SOLO PICO User Manual

Part Number: SLP0123_5816

Product Description

SOLO PICO 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 PICO supports sensor-based Torque, Speed and Position controlling plus other options like full digital and analogue controls and active safety measures to keep the applications safe from unforeseen behaviours.

Power Range

Supply Voltage Range: 8- 58 VDC

Continuous DC Current: 16 ADC
Continuous AC Current: 11.5 Arms
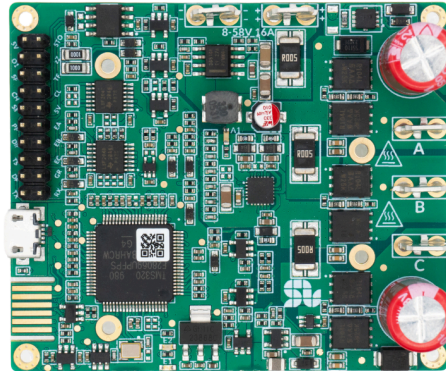
Features

- 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
- Safe Torque off (STO) input
- USB, UART and CANopen
- Supports PT1000 temperature sensors
- Sleep mode with current consumption of 200µA

- 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
- Full Digital and Analogue Control
- Space Vector Modulation (SVPWM)
- Embedded Motion Profile (St-Curve) for Position and Speed

Modes of Operation

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

Commands and feedback Source

- 0-5V Analogue/ PWM inputs for Speed or Torque control
- Analogue torque and speed feedback
- Quadrature Encoder and Hall sensor inputs
- UART, USB and CAN bus

Applications

- Industrial Automation
- 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.
ⓘ	Recommendations, tips, references to other documentation.
⚙	Essential or useful accessories.

Revision History:

Revision	Date	Changes	Firmware version
V1.0.0	11/06/2023	- First Release	0x0000B00F
V1.0.1	10/05/2024	- P/F pin description changed - Certification Table updated - Temperature ratings update per UL 61800-5-1 - STO Timing diagram added - PT1000 formulas changed	0x0000B020

Table of Contents

Power Specifications:

Description	Units	Values
DC Supply Voltage Range (continuous)	VDC	8 to 58
Software Overvoltage Activation Voltage	VDC	60V
DC Bus Undervoltage Limit	VDC	7
Maximum Continuous Output Current	ADC	16
Maximum Continuous Output Current	Arms	11.5
Maximum Continuous Output Power	W	300
Peak Output Power	W	450
Internal Bus Capacitance	µF	440
Switching Frequency (Output PWM Frequency)	kHz	8 to 80

Control and Timings specifications:

Description	Units	Values
Analogue Speed or Torque Commands	**VDC**	0-5V Analogue voltages or PWM inputs with frequency above 5kHz
Digital Direction Control	**VDC**	0 - 3.3/5
Modes of Operation	**-**	Torque - Speed- Position
Motors supported	**-**	DC brushed - BLDC - PMSM - EC Coreless
Hardware Protections	**-**	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**	18
Current Measurement Resolution	**mA**	16

Thermal Specifications:

Description	Units	Values
Board Temperature Range	°C	-20 to +120
Heatsink (base) Temperature Range	°C	-20 to +85
Cooling system	-	Natural Convection

Mechanical Specifications:

Description	Units	Values
Size (H x W x D)	mm	23.90 x 67.73 x 56.82
Weight (without heatsink)	gr	28
Form Factor	-	Wall Mount

Mechanical Dimensions (No Heatsink):
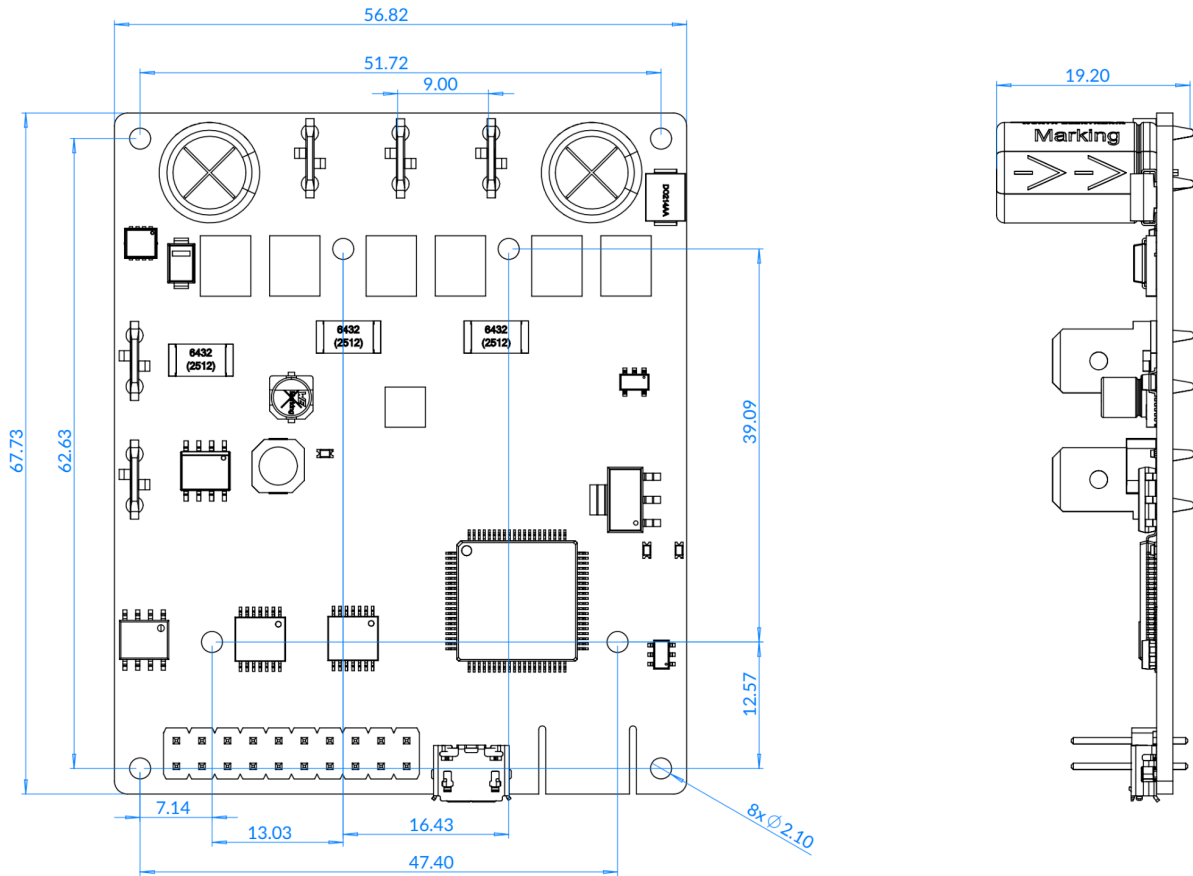
- All the measurements are in millimeters.

Mechanical Dimensions (With Heatsink):

- Heat Sinks can be provided upon customer request.

- 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.

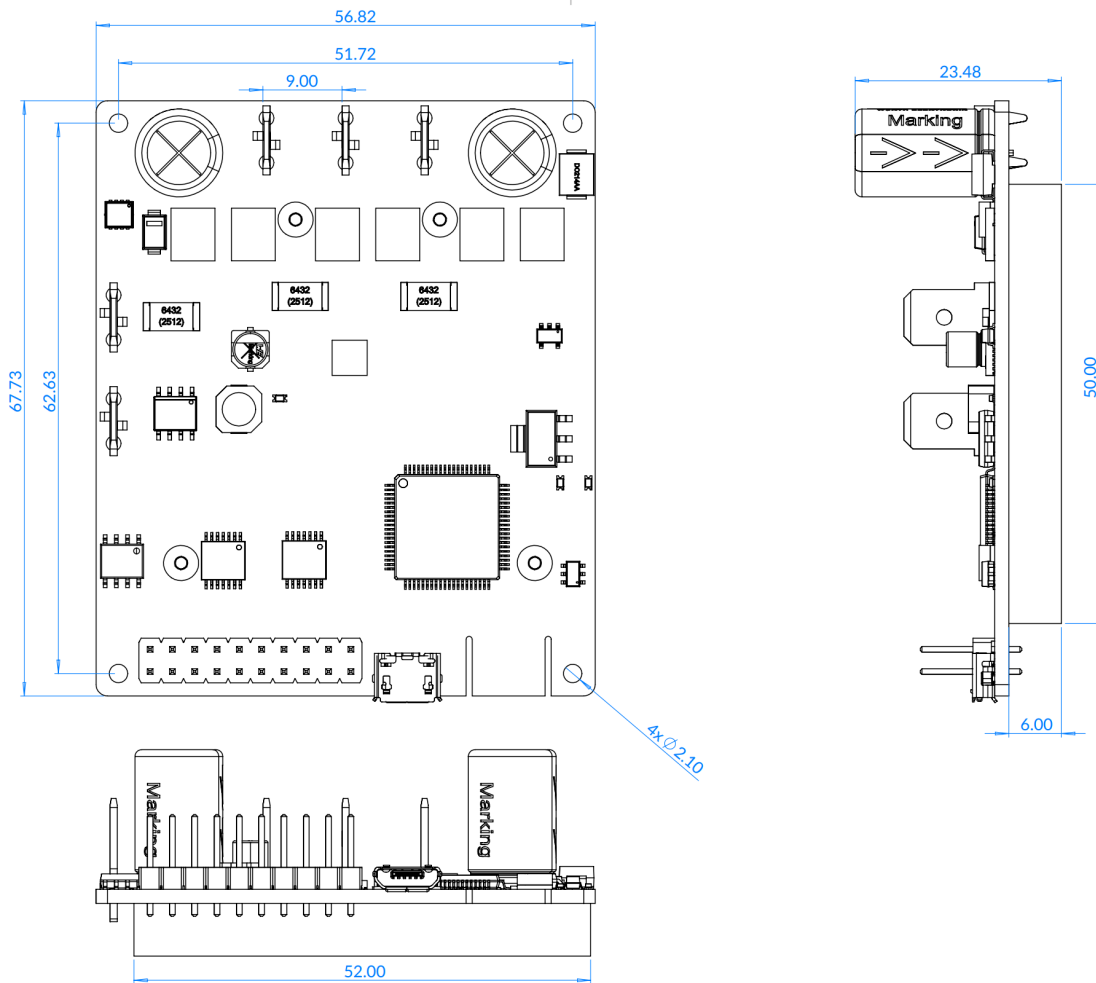| Section	PIN/Connector name	Input / Output	Units	Min	Typical Max	Absolute Max
[2 ,3]	Supply Input	Input	VDC	+8	+58	+63
[10]	S/T (speed/torque)	Input	VDC	0	+5	+5.25
[10]	P/F (Analogue Input)	Input	VDC	0	+5	+5.25
[10]	SF (Analogue Speed feedback)	Output	VDC	0	+5	+5.25
[10]	TF (Analogue Torque feedback)	Output	VDC	0	+5	+5.25
[10]	TS (PT1000 input)	Input	VDC	0	+3.3	+3.75
[10]	DF (DFU mode input)	Input	VDC	0	+3.3	+3.75
[10]	Dir (Direction control)	Input	VDC	0	+5	+5.25
[10]	STO(Safe Torque off input)	Input	VDC	0	+5	+5.25
[10]	5V (External supply)	Output	VDC	+4.95	+5.0	+5.05
[10]	EA (Encoder channel A)	Input	VDC	0	+5	+5.25
[10]	EB (Encoder channel B)	Input	VDC	0	+5	+5.25
[10]	EC (Encoder channel C)	Input	VDC	0	+5	+5.25
[10]	RX	Input	VDC	-0.5	-	+5.5
[10]	TX	Output	VDC	-0.5	-	+5.5
[10]	CH	-	VDC	-2	-	+7
[10]	CL	-	VDC	-2	-	+7
[10]	O1	Output	VDC	0	-	+5.5

Standards and Conformities:

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 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 PICO is a family of low-power motor controllers that are designed for low-current applications. This product is designed to support various types of electrical motors like DC brushed, Brushless DC and PMSM motors up to 58V DC with the supply voltage and the continuous current of up to 16 Amps, this will enable SOLO PICO to be utilized in wide range of products and projects and eventually speeding up the developments and time to market for its users.

