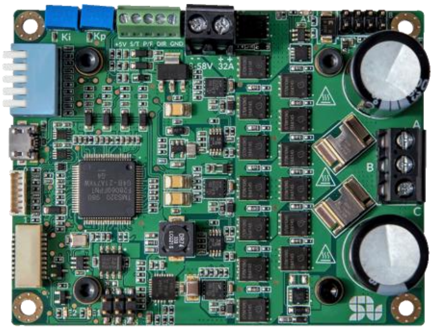
SOLO UNO_v2 User Manual
Part Number: SLU0722_5832

Product Description

SOLO UNO_v2 with part number of SLU0722_5832 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 plus other options like full digital and analog controls and active safety measures to keep the applications safe from unforeseen behaviors.

Power Range

Supply Voltage Range : 8- 58 VDC
Peak Current: 100A
Continuous Current: 32A



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 Sensor-less control
- Four Quadrant Regenerative operation
- Automatic parameter Identification and self-tuning
- Field Oriented 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 Brake Chopper circuitry
- Full Digital and Analogue Control

Modes of Operation

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

Commands and feedbacks Source

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

Applications

- Industrial Automations
- Robotics and Traction Units
- Drones

Revision History:

Revision	Date	Changes	Firmware version
V1.0.6	10/02/2021	- First Release	0x000B006
V1.0.7	15/04/2021	- Updating the document for Firmware version 0x000B007 - Introduction of Dual core - Sensor connection and calibration enhanced - The performance of the system updated	0x000B007
V1.0.8	06/09/2021	- Updating the document for Firmware version 0x000B009 - Introduction of new graphics for wiring - Introduction of CANopen wirings	0x000B009
V1.0.9	15/05/2022	- SOLO UNO_v2 updates added -	0x00BB00A

Table of Contents

Power Specifications:

Description	Units	Values
DC Supply Voltage Range (continuous)	**VDC**	**8 to 58**
DC Bus Overvoltage Limit	**VDC**	**60**
DC Bus Undervoltage Limit	**VDC**	**8**
Maximum Peak Output Current	**A**	**100**
Maximum Continuous Output Current	**A**	**32**
Maximum Continuous Output Power	**W**	**800**
Maximum Peak Output Power	**W**	**1500**
Internal Bus Capacitance	**µF**	**2000**
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 - 3.3/5V
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)

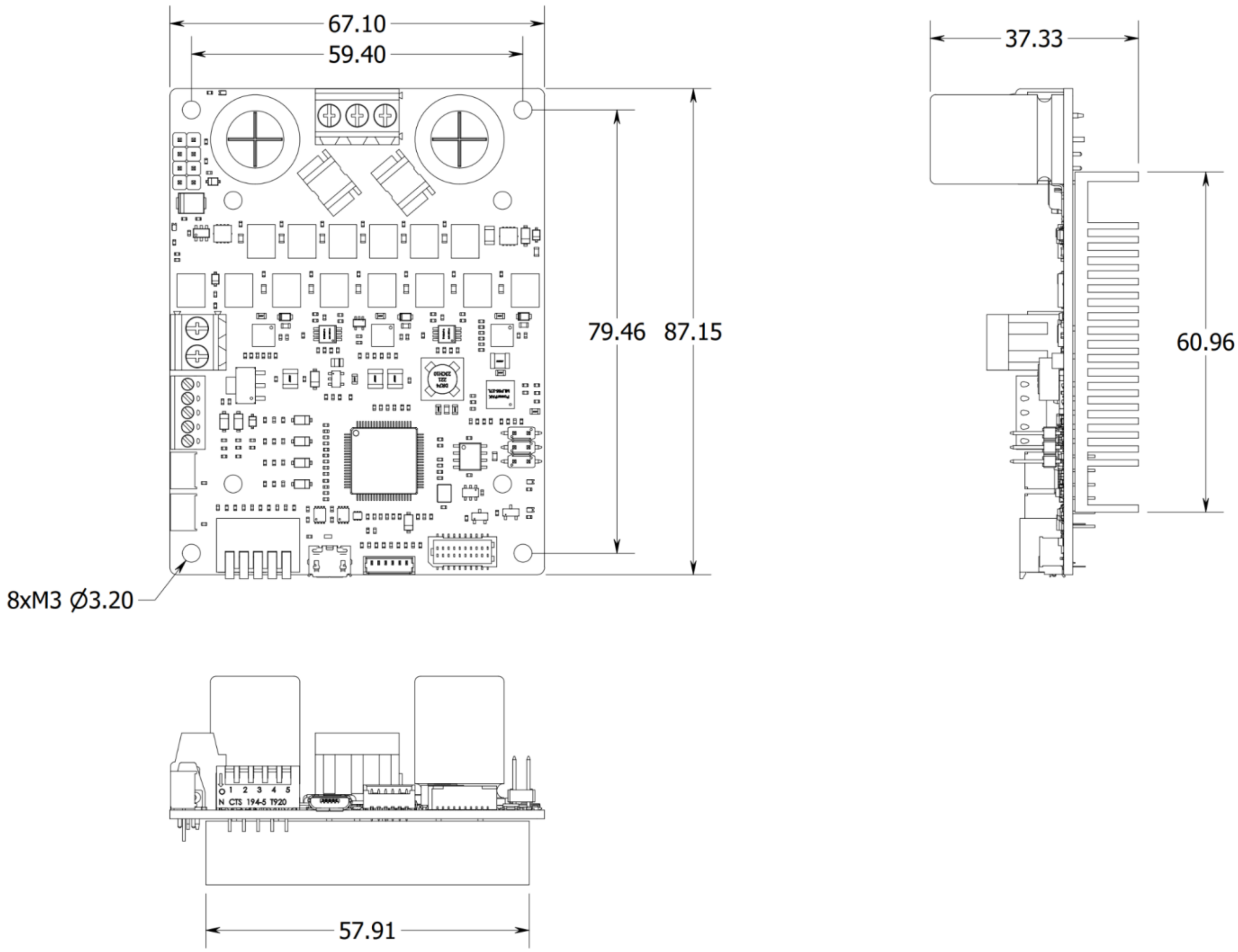
Thermal Specifications:

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

Mechanical Specifications:

Description	Units	Values
Size (H x W x D)	**mm**	37.17 x 87.15 x 67.10
Weight (with heatsink)	**gr**	99
Form Factor	**-**	Wall Mount

Mechanical Dimensions:



- All the measurements are in millimeters.
- Download the 3D step model from [here].

Absolute Maximum Voltage Ratings:

- All The sections are referred to **Figure 3** 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**	+8	+58	+63
3	**S/T** (speed/torque)	**Input**	**VDC**	0	+5.0	+5.5
3	**P/F** (current limit/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	+3.56
13	**CANH**	-	**VDC**	-2	-	+7
13	**CANL**	-	**VDC**	-2	-	+7

Overview of the product

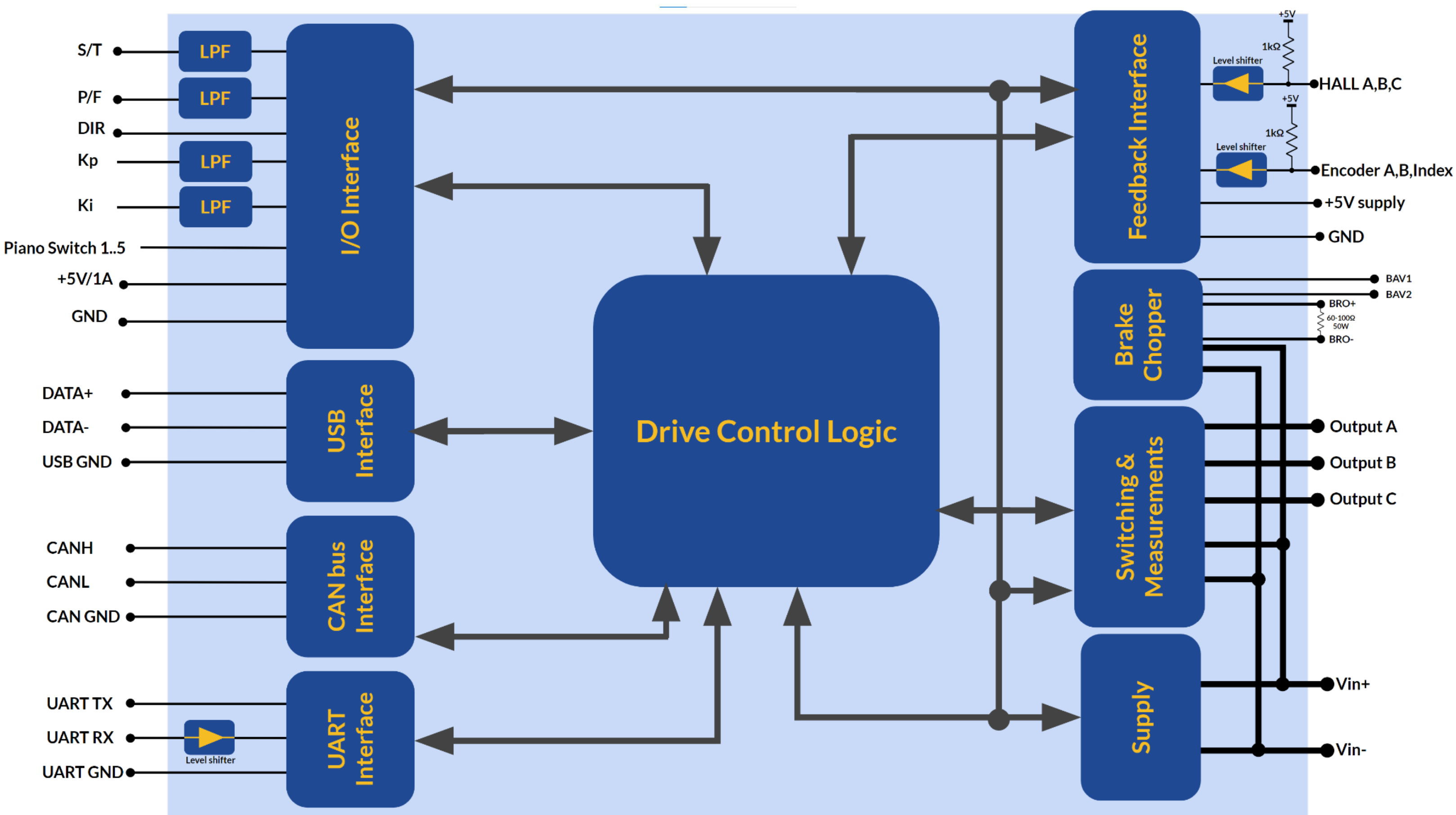
SOLO UNO_v2 is the latest version of SOLO UNO controllers with enhanced performance and some extra features compared to previous versions, it serves the purpose of being universal and easy to use for a wide range of users from different backgrounds. This product is designed to support various types of electrical motors like DC brushed, Brushless DC, Brushless AC or Permanent Magnet Synchronous Motors as well as AC Induction motors up to 58V with the supply voltage and the continuous current of up to 32 Amps, this will enable SOLO UNO_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 UNO_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 UNO_v2 are listed as below:

