ESC3–SC controller series

Short datasheet

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Contents

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Chapter 1: Introduction

The SC is a ESC3 family controller with excellent performance-to-weight ratio. It can be used in wide range of applications, especially in industry and automotive. Using most modern technologies it achieves extreme dynamics and maximum efficiency, it implements smooth start or regenerative braking, all this with minimum dimensions. The SC controller is capable of driving all common types of electric motors.

Applications

- Automotive or industrial motor control
- Electric hand tools and equipment
- Hi-end sport motorbikes, e-bikes, surf boards
- Combustion engine starter-generators
- Military inertial stabilization
- Professional drones, RC models
- Research & development
- Servo drive

Chapter 2: Safety and warnings

2.1 Product purpose

All ESC3 controllers are designated for 3-phase PMSM and induction motor control. Any other use of product or its parts without siliXcon written permission is prohibited. Software tools supplied with the ESC3 controllers are designed exclusively for siliXcon's products. Their other uses are not allowed.

2.2 Warnings

Read carefully all instructions and and make sure you understand them *before* you start using the ESC3 controller. Pay special attention for instructions and warnings in this chapter.

2.2.1 Safety

- ESC3 controller is electronic device and should be installed or replaced by trained personell only. Incompetent manipulation could lead to electrical shock, burns or property damage.
- Wear safety glasses and use properly insulated tools to prevent short-circuits
- Use the ESC3 controller only in proper enviroment. Check the temperature, water resistance and dust resistance (described in chapters 5 and 7 of this document).
- ESC3 controller can be used in vehicles. Secure the vehicle against uncontrolled operation (lift it of the ground, block wheels ...) before you start any work on the vehicle. There is always small chance, that motor can run out of control and cause injury.
- ESC3 controllers are usually powered from battery. Battery is able to supply very high currents and create electric arcs when short-circuited. Always disconnect the battery and use insulated tools to prevent short-circuiting the battery. Do not wear metal jewelery and do not use metal items that can accidentally short-circuit the battery.
- Read carefully the manual for used battery and battery charger. Many safety issues are related to battery and proper charger.
- ESC3 controllers are not designed to be used in life-critical applications.
- ESC3 controllers are capable of regenerative braking. This feature is not considered to be safety brake and can be used only on vehicle with independent mechanical brake.

2.2.2 Electrical risks

- Power stage of ESC3 controller containts high quality capacitors that could remain charged long after battery is disconnected. To avoid electric shock, always check voltage between BATT+ and BATT− terminals of the ESC3 controller. When needed, capacitors could be discharged by shorting BATT+ and BATT− via resistor.
- Always disconnect battery (or other power supply) and discharge power stage capacitors before handling ESC3 controller (replacing controller, connecting or disconnecting cables ...)
- Do not disconnect battery when motor is controlled. Overvoltage and damage of controller could occur. If a mechanical switch or contactor is used between battery and controller, bypass it always by proper diode in reverse direction.

- Sparking could occur when connecting controller to the battery. Do not use the controller in explosive enviroment. Use precharge feature with contactor control or anti-spark connectors to minimize this problem.
- ESC3 controllers has functions, that protects connected battery. This is only additional feature and can not be used instead of proper battery fuse and proper BMS. Using battery without fuse or BMS could lead to battery damage, explosion or fire.

2.2.3 Thermal issues

- ESC3 controller and power wires could became hot during operation. Check their temperature before handling.
- Use power wires with sufficient crossection. Using too small wire crossection leads to generation excessive amount of heat. This could result in faster insulation degeneration, shortcuts or even fire.
- Provide sufficient cooling for the ESC3 controller. This usually requires tightening the controller to heatsing. Secure the screws and bolts against vibrations by glue or spring lock washer.

2.2.4 Communication and control issues

- Turn off ESC3 controller and disconnect it from power supply before you upgrade firmware or change settings via USB.
- Using USB for run-time settings and debugging is not advised. If you decide to do it, it is on your own risk. It is recommended to use galvanically isolated communication (CAN Bus or isolated UART) for run-time settings and debugging.
- Never connect USB to controller during battery charging. This could provide path for short-circuit current. Do not do it especially when the host PC and charger are connected to the wall plug.
- Do not change internal software parameters when motor is controlled. This could lead to unexpected and potentially dangerous states. Always stop the motor before you change settings. Change of settings could cause motor to spin-up. Secure the vehicle (lift it of the ground) before you start setting parameters.

2.2.5 Device's lifespan

- Device's operation at (or near to) limit values (voltage, current or temperature) reduces its lifespan.
- Exposing device to repetitive short-cuts on its protected outputs reduces its lifespan and increases risk of malfunction.

2.3 EMC

ESC3 controller creates electromagnetic interference, that could influence other electronic devices. Character and amount of the interference is dependent on various factors (such as voltage level, maximum currents, wiring topology, wiring geometrical properites ...). EMC should be tested carefully with each new end-product and with any change in existing end-product.

2.4 Warranty

ESC3 controller contain no serviceable parts. Its disassemble leads to immediate viod of warranty. Controller firmware and supplied software tools are considered to be a part of the ESC3 controller. Any unauthorized changes in the software or firmware leads to immediate void of warranty.

ESC3 controller and supplied software contain system of user accounts and passwords with different acces rigts. Any attempt (succesfull or not) for unautohorized access leads to immediate void of warranty.

Chapter 3: Ordering codes

3.1 Product identification – *MPN* and *s/n*

Each product is identified by two identification numbers. First number is *MPN* (manufacturer part number) and second number is *s/n* (serial number). First number fully defines type and variant of the product and is not unique – two products with same number can (and will) exist. Second number is *s/n*, and is unique for each product. Two products with same *s/n* can not exist. Both numbers are printed on product's tag, as shown in the figure 3.1.

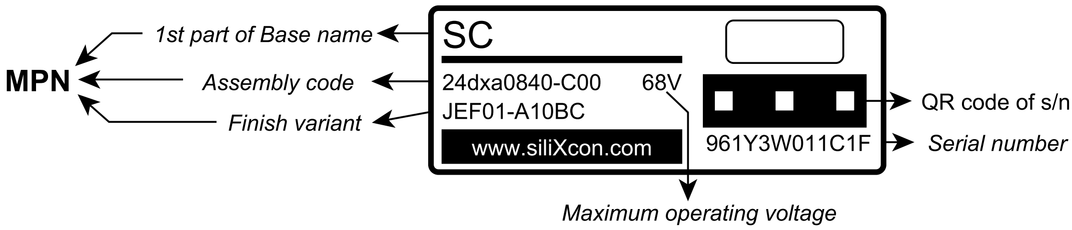

Figure 3.1: SC controller product tag

MPN constists of several parts, as shown in the figure 3.2. First part of the *MPN* is so called *Base name*. This name denotes firmwares that could be loaded into the product. For each *Base name* could be available one or more firmwares. Examples of *Base names* and compatible firmwares:

- *SC-felix* – firmwares for ground vehicles (bikes, motocycles, scooters, cars ...)
  - LYNX – firmware for e-bikes
- *SC-raptor* – firmwares for RC models (cars, planes, boats, drones ...)
  - FALCON – firmware for drones and planes
- *SC-serpent* – firmwares for electric drives in indrustry
  - OPHION – firmware for industrial applications
- Custom firmware – siliXcon can develop custom firmware to meet customer requirements

Second part of the *MPN* is so called *Assembly code*. It defines size of the controller, its voltage and current rating, present communication interfaces, compatible motor sensors and power features of the controller.

Third part of the *MPN* is so called *Finish variant*. It defines some additional HW configuration, used signal and power wiring, heatsing and enclosure.

3.2 Product variants

The SC controller is very versatile product. To match all specific requirements, multiple properites can be adjusted, so many variants exists. Different variants are denoted by different *MPN*. In the following section are described the most usual configurations of the SC controller, reffered as *standard variants*, *default variants* and also as controller *models*. All of these configuration have a lot in common, differences are in:

- Avaliable firmware releases, thus different functionality
- Operating voltage
- Motor and battery continuous current

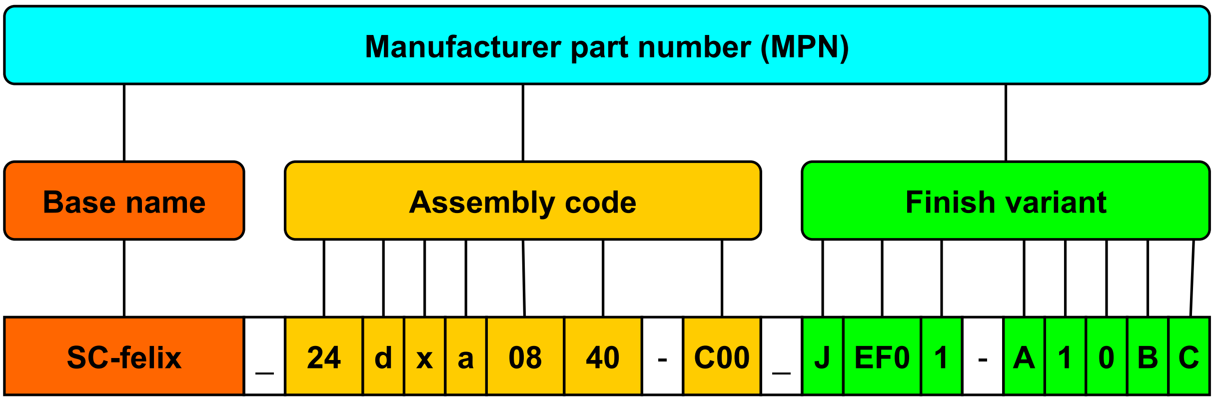

Figure 3.2: Example of *MPN*

SC controller is available for three basic categories, denoted by its *basename*:

- SC-felix – with LYNX firmware, specially designed for wheeled vehicles, such as cars, e-bikes or scooters
- SC-raptor – with FALCON firmware, specially designed for aircraft appliance, such as powerful RC models or drones
- SC-serpent – with OPHION firmware, specially designed for use in industry

Each basename of the SC controller is available in two voltage variants:

- Model 1 – 80 V limit voltage (refer to chapter 4 for more information)
- Model 2 – 100 V limit voltage (refer to chapter 4 for more information)

Possibilites listed above gives together six variants of the SC controller, each with ist unique MPN (manufacturer part number):

- SC-felix model 1: SC-felix_24dxa0840-C00_JEF01-A10BC
- SC-felix model 2: SC-felix_24dxa1040-C00_JEF01-A10BC
- SC-raptor model 1: SC-raptor_24dxa0840-C00_JEF01-A10BC
- SC-raptor model 2: SC-raptor_24dxa1040-C00_JEF01-A10BC
- SC-serpent model 1: SC-serpent_24dxa0840-C00_JEF01-A10BC
- SC-serpent model 2: SC-serpent_24dxa1040-C00_JEF01-A10BC

Table 3.1: Parameters of SC controllers

Parameter	Variant code	Description
Controller size	24	24 transistors in the power stage
Power features	d	No additional power features
Connectivity	x	USB, isolated CAN Bus, isolated UART (5 V log. levels), General purpose I/O
Motor sensors	a	Analog sensor input (Sin-Cos), three Hall sensors, single-ended digital sensor (SSI), sensorless control
Limit voltage (model 1)	08	80 V abslotute maximum, refer to chapter 4
Limit voltage (model 2)	10	100 V abslotute maximum, refer to chapter 4
Current range	40	400 A measurement range of phase current (amplitude)
Internal HW configuration	C00	*Flip-flop circuit* is used for powering the controller (refer to chapter 8), galvanic isolation enabled, no CAN terminator
Signal connectors type	J	JST JWPF connectors used in signal wiring
Present signal connectors	EF0	USB, CAN, UART 5 V, Powering connector, Control I/O 1, Control I/O 2, Motor sensors (refer to chapter 11 for pinout)
Signal wires	1	10 cm length, AWG24, PVC insulation
Power connectors	A	Amass AS150 for battery, Amass XT150 female for motor
Power wires	1	10 mm^2 (AWG7), SIFF insulation, 10 cm length
Charging	0	Controller is not capable of battery charging
Housing	BC	Aluminium housing with mounting holes, waterproof, black color

3.3 Connectors ordering codes

If ordering custom combination of connectors, complementary connectors or spare connectors, please refer to the table below. Second column is code of connector which goes from the controller, third column is code of complementary connector to it, this connector goes from battery, motor, display etc...