SOLO PICO 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 UART, USB or 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 PICO are listed as below:

- Wide input voltage supply range from 8V to 58V
- The continuous output current of 16 Amps
- Capable of controlling DC brushed, BLDC and PMSM motors
- [Dual Core](#) with parallel processing architecture
- CAN, USB and UART Communications
- STO(Safe Torque off) for safe emergency stops
- 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
- Encoder and Hall Sensor Input with up to +5V supply
- +5V/500mA (2.5W) outputs to supply external modules
- 200μA current consumption in sleep mode
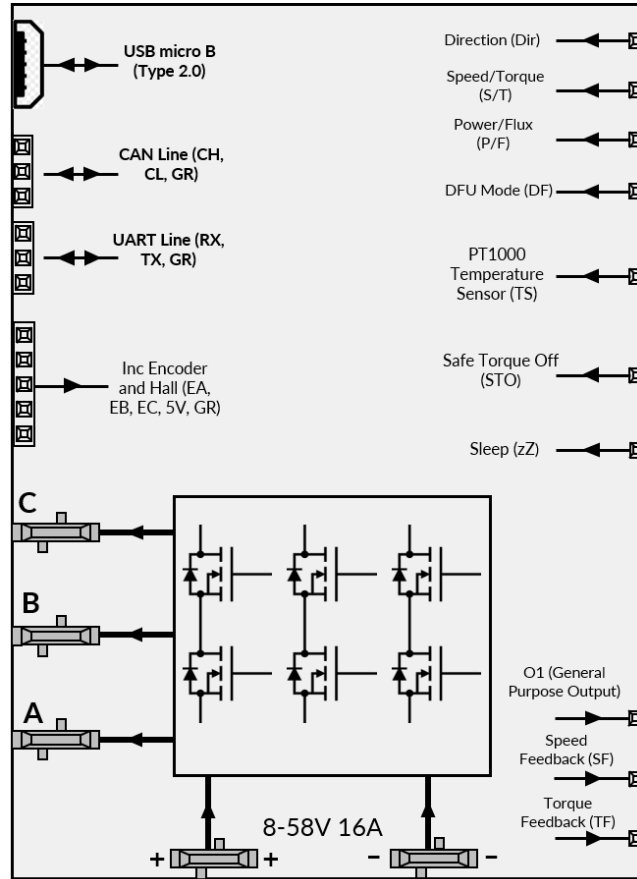
Functional Block Diagram:

Figure 1 - Functional Block Diagram of SOLO PICO
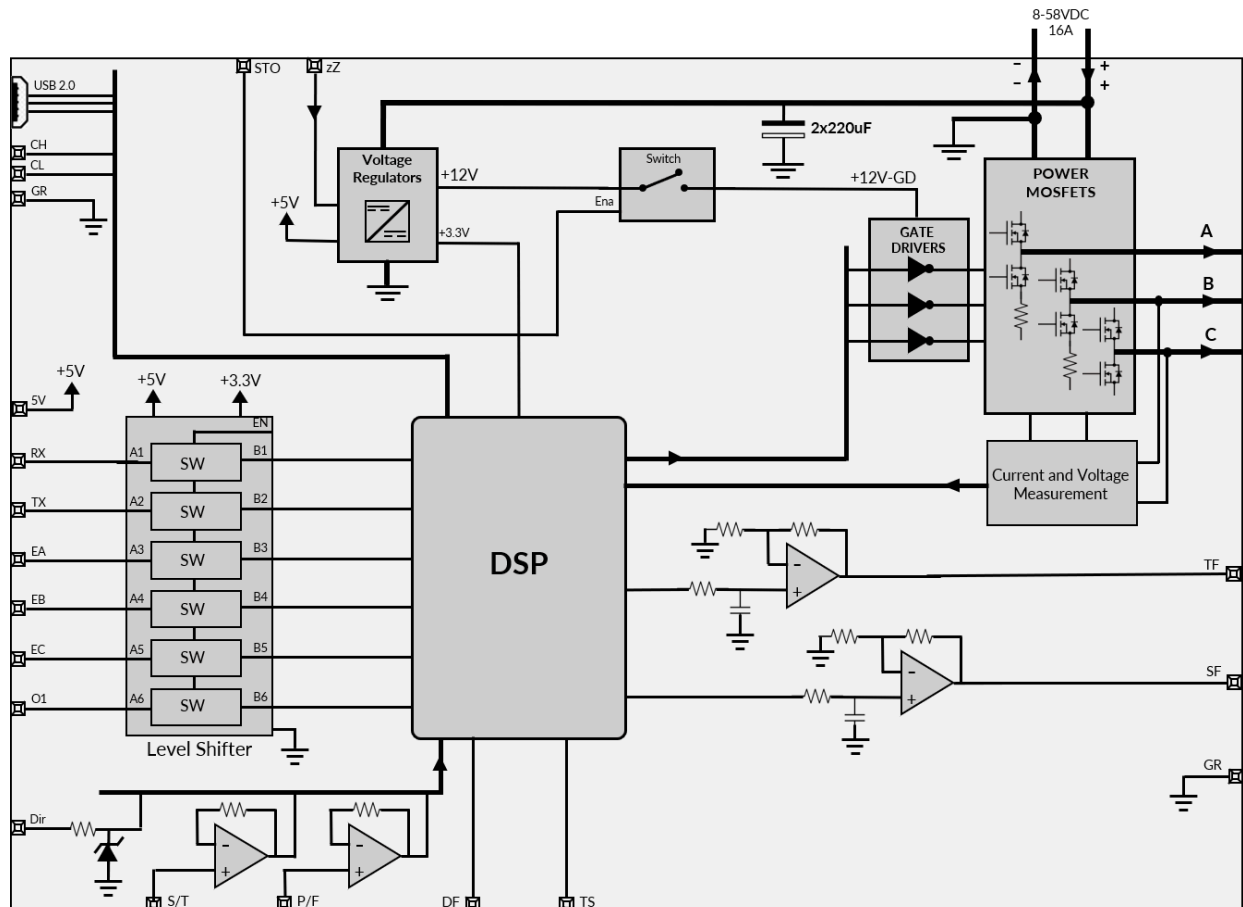
Architecture:

Figure 2 - Architecture of SOLO PICO

Theory of Operation:

SOLO PICO 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 three 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.

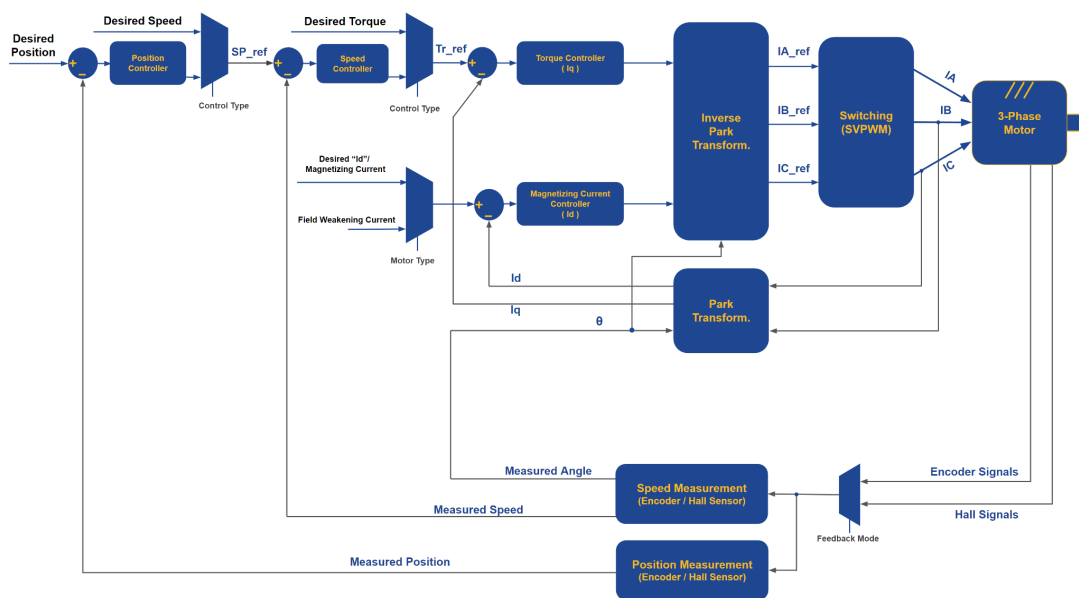## FOC control Architecture in SOLO PICO for 3-phase Motors:

Figure 3 - FOC Control Architecture of SOLO PICO 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 **16mA** in SOLO PICO.

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.

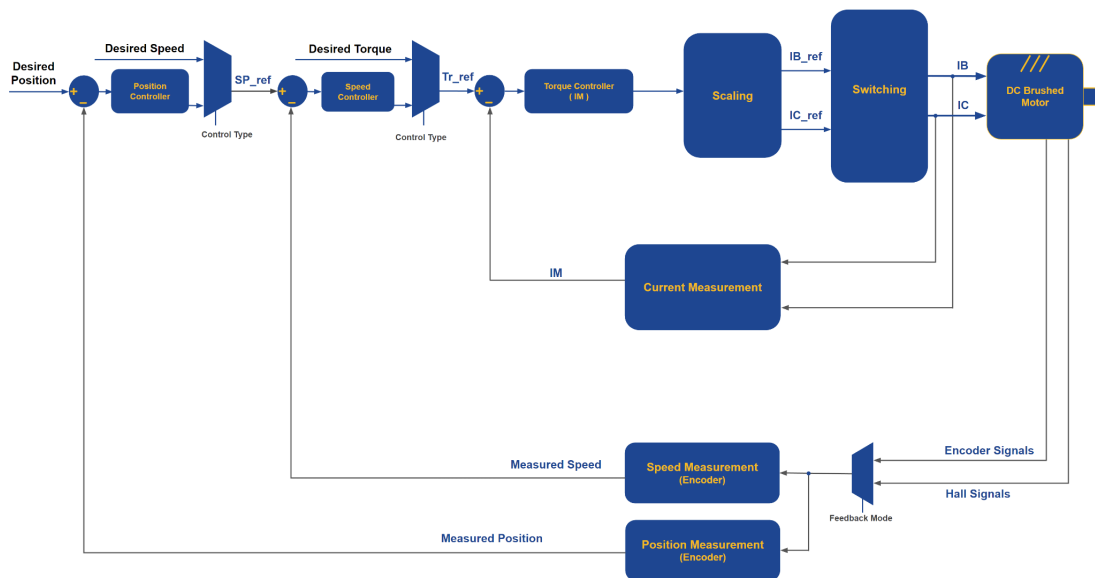# Cascade control Architecture in SOLO PICO for DC Motors:

Figure 4 - Control Architecture of SOLO PICO 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 PICO's Interactional Sections:

SOLO PICO can be decomposed into 10 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 PICO unit.
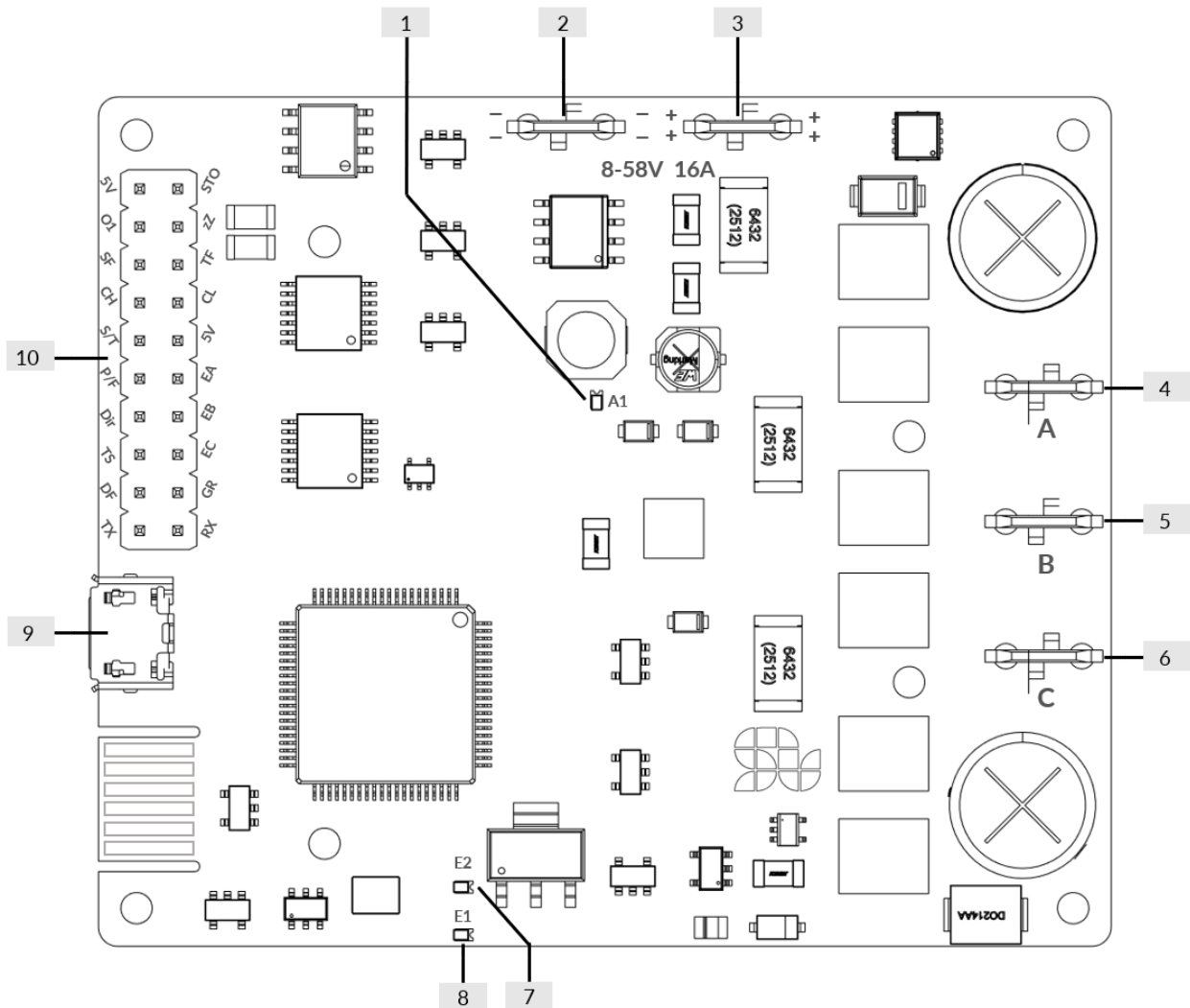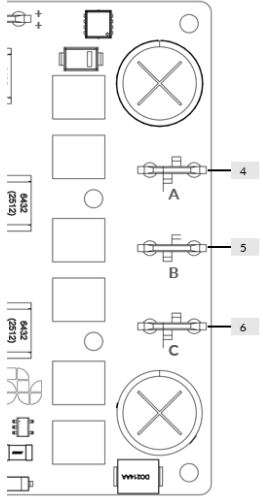

**Figure 5 - SOLO PICO's interactional sections**

Connectors and Sections:

Sections [4, 5, 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 PICO 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 PICO avoids connecting power supply cables into motor outputs, this can cause serious damages to the unit.

