ESC3–AM controller series

Full datasheet

rev_C

28th November, 2018

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Chapter 1: Introduction

The AM is the lightest standard member of the ESC3 controller family. It can be used in wide range of applications, especially in industrial and automotive. Using most modern technologies it achieves extreme dynamics and maximal efficiency, it implements smooth start or regenerative braking, all this with minimum dimensions. The AM controller is capable of driving all common types of electric motors.

Applications

- Automotive or Industrial motor control
- Electric hand tools and equipment
- Hi-end, 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.

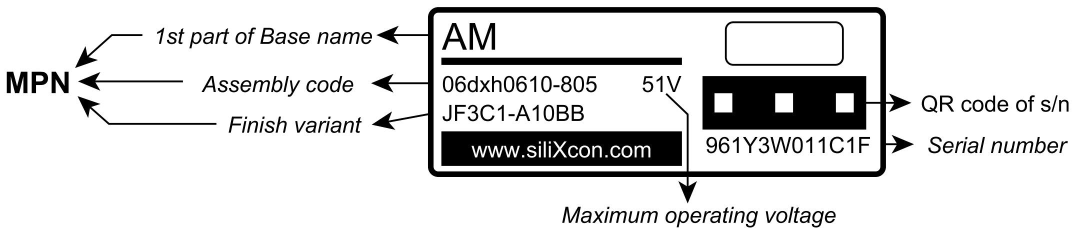


Figure 3.1: AM controller product tag

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:

- *AM-felix* – firmwares for ground vehicles (bikes, motocycles, scooters, cars ...)
  - LYNX – firmware for e-bikes
- *AM-raptor* – firmwares for RC models (cars, planes, boats, drones ...)
  - FALCON – firmware for drones and planes
- *AM-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, internal hardware configuration and power features of the controller. Exact meaning and available variants are listed in following sections of this datasheet.

Third part of the *MPN* is so called *Finish variant*. It defines used signal and power wiring, heatsing and enclosure. Exact meaning and available variants are listed in following sections of this datasheet.

3.2 Product variants

The AM 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*. Each field in the *MPN* stands for one thing, that can be configured. *MPN* consists of many fields (as shown in the figure 3.2) and each field can be configured almost independently. This gives very large amount of available configurations. The most common combinations are reffered as *standard variants*, *default variants* and also as controller *models*.

- Standard cofiguration – the most usual configurations of controller. Samples are available in this configuration only. This configuration has usually shortest delivery time. In following description is this configuration denoted by gray background of the text. MPN (manufacturer part numbers) are assigned to individual controller models as follows:
  - **AM-felix model 1** – AM-felix_06dxh0610-805_JF3C1-A10BB
  - **AM-felix model 2** – AM-felix_06dxh0610-825_H8131-A10BB
  - **AM-felix model 3** – AM-felix_06dxh0610-825_H8031-HH0BB
  - **AM-raptor model 1** – AM-raptor_06dxh0610-805_JF3C1-A10BB
  - **AM-serpent model 1** – AM-serpent_06dxh0610-805_JF3C1-A10BB
- Other configuration – any non-standard configuration of the controller described in this datasheet.
- OEM solution – controller could be customized even deeper, than described in this datasheet. Contact siliXcon for more information.

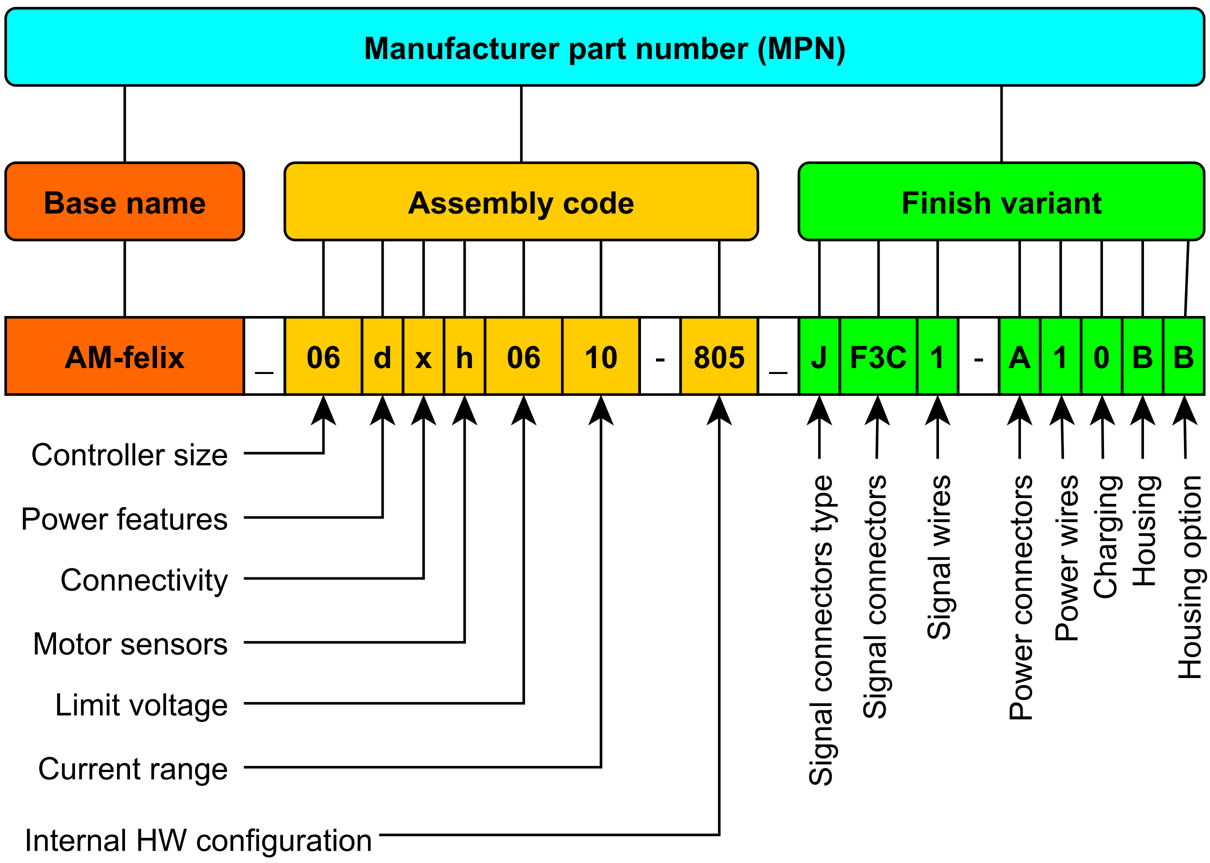


Figure 3.2: Example of *MPN*

3.2.1 Assembly code

Assembly code refer to modification in assembly of PCB. Behavior of these modifications is described in following chapters of this datasheet:

- *Power features* – AM controller has no advanced power features. This character is reserved for future use.
- *Connectivity* – refer to section 9.4
- *Motor sensors* – refer to chapter 10
- *Limit voltage* – refer to section 4.1
- *Current range* – refer to section 4.4
- *Internal HW configuration* – refer to chapter 8 and sections 9.4 and 9.5

