SOLO MEGA User Manual
Part Number: SLSGB002PW2000

Product Description

SOLO MEGA with part number of SLSGB000PW2000 is a member of the SOLO motor controllers family of devices capable of driving and controlling various types of electrical motors like DC brushed, BLDC, PMSM and EC coreless motors in a single platform.They are made to be easy to use with state of art technologies and Dual Core parallel processing architecture on top of FOC control methods.
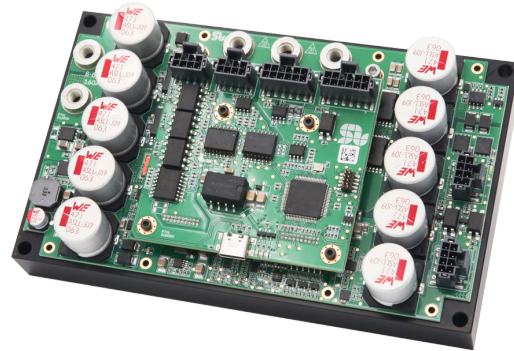
SOLO MEGA supports sensor-based Torque, Speed and Position controlling plus other options like full digital and analog controls and active safety measures to keep the applications safe from unforeseen behaviors.

Power Range

Supply Voltage Range : 8- 60 VDC

Peak Current: 220A peak to peak

Continuous Current: 120A DC, 110A RMS

Features

- Easy to use
- Drives and Controls DC brushed, BLDC, PMSM and EC coreless motors
- Torque, Speed and Position controlling
- Four Quadrant Regenerative operation
- Automatic parameter Identification and self-tuning
- Isolated STO(Safe Torque off)
- Isolated USB, UART and CANopen
- Supports PT1000 temperature sensors
- Sleep mode with consumption of 2.6mA

- Field Oriented Control with Nested Position-Speed-Torque loops
- Dual Core with Parallel Processing Architecture
- Bus over-voltage, Bus under-voltage , over-current and over temperature protections
- Active Brake Chopper
- Full Digital and Analogue Control
- Space Vector Modulation (SVM)
- Embedded Motion Profile (St-Curve) for Position and Speed

Modes of Operation

- Analogue or Digital commanding
- Torque Control
- Speed Control
- Position Control

Commands and feedbacks Source

- 0-10V Analogue/ PWM inputs for Speed or Torque control
- Analogue torque and speed feedbacks
- Optically isolated quadrature Encoder and Hall sensor inputs
- Isolated UART, USB and CAN bus

Applications

- Industrial Automations
- Robotics and Traction Units
- Drones
- Automotive Industries
- Household Appliances
- Medical Devices
- Aerospace
- Textile Industry
- Automated Guided Vehicles (AGVs)
- Heating, Ventilation and Air-Conditioning (HVAC)

Identification of hazards and instructions on how to prevent them	
⚠️	**Danger** Immediate dangers which can lead to death or serious injuries.
⚠️	**Warning** Hazards that can cause serious damages or injuries.
⚠️	**Caution** Hazards that can cause minor injuries or material damage.
ℹ️	Recommendations, tips, references to other documentation.
⚙️	Essential or useful accessories.

Revision History:

Revision	Date	Changes	Firmware version
V1.0.0	31/05/2023	- First Release	0x0000B00F

Table of Contents

Power Specifications:

Description	Units	Values
DC Supply Voltage Range (continuous)	VDC	8 to 60
Active Brake Chopper Activation Voltage	VDC	61
Software Overvoltage Activation Voltage	VDC	63V
Hardware Overvoltage Activation Voltage	VDC	66.4
DC Bus Undervoltage Limit	VDC	7
Maximum Peak Output Current	A	220A peak to peak
Maximum Continuous Output Current	A	120A DC, 110A RMS
Maximum Continuous Output Power	W	6000
Internal Bus Capacitance	µF	4700
Switching Frequency (Output PWM Frequency)	kHz	8 to 80

Control and Timings specifications:

Description	Units	Values
Analogue Speed or Torque Commands	**VDC**	0-10V Analogue voltages or PWM inputs with frequency above 5kHz
Digital Direction Control	**VDC**	0 - 3.3/5/12V
Modes of Operation	**-**	Torque - Speed- Position
Motors supported	**-**	DC brushed - BLDC - PMSM - EC Coreless
Hardware Protections	**-**	Bus over-voltage, Bus under-voltage, over-current and over temperature
Current (Torque) Loop sampling time	**µs**	Synched to PWM frequency (Min 7 µs)
Current (Torque) Loop execution time	**µs**	7
Speed controller Loop sampling time	**µs**	500
Speed controller Loop execution time	**µs**	75
Position controller Loop sampling time	**µs**	500
Position controller Loop execution time	**µs**	75
Maximum Encoder Frequency (Pre-Quad)	**MHz**	2
Current Measurement Resolution	**mA**	80

Thermal Specifications:

Description	Units	Values
Board Temperature Range	°C	-20 to 85
Heatsink (base) Temperature Range	°C	0 - 85
Cooling system	-	Natural Convection

Mechanical Specifications:

Description	Units	Values
Size (H x W x D)	mm	42.21 x 154 x 94
Weight (with heatsink)	gr	933
Form Factor	-	Wall Mount

Mechanical Dimensions:
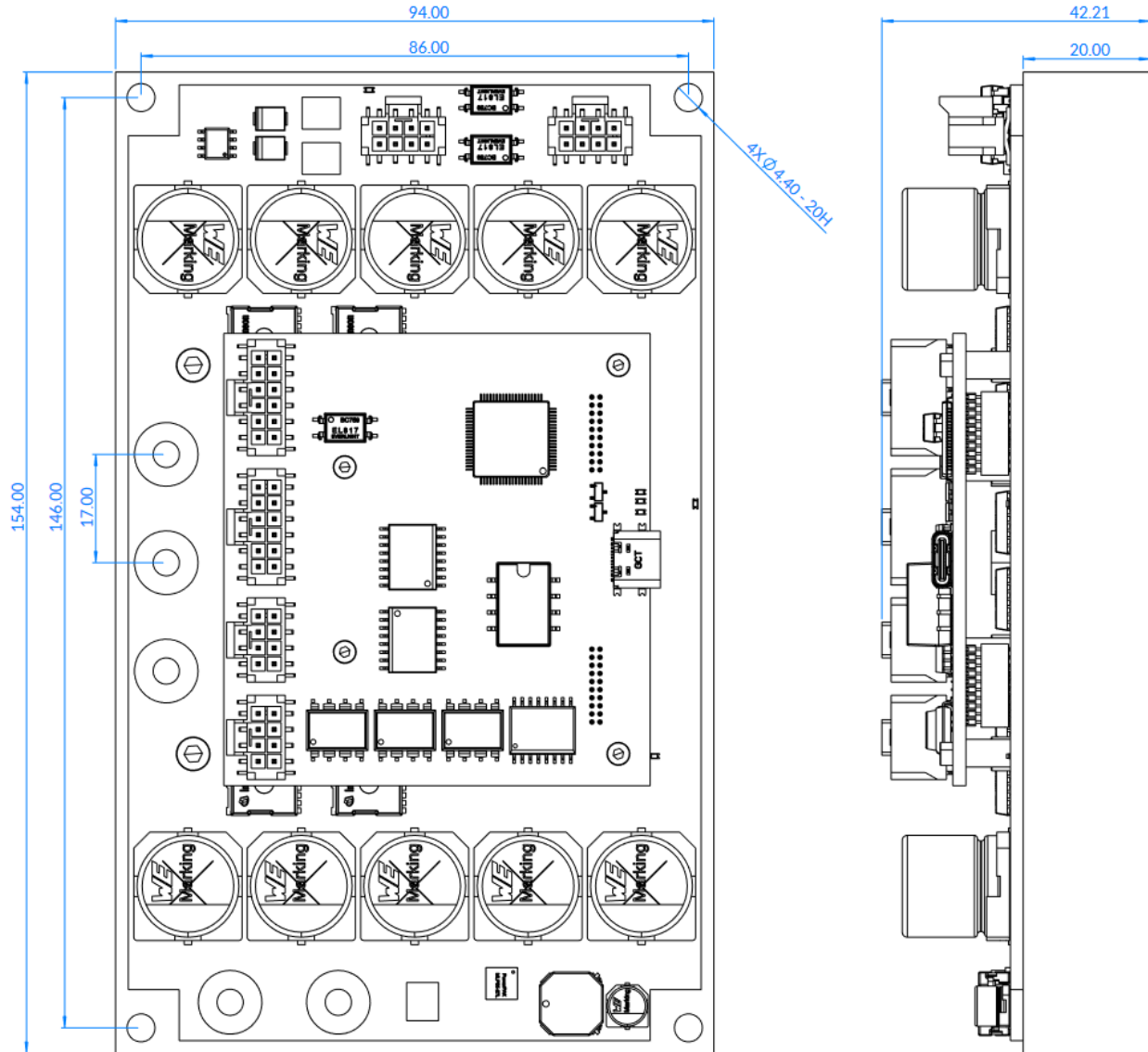
- All the measurements are in millimeters.

Absolute Maximum Voltage Ratings:

- All The sections are referred to Figure 5 below

⚠️

- **The +3.3V parts are NOT +5V tolerant**, and in case of applying more than 3.3V, the device might get permanently Damaged.
- The users should refer to "Typical Max" for the maximum voltage allowed on each pin, the "Absolute Max" is just for very short times considering the effect of spikes and fast harmonics.

Section	PIN/Connector name	Input / Output	Units	Min	Typical Max	Absolute Max
[18 ,17]	**Supply Input**	Input	VDC	+8	+60	+66
[5]	**S/T** (speed/torque)	Input	VDC	0	+10	+10.25
[5]	**P/F** (current limit/power/flux)	Input	VDC	0	+10	+10.25
[5]	**Speed-FB**	Output	VDC	0	+10	+10.25
[5]	**Torque-FB**	Output	VDC	0	+10	+10.25
[5]	**PT1000-IN**	Input	VDC	0	+3.3	+3.75
[5]	**DFU**	Input	VDC	0	+3.3	+3.75
[5]	**DIR** (Direction control)	Input	VDC	0	+12	+12.25
[10]	**STO1**(Safe Torque off input 1)	Input	VDC	0	+5	+5.25
[10]	**STO2**(Safe Torque off input 2)	Input	VDC	0	+5	+5.25
[5]	**+5V-NISO** (External supply)	Output	VDC	+4.95	+5.0	+5.05
[5]	**+12V-NISO**(External supply)	Output	VDC	+11.95	+12	+12.05
[1]	**+5V-ISO**(External supply)	Output	VDC	+4.95	+5	+5.05
[1]	**ENC-A**(Encoder channel A)	Input	VDC	0	+12	+12.25
[1]	**ENC-B**(Encoder channel B)	Input	VDC	0	+12	+12.25
[1]	**ENC-C**(Encoder channel C)	Input	VDC	0	+12	+12.25
[3]	**ISO-UART_RX**	Input	VDC	-0.5	-	+5.5
[3]	**ISO-UART_TX**	Output	VDC	-0.5	-	+5.5

[3]	ISO-CAN-H	-	VDC	-2	-	+7
[3]	ISO-CAN-L	-	VDC	-2	-	+7
[3]	ISO-GPO1	Output	VDC	0	-	+5.5
[3]	ISO-GPI1	Input	VDC	0	-	+5.5

Standards and Conformities:

Standard	Code	Class*
Radiated emissions – enclosure port	CISPR 16-2-3 EN 55016-2-3	B
Enclosure ports – Electrostatic discharges	IEC / EN 61000-4-2	B
Enclosure ports – Radio-frequency electromagnetic field (AM)	IEC / EN 61000-4-3	B
I/O DC power ports – Fast transients	IEC / EN 61000-4-4	B
I/O DC power ports – Surges	IEC / EN 61000-4-5	B
I/O 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	-

* : Without using any external Filters.

Overview of the product

SOLO MEGA is a family of high-power motor controllers that are designed for high-current applications. This product is designed to support various types of electrical motors like DC brushed, Brushless DC and PMSM motors up to 60V with the supply voltage and the continuous current of up to 120 Amps DC or 110 Amps RMS, this will enable SOLO MEGA to be utilized in wide range of products and projects and eventually speeding up the developments and time to market for its users.

SOLO MEGA can be commanded in two different ways, either by sending Analogue voltages or PWM pulses which is called Analogue Mode, or totally by sending Digital data packets through isolated UART, isolated USB or isolated CAN bus lines. This will give a high flexibility in terms of system setup to the users and they can choose the best way to wire up their systems using SOLO, The main features of SOLO MEGA are listed as below:

- Wide input voltage supply range from 8V to 60V
- The continuous output current of 120 Amps DC or 110 Amps RMS
- Capable of controlling DC brushed, BLDC and PMSM motors
- Dual Core with parallel processing architecture
- Isolated CAN, USB and UART Communications
- Isolated STO(Safe Torque off) for safe emergency stops
- Active Brake Chopper with selectable activation voltage using an external resistor
- Extremely fast F.O.C loop-rate up to 140kHz (7µs complete execution time)
- Over-current, Over-voltage, Over-Temperature and Under-voltage Protection
- Selectable output PWM switching frequency from 8kHz to 80kHz
- Automatic self-tuning and identification of Motor parameters
- Closed-loop Torque, Speed or Position control
- Advance Field Oriented Control
- PWM and Analogue voltage input for Controlling Speed and Torque
- Pure Analogue feedbacks output for Speed and Torque
- Optically isolated Encoder and Hall Sensor Input with up to +12V supply
- +5V/1A (5W) and +12/0.25A(3W) outputs to supply external modules
- 2.6mA current consumption in sleep mode
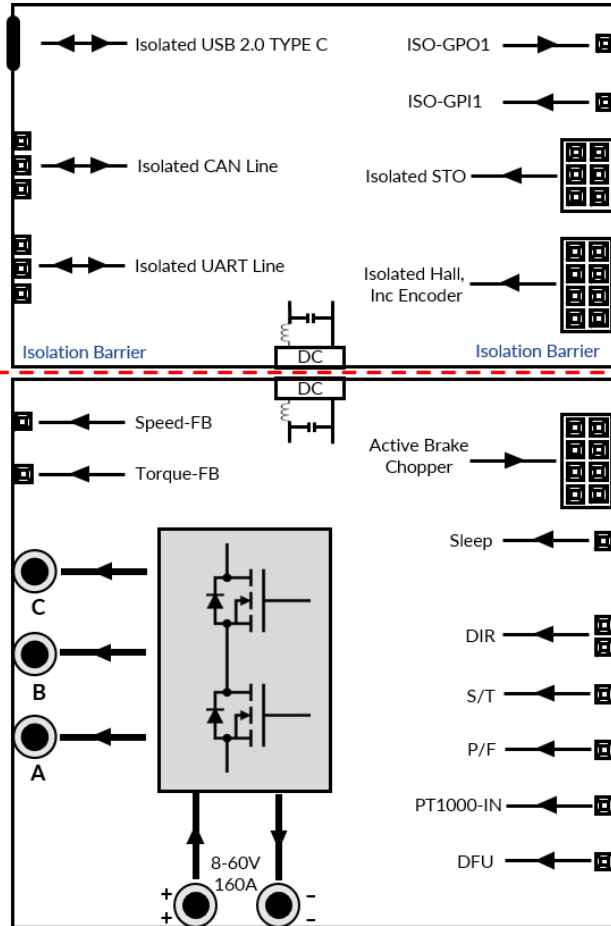
Functional Block Diagram:

Figure 1 - Functional Block Diagram of SOLO MEGA
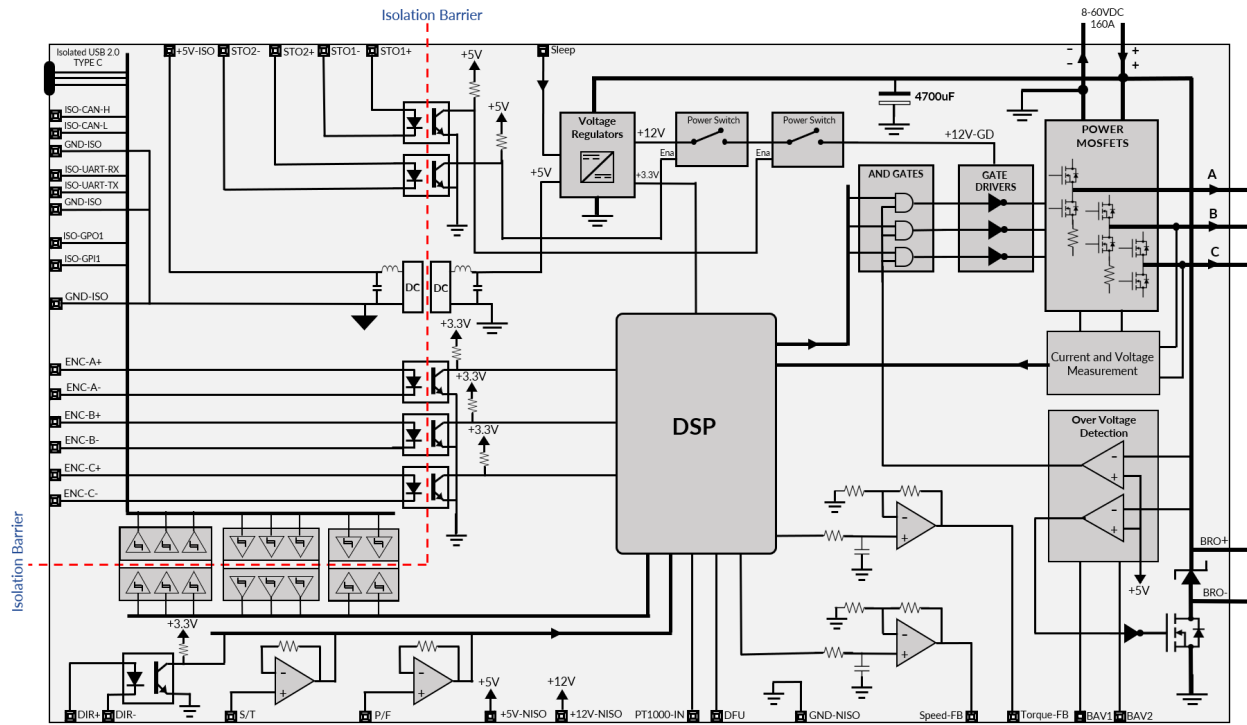
Architecture:

Figure 2 - Architecture of SOLO MEGA

Theory of Operation:

SOLO MEGA is designed to operate in closed-loop fashion with nested Torque, Speed and Position controlling loops, this type of topology gives the possibility of controlling each of these phenomenons (Torque, Speed, Position) separately and almost independently, resulting in very robust and smooth control for systems with variable dynamics and loads, for 3-phase motors like Brushless DC and PMSM this topology is known as Field Oriented Control or Vector Control.
In general we can divide the whole control architecture of SOLO for two different types of Motors, the 3-phase motors that can be seen in Figure 3 and Brushed DC motors that can be seen in Figure 4 below. As can be seen in these figures, the main foundation of the architecture of motor controlling in SOLO is based on four fundamental controllers:

1- The Torque Controller: This is the closest controller to the motor and the fastest one, it will only control the Torque of the Motor which is generated by injection of Current into the stator, that's why this controller is known as Current Controller too, this controller will try to stabilize the required torque (current) in the motor to make the whole system capable of overcoming the dynamics changes in the load.