Sections [2, 3] - 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 58 volts in continuous mode, depending on the voltage rating of the Motor Connected at the output. The max rating for supply input is 59.5V, meaning that SOLO PICO will go into over-voltage protection mode in case the supply or BUS voltage rises above almost 59.5 volts.

⚠️
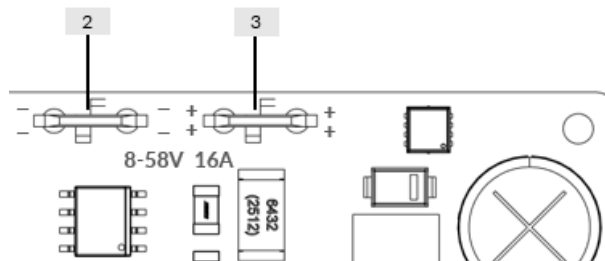
- SOLO PICO doesn't have Reverse Polarity Protection, thus the user has to make sure their supply is correctly connected to the unit before turning it ON. By applying the supply reversely, the damage to the unit is imminent.

	Section [10] - Control I/O Port		
PIN	**Name**	**Descriptions / Notes**	**I/O**
1	5V	+5V/500mA supply output for external modules	O
2	STO	Safe Torque Off input (STO)	I
3	O1	General Purpose Output	O
4	zZ	Sleep input	I
5	SF	Analogue speed feedback	O
6	TF	Analogue torque feedback	O
7	CH	CAN High Bus Output (ISO 11898)	-
8	CL	CAN Low Bus Output (ISO 11898)	-
9	S/T	Speed or Torque reference	I
10	5V	+5V/500mA supply output for external modules	O
11	P/F	General purpose Analogue input	I
12	EA	Input of channel A of the Encoder or Hall position sensors	I
13	Dir	Direction input	I
14	EB	Input of channel B of the Encoder or Hall position sensors	I
15	TS	PT1000 temperature sensor input	I
16	EC	Input of channel C of the Encoder or Hall position sensors	I
17	DF	Firmware Upgrade Mode is selected by grounding this PIN	I
18	GR	Ground of SOLO PICO	-
19	TX	UART protocol transmitter output	O
20	RX	UART protocol transmitter input	I

Description

This is the Control I/O port of SOLO that can be used in both Analogue or Digital Modes, It provides the sensor inputs (like the encoders, temperature sensors) as well as other functionalities like Safe Torque Off or Sleep mode.

 Once In "Analogue Command Mode" you can control the Speed or Torque of your motor by sending Analogic commands using PWM pulses rated at 0-5V with any frequency above 5kHz or by sending pure Analogue voltages rated from 0V to 5V, you can also use them to limit the current fed into your Motor in a completely Analogue manner. This connector also provide you with Analogue Feedback for Speed and Torque measured on the motor with tunable resolutions. This connector is composed out of 20 pins:
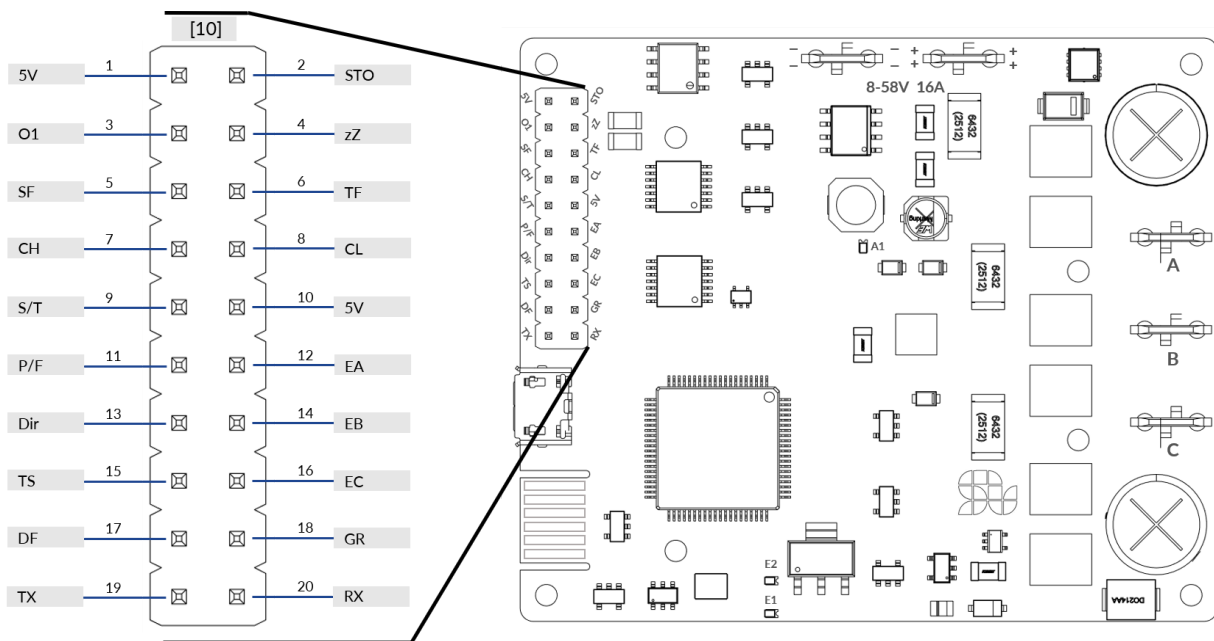
"GR" PIN:

This is the 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 (or sending data packets), 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" PIN:

This is a 5V/500mA output to supply external peripherals or controllers with a maximum of 2.5 Watt power output.

"Dir" PIN:

This Direction control pin in Analogue Mode, accepting voltage levels of **0V or 3.3V/ 5V,** by giving each of these values, the connected Motor to SOLO, will rotate in C.W. direction or C.C.W. direction.

"P/F" PIN:

This pin can be used as a general-purpose Analogue input.

"S/T" PIN:

This is the input for controlling Speed or Torque of the Motor connected to SOLO once in Analogue 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 5V 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 16 Amps into your motor , given this, the amount of Torque for motors generally can be calculated as: 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) * 16.0 **In case of using Analogue Voltages:** The torque generation Current = ((5.0 - the voltage at S/T input)/5.0) * 16.0
In Closed_loop **Speed** mode:	Once in Analogue 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 5V 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] = ((5.0 - the voltage at S/T input)/5.0) * (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.

"EA, EB, EC" PINs:

These pins are the Quadrature Encoders or Hall sensor inputs; it accepts single-ended signals leveled at +3.3V or +5V while providing a +5V/500mA supply for powering up the 5 volts logic encoders.

⚠️

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

⚠️

- The presence Index pulse known as Z connected to "EC" input of SOLO for 3 phase Motors is mandatory as it's required for the Encoder Calibration process, for DC brushed motors, the presence of Index pulse is not needed.

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

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

"TX, RX" PINs:
These are pins that give you access to UART communication in order to send/receive digital commands in the form of data packets.

"CH, CL" PINs:
These are pins that give you access to CAN bus communication in order to send/receive digital commands in the form of data packets

"STO" PIN:
This is STO or "Safe Torque off" input which is a hardware level protection that safely disconnects the motor from electronics causing the Motor to stop naturally. For SOLO to operate the motor this pin has to be connected to +5V.

⚠️

- For proper working of SOLO PICO providing STO wiring is mandatory.

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

"zZ" PIN:

By connecting this pin to ground the SOLO PICO will go into the Sleep mode, consuming less than 200µA, in sleep mode none of the functional activities of SOLO is accessible.to learn about it's functionality please refer to "Wiring of Sleep Mode input" section.

"DF" PIN:

By connecting this pin to ground SOLO PICO will go into the DFU mode.

"TS" PIN:

This pin is the external PT1000 temperature sensor input, that can be a temperature sensor attached to the motor. To learn about it's functionality please refer to the "PT1000 temperature sensor wiring" section.

"O1" PIN:

This pin is a 5V General purpose output pin capable of outputting a digital output for external usages, the voltage state can be controlled using USB,UART or CANopen commands.

Section [9] - USB Connection

Name	Descriptions / Notes	I/O
USB	Virtual COM port or Device Firmware upgrader	-
Description		
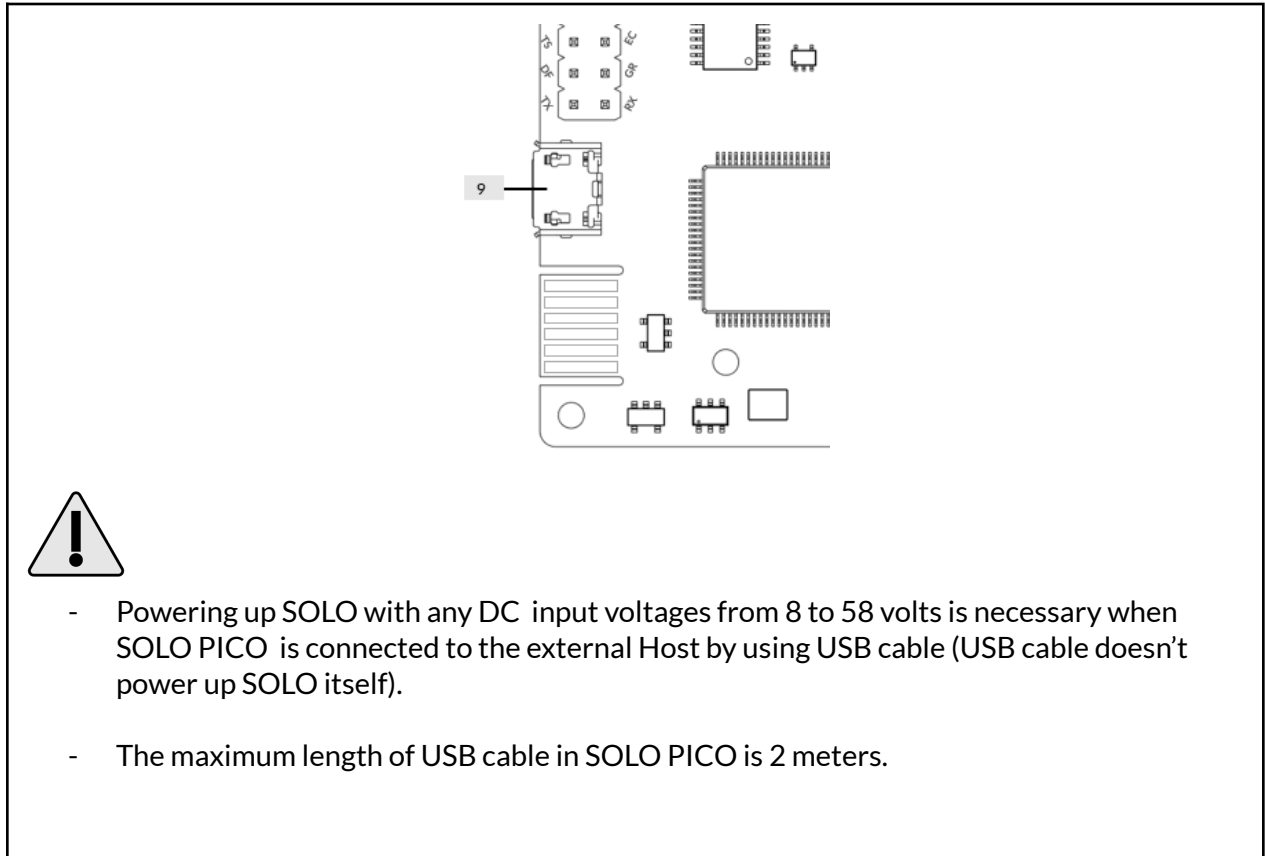
This is a micro B USB 2.0 connector which is used for sending and receiving digital packets and commands as well as upgrading the firmware. In Commanding mode, this USB will be a virtual COM port (VCP) capable of putting SOLO into digital control mode and functioning in a standalone fashion with only 1 USB cable and the Motor connected at the output.

- Powering up SOLO with any DC input voltages from 8 to 58 volts is necessary when SOLO PICO is connected to the external Host by using USB cable (USB cable doesn't power up SOLO itself).

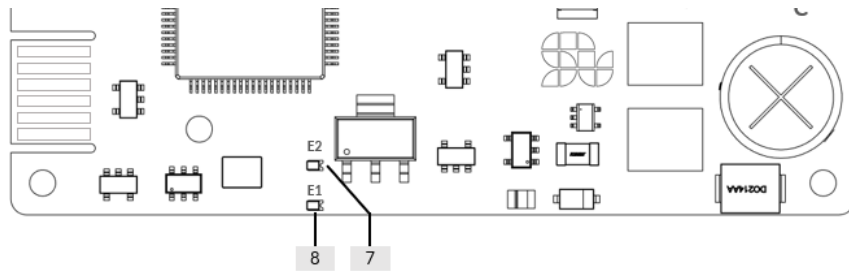- The maximum length of USB cable in SOLO PICO is 2 meters.