Table 3.1: Assembly code of the AM controller

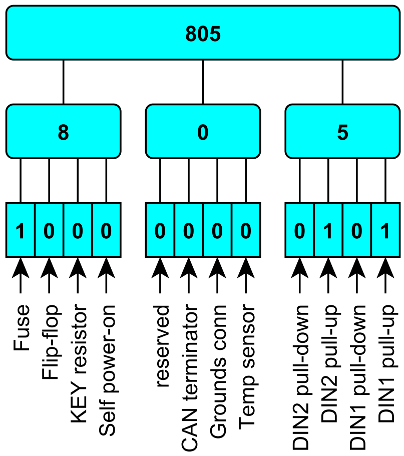
Letter	Variant	Description
Controller size		Size of the controller – number of transistors in the power stage
	06	Six transistors
Power features		Additional features for powering controller
	d	No additional features
Connectivity		Present communication interfaces
	x	USB, isolated CAN Bus, isolated 5 V UART
Motor sensors		Compatible motor sensors
	h	Three Hall sensors
Limit voltage		Absolute maximum voltage (see chapter 4)
	06	60 V
Current range		Measuring current range
	10	100 A (amplitude)
Internal HW configuration		Solder jumpers, fuses, temperature sensor ...
	805	Internal fuse connected, DINs with pull-up resistors, CANGND and GND isolated
	825	Internal fuse connected, DINs with pull-up resistors, CANGND and GND connected
	???	Refer to subsection 3.2.1

Internal HW configuration

Internal HW configuration describes all small modifications in hardware, such as solder jumpers, connection of temperature sensor or presence of fuse between BATT+ and KEY pins. Each item can be present (marked with 1) or not present (marked with 0). 12 bits are used for description and they form 12 bit binary number. This number is converted to the hexadecimal form. Meaning of bits and examples are listed in following table 3.2.

Table 3.2: Internal HW configuration encoding

Variant	Fuse	Flip-flop	KEY resistor	Self power-on	reserved	CAN terminator	Grounds conn (Note 1)	Temp sensor (Note 2)	DIN2 pull-down	DIN2 pull-up	DIN1 pull-down	DIN1 pull-up
805	x									x		x
825	x						x			x		x
800	x											
A00	x		x									
900	x			x								
000												
000												



Note 1: When selected, CANGND and GND connected together – galvanic isolation is not present
Note 2: GPIO1 used as temperature sensor on motor sensor connector
Note 3: If the Flip-flop circuit is selected, pin 10 DOUT2 is not available

3.2.2 Finish variants

Finish variants describes different modificaions of signal wiring, power wiring and housing. These modifications are described in following parts of this datasheet:

- *Signal connectors type*, *Present signal connectors*, *Signal wires* – refer to chapter 11
- *Power connectors*, *Power wires* – refer to chapter 11
- *Housing*, *Housing option* – refer to chapter 5

Table 3.3: Finish variants of the AM controller

Letter	Variant	Description
Signal connectors type		Used type of the signal connectors
	J	JST JWPF (refer to table 3.4)
	W	No connectors, wires only (refer to table 3.4)
	H	HIGO e-bike connector and JST JWPF (refer to table 3.5)
	E	Something else – other combinations (refer to table 3.6)
	Z	Custom combination
Present signal connectors		Which signal connectors are present
	F3C	Connectors: USB, CAN, UART, Powering, Control I/O 1, Motor sensors, DIN1, DIN2
	803	Connectors: USB, PAS, HIGO combined wiring connector
	813	Connectors: USB, PAS, Motor sensors, HIGO combined wiring connector
	???	Refer to subsection 3.2.2 according previous letter.
Signal wires		Crossection, insulation and length of signal wires
	1	10 cm, AWG 24, PVC insulation
Power connectors		Present power connectors
	0	No connectors, no power wires
	A	XT60 male for battery, MT60 female for motor
	H	XT60 male for battery, HIGO Z9AM P for motor (with motor sensors)
Power wires		Crossection, insulation and length of power wires
	0	no power wires
	1	4 mm^2 (AWG11), SIFF insulation, 10 cm for battery wires, 6 cm for motor wires
	H	15 cm 4 mm^2 (AWG11) SIFF insulation for battery, 10 cm HIGO Z9AM P
	other	other length, crossection and insulation on request
Charging		Type of charging, if present
	0	No charging
Housing		Style of heatsing and enclosure
	E	Assembled, non-waterproof
	0	No housing, PCB only (Note 1)
	B	Assembled and sealed enclosure, waterproof
	Z	Custom housing, contact siliXcon for more information
Housing option		Color of housing
	B	Aluminium housing with mounting holes, black elox
	0	No heatsink

Note 1: No warranty, only limited product testing.

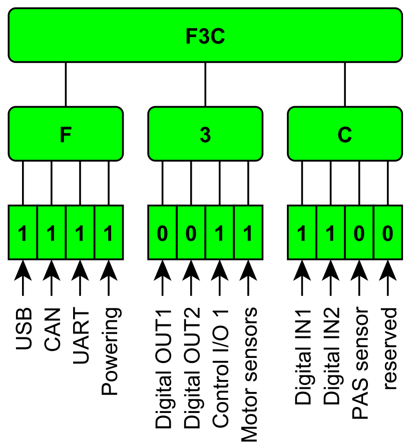
Present signal connectors

Three characters marked as *Present signal connectors* in figure 3.2 are encoded differently for each previous character. Basically, 12 connectors could be present on AM controller. If connector is present, on corresponding position is 1, if connector is not present, on corresponding position is 0. It forms 12 digit binary number. This binary number is converted to hexadecimal number which has exactly three characters. These characters are part of the *MPN* on this positin – *Present signal connectors*.

Letter J and W – JST JWPF connectors and bare wires If the letter on position *Signal connectors type* is J (JST JWPF connectors are used) or W (only signal wires without connectors are soldered to the PCB), following table are used for creating *MPN*. Encoding mechanism is as it was described before – 12 connectors are represented by 12 ones or zeroes, result number is then converted to hexadecimal.

Table 3.4: Present signal connectors for **W** (wires only) and **J** (JST JWPF)

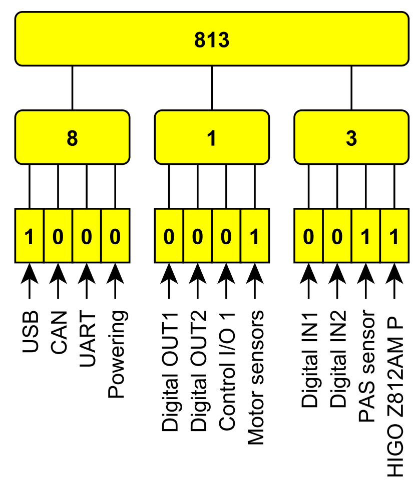
Variant	USB	CAN Bus	UART	Power	Digital OUT1	Digital OUT2	Control I/O 1 (analog)	Motor sensors	Digital IN1	Digital IN2	PAS sensor	reserved
000												
800	x											
920	x			x			x					
F3C	x	x	x	x			x	x	x	x		
D30	x	x		x			x	x				
C0C	x	x							x	x		
D3C	x	x		x			x	x	x	x		
DF0	x	x		x	x	x	x	x				
802	x										x	
8C2	x				x	x					x	
93C	x			x			x	x	x	x		
F30	x	x	x	x			x	x				
FFC	x	x	x	x	x	x	x	x	x	x		
D00	x	x		x								



Letter H – HIGO + JST JWPF connectors If the letter on position *Signal connectors type* is H, HIGO Z812AM P connector is used as combined wiring connector. UART, Control I/O 1 and Powering connector are contained in this connector (refer to section 11.3.2 for pinout). For other connectors are used JST JWPF connectors. Following table is used in this case for creating *MPN*. Encoding mechanism is as it was described before – 12 connectors are represented by 12 ones or zeroes, result number is then converted to hexadecimal.