2- The Speed Controller: The Speed Controller comes behind the Torque Controller, it is slower than the Torque controller (at least around tenfold) and it basically tries to fix the Speed on a desired value, this controller will keep the rotational speed fixed regardless of the load variation and it will adjust the torque accordingly. One might ask why the Speed controller comes after the Torque controller, this is a big topic, but to simplify it drastically , in principle an Electrical Motor is a Torque Generation machine, even the Speed is controlled finally by controlling the Torque, so the Speed commands to the Torque Controller to increase or decrease the Torque on the Motor to stabilize the motor on a specific desired Speed based on the effect of the load on the shaft.

3- The Position Controller: This is the last controller coming behind the speed controller, it basically tries to set the exact position of the Motor on a specific value, so to make this loop functional, the user needs to make sure the Torque and Speed loops are firstly tuned and ready.

FOC control Architecture in SOLO MEGA for 3-phase Motors:
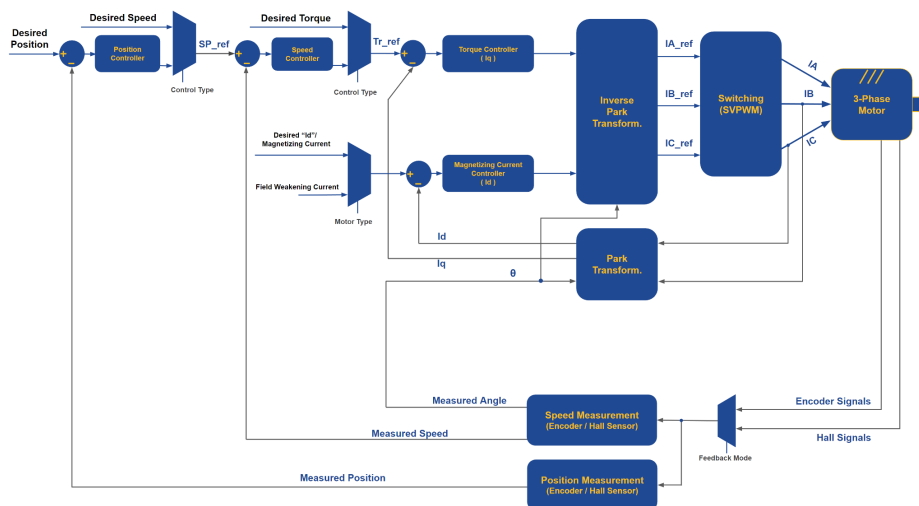

Figure 3 - FOC Control Architecture of SOLO MEGA for 3-phase Motors

As can be seen in Figure 3, to control any of the Torque, Speed and even position of a 3-phase motor in FOC fashion, there is a need to have at least 4 different feedbacks:

1- Current Feedback: This feedback is necessary to control the current inside of the motor and for Torque Controlling and it's measured internally by SOLO, the accuracy of current measurement is **80mA** in SOLO MEGA.

2- Speed Feedback: This feedback is measured using the sensors mounted on the motor (Encoders, Halls, …), and it's used for Speed Controlling purposes.

3- Position Feedback: This feedback comes from external sensors like Encoders, and it enables the Servo-Driving Capabilities of SOLO

4- Motor Electrical Angle: This feedback is essential for any type of closed-loop control on SOLO, this feedback is Measured by SOLO internally.

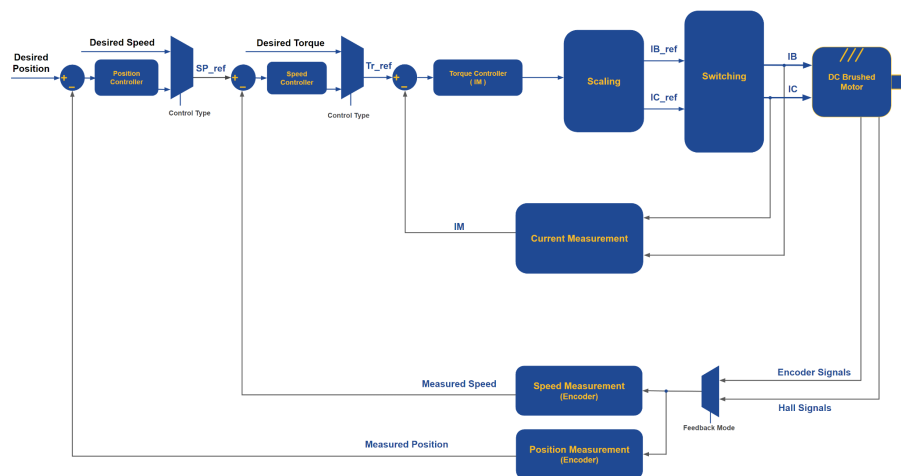# Cascade control Architecture in SOLO MEGA for DC Motors:

Figure 4 - Control Architecture of SOLO MEGA for DC Brushed Motors

As can be seen in Figure 4, the main architecture of Motor Controlling for DC brushed motors in SOLO follows a very similar pattern to 3-phase Motors Controlling with FOC, however the architecture is generally simple with only one cascade loop of Torque, Speed and Position.

Similar to 3-phase motors, for DC brushed Motors, SOLO offers Sensor-based controls as well as Servo-Driving in case an Incremental Encoder is attached to the Motor, so the whole control strategy and tunings are identical to the 3-phase motors with minor differences on the processing methods.

SOLO MEGA's Interactional Sections:

SOLO MEGA can be decomposed into 18 main interactional sections as shown in Figure 5, all the sections will be explained in detail and their electrical and maximum ratings will be mentioned later in this user manual, the user has to make sure they don't exceed those maximum ratings to avoid damaging themselves or the SOLO MEGA unit.
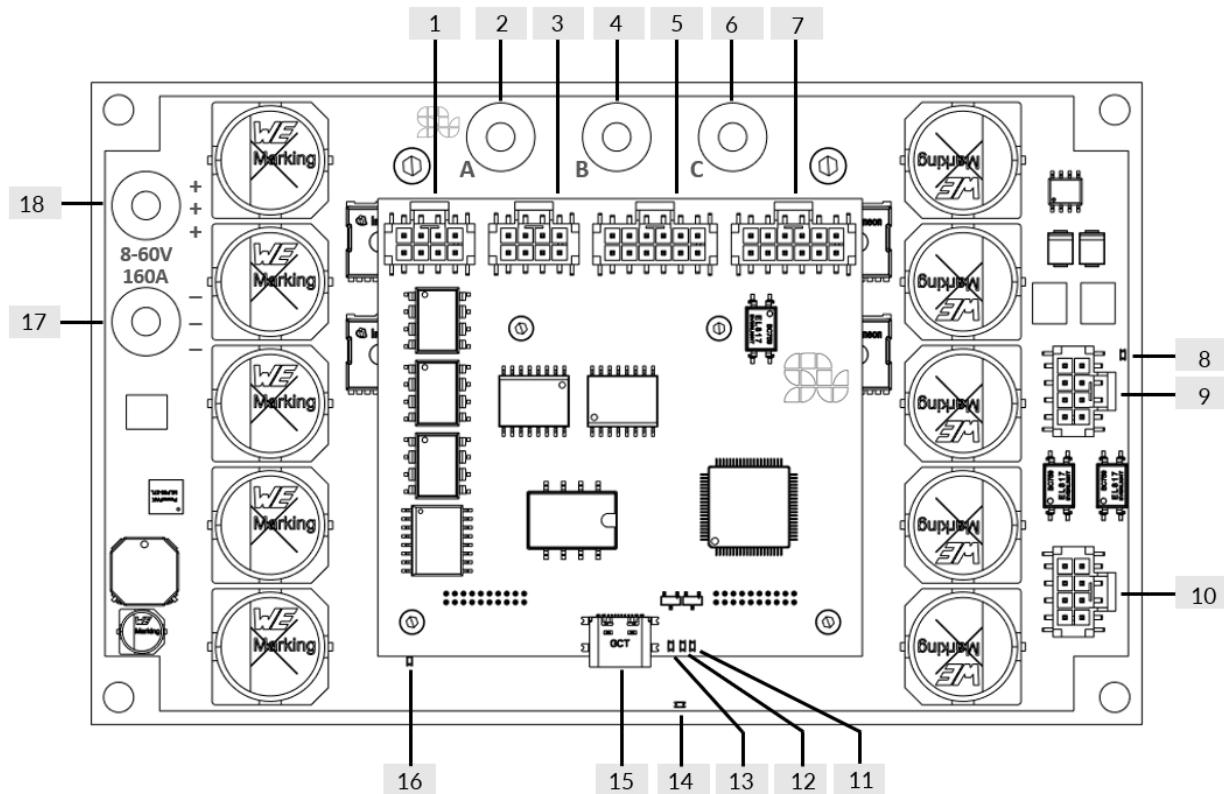

Figure 5 - SOLO MEGA's interactional sections
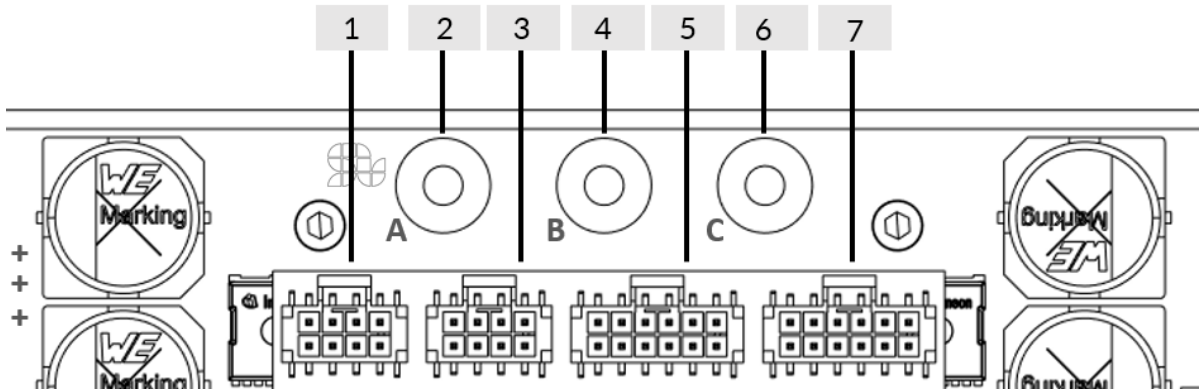
Connectors and Sections:

Sections [2, 4, 6] - Motor Outputs		
Name	**Descriptions / Notes**	**I/O**
A	Motor Output 1	-
B	Motor Output 2	-
C	Motor Output 3	-
Description		

This connector of SOLO should be connected to the Motors' wires. You can find out more about how to connect them by looking at the "SOLO MEGA Wirings" Section, but in general for 3 phase motors the A,B,C pins should get connected to the 3 phase wires of the motor and for DC brushed motors only B and C pins are required to be connected to the motor.

- While wiring SOLO MEGA avoid connecting power supply cables into motor outputs, this can cause serious damages to the unit.

Sections [17, 18] - Supply Inputs

| Name	Descriptions / Notes	I/O
+++	Positive Voltage Input	-
- - -	Negative Voltage Input (Ground)	-

Description

This is the Power Supply input of SOLO and it can be supplied with any DC input voltages from 8 to 60 volts in continuous mode, depending on the voltage rating of the Motor Connected at the output. The max rating for supply input is 60V, meaning that SOLO MEGA will go into over-voltage protection mode in case the supply or BUS voltage rises above almost 61.0 volts, the Brake Chopper circuit will get activated at approximately 61V in default mode, to know more on how to tune this please check Section [9] J8.
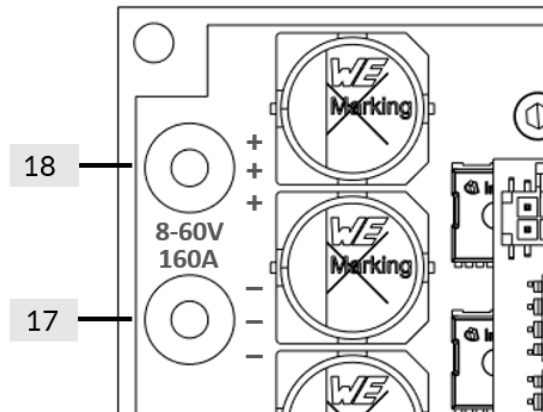
- SOLO MEGA doesn't have Reverse Polarity Protection, thus the user has to make sure their supply is correctly connected to the unit before turning it ON. By applying the supply reversely, the damage to the unit is imminent.
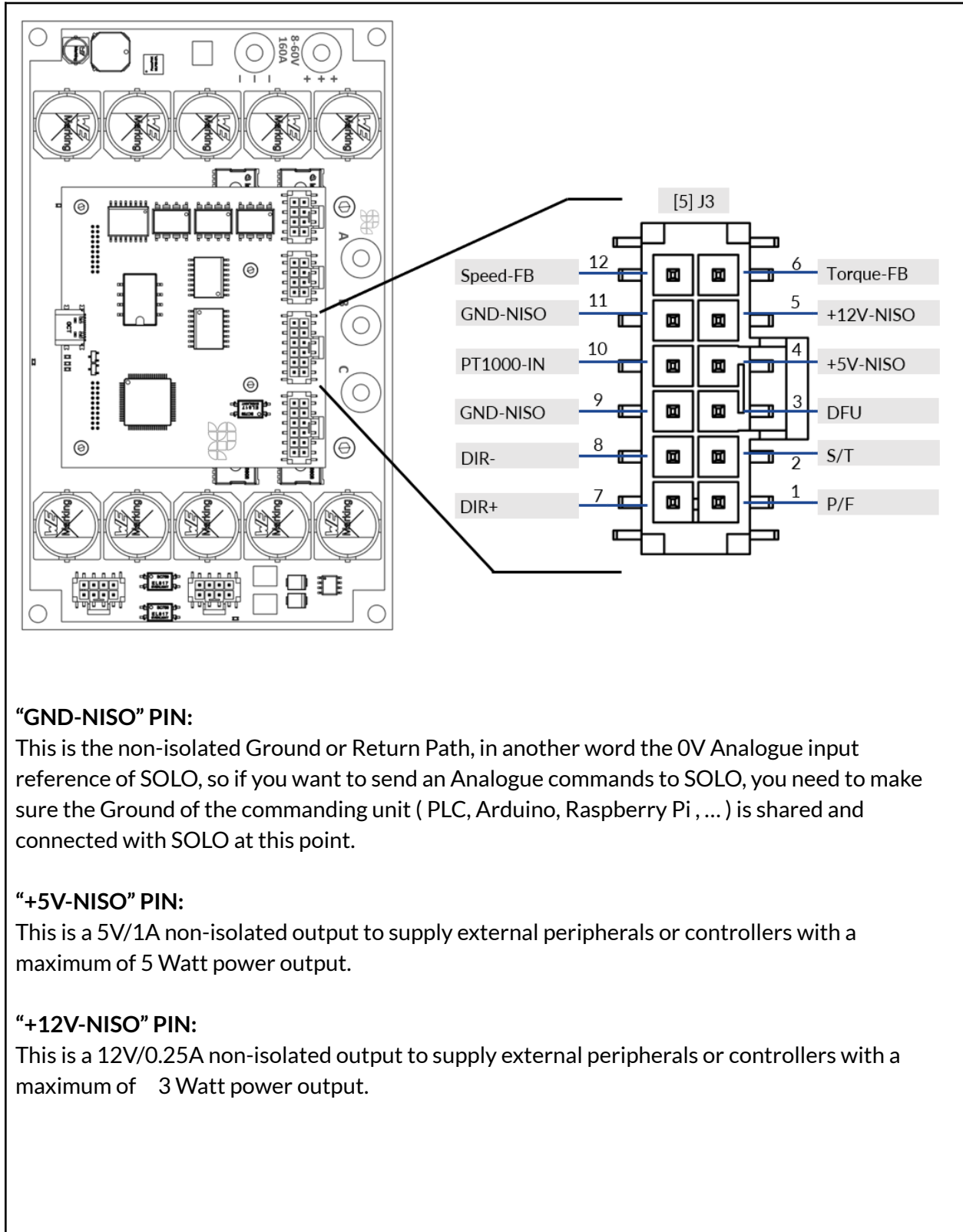
Section [5] J3 - Analogue I/O Port

PIN	Name	Descriptions / Notes	I/O
1	P/F	Current Limit, Power or Flux reference	I
2	S/T	Speed or Torque reference	I
3	DFU	Firmware Upgrade Mode is selected by grounding this PIN	I
4	+5V-NISO	Non isolated +5V/1A supply output for external modules	O
5	+12V-NISO	+12 volts non isolated supply output for external modules	O
6	Torque-FB	Analogue torque feedback	O
7	DIR+	Positive pin of direction input (optically isolated)	I
8	DIR-	Negative pin of direction input (optically isolated)	I
9	GND-NISO	Non isolated ground of SOLO	-
10	PT1000-IN	PT1000 temperature sensor input	I
11	GND-NISO	Non isolated ground of SOLO	-
12	Speed-FB	Analogue speed feedback	O

Description

This is the Analogue Port of SOLO, it's useful when SOLO is in "Analogue Command Mode" and using that you can control the Speed or Torque of your motor by sending Analogic commands using PWM pulses rated at 0-10V with any frequency above 5kHz or by sending pure Analogue voltages rated from 0V to 10V, you can also use them to limit the current fed into your Motor in a completely Analogue manner. This connector is composed out of 12 pins:

"GND-NISO" PIN:

This is the non-isolated Ground or Return Path, in another word the 0V Analogue input reference of SOLO, so if you want to send an Analogue commands to SOLO, you need to make sure the Ground of the commanding unit (PLC, Arduino, Raspberry Pi , …) is shared and connected with SOLO at this point.