- Wide input voltage supply range from 8V to 58V
- The continuous output current of 32A, Max Current of 100A
- Capable of controlling DC, BLDC, PMSM and ACIM motors
- Dual Core with parallel processing architecture
- CANopen, USB and UART Communications
- Active Brake chopper circuitry with selectable activation voltage
- 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
- Advance 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 behavior

- 2000µF onboard BUS capacitance

Functional Block Diagram:



Theory of Operation:

SOLO UNO_v2 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, PMSM and AC Induction motors this topology is known as Field Oriented Control or Vector Control, it worth mentioning that SOLO UNO_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 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 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 at the moment 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 UNO_v2 for 3-phase Motors:

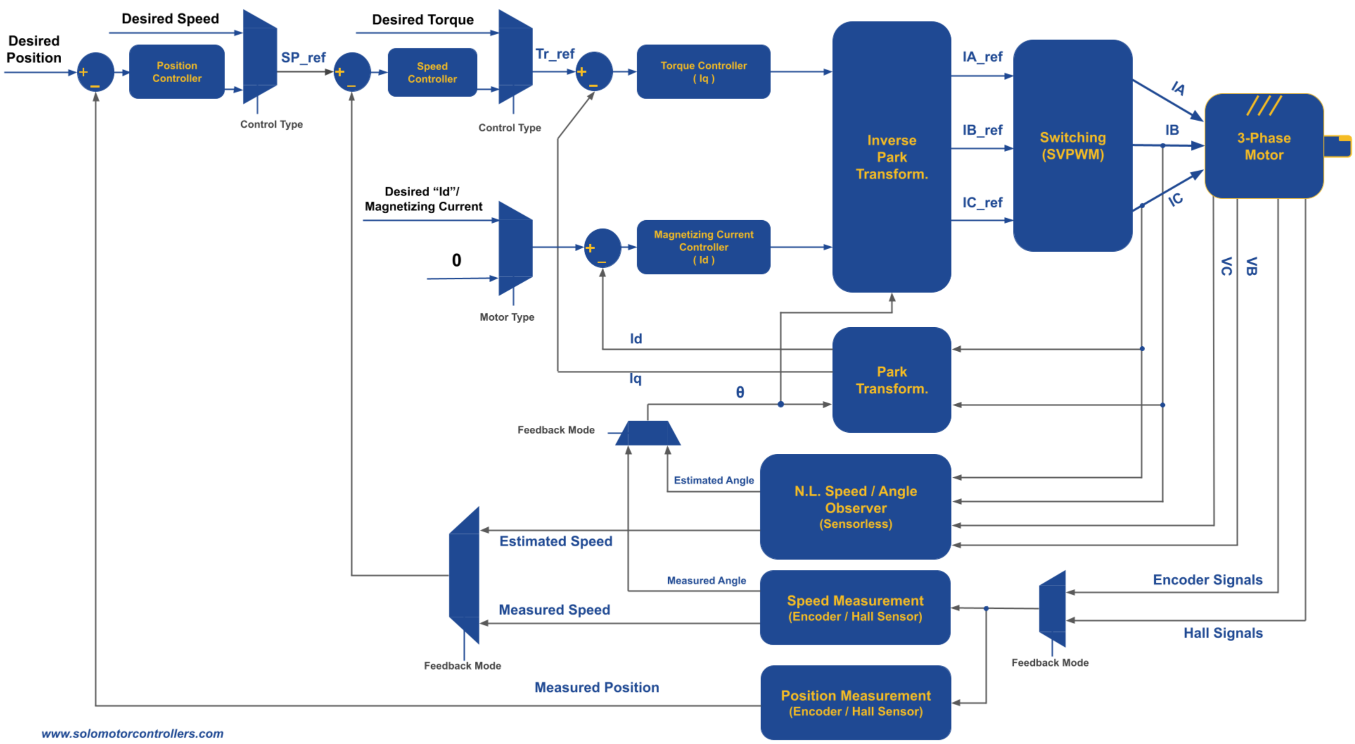


Figure 1 - FOC Control Architecture of SOLO UNO_v2 for 3-phase Motors

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 UNO_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 UNO_v2 for DC Motors:

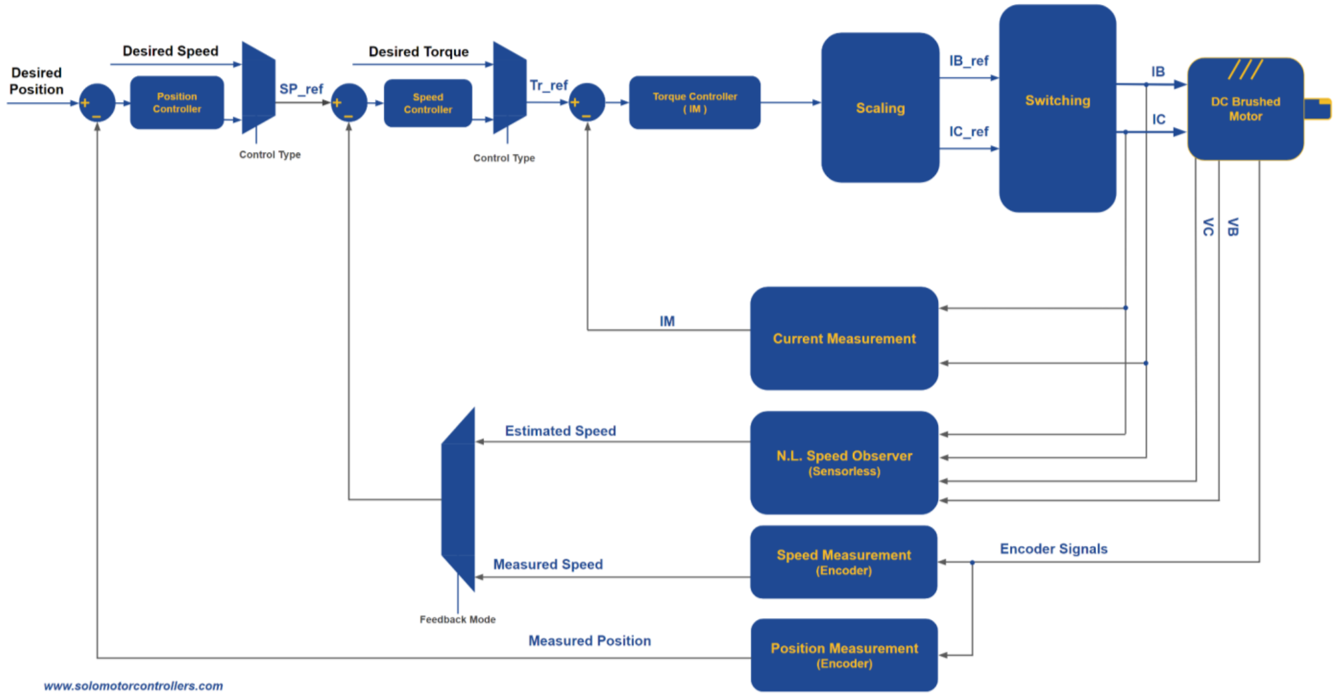


Figure 2 - Control Architecture of SOLO UNO_v2 for DC Brushed Motors

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 Sensorless 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 UNO_v2 can be decomposed into 14 main interactional sections as shown in Figure 3, 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 they don't exceed those maximum ratings to avoid damaging themselves or the SOLO UNO_v2 unit.

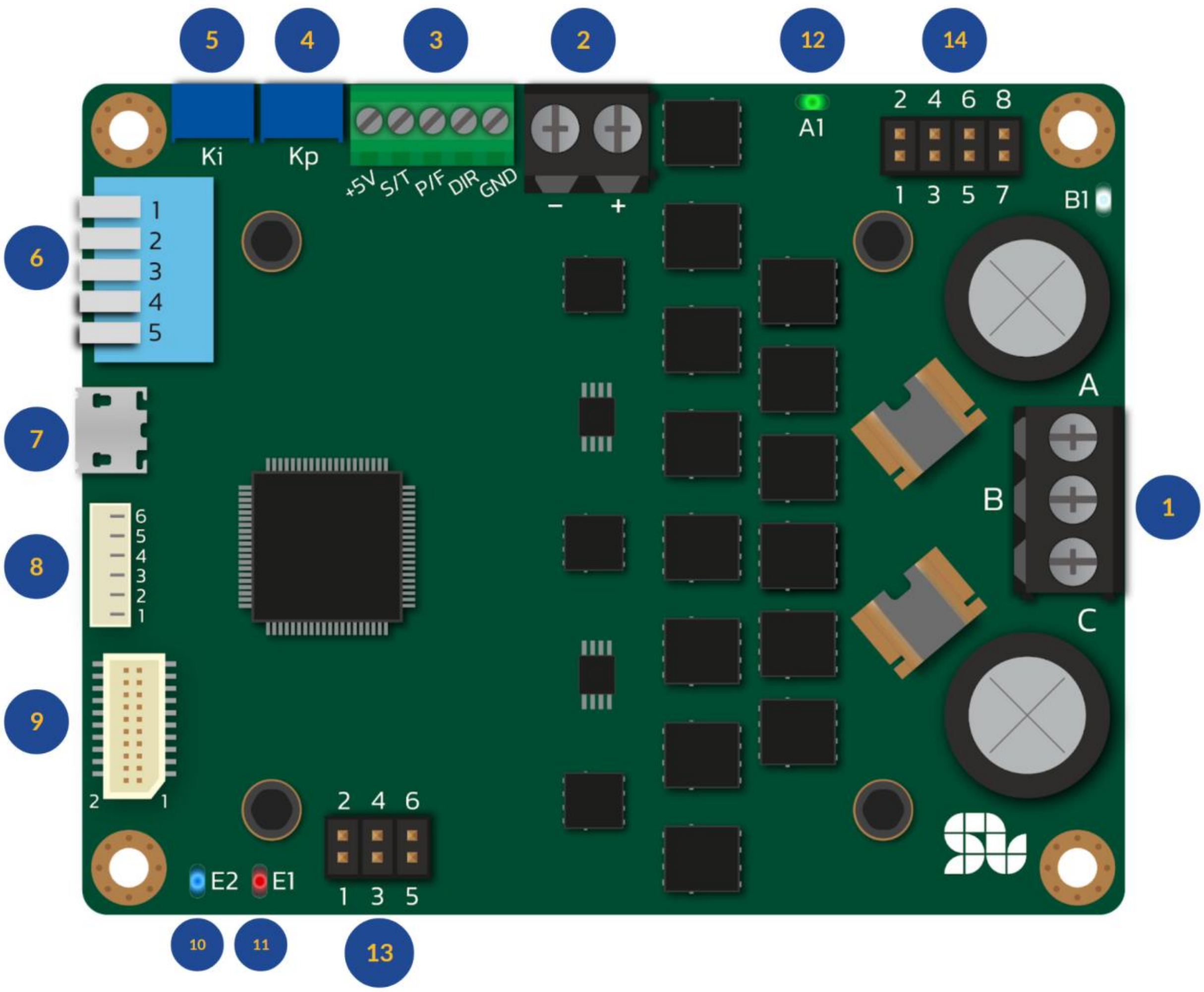
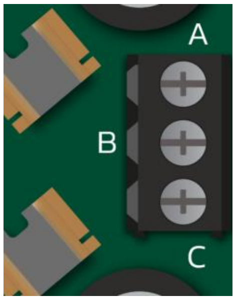


Figure 3 - SOLO UNO_v2's interactional sections

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.			