Table 3.2: JST JWPF connectors order codes

Connector name	Connector ordering code	Complementary connector ordering code
USB	JM4_USB/11	C-JF4_USB/11
Power	JF3_PWR/11	C-JM3_PWR/11
UART COM +5V	JF4_UARTCOM5/11	C-JM4_UARTCOM5/11
Control I/O 1 (Analog in)	JF4_CNTRL1/11	C-JM4_CNTRL1/11
Control I/O 2	JF8_CNTRL2/11	C-JM8_CNTRL2 /11
CAN	JM3_CAN/11	C-JF3_CAN/11
Motor sensors	JM8_MSENS/11	C-JF8_MSENS/11

Note: All listed connectors are with wires, length 11 cm, AWG24, PVC insulation.

Table 3.3: Power connectors order codes

Connector name	Connector ordering code	Complementary connector ordering code
Set of battery connecotrs AS150 (Note 2)	AS150-SET	—
Motor connector XT150 (female)	XT150-F	C-XT150-M

Note 1: All listed connectors are without wires – connectors only.
Note 2: Set consists of one pair of black connectors and one pair of red connectors. Red male connector is the antispark one.

Table 3.4: JST JWPF connectors housings and crimps

Connector	Male order code	Female order code
2 pin	JM2	JF2
3 pin	JM3	JF3
4 pin	JM4	JF4
8 pin	JM8	JF8
crimps	CONTACT_SWPT-001T-P0.25-M	CONTACT_SWPR-001T-P0.25-F

Chapter 4: Electrical specifications

4.1 Input voltage

Table 4.1: Voltage rating

Parameter	Assembly code	
	0840	1040
Non–operational overvoltage limits	16 – 80 V DC	16 – 100 V DC
Safe voltage range	18 – 74 V DC	18 – 92 V DC
Operating voltage range	18 – 68 V DC	18 – 84 V DC
Battery configuration	16 S	20 S
Battery nominal voltage	57.6 V DC	72 V DC

Note: specifications are valid only in motor mode with field weakening turned off. Contact siliXcon for more information when using motor in generator mode and/or when using field weakening.

Non-operational overvoltage limits: outside given range is controller in critical error and power stage is completely turned off, hardware damage is possible. When overvoltage conditions pass over, controller remains shut down and has to be disconnected from battery manually. After reconnecting it to battery again, controller may work, but its reliability could be lower due to partial damage of FETs caused by overvoltage. If controller is shut down by undervoltage, no risk of hardware damage is taking place, but still it has to disconnected from battery and then connected to battery with sufficient voltage.

Safe voltage range: outside given range controller power stage is shut down, there is no risk of damage until voltage reaches non-operational overvoltage limits. Limiter is cycle-by-cycle type, crossing safe voltage range results in power limiting or power stage shutdown to prevent further damage. When voltage get back to limits, power stage is re-enabled again automatically. When using regen braking, controller could limit braking power to prevent battery reaching *Safe voltage range limit*.

Operating voltage range: inside given range controller is active and output power is not limited.

Battery configuration: number of cells in series for Li-ion or Li-Po battery pack.

Battery nominal voltage: nominal voltage of Li-ion or Li-Po battery pack.

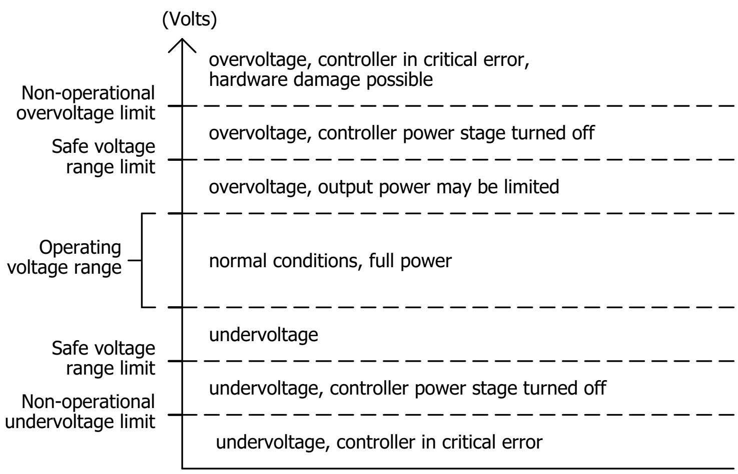

Figure 4.1: Controller voltage limits

4.2 Back-EMF of the permanent magnet motors

Motor with permanent magnets induce voltage (back-EMF) when spinning. This voltage is proportional to motor's rpm. When operating the motor over its nominal rpm, the amplitude of the back-EMF should never exceed *Non-operational overvoltage limit*. This could be achived by proper settings of flux-weakening (refer to *Driver manual*). In addition, battery can not be disconnected from controller during such operation (not by manual switch nor by safety feature of possibly integrated BMS). Impedance of the used battery has to be comparable to impedance of the motor.

4.3 Motor nominal voltage

The SC controller is basically DC to AC converter and it can drive many types of electric motors. Considering nominal voltage, electric motors can be divided to the two main groups – DC motors and AC motors. Nominal voltage of these two groups of motors are defined in a different way, so the relationship between nominal voltage of motor and nominal voltage of battery is different. These voltages should match in the following way:

For DC motors – brushed DC motor and brushless DC motor (called also BLDC or trapezoidal motor) – nominal voltage of the motor should be equal to nominal voltage of battery pack, because nominal voltage of the motor is defined as *DC voltage*.

For AC motors – induction motor and brushless AC motor (called also BLAC or sinusoidal motor) – nominal voltage of the motor should be 1.414 times lower than battery nominal voltage, because nominal voltage of the motor is defined as *link voltage* (RMS value of sinusoidal voltage between two phases).

4.4 Output power and current

Similar to nominal voltage, nominal current is defined in different way for *AC motors* and for *DC motors*. Also motor power is calculated in different way. For each group of motors there is one table with current and power output rating.

Table 4.2: Power and current rating of the SC controller with BLDC motor connected

Parameter	**Assembly code**	
	0840	**1040**
Maximal power dissipation	120 W (2)	
Nominal power (60 min)	10900 W	12600 W
Nominal current (60 min)	190 A	175 A
Battery current	190 A	175 A
Peak power (10 sec)	17300 W	18000 W
Peak current (10 sec)	300 A	250 A

Note 1: listed power (peak and nominal) is output power from the controller (input power to the motor). Output power from the motor (mechanical power) is dependent on the efficiency of the motor and controller setting.
Note 2: Controller bottom pad thermally connected to infinite heatsink which does not exceed 60°C

Table 4.3: Power and current rating of the SC controller with BLAC or induction motor connected

Parameter	Assembly code	
	0840	1040
Maximal power dissipation	120 W (2)	
Nominal power (60 min)	10600 W	11500 W
Nominal current (60 min)	150 A	130 A
Battery current	185 A	160 A
Peak power (10 sec)	17000 W	17600 W
Peak current (10 sec)	240 A	200 A

Note 1: listed power (peak and nominal) is output power from the controller (input power to the motor). Output power from the motor (mechanical power) is dependent on the efficiency of the motor and controller setting.
Note 2: Controller bottom pad thermally connected to infinite heatsink which does not exceed 60°C

4.5 Additional electrical parameters

Table 4.4: Additional electrical parameters

Parameter	Value	Notes
PWM frequency	20 kHz	
Minimum pulse width	1 µs	
Maximum electrical revolutions	100 000 el. RPM	
Minimum motor inductance	15 µH	phase to phase
Battery / power supply impedance	—	comparable or less than motor impedance (Note)

Note: The higher the battery impedance is, the higher are voltage spikes caused by flowing current. If the voltage spikes are higher than Non-operational overvoltage limit, damage of the controller could occur.

4.6 Output protection and current limiting

Inputs and outputs of the controller are protected against shorting it to each other in following manner:

- Each phase is protected against shorting it to another phase
- Phase A and C are protected against shorting it to BATT+ and $BATT-$
- Signal pins with voltage lower than 5 V are protected against shorting them to each other.

Advanced protections such as maximal power protection, undervoltage, overvoltage, thermal protection or cycle-by-cycle current limiting are also implemented in the SC controller. These advanced protections are described in detail in the *Driver manual*.

4.7 EMC specifications and guidelines

Controller performs very rapid switching of high currents. This is a key principle of it's operation and it can generate electromagnetic interference. The EMC performance is always matter of the whole product, not only of the controller itself.

RC network is connected batween power stage of the controller and aluminium heatsing to improve the EMC performance. Schematic of this network is shown in the figure 4.2.

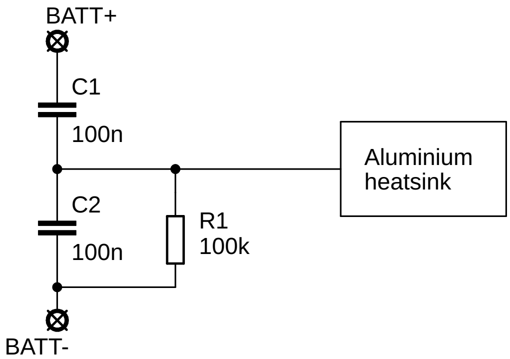

Figure 4.2: RC network between power stage and heatsink

To improve EMC performance, following guidelines should be kept in mind:

- Use power wires with appropriate cross-section. Higher cross-section means lower resistance, lower voltage drops and lower thermal losses.
- If possible, use short wires. Similarly to the previous point, shorter wires have lower resistance.
- Use shielded cables. Shielding should be connected to appropriate ground. Shielding should be connected only on one side of the cable to prevent ground loops.
- Use twisted pairs. Wires with differential signals (such as CAN Low and CAN High) should be twisted together. Wires with non-differential signals should be twisted together with appropriate ground.
- Twist power wires. To improve EMC performance, twist BATT+ with BATT− and twist together phases A, B and C.
- Place signal wires separately from power wires. When crossing power wires with signal wires, power wires should be perpendicular to signal wires.
- If possible, connect motor chassis to BATT− close to the controller. If the motor chassis can not be connected to BAT−directly, connect safety capacitor (Y capacitor) between them.
- To prevent ground loops, use galvanic isolation.
- Use signals with appropriate grounds. Do not mix signal grounds and power grounds. Even if the power ground and signal grounds are galvanically connected inside of the controller, they can not be mixed up outside of the controller.