"+5V-NISO" PIN:

This is a 5V/1A non-isolated output to supply external peripherals or controllers with a maximum of 5 Watt power output.

"+12V-NISO" PIN:

This is a 12V/0.25A non-isolated output to supply external peripherals or controllers with a maximum of 3 Watt power output.

"DIR+, DIR-" PINs:

These Direction control pins, which are digital pins connected to an Optocoupler, accepting voltage levels of **0V or 3.3V/ 5V/12V,** by giving each of these values, the connected Motor to SOLO, will either rotate in C.W. direction or C.C.W. direction.

"P/F" PIN:

This is a pin with functionality as below:

Mode of Operation	Functionality
In Closed-Loop mode of DC Brushed, BLDC and PMSM motors	It will act as the current Limit, so if the voltage applied to this pin is 10V, it will stop the current floating to the motor (current Limit at zero or Free-Wheeling), and if this pin is left open it will allow up to 130 Amps DC floating into your Motor, so any value between these will define the value of current limit. You can calculate the current limit value based on following formulas: **In case of using PWM:** The current Limit value = ((100 - duty cycle precentage of PWM at P/F input)/100) * 130.0 **In case of using Analogue Voltages:** The current Limit value = ((10.0 - the voltage at P/F input)/10.0) *130.0

"S/T" PIN:

This is the input for controlling Speed or Torque of the Motor connected to SOLO depending on the selected Mode. The Analogue voltage or the duty cycle of PWM pulse applied at this input will be treated as a desired reference or set-point based on table below:

Mode of Operation	Functionality
In Closed_loop **Torque** mode	If you apply an Analogue 10V or in case of using PWM inputs, a 100% duty cycle to this pin will cause the injection of current limited to current limit up to 130 Amps DC into your motor , given this, the amount of Torque for motors generally can be calculated: Applied Motor Torque = Current acting in torque generation * Motor Torque Constant

	The "Current acting in torque generation" for DC motors is shown with "**IM**" while for 3 phase motors (BLDC or PMSM) is shown by "**Iq**" or namely the "Quadrature current". So the amount of active current in torque generation based on the amount of voltage or duty cycle applied to S/T pin can be calculated as: **In case of using PWM:** The torque generation Current = ((100 - duty cycle of PWM at S/T input)/100) * 130.0 **In case of using Analogue Voltages:** The torque generation Current = ((10.0 - the voltage at S/T input)/10.0) * 130.0
In Closed_loop **Speed** mode:	If you apply an Analogue voltage of 0V or in case of using PWM inputs, a 0% duty cycle to this pin , it will keep your motor's speed at 0 RPM, and at the same time by applying 100% duty cycle or 10V Analogue input, SOLO will force your motor to go to the maximum speed based on the Motor's type divided by **ASRDC** coefficient (Analogue Speed Resolution Division Coefficient), to learn more about ASRDC coefficient please refer to our UART, USB or CANopen user manuals, the default value of ASRDC is set at 1, and it basically allows you to increase the resolution at S/T input for low speed motors.

Motor code	Motor Name	Maximum Speed in Closed-loop mode
0	DC brushed	**8000RPM/ASRDC** at 10V or 100% PWM input duty-cycle
1	Normal Brushless Motors (BLDC, PMSM)	**8000RPM/ASRDC** at 10V or 100% PWM input duty-cycle
2	Ultra Fast Brushless Motors (BLDC, PMSM)	**30000 RPM/ASRDC** at 10V or 100% PWM input duty-cycle

For instance, if we take Normal Brushless motors as an example, and in case of applying Analogue voltages, the speed of the motor can be found based on the following formula:

The Normal BLDC motor speed [RPM] = ((10.0 - the voltage at S/T input)/10.0) * (8000/ASRDC)

⚠️

- To have accurate motors speed measurements for 3 phase motors, you need to set the number of Poles of your motor using the SOLO Motion Terminal or by using USB or UART or CANopen interfaces, the default value for the number of poles in SOLO is set at 8.

Section [15] - Isolated USB Connection

Name	Descriptions / Notes	I/O
USB	Virtual COM port or Device Firmware upgrader	-

Description

This is and isolated USB 2.0 with type C connector which is used for sending and receiving digital packets and commands as well as upgrading the firmware, in Commanding mode, this isolated USB will be a virtual COM port (VCP) capable of putting SOLO into digital control mode and functioning in standalone fashion with only 1 USB cable and the Motor connected at the output.
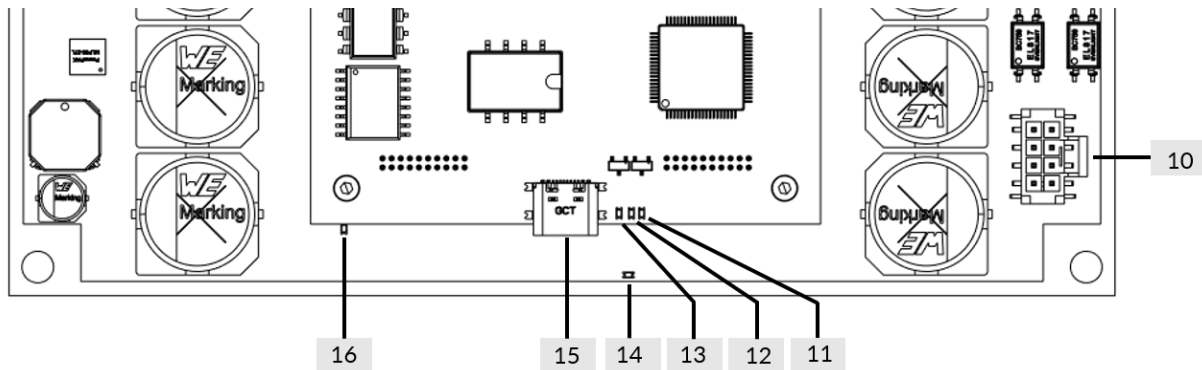
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- Powering up SOLO with any DC input voltages from 8 to 60 volts is necessary when SOLO MEGA is connected to the external Host by using USB cable (USB cable doesn't power up SOLO itself).

- The USB type C connector has no up or down orientation, so it's very robust and can be used for industrial applications.

- The maximum length of USB cable in SOLO MEGA is 5 meters.

Section [1] J2 - Encoder/Hall Connector

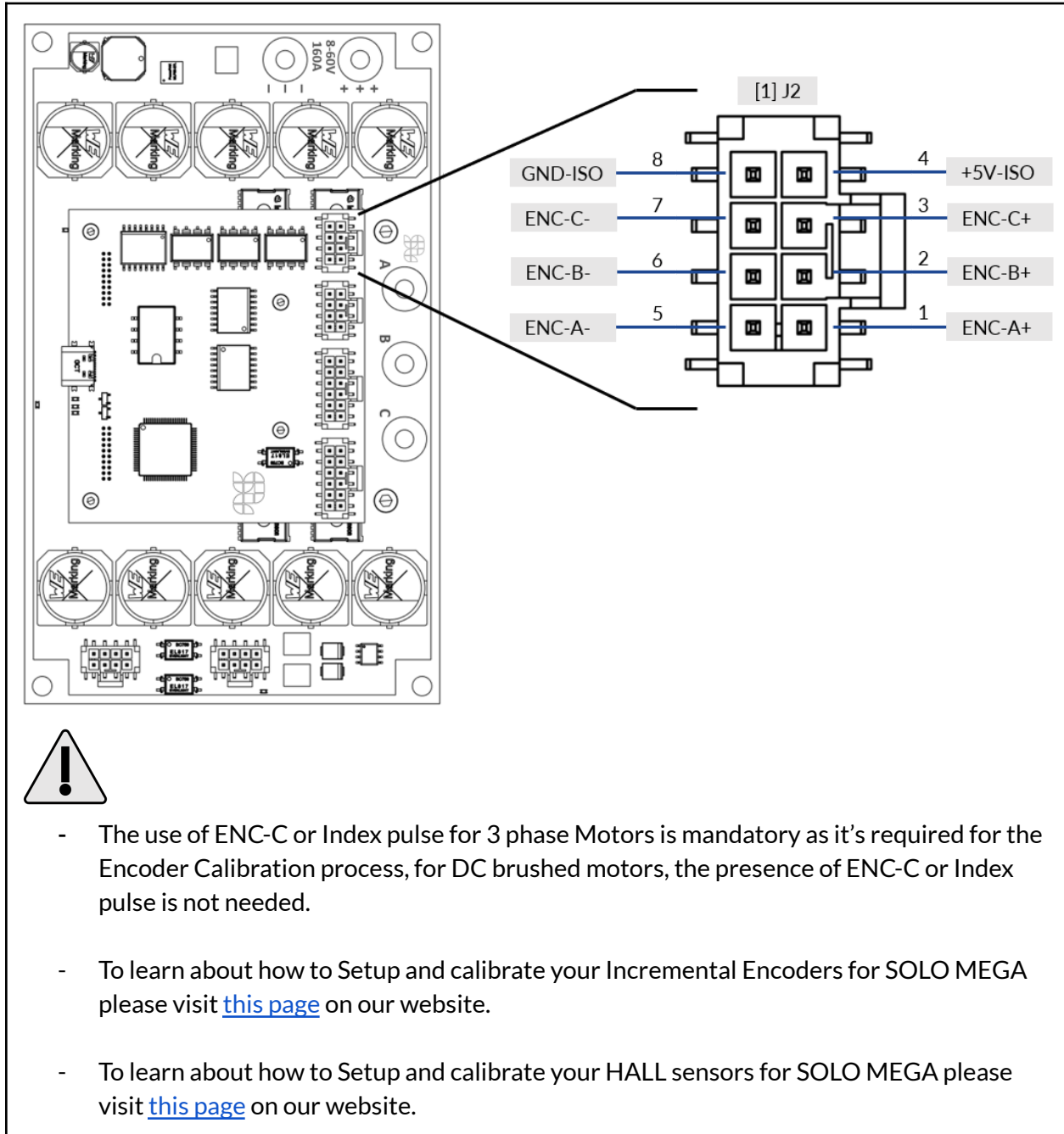| PIN	Name	Descriptions / Notes	I/O
1	ENC-A+	Positive input of channel A of the Encoder or Hall position sensors	I
2	ENC-B+	Positive input of channel B of the Encoder or Hall position sensors	I
3	ENC-C+	Positive input of channel C of the Encoder or Hall position sensors	I
4	+5V-ISO	Isolated +5V/200mA output	O
5	ENC-A-	Negative input of channel A of the Encoder or Hall position sensors	I
6	ENC-B-	Negative input of channel B of the Encoder or Hall position sensors	I
7	ENC-C-	Negative input of channel C of the Encoder or Hall position sensors	I
8	GND-ISO	Isolated Ground of SOLO	-

Description

This connector is the Quadrature Encoders or Hall sensors input; it accepts single-ended or differential signals leveled at +3.3V/5V/12V while providing an isolated +5V/200mA supply for powering up the 5 volts logic encoders. For powering up 12 volts logic encoders an isolated external 12V supply is required.

⚠️

- Use isolated +5V/200mA supply output only for supplying encoder or Hall position sensor. Do not use this supply for other peripherals.

- The maximum length of the Encoder or Hall sensor cable in SOLO MEGA is 3 meters.

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable's shield to ground.

[1] J2

Pin	Signal	Pin	Signal
8	GND-ISO	4	+5V-ISO
7	ENC-C-	3	ENC-C+
6	ENC-B-	2	ENC-B+
5	ENC-A-	1	ENC-A+

⚠️

- The use of ENC-C or Index pulse for 3 phase Motors is mandatory as it's required for the Encoder Calibration process, for DC brushed motors, the presence of ENC-C or Index pulse is not needed.

- To learn about how to Setup and calibrate your Incremental Encoders for SOLO MEGA please visit this page on our website.

- To learn about how to Setup and calibrate your HALL sensors for SOLO MEGA please visit this page on our website.

Section [3] J7 - Communication Connector

PIN	Name	Descriptions / Notes	I/O
1	ISO-CAN-L	Isolated CAN Low Bus Output (ISO 11898)	-
2	ISO-CAN-H	Isolated CAN High Bus Output (ISO 11898)	-
3	ISO-UART-TX	Isolated UART protocol transmitter output	O
4	ISO-UART-RX	Isolated UART protocol transmitter input	I
5	+5V-ISO	Isolated +5V/200mA output	O
6	GND-ISO	Isolated Ground of SOLO	-
7	ISO-GPI1	Isolated General purpose input 1	I
8	ISO-GPO1	Isolated General purpose output 1	O

Description

This is a connector that gives you access to isolated UART and isolated CAN bus communication pins in order to send/receive digital commands in the form of data packets.
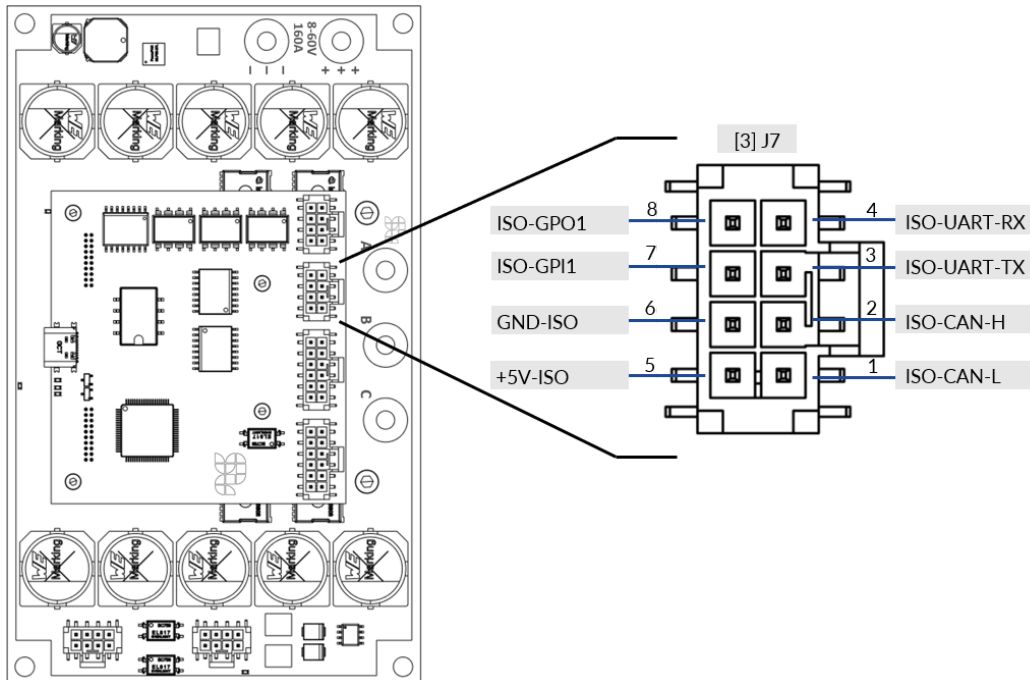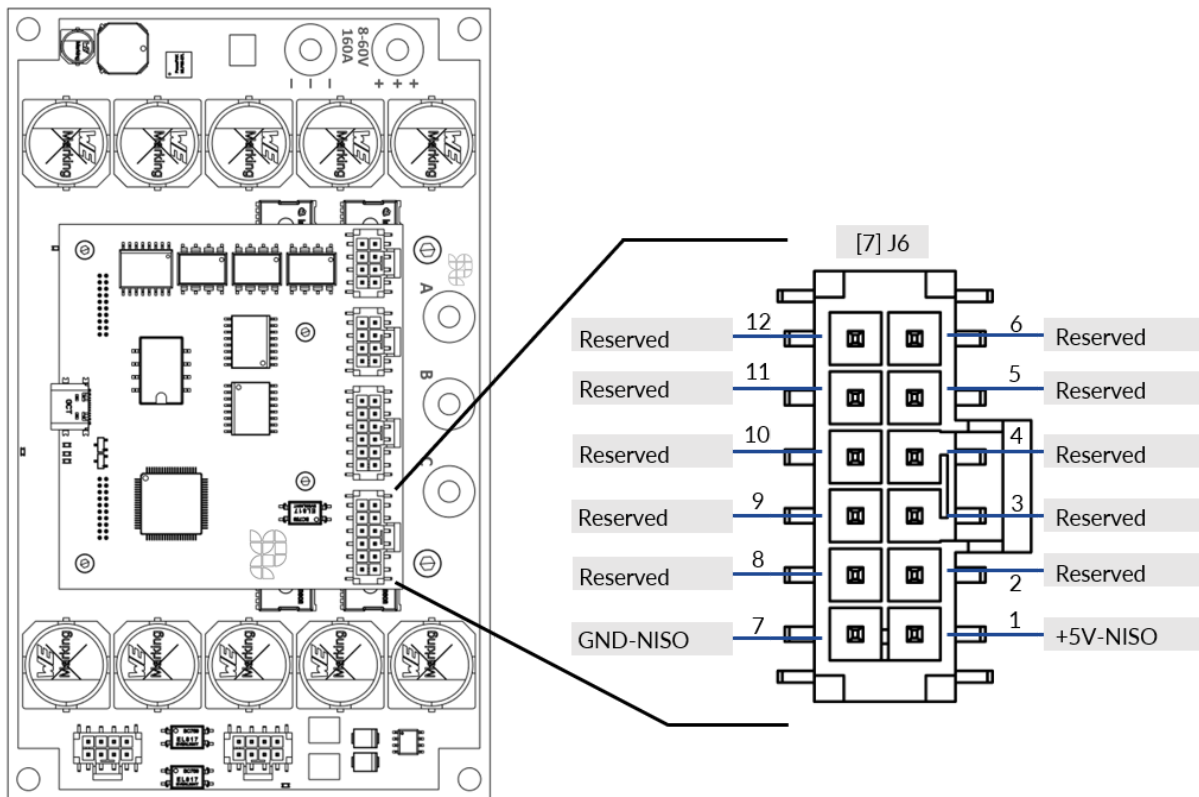
Section [7] J6 - Future Reserved Connector

PIN	Name	Descriptions / Notes	I/O
1	+5V-NISO	Non-Isolated +5V external supply	O
2, 3, 4, 5, 6, 8, 9, 10, 11, 12	Reserved	These pin are reserved for future purposes	-
7	GND-NISO	Non isolated ground of SOLO	-

Description

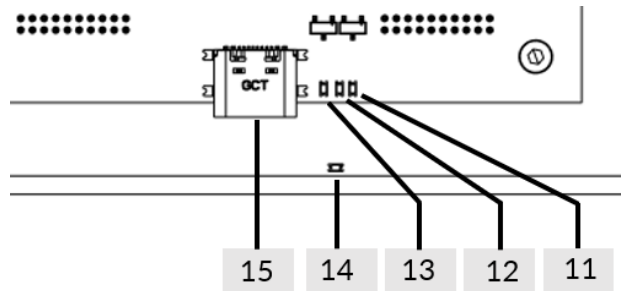This is a connector that is reserved for future purposes.

