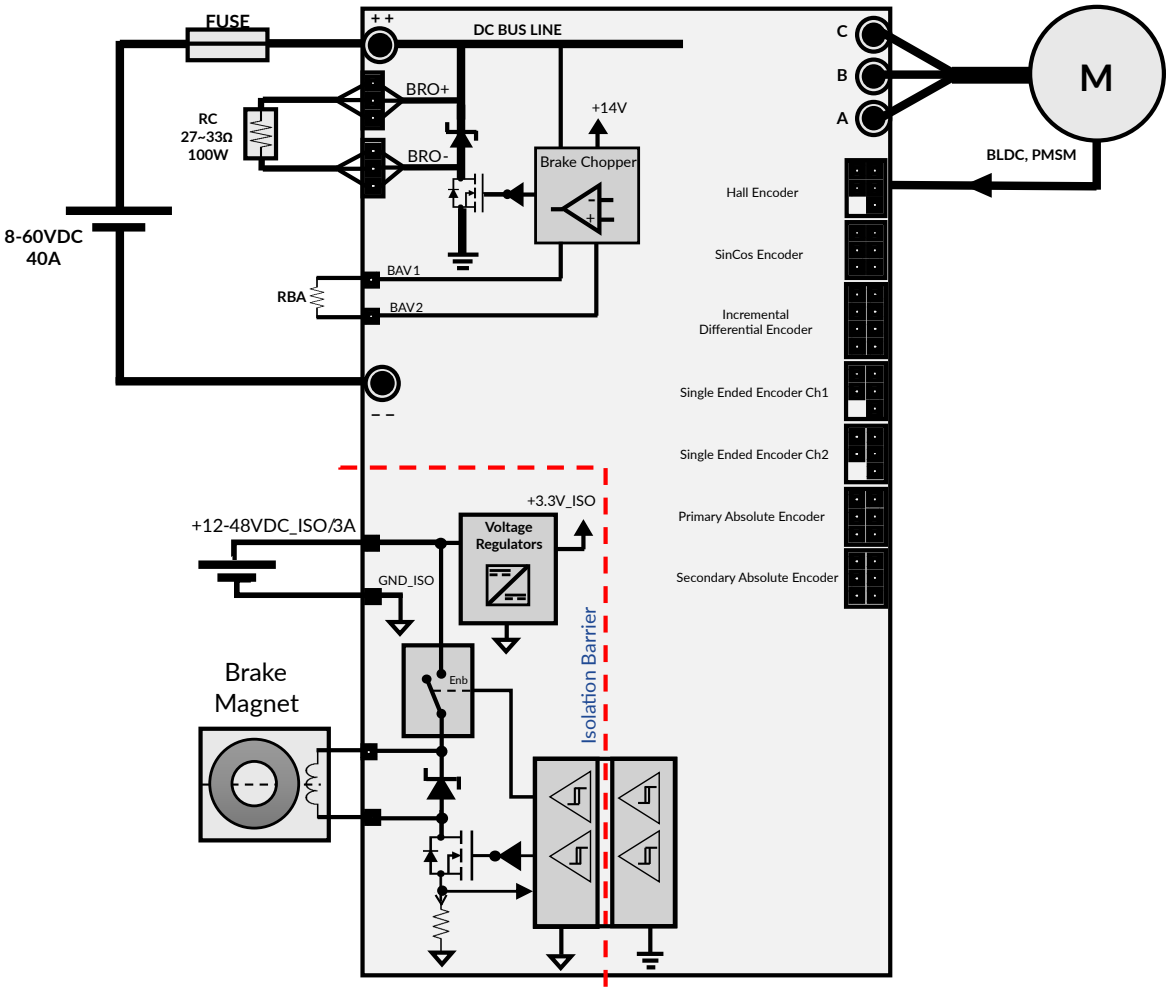

Figure 39. Safe Brake Off wiring to an external safe brake in the complete system.

When wiring the function:

- Supply J9 from an isolated 12–48 VDC source sized for the brake's inrush and holding current, up to 3 A. Observe the polarity. There is no reverse-polarity protection.
- Select the brake so that its coil voltage matches the supply and its current stays within the 3 A rating.
- Drive SBO1_ISO and SBO2_ISO from the machine's safety system, in the same way as the STO inputs.

> ⚠ **WARNING:** A holding brake is designed to hold a stationary load, not to stop a moving one. Sizing an SBO installation for repeated dynamic braking will wear the brake and can leave the axis unheld. Coordinate SBO with STO so that torque is removed and the brake is applied in the order the machine requires.

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13. ACTIVE BRAKE CHOPPER

13.1 PRINCIPLE

When a motor decelerates or is driven by its load, it acts as a generator and returns energy to the DC bus. With only 44 µF of internal bus capacitance (Section 5.1), that returned energy raises the bus voltage quickly. The active brake chopper protects against this: whenever the bus voltage exceeds the activation threshold, the circuit internally connects the **RB1** and **RB2** terminals, and the excess energy is dissipated in an external power resistor connected across them.

The default activation voltage is approximately **61 V**, and it can be lowered to any value down to about 10 V using a single external resistor across **BRKA** and **BRKB** (Section 13.3).

> ⚠ **WARNING:** If the load connected to the motor shaft has a large moment of inertia, or if the axis can be driven by gravity, the brake chopper and its resistor are **mandatory**. Without them, excessive regeneration will raise the bus into over-voltage and damage the drive or the power supply.

13.2 WIRING

Connect a power resistor of at least **27 Ω** and **100 W** across RB1 and RB2, as shown in Figure 40.

