SOLO MINI_v2 User Manual

Part Number: SLM0322_4020

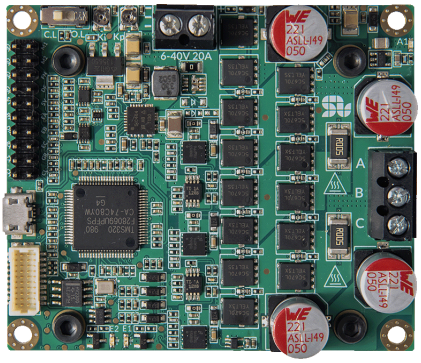
Product Description

SOLO MINI_v2 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, AC Induction 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.
They offer both sensor-based and sensor-less options for Speed, Torque and Position controlling of motors supported plus numerous types of 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 - 40 VDC

Continuous DC Current: 27ADC
Continuous AC Current: 16Arms



Features

- Easy to use
- Drives and Controls DC, BLDC, PMSM EC coreless and ACIM motors
- Closed-loop and Open-loop controls
- Speed, Torque and Position control
- Sensor-based and sensorless control
- Four Quadrant Regenerative Operation
- Automatic parameter Identification and self-tuning
- Field Oriented Based Controls with Nested Position-Speed-Torque loops
- Dual Core with Parallel Processing Architecture
- Reverse Polarity, Bus over-voltage, Bus under-voltage, over-current and over-temperature protections
- Active temperature control
- Full Digital and Analogue Control

Modes of Operation

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

Commands and feedback Source

- 0-5V Analogue/ PWM inputs for Speed or Torque control
- Quadrature Encoder input (RS422)
- Hall sensors input
- UART, USB, CANopen

Applications

- Industrial Automation
- Robotics and Traction Units
- Drones

Revision History:

Revision	Date	Changes	Firmware version
V1.0.0	30/09/2021	- First Release	0x001B009
V1.0.1	12/05/2022	- SOLO MINI_v2 updated	0x00BB00A
V1.0.2	10/05/2024	- P/F pin description changed - Certification Table updated - Temperature ratings update per UL61800-5-1 - Current ratings updated for units sold after 10/05/2024	0x0000B020

Table of Contents

Power Specifications:

Description	Units	Values
DC Supply Voltage Range (continuous)	**VDC**	**8 to 37**
DC Bus Overvoltage Limit	**VDC**	**40**
DC Bus Undervoltage Limit	**VDC**	**6***
Maximum Continuous Output Current	**ADC**	**27****
Maximum Continuous Output Current	**Arms**	**16**
Maximum Continuous Output Power	**W**	**600**
Maximum Peak Output Power	**W**	**800**
Internal Bus Capacitance	**µF**	**880**
Switching Frequency (output PWM frequency)	**kHz**	**8 to 80**

*The minimum recommended voltage for high-current applications is 8V.
** Only for batches sold after 10/05/2024, for previous batches this value is 20ADC.

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 - 3.3/5V
Modes of Operation	-	Torque - Speed- Position
Motors supported	-	DC - BLDC - PMSM - EC Coreless- ACIM
Hardware Protections	-	Reverse Polarity, 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	**MHz**	18 (Pre-Quad)

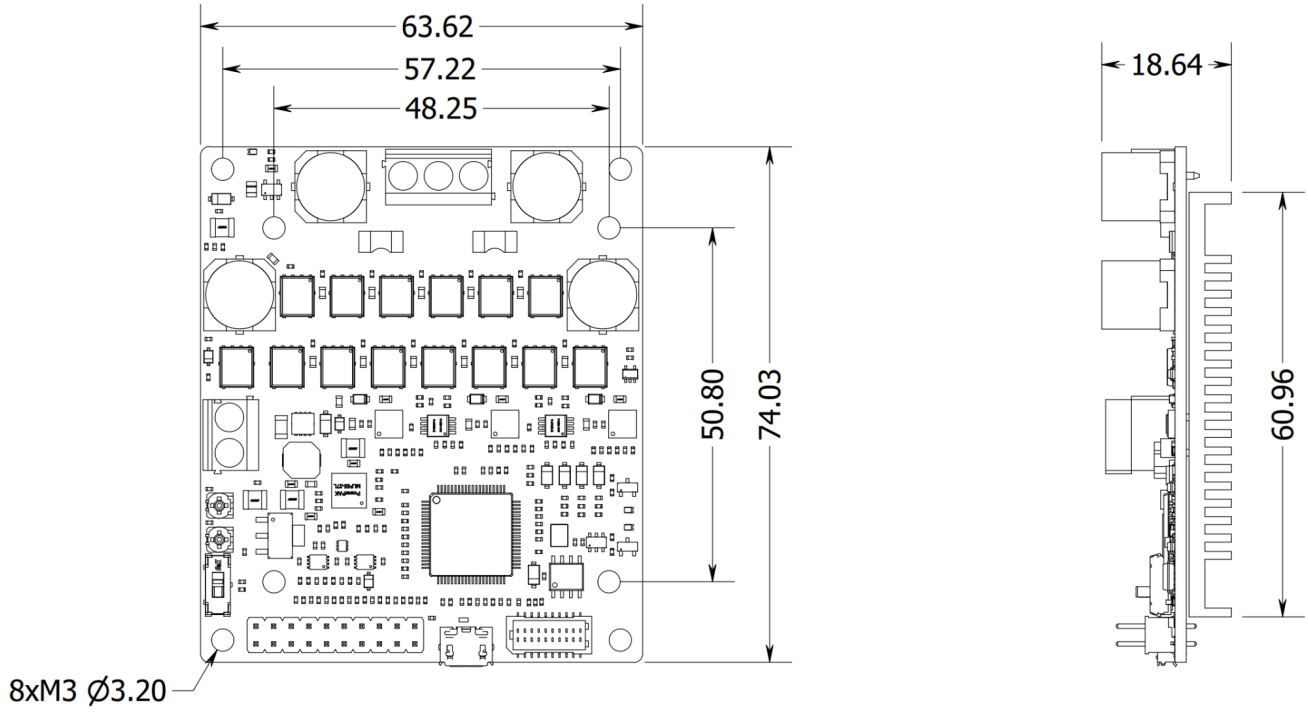
Thermal Specifications:

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

Mechanical Specifications:

Description	Units	Values
Size (H x W x L)	**mm**	18.64 x 63.62 x 74.03
Weight (with heatsink)	**gr**	69
Form Factor	-	Wall Mount

Mechanical Dimensions:



- All the measurements are in millimetres.
- Download the 3D step model from here.

Absolute Maximum Voltage Ratings:

- All The sections are referred to in **Figure 2** 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	**Supply Input**	**Input**	**VDC**	**+6**	**+37**	**+40**
3	**S/T** (speed/torque)	**Input**	**VDC**	**0**	**+5.0**	**+5.5**
3	**P/F** (power/flux)	**Input**	**VDC**	**0**	**+5.0**	**+5.5**
3	**DIR** (Direction control)	**Input**	**VDC**	**0**	**+5.0**	**+5.5**
3	**+5V** (External supply)	**Output**	**VDC**	**+4.95**	**+5.0**	**+5.2**
8	**CHA**(Encoder)**/HALL_A**	**Input**	**VDC**	**0**	**+5.0**	**+5.5**
8	**CHB**(Encoder)**/HALL_B**	**Input**	**VDC**	**0**	**+5.0**	**+5.5**
8	**Index**(Encoder)**/ HALL_C**	**Input**	**VDC**	**0**	**+5.0**	**+5.5**
9	**UART_RX**	**Input**	**VDC**	**0**	**+5**	**+5.5**
9	**UART_TX**	**Output**	**VDC**	**0**	**+3.3**	**+3.6**
9	**CAN_RX**	**Input**	**VDC**	**0**	**+3.3**	**+3.6**
9	**CAN_TX**	**Output**	**VDC**	**0**	**+3.3**	**+3.6**
9	**+3.3V**(External supply)	**Output**	**VDC**	**+3.25**	**+3.3**	**+3.38**
13	**CANH**	-	**VDC**	**-2**	-	**+7**
13	**CANL**	-	**VDC**	**-2**	-	**+7**

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.

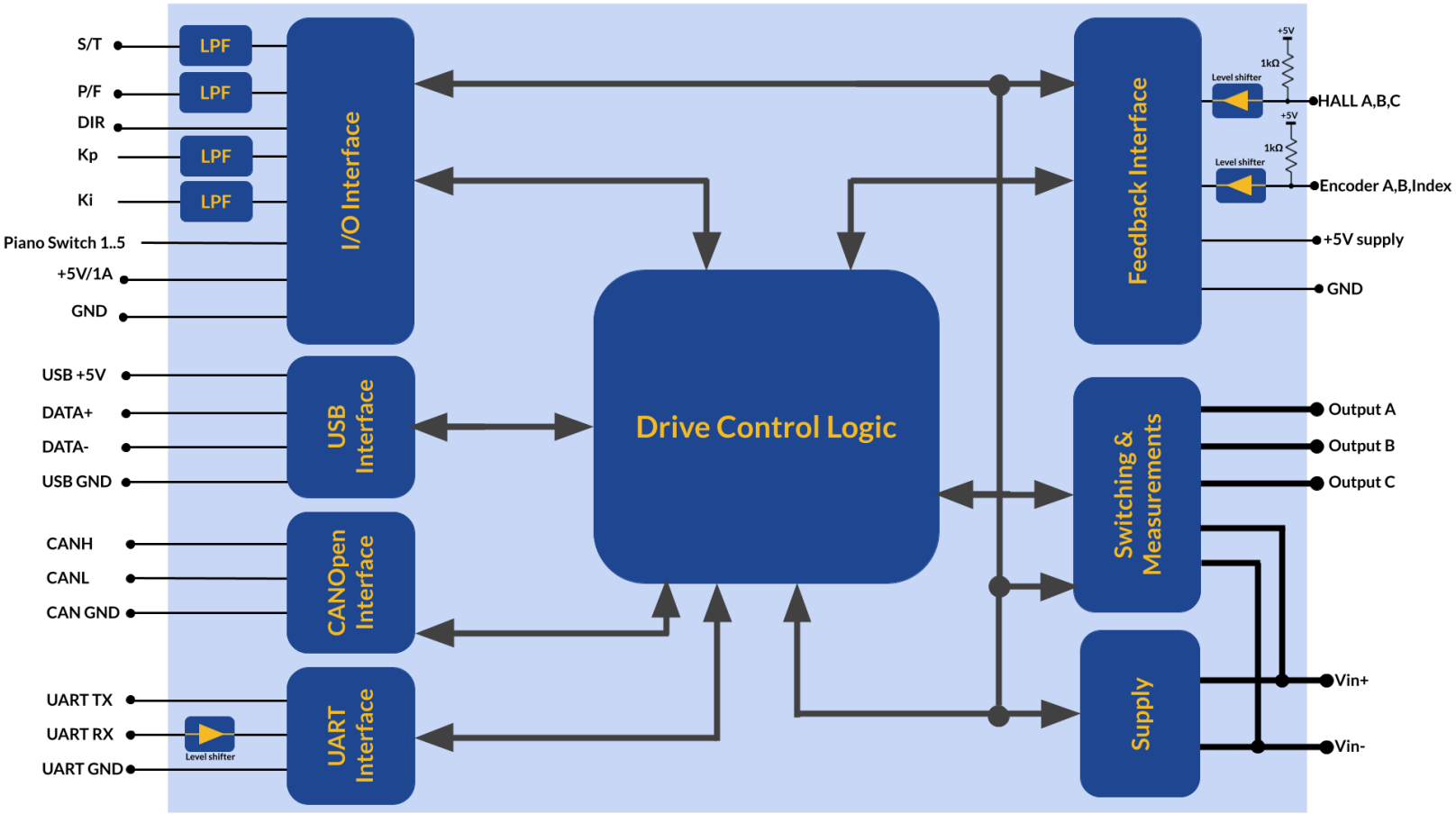
Overview of the product

SOLO MINI_v2 is one of the products designed and manufactured by solo motor controllers, it serves the purpose of being universal and easy to use for a wide range of users from different backgrounds. This product is designed to support various types of electrical motors like DC brushed, Brushless DC, Brushless AC or Permanent Magnet Synchronous Motors as well as AC Induction and EC coreless motors up to 37V with the supply voltage and a continuous current of up to 20 Amps, this will enable SOLO MINI_v2 to be utilized in wide range of products and projects and eventually speeding up the developments and time to market for its users.