Section	Name	Descriptions / Notes	I/O
		Sections [7,8] - Functionality LEDs	
7	E2	Normal Activity LED	-
8	E1	Error Indicator LED	-
Description			

There are three LEDs on SOLO PICO, 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	Name	Descriptions / Notes	I/O
Section [1] - Power Up LED			
1	A1	Power Up LED	-
Description			

This LED will start glowing once SOLO is correctly powered up with a voltage from 8 to 58V.
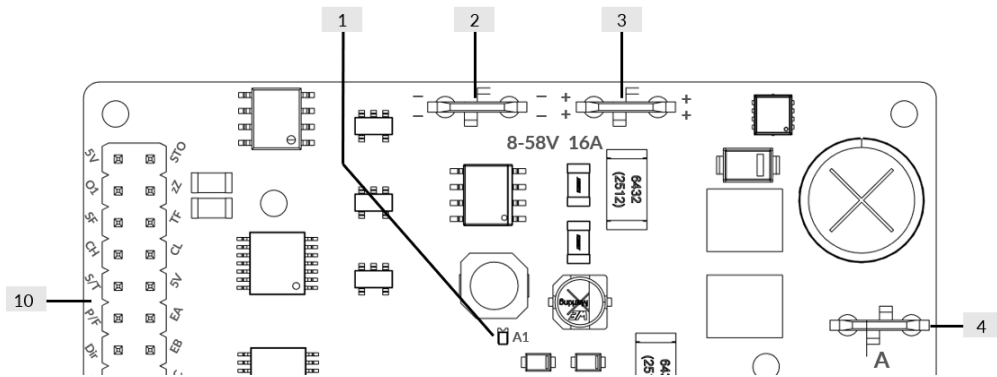
Connectors and their Matings Part Number:

Section	Manufacturer	Mating Part Number
[2,3,4,5,6]	Molex	0190160085
[10]	Amphenol ICC (FCI)	76342-310LF , 89898-310LF , 71609-310LF

Analogue versus Digital Control in SOLO PICO

The "Analogue" control in SOLO puts the unit in a mode that can accept Torque or Speed references in a pure analogue fashion or by using PWM inputs plus the Direction of the rotation through a simple switch, however in Digital Mode all the commands and feedbacks are transferred through data packets

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

SOLO PICO Wirrings

The wiring legends in SOLO PICO are as below:

Wiring Legend:

Shape	Description
	SOLO PICO 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 PICO 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 PICO providing STO wiring is mandatory. The STO has a negative logic, meaning that once the STO line is powered up to a high state (e.g. +5V) the unit will activate the power electronics dealing with the Motor, subsequently once the STO pin is 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 three 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. The safety relay can be commanded from external commanding devices.
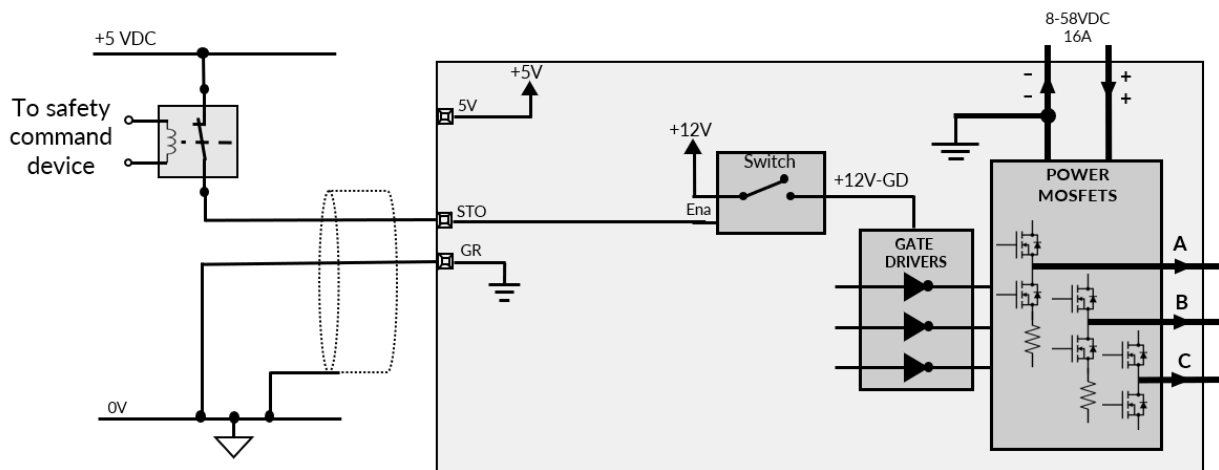

Figure 6 - STO wiring to external safety relay using external supply voltage

- 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 supply voltage:

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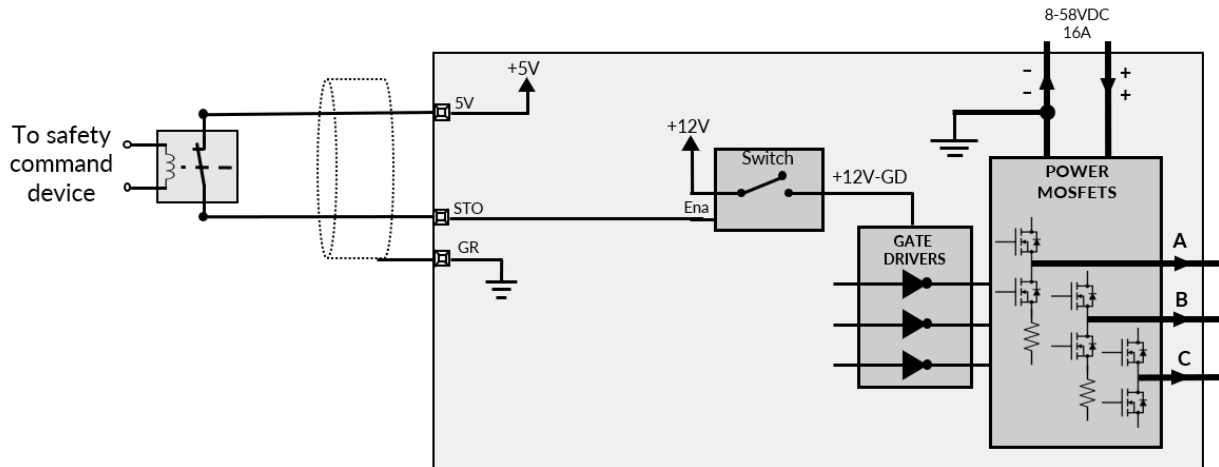

Figure 7 - STO wiring to external safety relay using +5V supply voltage of SOLO PICO

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

3- By Passing STO without external commanding devices:

As shown in Figure 8, the +5V voltage of SOLO PICO is used for wiring up STO input. 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.
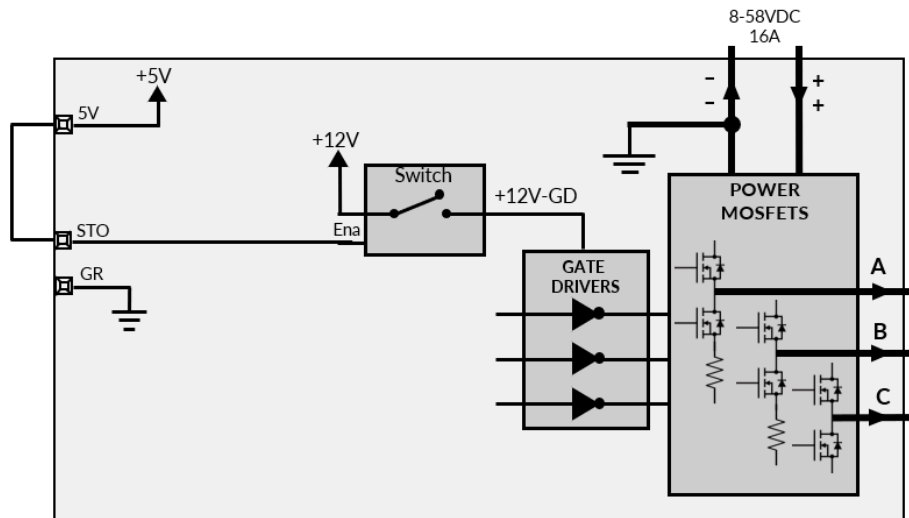

Figure 8 - STO wiring without external commanding devices by using +5V supply voltage of SOLO PICO

STO Timing Diagram

In SOLO PICO there is a dedicated STO input that provides redundancy and extra safety.

- When STO input is 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 9 when the external controller sets STO input at least for 150 microseconds the "Safe Torque Off" unit of SOLO PICO will be deactivated and lets power 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 input at least for 200 microseconds, this time is also called activation time and stops any power going into the motor. As demonstrated in Figure 9 any pulses below 100 microsecond can not affect STO functionality.
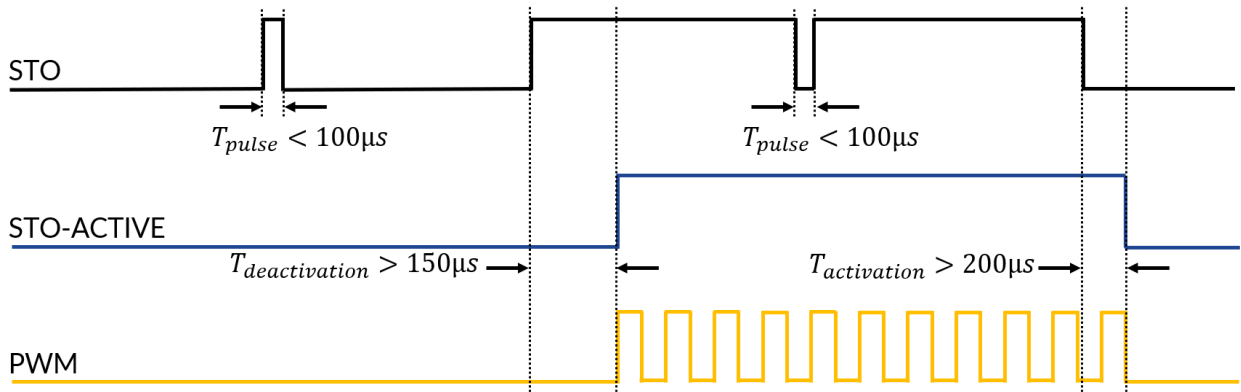
Figure 9 - STO Activation, Deactivation and Pulse Time

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

Parameters	Descriptions	Values
Type of input	STO type of input	Non isolated
Voltage range	The acceptable voltage range that can be applied to STO input	+3.3V to +5V
Input current	STO channel input current	2.1mA to 3.3 mA
Low level input voltage threshold	For +3.3V logic	+0.3V
	For +5V logic	+0.3V
High level input voltage threshold	For +3.3V logic	+3V
	For +5V logic	+4.7V
Pulse time	The maximum width of the short pulse that will be ignored by STO unit	< 100 microseconds
Deactivation time	Minimum time for deactivating the STO unit	> 150 microseconds
Activation time	Minimum time for activating the STO unit	> 200 microseconds

Analogue wiring in SOLO PICO:

In SOLO PICO it is possible to control Torque and Speed of motors by applying pure analogue voltages or PWM pulses to S/T input. 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 10 the Dir pin is connected to controller NPN output and also is pulled up to +5V of SOLO PICO through a 2.2KΩ resistor. Also 0-5V analogue outputs are connected to S/T input.
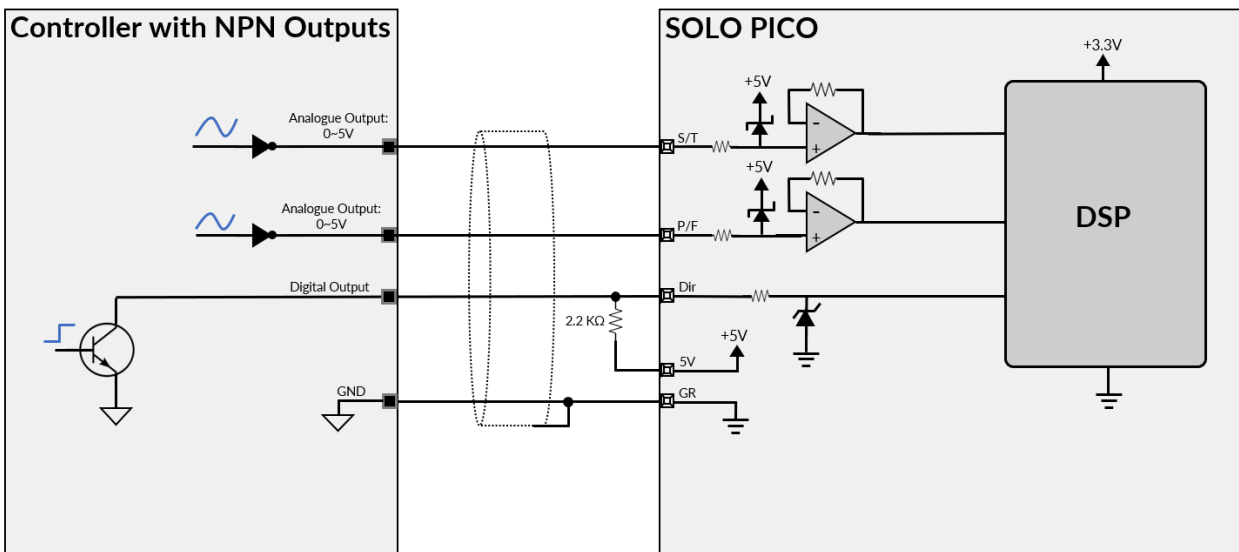

Figure 10 - Analogue wiring in case of NPN outputs controller

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

- The SOLO PICO ground must be connected to the controller ground.