Table 3.5: Present signal connectors for **H** (HIGO + JST JWPF)

Variant	USB	CAN Bus	UART	Power	Digital OUT1	Digital OUT2	Control I/O 1 (analog)	Motor sensors	Digital IN1	Digital IN2	PAS sensor	HIGO combined wiring
C01	x	x										x
C03	x	x									x	x
C0D	x	x							x	x		x
C07	x	x								x	x	x
CC1	x	x			x	x						x
CC3	x	x			x	x					x	x
803	x										x	x
813	x							x			x	x
C11	x	x						x				x



Letter E – Other combinations of connectors If the letter on position *Signal connectors type* is E, Other combination of connectors is used. Available combinations of connectors are listed in table 3.6. JWPF stands for usage of JST JWPF connector, 2.54 stands for usage of standard connector with pitch 2.54 mm (servo plug).

Table 3.6: Present signal connectors for **E** (other combination of connectors)

Variant	USB	CAN Bus	UART	Power	Digital OUT1	Digital OUT2	Control I/O 1 (analog)	Motor sensors	Digital IN1 diff	Digital IN2 diff	PAS sensor	reserved
008									2.54			
808	JWPF								2.54			
C08	JWPF	JWPF							2.54			
408		JWPF							2.54			

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 3.7: 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
Digital out 1	JF2_DO1/11	C-JM2_DO1/11
Digital out 2	JF2_DO2/11	C-JM2_DO2/11
UART COM +10V	JF4_UARTCOM10/11	C-JM4_UARTCOM10/11
EXT connector	JF4_UARTEXT10/11	C-JM4_UARTEXT10/11
Control I/O 1 (Analog in)	JF4_CNTRL1/11	C-JM4_CNTRL1/11
CAN	JM3_CAN/11	C-JF3_CAN/11
PAS	JM3_PAS/11	C-JF3_PAS/11
Digital in 1	JM2_DI1/11	C-JF2_DI1/11
Digital in 2	JM2_DI2/11	C-JF2_DI2/11
Motor sensors (variant h)	JM8_MSENS_H/11	C-JF8_MSENS_H/11
Motor sensors (variant h with temp sensor)	JM8_MSENS_H+T/11	C-JF8_MSENS_H+T/11
Motor sensors (variant a)	JM8_MSENS_A/11	C-JF8_MSENS_A/11
Motor sensors (variant r)	JM8_MSENS_R/11	C-JF8_MSENS_R/11
Motor sensors (variant d)	JM8_MSENS/11	C-JF8_MSENS/11
HIGO 8 pin combined wiring connector (female) (Note 2)	HIGO_Z812AMP-F/15	C-HIGO_Z812AGP-M/15

Note 1: All listed JST JWPF connectors are with wires, length 11 cm, AWG24, PVC insulation.
Note 2: 15 cm length

Table 3.8: Power connectors order codes

Connector name	**Connector ordering code**	**Complementary connector ordering code**
Battery connector XT60 (male) (Note 1)	XT60H-M	C-XT60H-F
Motor connector MT60 (female) (Note 1)	MT60-F	C-MT60-M
HIGO 3+6 pin motor connector (female) (Note 2)	HIGO_Z910AMP/15	C- HIGO_Z910AGP/15

Note 1: Connector is without wires – connectors only.
Note 2: Connector is with 15 cm cable.

Table 3.9: 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**			
	0420	**0610**	**0810**	**1010**
Non–operational overvoltage limits	9 – 40 V DC	9 – 60 V DC	9 – 80 V DC	9 – 100 V DC
Safe voltage range	11 – 36 V DC	11 – 55 V DC	11 – 74 V DC	11 – 92 V DC
Operating voltage range	12 – 34 V DC	12 – 51 V DC	12 – 68 V DC	12 – 84 V DC
Battery configuration	8 S	12 S	16 S	20 S
Battery nominal voltage	28.8 V DC	43.2 V DC	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.

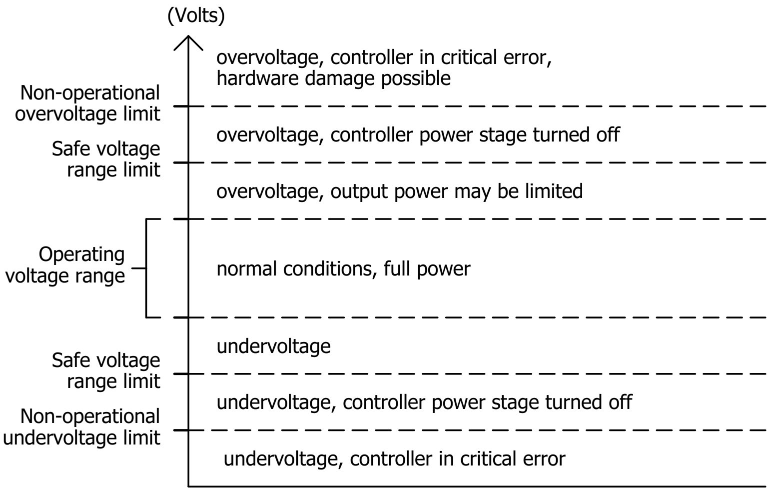


Figure 4.1: Controller voltage limits

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 AM 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. This is the reason why following tables are divided into two parts, first is for *DC motors* and second is for *AC motors*.

Output power and current capability is dependent on controller *Housing* (refer to chapter 3). For each *Housing* is given separate table.

4.4.1 Aluminium enclosure, infinite heatsink

Controller mounted inside the aluminium enclosure, thermally connected to infinite heatsink which does not exceed 60°C.

Table 4.2: Power and current rating of the AM controller with BLDC motor connected, infinite heatsink

Parameter	Assembly code			
	0420	**0610**	**0810**	**1010**
Maximal power dissipation	20 W			
Nominal power (60 min)	1700 W	2200 W	2400 W	2700 W
Nominal current (60 min)	60 A	51 A	42 A	38 A
Battery current	60 A	51 A	42 A	38 A
Peak power (10 sec)	3400 W	4300 W	4600 W	5000 W
Peak current (10 sec)	120 A	100 A	80 A	70 A

Note: 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.