SOLO MINI_v2 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 the CAN bus with CANopen software layer which is called Digital Mode Control. 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 MINI_v2 are listed as below:

- Wide input voltage supply range from 8V to 40V
- The continuous output current of 20A, Max Current of 80A
- Capable of controlling DC, BLDC, PMSM and ACIM motors, EC coreless
- Dual Core with parallel processing architecture
- CANopen, USB and UART Communications
- Extremely fast F.O.C loop-rate up to 140kHz (7µs complete execution time)
- Over-current, Over-voltage, Over-Temperature, Under-voltage and Reverse Polarity Protection
- Selectable output PWM switching frequency from 8kHz to 80kHz
- Automatic self-tuning and identification of Motor parameters
- Open-loop or Closed-loop Control modes
- Torque, Speed or Position control
- Advanced Sensor-less and Sensor-based Control
- Advanced Field Oriented Control
- PWM and Analogue voltage input for Controlling Speed and Torque
- SVPWM modulation
- Encoder and Hall Sensor Input with +5V supply
- +5V/1A (5W) output to supply external modules
- Updatable Firmware
- Heatsink mounted on the back of the board to enhance the thermal behaviour
- 880µF onboard BUS capacitance

Functional Block Diagram:



Theory of Operation:

SOLO MINI_v2 is designed to operate in a 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, PMSM and AC Induction motors this topology is known as Field Oriented Control or Vector Control, it worth mentioning that SOLO MINI_v2 can operate in Open-loop mode as well which can be used for simple applications.
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 1 and the Brushed DC motors that can be seen in Figure 2 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 the 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.
4. **The Magnetizing Current Controller:** This controller is useful to control the amount of magnetizing current for only AC induction motors, the magnetizing current will help to generate flux for controlling the AC induction Motor, for Brushless motors, this loop will stabilize the Id (direct current) at zero which is necessary for FOC.

FOC Control Architecture in SOLO MINI_v2 for 3-phase Motors:

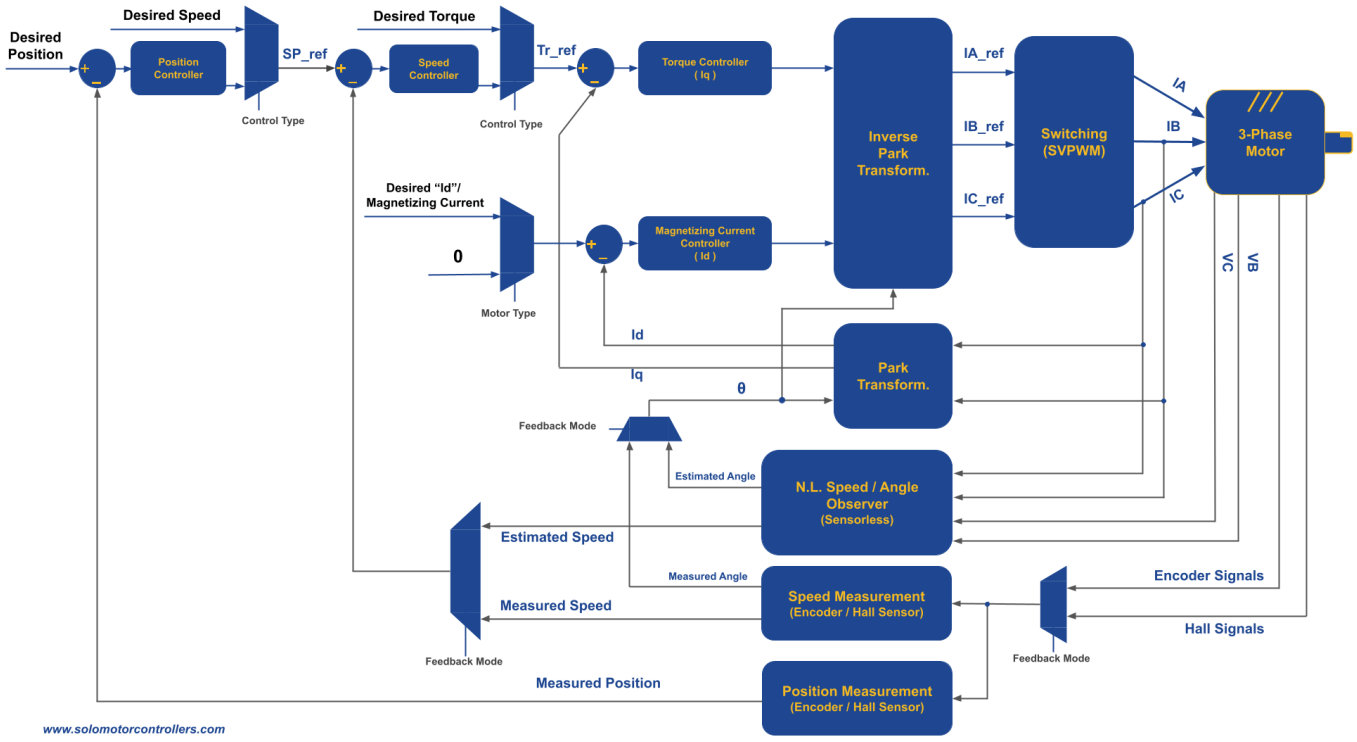


Figure 1 - FOC Control Architecture of SOLO MINI_v2 for 3-phase Motors

As can be seen in Figure 1, 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 MINI_v2.
2. **Speed Feedback:** This feedback is either measured using the sensors mounted on the motor (Encoders, Halls, ...) or it's estimated by the Nonlinear observer in sensorless modes, 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 types of closed-loop or open-loop control on SOLO, this feedback is either Estimated or Measured by SOLO internally.

Cascade Control Architecture in SOLO MINI_v2 for DC Motors:

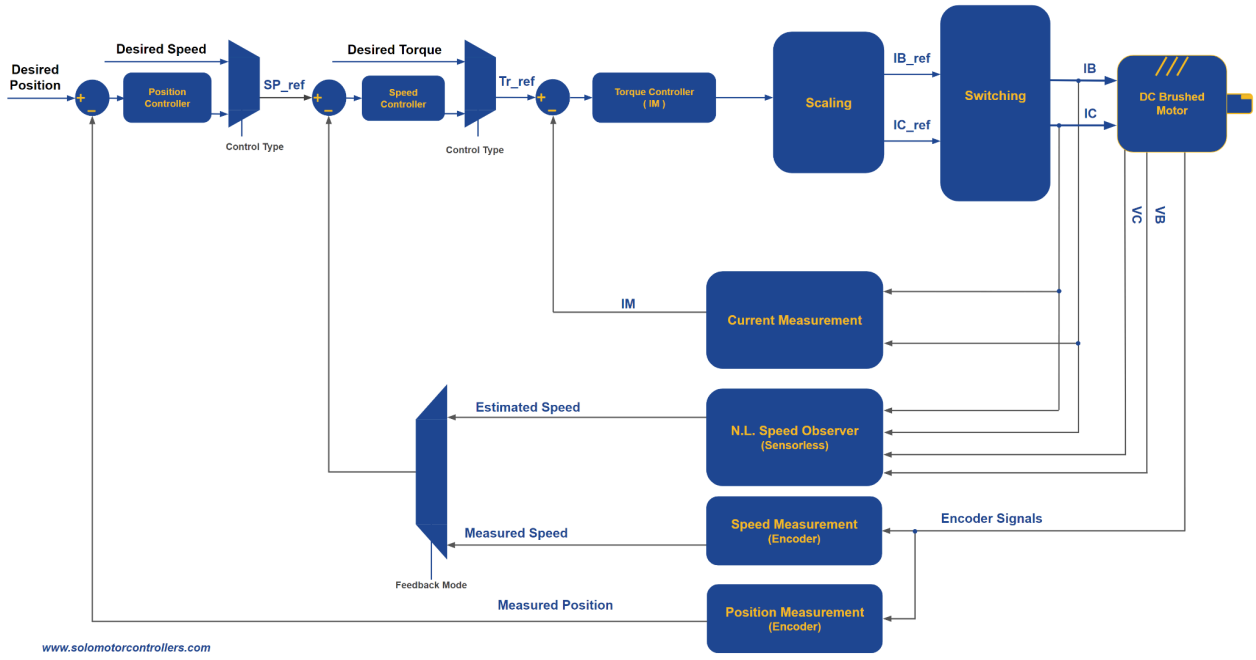


Figure 2 - Control Architecture of SOLO MINI_v2 for DC Brushed Motors

As can be seen in Figure 2, 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 both Sensor-less and 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's Interactional Sections:

SOLO MINI_v2 can be decomposed into 11 main interactional sections as shown in Figure 3 below, all the sections are explained in detail and their electrical and maximum ratings are mentioned later in this user manual, the user has to make sure that they don't exceed those maximum ratings to avoid damaging themselves or SOLO MINI_v2 unit.