Sections [11,12] - Functionality LEDs

Section	Name	Descriptions / Notes	I/O
12	E2	Normal Activity LED	-
11	E1	Error Indicator LED	-

Description

There are three LEDs beside the USB connector of SOLO, two of them are named as "E1" and "E2" and have functionalities as below:

- **E2 :** This is the status or heart-beat indicator, after the device startup, in case of having a safe boot up , it will start blinking and remain in the blinking state.

- **E1:** This is the Error indicator, and in case of an error, it will act as below:
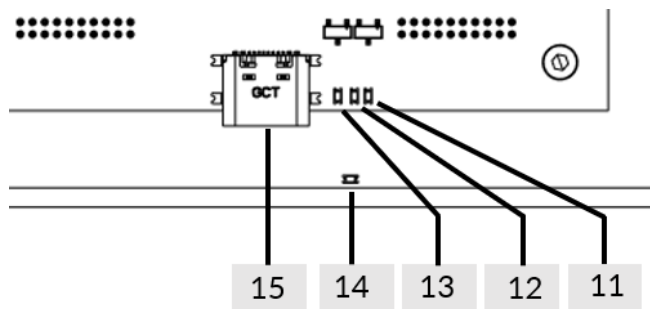   - *Over voltage, Over Current and Over Temperature Error:* Starts Blinking

Section [13] - Power Up LED

section	Name	Descriptions / Notes	I/O
13	A1	Power Up LED	-

Description

This LED will start glowing once SOLO is correctly powered up with a voltage from 8 to 60V.

Section [10] J9 -STO and Sleep Connector

PIN	Name	Descriptions / Notes	I/O
1	+5V-NISO	Non isolated +5V/1A external supply	O
2	GND-NISO	Non isolated ground of SOLO	-
3	Sleep	Sleep Mode input	I
4	Reserved	Reserved for future purposes	-
5	STO1+	STO channel 1 positive input (optically isolated)	I
6	STO1-	STO channel 1 negative input (optically isolated)	I
7	STO2+	STO channel 2 positive input (optically isolated)	I
8	STO2-	STO channel 2 negative input (optically isolated)	I

Description

The "Safe Torque off" is a hardware level protection that safely disconnects the motor from electronics causing the Motor to stop naturally.
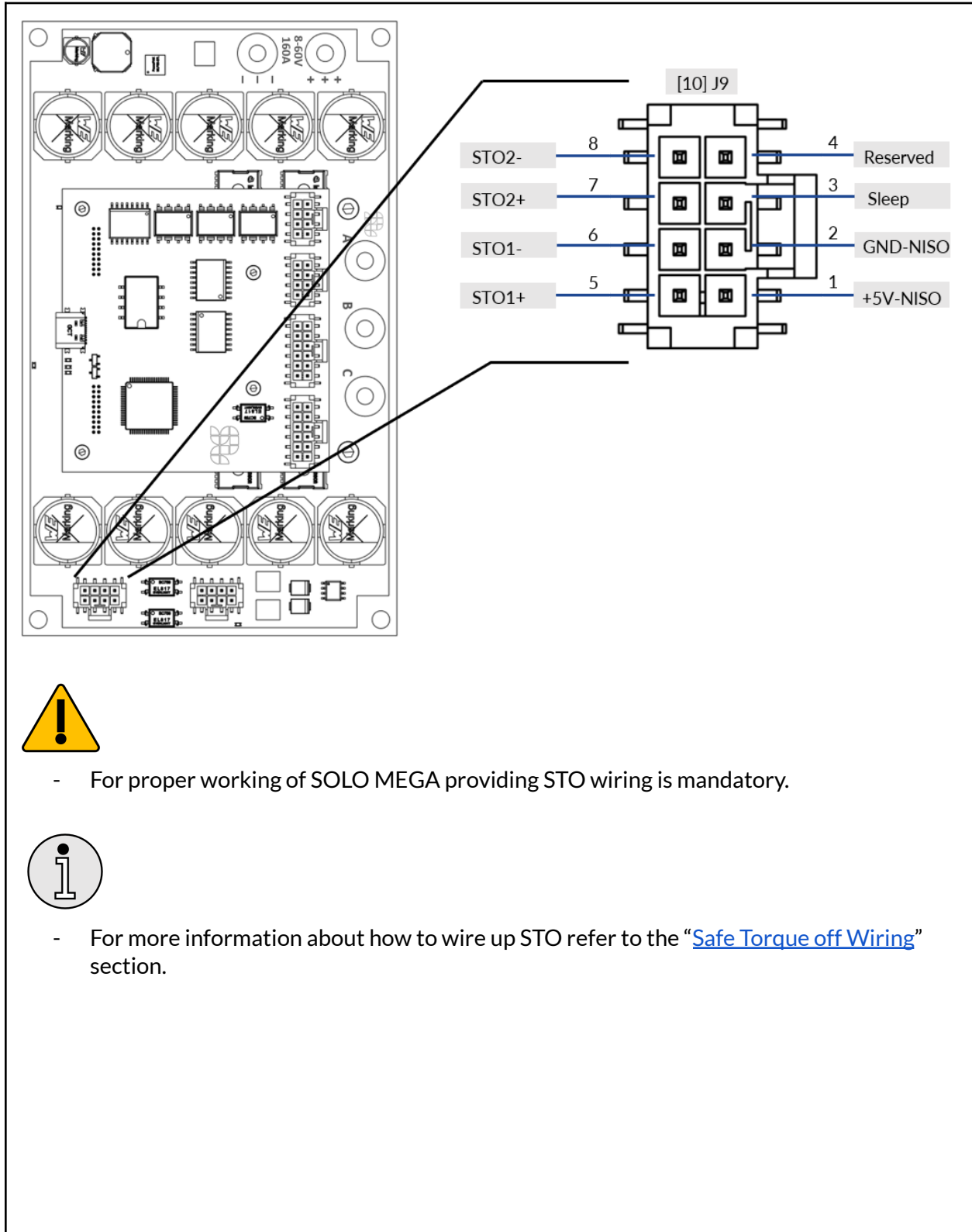
- For proper working of SOLO MEGA providing STO wiring is mandatory.

- For more information about how to wire up STO refer to the "Safe Torque off Wiring" section.

Section [9] J8 - Active Brake Chopper

PIN	Name	Descriptions / Notes	I/O
1	BAV2	Brake voltage activation external resistor input 2	I
2	BRO-	Brake chopper negative output	O
3	BRO-	Brake chopper negative output	O
4	BRO-	Brake chopper negative output	O
5	BAV1	Brake voltage activation external resistor input 1	I
6	BRO+	Brake chopper positive output	O
7	BRO+	Brake chopper positive output	O
8	BRO+	Brake chopper positive output	O

Description

This section provides a compact Active Brake Chopper circuitry to protect the device from over-voltage conditions caused by powered fed back from the motor to the DC BUS LINE due to regeneration by dissipating of the power on a high-power resistor through BRO+ and BRO- output with tunable activation voltage using an external resistor through BRA1 and BRA2 inputs from 61V down to 10.0V.

- The default activation voltage for this circuitry on SOLO MEGA is set at **61V**, however this voltage can be changed to any desired voltage using the below formula mentioned in Wiring and Setup of Active Brake Chopper.

- To find out more about brake chopper please refer to Wiring and Setup of Active Brake Chopper later in this document.

- If the connected load to the motor shaft has an extreme moment of inertia, using the active brake chopper is mandatory, otherwise in case of excessive regeneration SOLO or power supply will be damaged due to over-voltage condition.

- Note that never set Brake Chopper Activation Voltage below the power supply voltage, this will cause continuous power dissipation on the Brake Resistor and will increase the current consumption with no effective use.

- Try to correctly select Brake Resistor power rating, otherwise the Brake Resistor will be damaged due to overheating.

Section [8] - Brake Activation LED

Section	Name	Descriptions / Notes	I/O
8	B1	Brake Activation LED	-

Description

This LED will turn on once the Brake circuitry is actively dissipating Energy on the RC power resistor.

ⓘ
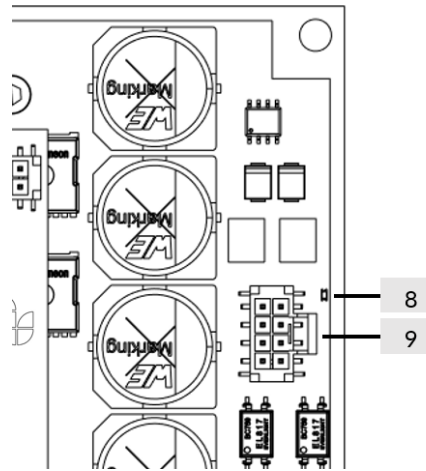
- If the Brake Activation LED is permanently turned on while the motor is not connected to the output, it shows the Brake Activation Voltage has been set below the power supply voltage and you have to recalculate it again.

Connectors and their Matings Part Number:

Section	Manufacturer	Mating Part Number
[2, 4, 6, 17, 18]	Wurth Electronics	5580516
[1, 3, 9, 10]	Molex	1053081208
[5, 7]	Molex	1053081212

Analogue versus Digital Control in SOLO MEGA

The "Analogue" control in SOLO puts the unit in a mode that can accept Torque or Speed references along with Current limit and the Direction of the rotation through an analogue mean like a pure analogue voltage or PWM pulses, however in Digital Mode all the commands and feedbacks are transferred through data packets

On SOLO MEGA there are two Analogue feedbacks for Torque and Speed, those feedbacks are going to be functional regardless of the mode of the operation.

SOLO MEGA Wirrings

The wiring legends in SOLO MEGA are as below:

Wiring Legend:

Shape	Description
⏚	Non isolated ground
▼	Isolated ground
▽	External ground(peripheral ground, PLC ground, Embedded MCU boards ground, External supply ground)
▭	Fuse, the value must be selected based on the system requirements
⊓⊔⊓	Line carrying pulses with PWM (fixed frequency above 5kHz)
∿	Line carrying Pure Analogue voltage
⌐	Line carrying ON / OFF type of signals (low frequency)
▤	SOLO inputs/outputs pins
■	External controller inputs/outputs pins

Safe Torque Off (STO) Wiring:

The "Safe Torque off" is a hardware level protection that reliably disconnects the energy supply to the motor in your particular application. For proper working of SOLO MEGA providing STO wiring is mandatory. The STO has a negative logic, meaning that once the STO lines are powered up to a high state (e.g. +5V) the unit will activate the power electronics dealing with the Motor, subsequently once the STO pins are left open or grounded (e.g. connected to the Ground) the unit will stop feeding any current into the Motor causing the Motor to stop with its own natural time constant. There are four different ways to wire up STO inputs:

1- Wire STO to a safety relay using external +5V DC supply voltage:

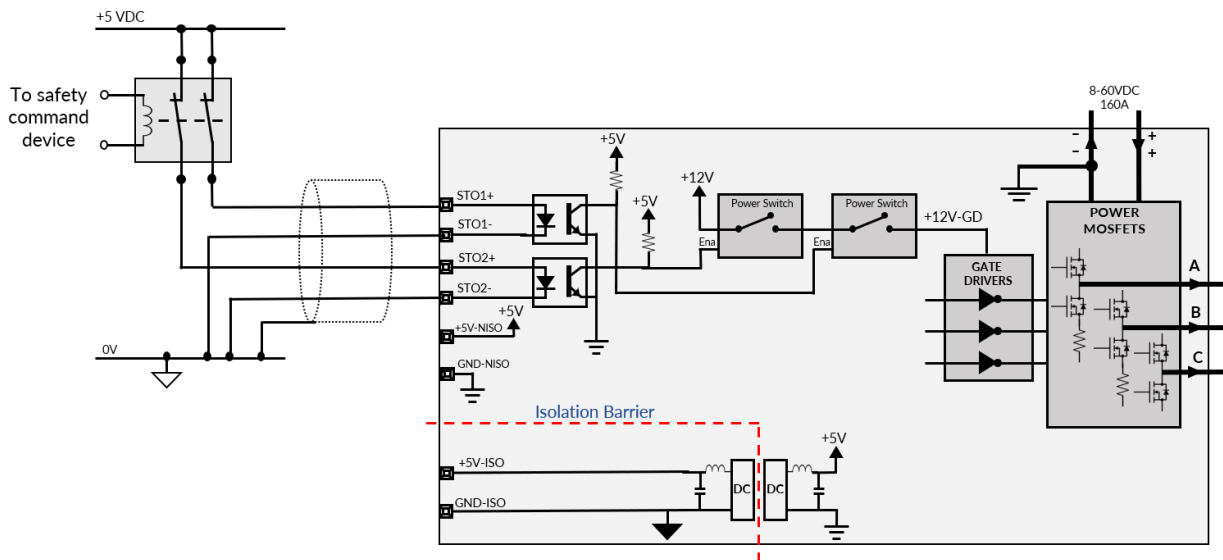As shown in Figure 6 a safety relay is used to deactivate or activate STO while the device is operational.

Figure 6 - STO wiring to external safety relay using external supply voltage

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect the cable's shield to the external supply ground.

2- Wire STO to a safety relay using internal +5V isolated supply voltage:

As shown in Figure 7 the +5V internal isolated voltage is used to wiring up STO inputs. The safety relay can be commanded from external commanding devices, this wiring can be used to keep the ground of the STO relays and SOLO isolated for highly critical systems.
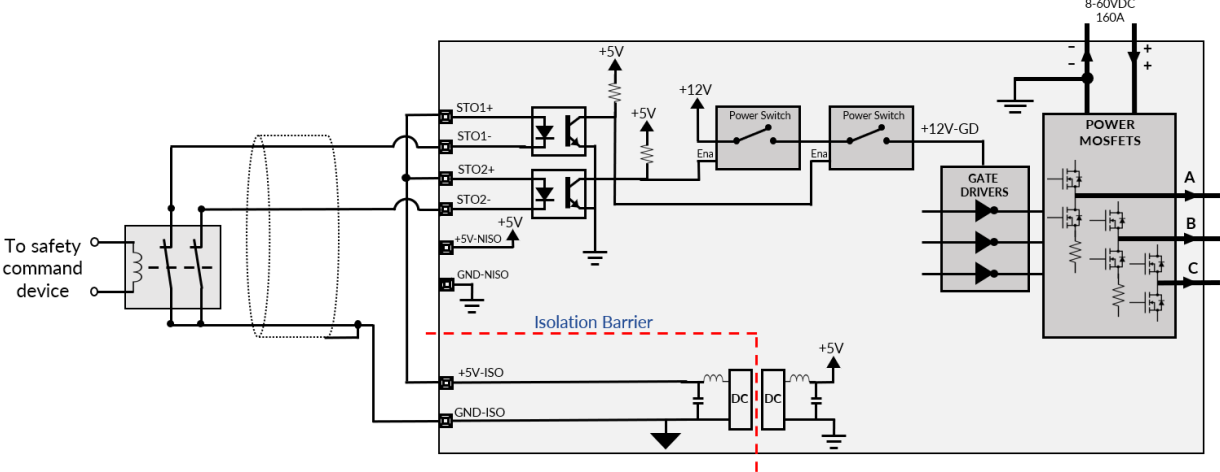

Figure 7 - STO wiring to external safety relay using internal isolated +5V supply voltage

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable's shield to internal isolated ground.