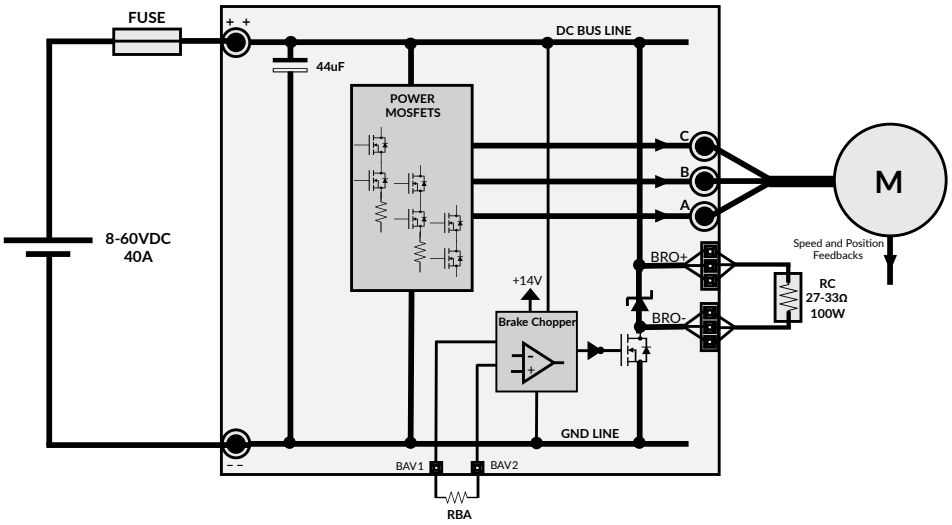

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Figure 40. Active brake chopper wiring — the brake resistor across RB1 / RB2 and the threshold-setting resistor across BRKA / BRKB.

Two candidate resistors:

Part number	Resistance and power
HSC10027RJ	27 Ω, 100 W
HS100E6 33R F M193	33 Ω, 100 W

> ⚠ **CAUTION:** Do not fit a brake resistor below **27 Ω**. A lower resistance draws more current than the chopper circuitry can dissipate and can destroy it.
>
> ⚠ **CAUTION:** Select the resistor's power rating for the energy the application actually returns. An under-rated resistor will overheat and fail, and it will do so while carrying the full bus voltage.

Whenever the brake circuit conducts, the **B1** LED in section [17] turns on. The regeneration current can additionally be limited from the SOLO Motion Terminal.

13.3 SETTING THE ACTIVATION VOLTAGE

Leaving BRKA and BRKB open selects the default threshold of 61 V. To set a lower threshold, fit a resistor R_{BA} across BRKA and BRKB, calculated in two steps from the desired activation voltage V:

```
X    = ((V / 3.3) × 10000) − 10000
R_BA = (X × 172000) / (172000 − X)      [Ω]
```

Table 1 lists worked values for common bus voltages. Any arbitrary threshold down to about 10 V can be obtained from the formula.

Table 1. R_{BA} selection for a desired brake activation voltage.

Nominal DC bus voltage	Desired activation voltage (approx.)	R_{BA} (approx.)
58 V	61.0 V	∞ (leave BRKA / BRKB open)
48 V	50 V	800 kΩ
36 V	40 V	314 kΩ
24 V	26 V	114 kΩ
12 V	14 V	39 kΩ

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Choose R_{BA} as close as possible to the calculated value: the relationship is steep, so a loose tolerance moves the threshold appreciably.

> ⚠ **CAUTION:** Never set the activation voltage **below** the supply voltage. The chopper would then conduct continuously, dissipating power in the brake resistor for no purpose, raising the current consumption and overheating the resistor. If **B1** is permanently on with no motor connected, the threshold has been set too low. Recalculate it.
>
> ℹ **NOTE:** Always verify the threshold before committing a motor to the drive: raise the supply slowly and confirm that **B1** turns on at the intended voltage.

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14. SLEEP MODE AND FIRMWARE UPDATE

14.1 SLEEP MODE

Sleep mode reduces the drive's own consumption to approximately **2.6 mA**, which matters in battery-powered equipment that idles between duty cycles. Pull the **Sleep** input, J5 pin 1, to ground through an external switch to enter the mode, as shown in Figure 41.

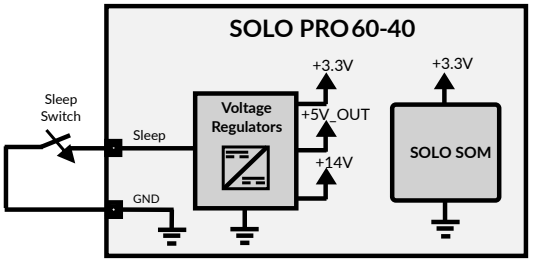

Figure 41. Sleep mode wiring — a switch pulling the Sleep input to ground.

> **i NOTE:** A relay can be used in place of the switch for remote control of sleep mode, or the Sleep input can be driven directly by an external controller that grounds it when required. The input is rated to +60 V (Section 5.5).

14.2 FIRMWARE UPDATE (DFU MODE)

Firmware is updated over the USB Type-C port using the SOLO Motion Terminal. To place the unit in Device Firmware Upgrade mode, the **DFU** input, J4 pin 18, must be held at **+5 V**. The most convenient source is pin 20 of the same connector, which is one of the +5 V outputs: fitting a link between **pin 18 and pin 20** puts the drive into DFU mode on the next power-up. Figures 42 and 43 show the connection.

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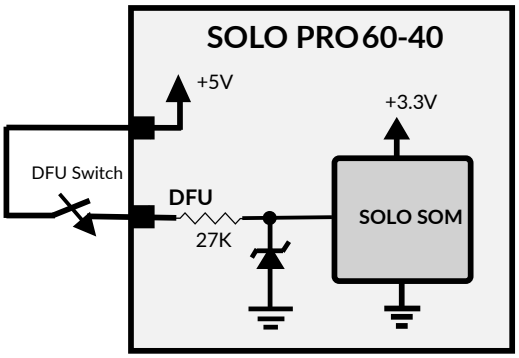

Figure 42. DFU mode wiring — the DFU input pulled to +5 V.