Chapter 5: Mechanical specifications

5.1 Basic information

Table 5.1: Basic mechanical parameters of the SC controller

Parameter	Bare board	Sealed enclosure
Width	114 mm	131 mm
Height	29 mm	35 mm
Depth	50 mm	66 mm
Weight	55 g	570 g

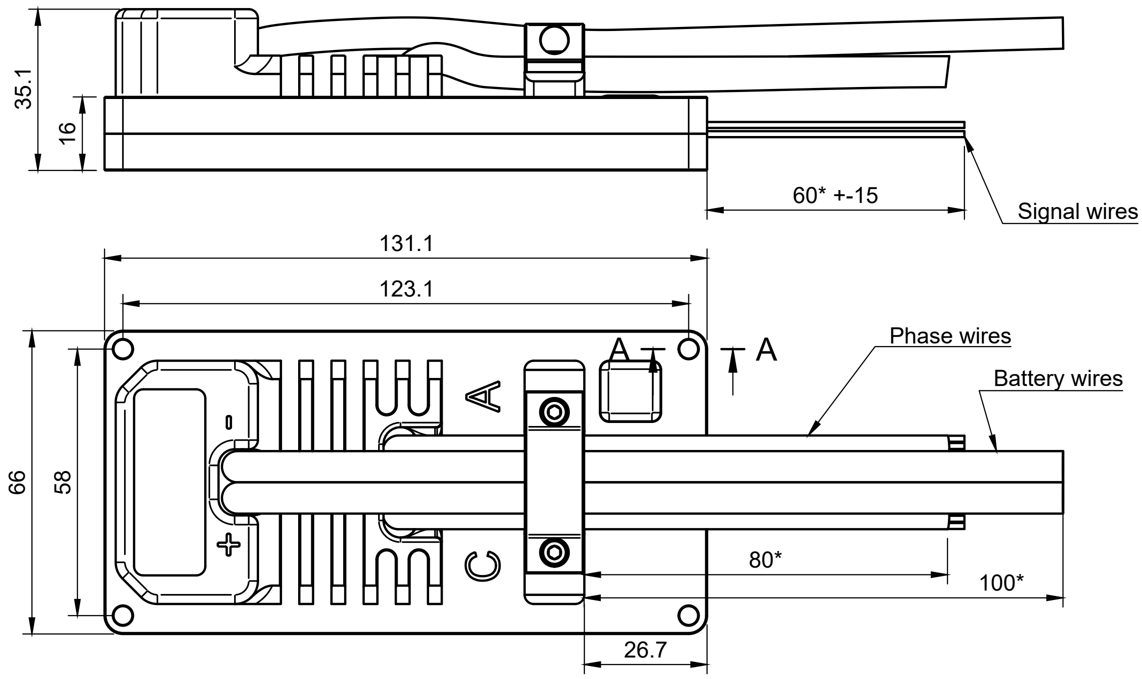

Figure 5.1: Dimensions of the SC controller

Mounting torque Recommended mounting torque for M4 screws is $T_{M4} = 3\,\mathrm{Nm}$ and for M5 screws is $T_{M5} = 6\,\mathrm{Nm}$.

Chapter 6: Enviromental specifications

Table 6.1: Storage and operation conditions of the SC controller

Parameter	**Value**			
	min.	**typ.**	**max.**	**units**
Temperature				
Operation (no power limitation)	−20		60	°C
Operation (limited power) (1)	−20		80	°C
Humidity				
Operation	5		85	%
Ingress of dust and water				
Internal electronics – sealed (2)		IP65		
Internal electronics – non-sealed (3)		IP40		
Connectors – JST JWPF (4)		IPX7		
Connectors – Amass AS150 and XT150		—		
Other connectors	according manufacturer specification			

Note 1: Long device operation at high temperatures reduces device's life
Note 2: Sealed enclosure and cables secured against any movement
Note 3: Non-sealed enclosure or cables not secured against movement
Note 4: All connectors has to be properly mated

Chapter 7: Thermal specifications

Table 7.1: SC controller thermal specification

Parameter	Value	Conditions
Maximal power dissipation	120 W	controller thermally connected to infinite heatsink which does not exceed 60°C
	15 W	controller in aluminium housing, in still air of temperature 25°C
Thermal resistance	0.25 K/W	to the bottom pad of aluminium housing
Limiting temperature	90°C	Temperature is measured inside the controller, near transistors, above this temperature is output power limited to prevent controller overheat.

7.1 Power dissipation calculation

During controller operation heat is generated inside the controller. Two major mechanisms are taking place: conductance losses and switching losses. First mechanism is in low-voltage high-current (such as SC controllers) application dominant, the second one is rather marginal. Conductance losses are proportional to resistance and square of current, switching losses are proportional to frequency, battery voltage, motor current and switching time of transistors.

You should also consider the type of driven motor, because their nominal values has different meaning.

For **AC motors** (BLAC, Induction) the nominal values are RMS value of *link* voltage and RMS vlaue of *phase* current.

For **DC motors** (BLDC, brushed motor) the nominal values are DC value of voltage and DC value of current.

With respect to the facts listed above, the calculation of power losses is different for DC motors and for AC motors. In additon, the losses are affected by assembly variant of controller. Power dissipation is calculated from this formula:

$$P_{TOT} = 1 + k_c \cdot I_N^2 + k_s \cdot V_{BATT} \cdot I_N \qquad [\mathrm{W}] = [\mathrm{A}]; [\mathrm{V}]; [\mathrm{A}]$$

V_{BATT} is battery voltage in volts, I_N is nominal current of motor in Amps (DC value for DC motors and RMS value for AC motors). Units of result P_{TOT} are Watts. Coefficient k_c describes conductance losses and coefficient k_s describes switching losses. Both coefficients are dependent on assembly variant and on type of motor. All of them are listed in table 7.2.

Table 7.2: Power losses coeficients for SC controllers

Assembly code	DC motor		AC motor	
	k_c	k_s	k_c	k_s
0840	0.0029	0.00095	0.0043	0.0026
1040	0.0034	0.00097	0.0051	0.0026

7.2 Mounting notes

To achieve maximal performance and reliability of controller you should provide sufficient cooling for it. Below are listed several tips, which could help to achieve this:

- Place controller in well ventilated area. Rather use sealed, waterproof housing and put it out of the vehicle than putting it inside. Contact with moving air improves cooling.

- If possible, fasten the controller to large metal parts, such as frame. It works as heatsink and help to conduct heat away.
- If using external heatsink or fastening controller to metal parts, make sure that both surfaces are flat, clean and fit to each other. After that, apply suitable amount of thermal grease to both surfaces.
- When applying thremal grase, use rather little of it than too much.
- If thermal grase is not available, you could use normal grase instead.

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Chapter 8: Powering interface

Control electronics of the SC controller is powered from pin 1 KEY. This pin is connected to BATT+ via internal fuse by default. However, this pin do not control power state of the controller, it only supplies voltage to the control electronics. Power state of the SC controller is controlled by pin 2 POWER. Prefered method of the SC controller powering is the two buttons control. Controller is powered on by pressing ON button and powered off by pressing OFF button. Using the OFF button is not mandatory, controller can be turned off automatically, by software. Schematic of this connection is shown in the figure 8.1.

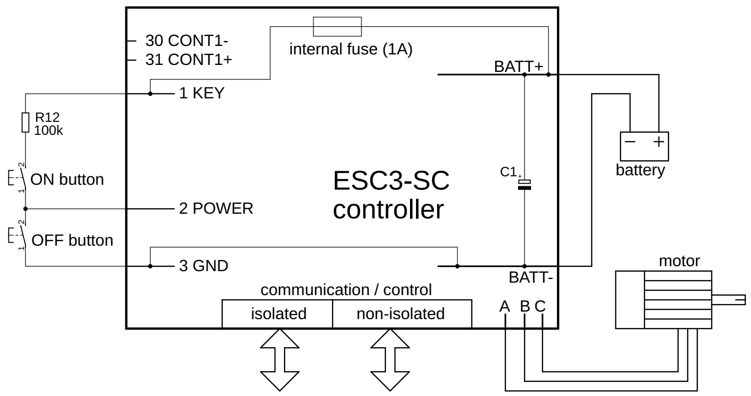

Figure 8.1: Two buttons powering scheme

8.1 Control electronics powering

Control electronics is powered from pin 1 KEY, which is connected to BATT+ via internal fuse by default. If the internal fuse is blown, it is possible to power the controller by connecting the pin 1 KEY to BATT+ via external fuse (1 A rating, non-reversible fuse). For correct function of battery voltage measurement, pins 1 KEY and BATT+ has to be connected by low impedance (either internal or external fuse).

Pin 2 POWER is used for managing controller power state. Input of the flip-flop circuit is connected to this pin. Flip-flop circuit allows to control power state by pulses. Positive pulse sets the flip-flop and power on the controller, negative pulse resets the flip-flop and power off the controller. Presence of the flip-flop circuit also enables the auto power-off feature of the controller – controller can power itself down automatically, by software.

8.2 Capacitors discarge

Power stage of the controller employs a capacitor bank with high capacity high-quality and low-ESR electrolytic capacitors. These capacitors are required for proper function of the controller. When connecting controller to the battery, sparking could occur because of high inrush current. This high inrush current is caused by charging the discharged capacitors. Capacitors could stay charged for a long time after battery is disconnected (even several hours). This could lead to electric shock and injury even if controller is completely disconnected.

Always check the voltage between terminals BATT+ and BATT− before handling the controller.

8.3 Power pins specifications

Table 8.1: Power control pins

Pin	Name	Description	Direction	Parameters, max. range
1	KEY	Power input for internal electronics, capacitors precharge and contactors, can be connected to BATT+ via internal fuse	Power I/O	0–V_{NOM}, max. 1 A
2	POWER	Controller ON/OFF input, active high	Input	0–V_{NOM}, max. 10 mA
3	GND	Ground, internally connected to BATT−	Power I/O	0 V, max.1 A

Note 1: All pins are related to the pin 3 GND.
Note 2: V_{NOM} is upper limit of *Operating voltage range*, refer to section 4.1.