Table 4.3: Power and current rating of the AM controller with BLAC or induction motor connected, infinite heatsink

Parameter	Assembly code			
	0420	**0610**	**0810**	**1010**
Maximal power dissipation	20 W			
Nominal power (60 min)	1700 W	2100 W	2200 W	2500 W
Nominal current (60 min)	50 A	40 A	32 A	28 A
Battery current	61 A	49 A	39 A	34 A
Peak power (10 sec)	3500 W	3700 W	4200 W	4400 W
Peak current (10 sec)	100 A	70 A	60 A	50 A

Note: 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.

4.4.2 Aluminium enclosure, in still air

Controller mounted inside the aluminium enclosure, placed in still air of temperature 25°C.

Table 4.4: Power and current rating of the AM controller with BLDC motor connected, Al housing, still air

Parameter	Assembly code			
	0420	**0610**	**0810**	**1010**
Maximal power dissipation	20 W			
Nominal power (60 min)	1200 W	1500 W	1600 W	1800 W
Nominal current (60 min)	41 A	35 A	28 A	25 A
Battery current	41 A	35 A	28 A	25 A
Peak power (10 sec)	3400 W	4300 W	4600 W	5000 W
Peak current (10 sec)	120 A	100 A	80 A	70 A

Note: 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.

Table 4.5: Power and current rating of the AM controller with BLAC or induction motor connected, Al housing, still air

Parameter	Assembly code			
	0420	**0610**	**0810**	**1010**
Maximal power dissipation	20 W			
Nominal power (60 min)	1100 W	1300 W	1400 W	1600 W
Nominal current (60 min)	32 A	25 A	20 A	18 A
Battery current	39 A	30 A	25 A	22 A
Peak power (10 sec)	3500 W	3700 W	4200 W	4400 W
Peak current (10 sec)	100 A	70 A	60 A	50 A

Note: 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.

4.4.3 Shrinking tube, in still air

Controller mounted in shrinking tube, placed in still air of temperature 25°C.

Table 4.6: Power and current rating of the AM controller with BLDC motor connected, shrinking tube

Parameter	Assembly code			
	0420	**0610**	**0810**	**1010**
Maximal power dissipation	5 W			
Nominal power (60 min)	1200 W	1500 W	1600 W	1800 W
Nominal current (60 min)	27 A	22 A	18 A	16 A
Battery current	27 A	22 A	18 A	16 A
Peak power (10 sec)	2700 W	3200 W	3700 W	4300 W
Peak current (10 sec)	95 A	75 A	65 A	60 A

Note: 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.

Table 4.7: Power and current rating of the AM controller with BLAC or induction motor connected, shrinking tube

Parameter	Assembly code			
	0420	**0610**	**0810**	**1010**
Maximal power dissipation	5 W			
Nominal power (60 min)	700 W	850 W	850 W	970 W
Nominal current (60 min)	20 A	16 A	12 A	11 A
Battery current	25 A	20 A	15 A	14 A
Peak power (10 sec)	2600 W	3400 W	3500 W	4000 W
Peak current (10 sec)	75 A	65 A	50 A	45 A

Note: 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.

4.5 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 AM controller. These advanced protections are described in detail in the *Driver manual*.

4.6 Additional electrical parameters

Table 4.8: 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.

4.7 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. 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 AM controller

Parameter	**Bare board (1)**	**Shrinking tube**	**Non-sealed aluminium housing (2)**	**Sealed aluminium housing (2)**
Width	66 mm	89 mm	101 mm	101 mm
Height	9 mm	10 mm	13 mm	13 mm
Depth	31 mm	35 mm	35 mm	35 mm
Weight	12 g	92 g	130 g	130 g

Note 1: bare PCB with electrolytic capacitors, without any wiring
Note 2: JST JWPF signal connectors, Amass XT60 and MT60 power connectors

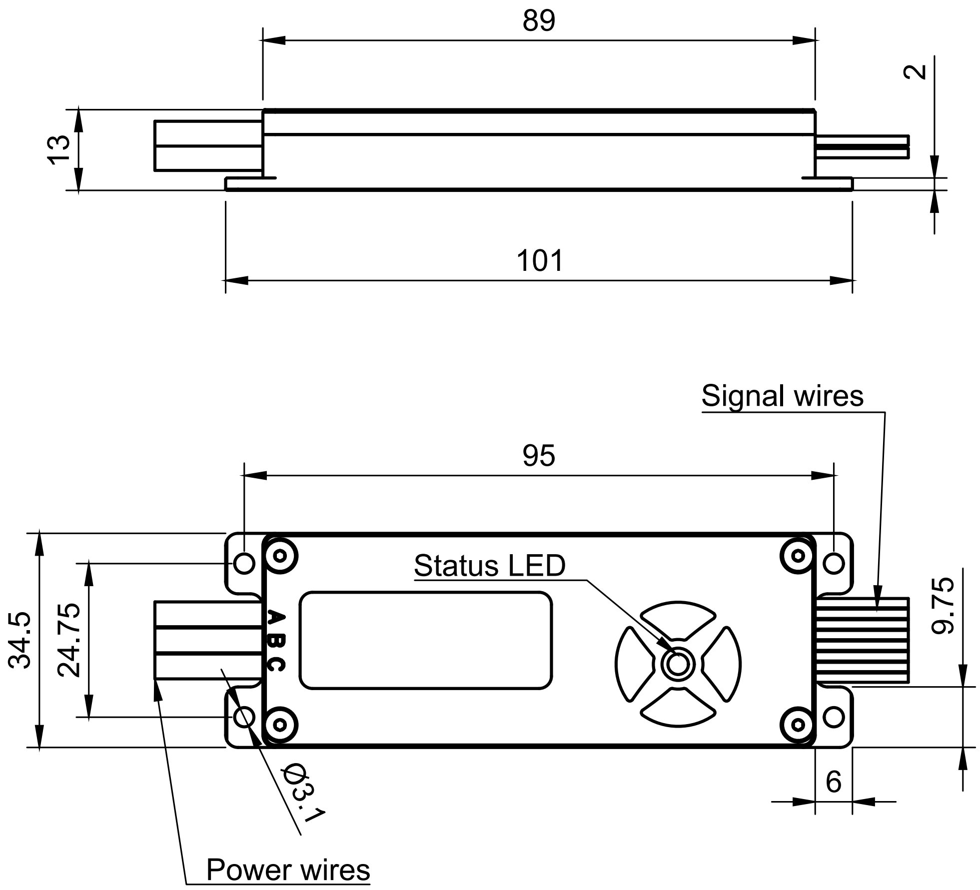


Figure 5.1: Aluminium housing for AM controller

Mounting torque Recommended mounting torque for M3 screws is $T_{M3} = 1.3\,\mathrm{Nm}$

Chapter 6: Enviromental specifications

Table 6.1: Storage and operation conditions of the AM 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 – HIGO (4)		IP66		
Connectors – Amass XT60 and MT60		—		
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: AM controller thermal specification

Parameter	Value	Conditions
Maximal power dissipation	20 W	controller thermally connected to infinite heatsink which does not exceed 60°C
	10 W	controller in aluminium housing, in still air of temperature 25°C
	5 W	controller in shrinking tube or bare PCB, in still air of temperature 25°C
Thermal resistance	2.5 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. 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:

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

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 the AM controller

Assembly code	DC motor		AC motor	
	k_c	k_s	k_c	k_s
0420	0.0047	0.00084	0.0070	0.0023
0610	0.0063	0.00087	0.0094	0.0024
0810	0.0092	0.00095	0.0139	0.0026
1010	0.0112	0.00097	0.0166	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.