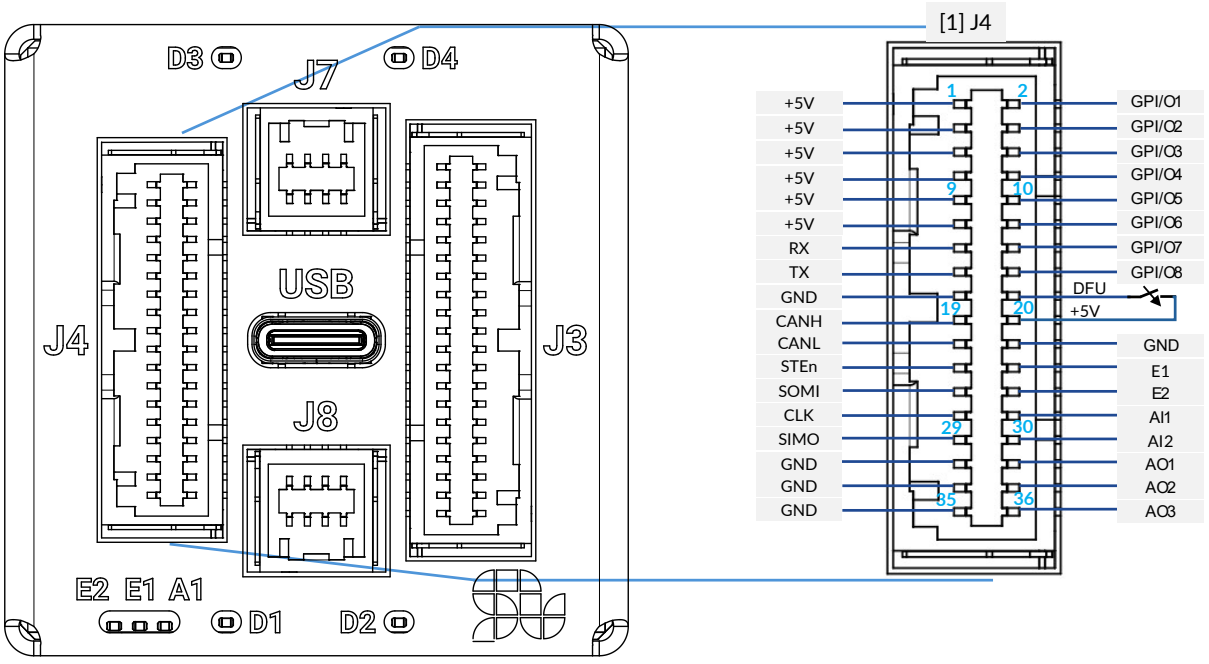

Figure 43. DFU mode wiring at connector J4 — a link between pin 18 (DFU) and pin 20 (+5 V).

> **NOTE:** The DFU pin is connected directly to the control module and is rated to +5 V (Section 5.5). Remove the link after the update so that the drive boots the application firmware normally.

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15. LED INDICATORS

The drive carries nine LEDs. Four report the state of the unit, one reports the brake chopper, and four report the two EtherCAT ports (Section 8.1). Sections 7.1 to 7.3 show where each one sits on the unit. Two of them are labelled **A1**: section [10] on the top face is the power LED of the carrier board, and section [20] on the logo face is the power LED of the SOLO SOM.

Section	LED	Indicates	Behaviour
[10]	**A1**	Power, carrier board	Glows continuously once the drive is correctly powered from 8 to 60 V
[20]	**A1**	Power, SOLO SOM	Glows continuously once the SOLO SOM control module inside the drive is powered
[12]	**E2**	Heartbeat / normal activity	Starts blinking after a successful boot and stays blinking
[11]	**E1**	Error	Blinks when a fault is active: over-current, over-voltage or over-temperature
[17]	**B1**	Brake activation	On while the brake circuit is actively dissipating energy in the brake resistor
[2], [4], [7], [9]	**D3, D4, D2, D1**	EtherCAT link and activity	See Section 8.1

In summary: the two **A1** LEDs show that the unit and its control module have power, **E2** shows that the firmware is running, and **E1** shows a fault. A correctly operating drive shows both A1 LEDs on, E2 blinking and E1 off.

The E1 and E2 states are also available as outputs on **J4 pins 24 and 26**, so they can be mirrored on an enclosure front panel. Drive each panel LED through a current-limiting resistor.

> **i NOTE:** If **B1** is permanently on while no motor is connected to the output, the brake activation voltage has been set below the supply voltage. Recalculate it as described in Section 13.3.

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16. COMPLETE WIRING EXAMPLES

16.1 WIRING LEGEND

The wiring diagrams in this manual use the following conventions.

Symbol	Meaning
Ground symbol	Ground of the SOLO PRO 60-40 CUBE
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 60-40 CUBE
Open pin	Input/output pin of the external controller

16.2 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 wiring for closed-loop operation of a BLDC or PMSM motor from a single potentiometer, with a general-purpose input used for direction.

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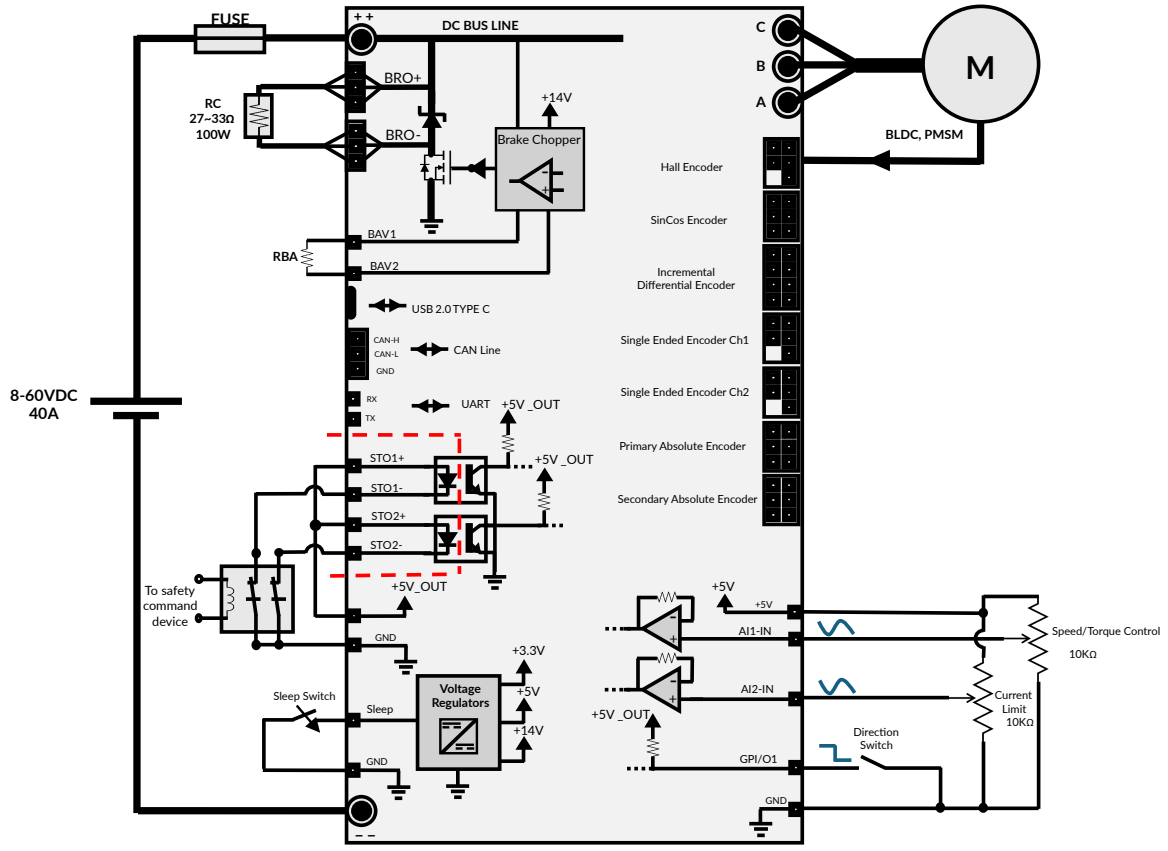