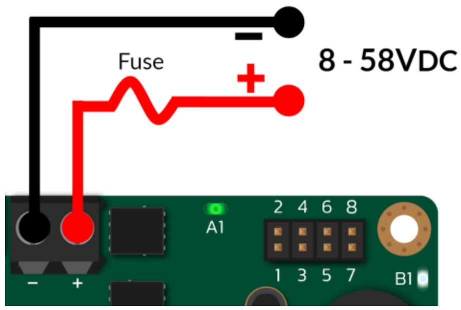


Section 2 - Supply Input

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 58 volts in continuous mode, depending on the voltage rating of the Motor Connected at the output. The max rating for supply input is 59V in transient mode, meaning that SOLO UNO_v2 will go into over-voltage protection mode in case the supply or BUS voltage rises above almost 60.0 volts, the Brake Chopper circuit will get activated at approximately 59.5V in default mode, to know more please check Section 14 below.

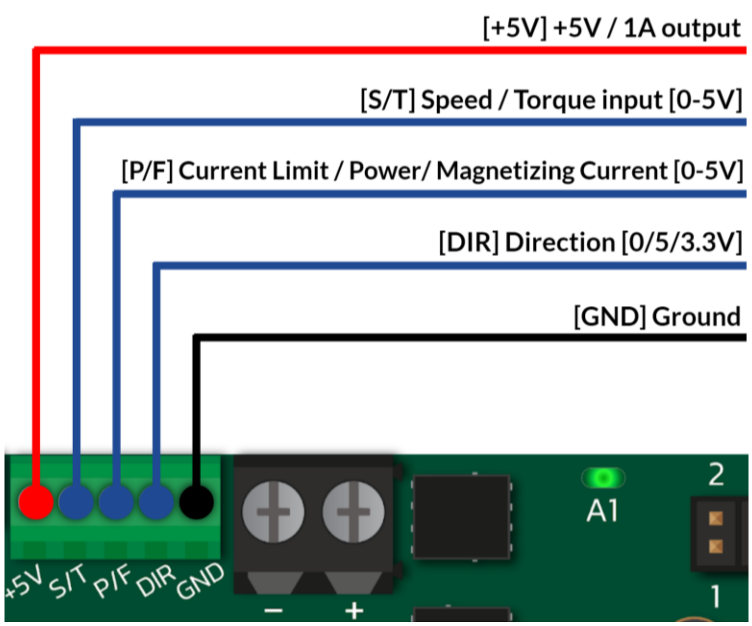


Section 3 - Analogue Inputs and +5V External Supply

PIN	Name	Descriptions / Notes	I/O
1	GND	Analogue Ground of SOLO	-
2	DIR	Direction of rotation of the motor control	I
3	P/F	Current Limit, Power or Flux reference	I
4	S/T	Speed or Torque reference	I
5	+5V	Supply output for external modules	O

Description

This is the Analogue commanding port of SOLO,it's useful when SOLO is in "Analogue Command Mode" and using that you can control the Speed or Torque of your motor by sending Analogic commands using PWM pulses 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 (see the Minimum Required Wirings Section) This part is composed out of 5 pins:



“GND” 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, 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/1A output to supply external peripherals or controllers with maximum of 5W.

“DIR” PIN:
This is the Direction control pin which is a digital pin, accepting voltage levels of **0V or 3.3V/5V,** by giving each of these values, the connected Motor to SOLO, will either rotate in C.W. direction or C.C.W. direction.

“P/F” PIN:
This is a pin with three main different functionalities depending on the control Mode and the type of the motor selected based on table below:

Mode of Operation	Functionality
In 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.
In Closed-Loop mode of DC, BLDC and PMSM motors	It will act as the current Limit, so if the voltage applied to this pin is 5V, it will stop the current floating to the motor (current Limit at zero or Free-Wheeling), and if this pin is left open it will allow up to 32A floating into your Motor, so any value between these will define the value of current limit. You can calculate the current limit value based on following formulas: **In case of using PWM:** The current Limit value = ((100 - duty cycle precentage of PWM at P/F input)/100) * 32.0 **In case of using Analogue Voltages:** The current Limit value = ((5.0 - the voltage at P/F input)/5.0) * 32.0

In Closed-loop mode of AC Induction Motors	It will act as the reference for magnetizing current reference known as **"Id"** which is in charge of generation of stator flux. The maximum amount of current that can be injected into the motor using this pin is 10 Amps. So in order to calculate the amount of magnetizing current you can use the following formulas: **In case of using PWM:** The Magnetizing current value = ((100 - duty cycle of PWM at P/F input)/100) * 10.0 **In case of using Analogue Voltages:** The Magnetizing current value = ((5.0 - the voltage at P/F input)/5.0) * 10.0

"S/T" PIN:

This is the input for controlling Speed or Torque of the Motor connected to SOLO depending on the selected Mode on the Piano switch mentioned in section 6, 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, 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**" for 3 phase motors (BLDC , PMSM or ACIM) is shown by "**Iq**" or namely the "Quadrature current". 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:**

<table>
<tr><td></td><td>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 selected by the Piano Switch 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 one, and it basically allows you to increase the resolution at S/T input for low speed motors.
<table>
<tr><th>Motor code</th><th>Motor Name</th><th>Maximum Speed in Closed-loop mode</th><th>Speed and Position Controller Sampling Rate</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><td>2kHz</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><td>2kHz</td></tr>
<tr><td>2</td><td>AC Induction Motors (ACIM)</td><td>4000RPM/ASRDC at 5V or 100% input duty-cycle</td><td>2kHz</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><td>2kHz</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:</td></tr>
</table>

	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.

"S/T" and "P/F" PINs in Open_loop Mode:

In Open-loop Mode to control the speed of 3 phase Motors, you need to set both "S/T" and "P/F" voltage values to apply the desire speed and power respectively, and for each of them you can find the explanation below:
The speed of the motors in **RPM** can be derived from the following formulas based on the motor type selected on Piano Switch shown in Section 6:

Number of Motor Pole Pairs = Number of Motor Poles / 2

In case of using Analogue Voltages on "S/T":

- **Normal Brushless Motor** = (voltage applied at "S/T")/(5.0* Number of Pole pairs)*8000
- **Ultrafast Brushless Motor** = (voltage applied at "S/T")/(5.0* Number of Pole pairs)*30000
- **AC induction Motors** = (voltage applied at "S/T")/(5.0* Number of Pole pairs)*4000

In case of using PWM inputs on "S/T":

- **Normal Brushless Motor** = (PWM duty-cycle Percentage at "S/T")/(100%* Number of Pole pairs)*8000
- **Ultrafast Brushless Motor** = (PWM duty-cycle Percentage at "S/T")/(100%* Number of Pole pairs)*30000
- **AC induction Motors** = (PWM duty-cycle Percentage at "S/T")/(100%* Number of Pole pairs)*4000

Three phase Motors "Power" Notation in Open-loop Mode:
The "P/F" input in open loop mode of 3 phase motors acts as the output voltage adjuster, so by going all the way up from 0V of Analogue voltage or 0% duty-cycle of PWM inputs at this

pin to +5V or 100%, you will increase the peak 3 phase voltage resulted by SVPWM modulation on SOLO to the motor **linearly from 0V to Vbus/sqrt(3) or equivalently to Vbus*0.577 at maximum,** Vbus here refers to the DC supply input voltage (or battery voltage), the action of increasing the output voltage peak, will result in higher consumption by the motor depending on their phase resistance and finally having more power for their rotation.

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 cause vibrations, so you need to tune it carefully. 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 randomly, since it might cause instability and it totally depends on your system.

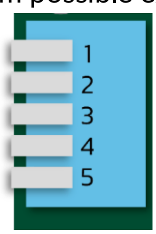
Ki Potentiometer :
This potentiometer defines how good your motor during time should reach the goal and stay in steady state, so by increasing this value your motor might reach the set-point slower but more consistently. Also by increasing this gain too much your motor might get unstable. So you need to tune this similarly to Kp gain 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 - Piano Switch Settings

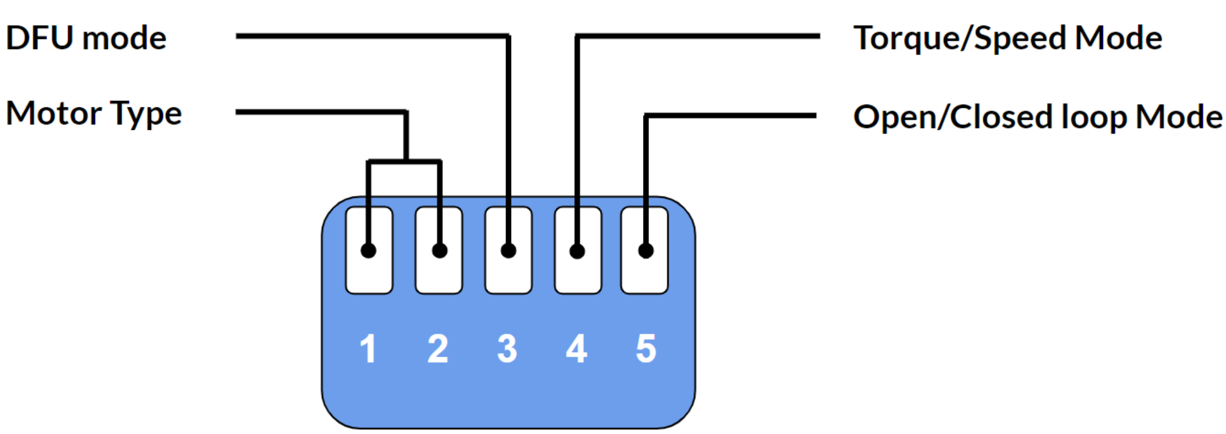
PIN	Name	Descriptions / Notes	I/O
1	Motor Select-1	Selects the Type of the Motor	-
2	Motor Select-2	Selects the Type of the Motor	-
3	DFU Mode	Puts the device into Firmware Upgrade Mode	-
4	Speed / Torque	Speed or Torque control	-
5	Open / Closed loop	Open-loop or Closed-loop selection, Motor Identification	-

Description

The piano switch in SOLO is used for the Analogue mode settings and for the convenience of those who want to use SOLO with minimum possible external modules and wirings.



The main roles of the Piano switch as can be seen are as following:



Pin number 5, Defining the Control Mode - Motor Identification:

By putting this pin in the UP position we are in open-loop mode, and if this pin is in DOWN position we are in closed-loop mode, this is the only functionality shared between Analogue and Digital control in SOLO UNO_v2.

- If you go from open-loop to closed-loop mode, while SOLO is powered ON, it will result SOLO to identify your motor parameters right after this transition, which is necessary for closed-loop controls. You can also Identify the motor parameters by sending a Motor ID. command through UART, USB or CANopen, the Identified Motor parameters will reside in NVM memory of SOLO, so there will be no need to re-do this process unless the motor has been changed.
- Once you are in Open-loop mode, the “P/F” input acts as Power input and it has direct relation with the value of the voltage at this pin (the higher the voltage at P/F, the higher the power injected into motor), but in closed loop mode “P/F” acts as current limit and it has a reverse relation with the voltage on this pin (the higher the voltage the lower will be the allowed current into the motor), so if this is the first time you are going to identify your motor parameters, and going to closed-loop mode, make sure the “P/F” input has zero voltage on it (you can leave it open or apply 0v or 0% duty cycle to it), after you do the Identification by pushing Pin number 5 down, you can leave PIN number 5 of Piano Switch there forever even after turning the whole system OFF and then later ON. (as long as the motor and wiring are the same). You can also re-identify the parameters by putting Pin Number 5 Up and Down again. The identified Motor parameters will remain in long term non-volatile memory of SOLO (NVM), and after power recycling they will be remembered, so no need to re-identify the motor every time you turn on the system.