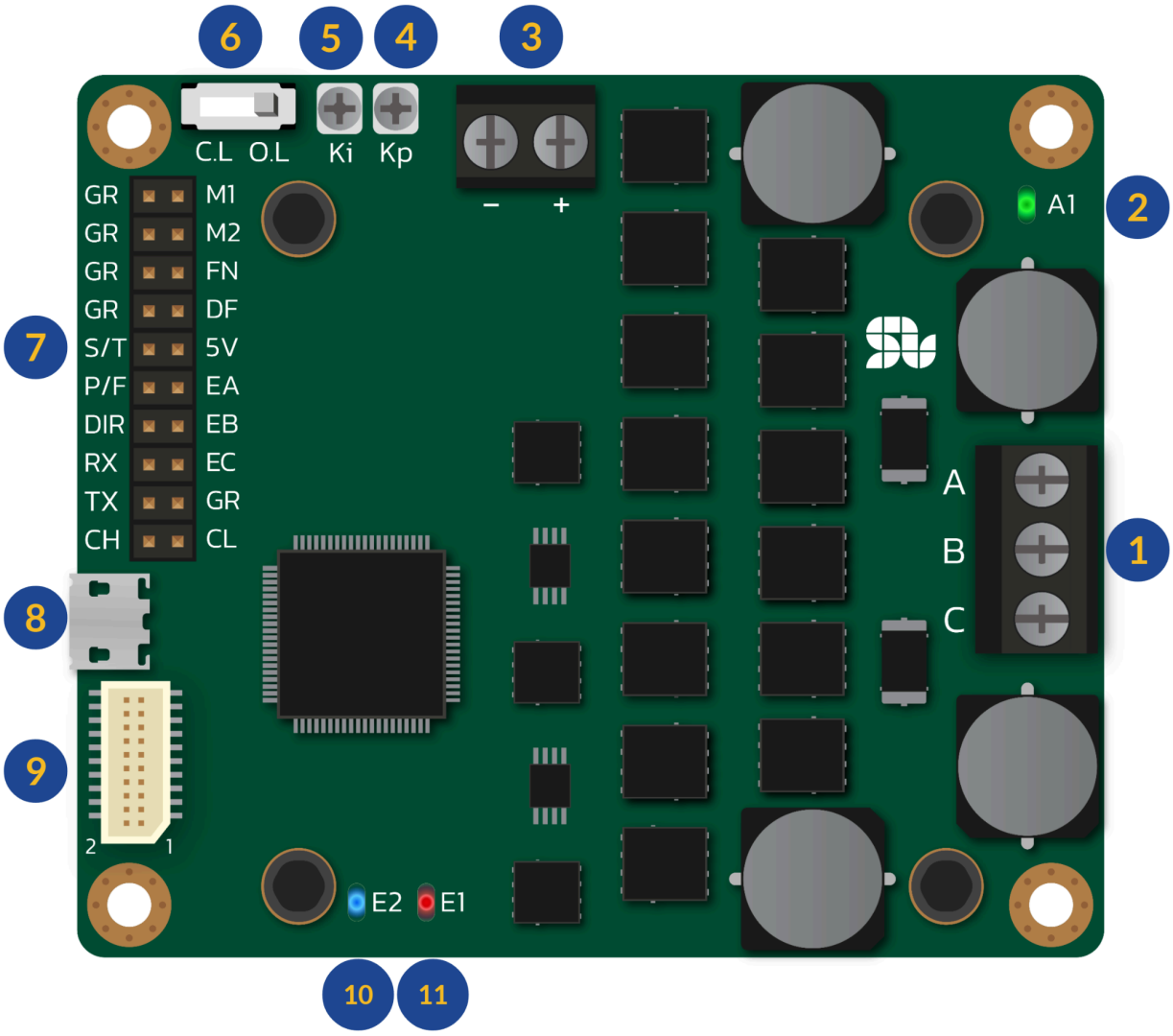


Figure 3 - SOLO MINI_v2's interactional sections

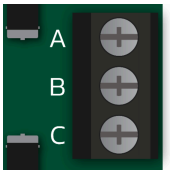
Connectors and Sections:

Section 1 - Motor Output

PIN	Name	Descriptions / Notes	I/O
1	A	Motor Output 1	-
2	B	Motor Output 2	-
3	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 "Minimum Required Wirings" part, 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.



Section 2 - Power Up LED

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

Description

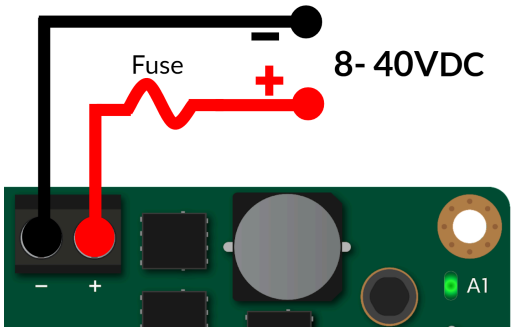
This LED will start glowing once SOLO is correctly powered up with a voltage from 8 to 40V.

Section 3 - Supply Input

PIN	Name	Descriptions / Notes	I/O
1	+	Positive Voltage Input	-
2	-	Negative Voltage Input (Ground)	-

Description

This is the Power Supply input of SOLO and it can be supplied with any input voltages from 8 to 37 volts in continuous mode, depending on the voltage rating of the Motor Connected at the output. The max rating for supply input is 40V in transient mode, meaning that SOLO will go into over-voltage protection mode in case the supply or BUS voltage rises above almost 39.5 to 40.5 volts.

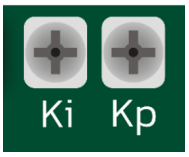


Section 4 and 5 - Speed Controller Gains

section	Name	Descriptions / Notes	I/O
4	Kp	Proportional Gain of speed controller	-
5	Ki	Integral Gain of speed controller	-

Description

These are two potentiometers, defining the speed controller gains in closed-loop Analogue mode, You can increase their values by rotating them in Counter ClockWise direction, subsequently by rotating them in Clockwise direction their value reduces until they get blocked in that direction which means a value of ZERO, to work with SOLO, in Analogue closed-loop speed mode you need to tune these two potentiometers, their simple definitions can be given as following :



Kp Potentiometer :
This potentiometer defines for you how fast your motor should react and reach the speed you asked, so if you increase this value, your motor will be more reactive, but too much of this gain might make vibrations, so you need to tune it enough. Also another effect of this gain will be how “harshly” the controller (here SOLO) should react to the variation of the load on the shaft of the motor to keep the speed constant. It's not always good to increase this gain excessively, since it might cause instability.

Ki Potentiometer :
This potentiometer defines how good your motor during time should reach the goal and stay in steady state, by increasing this gain your motor might reach the goal slower but more consistently. Also by increasing this gain too much your motor might get unstable. So you need to tune this similar to Kp with patience and accuracy, to have zero error at steady state this gain must be anything greater than zero, and zero error in steady state means, the controller reaches to desired speed and remains there with zero error in theory (in practice with minimum possible error)

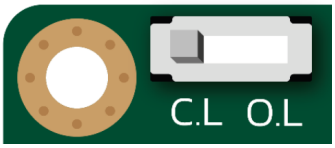
Section 6 - Control Mode Switch

section	Name	Descriptions / Notes	I/O
6	C.L	Operation in Closed-loop Mode	-
6	O.L	Operation in Open-loop Mode	-

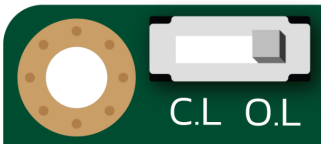
Description

Through this switch, you can select what type of control Mode SOLO MINI_v2 should operate on, you can select between Closed-loop or Open-Loop operations by Putting the switch in any of the positions shown below, Selection of this mode will affect both Analogue and Digital commanding modes and to use SOLO with its best performance it is recommended to use it in Closed-loop mode as Open-loop mode is mainly good for experimental purposes or applications that don't have any load variations on the shaft of the Motor.

Operation in Closed-loop Mode:



Operation in Open-loop Mode:



By Going from Openloop to Closed-loop modes once SOLO is ON, SOLO will run one time the Motor Identification process which will take less than a second, this is useful if you want to identify the Motor's parameters fully manually, however the Motor Identification can be done by sending commands through UART, USB or CANopen once needed.

- Once you are in Open-loop mode, the “P/F” input acts as Power input and it has a direct relation with the value of the voltage at this pin, the higher the voltage at P/F, the higher the power injected into the motor, the user has to make sure they increase this value slowly to make sure the current in the motor doesn’t exceed than required as the whole process is open-loop.

  The identified Motor parameters will remain in the long-term non-volatile memory of SOLO (NVM memory), and after power recycling they will be remembered, so no need to re-identify the motor every time you turn the system ON.

Section 7 - I/O Port

PIN	Name	Descriptions / Notes	I/O
1	GR	SOLO's Ground	-
2	M1	Motor Select-1 used in Analogue Mode for Motor type selection	I
3	GR	SOLO's Ground	-
4	M2	Motor Select-2 used in Analogue Mode for Motor type selection	I
5	GR	SOLO's Ground	-
6	FN	Speed / Torque Control Type selection used in Analogue Mode	I
7	GR	SOLO's Ground	-
8	DF	DFU Mode, Puts the device into Firmware Upgrade Mode	I
9	S/T	Speed or Torque reference used in Analogue Mode	I
10	5V	+5V/1A output for external modules	O
11	P/F	Power or Flux reference used in Analogue Mode	I
12	EA	Channel A of the Encoder or Hall position sensors	I
13	DIR	Direction of rotation of the motor used in Analogue Mode	I
14	EB	Channel B of the Encoder or Hall position sensors	I
15	RX	RX input of UART protocol for SOLO (Receiver)	I
16	EC	Index Input of the Encoder or Channel C of Hall position Sensors	I
17	TX	TX input of UART protocol for SOLO (Transmitter)	O
18	GR	SOLO's Ground	-
19	CH	CAN High Bus Output (ISO 11898)	-
20	CL	CAN Low Bus Output (ISO 11898)	-

Description

This port is the main section for accessing the I/Os on SOLO MINI_v2 and it serves the following functionalities:

1. Motor Type Selection in Analogue Mode (M1 and M2 Pins)

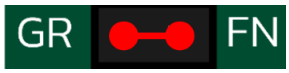
The Motor Type selection once SOLO is in Analogue command mode, done through M1 and M2 pins, they can accept 0V logic or they can be left open, it's also possible to apply +5V or +3.3V to these Pins instead of leaving them open in case you want to control the Motor Type selection externally by a module.
Across each of the M1 and M2 there is a Ground pin (GR), and they provide the possibility of placing a Jumper between M1 or M2 to the GR pins in front of them to apply 0V logic or leaving them open in case of having no external module to apply the voltages, the Motor Type selection based on the logic voltage applied to M1 and M2 is shown in table below, for that we take connection of M1 or M2 to the Ground (GR) as Logic Low and leaving these pins Open or connecting it to +5V or +3.3V as logic High.

M1 Pin Logic	M2 Pin Logic	Motor Name	Motor code	Default Switching Frequency	Max Speed with +5V at "S/T" in Closed-Loop	Speed / Position Controller Sampling Rate
High 	High 	Brushless (ultra-fast / Low inductance)	3	80kHz	30000/ASRDC RPM	**2kHz**
High 	Low 	AC Induction	2	20kHz	4000/ASRDC RPM	**2kHz**
Low 	High 	Brushless (normal)	1	20kHz	8000/ASRDC RPM	**2kHz**
Low 	Low 	DC brushed	0	20kHz	Nominal Speed of the motor	**2kHz**

- The **ASRDC** Coefficient defines the resolution of the speed reference at the analogue inputs, this coefficient is tunable using USB, UART or CANopen protocols and it has a default value of 1, to know more about it, please refer to USB, UART or CANopen manuals.
- By selecting each motor type, the switching frequency of SOLO at the output will be adapted to what has been mentioned in the table above. These are default values and you can overwrite them using Digital commanding like by USB, UART or CANopen, by setting them digitally to any value from 8kHz to 80kHz with incremental steps of 1kHz.
- As a rule of thumb for Low inductance motors you should select higher values for switching frequency at the output of SOLO, default 20kHz can be low for some types of motors mainly with phase inductance lower than 200µH, and in case you are using Brushless or PMSM motors, you can select the motor type number 3, which by default has 80kHz of switching at the output, you can also change these values to your desired value as mentioned above for any type of motor you select.