Figure 44. Standalone wiring — closed-loop control from a single potentiometer, with no external modules.

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

16.3 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.

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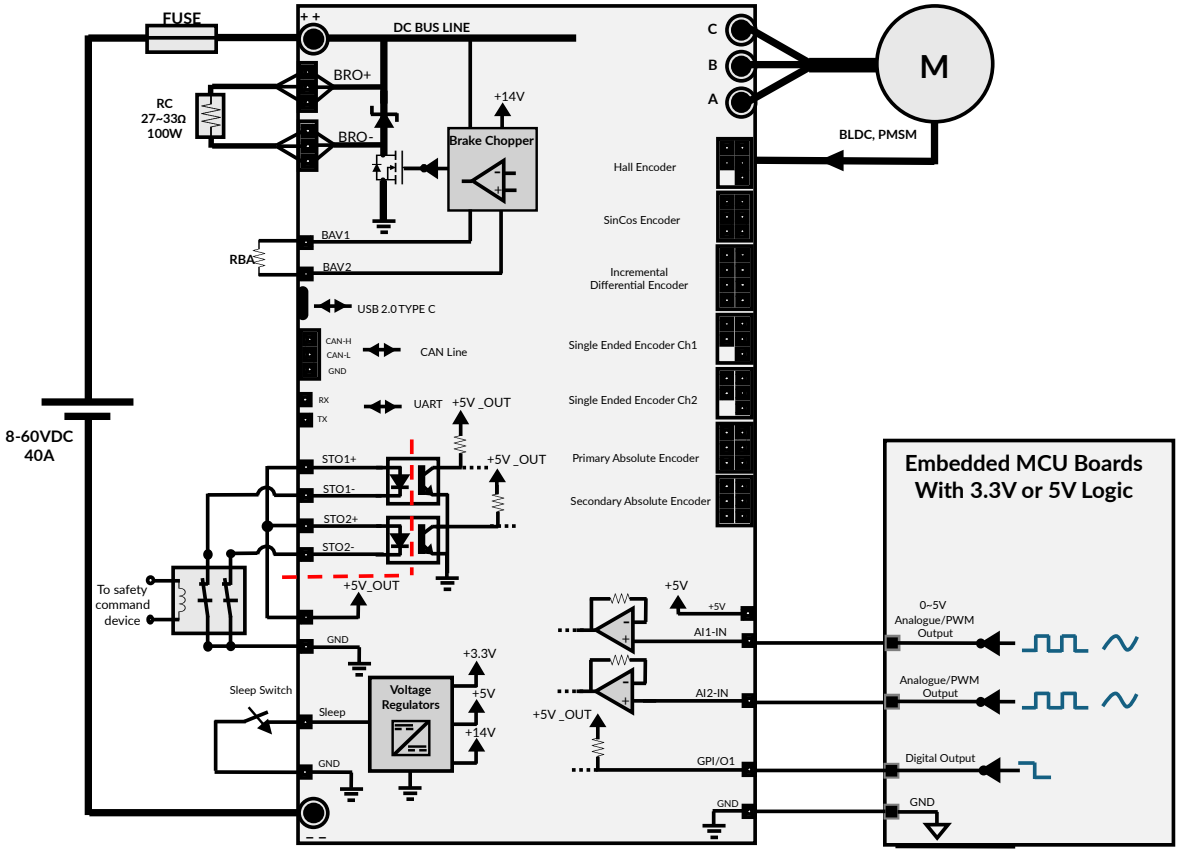

Figure 45. Complete wiring with an embedded MCU board commanding the drive over analogue/PWM.

- The **GND** pin of the drive must be connected to the ground of the MCU board at least at one common point. Get this wrong and the analogue command has no defined value. Nothing else in the configuration matters as much.
- The GPI/O pins accept input voltages up to +5 V.
- When using a PWM output to drive AI1 or AI2, the PWM frequency must be at least **5 kHz**.

16.4 EMBEDDED MCU BOARD USING AN ANALOGUE OUTPUT

Figure 46 shows the same arrangement where the MCU board provides a true analogue output rather than a PWM signal.