3- Wire STO to a safety relay using internal +5V non- isolated supply voltage:

As shown in Figure 8 the +5V internal non- isolated voltage is used to wiring up STO inputs. The safety relay can be commanded from external commanding devices.
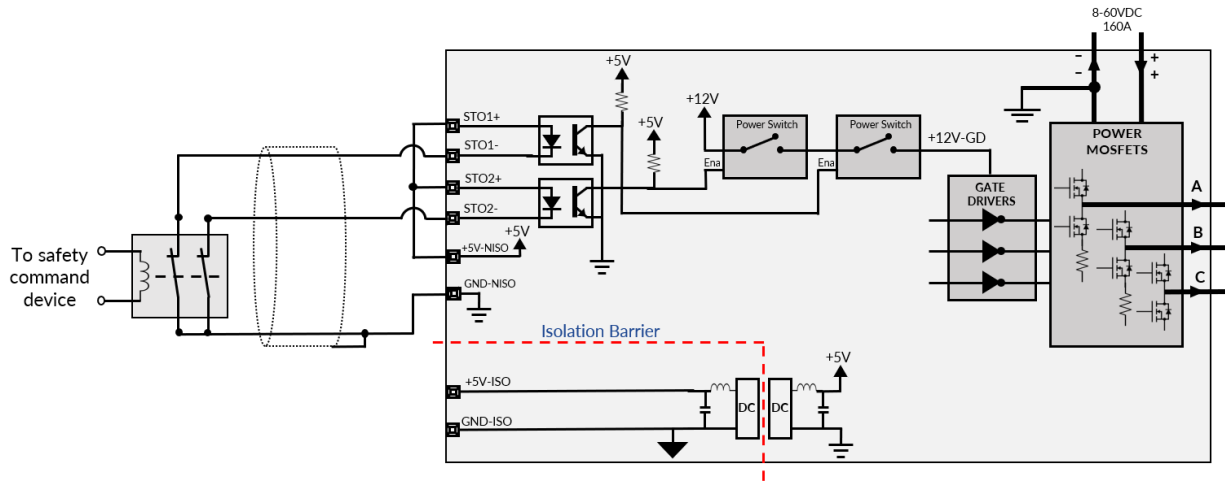

Figure 8 - STO wiring to external safety relay using internal non- isolated +5V supply voltage

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable's shield to internal non-isolated ground

4- By Passing STO without external commanding devices:

As shown in Figure 9, the +5V internal non- isolated voltage is used for wiring up STO inputs. This STO wiring is a very simple way to run SOLO as quickly as possible since it essentially bypasses the STO functionality . For maximum safety we don't recommend this wiring, only use this wiring for initial tests.
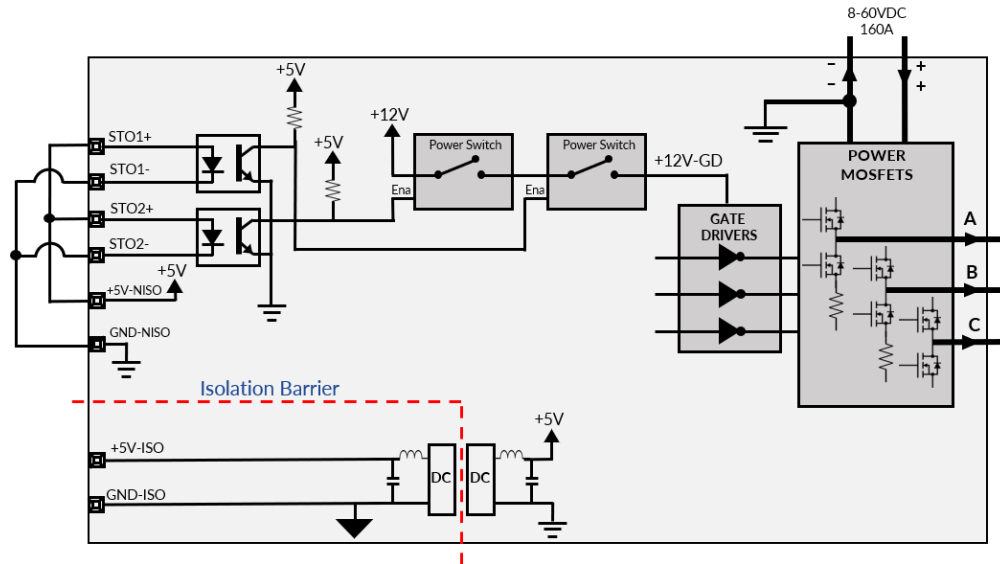

Figure 9 - STO wiring without external commanding devices by using internal non- isolated +5V supply voltage

STO Timing Diagram

In SOLO MEGA there are two dedicated STO inputs, STO1 and STO2 inputs that are providing redundancy and extra safety.

- When one of the STO inputs or both of them are disconnected at any given point, the motor continues to move with its own inertia till stopping and it can be dangerous in some situations, the user must provide other external safety to prevent any such undesired motion.

As can be seen in Figure 10 when the external controller sets STO1 and STO2 inputs at least for 13 milliseconds the "Safe Torque Off" unit of SOLO MEGA will be deactivated and stops any power from going into the motor, This time is called deactivation time. Also if the external controller

wants to activate STO unit, the controller must reset STO inputs at least for 7 milliseconds, this time is also called activation time. As demonstrated in Figure 10 any pulses below 1 millisecond can not affect STO functionality.
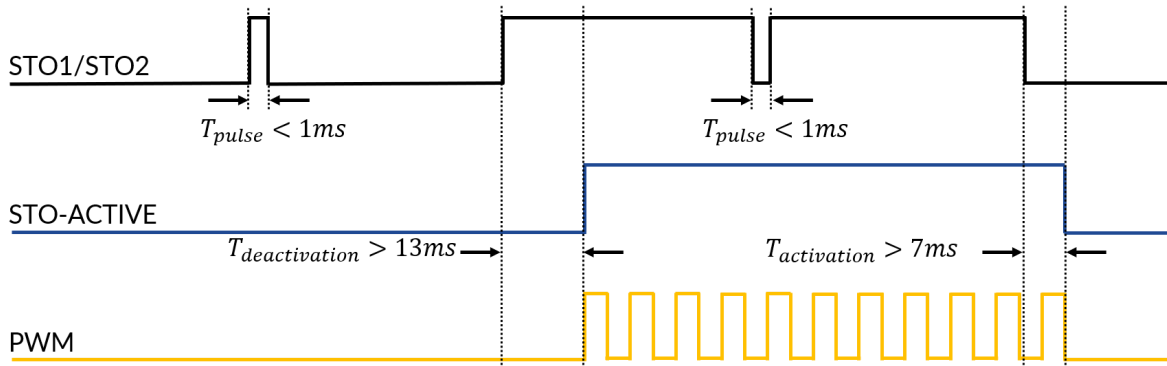

Figure 10 - STO Activation, Deactivation and Pulse Time

The following table summarizes the parameters of the STO unit of SOLO MEGA:

Parameters	Descriptions	Values
Type of input	STO1+, STO1-, STO2+ and STO2- type of inputs	Optically isolated
Voltage range	The acceptable voltage range that can be applied to STO inputs	+3.3V to +5V
Input current	STO1 and STO2 channels input current	2.1mA to 3.3 mA
Low level input voltage threshold	For +3.3V logic	
	For +5V logic	
High level input voltage threshold	For +3.3V logic	
	For +5V logic	
Pulse time	The maximum width of the short pulse that will be ignored by STO unit	< 1 milliseconds
Deactivation time	Minimum time for deactivating the STO unit	> 13 milliseconds
Activation time	Minimum time for activating the STO unit	> 7 millisecond

Analogue wiring in SOLO MEGA:

In SOLO MEGA it is possible to control Torque and Speed of motors by applying pure analogue voltages or PWM pulses to S/T and P/F inputs. There are three different ways for wiring up SOLO in Analogue Mode:

1- Analogue wiring in case of controller with NPN outputs:

In general a PLC has two kinds of output, NPN output and PNP output. In NPN output when an output becomes activated the corresponding output pin will pull down to ground, but in PNP output when an output becomes activated the corresponding output pin will pull up to the positive supply of the controller. As can be seen in Figure 11 the DIR- pin is connected to controller NPN output and DIR+ is connected to +12VDC of the controller. Also 0-10V analogue outputs are connected to S/T and P/F inputs.
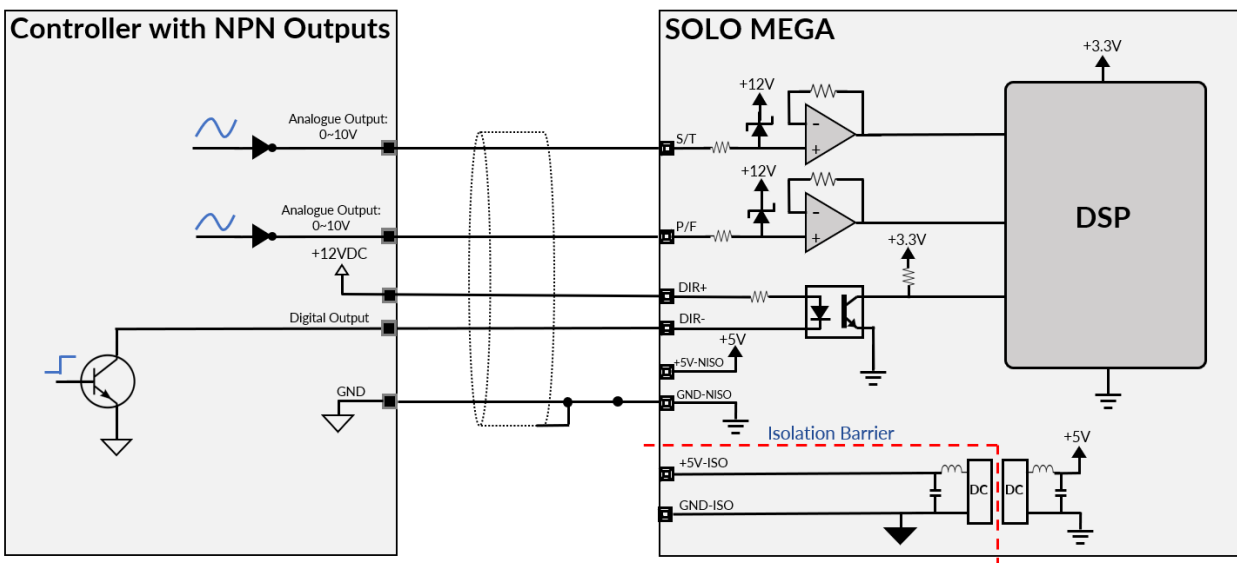

Figure 11 - Analogue wiring in case of NPN outputs controller

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable's shield to internal non-isolated ground or to controller ground at one side.

⚠️

- The non-isolated ground of SOLO must be connected to the controller ground.

2- Analogue wiring in case of controller with PNP outputs:

As can be seen in Figure 12 the DIR+ pin is connected to controller PNP output and DIR- is connected to ground of the controller. Also 0-10V analogue outputs are connected to S/T and P/F inputs.
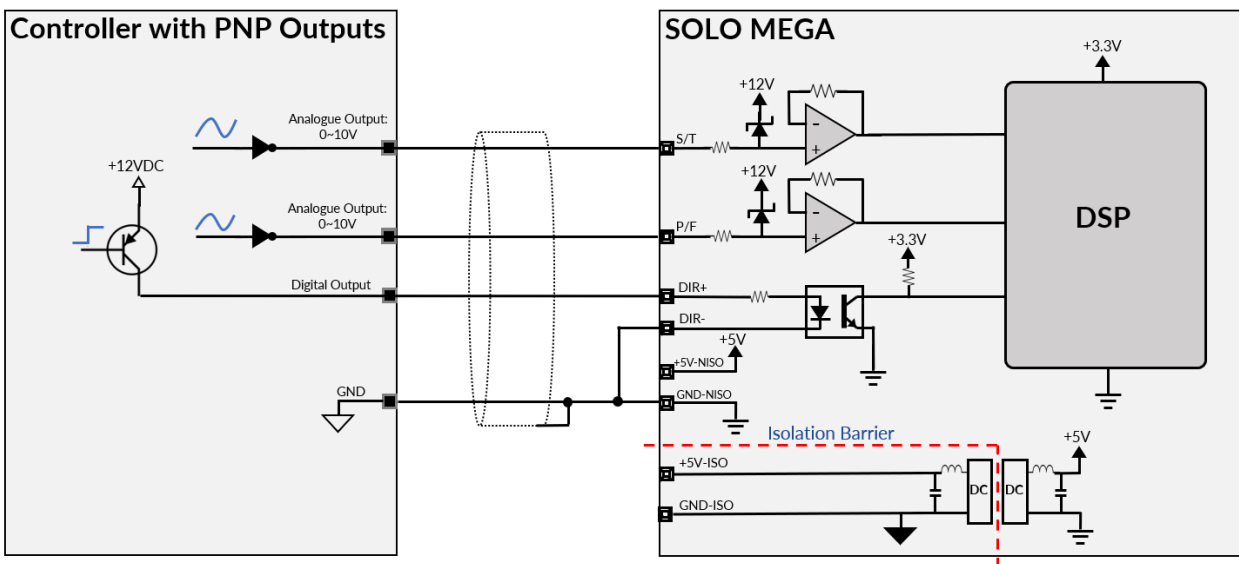

Figure 12 - Analogue wiring in case of PNP outputs controller

ℹ️

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to internal non-isolated ground or to controller ground only at one side.

⚠️

- The non-isolated ground of SOLO must be connected to controller ground

3- Analogue wiring in case of Embedded MCU Boards:

SOLO MEGA can be controlled by any Embedded MCU boards with 3.3V or 5V logic like Arduino, Raspberry Pi and so on. As can be see in Figure 13 the DIR- is connected to non-isolated ground of SOLO MEGA and DIR+ is connected to any digital outputs of Embedded MCU Board, also S/T A and P/F pins are connected to analogue or PWM outputs of Embedded MCU Board.
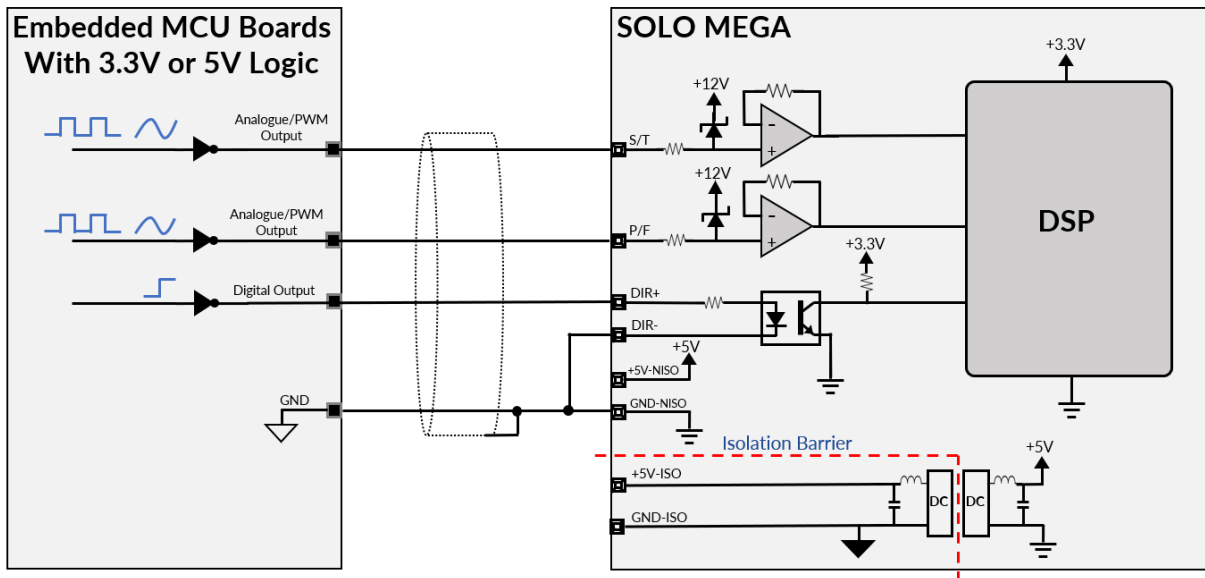

Figure 13 - Analogue wiring in case of Embedded MCU Boards

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to internal non-isolated ground or to controller ground only at one side.

- The PWM frequency must be at least 5KHz.

- The non-isolated ground of SOLO must be connected to Embedded MCU Board ground.

Wiring with HALL Sensors:

Using HALL sensors mounted on BLDC or PMSM motors, you can accurately control Torque, Speed and Position of motors. Once using HALL sensors you need to make sure you apply the correct setup followed by one-time calibration of the system, to learn about the process please visit this page on our website.

As can be seen in Figure 14 Hall A, B, and C outputs are connected to negative inputs of optocouplers and all positive inputs of optocouplers are connected to +5V isolated supply of SOLO MEGA.
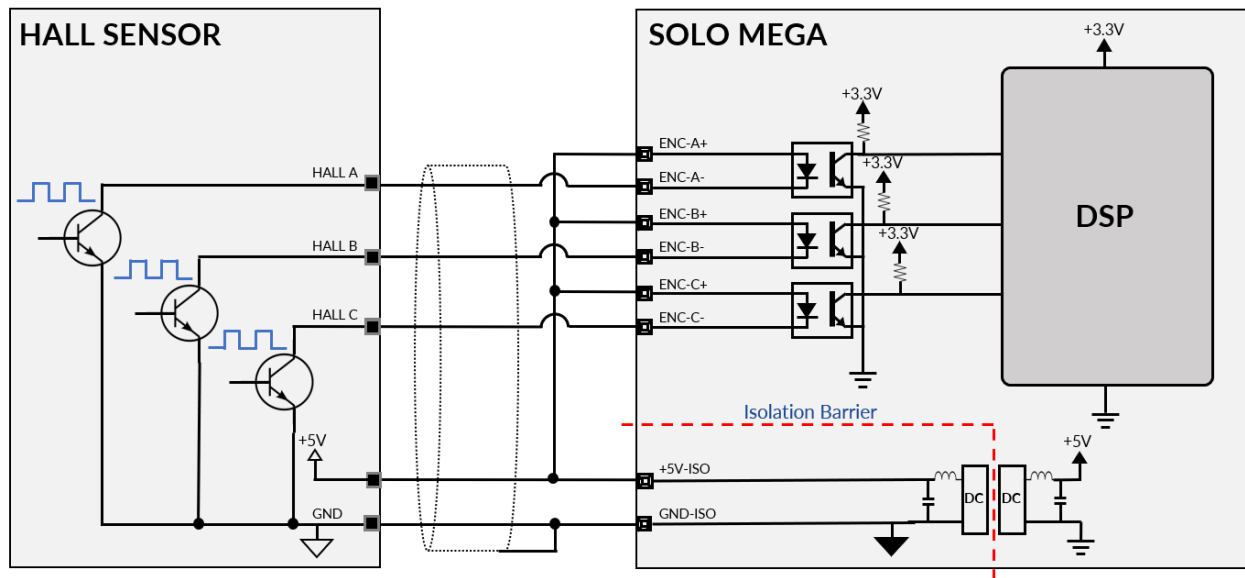

Figure 14 - Hall Sensor wiring in SOLO MEGA

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to internal isolated ground or to controller ground only at one side.