2. Speed / Torque Control Type selection in Analogue Mode (FN Pin)

The FN pin once it's connected to Logic High (left open or connected to +3.3V or +5V) defines that SOLO will operate in Analogue Torque mode, and once it's at logic Low (connected to the 0V or the GR pins in front of it) means SOLO will operate in Analogue Speed control mode.

FN Pin Logic	Operation
High 	SOLO will operate in **Torque mode** once in Analogue Commanding mode
Low 	SOLO will operate in **Speed mode** once in Analogue Commanding mode

3. Speed or Torque reference used in Analogue Control Mode (S/T Pin)

This is the input for controlling Speed or Torque of the Motor connected to SOLO depending on the selected Mode (Torque or Speed on FN pin) and the Position of the Control Mode switch shown in section 6 (Closed-loop or Open-loop Operation), the Analogue voltage or the duty cycle of PWM pulse applied at this input in either of the conditions will be treated as a desired reference of the user based on following situations:

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, without having a current limit, SOLO will try to inject 32A of current inside 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"** and the same for 3 phase motors (BLDC , PMSM or ACIM) is shown by **"Iq"** or namely the "Quadrature current".

<table>
<tr><td></td><td>So the amount of active current in torque generation injected to your motor based on the amount of voltage or duty cycle you apply 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) * 32.0
In case of using Analogue Voltages:
The torque generation Current = ((5.0 - the voltage at S/T input)/5.0) * 32.0</td></tr>
<tr><td>In Closed_loop Speed mode:</td><td>if you apply an Analogue 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 as below, of course your motor should be able to reach to that speed, otherwise it will stay at its nominal speed even if you keep increasing the duty cycle.
<table>
<tr><th>Motor code</th><th>Motor Name</th><th>Maximum Speed in Closed-loop mode</th></tr>
<tr><td>0</td><td>DC brushed</td><td>Depends on BEMF constant of the Motor, but it will go to nominal speed at 5V or 100% input duty-cycle</td></tr>
<tr><td>1</td><td>Normal Brushless Motors (BLDC, PMSM)</td><td>8000RPM/ASRDC at 5V or 100% PWM input duty-cycle</td></tr>
<tr><td>2</td><td>AC Induction Motors (ACIM)</td><td>4000RPM/ASRDC at 5V or 100% input duty-cycle</td></tr>
<tr><td>3</td><td>Ultra Fast Brushless Motors (BLDC, PMSM)</td><td>30000 RPM/ASRDC at 5V or 100% PWM input duty-cycle</td></tr>
</table></td></tr>
</table>

	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; If you don't change this value SOLO will still function but you might need to tune this value if you need the best performance in speed tracking and estimation in sensorless and sensor-based modes.

4. Power or Flux reference used in Analogue Mode (P/F Pin)

This is a pin can be either used as a “Power” input once in Open-loop mode or as a general-purpose Analogue input.

Mode of Operation	Functionality
The open-loop mode of 3-phase motors	It will act as increasing or decreasing the injected power into the Motor, so by applying 0V of Analogue voltage or 0% duty cycle of PWM, there will be no power injected inside the Motor, and at 5V or 100% duty cycle of PWM, it will apply the maximum deliverable power into the Motor.

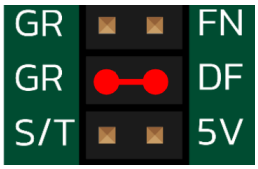
5. Direction of rotation of the motor used in Analogue Control Mode (DIR Pin)

This is the Direction control pin once SOLO operates in Analogue Command Mode, accepting voltage levels of 0V(logic Low) or 3.3V and 5V(Logic High), so by giving each of these values, the connected Motor to SOLO, will either rotate in C.W. direction or C.C.W. direction.

6. DFU Mode selection for upgrading the firmware (DF Pin)

This pin should never be at logic Low, except the moments you want to upgrade the firmware of SOLO, in that case, you need to do the following:

a. Turn OFF SOLO
b. Put the DF pin at logic Low (put a jumper between DF and GR pin in front of it)



c. Turn ON SOLO
d. Upgrade the Firmware
e. Put back the DF pin in Logic High (leave it Open)

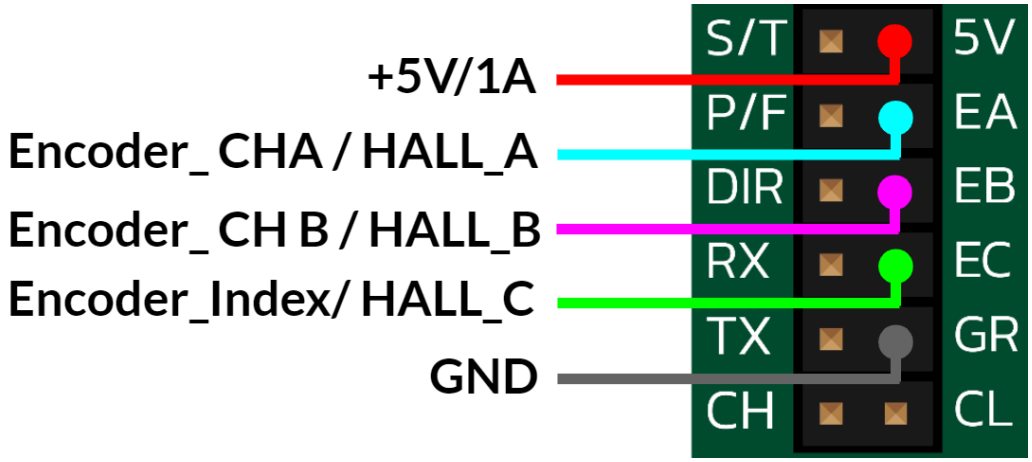
f. Turn OFF / Turn ON SOLO (recycle the Power with 5 seconds of delay in between)

7. **+5V/1A output (5V Pin)**

This is a +5V/1A output to supply external peripherals or controllers, notice that draining more than 1A from this pin is not allowed and it can damage the supply control part of the circuit.

8. **Incremental Encoder or Hall sensors input (EA, EB and EC Pins)**

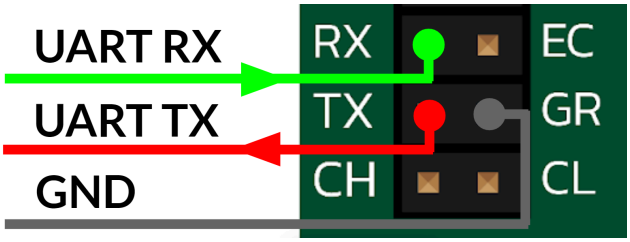
Through EA, EB and EC pins Quadrature Encoders or Hall sensors can be interfaced with SOLO MINI_v2, there is also a +5V/1A supply for external usages and powering up the sensors. The digital inputs are internally pulled up to +5V with 1kΩ resistance to provide 5mA current for open drain/collector configurations.



- The use of an Index pulse for 3-phase Motors is mandatory as it's required for 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 MINI_v2 please visit this page on our website.
- To learn about how to Setup and calibrate your HALL sensors for SOLO MINI_v2 please visit this page on our website.

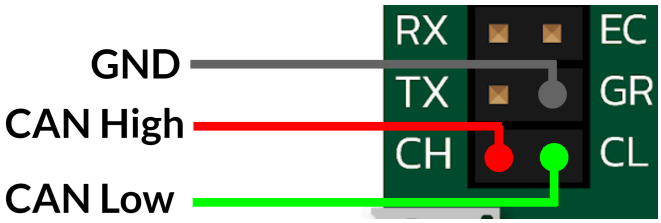
9. **UART TX and UART RX pins (TX and RX Pins)**

The UART RX and TX pins are accessible tthrough RX and TX pins on the I/O connector, the RX pin is only an Input and the TX is only output, the RX and TX pins are +5V tolerant,and they can be fed both by signals leveled at +3.3V or +5V.



10. CAN High (CH) and CAN Low (CL) pins for CANopen (CH and CL Pins)

Through CH (CAN Hight) and CL (CAN Low) pins on the I/O port, you can have access to CANbus on SOLO MINI_v2 and communicate with it using the CANopen protocol, it worth mentioning that the CAN High and CAN Low connections can be accessed through Communication Port too.

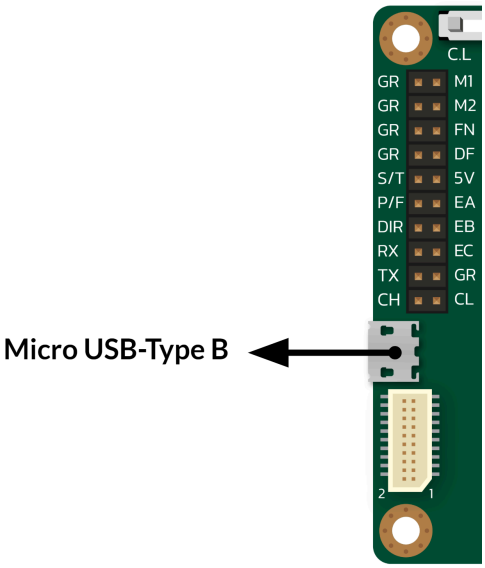


Section 8 - USB Connection

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

Description

This is the micro_USB 2 connector of SOLO 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 standalone fashion with only 1 USB cable and the Motor connected at the output. You can download the latest drivers for this part from our website.

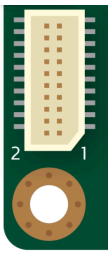


Section 9 - Communication Port

PIN	Name	Descriptions / Notes	I/O
1	+3.3V / 100mA	+3.3V external supply	O
2	+5V/500mA	+5V external supply	O
3	GND	SOLO's Ground	-
4	GND	SOLO's Ground	-
5	+5V/500mA	+5V external supply	O
7	GND	SOLO's Ground	-
9	CANL	CAN Low Bus Output (ISO 11898)	-
11	CANH	CAN High Bus Output (ISO 11898)	-
13	CAN_RX	CAN protocol receiver input	I
15	CAN_TX	CAN protocol transmitter output	O
17	UART_TX	UART protocol transmitter output	O
19	UART_RX	UART protocol transmitter input	I
20	GND	SOLO's Ground	-

Description

This is the port that gives you access to UART and CAN communication pins in order to send/receive fully digital commands in the form of data packets.

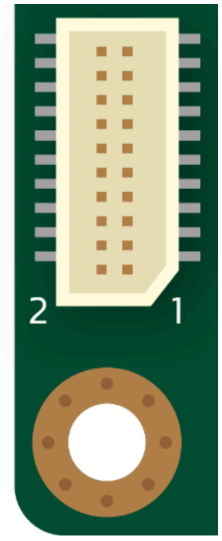


CAN_TX and CAN_RX are not useful for CANbus or CANopen networks as they come out of the DSP directly without any CAN transceiver in between, to use **CANbus for CANopen networks the user must use the CANH and CANL pins** provided in Section 13 below.