Pin number 4,Defining The Type of the control- Speed or Torque:
This pin once it’s UP it means we want SOLO to operate in Analogue Torque mode, and once it’s DOWN it means SOLO should go to Analogue Speed control mode.

Pin number 3, Defining the DFU mode for upgrading the firmware:
This pin should never be DOWN except the moments you want to upgrade the firmware of SOLO, in case of the desire to upgrade the device firmware, you need to do the followings:

- Turn OFF SOLO
- Put the pin number 3 in DOWN position
- Turn ON SOLO
- Upgrade the Firmware
- Put back the pin number 3 in UP position

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

Pin number 1 and 2 ,Defining the Motor type:
using these two pins you can define the type of the electrical motor you are using in Analogue mode with specific features mentioned in following table:

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

- 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.

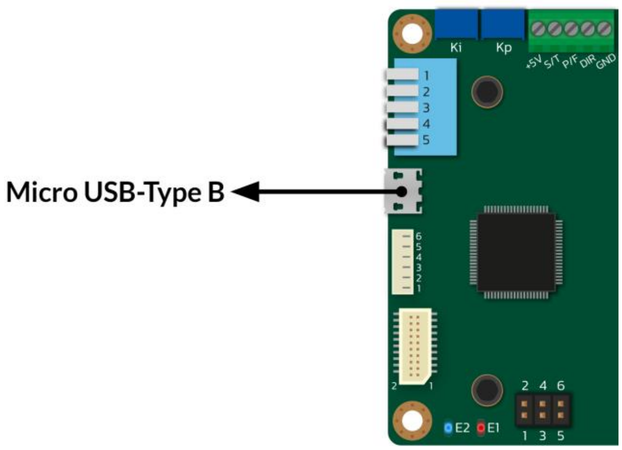
- As a rule of thumb for Low inductance motors you should select higher switching frequencies at the output of SOLO, default 20kHz can be low for some types of motors mainly with phase inductance lower than 200µH, and in case you are using Brushless or PMSM motors, you can select the motor type number 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 selected.

Section 7 - 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 from our website.

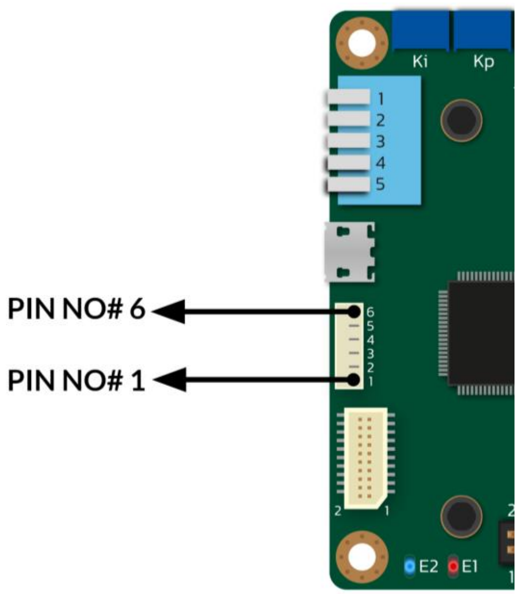


Section 8 - Encode/Hall connector

PIN	Name	Descriptions / Notes	I/O
1	+5V/500mA	Encoder +5V external supply	O
2	Encoder CHA/HALL_A	Channel A of the Encoder or Hall position sensors	I
3	Encoder CHB/HALL_B	Channel B of the Encoder or Hall position sensors	I
4	Encoder Index/ HALL_C	Index Input of the Encoder or Channel C of Hall position Sensors	I
5	Encoder Strobe	Encoder Strobe (not needed)	I
6	GND	SOLO's Ground	-

Description

This port is the Quadrature Encoders or Hall sensors input, it accepts single-ended signals leveled at +5V (RS422) while providing a +5V/500mA supply for powering up the sensors. All the sensor inputs are internally pulled-up to +5V with 1kΩ resistance to provide 5mA current for open drain/collector configurations.



PIN NO#	FUNCTIONALITY
1	+5V (500mA)
2	Encoder_CHA / HALL_A
3	Encoder_CHB / HALL_B
4	Encoder_Index/ HALL_C
5	NC
6	GND

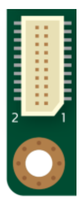
- The use of Index pulse for 3 phase Motors is mandatory as it's required for Encoder Calibration process, for DC brushed motors, the presence of Index pulse is not needed.
- To learn about how to Setup and calibrate your Incremental Encoders for SOLO UNO_v2 please visit this page on our website.
- To learn about how to Setup and calibrate your HALL sensors for SOLO UNO_v2 please visit this page on 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 an Auxiliary port that gives you the access to UART and CAN bus communication pins in order to send/receive fully digital commands in form of data packets if necessary.



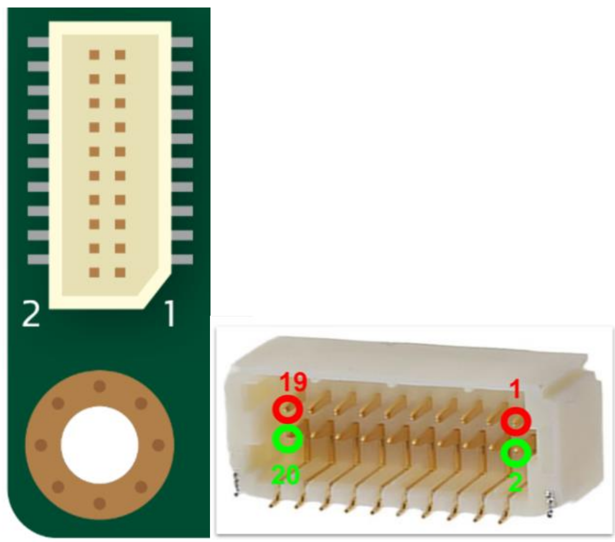
Notice that, The CAN_TX and CAN_RX are strictly leveled at 3.3V and they are NOT 5V tolerant, applying 5V leveled signals to these pins will cause permanent damage to the main controller unit.

CAN_TX and CAN_RX are not useful for CANbus CANopen networks as they are coming 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 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, the communication port on SOLO UNO might be from right-angle or the vertical type, the pin numbering for each shown in images below:

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 a functionality as below:

- **E2 :** This is the status or heart-beat 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 remain in the blinking state as long as no error occurs.

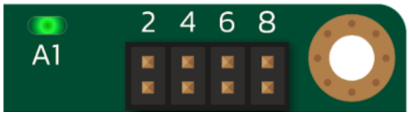
- **E1:** This is the Error indicator, and in case of an error, it will act as below:
  - ***Over voltage Error:*** Starts Blinking
  - ***Over Current Error:*** Stays ON
  - ***Over Temperature Error:*** Stays ON

Section 12 - Power Up LED

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

Description

This LED will start glowing once SOLO is correctly powered up with a voltage from 8 to 58V.



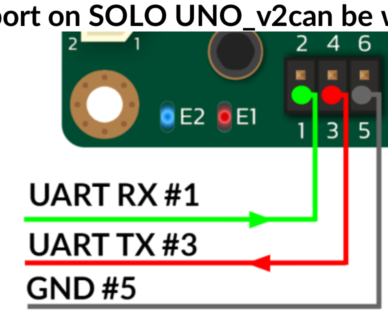
Section 13 -CAN BUS / UART PINOUT

PIN	Name	Descriptions / Notes	I/O
1	UART_RX	UART protocol transmitter input	I
2	CANL	CAN Low Bus Output (ISO 11898)	-
3	UART_TX	UART protocol transmitter output	O
4	CANH	CAN High Bus Output (ISO 11898)	-
5	GND	SOLO's Ground	-
6	GND	SOLO's Ground	-

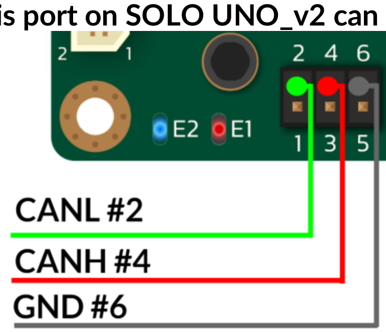
Description

This section provides easy access to both of the CANopen and UART interfaces; these pins can also be found on the "Communication Port" on section 9 with the exact same functionality.

The UART interface from this port on SOLO UNO_v2can be wired as:



The CANopen interface from this port on SOLO UNO_v2 can be wired as:

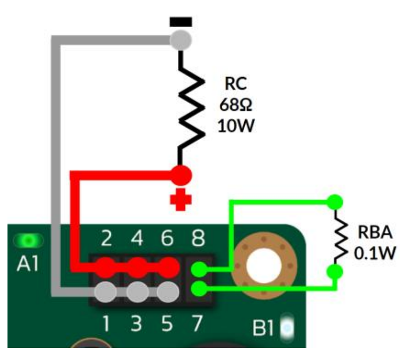


Section 14 - Active Brake Chopper

PIN	Name	Descriptions / Notes	I/O
1	BRO-	Brake chopper negative output	O
2	BRO+	Brake chopper positive output	O
3	BRO-	Brake chopper negative output	O
4	BRO+	Brake chopper positive output	O
5	BRO-	Brake chopper negative output	O
6	BRO+	Brake chopper positive output	O
7	BRA1	Brake voltage activation external resistor input 1	I
8	BRA2	Brake voltage activation external resistor input 2	I

Description

This section provides a compact Active Brake Chopper circuitry to protect the device from over-voltage conditions caused by powered fed back from the motor to the DC-Bus due to regeneration by dissipating of the power on a high-power resistor through BRO+ and BRO- output with tunable activation voltage using an external resistor through BRA1 and BRA2 inputs from 59.5V down to 10.0V.
The default activation voltage for this circuitry on SOLO UNO_v2 (SLU0722_5832) is set at **59.5V**, however this voltage can be changed to any desired voltage using the below formula mentioned in Active Brake Chopper wirings.
The general wiring for the brake chopper section can be as below, to find out more about brake chopper please refer to Active Brake Chopper wirings later in this document.



Section 15 - Brake Activation LED

section	Name	Descriptions / Notes	I/O
15	B1	Brake Activation LED	-

Description

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

Analogue versus Digital Control in SOLO UNO_v2

By notion of "Analogue" in SOLO we mean any interface that can be done using Analogue voltages or mechanically at hardware level to SOLO, for instance in SOLO UNO_v2 you can do the following actions completely at hardware level:

1. Set the Speed or Torque Reference through "S/T" input
2. Set the Current Limit or 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 Piano switch (4 types)
5. Set the Control Mode of Torque or Speed through Piano switch
6. Set the Open-loop or Closed-loop type of control through Piano switch
7. Put SOLO into DFU mode through Piano switch

For SOLO, once you are in "Analogue Mode", these settings have the highest priority over all the settings from the same nature in Digital mode, for example, if you are in Analogue Mode, you can only select the motor type from the Piano switch, and if you set it using Motion Terminal or you send the data packet through UART or CAN bus 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 a software and to minimize the interfacing effort to SOLO for simple applications.
However, there are tons of settings that you can't do them at 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 or 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 UNO_v2 are "Closed-loop" or "Open-loop" selection as well as putting SOLO into DFU mode using the Piano switch, this means you will need to do this setup at hardware level regardless of the fact that you are in "Analogue Mode" or "Digital Mode".