- The isolated ground of SOLO must be connected to the Hall Sensor ground.

Wiring with Incremental Encoders:

By using Incremental Encoders you can turn SOLO into a servo drive controlling Torque, Speed and Position of your Motor, once using Incremental Encoders you need to make sure you apply the correct setup followed by one-time calibration of the system, to learn about the process please visit this page on our website.

In SOLO MEGA the Incremental Encoder inputs are optically isolated and can be wired in two different ways according to type of encoder both in Differential or Single Ended fashion.

1- Wiring in case of Single Ended Incremental Encoders:

As can be seen in Figure 15, channels A, B and C of Single Ended Encoder are connected to positive inputs of optocouplers and all of negative inputs of optocouplers are connected to isolated ground of SOLO MEGA.
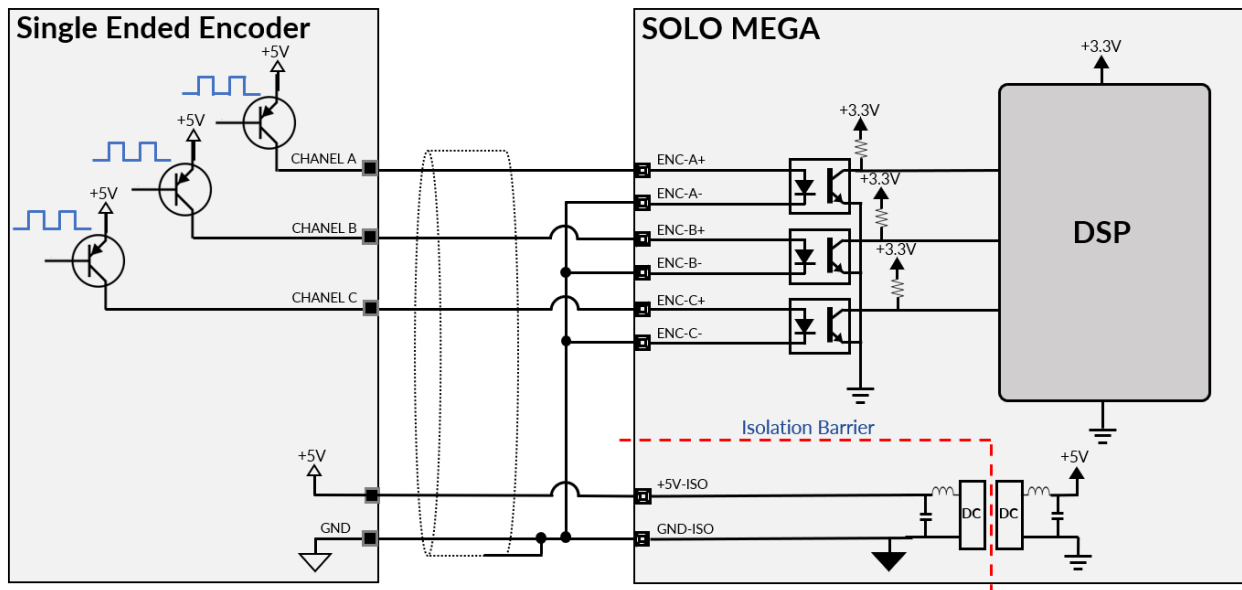

Figure 15 - Single Ended Incremental Encoder wiring in SOLO MEGA

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to internal isolated ground or to controller ground only at one side.

⚠️

- The isolated ground of SOLO must be connected to the Single Ended Encoder ground.

2- Wiring in case of Differential Incremental Encoders:

As can be seen in Figure 16, positive outputs of Differential Encoder are connected to positive inputs of optocouplers and negative outputs of Differential Encoder are connected to negative inputs of optocouplers.
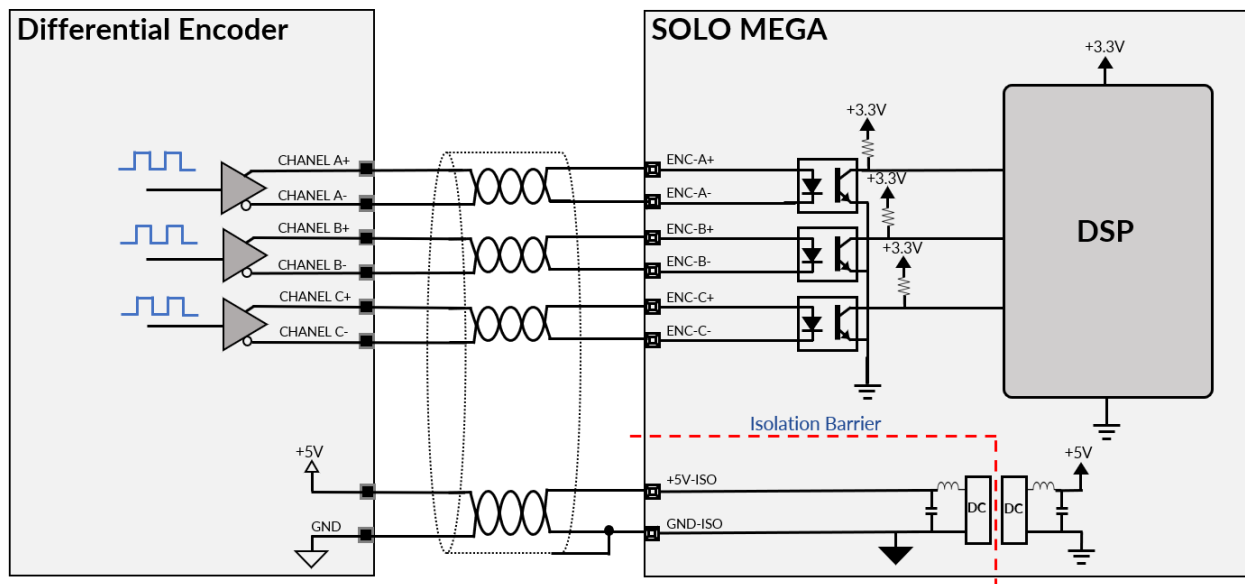

Figure 16 - Differential Incremental Encoder wiring in SOLO MEGA

ℹ️

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to internal isolated ground or to controller ground only at one side.

- It's highly recommended to wire positive and negative wires as twisted pairs as shown in Figure 16, it will reduce noise significantly.

⚠️

- The isolated ground of SOLO must be connected to the Differential Encoder ground.

Wiring of Sleep Mode input:

In SOLO MEGA it is possible to put SOLO at very low current consumption which is called sleep mode. As shown in Figure 17 a switch is used to pull down Sleep input to ground in order to put SOLO in Sleep Mode, the current consumption in this mode will be around 2.6mA.
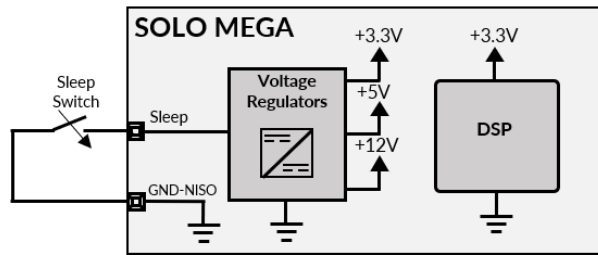

Figure 17 - Sleep Mode wiring

- To have external control on Sleep Mode a relay can be used. Also users can directly connect Sleep input to external controller outputs and Ground it whenever necessary.

Wiring of DFU Mode input:

As can be seen in Figure 18 and Figure 19 in order to put SOLO in DFU Mode, the DFU input (pin 3 of J3 connector) must be connected to non-isolated ground (pin 9 of J3 connector).
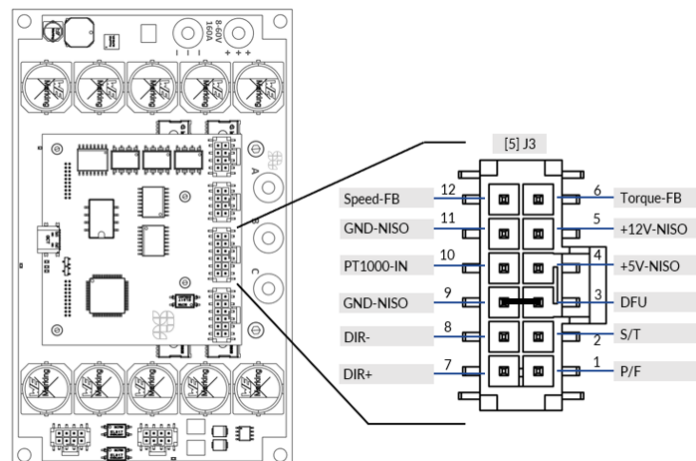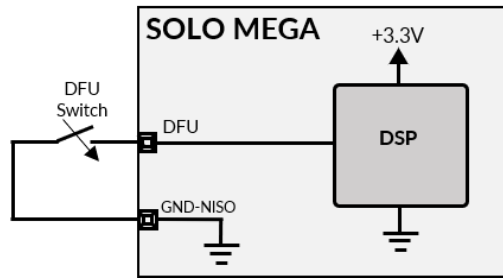

Figure 18 - DFU Mode Wiring

Figure 19 - DFU Mode Wiring

⚠️

- The DFU pin is directly connected to the DSP, so it is not +5 volts tolerant, to put SOLO on DFU mode just connect the DFU pin to no-isolated ground.

PT1000 temperature sensor wiring:

PT1000 temperature sensor is a positive-temperature-coefficient resistor. As shown in Figure 20 in SOLO MEGA by connecting a PT1000 temperature sensor to PT1000-IN pin, the temperature can be measured.
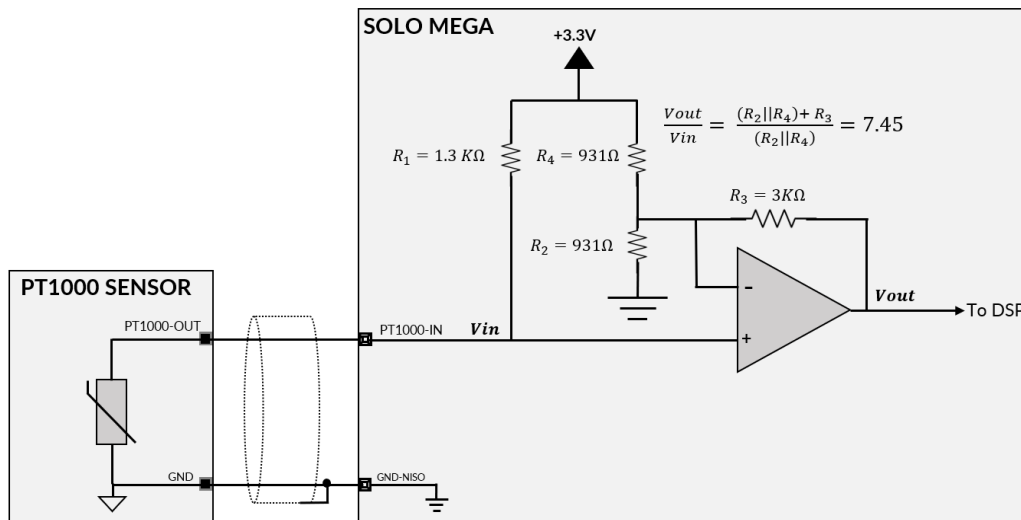

$$\frac{Vout}{Vin} = \frac{(R_2||R_4) + R_3}{(R_2||R_4)} = 7.45$$

$R_1 = 1.3\ K\Omega$ $R_4 = 931\Omega$ $R_3 = 3K\Omega$ $R_2 = 931\Omega$

Figure 20 - PT1000 temperature sensor wiring

In order to measure the temperature do the following steps:

1. Read the PT1000 output voltage value through one of the data lines (UART, USB or CAN bus)
2. Calculate Vin by using amplifier gain that is 7.45.
3. Compute the PT1000 resistance as the PT1000 temperature sensor is practically a resistor, it will form a resistor divider network with R1 resistor shown above in Figure 17 .
4. Put the PT1000 resistance value in PT1000 characteristic curve and extract the temperature (the user has to refer to their PT1000 datasheet to find out about this curve)

For example consider Figure 21 as a sample PT1000 temperature sensor characteristic curve and assume that the PT1000 Voltage read from SOLO 2.25V, the temperature will be calculated as below:

$$1 \rightarrow Vout = 2.25$$
$$2 \rightarrow Vin = \frac{Vout}{7.45} = \frac{2.25}{7.45} = 0.302\ V$$
$$3 \rightarrow R/ohm = \frac{1.3 \times Vin}{3.3 - Vin} = \frac{1.3 \times 0.302}{3.3 - 0.302} = 130.9\ \Omega$$
$$4 \rightarrow R/ohm = 0.385xT(\dot{C}) + 100 \rightarrow T(\dot{C}) = 80.256\ \text{celsius degree}$$
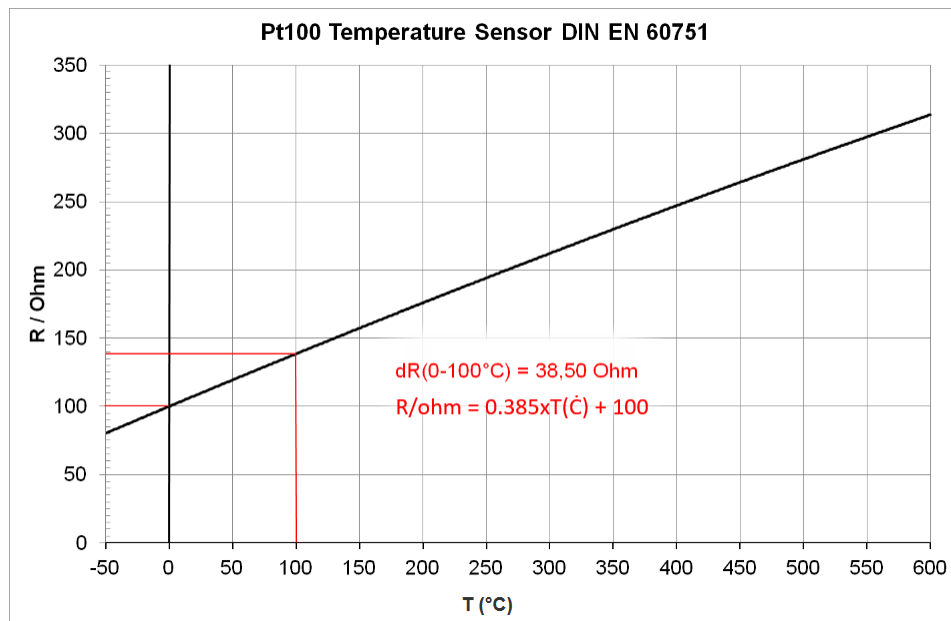

Figure 21 - A sample PT1000 temperature sensor characteristic curve

Wiring and Setup of Active Brake Chopper:

This circuit provides a compact Active Brake Chopper circuitry to protect the device from over-voltage conditions caused by power fed back from the motor to the DC BUS line due to regeneration. This circuit dissipates the extra power on a high-power resistor through BRO+ and BRO- outputs with tunable activation voltage using an external resistor through BRA1 and BRA2 inputs.

The default activation voltage for this circuitry on SOLO MEGA is set approximately at **61V**, however this voltage can be changed to any desired voltage using the formula mentioned later in this part.

The general principle of this circuit is whenever the DC BUS voltage goes above the activation voltage limit, the circuit shorts the BRO+ to BRO- thus by placing a high power resistor with minimum value of **27-33Ω 100Watts,** the extra power will be dissipated in the "RC" resistor shown below in the wiring.
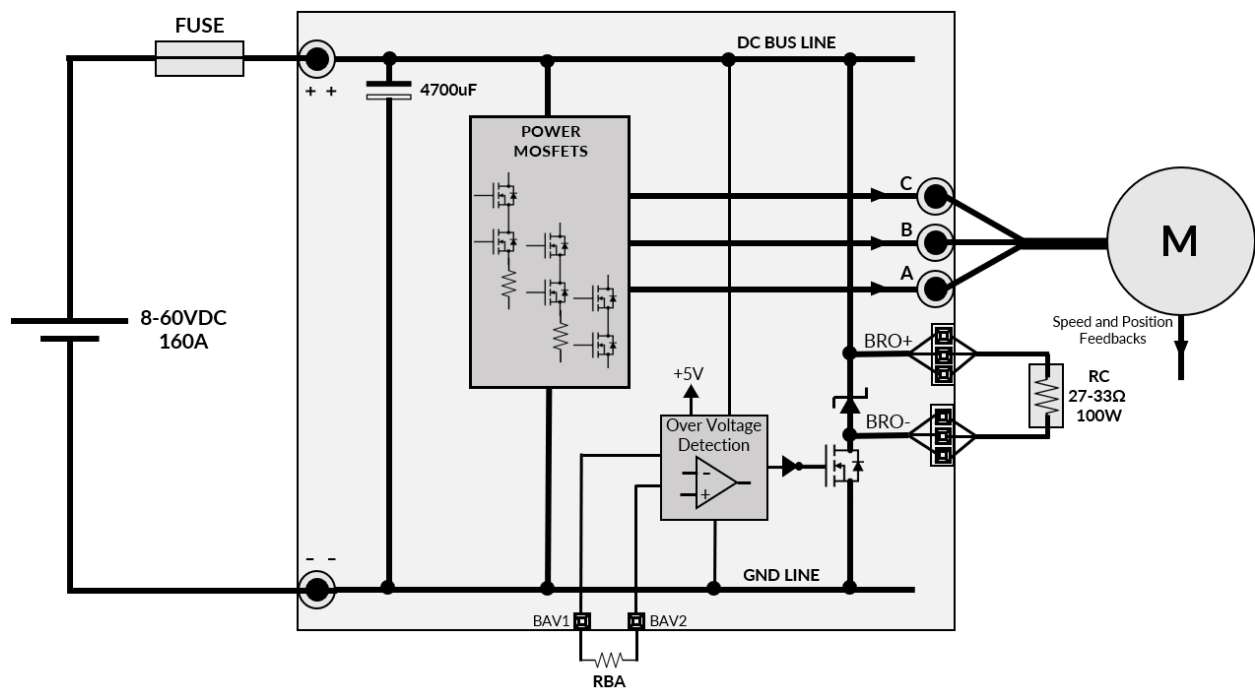

Figure 22 - Active Brake Chopper wiring

⚠️

- Do not use power resistors with resistance below **27Ω for "RC" resistor,** by doing so, the brake circuitry might get damaged due to excessive power dissipation.
- Whenever the brake circuit turns on, the "**B1"** LED in section[8] will turn ON too.