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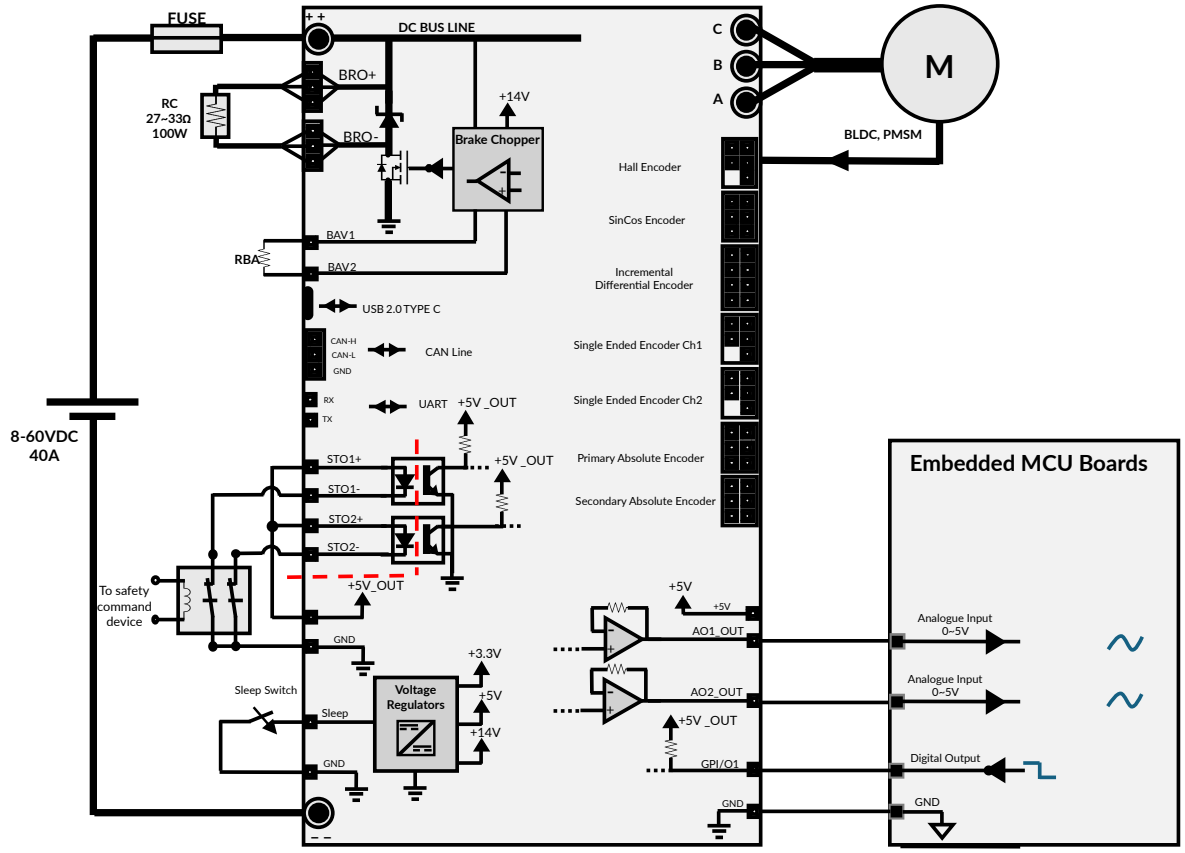

Figure 46. Complete wiring with an embedded MCU board commanding the drive from an analogue output.

> ⚠ **CAUTION:** Where a potentiometer is used on this input, its resistance must not fall below **1 kΩ** at any position, or the drive's internal +5 V source will be short-circuited.

16.5 EMBEDDED MCU BOARD USING CANOPEN

Figure 47 shows the drive commanded digitally over CANopen from an embedded MCU board.

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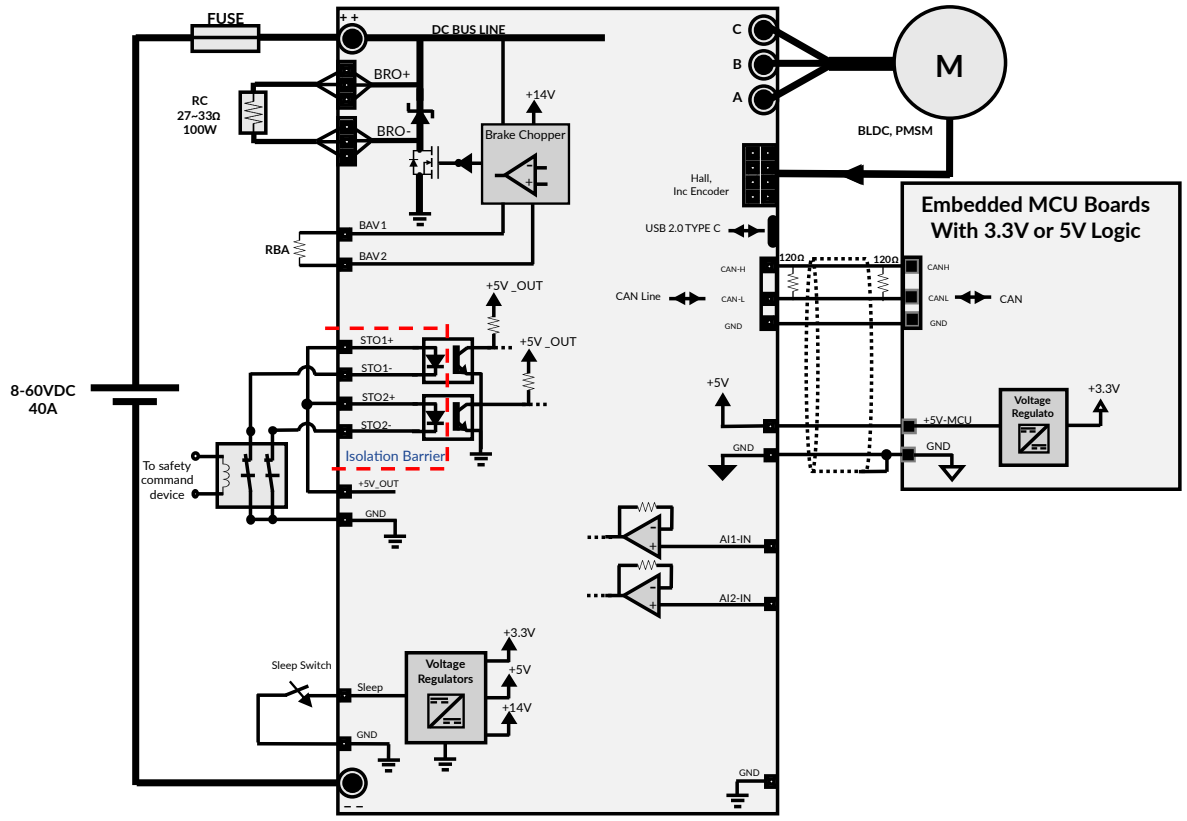

Figure 47. Complete wiring with an embedded MCU board commanding the drive over CANopen.