Chapter 8: Powering interface

This chapter deals with controller powering – its activating and deactivating and problematics connected with it. Summary powering scheme is shown in the figure 8.1.

Control electronics of the AM controller is powered from pin 5 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 AM controller is controlled by pin 8 POWER.

This pin could be configured as *Activation input* or as *Flip-flop* during controller manufacturing. This configuration is reflected to controller's *MPN*, to part *Internal HW configuration* (see section 3.2.1). When the *Flip-flop* bit is 0, Power pin is configured as activation input (described in section 8.1). When this bit is 1, POWER pin is configured as flip-flop (described in section 8.2) and controller also gains auto power-off feature.

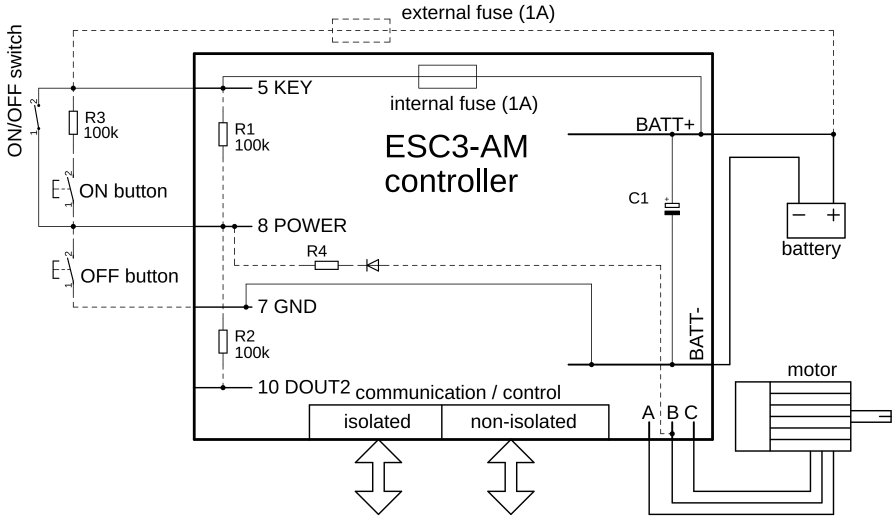


Figure 8.1: AM controller powering scheme

8.1 Activation input

When the pin 8 POWER is configured as activation input, power state of the AM controller is defined by voltage **level** on this pin. Controller is powered on, when logic high (more than 5 V in relation to GND) is present on this pin. Controller is powered off, when the logic low (less than 2 V) is on this pin. Controller is also powered off, when this pin is left unconnected (floating). Pull down resistor is connected internally to power down the controller when the POWER pin is left unconnected.

By default, the AM controller is powered on simply by connecting pin 5 KEY with pin 8 POWER (POWER pin is tollerant to battery voltage). Another possibility is to control power state of the AM controller from supperior system by logic signal. By logic high level is controller powered on and by logic low level is controller powered off.

8.2 Flip-flop circuit, auto power-off capability

Flip-flop circuit is alternative configuration to activation input, described in previous subsection. If the pin 8 POWER is configured as flip-flop, power state of the AM controller is controlled by positive and negative pulses. Positive pulse powers the controller up, negative pulse powers controller down. Pulses could be sent by two pushbuttons (first between BATT+ and POWER, second between BATT− and POWER), or by supperior sytem, if desired.

If the flip-flop is selected, auto power-off feature is also present. This feature allows the AM controller to power itself down by software (for example after set period of inactivity). This feature uses internally pin 10 DOUT2, so this pin is not available for user functionality.

8.3 Internal fuse

Control electronics is powered from pin 5 KEY. This pin is connected internally to BATT+ terminal by **internal fuse** in default configuration af the AM controller. Fuse's presence is indicated in *MPN*, in part *Internal HW configuration*; refer to section 3.2.1 and table 3.2. If theinternal fuse is not present (or is blown), connect pin 5 KEY with BATT+ via external fuse with rating 1 A max. For correct function of battery voltage measurement, pins 5 KEY and BATT+ has to be connected by low impedance (either internal or external fuse).

8.4 Self power-on

The AM controller could be powered on from off-state, when motor starts to spin. Motor with permanent magnets has to be used. When enabled, resistor R4 with diode beween phase B and POWER input is added (see picture 8.1). When motor starts to spin, it induces voltage and this voltage activates the controller. Refer to section 3.2.1), to part *Internal HW configuration* when choosing proper *MPN* of the product. When using self power-on ability, flip-flop circuit has to be present.

This ability could be used as anti-theft system for vehicle. When motor starts to spin without proper activation, controller powers up, lock the motor and also could start alarm or perform other required action. Another usage of the self power-on ability is for wind turbines. When turbine starts to spin, controller is powered on automatically.

8.5 Capacitors discharge

High quality capacitors with low ESR and low self-discharge are used in power stage of the AM controller. To achieve minimum power consumption in off-state, no discharge resistors are used in the AM controller. It means that power stage capacitors could remain charged long after controller is disconnected from the battery.

This could lead to electric shock or damage of other electronics, if handled improperly. Capacitors should be discharged by connecting resistor between BATT+ and BATT− pins after battery disconnection. **Always check the voltage between terminals BATT+ and BATT− before handling the controller.**

8.6 Charging

The AM controller supports connection of charger, as shown in the figure 8.2. External switch controlled from the AM controller **is required**. Positive terminal of the charger is connected to the switch, negative terminal of the charger is connected to the phase B.

The AM controller provides step-up charging. It means that controller work as step-up (boost) converter during charge, using connected motor as inductance. Any DC power supply could be used in this mode, **but it has to meet following two conditions:**

- Voltage of DC power source has to be lower than voltage of discharged battery.
- DC power supply has to have sufficient current capability

If the voltage was not lower than voltage of discharged battery, controller could not operate in step-up mode and charging would not be possible. If the DC power source had not sufficient current capability, step-up charging could damage this power supply by overloating it.

Warning: When charger is connected to the AM controller, negative terminal of the charger must not be connected to the negative terminal of the battery. Otherwise, short-circuit could take place. Do not connect any other equipment (such as laptop via USB) to the AM controller during charge. This could provide current path for the short circuit !!!