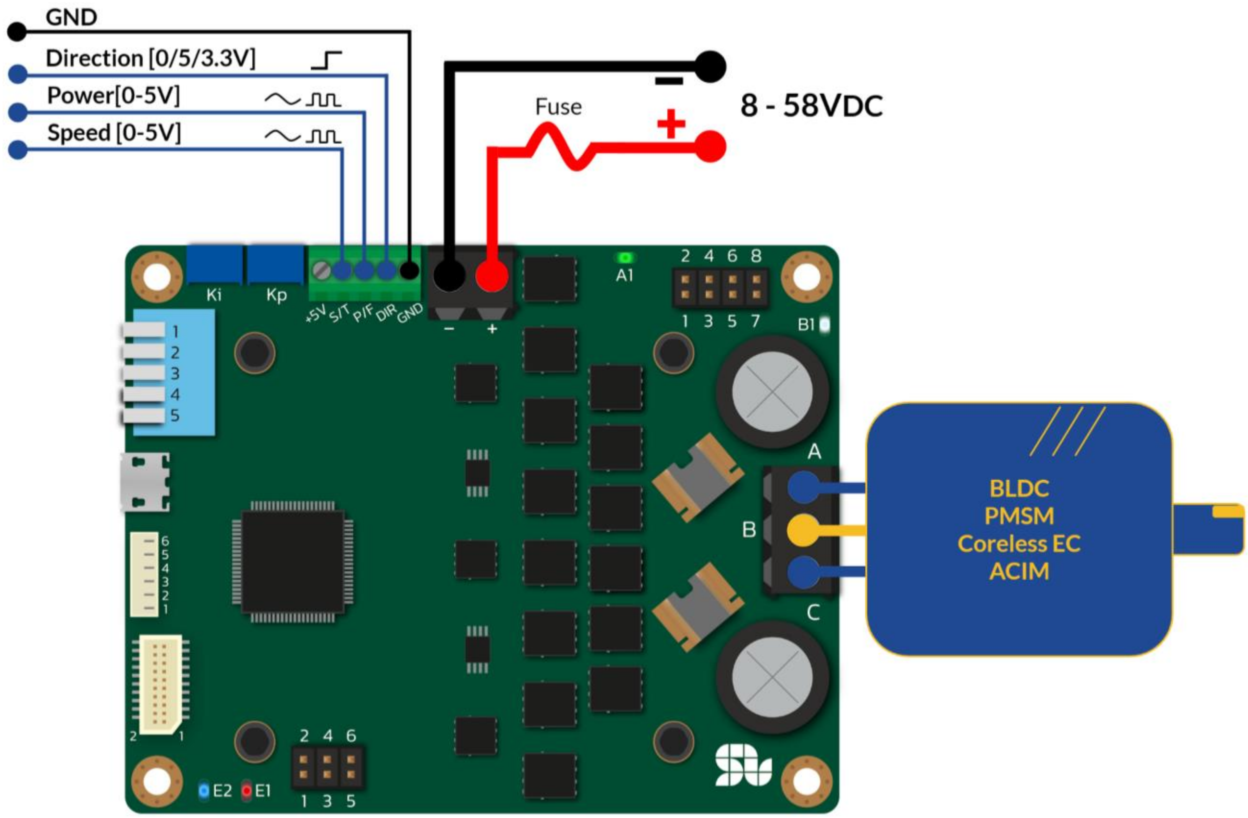
Minimum Required Wirings in Analogue Mode:

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:

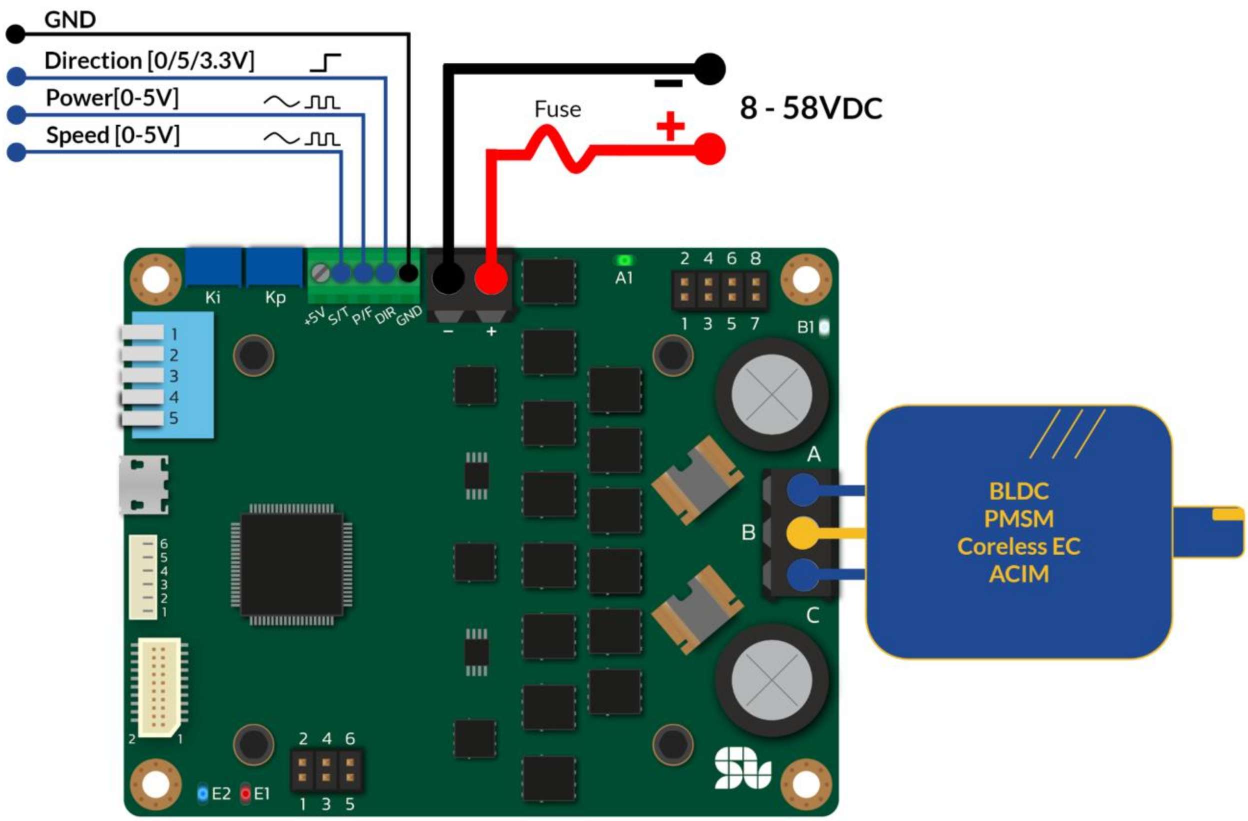
Shape	Description
	Input Positive of the DC supply
	Input Negative or Return of the DC supply
	Fuse, the value can be selected based on the system requirements
	Line carrying pulses with PWM (fixed frequency above 5kHz)
	Line carrying Pure Analogue voltage
	Line carrying ON / OFF type of signals (low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

BLDC, PMSM Motors _ Sensorless Closed-loop Mode:



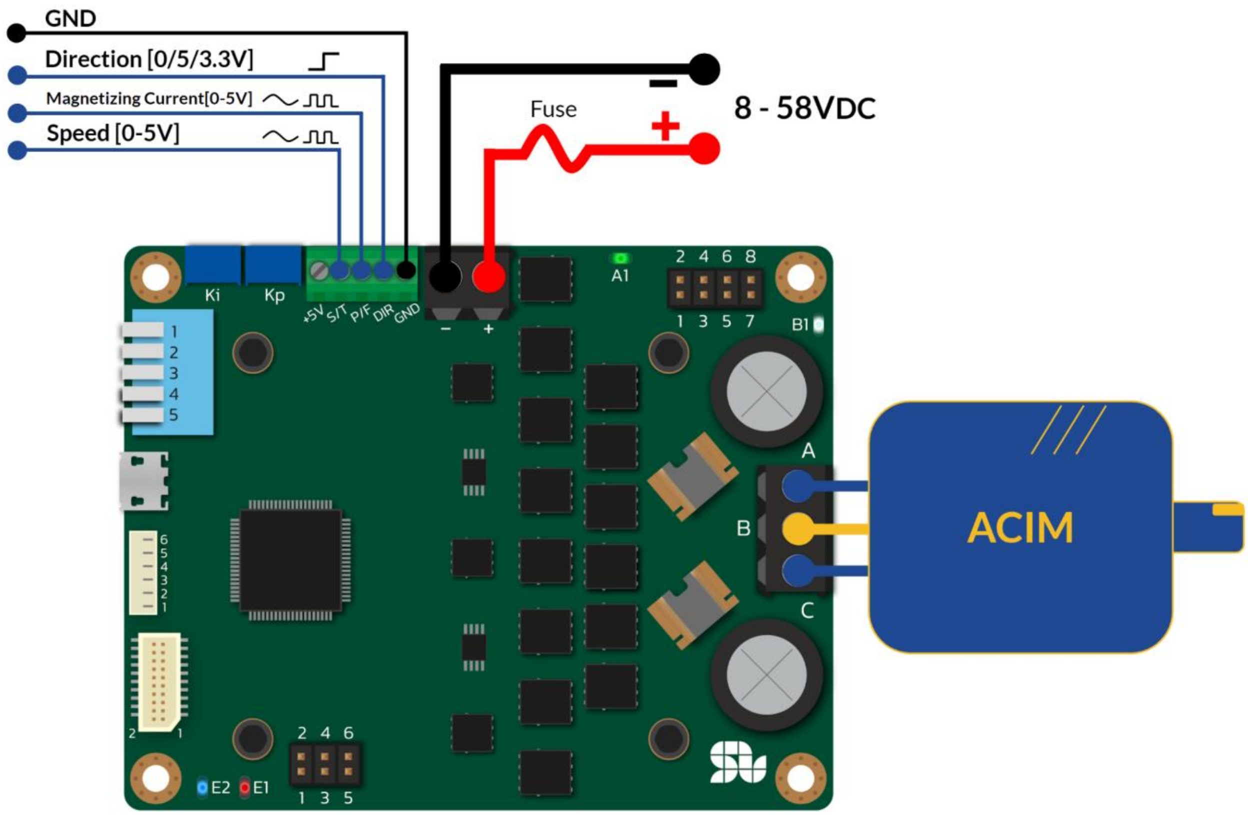
- To put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down.
- In sensorless closed-loop mode, the order of the connection of Motor wires to A,B,C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.