> ℹ **NOTE:** For reliable CAN communication, power the embedded MCU board from the drive's +5 V 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.

16.6 EMBEDDED MCU BOARD USING SPI

Figure 48 shows an embedded MCU board with 3.3 V or 5 V logic wired to the drive's SPI port. The link reaches the User Core, so what the board can do with it is set by the application programmed there (Sections 4 and 8.5); the motion side is commanded over one of the interfaces in Section 8.

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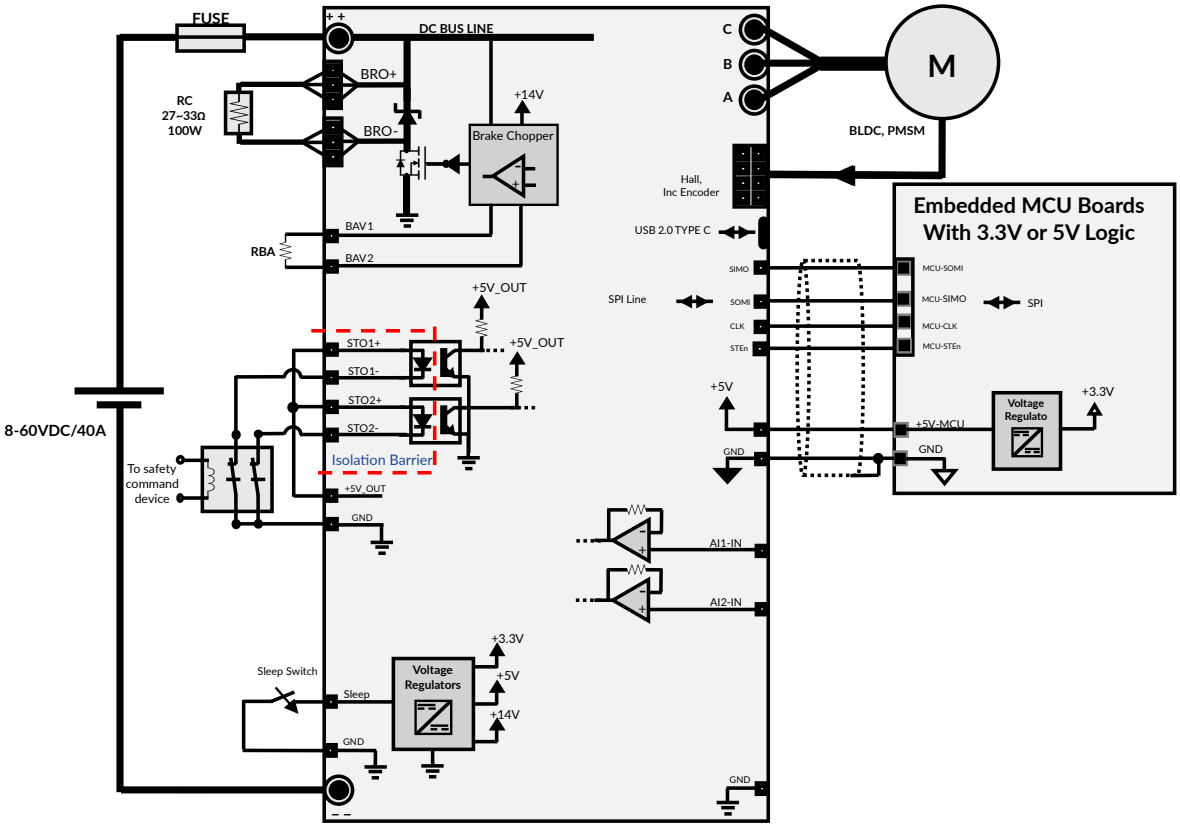

Figure 48. Complete wiring with an embedded MCU board on the drive's SPI port, which reaches the User Core.

> **i NOTE:** For reliable SPI communication, power the embedded MCU board from the drive's +5 V 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.