The Activation voltage limit can be tuned using the "**RBA**" resistor based on the below formula, by leaving BAV1 and BAV2 pins open the default activation voltage of 61V will be applied.

*X= ((((Desired Brake Activation Voltage) / 3.3) * 10000) - 10000)*
*RBA [Ω] = (X * 172000 / (172000 - X)*

Table1 below shows some sample activation voltages based on the nominal DC bus voltage, however any arbitrary voltage down to 10V can be achieved using this formula for various systems.
The brake activation voltage should be always above the nominal applied DC BUS voltage to the system to avoid power dissipations on "RC" resistor once not necessary, it's always better to test the activation voltage by looking at "B1" LED and verify if the LED turns on at the desired value before committing the Motor to the controller.

Table 1: Examples of "RBA" resistance selection based on desired brake activation voltage

Nominal DC bus voltage based on the Motor	Possible Desired Brake Activation Voltage (approximately)	"RBA" resistance value [kΩ] (approximately)
58V	61.0V	∞ (open)
48V	50V	800
36V	40V	314
24	26V	114
12	14V	39

The resistor values for "RBA" should be chosen as close as possible to the theoretically calculated values to have the highest resolution possible in Brake activation, some candidates for power resistor "RC" are listed in below table 2:

Table 2: Some candidates for "RC" power resistor

Candidate Part Number for "RC" resistor	Resistance and Power
HSC10027RJ	27Ω 100W
HS100E6 33R F M193	33Ω 100W

Analogue Torque and Speed Feedbacks and Wiring:

There are two analogue feedbacks in SOLO MEGA. These analogue feedbacks generate an analogue voltage between 0-10V according to measured motor Speed and Torque in both directions. This feedback once the measure Speed or Torque is at 0 will stay at 5V (mid-point), thus depending on the direction of the rotation, this feedback will either be greater than mid-point or smaller than that. The resolution of the measurement can be adjusted by changing the "S/T resolution" for speed measurement or "Current Limit" for Torque measurements.

As can be seen in Figure 23_1, the "S/T resolution" has been set at 2000 RPM and we have the following conditions based on the sections shown with Green numbers:
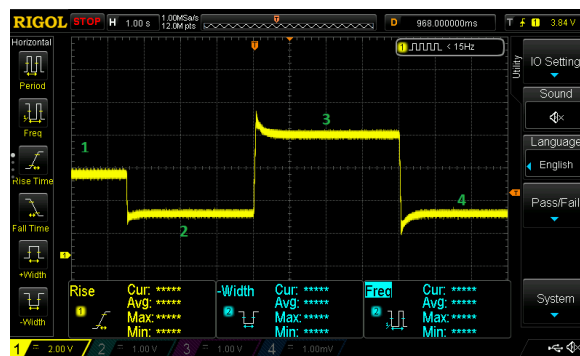

Figure 23_1- Speed Analogue Feedback

Section 1) The Motor is standing still, thus the feedback signal is at mid-point (+5V)

Section 2) The Controller leads the Motor to go to -1,000RPM as a Step response, the voltage stays at +2.5V

Section 3) The Controller leads the Motor to go to +1,000RPM as a Step response, the voltage stays at +7.5V (Figure 23_2 shows the transition from section 2 to 3 zoomed in)
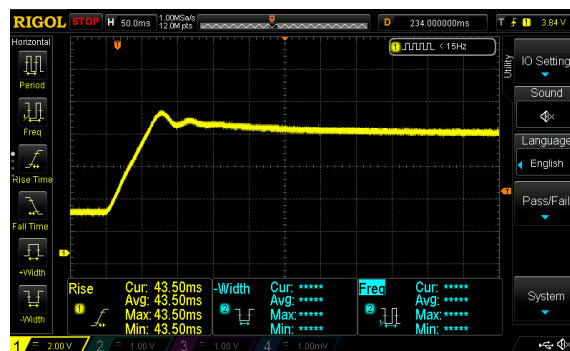

Figure 23_2- Analogue Feedback of Speed step response

As can be seen in Figure 23_3 in order to connect these feedbacks to Embedded MCU Boards a voltage divider is necessary in the feedback path if the MCU board is not rated for 10V outputs. The recommended resistor values are shown in Figure 23_3.
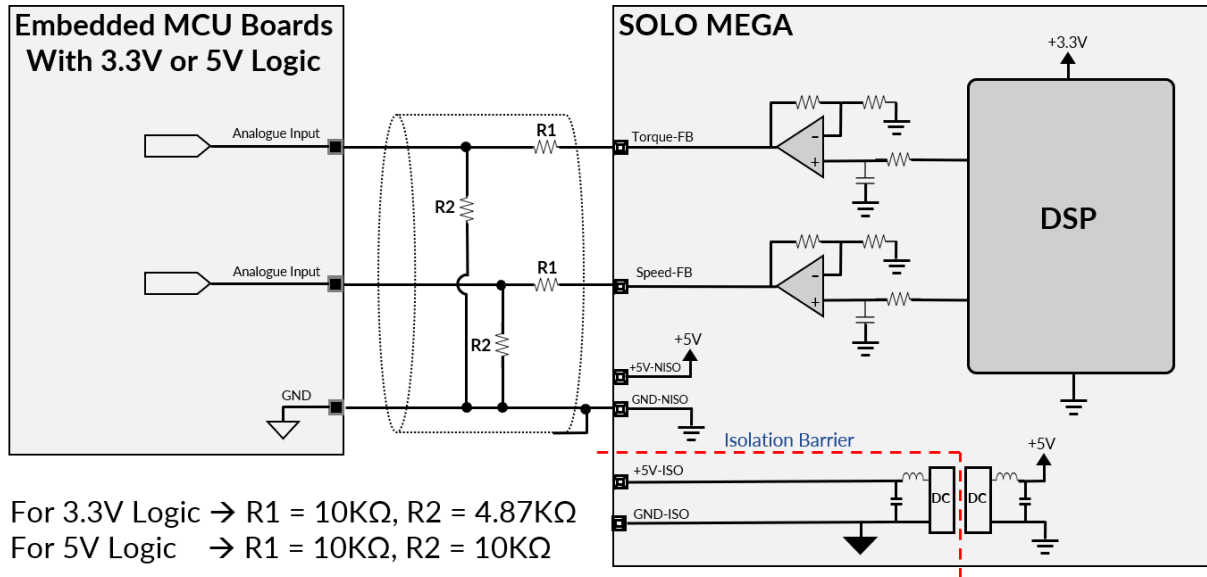

For 3.3V Logic → R1 = 10KΩ, R2 = 4.87KΩ
For 5V Logic   → R1 = 10KΩ, R2 = 10KΩ

Figure 23_3- Analogue Torque and Speed feedbacks wiring

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to the internal non-isolated ground or to the Embedded MCU Board ground only at one side.

- Selecting wrong resistors can permanently damage Embedded MCU Boards, try to use resistors that are shown in Figure 23_3.

Digital Mode Wirings:

All of the functionalities of SOLO MEGA can be controlled fully digitally by sending data packets through isolated UART, isolated USB or isolated CAN bus with CANopen software layer, below there are three main examples of possible wirings of SOLO MEGA in Digital Mode.

Isolated USB Interface Wiring

By using isolated USB connection, you have the access to the simplest form of wiring of SOLO MEGA to be commanded using only the USB cable thanks to the digital control that it offers, in this mode the only thing you will need is a USB 2.0 Type C cable that makes SOLO able to communicate with a local PC or controller through USB communication as a Virtual COM Port, in such a setup SOLO offers full control over every possible and existing feature that it supports.
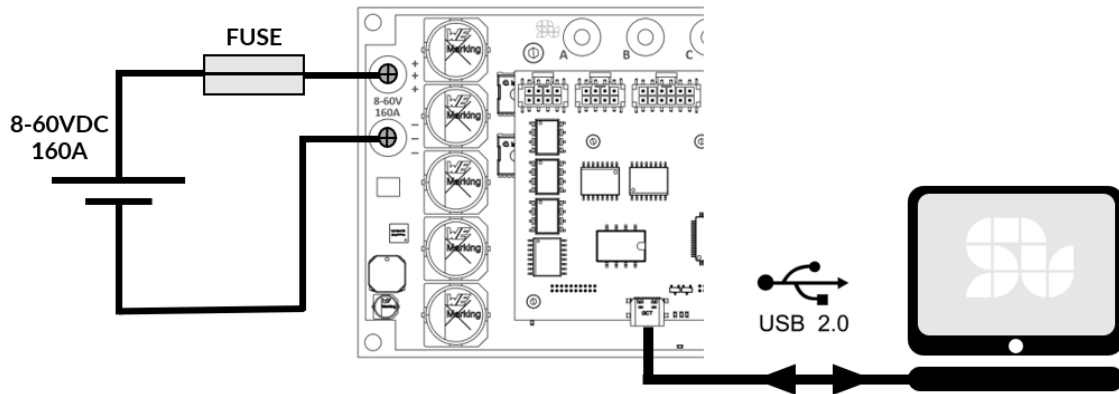

Figure 24 - USB 2.0 Type C wiring.

- Powering up SOLO with any DC input voltages from 8 to 60 volts is necessary when SOLO MEGA is connected to the external Host by using USB cable (USB cable doesn't power up SOLO itself).

- The USB type C connector has no up or down orientation, so it's very robust and can be used for industrial applications.

- The maximum length of USB cable in SOLO MEGA is 3 meters.

Isolated UART Interface Wiring

As can be seen in Figure 25, the MCU-TX pin of the Embedded MCU board is connected to the ISO-UART-RX pin of SOLO and MCU-RX pin is connected to the ISO-UART-TX pin.
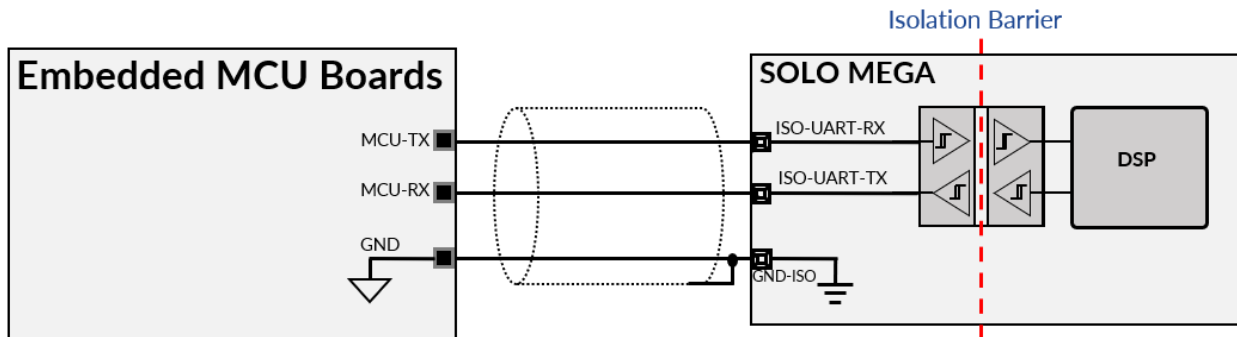

Figure 25 - UART wiring

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to isolated ground or to Embedded MCU Board ground only at one side.

- In the SOLO MEGA the ISO-UART-RX and ISO-UART-TX lines are +5V tolerant and they can be fed both by signals leveled at +3.3V or +5V.

Isolated CAN bus Interface Wiring

SOLO MEGA can be commanded in a CAN network by CANopen standards, using CANopen all of the functionalities of SOLO can be controlled digitally using data packets sent within CAN bus. To know more please refer to our CANopen user Manual here.
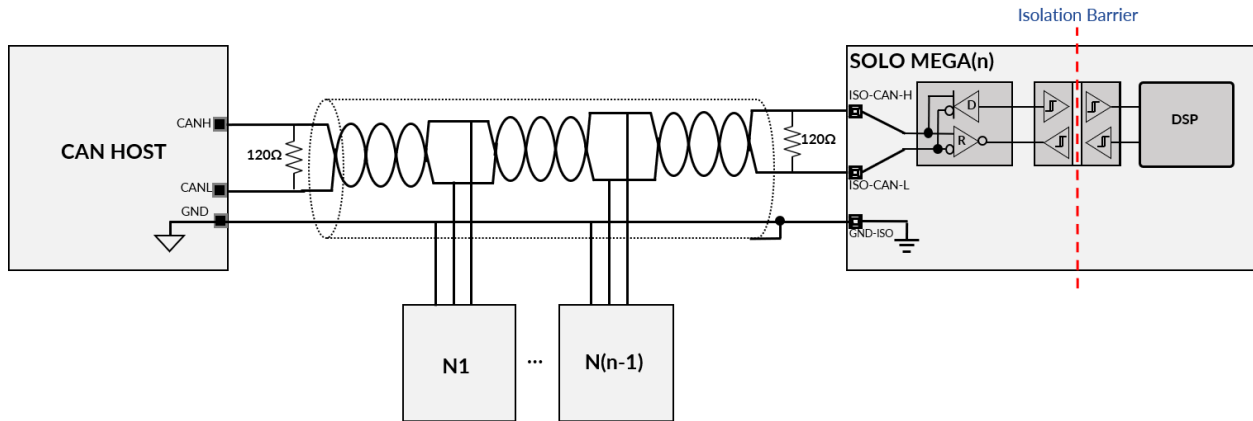

Figure 26 - CAN bus wiring

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to isolated ground or to CAN HOST ground only at one side.

Full Wirings of SOLO MEGA:

In this section some full wiring of SOLO MEGA will be demonstrated.

Standalone Wiring (No External Modules):

Here you can see an example of how to wire SOLO without having any external modules, just by using a couple of potentiometers and a switch. In Figure 27, you can see a wiring of a DC Brushless or PMSM Motor in Closed-Loop Mode with Current Limit all done using only two potentiometers.
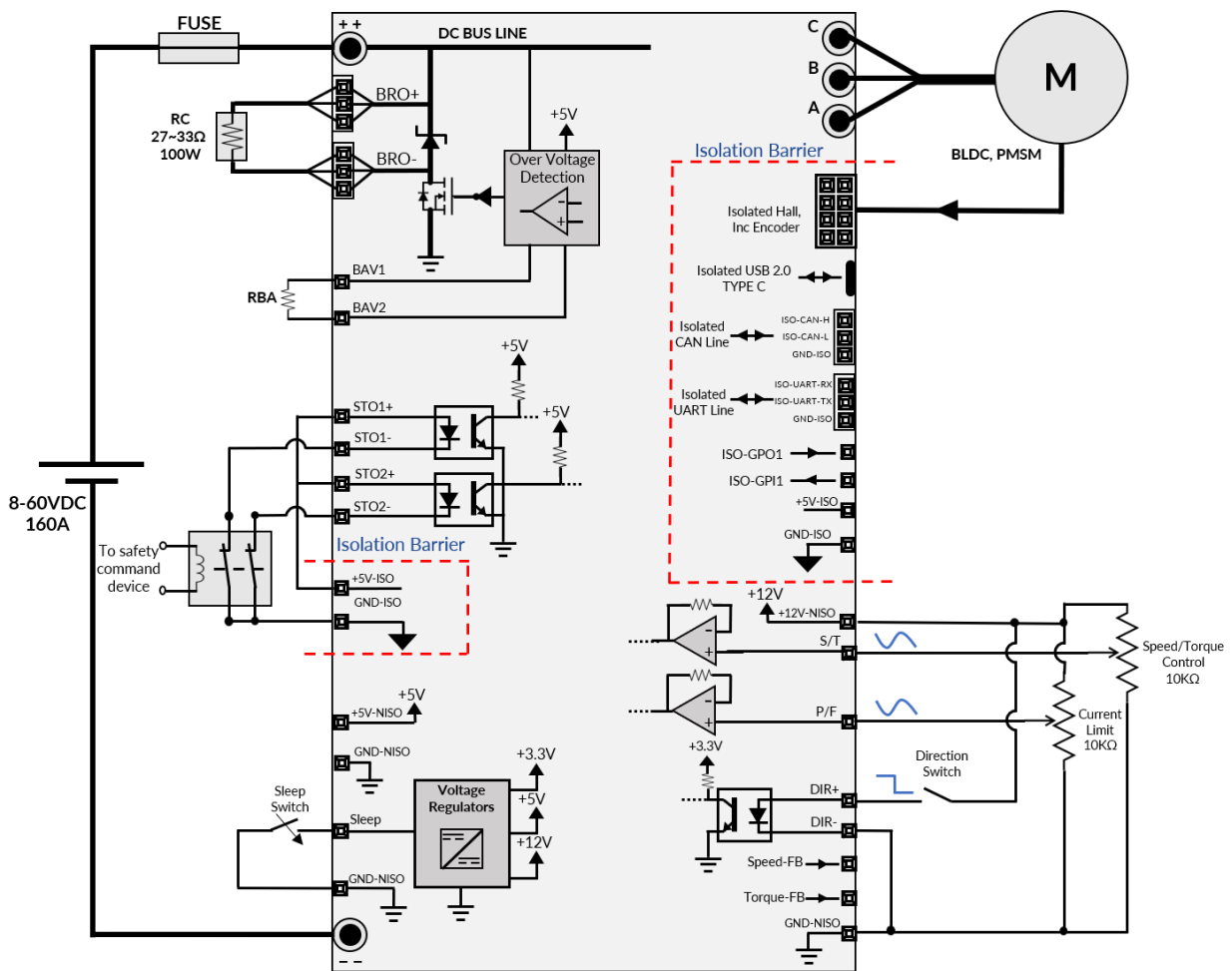

Figure 27 - Standalone wiring without external modules

- The current Limit Potentiometer is not mandatory to use, and if you leave the "P/F" input open, the current Limit will be automatically set at 130 Amps DC. This input in closed-loop mode acts as if the voltage applied to this pin is 10V, it will stop the current floating to the motor resulting in free-wheeling(Current Limit at zero), and if this pin is left open it will allow up to 130 Amps DC floating into your Motor, so any value between these will define the value of current limit.
  The current Limit value = ((10.0 - Analogue Voltage applied at P/F input)/10.0) * 130

- "DIR+, DIR-" pins in SOLO MEGA accept voltage from +3.3V to +12V.