The communication port provides you with two supply voltages of 3.3V and 5V with the main Ground (reference) of SOLO, so you can use them to feed external modules with the mentioned current limit.

Communication Port

PIN NO#	FUNCTION
1	+3.3V (100mA)
2 , 5	+5V (500mA)
3, 4, 20,7	GND
9	CANL
11	CANH
13	CAN_RX
15	CAN_TX
17	UART_TX
19	UART_RX

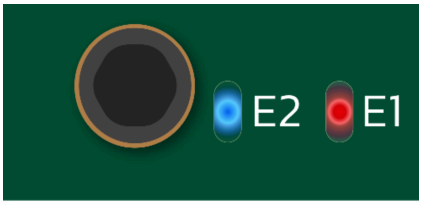


Section 10 and 11 - Functionality LEDs

section	Name	Descriptions / Notes	I/O
10	E2	Normal Activity LED	-
11	E1	Error Indicator LED	-

Description

There are two LEDs on the bottom right side of SOLO, which are named as “E1” and “E2” and each of them has functionality as below:



- **E2 :** This is the status LED indicator, after the device startup, in case of having a safe boot up with no errors like over-current, over voltage etc., it will start blinking and remains in the blinking state as long as no error occurred.

- **E1:** This is the Error indicator, and in case of an error it will start blinking.

Connectors and their Matings Part Number:

Section	Manufacturer	Mating Part Number
[7]	Sullins Connector Solutions / Amphenol ICC (FCI)	PPPC102LFBN-RC / 71600-020LF
[9]	JST Sales America Inc.	SHDR-20V-S-B

Analogue versus Digital Control in SOLO MINI_v2

By the notion of "Analogue" in SOLO we mean any interface that can be done using Analogue voltages or mechanically at the hardware level to SOLO, for instance in SOLO MINI_v2 you can do the following actions completely at the hardware level:

1. Set the Speed or Torque Reference through "S/T" input
2. Magnetizing current through "P/F" input
3. Tune the Speed controller Kp and Ki gains through two potentiometers mechanically
4. Set the Motor type through M1 and M2 pins (4 types)
5. Set the Control Mode of Torque or Speed through the FN pin
6. Set the Open-loop or Closed-loop type of control through the Control Mode Switch
7. Put SOLO into DFU mode through DF pin

So for SOLO, once you are in "Analogue Mode", these settings have the highest priority over all the settings of the same nature in Digital mode, for example, if you are in Analogue Mode, you can only select the motor type from the I/O port by using M1 and M2 pins, and if you set it using Motion Terminal or you send the data packet through UART, USB or CANOpen it will not change the Motor type unless you go to "Digital Mode" before.
The main reason that "Analogue Mode" exists on SOLO is to eliminate the need for the users to set a special parameter through software and to minimize the interfacing effort to SOLO for simple applications.
However, there are tons of settings that you can't do at the hardware Level, like setting the motor numbers of poles for 3-phase motors, or setting the output switching frequency, … so for all of these parameters, regardless of what mode you are in (Analogue or digital) you can only set them digitally using Motion Terminal or with UART, USB and CANopen commands.

So if you go from "Analogue Mode" to "Digital Mode", again for most of the Mentioned functionalities listed above you need to set them digitally like Motor type, speed or torque references and so on.

The only two functionalities that can be done only at Hardware level on SOLO MINI_v2 are "Closed-loop" or "Open-loop" selection using the Control Mode Switch as well as putting SOLO into DFU mode using the I/O port, this means you need to do this setup at hardware level regardless of the fact that you are in "Analogue Mode" or "Digital Mode".

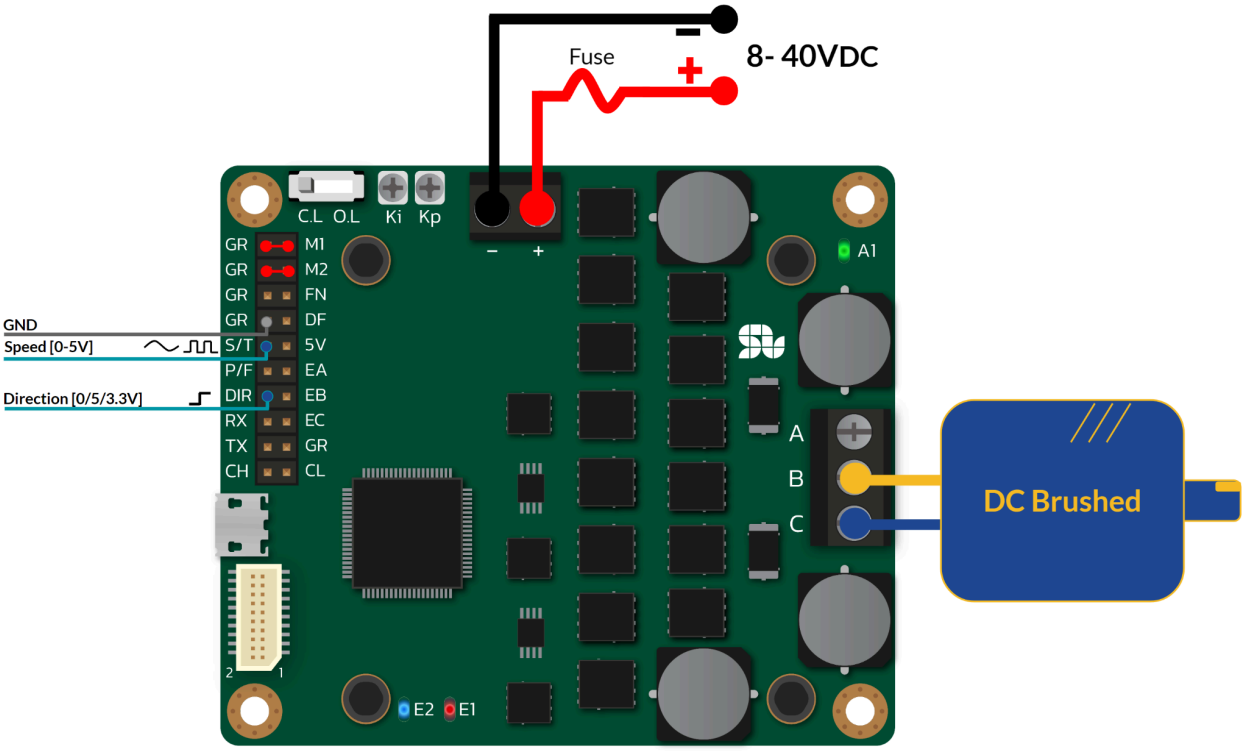
Minimum Required Wirings in Analogue Mode:

The minimum required wirings to run SOLO in Analogue control mode, by applying Analogue or PWM voltages depending on the type of the electrical motors connected are shown later in this chapter.

Wiring Legend:

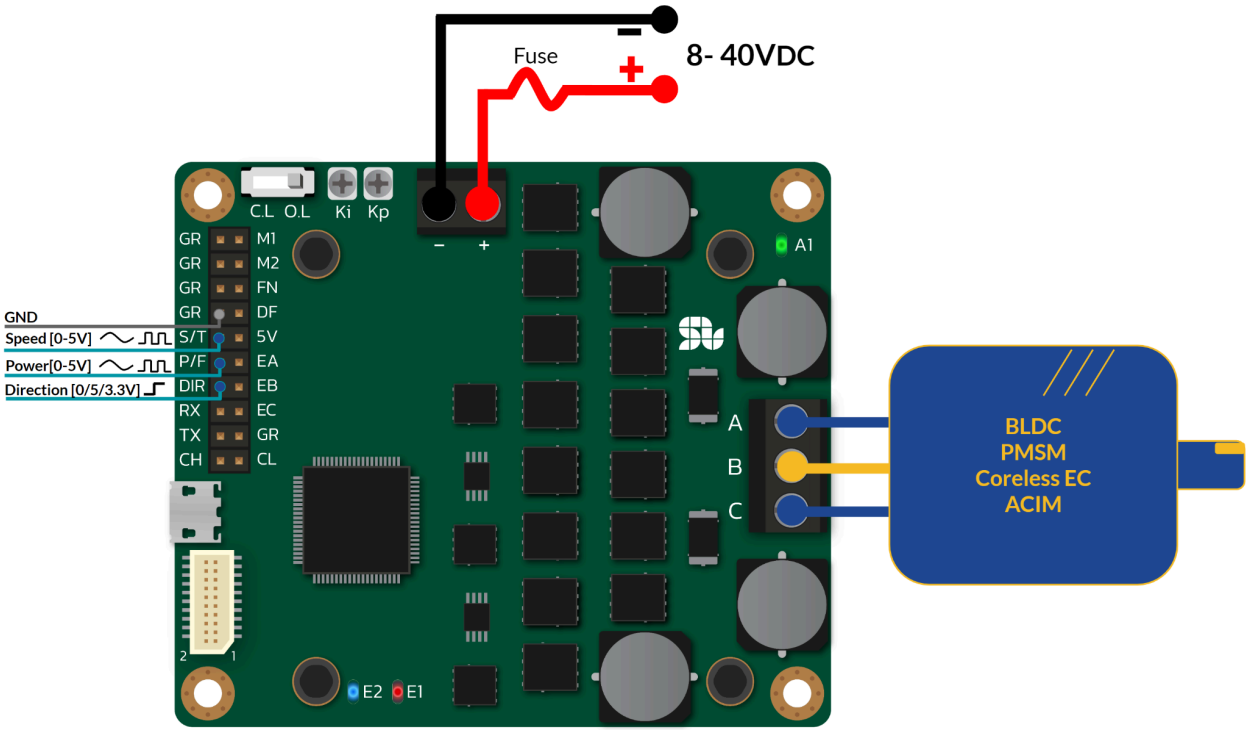
Shape	Description
	Input Positive of the DC supply
	Input Negative or Return of the DC supply
	Fuse, the value can be selected based on the system requirements
	Line carrying pulses with PWM (fixed frequency above 5kHz)
	Line carrying Pure Analogue voltage
	Line carrying ON / OFF type of signals (low frequency)
	Line with signal inputting to the circuit
	Line with signal outputting from the circuit

BLDC, PMSM Motors _ Sensorless Closed-loop Mode:



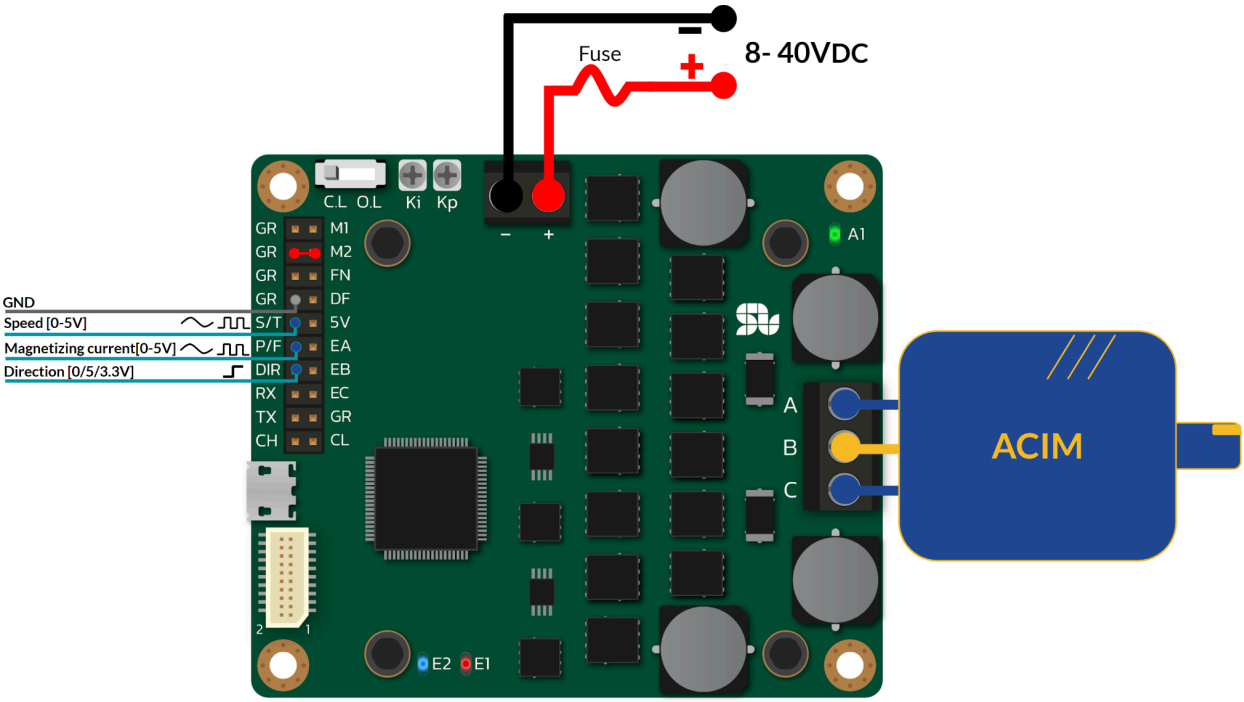
- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L as also shown in the image above.
- In sensorless closed-loop mode, the order of the connection of Motor wires to A, B, C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.
- To select the Motor Type in Analogue mode, the Pins M1 and M2 should be used as explained in the I/O port section.

BLDC, PMSM or ACIM Motors _ Sensorless Open-loop Mode:



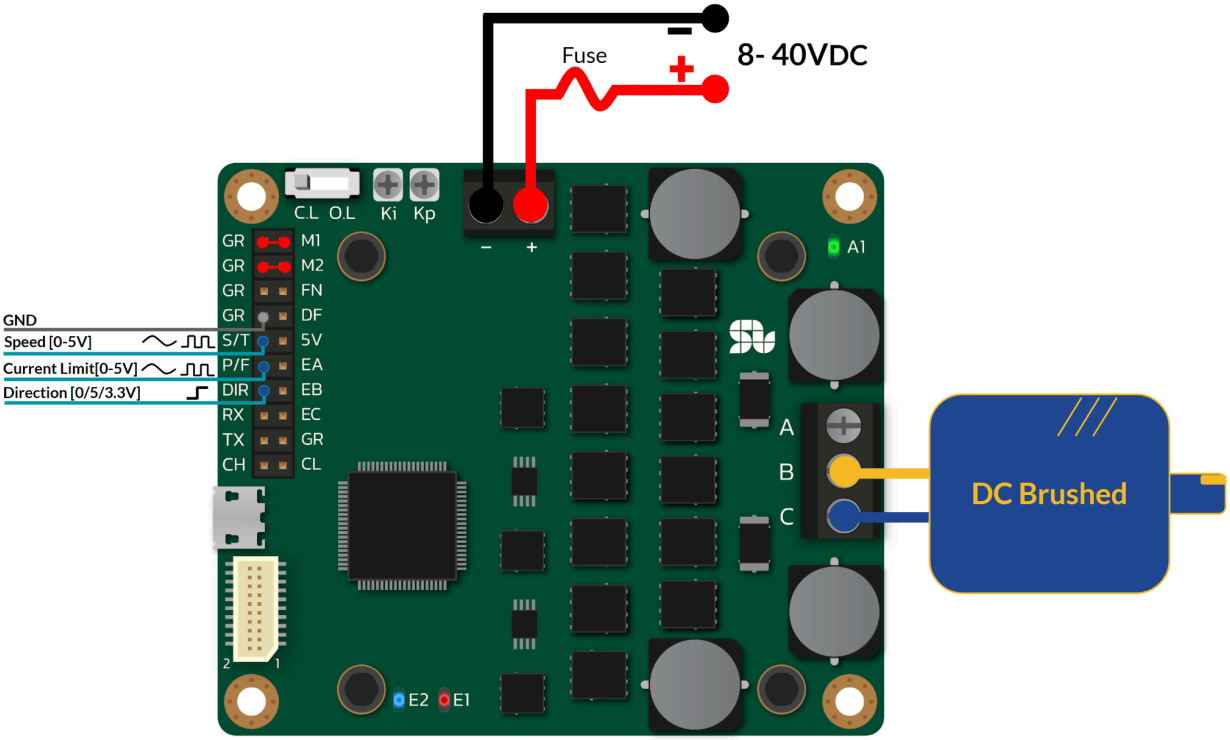
- To put SOLO in Open-loop Mode, the Control Mode Switch should be on O.L as also shown in the image above.
- In sensorless Open-loop mode, the order of the connection of Motor wires to A, B, C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.
- To select the Motor Type in Analogue mode, the Pins M1 and M2 should be used as explained in the I/O port section.

AC Induction Motors_ Closed_loop Sensorless Mode:



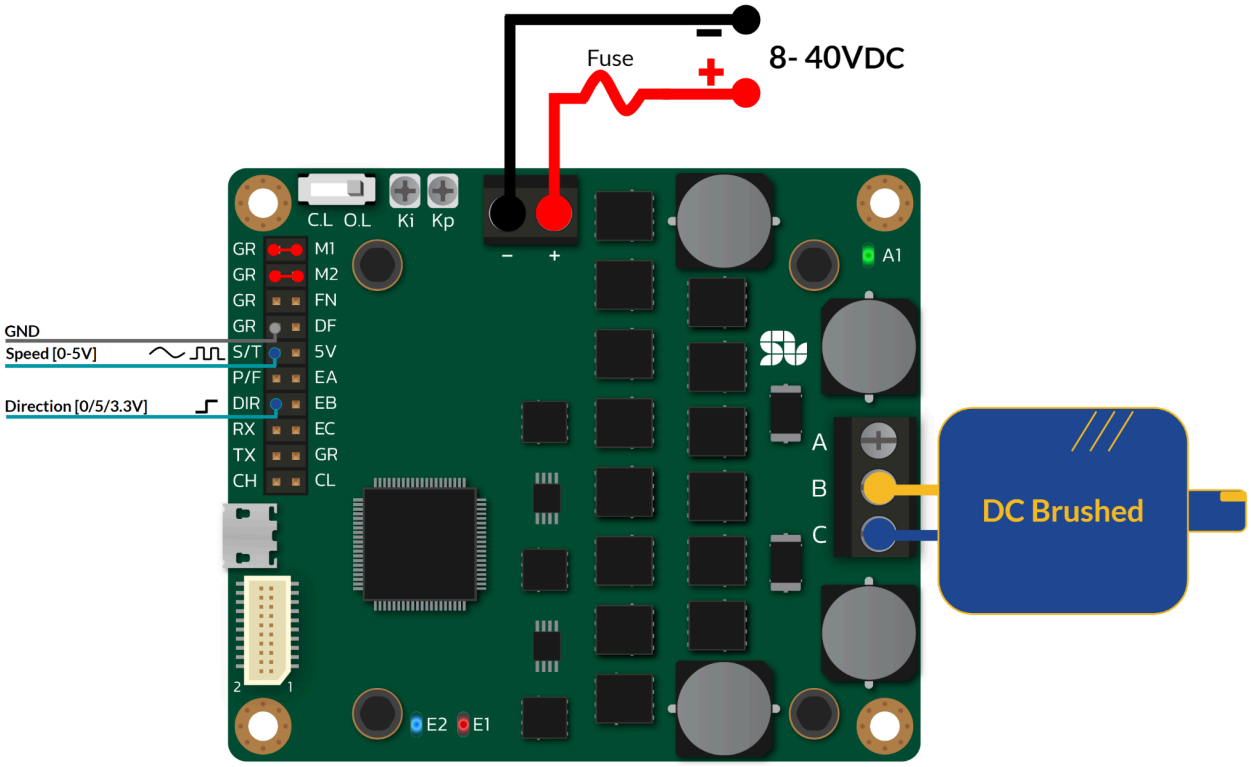
- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L. as also shown in the image above.
- In sensorless closed-loop mode, the order of the connection of Motor wires to A, B, and C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.
- To select the Motor Type in Analogue mode, the Pins M1 and M2 should be used as explained in the I/O port section.

DC brushed Motors_ Closed-loop Sensorless Mode:



- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L. as also shown in the image above.
- In sensorless closed-loop mode, the order of the connection of Motor wires to B and C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.
- To select the Motor Type in Analogue mode, the Pins M1 and M2 should be used as explained in the I/O port section.

DC brushed Motors_ Open-loop Sensorless Mode:



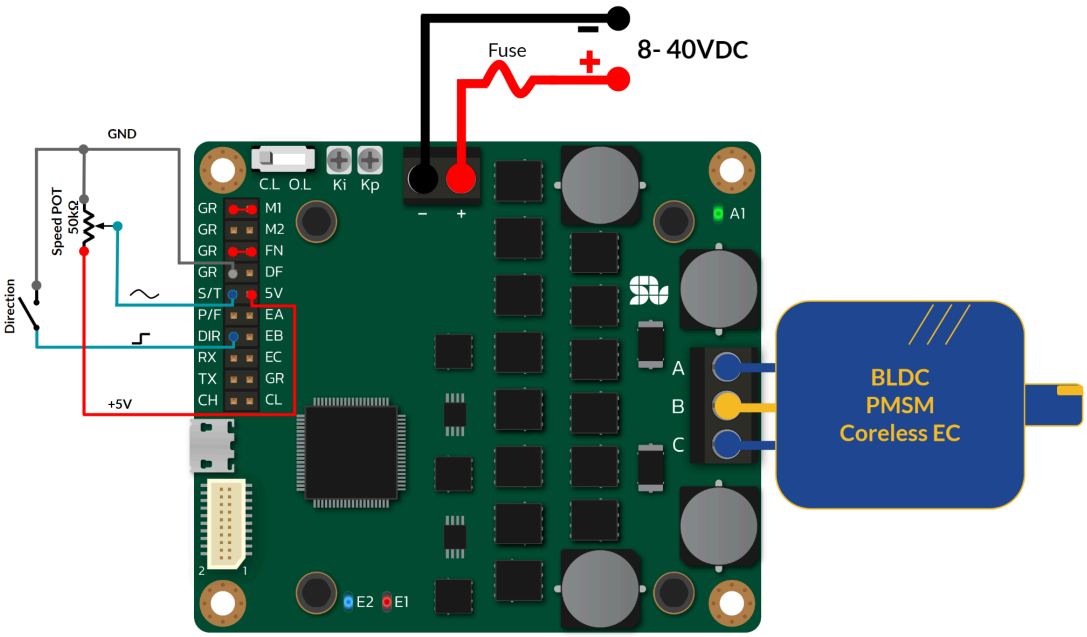
- To put SOLO in Open-loop Mode, the Control Mode Switch should be on O.L as also shown in the image above.
- In sensorless Open-loop mode, the order of the connection of Motor wires to B and C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.
- To select the Motor Type in Analogue mode, the Pins M1 and M2 should be used as explained in the I/O port section.