Chapter 9: Control interface

9.1 Power supplies in the controller

The SC controller has several power supplies, and power pins, each of them is intended for specific use. Block schematic is shown in the figure 9.1. These supplies are:

- Battery power supply – pins 01 KEY and 03 GND. Battery is connected to these pins via fuse (internal or external, internal is 1 A non-reversible fuse). Voltage is present even if the controller is powered off. Voltage is equal to V_{BATT}, maximum current consupmtion is 1 A.
- Contactor control – pins 30 CONT+ and 31 CONT−. Pin 30 CONT+ is connected to the pin 01 KEY internally. Pin 31 CONT− is open-drain type and in on-state is connected to the GND/BATT−.
- Motor sensors power supply – pins 29 HALL+5V and 24 HALLGND. Power supply for powering motor sensors. Voltage is 5 V, maximum current consumption is 50 mA. This power supply is galvanically connected with battery.
- Isolated power supply – power supply for GPIOs. IO+3V, IO+5V, IO+10V and IOGND. This power supply is galvanically isolated from battery, but is **not** isolated from CAN power supply and UART power supply. These communication power supplies are derived from the *isolated power supply*

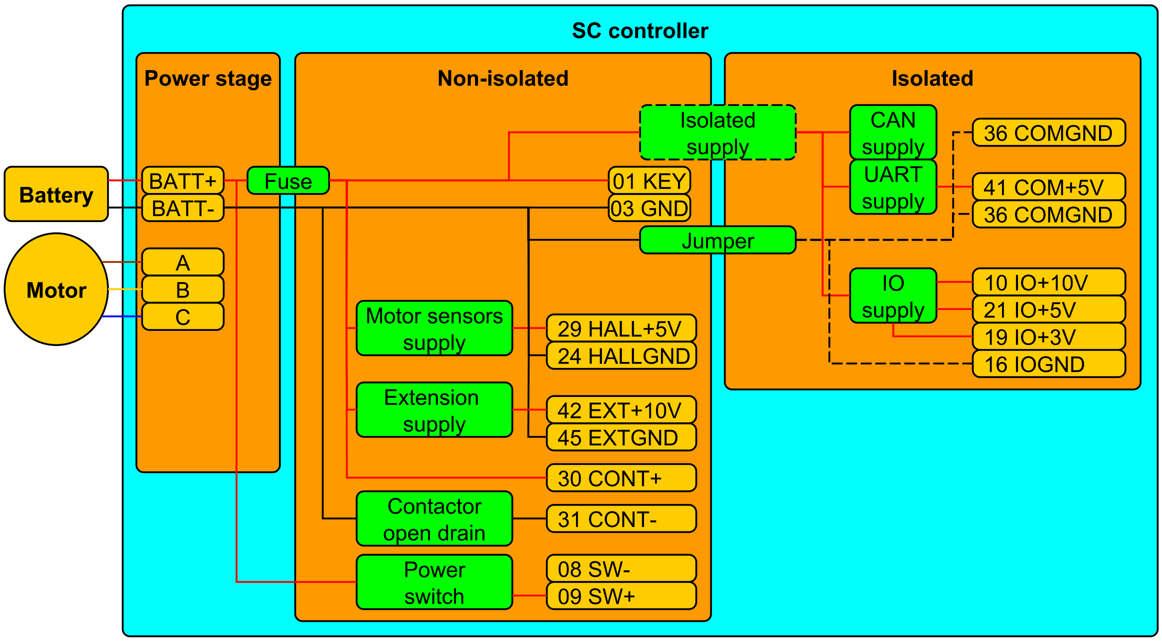

Figure 9.1: Block schematic of controller power supplies

9.2 Galvanic isolation

Some interfaces of the SC controller are galvanically isolated from rest of the controller. This feature enables easy and safe cooperatin between controller and other systems. If connected correctly, galvanic isolation helps to reduce electrical interference and give more options to connect system grounds and power supplies properly.

The SC controller is equipped with one galvanically isolated part. To this part belongs CAN Bus, UART and GPIOs. These three interfaces are galvanically isolated from rest of the controller (power stage, battery, USB, digital inputs ...) but they are **not** isolated from each other – CAN Bus, UART anf GPIOs use the same ground, which is accessible on pin IOGND (pins 16, 18, 20 and 22). Block schematic is shown in the figure 9.2. Grounds are isolated by default.

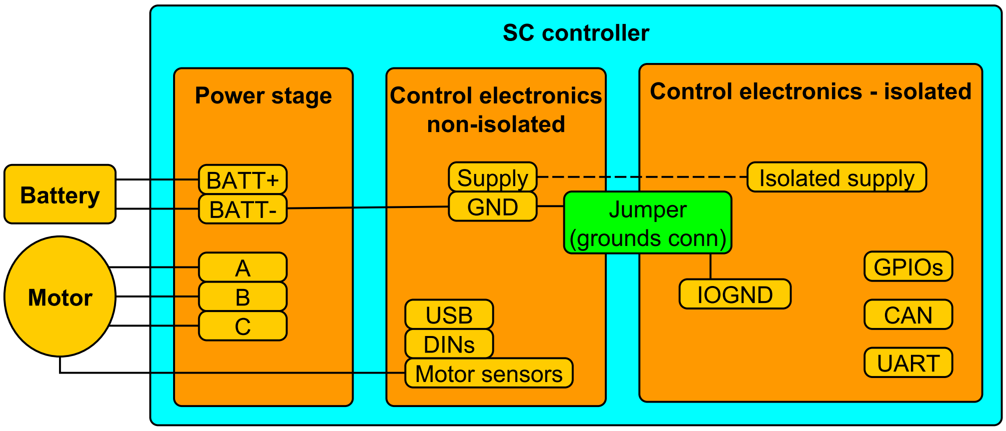

Figure 9.2: SC block schematics – galvanic isolation

9.3 Built-in LED

The SC controller has built-in LED which indicates propagation of the control program in microprocessor. When controller is powered on, followinf steps take place:

1. Bootloader – check some very basic information as firmware version and checksums. If ok, it passes control to the main program. During this stage is built-in LED not driven and it lights very briefly. If controller remains in this state for longer than few seconds, there is some problem with firmware. Try to update the firmware.
2. Main program – lits the built-in LED and starts initialization of the *Driver*. When initialized (successfully or not), main program passes control of the built-in LED to the *Driver*.
3. Driver – the part of the firmware, that deals with motor control. It also controls the built-in LED to inficate its own state:
   - LED is turned off – *Driver* was successfully initialized and motor could be driven or is driven already.
   - LED lights solidly – *Driver* status word is different than 0. Some *High priority limiter* could took place. If condition for LED light passed away, built-in LED is turned off after 2 seconds timeout. Refer to the *Driver manual* for more information about *High priority limiters* and *Driver* status word.
   - LED is blinking – some error occured during *Driver* initialization or during runtime. LED blinks for 16 times, then waits for longer time and repeat sequence again. Each blink has meaning of one bit from controller error word. Long blink is for logic 1, short blink is for logic 0. Blinks go from LSB to MSB. Refer to the *Driver* manual for more information about controller error word.

9.4 Communication

9.4.1 USB

The SC controller is equipped with native USB communication. USB pins are **not** galvanically isolated from power stage of the controller (it is recommended to use USB isolator). USB is intended for system maintenance like firmware update or off-line settings and is not intended for run-time settings and debugging. The best practice is to power off the controller, disconnect it from power source/battery and after that connect controller via USB to computer. USB provides enough power for microprocessor but left the power stage unpowered.

Run-time control, diagnostics and debugging via USB is possible but not recommened. If not connected properly, ground loops could take place and increase electrical interference. This can result in unreliable or not working USB connection or even hardware damage to controller or connected computer. Better way, how to do run-time diagnostics and debugging is to use UART or CAN communication which are both galvanically isolated. If using run-time USB connection, you have to connect controller *first* to battery (or another power source) and *after* that connect USB. Connecting USB first leads to powering microprocessor from USB and leaving the power stage unpowered, even if battery is connected additionally.

USB driver installation, communication between controller and computer and firmware updates are described in *OS Manual*.

Table 9.1: USB pins

Pin	**Name**	**Description**	**Direction**	**Parameters, max. range**
4	USB+5V	USB 5V	Power input	5 V max. 300 mA
5	USBGND	USB ground, internally connected to BATT−		0 V
6	USBDM	USB data −	Input/output	0–3.3 V, 5 V tolerant, max. 10 mA
7	USBDP	USB data +		

Note: All pins are related to the pin 5 USBGND.

9.4.2 CAN Bus

CAN Bus is modern type of communication bus, widely used in industry and automotive. The SC controller is equipped with one, galvanically isolated, CAN Bus interface which is excellent for fast and real-time communication with speed up to 1 Mbps. Typical example of CAN Bus usage are electrical vehicles. Each wheel has its own motor and controller, controllers communicate with superior system and with each other via CAN Bus.

When connecting multiple devices via CAN Bus, their CAN high and CAN low pins are connected to the bus. CAN ground has to be connected with appropriate grounds of the other devices on the bus. Usually, ground is used as shielding. Both ends of the CAN Bus line should be terminated by 120 Ω resistor. Example of CAN Bus connection is shown in the figure 9.3.

Communication with computer via CAN Bus, required hardware and driver instalation is described in detail in *OS Manual*.

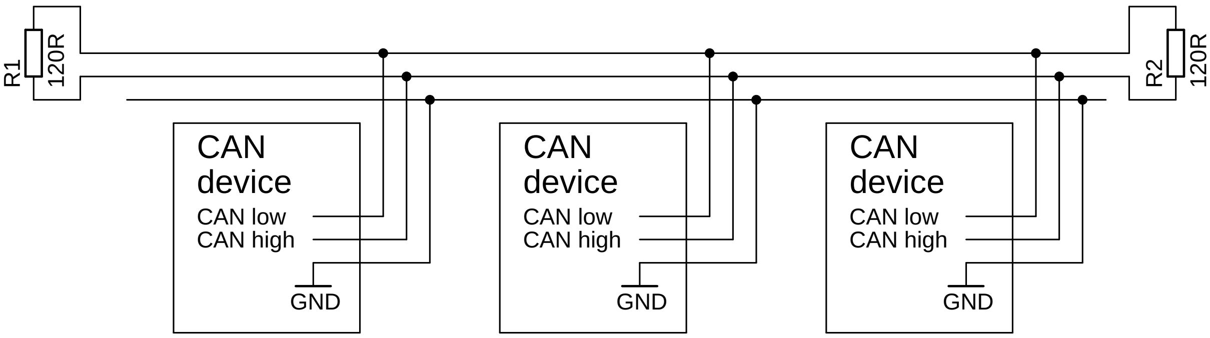

Figure 9.3: Connection of CAN Bus

Table 9.2: CAN Bus pins

Pin	Name	Description	Direction	Parameters, max. range
38	CANL	Galvanically isolated CAN LOW	Input/output	0–5 V, max. 10 mA
37	CANH	Galvanically isolated CAN HIGH		
36	COMGND	Galvanically isolated CAN ground Power output	0 V, max. 100 mA	

Note: All pins are related to the pin 36 COMGND.

9.4.3 Serial communication (UART)

The SC controller is equipped with one, galvanically isolated, UART by default. Logical levels are 0 V and 5 V. When UART is combined with UART-to-USB adapter, it can be used for controller run-time settings, diagnostics and debugging. USB-to-UART driver installation and communication between computer and controller is described in *OS Manual*.