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



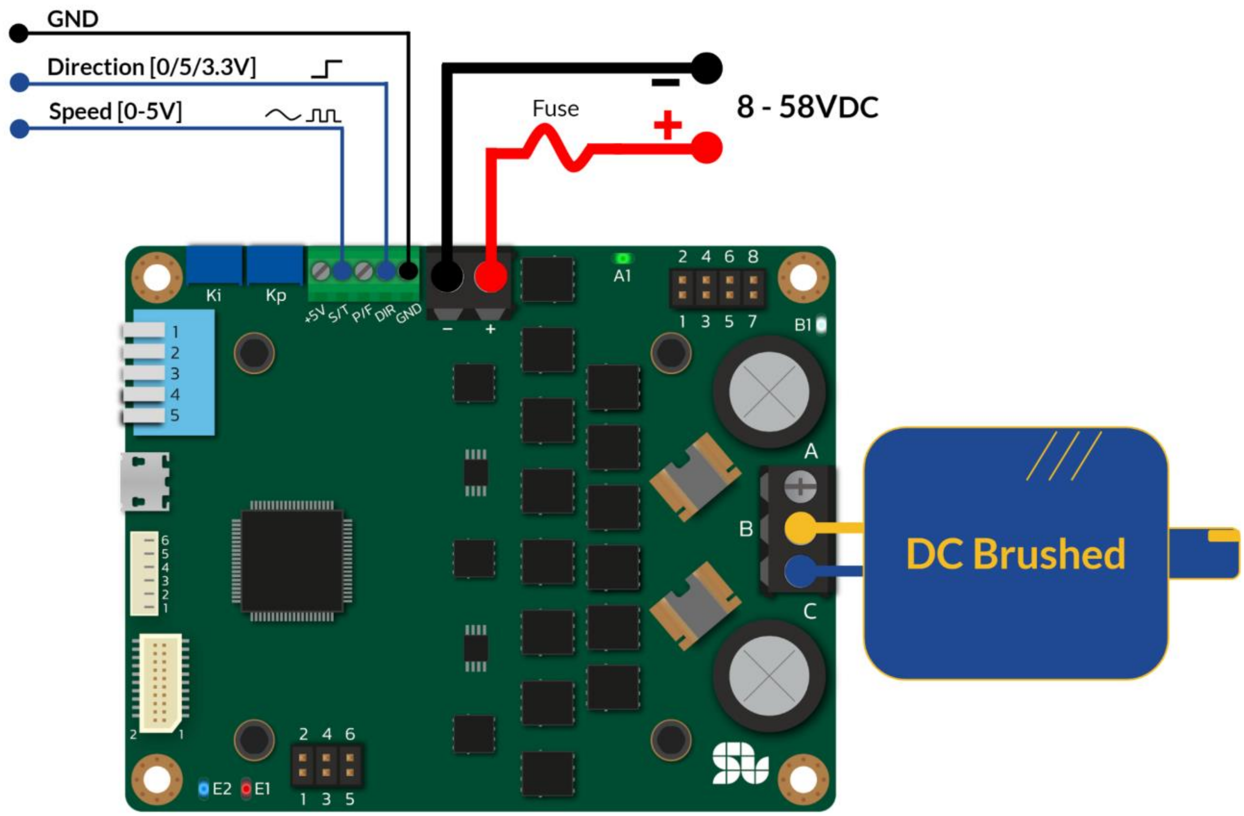
- To put SOLO in Open-loop Mode, the Pin Number 5 of the Piano switch must be UP.
- In sensorless or open-loop mode, the order of the connection of Motor wires to A,B,C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.

AC Induction Motors_ Closed_loop Sensorless Mode:



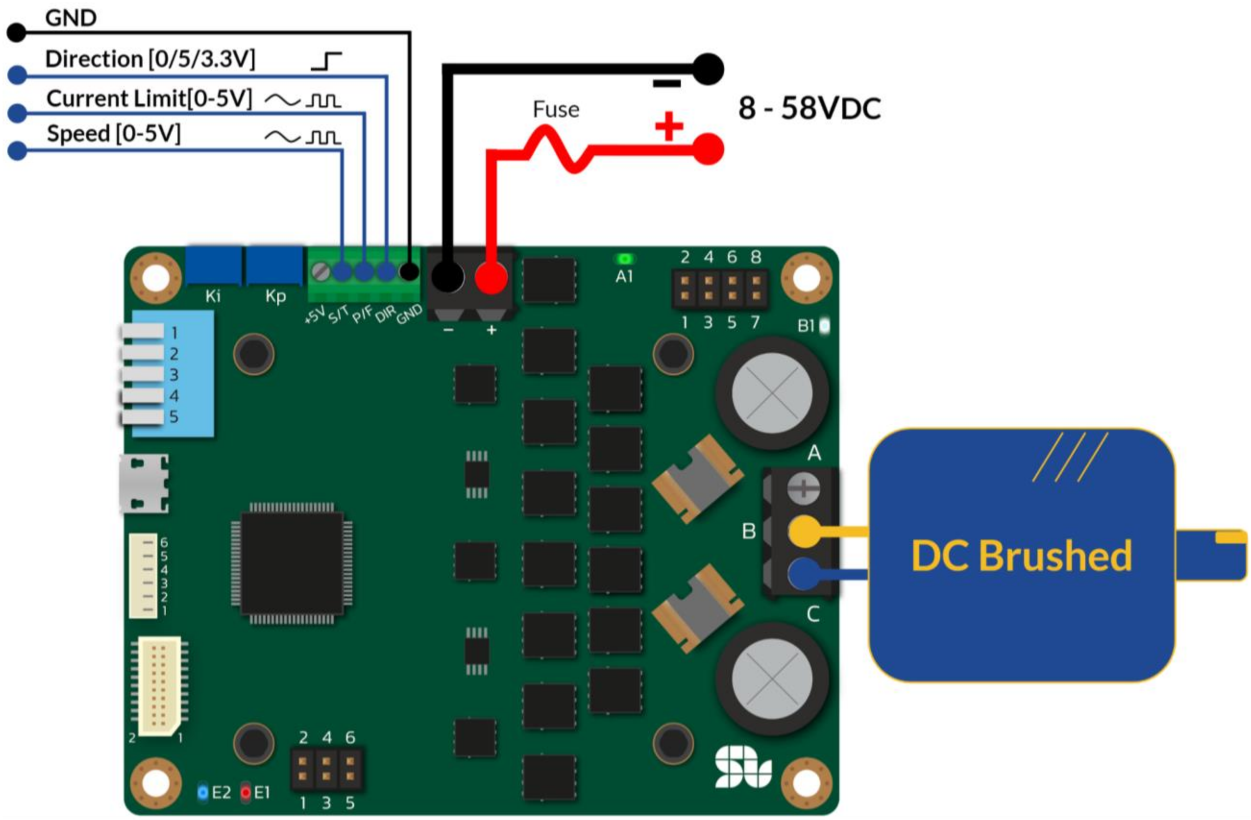
- To put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down.
- In sensorless closed-loop mode, the order of the connection of Motor wires to A,B,C output is not important and it will only affect the Direction of rotation which you can set using "DIR" input.

DC brushed Motors_ Open-loop Sensorless Mode:



- To put SOLO in Open-loop Mode, the Pin Number 5 of the Piano switch must be UP.

DC brushed Motors_ Closed-loop Sensorless Mode:

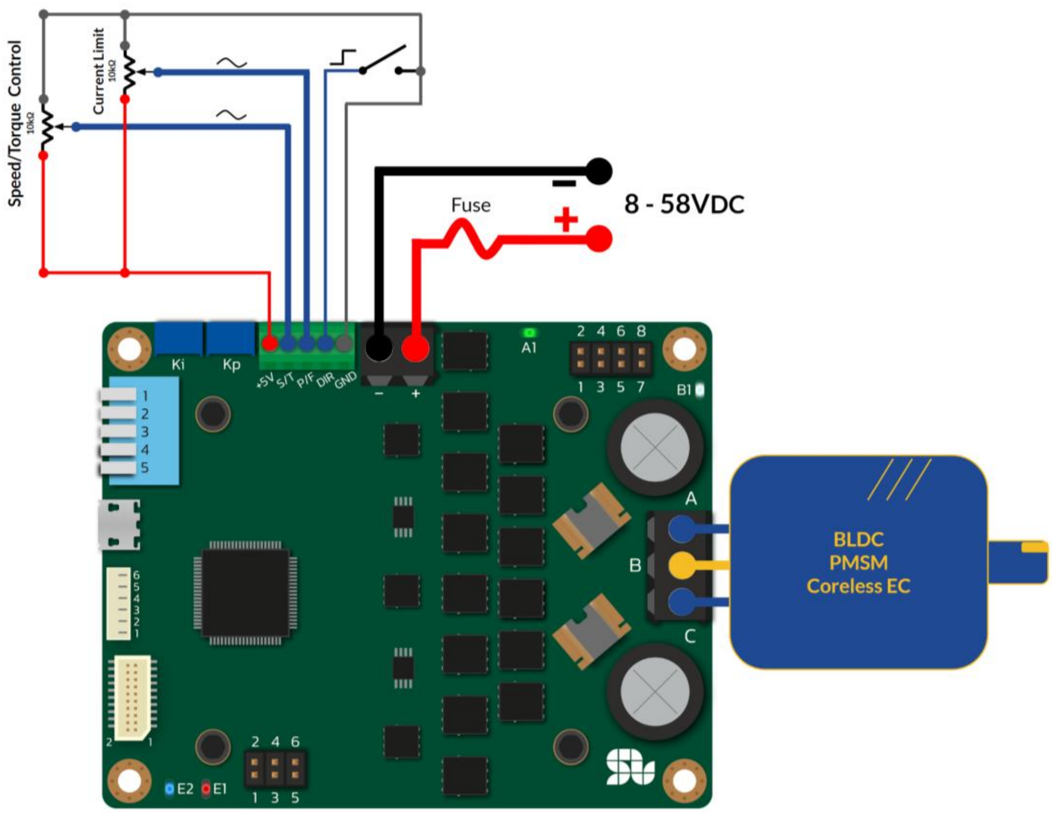


- To put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down.

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 a wiring of a Brushless Motor in Closed-Loop Mode with Current Limit all done using only two potentiometers. Please Not that:

- The current Limit Potentiometer is not mandatory to use, and if you leave the "P/F" input open, the current Limit will be automatically set at 32A. This input in closed-loop mode acts as if the voltage applied to this pin is 5V, it will stop the current floating to the motor resulting in free-wheeling(Current Limit at zero), and if this pin is left open it will allow up to 32A floating into your Motor, so any value between these will define the value of current limit.
  The current Limit value = ((5.0 - Analogue Voltage applied at P/F input)/5.0) * 32
- "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 Pin Number 5 of the Piano switch must be Down.