Standalone Wiring Example (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 this example, you can see the wiring of a Normal Brushless Motor in Sensorless Closed-Loop Mode using only one potentiometer. Please Note that:

- The "DIR" pin in SOLO UNO_v2 is +5V tolerant, you can also apply +3.3V on this pin.
- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L
- The Motor type selected in this example is Normal Brushless-PMSM on M1 and M2 (check here)
- To set the Current Limit during the operation you can use Motion Terminal.

- In the case of using Potentiometers or resistors, the user has to make sure the minimum resistance of the Potentiometer at any position is not below 1kOhm (residual resistance), applying lower resistance at the input might cause damage to the internal circuitry.

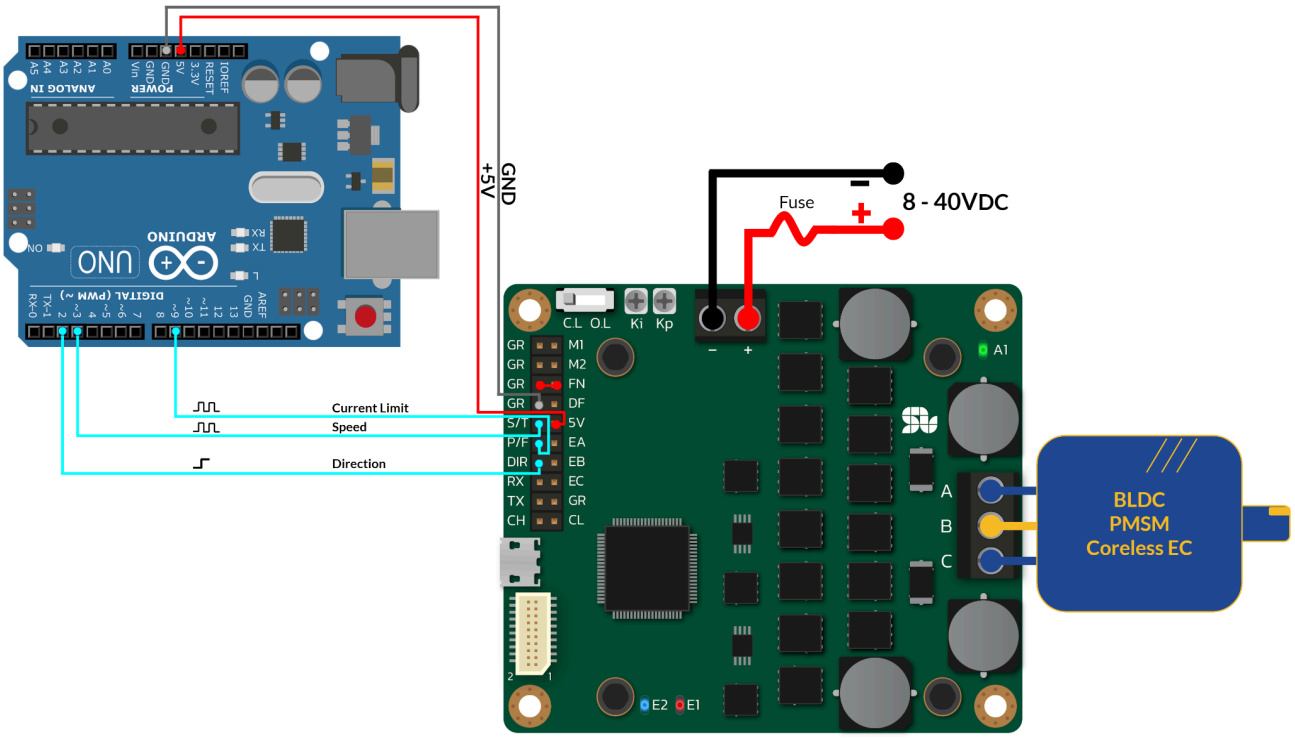


Essential Wiring Example (SOLO MINI_v2 + Arduino UNO)

Here is an example of wiring SOLO with an Arduino UNO, as can be seen:

- Arduino has been directly powered up by SOLO, depending on the Arduino models, the user can commit the USB of the Arduino at the same time, the most important point in power connection is to make sure the GND pin of SOLO has been connected to the GND of your Arduino or other modules at least in a single point.

- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L.
- The Motor type selected in this example is Normal Brushless-PMSM on M1 and M2 (check it here)

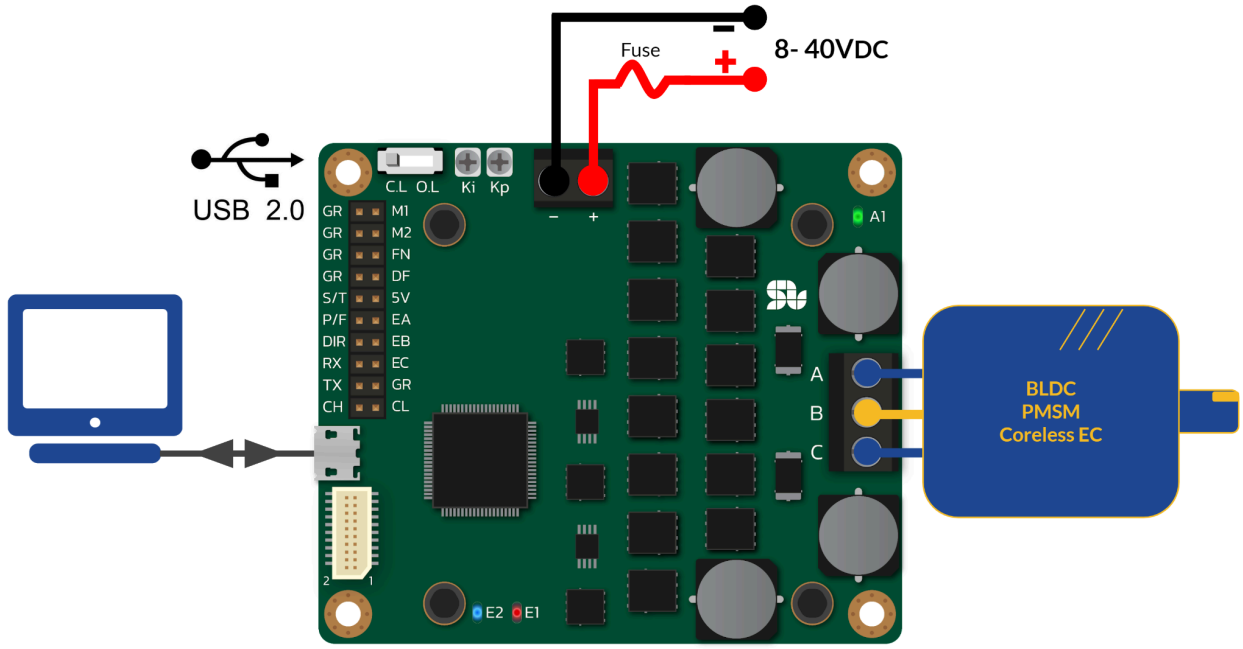


Minimum Required Wirings in Digital Mode:

All of the functionalities of SOLO MINI_v2 can be controlled fully digitally by sending data packets through UART, USB or CAN bus with the CANopen software layer, below there are three main examples of possible wirings of SOLO in Digital Mode for Brushless Motors (the same pattern of wiring applies for other types of motors)

USB Interface Wiring

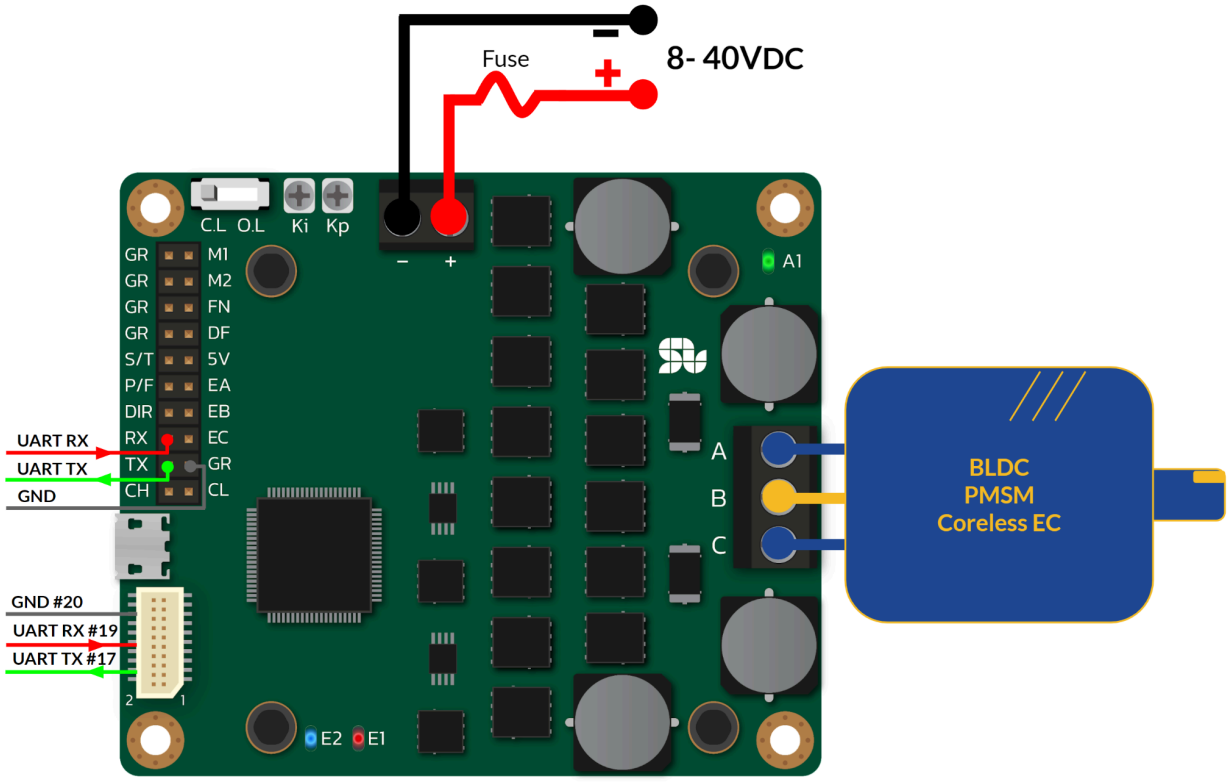
By using the USB connection, you have access to the simplest form of wiring of SOLO to be commanded using only the USB cable thanks to the digital control that it offers, in this mode the only thing you will need is a Micro USB cable that makes SOLO able to communicate with a local PC or controller through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



- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L and subsequently for SOLO to operate in Open-loop Mode the Control Mode Switch must be on O.L, regardless of being in Analogue or Digital Command Mode.