Table 9.3: UART COM pins

Pin	Name	Description	Direction	Parameters, max. range
39	COMRXD	Galvanically isolated UART COM RX	Input	0–5 V, max. 20 mA
40	COMTXD	Galvanically isolated UART COM TX	Output	0–5 V, max. 20 mA
36	COMGND	Galvanically isolated UART COM ground	Power output	0 V, max. 100 mA
41	COM+5V	Galvanically isolated supply		5 V, max. 100 mA
10	IO+10V	GPIO 10 V power supply	Power output	10 V, max. 50 mA

Note: All pins are related to the pin 36 COMGND.

9.5 General purpose inputs/outputs

The SC controller has five general input/output[1] pins, which are all galvanically isolated. In a input mode, these pins can either work as digital or analog input pins. Analog inputs has 16 bit resulotion and sampling frequency about 1 kHz. They are also equipped with internal pull-up and pull-down resistors, which can be connected by software. This allows to change measurement range if needed. In addition, pull-up resistor enables to use potentiometer and pushbutton simultaneously on one GPIO pin. If used as digital inputs, pins can be configured as counters or timers, they could serve for reading PWM and PPM signals.

Combination of IO+10V, IO+5V, IO+3V, IOGND and GPIOs can create multiplexer for pushbuttosn, up to four pushbuttons can be connected to one GPIO pin. Schematic is shown in the figure 9.4.

These pins are powered from galvanically isolated power supply, which is common for GPIO pins, UART and CAN Bus. Supply voltages IO+3V, IO+5V and IO+10V are all derived from this power supply. If SC controller is used in e-bike or similar vehicle, pin 14 GPIO1 is typically used for regen/brake and pin 15 GPIO0 is used for accelerator.

[1]GPIOs has impedance about 47 kΩ by default, this can be changed on reguest – to work as low-impedance outputs

Table 9.4: GPIO pins

Pin	Name	Description	Direction	Parameters, max. range
11	GPIO4	Isolated general purpose analog/digital I/O	Input/output	47 kΩ impedance (2) max. 10 mA 0–8.5 V (3) −3.5–7.5 V (4) 0–12 V (5)
12	GPIO3			
13	GPIO2			
14	GPIO1	Isolated general purpose analog/digital I/O, typically brake		
15	GPIO0	Isolated general purpose analog/digital I/O, typically accelerator		
10	IO+10V	GPIO 10 V power supply	Power output	10 V, max. 50 mA
17	IO+3V	GPIO 3 V power supply		3 V, max. 50 mA
19				
21	IO+5V	GPIO 3 V power supply		5 V, max. 50 mA
23				
16	IOGND	GPIO ground		5 V, max. 250 mA
18				
20				
22				

Note 1: All pins are related to the pin 16 IOGND.
Note 2: Input / output impedance is 47 kΩ by default, can be changed on request
Note 3: Internal resistor disconnected, parameter `/common/ioconf` set to 0 (refer to chapter 12.5.1.
Note 4: Internal resistor connected as pull-up, parameter `/common/ioconf` set to 1 (refer to chapter 12.5.1.
Note 5: Internal resistor connected as pull-down, parameter `/common/ioconf` set to 2 (refer to chapter 12.5.1.

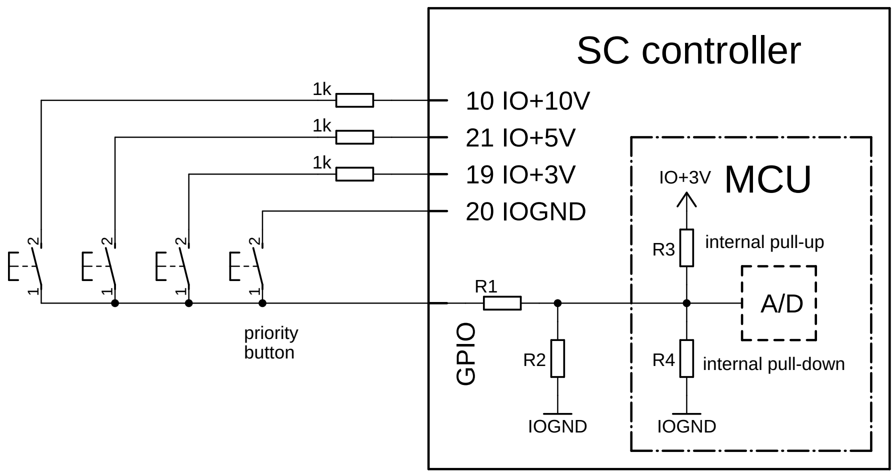

Figure 9.4: Four buttons multiplex schematic

Chapter 10: Motor sensors interface

Motor sensors interface of the SC controller is discussed in detail in this chapter. Physical principles and general advantages / disadvantages of the sensors are also briefly described in this chapter (more detail information can be found in the *Driver manual*).

10.1 Rotor position

Rotor positon (rotor angle) is the first variable to be sensed. This parameter is required by the motor driver algorithm. Especially when driving a PMSM motor, rotor position is updated periodically, as well as other measurements (motor currents and voltages). Based on these measurements and on demanded motor control mode, the driver algorithm switches the transistors in power stage of the controller.

In certain situations, the rotor position can be estimated from measurements of voltage and current. In this case rotor position sensor is not needed and motor is driven in *sensorless* mode. Situations, where rotor position sensor is present and working, are called *sensored* mode.

10.1.1 Sensored control

Advantages	**Disadvantages**
• Stable operation at zero-RPM • Do not depend on motor parameters • Sensor can be used for other purposes than motor control (trip counter, servo positioning ...)	• Additional hardware needed (sensor, wires...) • Certain probabily of hardware issues (sensor mounting position tolerance, vibraions ...) • Possible problems with sensor interference

10.1.2 Sensorless control

Advantages	**Disadvantages**
• No additional hardware needed (cheaper and more robust solution) • No positioning errors and smooth operation at higher speeds	• Motor parameters needed (could vary with temperature) • Sometimes do not work properly at zero-RPM

10.2 Motor temperature

Another parameter to be sensed is the temperature of motor. The temperature is sensed in order to protect insulation of the motor winding against thermal degradation. Temperature sensing in permanent magnet motor is also important to protect permanent magnets against demagnetization by temperature.

Motor temperature can be sensed by temperature sensor integrated in motor winding. Another possibility is to estimate motor temperature from resistance of motor winding.

10.2.1 Temperature sensor

Advantages	**Disadvantages**
• Better accuracy • Works even when motor is not driven • Sensing can be done in particular spots, where the risk of overheat is the highest	• Additional hardware needed (sensor, wires...) • Possible problems with sensor interference

10.2.2 Sensorless temperature estimation

Advantages	**Disadvantages**
• No additional hardware needed • Can be turned on for each motor • Average winding temperature is obtained	• Worse accuracy • Motor has to be driven (current needs to flow) • Motor parameters are needed • Can not be used in certain situation (field weakening, non-linear conditions, magnetic saturation ...) • Can not be used when BLDC driver algortihm is used

10.3 Electrical interface

This section describes the electrical interface of the SC controller which is used to obtain measurements from motor sensors (rotor position sensor and possibly also temperature sensor). Aim of this section is not to describe sensor physical principles. For more information regarding the sensor categhories, principles, advantages / disavantages and a selection guide, please refer to the *Driver manual*.

Motor control interface pins of the SC controller are listed in table 10.1. This interface has separated power supply with outputs on pins 35 HALL+5V and 24 HALLGND. Current capability of this power supply is 50 mA. This supply is not galvanically isolated from the battery. Using motor sensors' ground (pin 24 HALLGND) helps to connect all grounds properly without ground loops. Shielding of motor sensors' cable should be also connected to this pin.

Table 10.1: Motor sensors pins

Pin	Name	Description	Variant	Direction	Parameters
24	HALLGND	Hall sensors supply ground, internally connected to BATT−	h, a, r, d	Power output	0 V, max. 50 mA
29 35	HALL+5V	Hall sensors supply voltage	h, a, r, d	Power output	5 V, max. 50 mA
25	HALLW/COM	Hall sensor W	h, a	Input	0–3.3 V 5 V tollerant max. 10 mA
		Analog Sin–Cos SIN−, COS−	a	Input	
		Incremental encoder reference input	a	Input	
26	HALLV/SIN	Hall sensor V	h, a	Input	
		Analog Sin–Cos SIN+	a	Input	
27	HALLU/COS	Hall sensor U	h, a	Input	
		Analog Sin–Cos COS+	a	Input	
28	TEMP	Motor temperature sensor in	h, a, r, d	Input	
		General purpose analog input	h, a, r, d	Input	
34	ENCB/DATA	Incremental encoder B	h, a	Input	
		Digital input 1 (DIN1) (Servo PWM / PPM channel 1 input)	h, a	Input	
32	ENCA	Incremental encoder A	h, a	Input	
		Digital input 1 (DIN1) (Servo PWM / PPM channel 1 input)	h, a	Input	

Note 1: All pins are related to the pin 24 HALLGND.

10.4 Rotor angle sensors interface types

Several interfaces of rotor angle sensors exist. Usually, rotor angle sensor has one interface as output of he rotor position. Sensors with multiple interfaces also exists. In such case, user can choose which interface will be used. For example RLS AM4096 chip supports output of UVW commutation signal, Sin-Cos signal, incremental encoder signal and digital SSI interface.

10.4.1 UVW commutation signal

This signal is usually produced by three Hall sensors placed inside the motor in 120° (rarely by 60°) span along one electrical revolution. It can be also emulated by some advanced sensors, such as RLS AM4096. UVW commutation signal is composed of three digital signals. Each signal has two switchpoints per electrical revolution (first switchpoint is from log. HIGH to log LOW, second is from log. LOW to log. HIGH). Signals are shifted by 120° from each other (variants with signals shifted by 60° also exists). Example of the signals are shown in the picture 10.1. Example of connection is shown in the figure 10.2.