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

As can be seen in Figure 11 the Dir pin is connected to the controller PNP output through 1KΩ resistor. Also 0-5V analogue outputs are connected to S/T input.
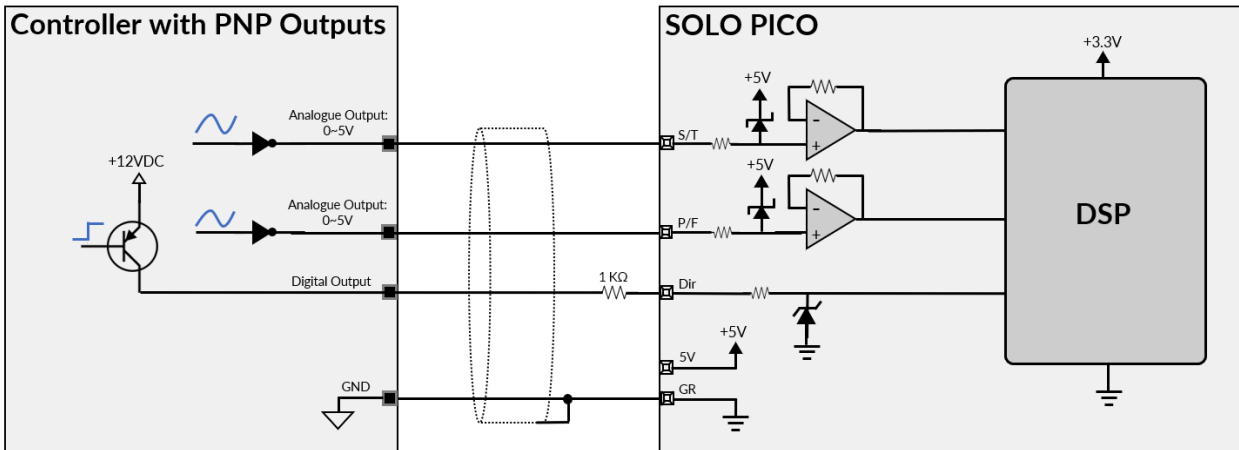

Figure 11 - Analogue wiring in case of PNP outputs controller

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

- The SOLO PICO ground must be connected to controller ground

3- Analogue wiring in case of Embedded MCU Boards:

SOLO PICO can be controlled by any Embedded MCU boards with 3.3V or 5V logic like Arduino, Raspberry Pi and so on. As can be seen in Figure 12 the Dir is connected to any digital outputs of Embedded MCU Board, also S/T and P/F pins are connected to analogue or PWM outputs of Embedded MCU Board.
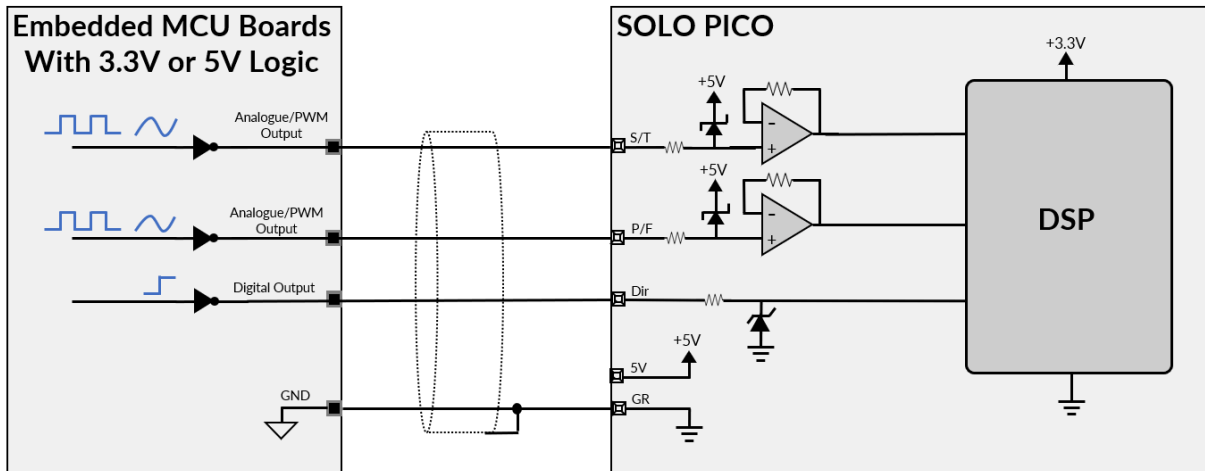
Figure 12 - Analogue wiring in case of Embedded MCU Boards

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

- The PWM frequency must be at least 5KHz.

- SOLO PICO's ground must be connected to the 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 13, Hall A, B, and C outputs are connected to EA, EB and EC inputs of SOLO PICO respectively. The Hall Sensor is powered using +5V output of SOLO PICO.
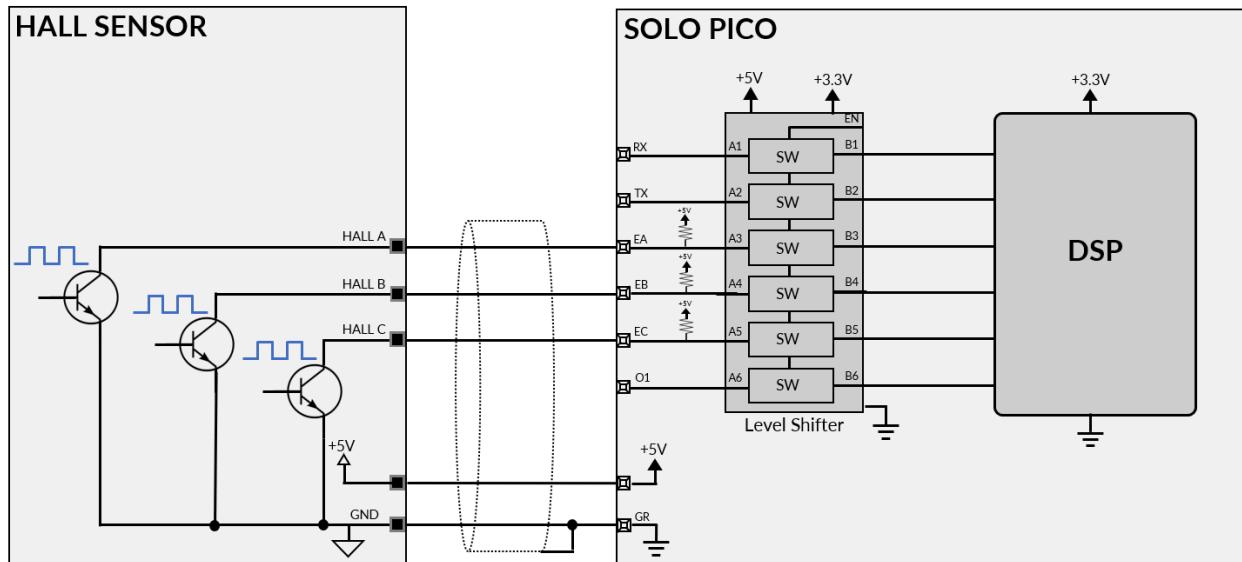
Figure 13 - Hall Sensor wiring in SOLO PICO

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

- The SOLO PICO ground 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 precisely the 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 PICO the Incremental Encoder can be wired in two different ways according to the 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 14, channels A, B and C of Single Ended Encoder are connected to EA, EB and EC inputs of SOLO PICO respectively, EC is known as Index pulse or Z pulse.
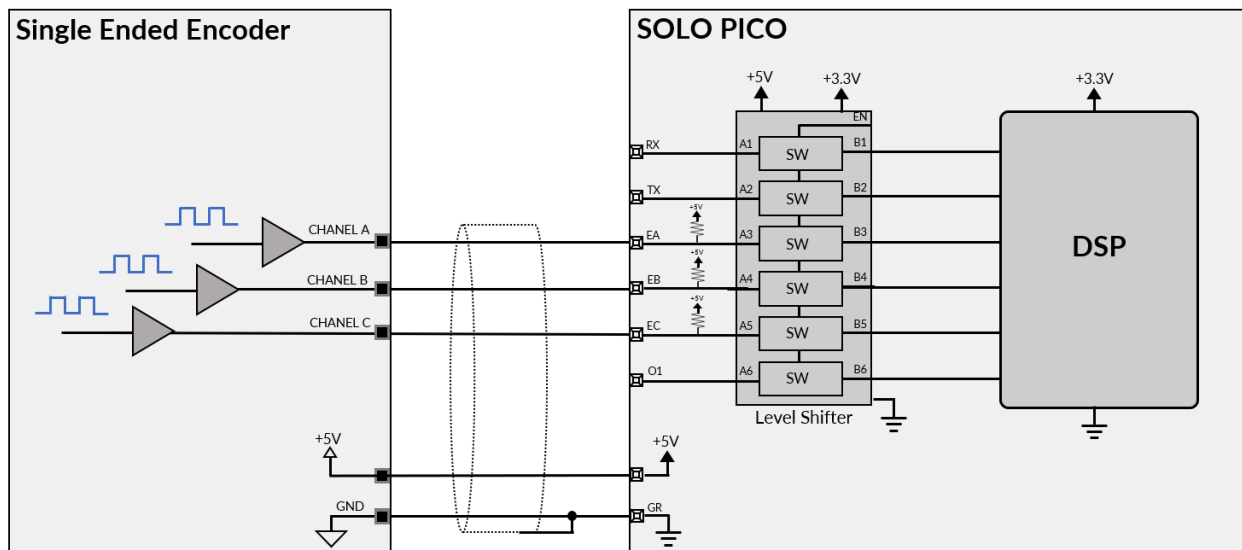

Figure 14 - Single Ended Incremental Encoder wiring in SOLO PICO

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to SOLO PICO ground or to controller ground only at one side.
- The Incremental Encoder is powered using +5V output of SOLO PICO.
- For 3 phase motors, the presence of Index pulse, occurring only once per mechanical turn is vital for proper calibration of the Motor and the Encoder.
- The Encoder has to be rigidly mounted with respect to the stator of the Motor, any movement in this sense will void the calibration results.

⚠️

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

2- Wiring in case of Differential Incremental Encoders:

As can be seen in Figure 15, positive outputs of Differential Encoder are connected to EA, EB and EC inputs of SOLO PICO respectively and all negative outputs of Differential Encoder are left disconnected.
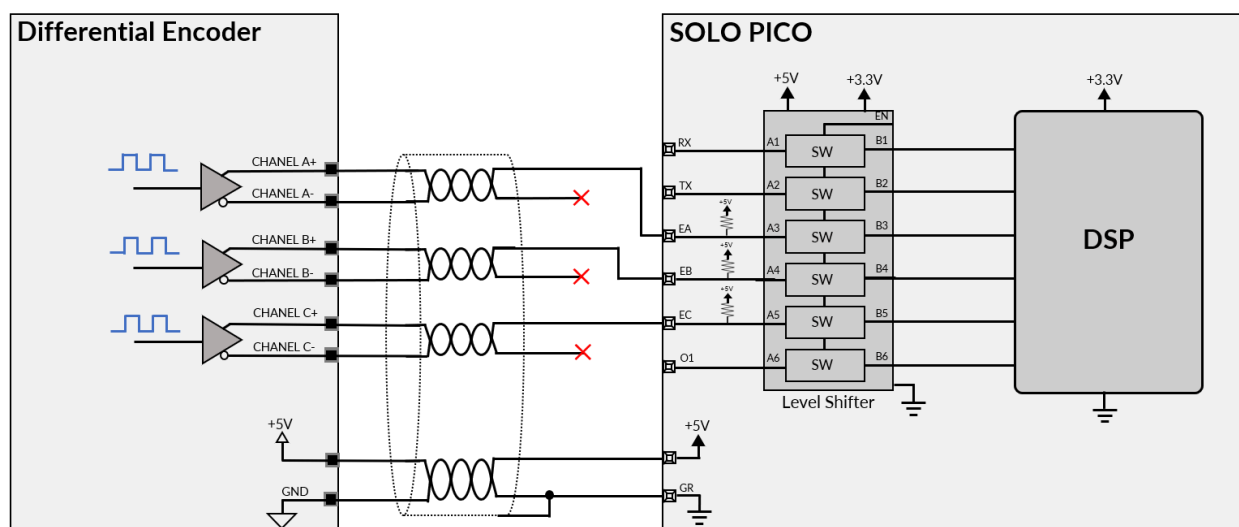

Figure 15 - Differential Incremental Encoder wiring in SOLO PICO

ℹ️

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to SOLO PICO ground or to controller ground only at one side.
- The Incremental Encoder is powered using +5V output of SOLO PICO.
- For 3 phase motors, the presence of Index pulse, occurring only once per mechanical turn is vital for proper calibration of the Motor and the Encoder.
- The Encoder has to be rigidly mounted with respect to the stator of the Motor, any movement in this sense will void the calibration results.

⚠️

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

Wiring of Sleep Mode input:

In SOLO PICO it is possible to put SOLO at very low current consumption which is called sleep mode. As shown in Figure 16 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 200μA.
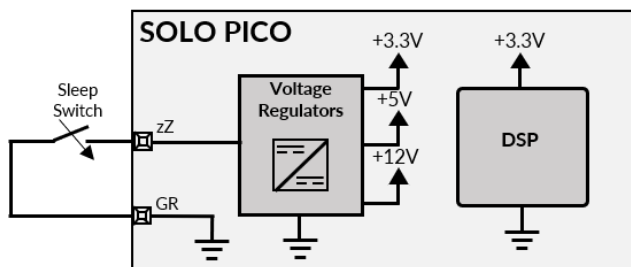

Figure 16 - Sleep Mode wiring

- 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 17 and Figure 18 in order to put SOLO in DFU Mode, the DFU input (pin 17 of control connector) must be connected to ground (pin 18 of control connector).
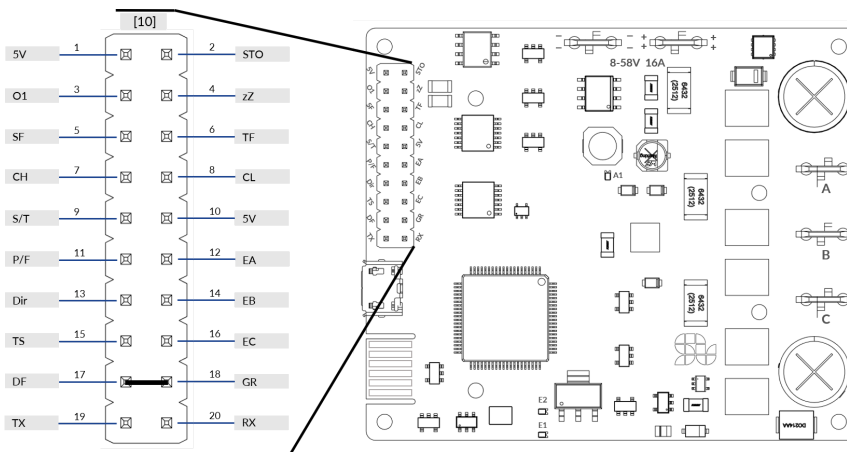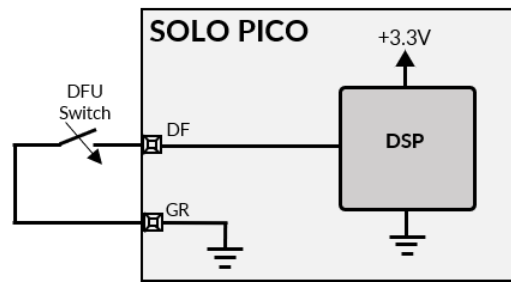

Figure 17 - DFU Mode Wiring

Figure 18 - DFU Mode Wiring

- The DFU pin is directly connected to the DSP, so it is not +5 volts tolerant.