UART Interface Wiring

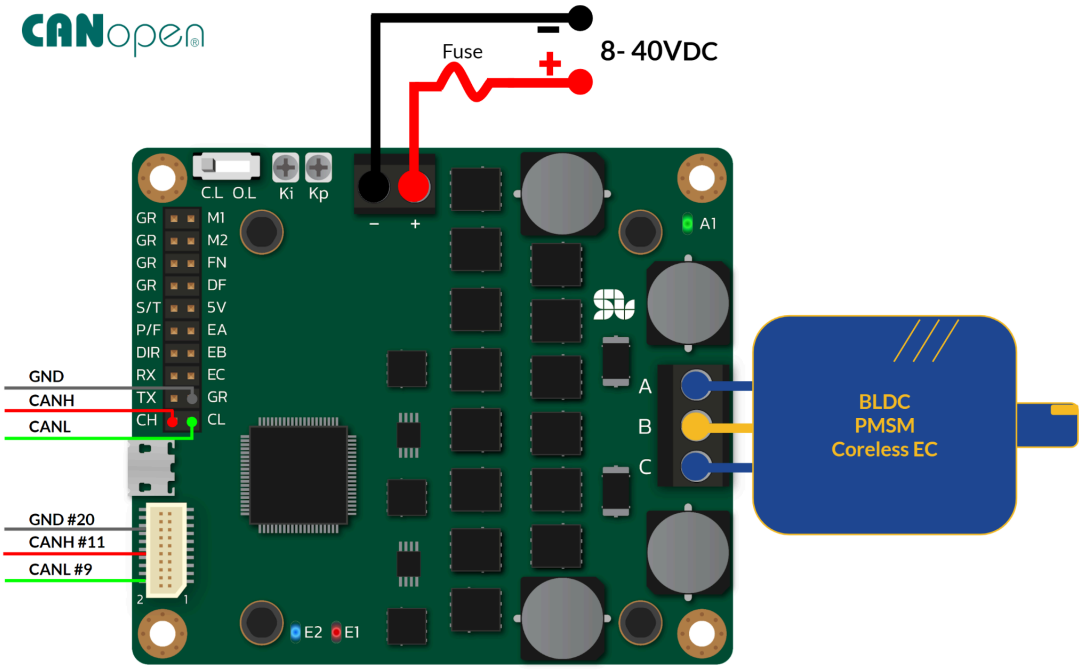
The UART line of SOLO is accessible both through the "I/O Port" or through the "Communication Port", in SOLO MINI_v2 models the UART_RX and UART_TX lines are +5V tolerant and they can be fed both by signals levelled at +3.3V or +5V.



- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L and subsequently for SOLO to operate in Open-loop Mode the Control Mode Switch must be on O.L, regardless of being in Analogue or Digital Command Mode.

CANopen Interface Wiring

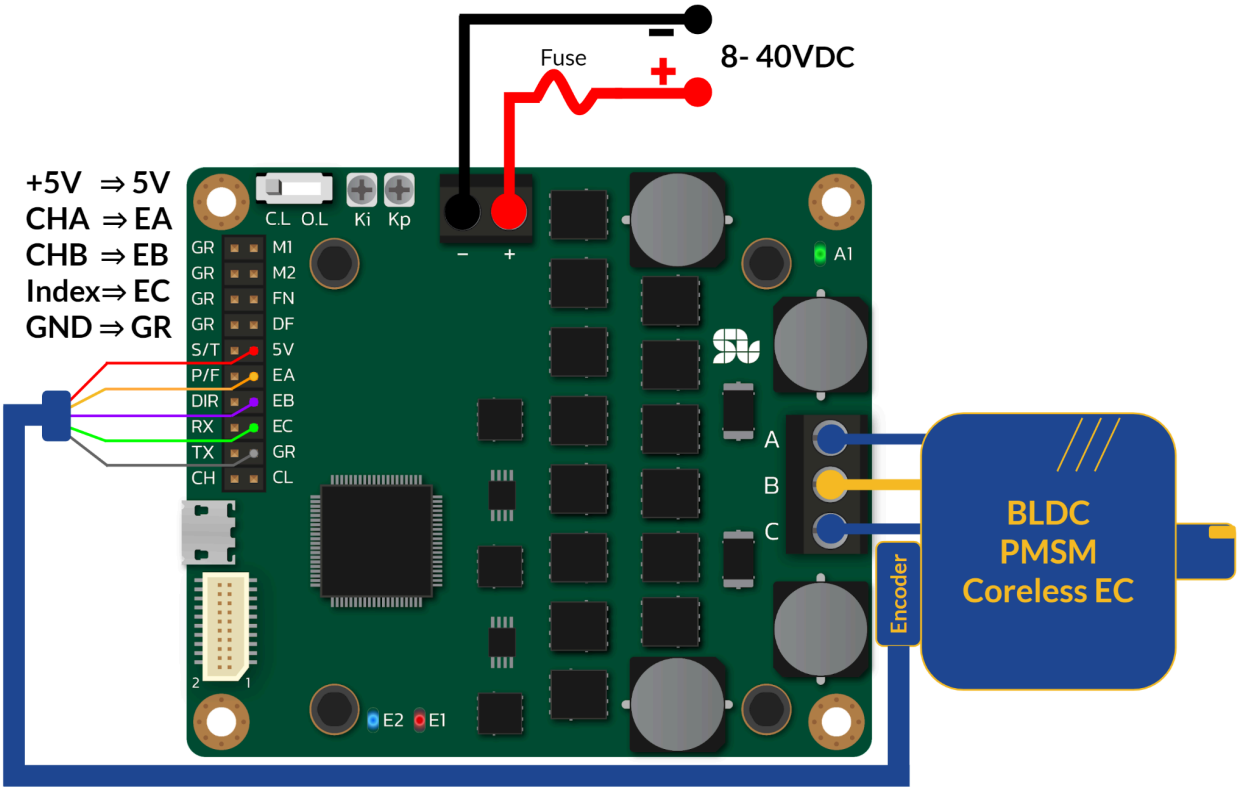
SOLO MINI_v2 can be commanded in a CAN network by the CANopen standard, using CANopen all of the functionalities of SOLO can be controlled digitally using data packets sent within the CAN bus. To know more please refer to the SOLO MINI_v2 CANopen User Manual here. CANopen can be accessed both through the "I/O port" or the "Communication Port" using CANH and CANL pins that are also shown with CH and CL on the I/O port.



- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L and subsequently for SOLO to operate in Open-loop Mode the Control Mode Switch must be on O.L, regardless of being in Analogue or Digital Command Mode.
- CAN_TX and CAN_RX pins are CAN outputs coming right off the DSP and they are only +3.3V levelled signals with no CAN Transceiver on the path, they are brought out just for special use, these pins **should not be used instead of CANH and CANL pins**, by doing so the damage to the DSP is imminent.

Wiring with Incremental Encoders:

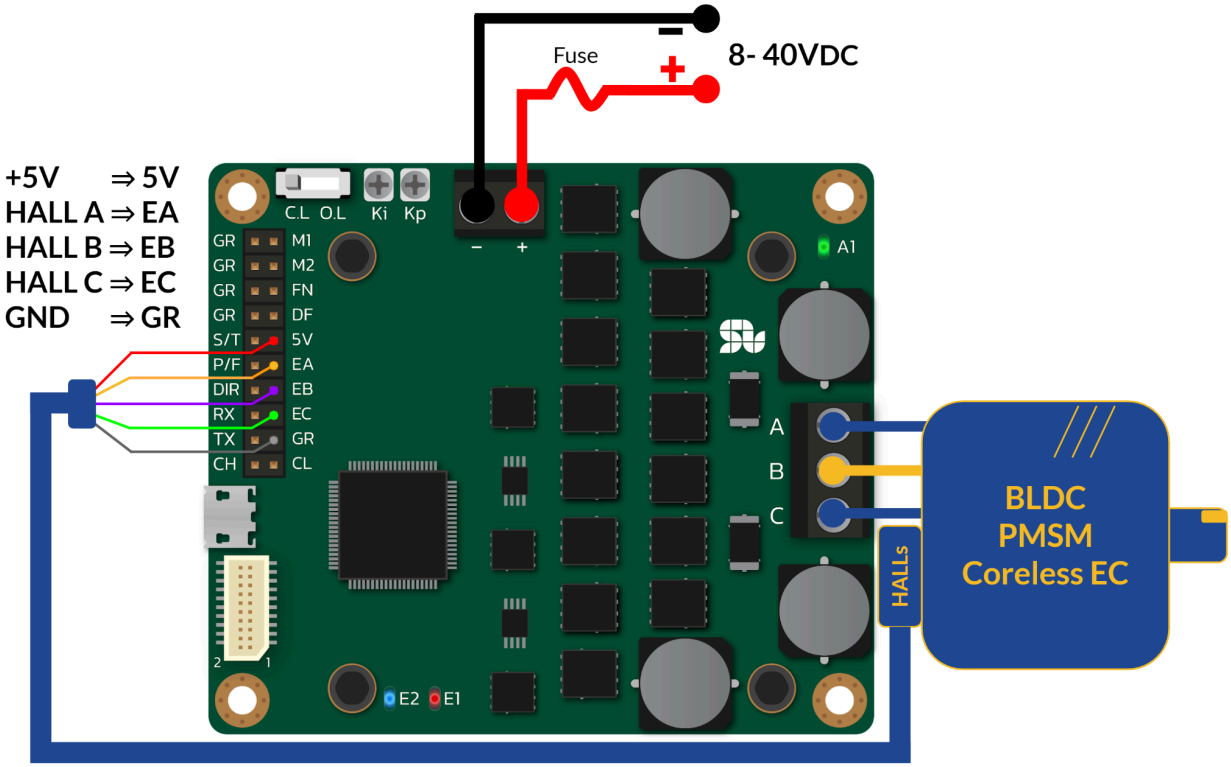
By using Incremental Encoders you can turn SOLO into a servo drive controlling the Torque, Speed and Position of your Motor, once using Incremental Encoders you need to make sure you apply the correct setup followed by one-time calibration of the system, to learn about the process please visit [this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



- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L and subsequently for SOLO to operate in Open-loop Mode the Control Mode Switch must be on O.L, regardless of being in Analogue or Digital Command Mode.

Wiring with HALL Sensors:

Using HALL sensors mounted on BLDC or PMSM motors, you can increase the accuracy of Speed and Torque control. 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.



- To put SOLO in Closed-loop Mode, the Control Mode Switch should be on C.L and subsequently for SOLO to operate in Open-loop Mode the Control Mode Switch must be on O.L, regardless of being in Analogue or Digital Command Mode.