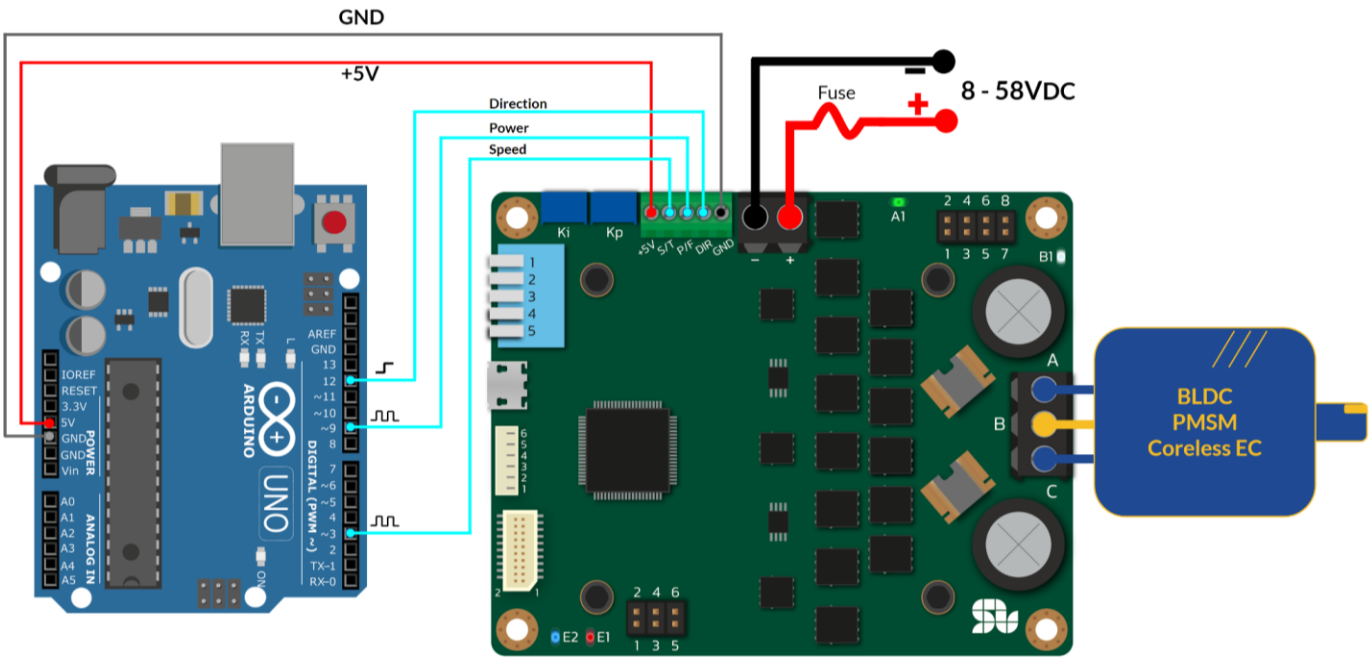


Essential Wiring Example (SOLO UNO_v2 + Arduino UNO)

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 conenction 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.

- "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 Pin Number 5 of the Piano switch must be Down.

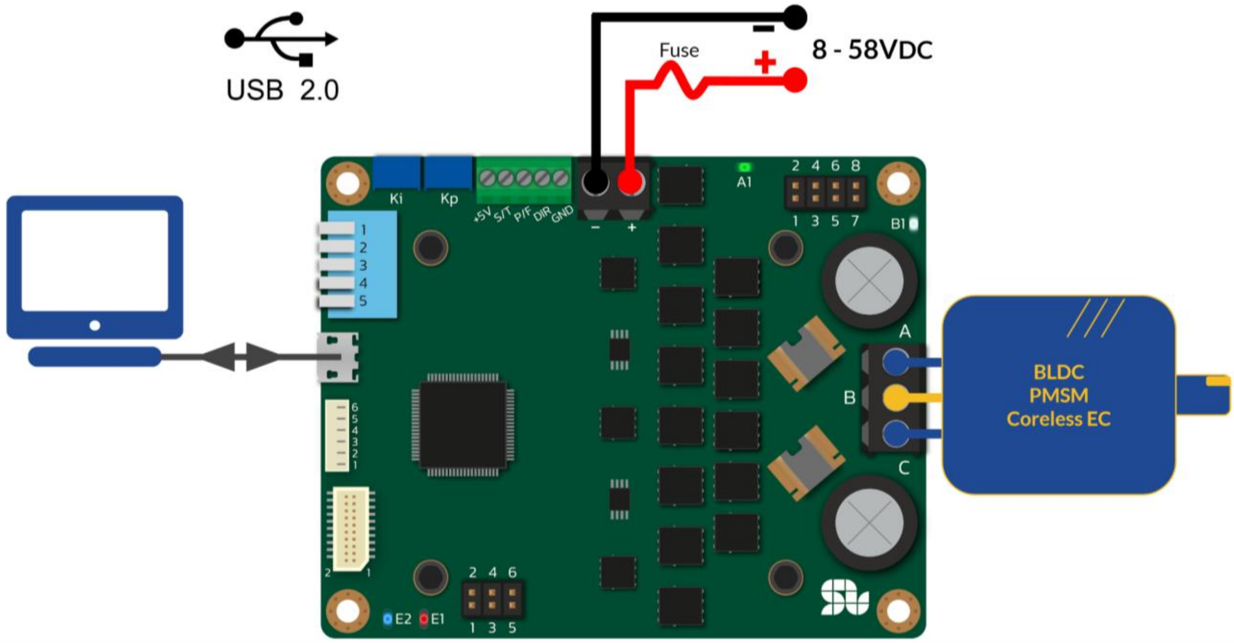


Minimum Required Wirings in Digital Mode:

All of the functionalities of SOLO UNO_v2 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 in Digital Mode for Brushless Motors (the same pattern of wiring applies for other types of motors)

USB Interface Wiring

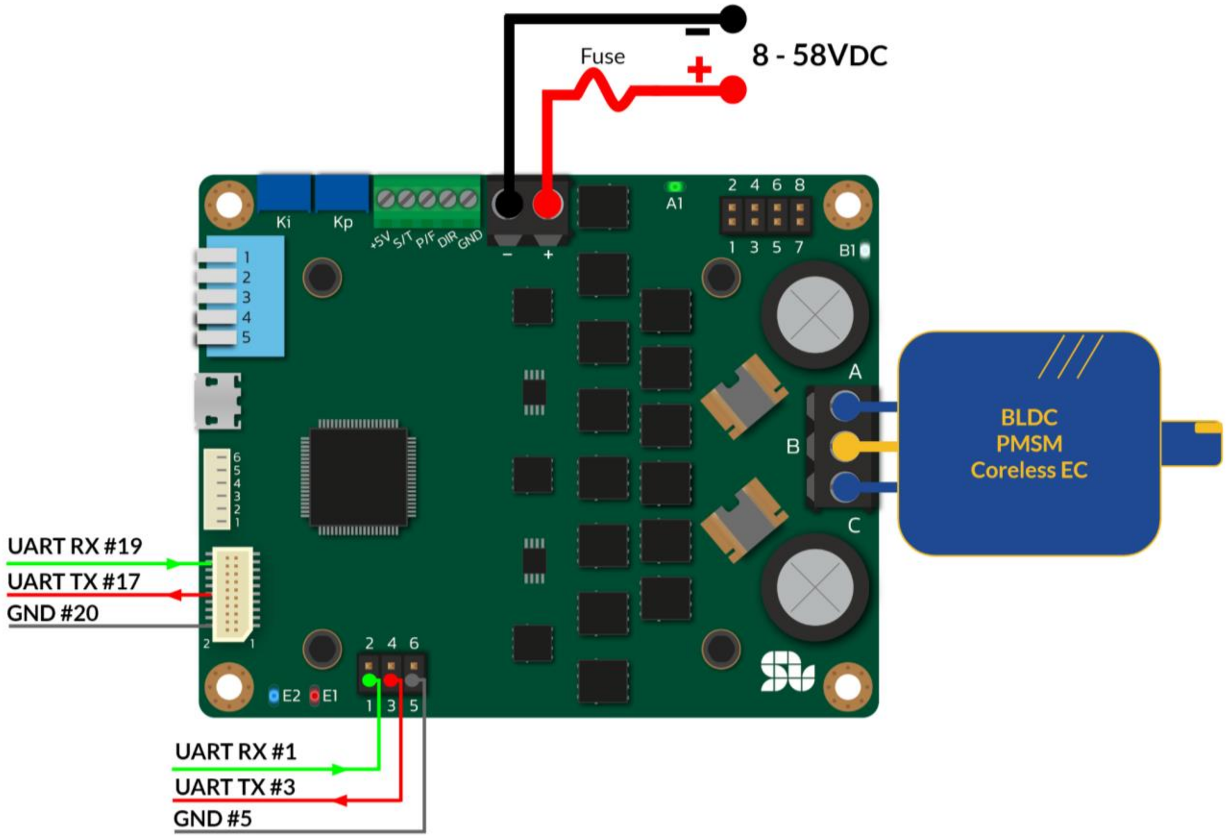
By using USB connection, you have the access to the simplest form of wiring of SOLO to be commanded using only the USB cable thanks to the digital control that it offers, in this mode the only thing you will need is a Micro USB cable that makes SOLO able to communicate with a local PC or controller through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



- Operation in Closed-loop or Open-loop is controlled by Piano Switch PIN Number 5 both in Analogue and Digital modes, so to put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down, subsequently for operating in Open-loop Pin Number 5 of the Piano switch must be UP.

UART Interface Wiring

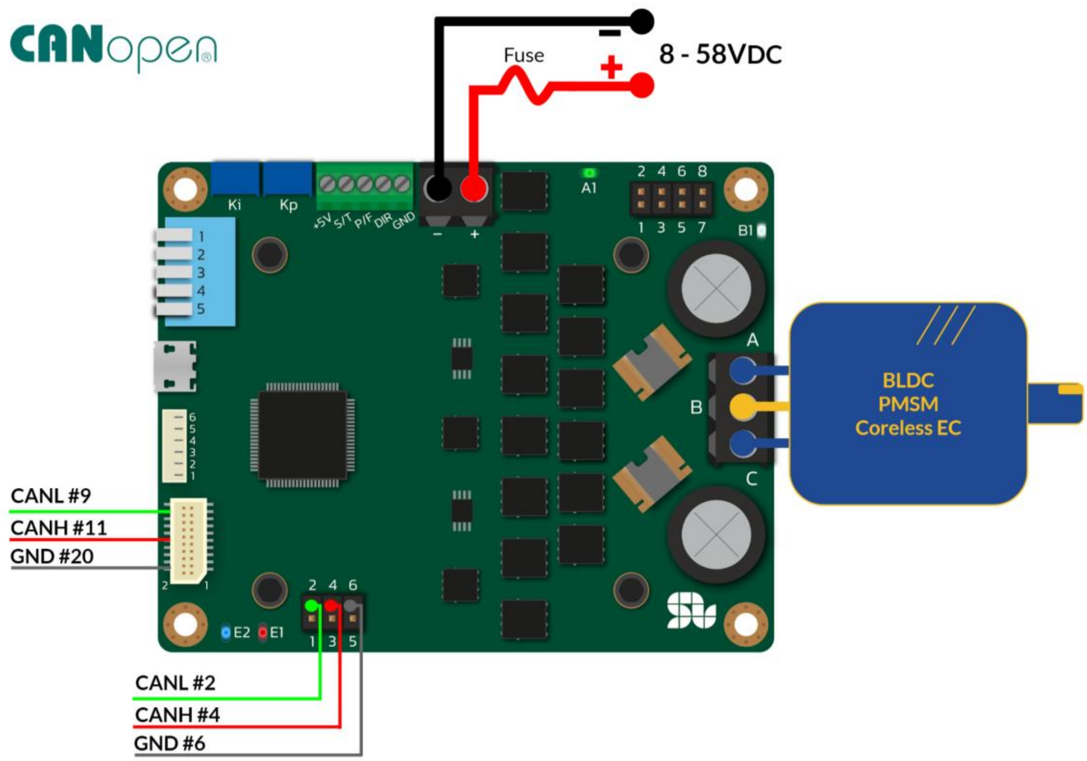
The UART line of SOLO is accessible both through the "Communication Port" or through the "CAN BUS / UART PINOUT" which makes it easier and faster to access these lines for testing purposes, in SOLO UNO_v2 model the UART_RX and UART_TX lines are +5V tolerant and they can be fed both by signals leveled at +3.3V or +5V.