Steps to put SOLO on DFU mode:

Once in a while, you might need to update the firmware on your unit, for that purpose you need to initially put your unit in DFU mode following the steps below:

1. Turn OFF SOLO
2. Connect the DFU pin to the ground.
3. Turn ON SOLO (both E2 and E1 LEDs will remain ON)
4. Updated the firmware using our updater tool.
5. Turn OFF SOLO
6. Disconnect the DF pin from the Ground, and Turn SOLO ON (E2 will start blinking and the unit will be operational)

PT1000 temperature sensor wiring:

PT1000 temperature sensor is a positive-temperature-coefficient resistor. As shown in Figure 19 in SOLO PICO by connecting a PT1000 temperature sensor to the TS pin, the temperature can be measured.
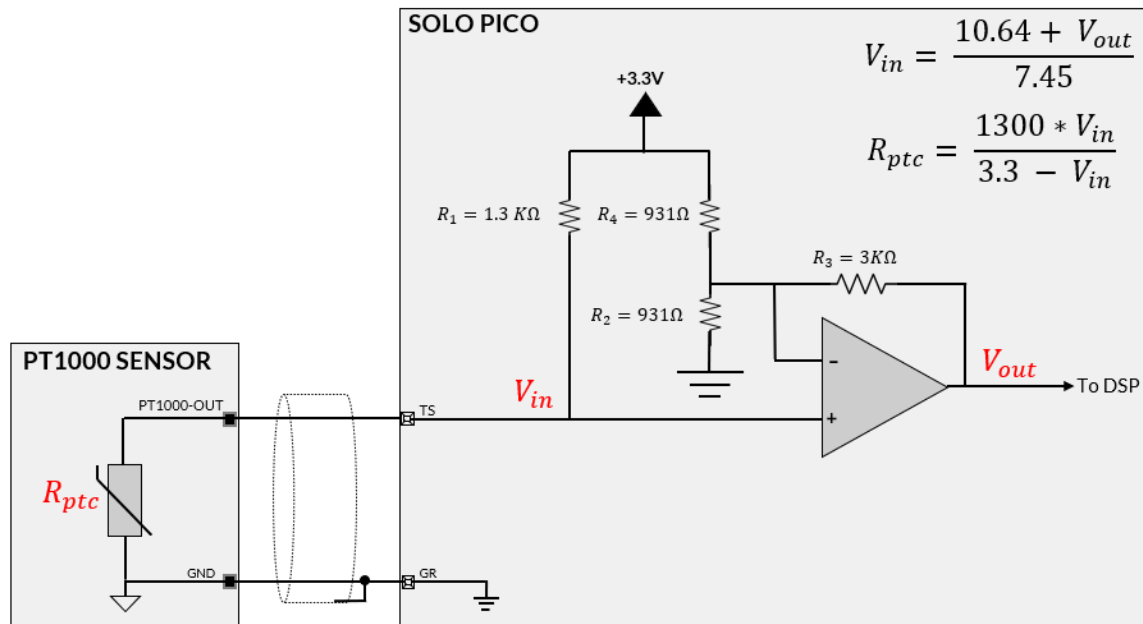

Figure 19 - PT1000 temperature sensor wiring

In order to measure the temperature do the following steps:

1. Read the PT1000 output voltage value (Vout) through one of the data lines (UART, USB or CAN bus)
2. Calculate Vin by using the below equation.

$$V_{in} = \frac{10.64 + V_{out}}{7.45}$$

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 19 .

$$R_{ptc} = \frac{1300 * V_{in}}{3.3 - V_{in}}$$

4. Put the PT1000 resistance value in the PT1000 characteristic curve or PT1000 characteristic table and extract the temperature (the user has to refer to their PT1000 datasheet to find out about this curve or table)

For example, consider Figure 20 as a sample PT1000 temperature sensor characteristic curve and assume that the PT1000 Voltage that read from SOLO is 2.9V, the temperature will be calculated as below:

1 → $Vout = 2.9$

2 → $V_{in} = \frac{10.64 + V_{out}}{7.45}$ → $V_{in} = \frac{10.64 + 2.9}{7.45} = 1.82\ V$

3 → R/ohm $= \frac{1300 \times Vin}{3.3 - Vin} = \frac{1300 \times 1.82}{3.3 - 1.82} = 1598\ \Omega$

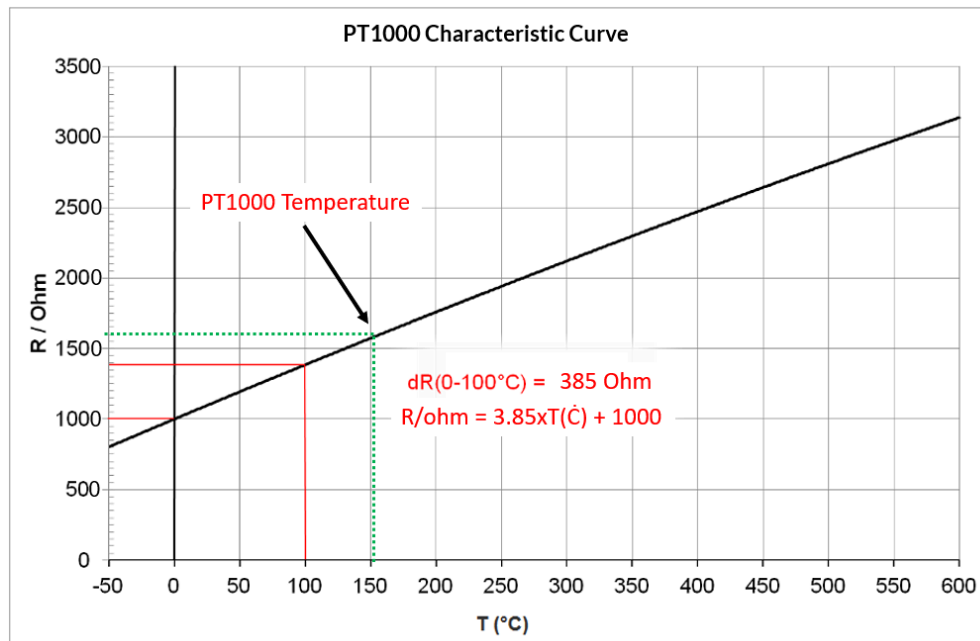4 → R/ohm = 3.85xT(Ċ) + 1000 → T(Ċ) = 155.5 celsius degree

Figure 20 - A sample PT1000 temperature sensor characteristic curve

Analogue Torque and Speed Feedbacks and Wiring:

There are two analogue feedbacks in SOLO PICO. These analogue feedbacks generate an analogue voltage between 0-5V according to measured motor Speed and Torque in both directions. This feedback once the measure Speed or Torque is at 0 will stay at 2.5V (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 21, the "S/T resolution" has been set at 2000 RPM and we have the following conditions based on the sections shown with Green numbers:
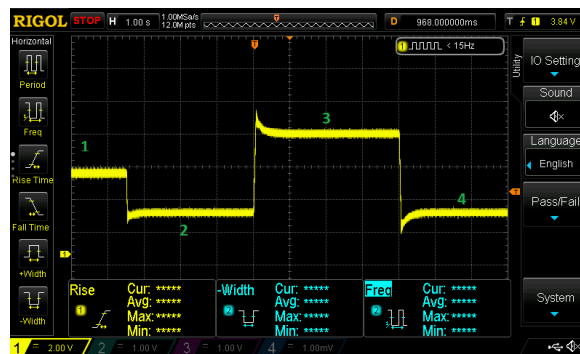

Figure 21- Speed Analogue Feedback

Section 1) The Motor is standing still, thus the feedback signal is at mid-point (+2.5V)
Section 2) The Controller leads the Motor to go to -1,000RPM as a Step response, the voltage stays at +1.25V
Section 3) The Controller leads the Motor to go to +1,000RPM as a Step response, the voltage stays at +3.75V (Figure 22 shows the transition from section 2 to 3 zoomed in)
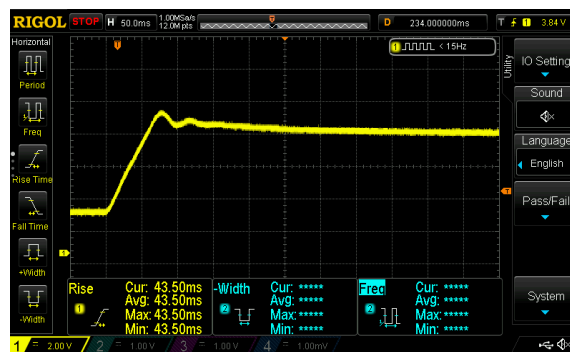

Figure 22- Analogue Feedback of Speed step response

As can be seen in Figure 23 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 5V outputs. The recommended resistor values are shown in Figure 23.
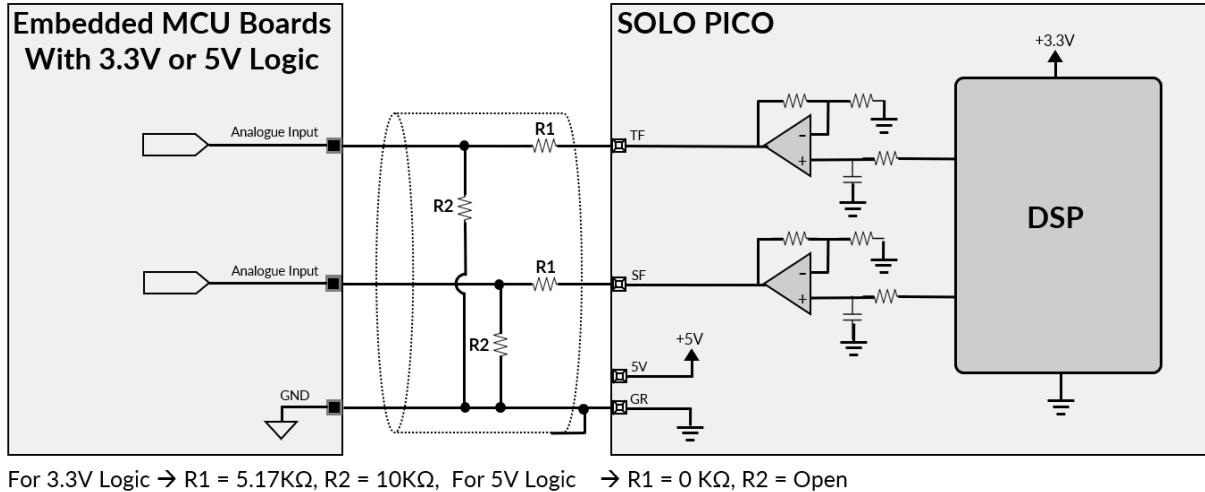

For 3.3V Logic → R1 = 5.17KΩ, R2 = 10KΩ, For 5V Logic   → R1 = 0 KΩ, R2 = Open

Figure 23- Analogue Torque and Speed feedback wiring

- In order to effectively reduce picking up noises from other EMI sources, It's recommended to connect cable shields to the SOLO PICO 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.

General Purpose Output (O1) wiring:

There is one general purpose output in SOLO PICO that can be used for general purpose use, like activating circuitries such as electrical valves, solenoids, etc ... as can be seen in Figure 24 which demonstrates a BJT and relay are used to run these external loads controlled by an Output from SOLO.
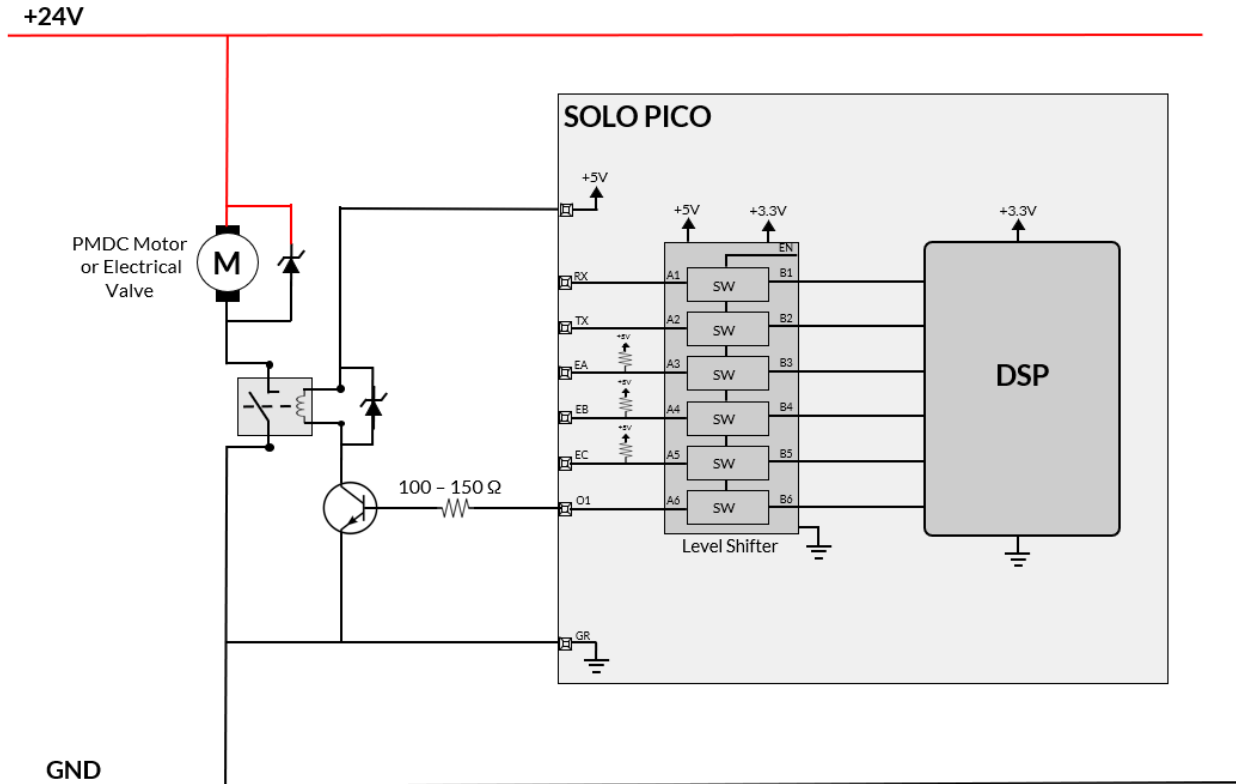

Figure 24- General purpose output (O1) wiring

⚠️

-   The maximum available current in general purpose output (O1) is 5mA, exceeding current above this value will damage the unit.