When the UVW commutation signal is processed, it gives six discrete levels of rotor position for one electrical revolution. In the six switchpoints between the levels, the motor position is known with the least ambiguity. This information is enough when BLDC motor driver algorithm is used. If the VECTOR control algorithm is used, these six switchpoints is not enough and positions between them has to be extrapolated. UVW commutation signal may not be the ideal choice (especially in applications where a high precission / motion control is required

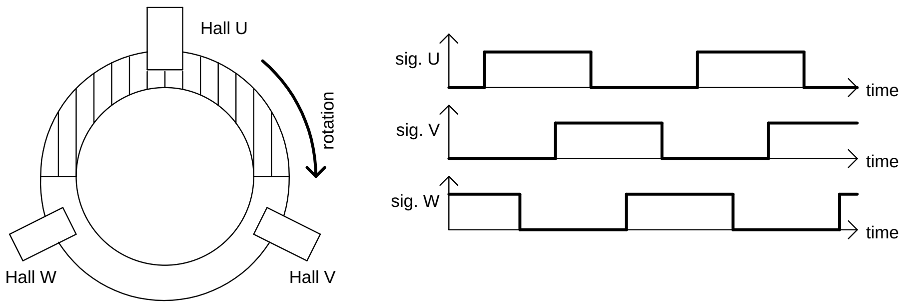

Figure 10.1: Example of UVW commutation signals

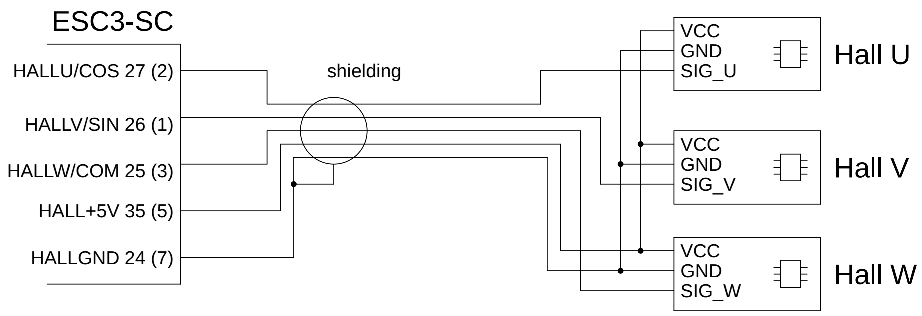

Figure 10.2: Connection of UVW commutation signal to the controller

at low RPM) for VECTOR driver algorithm since the position estimation is needed. Rotor position measuremnt using the UVW commutation signal is shown in the figure 10.3.

Advantages	Disadvantages
• Sense electrical (not mechanical) revolutions. No angle multiplication error occurs – it is suitable for motors with many polepairs. • Low frequency digital signal – good immunity against electrical interference. • Perfect solution for BLDC motors • Cheap	• Interpolation needed when used in VECTOR control algorithm • 13% ripple of generated torque during steady operation • About 13% to 50% torque ripple during stall or very low speed operation

Electrical interface parameters

- Sensor supply: 5 V, 50 mA
- Input type: with pull-up resistor (compatible with open-collector and with push-pull sensor output)
- Input impedance: 1 kΩ

Recommended types of Hall switches

- Infineon TLE4946-L2
- similar Hall switches types with *bipolar* sensing principle

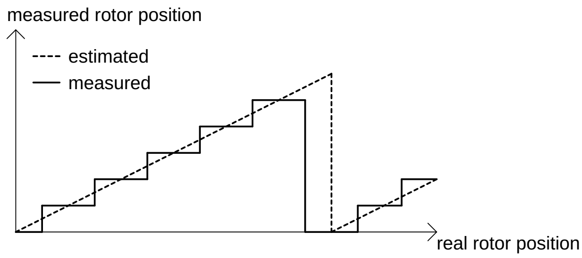

Figure 10.3: Rotor position estimation from UVW commuation signal

10.4.2 Sin-Cos signal

Sin-Cos signal is composed of two analog signals of sinusoidal shape. Signals are phase-shifted by quater of period and one period of sine (or cosine) signal corresponds to one mechanical turn of the motor (see figure 10.4 for ilustration). This type of signal is usually produced by sensor consisting of cylindrical permanent magnet glued to rotor and sensor chip located on the stator in defined distance from the cylindrical magnet. Connection of sensor with Sin-Cos interface to the SC controller is shown in the figure 10.5.

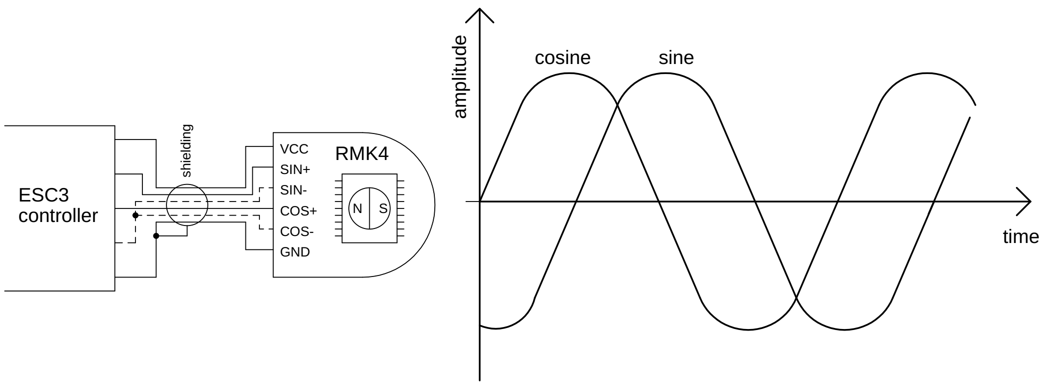

Figure 10.4: Sin-Cos sensor working principle

Advantages	**Disadvantages**
• Absolute and continuous position sensing • Suitable for VECTOR driver algorithm • Suitable for position servo drives • Usually very small dimensions	• Typically sense mechanical revolutions. Angle multiplication error could occur when using motor with many polepairs. • Analog interface – could be sensitive to electrical interference. • Need output offset calibration (can be done automatically by the controller) • Complicated semiconductor device prone to high temperatures, EMI ...

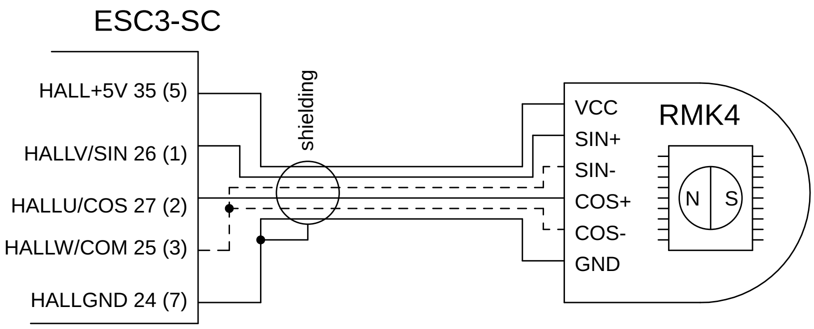

Figure 10.5: Connection of sensor with Sin-Cos interface

Electrical interface parameters:

- Sensor supply: 5 V, 50 mA
- Analog inputs type: single-ended or differential
- Input impedance: 1 kΩ

Recommended types of sensors with Sin-Cos output:

- RLS AM512B (evaluation board RMK1B)
- RLS AM256 (evaluation board RMK2)
- RLS AM8192B (evaluation board RMK3B)
- RLS AM4096 (evaluation board RMK4)
- Infineon TLE 5012

10.4.3 Incremental encoder interface

Incremental sensor inteface consists of, at least, two digital inputs (Enc A and Enc B). Sensor produces pulses on these two inputs. Each pulse means increment (or decrement) of current position by certain value. Since the pulses are phase-shifted by quater of period, direction of rotation can be determined from the phase shift.

When the absolute position (not only relative – the increments) is required, third input (Enc REF) is needed. This input provides short pulse once per turn of the sensor. This pulse marks the zero position of the sensor. Motor has to do one full mechanical turn to provide reference pulse and find the zero position (this procedure is called 'homing'). Then, the absolute position can be counted. Working principle of the incremental sensor is shown in the figure 10.6. Connection of the sensor to the SC controller is shown in the figure 10.7.

Advantages	Disadvantages
• Continuous position sensing • Sufficient precision • Suitable for driving induction machines	• Sense mechanical revolutions. Angle multiplication error could occur when using motor with many polepairs • Reference input and 'homing' procedure needed if the absloute position is required • Not suitable for permanent magnet motors

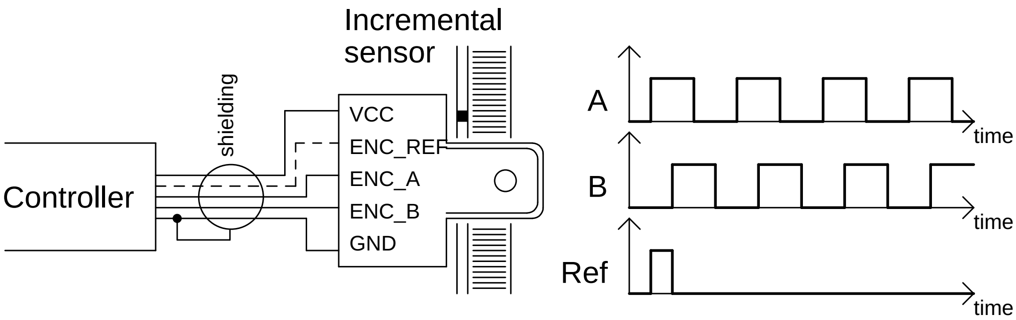

Figure 10.6: Incremental sensor working principle

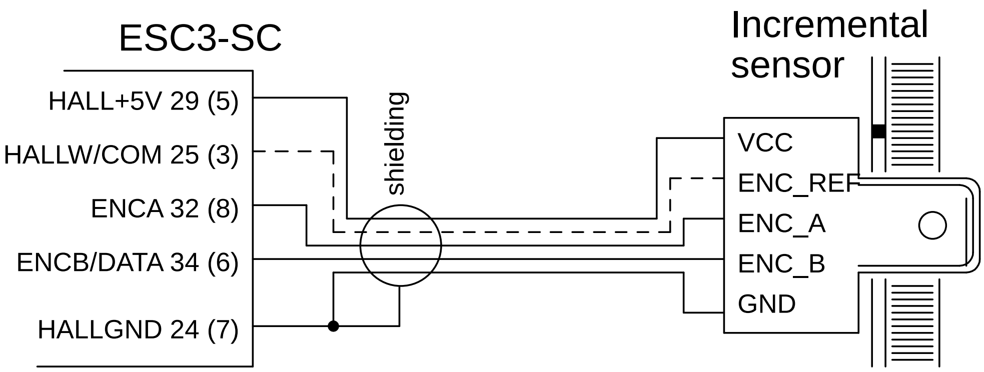

Figure 10.7: Connection of incremental sensor to the SC controller

Electrical interface parameters:

- Sensor supply: 5 V, 50 mA
- Input type: with pull-up resistor (compatible with open-collector and with push-pull sensor output)
- Input impedance: 1 kΩ

10.5 Winding temperature measurement

The SC controller has ability to measure temperature of motor winding using temperature sensor. Temperature sensor is connected between pin 28 TEMP and pin 24 HALLGND. Internal connection of the TEMP pin in the controller is shown in the figure 10.8. Various types of the sensors are supported, they has to meet following criteria:

- Measured temperature change results in change of resistance (thermocouples are not supported)
- Resistance of the sensor has to be within specified range (see specifications below)

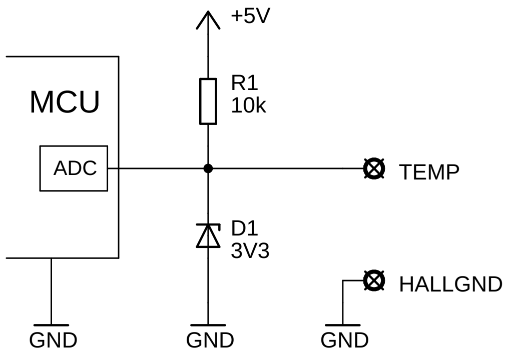

Figure 10.8: Internal connection of the TEMP pin

Electrical specifications

- Maximum voltage: 3.3 V
- Short-cut output current: 0.5 mA
- Resistance measure range: 15 Ω – 10 kΩ