- Operation in Closed-loop or Open-loop is controlled by Piano Switch PIN Number 5 both in Analogue and Digital modes, so to put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down, subsequently for operating in Open-loop Pin Number 5 of the Piano switch must be UP.

CANopen Interface Wiring

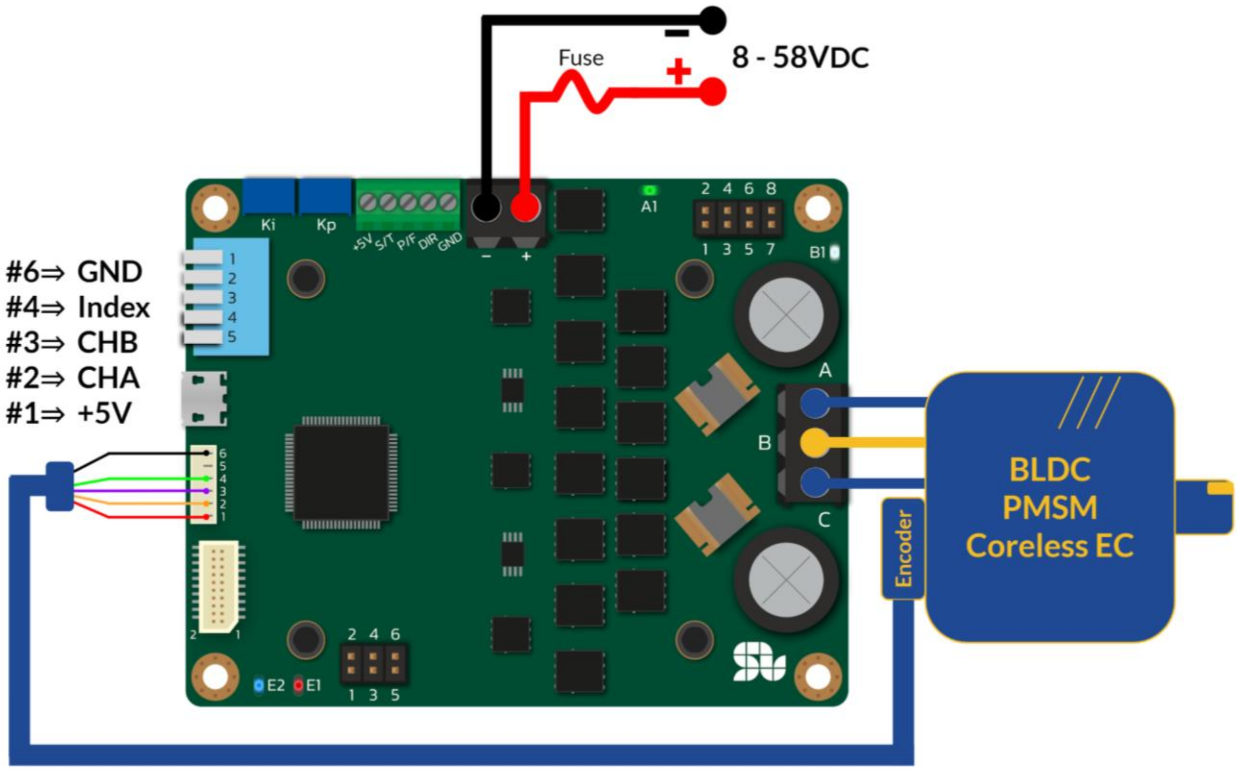
SOLO UNO_v2 can be commanded in a CAN network by CANopen standard, using CANopen all of the functionalities of SOLO can be controlled digitally using data packets sent within CAN bus. To know more please refer to SOLO UNO_v2 CANopen user Manual here. CANopen can be accessed both through "Communication Port" or the "CAN BUS / UART PINOUT" using CANH and CANL pins.



- Operation in Closed-loop or Open-loop is controlled by Piano Switch PIN Number 5 both in Analogue and Digital modes, so to put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down, subsequently for operating in Open-loop Pin Number 5 of the Piano switch must be UP.
- CAN_TX and CAN_RX pins are CAN outputs coming right off the DSP and they are only +3.3V leveled signals with no CAN Transciever 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:

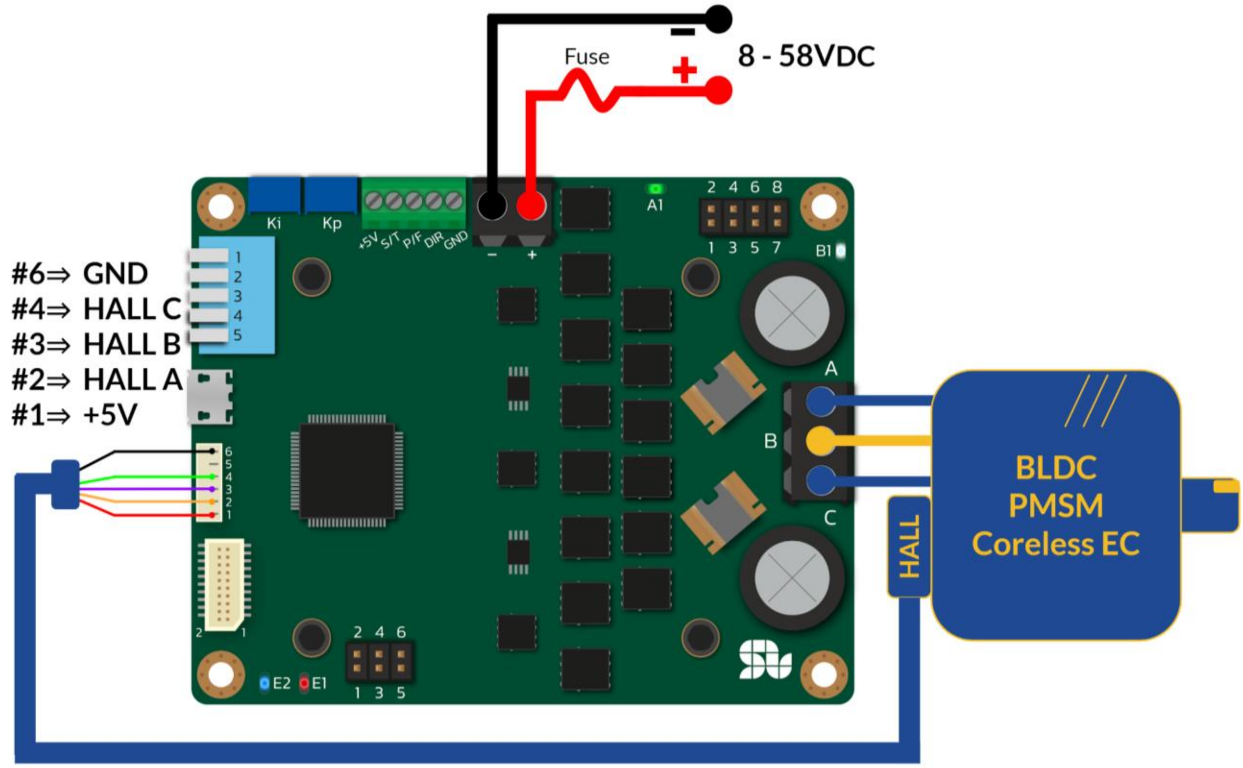
By using Incremental Encoders you can turn SOLO into a servo drive controlling Torque, Speed and Position of your Motor, once using Incremental Encoders you need to make sure you apply the correct setup followed by one-time calibration of the system, to learn about the process please visit [this page](#)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



- Operation in Closed-loop or Open-loop is controlled by Piano Switch PIN Number 5 both in Analogue and Digital modes, so to put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down, subsequently for operating in Open-loop Pin Number 5 of the Piano switch must be UP.

Wiring with HALL Sensors:

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



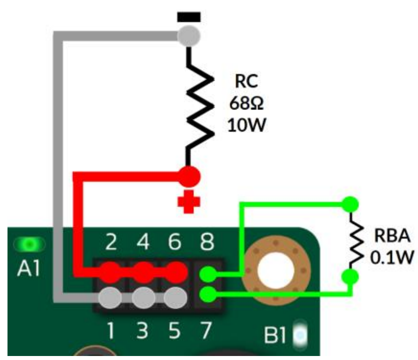
- Operation in Closed-loop or Open-loop is controlled by Piano Switch PIN Number 5 both in Analogue and Digital modes, so to put SOLO in Closed-loop Mode, the Pin Number 5 of the Piano switch must be Down, subsequently for operating in Open-loop Pin Number 5 of the Piano switch must be UP.

Wiring and Setup of Active Brake Chopper:

This circuit provides a compact Active Brake Chopper circuitry to protect the device from over-voltage conditions caused by powered fed back from the motor to the DC-Bus due to regeneration by dissipating of the power on a high-power resistor through BRO+ and BRO- outputs with tunable activation voltage using an external resistor through BRA1 and BRA2 inputs.
The default activation voltage for this circuitry on SOLO UNO_v2 (SLU0722_5832) is set approximately at **59.5V**, however this voltage can be changed to any desired voltage using the formula mentioned later in this part.
The general principle of this circuit is whenever the BUS voltage goes above the activation voltage limit, the circuit shorts the BRO+ to BRO- thus by placing a high power resistor with minimum value of **68Ω 10Watts,** the extra power will be dissipated in the "RC" resistor shown below in the wiring.

- Do not use power resistors with resistance below **68Ω for "RC" resistor,** since by doing so, the brake circuitry might get damaged due to excessive power dissipation.

Whenever the brake circuit turns on, the "**B1"** LED will turn ON too.



The Activation voltage limit can be tuned using the "**RBA**" resistor based on below formula, by leaving pin 8 and 7 open the default activation voltage of 59.5V will be applied.

X= ((((Desired Brake Activation Voltage) / 5.6) * 10200) - 10200)
RBA [Ω] = (X * 97600 / (97600 - X)

Table1 below shows some sample activation voltages based on the nominal DC bus voltage, however any arbitrary voltage down to 10V can be achieved using this formula for various systems.
The brake activation voltage should be always above the nominal applied DC bus voltage to the system to avoid power dissipations on "RC" resistor once not necessary, it's always better to test

the activation voltage by looking at "B1" LED and verify if the LED turns on at the desired value before committing the Motor to the controller.

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

Nominal DC bus voltage based on the Motor	Possible Desired Brake Activation Voltage (approximately)	"RBA" resistance value [kΩ] (approximately)
58V	59.5V	∞ (open)
48V	49V	415
36V	37V	138
24	25V	55
12	13V	16

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

Table 2: Some candidates for "RC" power resistor

Candidate Part Number for "RC" resistor	Resistance and Power
THS1075RJ	75Ω 10W
THS2568RJ	68Ω 25W
THS1568RJ	68Ω 15W
RHA05068R00FE02	68Ω 50W
HSC100-100R	100Ω 100W