Digital Mode Wirings:

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

USB Interface Wiring

By using USB connection, you have the access to the simplest form of wiring of SOLO PICO to be commanded using only a USB cable thanks to the digital control that it offers, in this mode the only thing you will need is a micro USB 2.0 cable (type B) that enables SOLO 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.
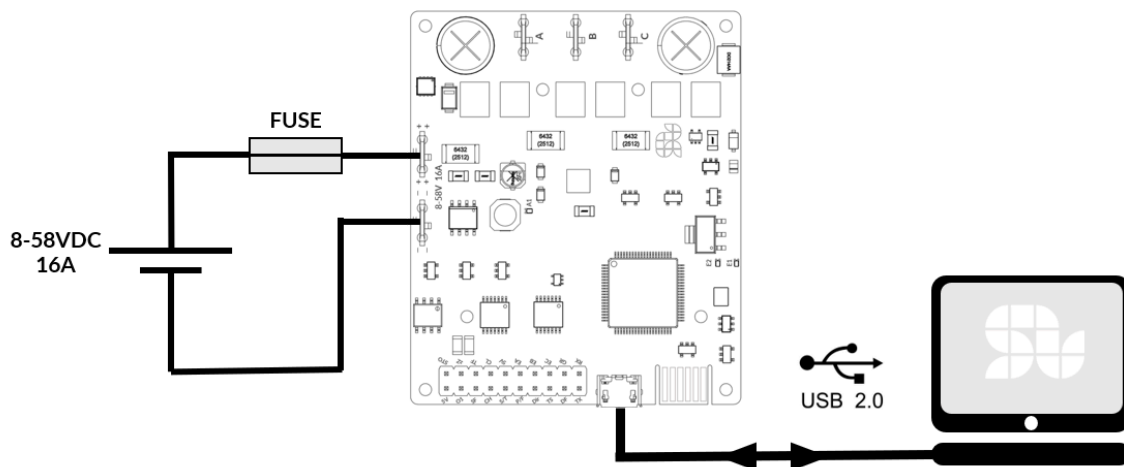

Figure 25 - USB 2.0 wiring.

- Powering up SOLO with any DC input voltages from 8 to 58 volts is necessary when SOLO PICO is connected to the external Host by using USB cable (USB cable doesn't power up SOLO itself).

- The maximum length of USB cable in SOLO PICO is 2 meters.

UART Interface Wiring

Another way to control SOLO in digital fashion is using UART communication. As can be seen in Figure 26, the MCU-TX pin of the Embedded MCU board is connected to the RX pin of SOLO and MCU-RX pin is connected to the TX pin.
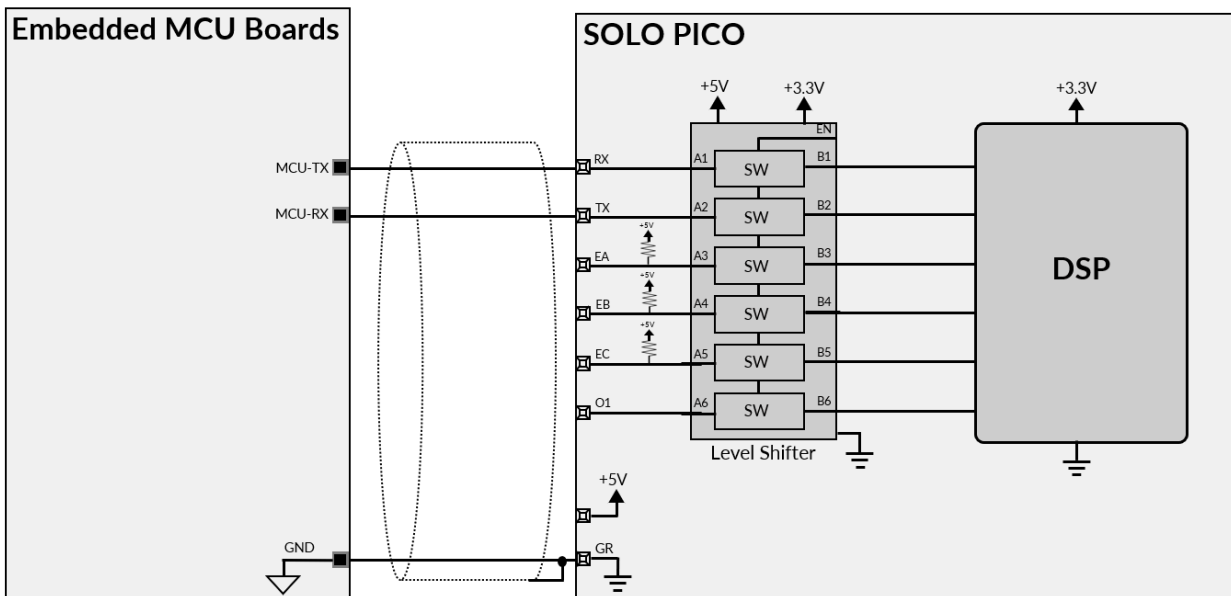

Figure 26 - UART wiring

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

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

CAN bus Interface Wiring

SOLO PICO 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](#).
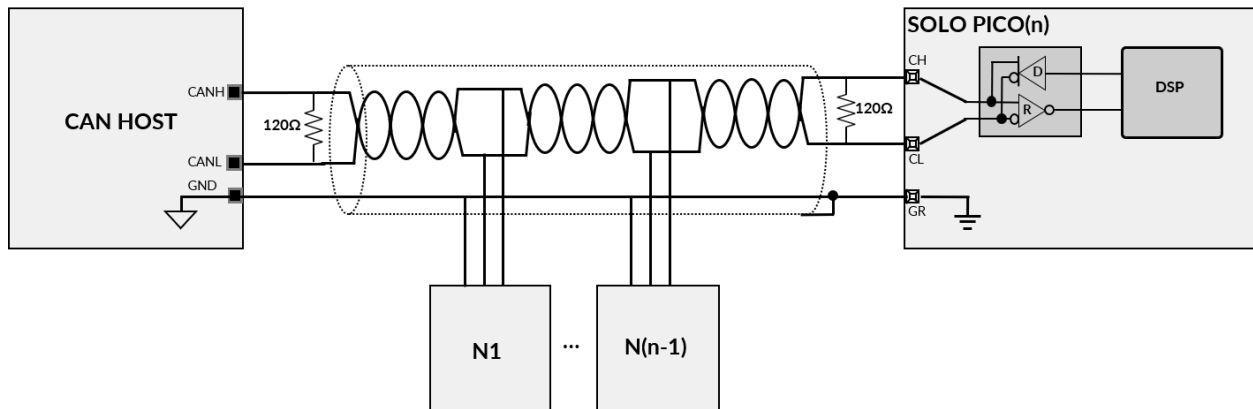

Figure 27 - CAN bus wiring

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

Full Wirings of SOLO PICO:

In this section, some sample wiring of SOLO PICO 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 potentiometer and a switch. In Figure 28, you can see the wiring of a DC Brushless or PMSM Motor in Closed-Loop Mode.
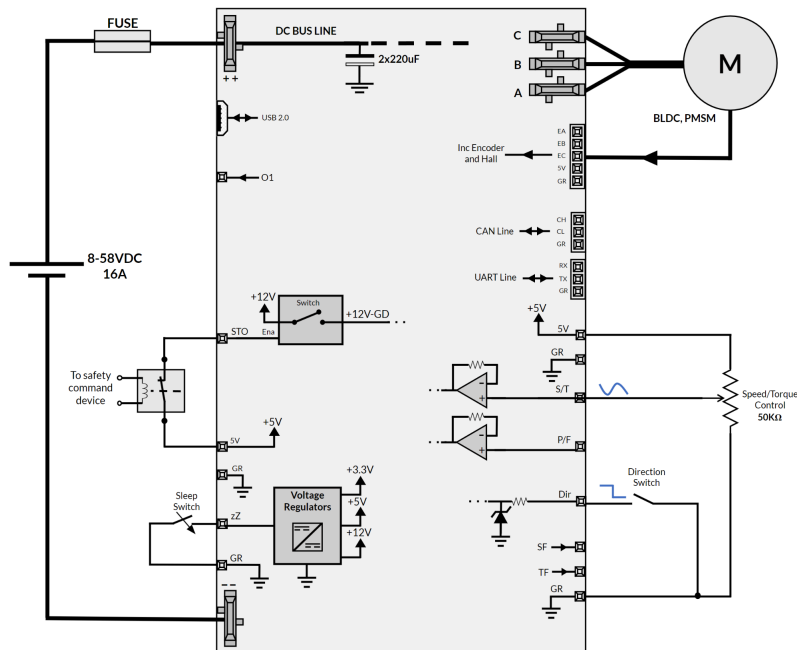

Figure 28 - Standalone wiring without external modules

- "Dir" pins in SOLO PICO accept voltage from +3.3V to +5V.

- To avoid short-circuiting the internal voltage source of SOLO (+5V), The Minimum allowed resistance at any position of the potentiometer must not be below 1kΩ, the user has to check the datasheet of the Potentiometer and verify that.

Embedded MCU Boards using Analogue/PWM:

Here is an example of wiring SOLO PICO with an Embedded MCU Board like Arduino or Raspberry PI , as can be seen in Figure 29.
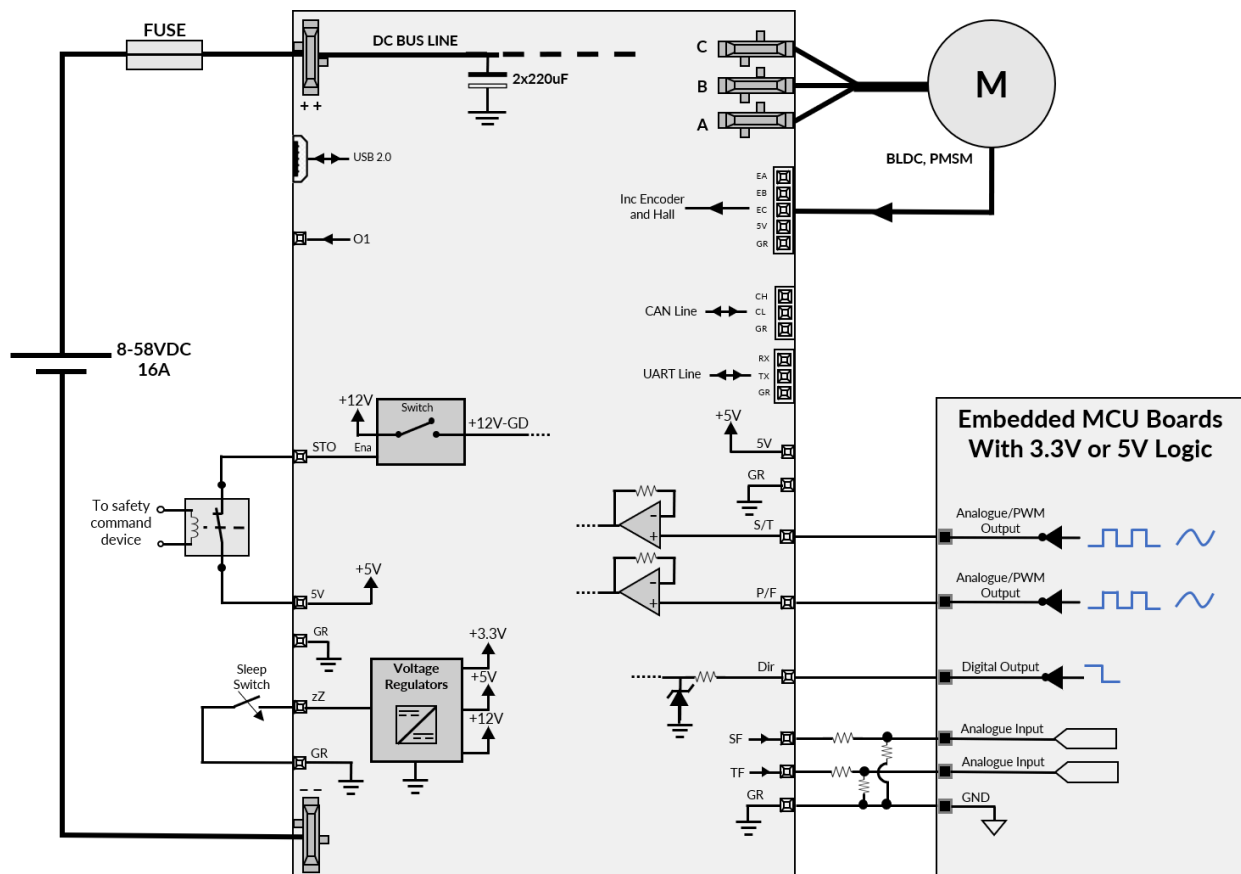

Figure 29 - Embedded MCU Boards using Analogue/PWM

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

- "Dir" pins in SOLO PICO accept voltage from +3.3V to +5V.