16.7 EMBEDDED MCU BOARD USING ETHERCAT

Figure 49 shows how the EtherCAT signals of sections [3] and [8] 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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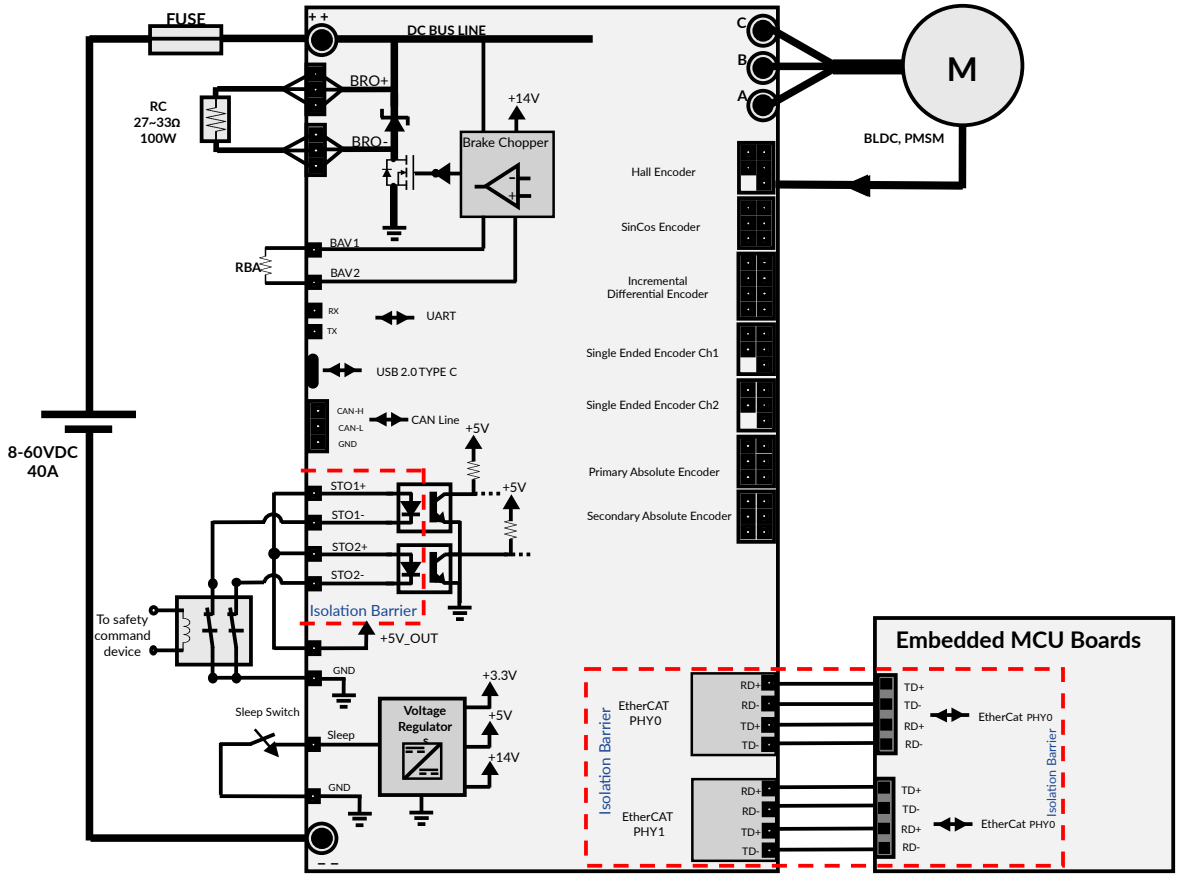

Figure 49. EtherCAT wiring between an embedded board and the SOLO PRO 60-40 CUBE.

16.8 EMBEDDED MCU BOARD USING UART

Figure 50 shows the UART connection to an embedded MCU board: the board's TX to the drive's RX, and the board's RX to the drive's TX.

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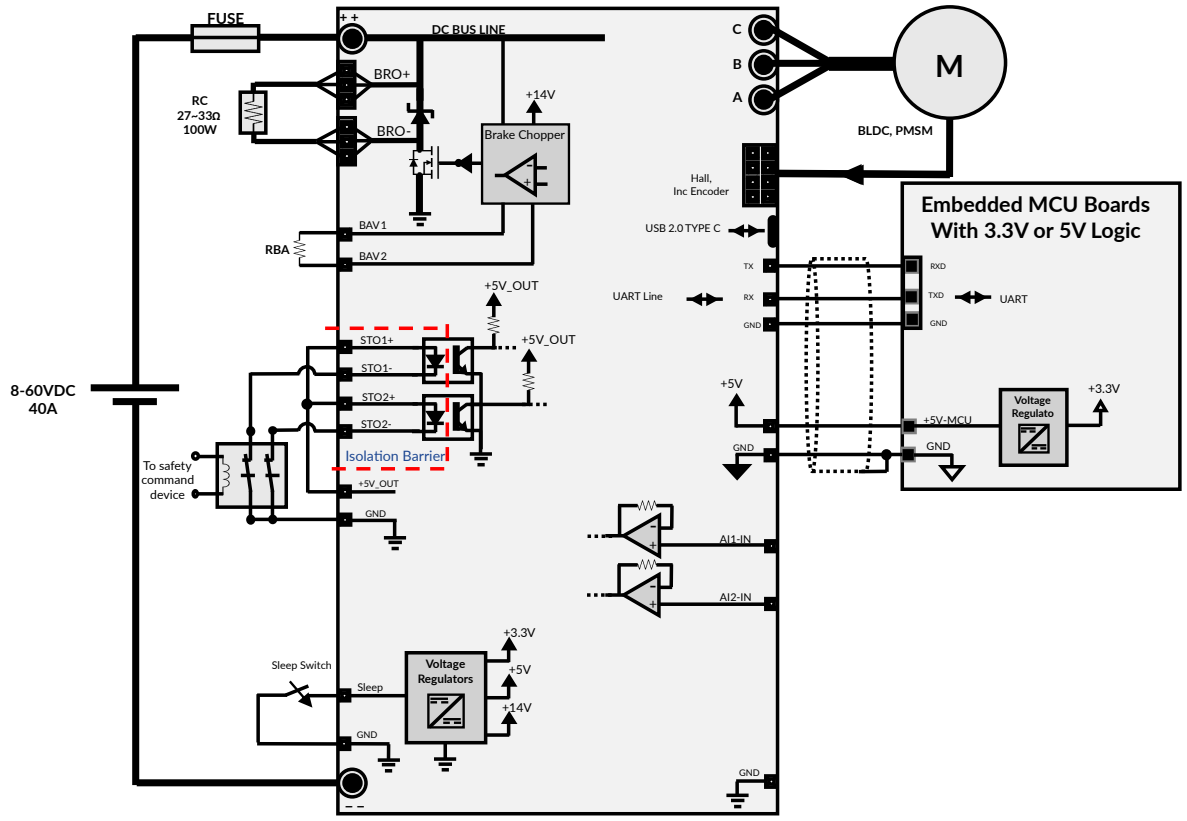

Figure 50. Complete wiring with an embedded MCU board commanding the drive over UART.

16.9 GENERAL WIRING CONSIDERATIONS

Nearly all noise problems in drive installations come down to two wiring mistakes.

Do not run feedback and power wiring together. Encoder, Hall and analogue signals are low-level. Motor phase and supply 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 51).