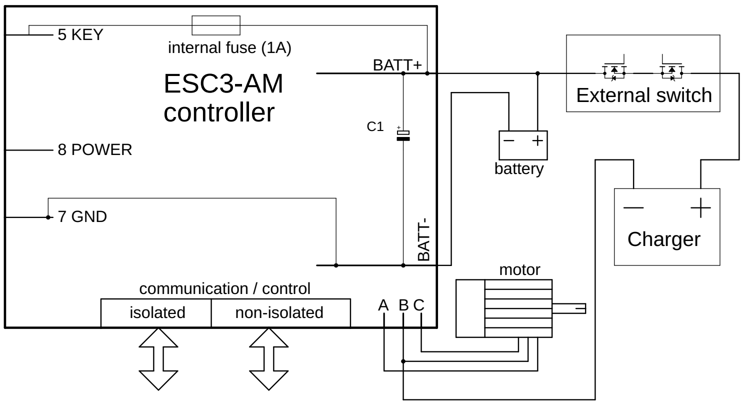


Figure 8.2: Connection of the AM controller as step-up charger

Table 8.1: Power control pins

Pin	Name	Description	Direction	Parameters, max. range
5	KEY	Internally connected to BATT+	Power output	0–V_{NOM}, max. 1 A
6	VBATSW	Internally connected to BATT+ when controller is ON		
7	GND	Internally connected to BATT−		0 V, max.1 A
8	POWER	Controller ON/OFF input, active high	Input	0–V_{NOM}, max. 10 mA

Note 1: All pins are related to the pin 7 GND.
Note 2: V_{NOM} is upper limit of *Operating voltage range*, refer to section 4.1.

8.7 Controller powering methods

8.7.1 Constant ON

Easiest and most straightforward method. Controller is powered on, when battery is connected to the power terminals BATT+ and BATT− and it remains powered on as long as the battery is connected. If using this method, controller has to have internal fuse connected and KEY resistor (R1) has to be present. Schematics of the connection is shown in the figure 8.3. First character of *Internal HW configuration* will be **A** (part of *MPN*. Refer to section 3.2.1).

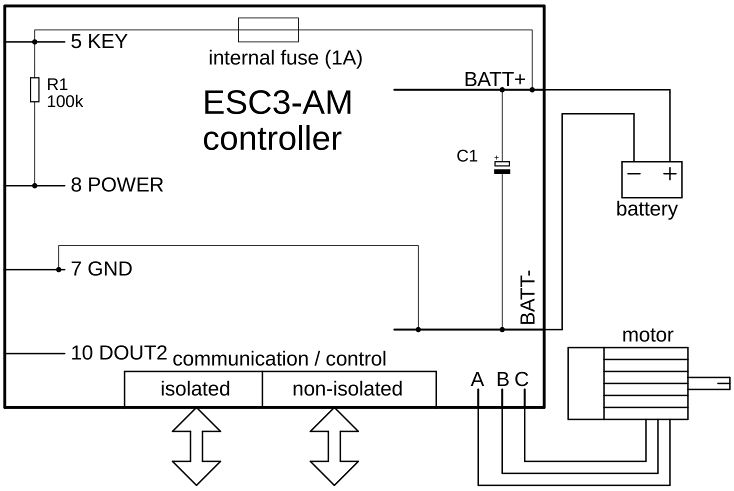


Figure 8.3: Constant on powering scheme

8.7.2 ON/OFF switch (default)

Prefered method of the AM controller powering is the ON/OFF switch. This switch is connected between pins 5 KEY and pin 8 POWER. When the switch is closed, controller is powered on and remains on until switch is opened. POWER pin is cofigured as *activation input*. Internal fuse has to be present, neither flip-flop nor KEY resistors are used. First character of *Internal HW configuration* will be **8** (part of *MPN*. Refer to section 3.2.1). Schematics of the connection is shown in the figure 8.4.

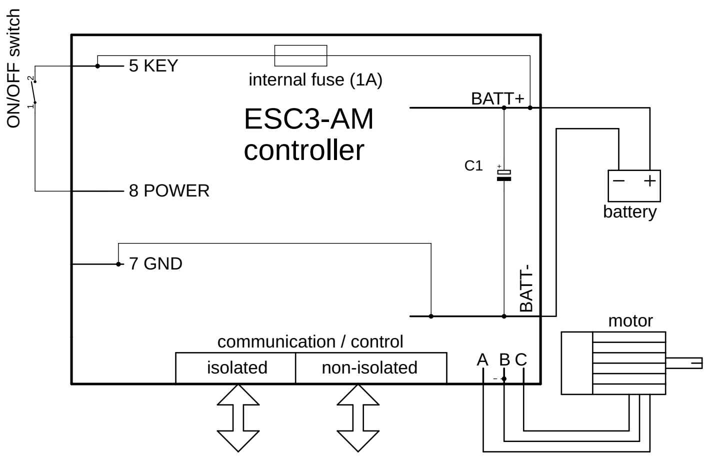


Figure 8.4: ON/OFF switch powering scheme

8.7.3 Two buttons with auto power-off

AM controller power state can be also controlled by two pushbuttons. Pin 8 POWER has to be configured as *flip-flop*, internal fuse has to be present and KEY resistor has to be disconnected. First character of *Internal HW configuration* will be **C** (part of *MPN*. Refer to section 3.2.1). Then, controller can be turned on and off by pulses. By positive pulse (higher than 5 V) is controller turned on, by negative pulse (lower than 2 V) is controller turned off. Between pulses is pin 8 POWER unconnected (floating).

Pulses could be created by two pushbuttons: by pressing ON button is created positive pulse, by pressing OFF button is created negative pulse. When both buttons are pressed simultaneously, controller is first turned off. If it is turned on again depends on which button is released first. If the ON button is released first, controller will not turn on again. Resistor R3 protects buttons and their wiring again short-circuit when both buttons are pressed simultaneously.

Auto power-off feature is enabled, when flip-flop circuit is used. Pin 10 DOUT2 is connected to the pin 8 POWER internally via resistor R2. The AM controller can be turned off by software using the pin 10 DOUT2. Schematics of the connection is shown in the figure 8.5.

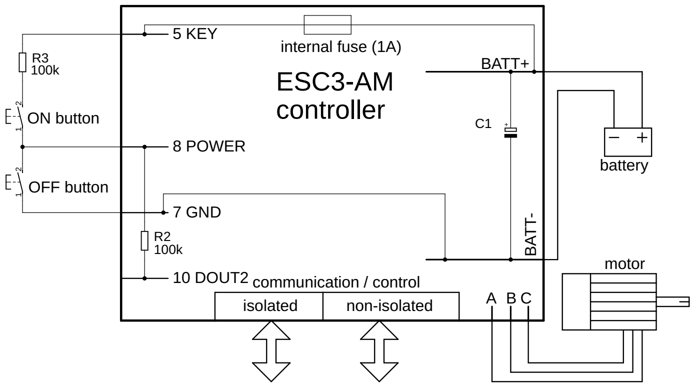


Figure 8.5: Two buttons powering scheme

8.7.4 Two buttons with auto power-off and self power-on

This powering method is very similar to the previous one. AM controller could be powered on and off by two pushbuttons. Controller is also capable of turning itself off by software (pin 10 DOUT2 is used). In addition, controller could be powered on automatically, when motor starts to spin. Motor with permanent magnets has to be used. Schematics of the connection is shown in the figure 8.6.