Recommended temperature sensors

- **KTY81**
- any NTC with suitable resistance value
- any PTC with suitable resistance value

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Chapter 11: Pinouts

11.1 Board pinout

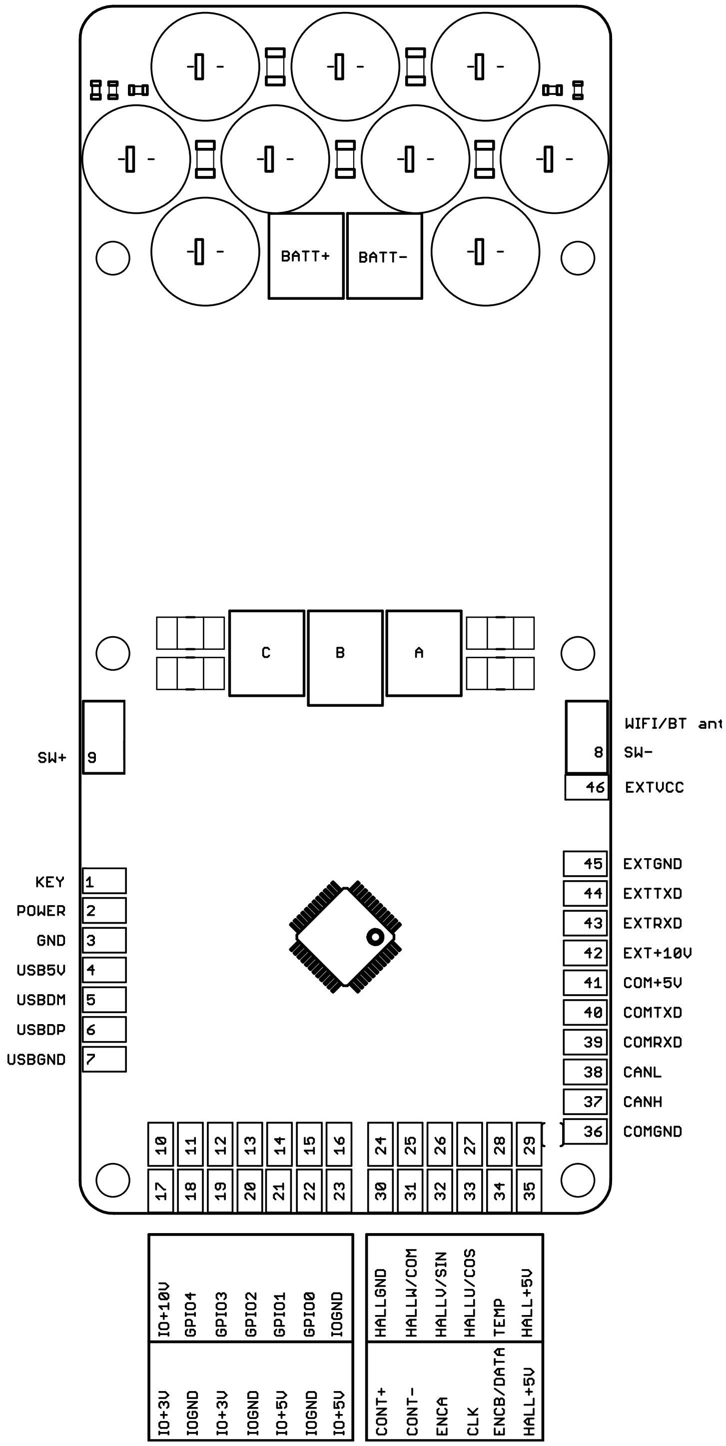

Figure 11.1: SC controller board pinout

11.2 Pin list & overview

Table 11.1: SC controller pin list

Pin	Name	Description	Direction
1	KEY	Control power supply	Power output
2	POWER	Controller ON/OFF input, active high	Input
3	GND	Ground, internally connected to B−	Power output
4	USB+5V	USB 5V	Power input
5	USBGND	USB ground, internally connected to B−	Power input
6	USBDM	USB data −	I/O
7	USBDP	USB data +	I/O
8	SW−	*Power switch* positive terminal	Power I/O
9	SW+	*Power switch* negative terminal	Power I/O
10	IO+10V	I/O 10 V power	Power output
11	GPIO4	General purpose I/O	I/O
12	GPIO3		
13	GPIO2		
14	GPIO1		
15	GPIO0		
16	IOGND	I/O ground, internally connected to B−	Power output
17	IO+3V	I/O 3 V power	
18	IOGND	I/O ground, internally connected to B−	
19	IO+3V	I/O 3 V power	
20	IOGND	I/O ground, internally connected to B−	
21	IO+5V	I/O 5 V power	
22	IOGND	I/O ground, internally connected to B−	
23	IO+5V	I/O 5 V power	
24	HALLGND	Motor sensors supply ground, internally connected to B−	Power output
25	HALLW/COM	Hall sensor W / common input	I/O
26	HALLV/SIN	Hall sensor V / SIN+	
27	HALLU/COS	Hall sensor U / COS+	
28	TEMP	Temperature sensor in / GPIO	
29	HALL+5V	Motor sensors 5 V supply	Power output
30	CONT+	Contactor output +	Power output
31	CONT −	Contactor output -	
32	ENCA	Encoder A	I/O
33	CLK	Clock	
34	ENCB/DATA	Encoder B / Data	
35	HALL+5V	Motor sensors 5 V supply	Power output

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Table 11.2: SC controller pin list

Pin	Name	Description	Direction
36	COMGND	Communication ground (CAN and USART)	Power output
37	CANH	CAN High	I/O
38	CANL	CAN LOW	I/O
39	COMRXD	Communication UART RX	Input
40	COMTXD	Communication UART TX	Output
41	COM+5V	Communication 5 V supply	Power output
42	EXT+10V	Extension 10 V supply	Power output
43	EXTRXD	Extension RXD	Input
44	EXTTXD	Extension TXD	Output
45	EXTGND	Extenson ground, internally connected to B−	Power output
	BATT+	Battery/power source input +	Power input
	BATT−	Battery/power source input −	Power input
	A	Motor phase A	Power output
	B	Motor phase B	Power output
	C	Motor phase C	Power output

11.3 Signal connectors pinout

11.3.1 JST JWPF connectors (variant J)

Table 11.3: USB connector

JST JWPF 4-pin male JM4_USB	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **white**	06 USBDP	USB data+
	2	● **green**	05 USBDM	USB data-
	3	● **black**	07 USBGND	USB ground
	4	● **red**	04 USB+5V	USB 5 V supply

Table 11.4: Power connector

JST JWPF 3-pin female JF3_PWR	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **brown**	01 KEY	Supply in/out
	2	● **yellow**	02 POWER	Power control input
	3	● **black**	03 GND	Ground

Table 11.5: UART COM connector (5 V variant)

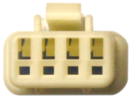
JST JWPF 4-pin female JF4_UARTCOM5	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **black**	36 COMGND	Communication GND
	2	● **white**	40 COMTXD	UART TX
	3	● **blue**	27 COMRXD	UART RX
	4	● **red**	41 COM+5V	+5 V output

Table 11.6: CAN connector

JST JWPF 3-pin male JM3_CAN	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **black**	36 COMGND	Communication GND
	2	● **yellow**	37 CANH	CAN high
	3	● **green**	38 CANL	CAN low

Table 11.7: Control I/O 1 (analog) connector

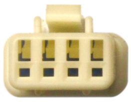
JST JWPF 4-pin female JF4_CNTRL1	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **black**	16 IOGND	Isolated ground
	2	● **blue**	14 GPIO1	Analog input (brake)
	3	● **green**	15 GPIO0	Analog input (throttle)
	4	● **red**	23 IO+5V	Isolated +5 V supply

Table 11.8: Control I/O 2 connector

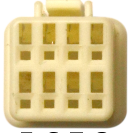
JST JWPF 8-pin female JF8_CNTRL2	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **orange**	10 IO+10V	Isolated +10 V supply
	2	● **yellow**	11 GPIO4	Isolated analog input
	3	● **blue**	12 GPIO3	Isolated analog input
	4	● **green**	13 GPIO2	Isolated analog input
	5	● **white**	17 IO+3V	Isolated +3.3 V supply
	6	● **black**	18 IOGND	Isolated ground
	7	● **black**	20 IOGND	Isolated ground
	8	● **red**	21 IO+5V	Isolated +5 V supply

Table 11.9: Motor sensors connector

JST JWPF 8-pin male JM8_MSENS_G	**Connector pin**	**Wire color**	**SC pin**	**Function**
	1	● **green**	26 HALLV/SIN	Hall V, Sin+ signal
	2	● **blue**	27 HALLU/COS	Hall U, Cos+ signal
	3	● **yellow**	25 HALLW/COM	Hall W, Sin−, Cos−
	4	● **white**	28 TEMP	Temperature sensor
	5	● **red**	35 HALL+5V	Sensor supply
	6	● **brown**	34 ENCB/DATA	Encoder B input
	7	● **black**	24 HALLGND	Sensor ground
	8	● **violet**	32 ENCA	Encoder A input

11.4 Power connectors pinout

11.4.1 Amass AS150, XT150 (variant A)

Figure 11.2: Battery connector pinout – Amass AS150 (controller side)

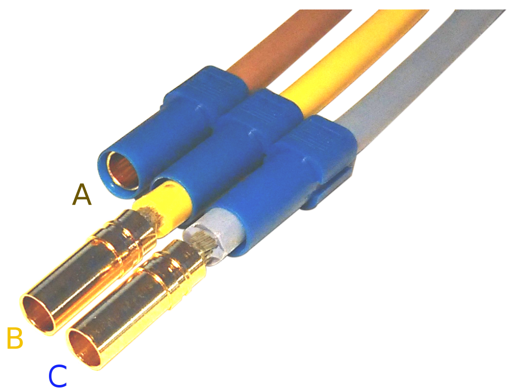


Figure 11.3: Motor connector pinout – Amass XT150 female (controller side)

Chapter 12: yOS interface

All ESC3 controllers runs yOS – propietary real-time operating system. This operating system is similar to Linux; items (directories and files) are organized in tree-like structure. States of hardware inputs are represented as values of variables in directory. Similarly, states of hardware outputs can be represented as values of variables in filesystem.

Variables representing state of hardware inputs are called *state variables*. These variables can not be modified by user or OS itself, because they only reflects what is happening in the input of the controller. State variables are time-dependent and their values are refresed automatically. For work with *state variables* is used command `stat`.

Another type of variables in yOS is *parameter*. This variable is not dependent on state of hardware input and can be modified by user or yOS. Parameters are used for configuration of hardware inputs. Setting parameter to certain value affects behavior of hardware inputs. For work with *parameters* is used command `param`.

Everything about filesystem, variable types and working with them is described in detail in *OS manual*.