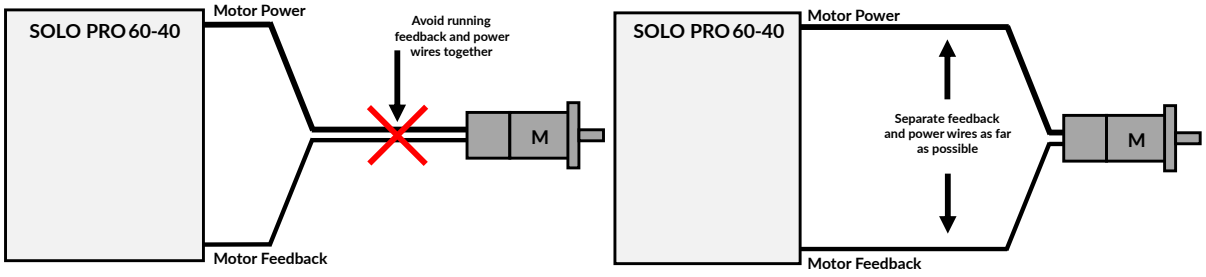

Figure 51. Keep feedback wiring away from power wiring.

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Do not create ground loops. Connect the ground of the drive 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 52). 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.

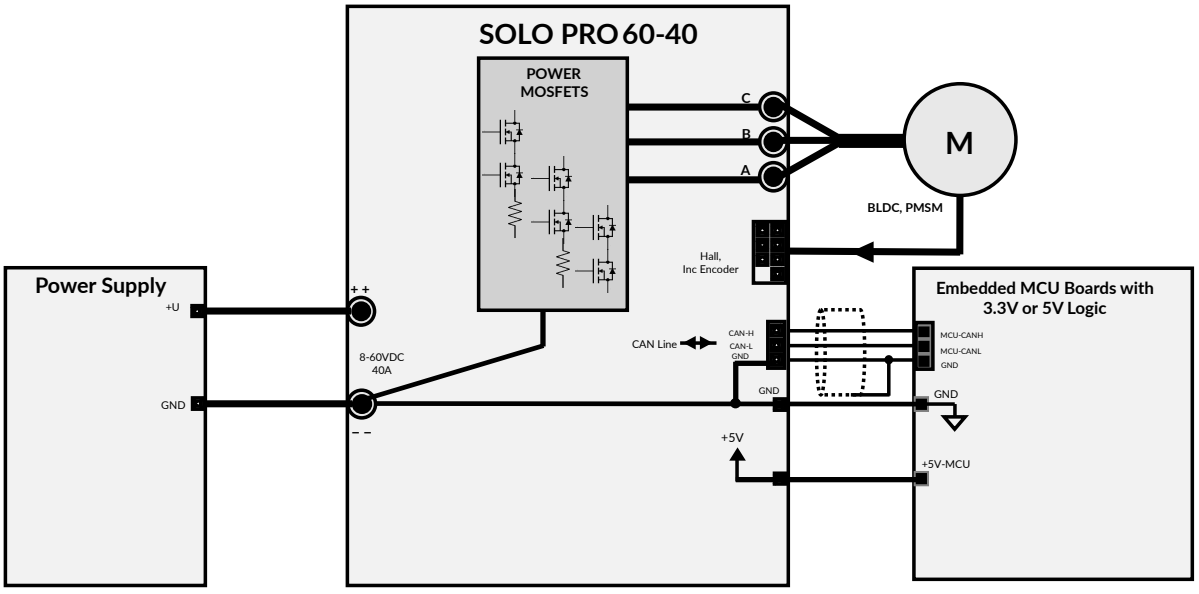

Figure 52. Improper ground wiring: parallel ground paths form a ground loop. Use a single star point instead.

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17. GETTING STARTED / INITIAL SETUP

17.1 REQUIRED EQUIPMENT

Commissioning the drive for the first time requires:

1. The SOLO PRO 60-40 CUBE.
2. A DC power supply between 8 V and 60 V, sized for the intended motor current, with a fuse in the positive line.
3. A brake resistor of 27–33 Ω / 100 W where the load can regenerate (Section 13).
4. The STO wiring: a safety relay for production use, or the bypass of Section 11.3.3 for bench testing only.
5. A USB Type-C cable, up to 3 m.
6. A PC running Windows 10/11 or Linux.
7. The SOLO Motion Terminal software, available from solomotorcontrollers.com.

17.2 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. Verify that the supply is between 8 and 60 VDC, and confirm its polarity at J1 before connecting it.
2. Confirm that every ground connection is secure.
3. Wire the STO inputs (Section 11.3). The drive will not produce torque until they are energised.
4. Connect the motor to J2: A, B and C for a three-phase motor, B and C for a DC brushed motor.
5. Connect the position sensor to J3 (Section 9), if one is used.
6. Connect the brake resistor across RB1 and RB2 if the application can regenerate.
7. Connect the USB cable between the drive and the PC.
8. Apply power. The **A1** LED lights immediately, confirming the supply.
9. Within a few seconds the **E2** heartbeat LED begins blinking, confirming that the firmware has booted.

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10. If the **E1** error LED is blinking, stop and check the supply voltage, the encoder wiring and the motor connections before proceeding.
11. If **B1** is on with no motor running, the brake activation voltage is set below the supply voltage. Recalculate it (Section 13.3).
12. Open the SOLO Motion Terminal. The drive appears automatically as a virtual COM port.

17.3 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 drive powered and 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).

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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18. REGULATORY COMPLIANCE & APPROVALS

The compliance status below applies to the SOLO PRO 60-40 CUBE. 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	DVC A
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*
RoHS	2011/65/EU	—

* Achieved without any external filters.

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19. REVISION HISTORY

Rev	Date	Firmware	Author	Change Description
V1.0.0	31/05/2023	0x0000B00F	SOLO Motor Controllers	First release
V1.0.1	10/05/2024	0x0000B020	SOLO Motor Controllers	P/F pin description changed; certification table updated; temperature ratings updated per UL 61800-5-1; PT1000 formulas changed
01	2026-08-16	—	SOLO Motor Controllers	Restructured hardware user manual
02	2026-09-18	—	SOLO Motor Controllers	SPI port added on J4 as the User Core's external interface, and J4 becomes a 36-pin connector; J4 pinout, mating connector and absolute maximum ratings updated; SPI wiring examples added
03	2026-09-25	—	SOLO Motor Controllers	Encoder frequency specification corrected to the control module's ratings: 10 MHz for incremental encoders, and a 2–8 MHz clock range for BiSS-C

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