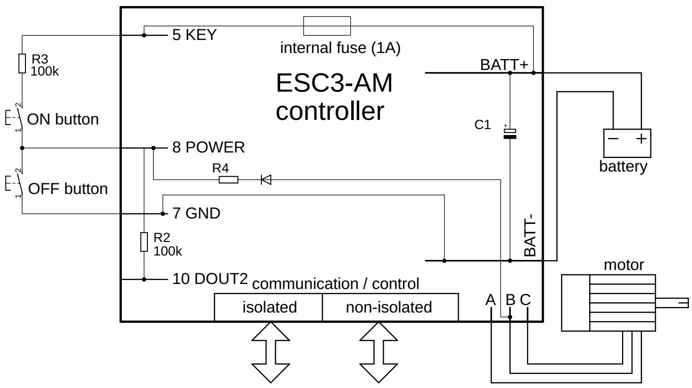


Figure 8.6: Two buttons powering scheme

Chapter 9: Control interface

9.1 Power supplies in the controller

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

- Battery power supply – pins 05 KEY and 07 GND. Battery is connected to these pins via fuse. Voltage is present even if the controller is powered off. Voltage is equal to V_{BATT}, maximum current consupmtion is 1 A. Sum of currents drained from 05 KEY and 06 VBATSW must not exceed 1 A.
- Switched battery power supply – pins 06 VBATSW and 07 GND. Battery is connected to these pins via non-reversible 1 A fuse and switch. This supply is active only when controller is powered on. Voltage is equal to V_{BATT}, maximum current consupmtion is 1 A. Sum of currents drained from 05 KEY and 06 VBATSW must not exceed 1 A.
- DOUTs switched ground – pins 10 DOUT1 and 09 DOUT2. Two open drain power outputs, each has current capability of 1 A. Designed to cooperate with pin 06 VBATSW. Refer to section 9.7.
- Motor sensors power supply – pins 15 HALL+5V and 11 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.
- Analog power supply – pins 20 AGND and 22 AVCC. Power supply for powering analog accessory (buttons, switchs, potentiometers, throttle handle ...) Voltage is 5 V, maximum current consumption is 20 mA. This power supply is galvanically connected with battery.
- CAN power supply – only pin 18 CANGND is accessible. CAN driver is powered from this supply, its ground is accessible on pin 18 CANGND. This pin is used for shielding. This pin is galvanically isolated from battery, but is galvanically connected with UART power supply.
- UART power supply – pins 30 COM+10V and 29 COMGND. Galvanically isolated power supply, used for powering UART. This supply can be used as auxiliary power supply that is galvanically isolated from battery. Voltage is 10 V, maximum current consumption is 100 mA.

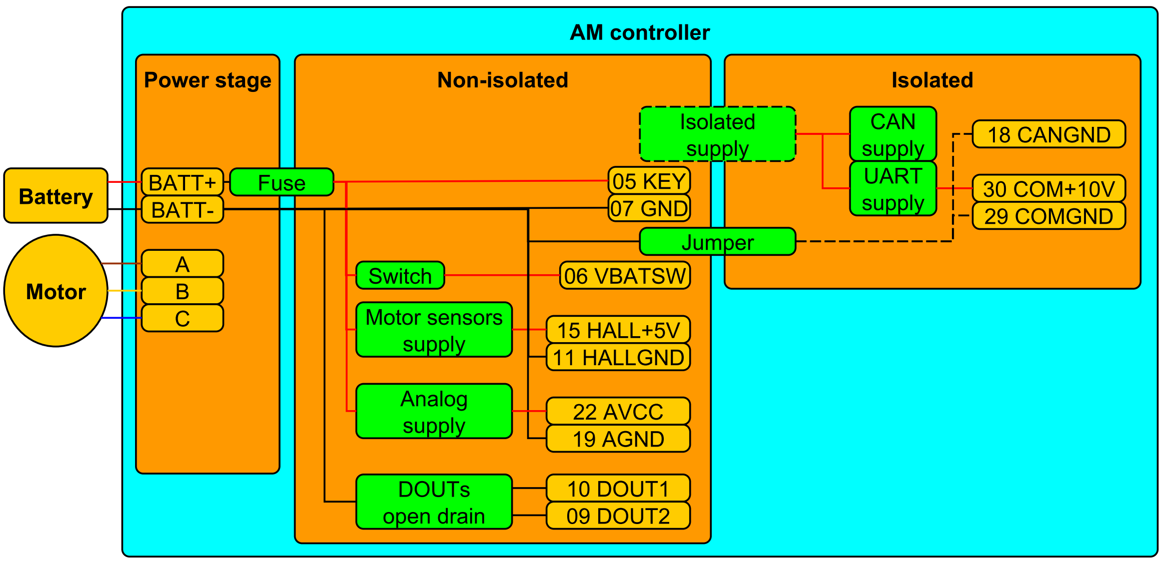


Figure 9.1: Block schematic of controller power supplies

9.2 Built-in LED

The AM 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.

9.3 Galvanic isolation

Some interfaces of the AM controller are galvanically isolated from rest of the controller. This feature enables easy and safe cooperation 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 AM controller could be possibly equipped with three independent, galvanically isolated parts. Block schematic is shown is the figure 9.2. First part is galvanically isolated power supply. Output of this supply is accessible on pins 29 COMGND and 30 COM+10V. Galvanically isolated communication interfaces – CAN Bus and UART are powered from this supply.

Second and third independent parts are digital inputs DIN1 and DIN2. If these inputs work in differential mode, they are isolated from rest of the controller and DIN1 is also galvanically isolated from DIN2. These pins can be galvanically connected to the rest of the controller using pull-up and pull-down jumpers. This could be done only during controller manufacturing and this configuration is reflected to its *MPN*, to the part *Internal HW configuration*. Refer to the section 3.2.1. For more information aboud DINs and their pull-up/down jumpers refer to section 9.5. By default, pull-up jumpers are used for both DINs, so they are not galvanically isolated.

Galvanic isolation (for isolated supply and for DINs) has a withstand voltage of 100 V DC.

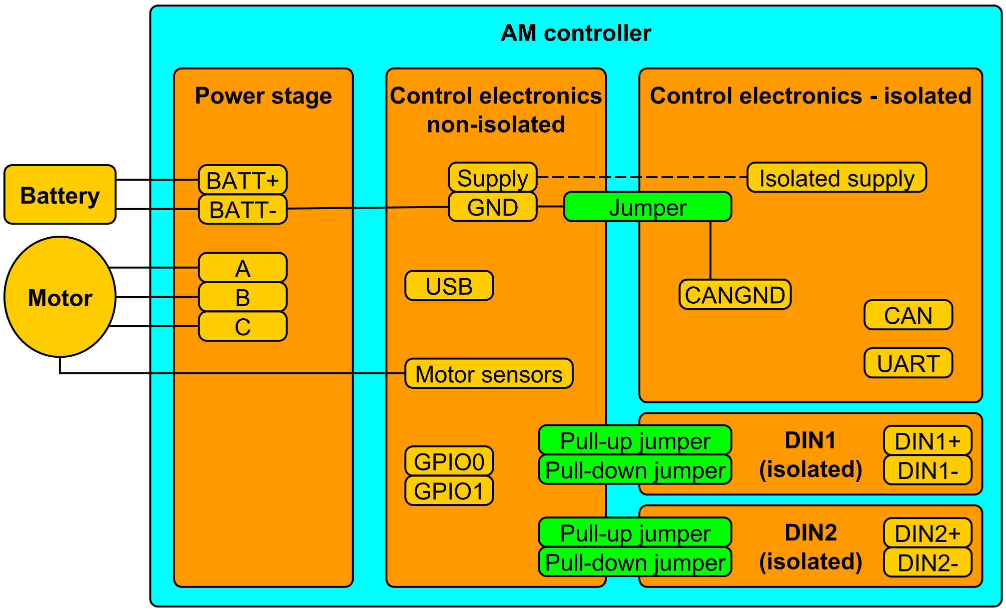


Figure 9.2: Block schematic of galvanic isolation

9.4 Communication

9.4.1 USB

The AM controllers are 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
1	USB+5V	USB 5V	Power input	5 V max. 300 mA
2	USBGND	USB ground, internally connected to BATT−		0 V
3	USBDM	USB data −	Input/output	0–3.3 V, 5 V tolerant, max. 10 mA
4	USBDP	USB data +		

Note: All pins are related to the pin 2 USBGND.