12.1 Firmware structure and versions

Whole controller firmware (called release) is divided into few functional blocks, as shown in the figure 12.1. Some blocks are common for all ESC3 product, some of them differs from type to type and each block has its own version. Following part of this datasheet describes **COMMON I/O** block of firmware with version 1.0.

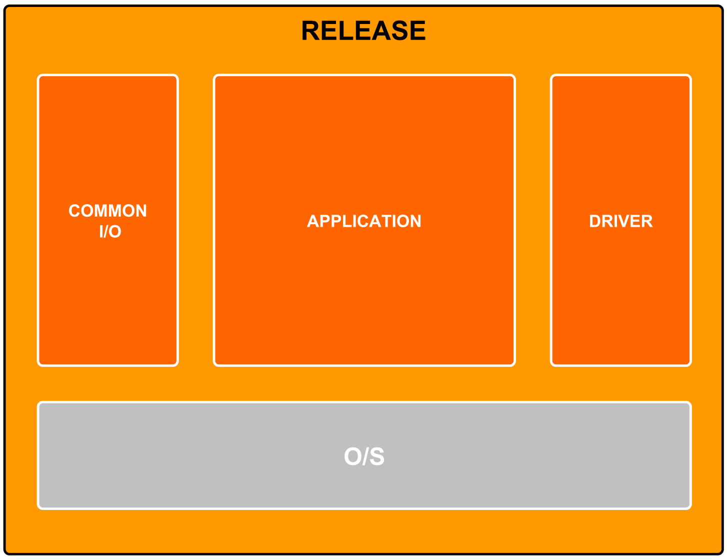


Figure 12.1: Block structure of release

12.2 Product signature

Each product has ability to identify itself during communication. This is done by *device signature*, which is number dedicated to certain type of the product. *Device signature* for the SC controller is number **11**.

12.3 Hardware inputs

State variables, representing hardware inputs, are located in directory `/common` in the root directory of the filesystem.

12.3.1 Vthermistor

`Vthermistor (float) [V]`
Thermistor voltage in volts. Thermistor is connected to pins 24 HALLGND and 28 TEMP. Thermistor has 10 kΩ pull-up resistor. Connection is shown in the figure 12.2.

12.3.2 Rthermistor

`Rthermistor (float) [Ω]`
Thermistor resistance in ohms. Thermistor is connected to pins 24 HALLGND and 28 TEMP. Thermistor has 10 kΩ pull-up resistor. Connection is shown in the figure 12.2.

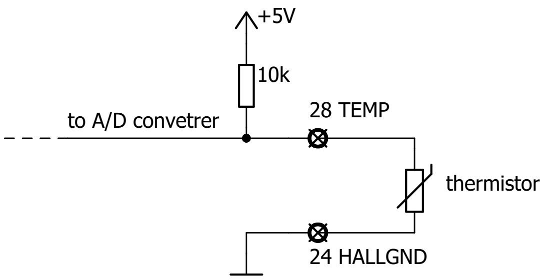


Figure 12.2: Thermistor connection

12.3.3 gpio0, gpio1 ... gpio4

```
gpio0 (int16) [mV]
gpio1 (int16) [mV]
...
gpio4 (int16) [mV]
```

Value on pin 15 GPIO0 (or other GPIOs) in real units, depending on application it can be milivolts, miliseconds or microseconds. When measuring voltage, effect of internal pull-up and pull-down resistor is counted, real voltage on pin of controller is displayed.

12.3.4 gdin0, gdin1 ... gdin4

```
gdin0 (int8)
gdin1 (int8)
...
gdin4 (int8)
```

Representation of digital state of pin 15 GPIO0 (or other GPIOs). Valid values of `gdin` and corresponding voltage levels are listed in table 12.1.

Table 12.1: `gdin` voltage treshold values

gdin value	pin voltage		
	`ioconf = 0` (pin floating)	`ioconf = 1` (pull-up)	`ioconf = 2` (pull-down)
3	$> 7.8\,\mathrm{V}$	$> 6.8\,\mathrm{V}$	$> 10.8\,\mathrm{V}$
2	$4.2\,\mathrm{V} < \mathrm{V_{gdin}} < 7.8\,\mathrm{V}$	$4.2\,\mathrm{V} < \mathrm{V_{gdin}} < 6.8\,\mathrm{V}$	$4.2\,\mathrm{V} < \mathrm{V_{gdin}} < 10.8\,\mathrm{V}$
1	$2.6\,\mathrm{V} < \mathrm{V_{gdin}} < 4.2\,\mathrm{V}$	$2.6\,\mathrm{V} < \mathrm{V_{gdin}} < 4.2\,\mathrm{V}$	$2.6\,\mathrm{V} < \mathrm{V_{gdin}} < 4.2\,\mathrm{V}$
0	$< 2.6\,\mathrm{V}$	$0.6\,\mathrm{V} < \mathrm{V_{gdin}} < 2.6\,\mathrm{V}$	$< 2.6\,\mathrm{V}$
−1	not defined	$< 0.6\,\mathrm{V}$	not defined

12.3.5 dout1

`dout1 (int8)`
CONT− pin output state representation. Digital outputs are open-drain type, when output is in ON-state, it is connected to the ground of the controller and value of the `dout1` state is 1. When pin is in OFF-state, it is disconnected (floating) and value of the `dout1` state is 0.

12.3.6 ch1, ch2

`ch1 (uint16) [us]`
`ch2 (uint16) [us]`
Raw servo pwm pulse length in microseconds. Pin 32 ENCB/DATA could be mapped to channel 1 and pin 34 ENCC/OUT could be mapped to channel 2.

12.3.7 ichg

`ichg (int16) [10 mA]`
Charger current in 10 mA (if value of `ichg` is 100, charger current is 1000 mA). During normal charging is this current equal to battery current. During step-up charging is this current always higher than battery current.

12.3.8 uchg

`din1 (int16) [10 mV]`
Charger voltage in 10 mV (if value of `uchg` is 1200, charger voltage is 12 V). During normal charging is the voltage almost equal to battery voltage. During step-up charging is charger voltage always lower than battery voltage.

12.3.9 gndio

`gndio (int16) [10 mV]`
Voltage between ground of the controller and galvanically isolated ground. Voltage is in 10 mV (if value of `gndio` is 100, voltage between grounds is 1 V). Reference is ground of the controller, so if the potential of isolated ground is higer than potential of controller ground, measured value is positive. This state is used for internal debug purposes only. Precision of the measurement is 1 V.

12.4 Input and output ID

Each state representing input or output pin has its own unique ID. This ID is used for mapping pins into application – rewriting IDs easily remap used pin. States and their IDs are listed in table 12.2.

Table 12.2: Input and output states and their IDs

ID (dec)	ID (hex)	State	Pin	Pin name
1	0x01	– error –		– error –
8	0x08	`gpio0`	15	GPIO0
9	0x09	`gpio1`	14	GPIO1
10	0x0A	`gpio2`	13	GPIO2
11	0x0B	`gpio3`	12	GPIO3
12	0x0C	`gpio4`	11	GPIO4
16	0x10	`gdin0`	15	GPIO0
17	0x11	`gdin1`	14	GPIO1
18	0x12	`gdin2`	13	GPIO2
19	0x13	`gdin3`	12	GPIO3
20	0x14	`gdin4`	11	GPIO4
32	0x20	`din1`	32	ENCA/CLK
33	0x21	`din2`	34	ENCB/DATA
34	0x22	`din3`	33	ENCC/OUT
48	0x30	`ch1`	32	ENCA/CLK
49	0x31	`ch2`	34	ENCB/DATA
64	0x40	`ichg`		
65	0x41	`uchg`		
66	0x42	`gndio`		
72	0x48	`Vthermistor`	28	TEMP
73	0x49	`Rthermistor`	28	TEMP
128	0x80	`dout1`	31	CONT–

12.5 Configuration of hardware inputs and outputs

12.5.1 ioconf0, ioconf1 ... ioconf4

```
ioconf0 (int16)
ioconf1 (int16)
...
ioconf4 (int16)
```

Internal pull-up and pull-down resistors can be configured by setting this parameter or pin functionality could be completely changed:

- 0 – no pull-up, nor pull-down
- 1 – internal pull-up connected
- 2 – internal pull-down connected
- 32 – pulse length measure, value of `gpio` is length of pulse in microseconds
- 64 – pulse length measure, value of `gpio` is length of pulse in miliseconds

12.5.2 contactor

`contactor1 (directory)`
Configuration of contactor is present in this directory. Following parameters configure contactor:

- `attack (uint8) [%] / [V]` – duty of PWM when contactor is switching from opened to closed state. To make contactor move requires more current than holding it closed so this PWM duty is higer than hold PWM duty. Duty can be set in range 0% – 100%). Voltage on contactor is then dependent on battery voltage. When set value is negative, it is not duty but average voltage in volts, voltage on contactor is then not dependent on battery voltage.
- `attacktime (uint16) [ms]` – time of contactor attack in miliseconds. It is the time, when PWM duty is higher to make contactor close. After the contactor is closed, PWM duty is lowered.
- `hold (uint8) [%] / [V]` – duty of PWM when contactor is closed and it only holds its position. To hold contactor closed is required less current, so the PWM duty can be lowered. Duty can be set in range 0% – 100%). Voltage on contactor is then dependent on battery voltage. When set value is negative, it is not duty but average voltage in volts, voltage on contactor is then not dependent on battery voltage.

12.6 Other configuration parameters

In directory `/common` are also located some other parameters that are associated with the *Common I/O* block of firmware. They are described in this section.

12.6.1 mtempsel

`mtempsel (uint8)`
This parameter configures, which pin will be used as input for motor temperature sensor.

- 0 – motor temperature sensor is not used
- other value – *Input ID* of the pin, where is motor temperature sensor conected. Refer to table 12.2.

12.6.2 beep_vol

`beep_vol (uint16)`
Controler can beep using connected motor's winding. This parameter sets volume of the beeping. Valid values are in range 0 – 1000.

12.6.3 appsel

`appsel (uint8)`
This parameter selects, which application will be loaded when controller starts. 0 is the default value and other values should not be used, since they can cause unpredictable behaviour of the controller.

12.6.4 ppmconf

`ppmconf (uint16)`
Configuration of PPM input. Value `0` is for normal PPM configuration, value `255` is for inverse PPM signal. Other values are not acceptable and can result in unexpected behaviour.

12.7 Commands

Some commands are associated with *Common I/O* block of firmware. They are described in this section.

12.7.1 shutdown

`shutdown`
Power off the controller. Works only if the flip-flop circuit is used. Refer to chapter **??**, especially to section **??** for more information about flip-flop circuit and controller powering. Note: this command switches on DOUT2 pin as side effect.

12.7.2 beep

`beep [tone] [length] [modulation]`
Play tone `[tone]` with length `[length]` and with modulation `[modulation]`.

12.7.3 play

`play [tones]`
Play sequence of tones `[tones]`.

Related documents

- ESC3-AM controller series datasheet
- ESC3-SL controller series datasheet
- yOS v2.0 & SWtools reference manual
- Driver v1.0 reference manual
- Application interface reference manual

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