Embedded MCU Boards using Analogue/PWM:

Here is an example of wiring SOLO MEGA with an Embedded MCU Board like Arduino or Raspberry PI , as can be seen in Figure 28.
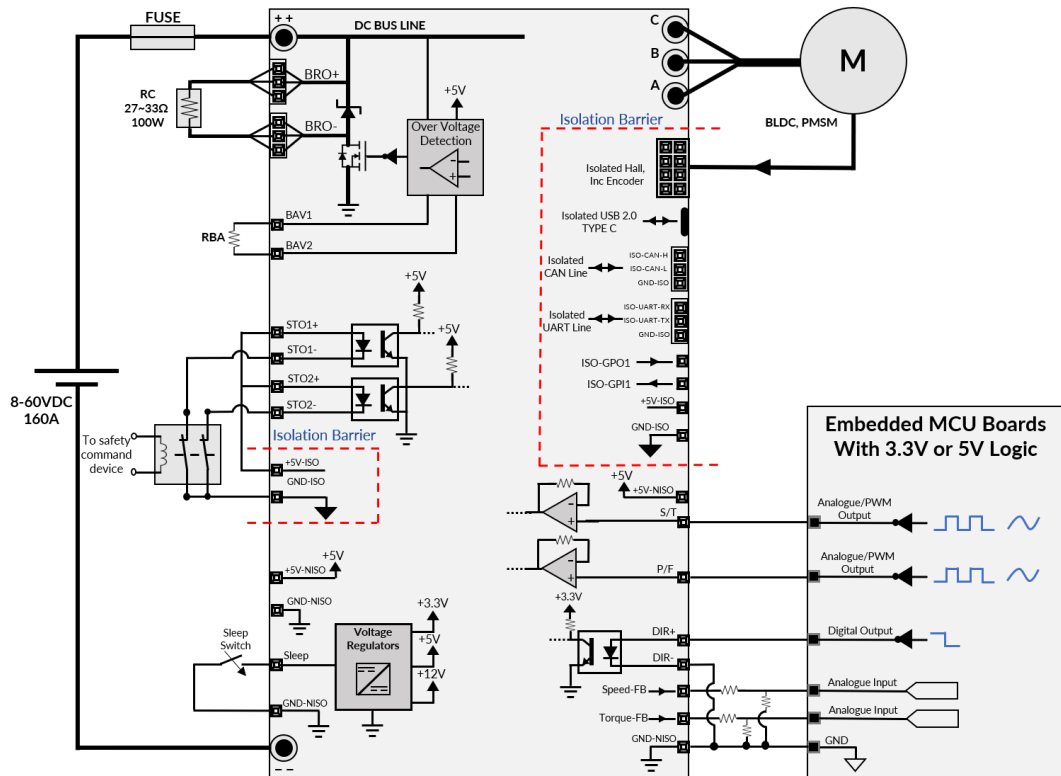

Figure 28 - Embedded MCU Boards using Analogue/PWM

- The most important point in such wirings is to make sure the non isolated ground pin of SOLO MEGA has been connected to the GND of your Arduino or other Embedded MCU Boards at least in a single point.

- "DIR+, DIR-" pins in SOLO MEGA accept voltage from +3.3V to +12V.
- In case of using PWM output to S/T or P/F, the PWM frequency must be at least 5KHz.

Embedded MCU Boards Using UART:

As can be seen in Figure 29, an Embedded MCU Board like Arduino or Raspberry PI is used to send commands through the UART line to SOLO. In order to have a complete isolated UART communication it is very important to power the Embedded MCU Board by +5V isolated supply of SOLO MEGA and properly applying the Grounding to avoid any loops.
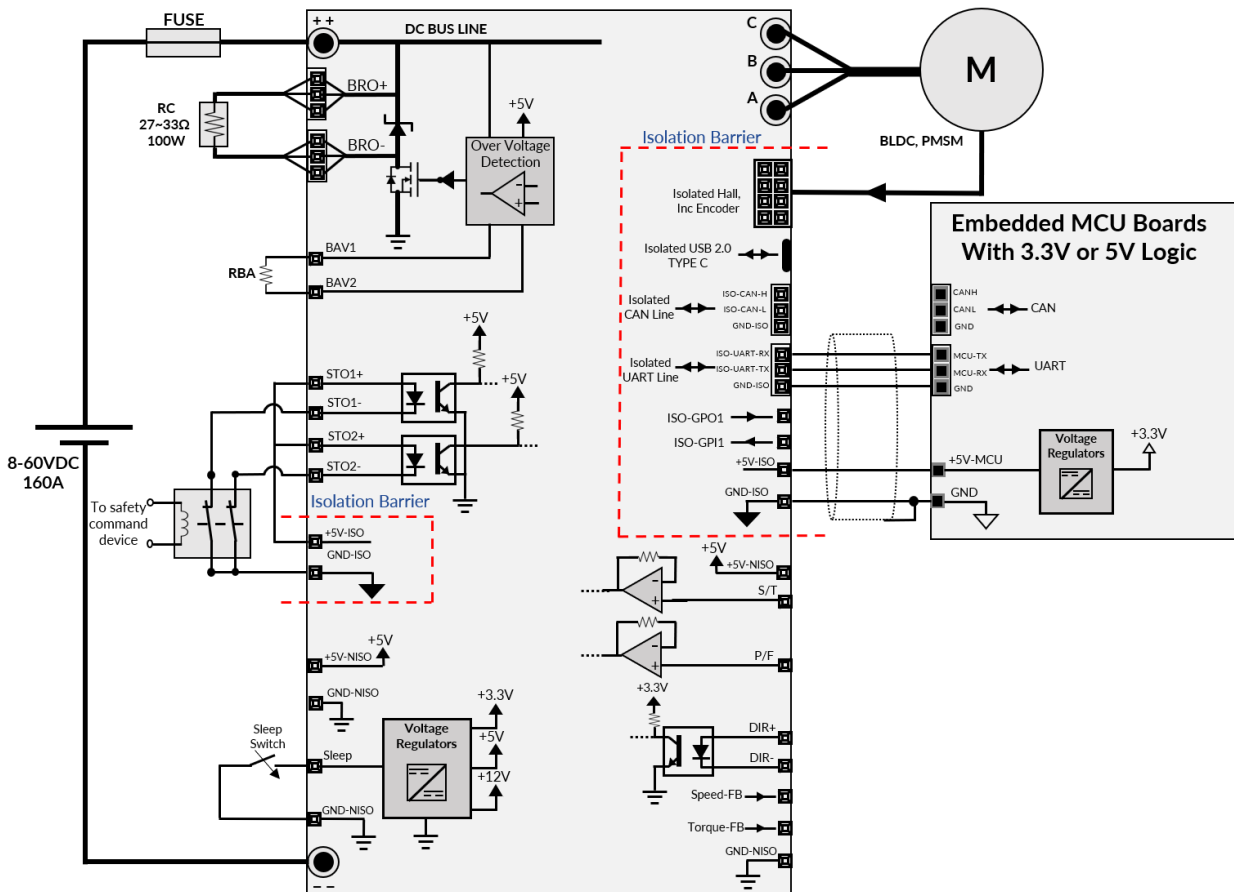

Figure 29 - Embedded MCU Boards using UART wiring

- The most important point in power connection is to make sure the isolated ground pin of SOLO MEGA has been connected to the GND of your Arduino or other Embedded MCU Boards at least in a single point.

Embedded MCU Boards Using CANopen:

As can be seen in Figure 30, in order to have a complete isolated CAN communication it is very important to power the Embedded MCU Board by +5V isolated supply of SOLO MEGA and properly applying the Grounding to avoid any loops.
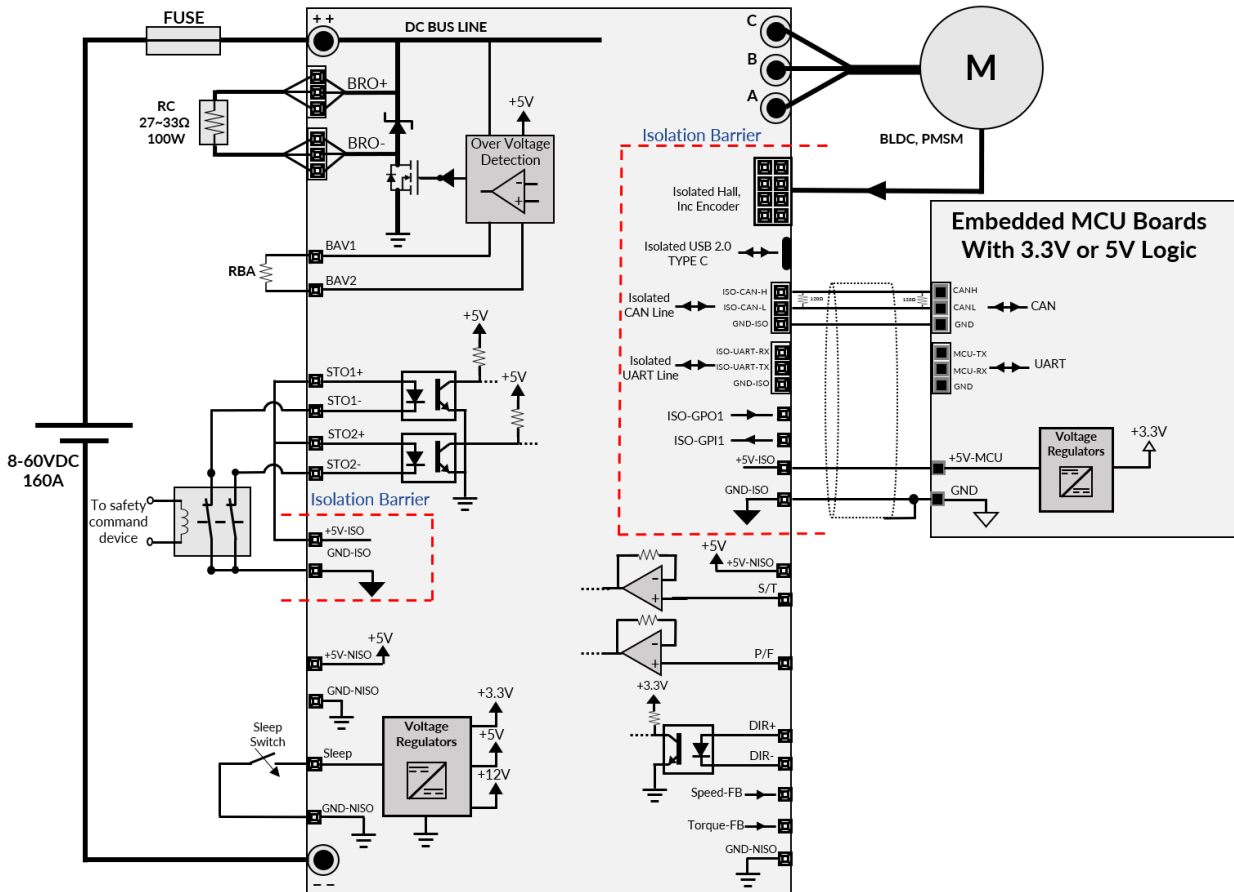

Figure 30 - Embedded MCU Boards using CANopen

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to isolated ground or to Embedded MCU Board ground only at one side.

General Wiring Considerations in SOLO MEGA:

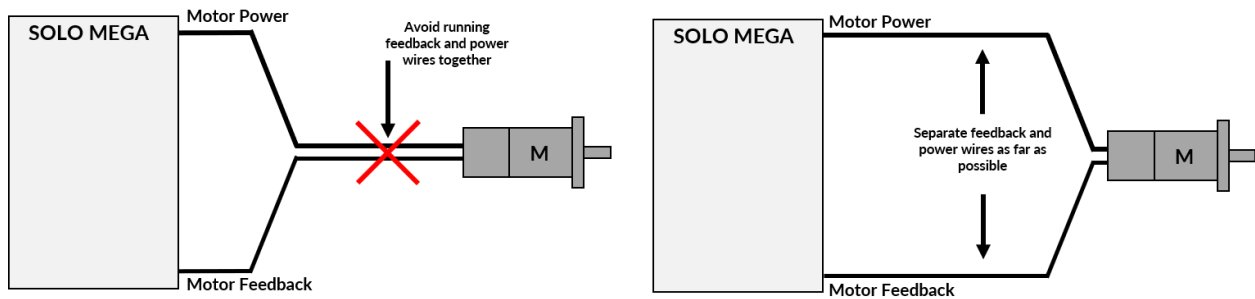## 1- Avoid running feedbacks and power wires together

Figure 31 -Avoid running feedbacks and power wires together

2- Avoid making ground loops

As can be seen in Figure 32 the Embedded MCU Board is powered from a power supply that has a common ground with SOLO MEGA, this wiring will make ground loop and destroy isolation. The proper wiring is to power the Embedded MCU Board from +5V isolated supply of SOLO or externally provide that isolated power.
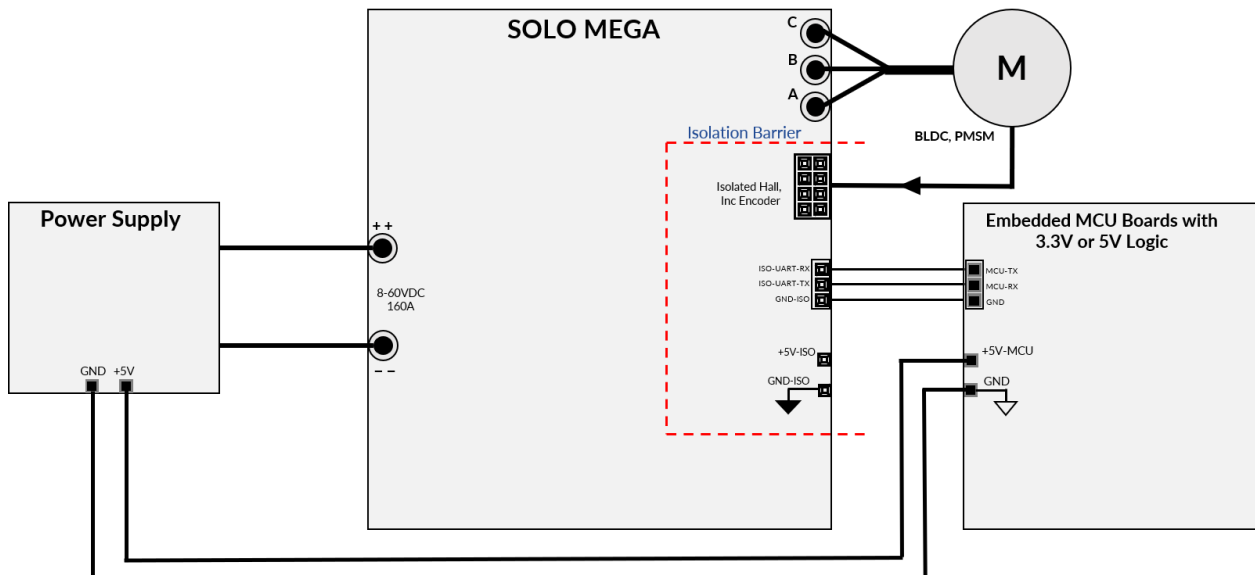

Figure 32 -Improper ground wiring

Temperature and Max Current Behaviour:

In SOLO MEGA the current limit is set according to the controller's temperature. As demonstrated in Figure 33 the current limit will be 120 Amps up to 65 ℃, after that the current limit decreases to zero at 85 ℃ linearly as temperature increases.
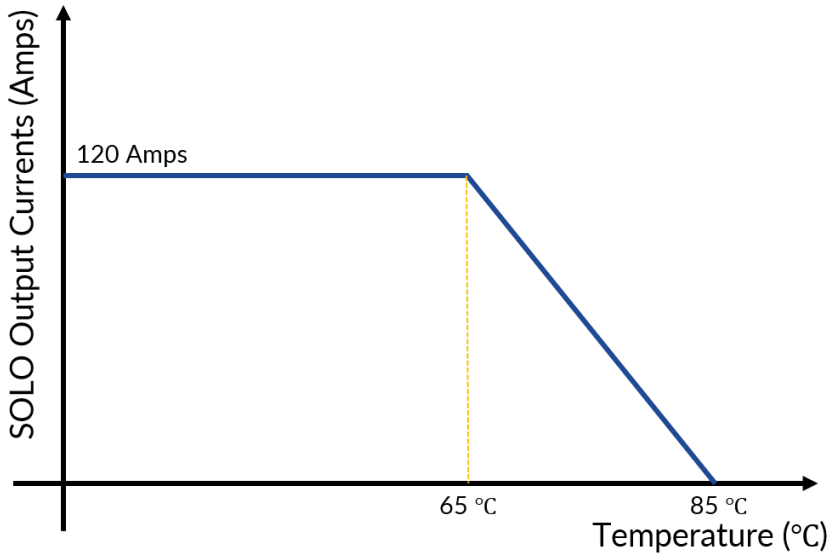

Figure 33 - SOLO Output Current versus Temperature