- 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 30, an Embedded MCU Board like Arduino or Raspberry PI is used to send commands through the UART line to SOLO.
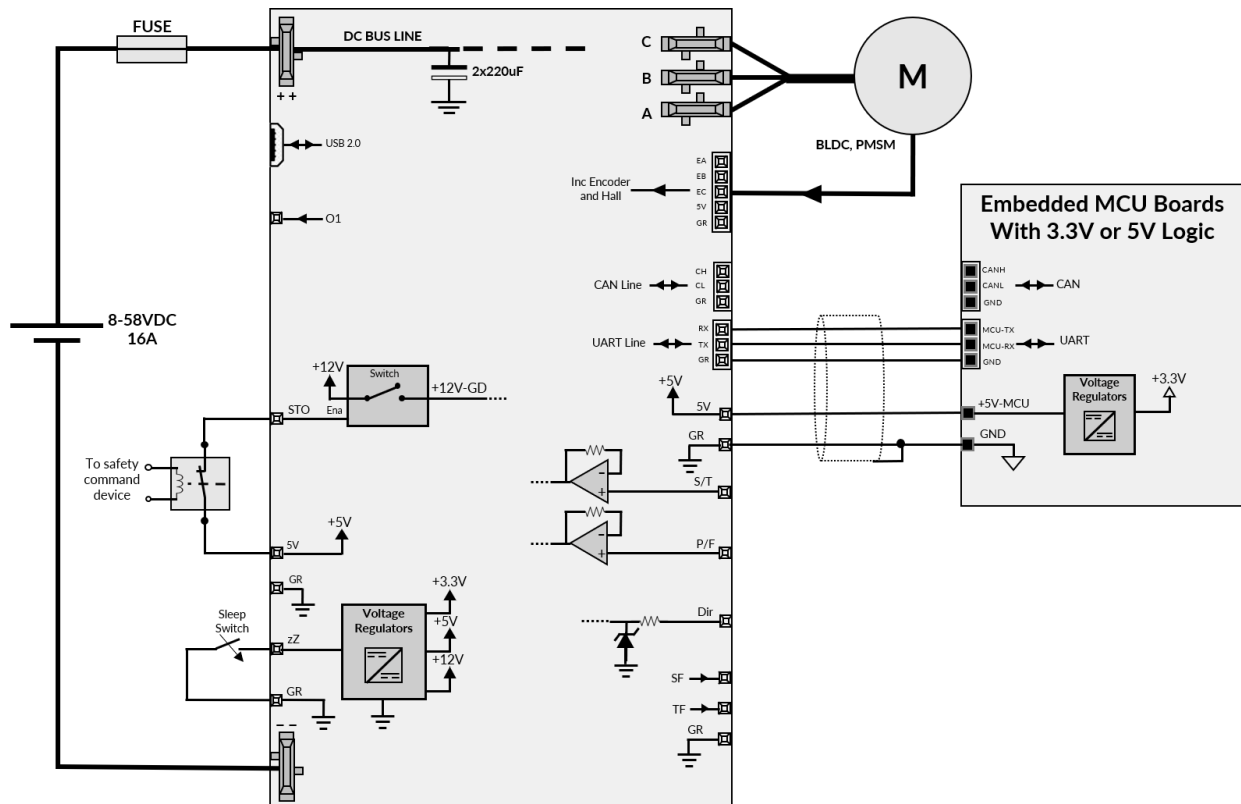

Figure 30 - Embedded MCU Boards using UART wiring

- The Embedded MCU Board is powered using +5V output of SOLO PICO.

- The most important point in power connection is to make sure the SOLO PICO ground 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:

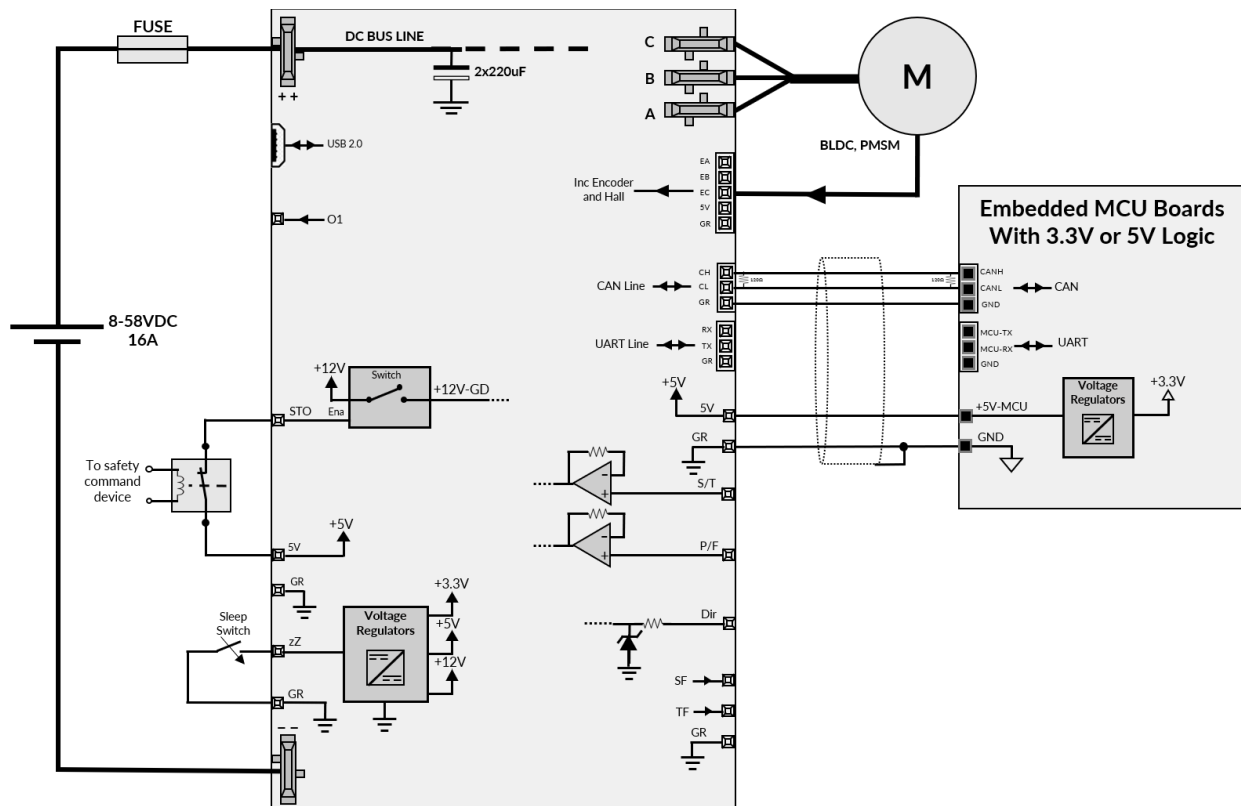Figure 31 demonstrates the CANopen interface between SOLO PICO and Embedded MCU Boards like Arduio or Raspberry Pi.

Figure 31 - 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 SOLO PICO ground or to Embedded MCU Board ground only at one side.

General Wiring Considerations in SOLO PICO:

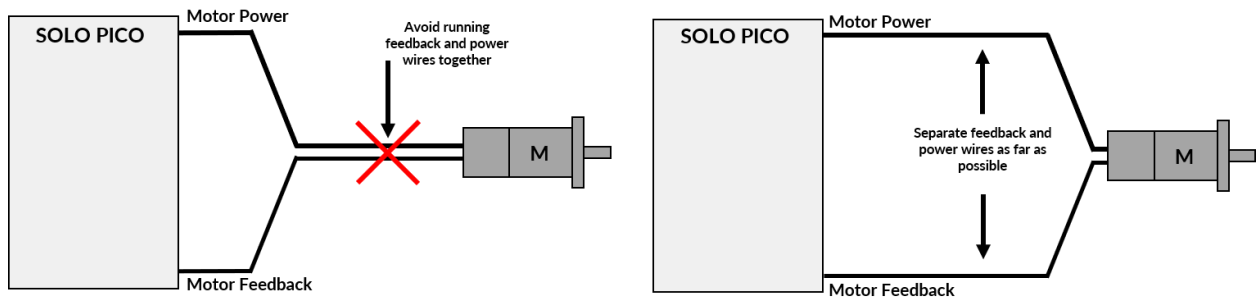## 1- Avoid running feedbacks and power wires together

Figure 32 -Avoid running feedbacks and power wires together

2- Avoid making ground loops

As can be seen in Figure 33 the Embedded MCU Board is powered from a power supply that has a common ground with SOLO PICO, this wiring will make a ground loop and can cause EMI problems. The proper wiring is to power the Embedded MCU Board from +5V supply of SOLO PICO (Figure 34).
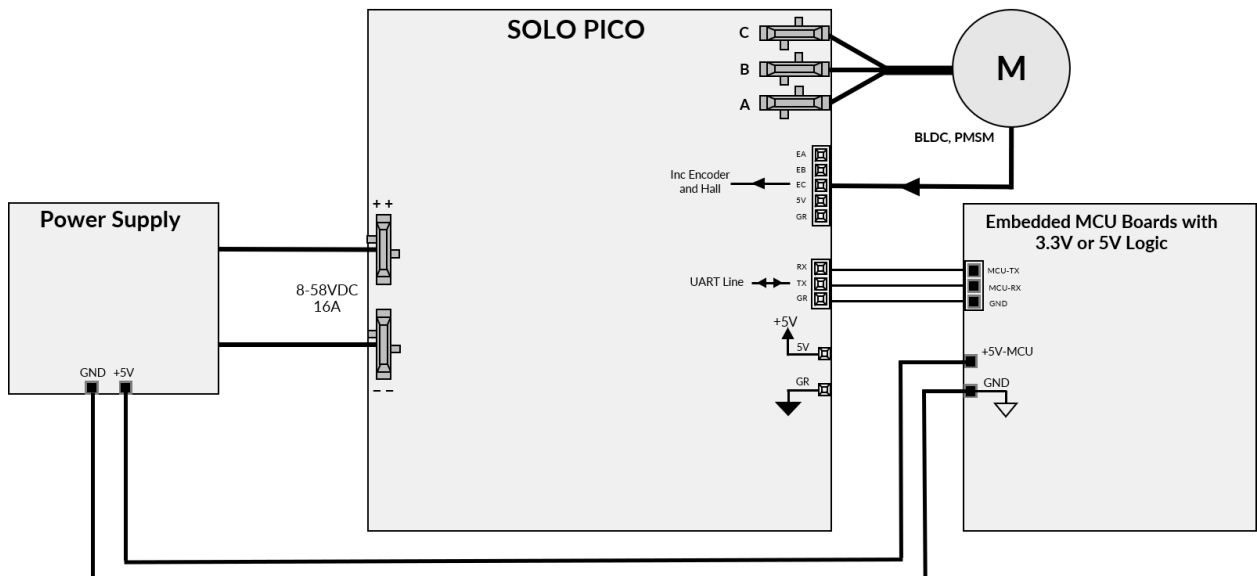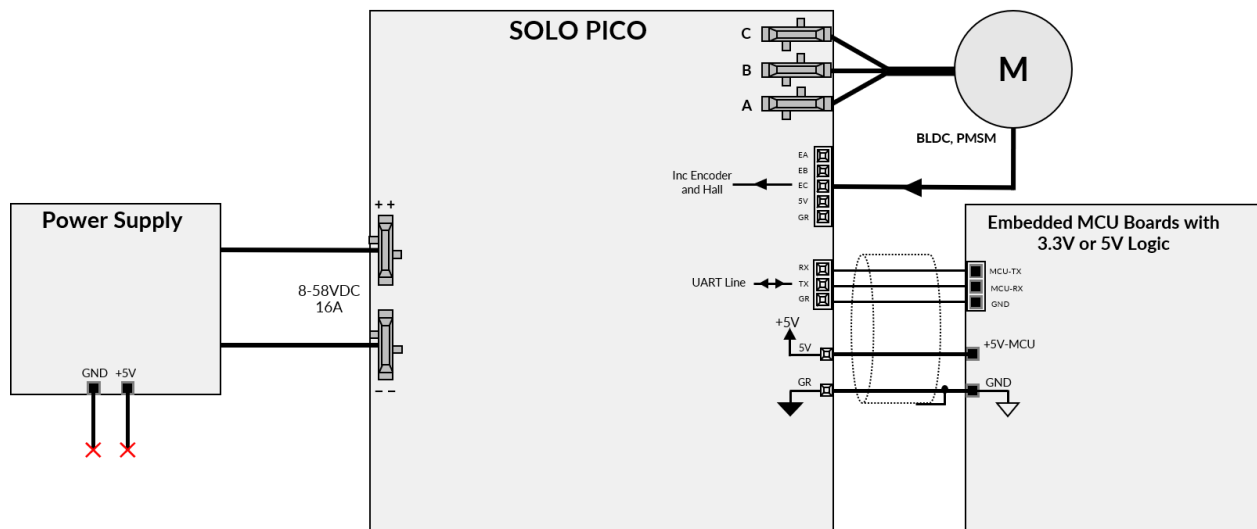

Figure 33 -Improper ground wiring

Figure 34 -Proper ground wiring

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