9.4.2 CAN Bus

CAN Bus is modern type of communication bus, widely used in industry and automotive. The AM controller is equipped with one, galvanically isolated[1], 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 could have 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. This resistor is present in the AM controller and could be connected during controller manufacturing. Its connection is reflected in the *MPN*, in part *Internal HW configuration* (refer to section 3.2.1). 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*.

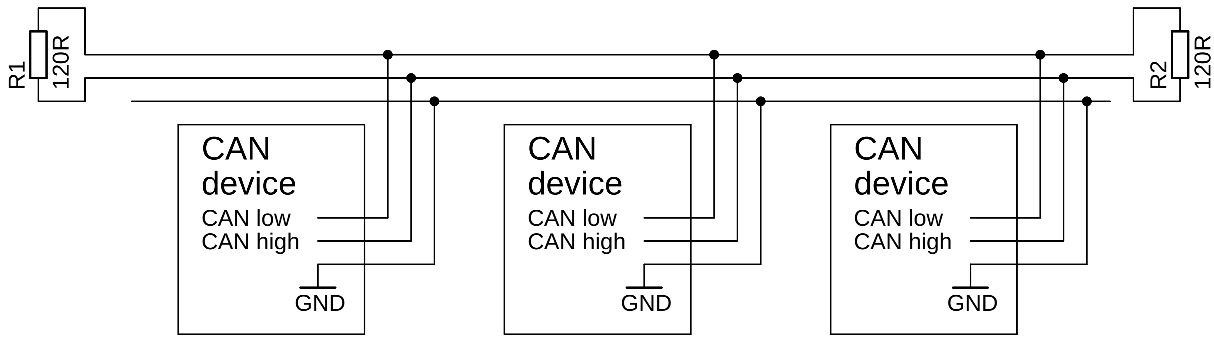


Figure 9.3: Connection of CAN Bus

Table 9.2: CAN Bus pins

Pin	Name	Description	Direction	Parameters, max. range
16	CANL	Galvanically isolated CAN LOW	Input/output	0–5 V, max. 10 mA
17	CANH	Galvanically isolated CAN HIGH		
18	CANGND	Galvanically isolated CAN ground	Power output	0 V, max. 100 mA

Note 1: All pins are related to the pin 18 CANGND.
Note 2: CAN is pesent in *Connectivity variants* **x** and **c**, refer to chapter 3.

9.4.3 Serial communication (UART), galvanically isolated power supply.

The AM controller is also equipped with serial communication (UART). UART is galvanically isolated[1] from rest of the controller (except CAN Bus) and it can be used for communication with other electrical devices. Typical usage is communication between the AM controller and display on e-bikes.

If the serial communication 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*.

[1]Depending on chosen variant/model. Some models has the galvanic isolation disabled, refer to section 3.2.

Table 9.3: TTL UART pins

Pin	Name	Description	Direction	Parameters, max. range
27	COMRXD	Galvanically isolated UART RX	Input	0–5 V, max. 20 mA
28	COMTXD	Galvanically isolated UART TX	Output	
29	COMGND	Galvanically isolated UART ground	Power output	0 V, max. 100 mA
30	COM+10V	Galvanically isolated supply		10 V, max. 100 mA

Note 1: All pins are related to the pin 29 COMGND.

9.5 Digital inputs

The AM controller has two digital inputs that could be galvanically isolated from rest of the controller and from each other when operated in differential mode. Inputs DIN+ and DIN− are connected directly to the optocoupler diode with 10 kΩ resistor in series. These inputs could work in differential mode (galvanically isolated) or in pull-up/pull-down mode. When using pull-up or pull-down mode, one end of the optocoupler's diode is connected to ground or 5 V supply in non-isolated part of the controller. Configuration of differential/pull-up/pull-down operation of DINs is done during controller manufacturing and this configuration is reflected to controller's *MPN*, to the part *Internal HW configuration*. Refer to the section 3.2.1.

By default, both DINs are configured as pull-up. When needed pull-down or differential operation, controller with different *MPN* has to be used. Refer to the section 3.2.1 for details about *MPN*.

When input is configured as pull-up, it is activated by logic low or by shorting it to the ground. When the input is configured as pull-down, it is activated by logic high. Elelctrical connection of digital input is shown in figure 9.4. Trigger voltage of the optocoupler is approximately 3.3 V.

Using these digital inputs allows controller to communicate with industrial computers such as PLC in safe and comfortable way. Digital inputs could be also used for precise PWM and PPM measurement with input frequency up to 1 kHz and resolution up to 1 µs. Digital inputs also allow controller to read A/B encoder or STEP input (when, for example, driving stepper motor or emulating work of stepper motor).

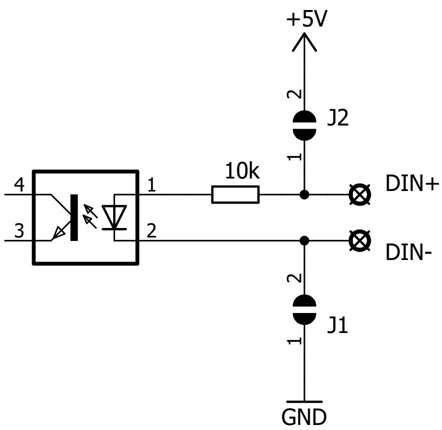


Figure 9.4: Digital input solder jumpers

Table 9.4: Digital input pins

Pin	Name	Description	Direction	Parameters, max. range
23	DIN1+	Diferential optocoupler input 1 , trigger voltage is 3.3 V	Input	-5 to V_{BATT}, max. 5 mA
24	DIN1−			
25	DIN2+	Diferential optocoupler input 2, trigger voltage is 3.3 V		
26	DIN2−			

Note: Pins are related to the pin 24 DIN1 (25 DIN2).

9.6 Analog inputs

The controller features two analog inputs with 12-bit resolution, synchronous operation and up to 20 kHz sampling rate. Analog pins are not galvanically isolated but proper use of pins 19 AGND and 22 AVCC leads to suppressing ground loops and reducing amount of electrical interference and noise in analog inputs. Analog control elements, such as Hall throttle sensor, potentiometers etc. should be powered from the corresponding inputs to achieve interference-free operation.

Analog input pins are 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 analog pin. Example schematic is in the figure 9.5.

Analog pins could be also used by some types of motor sensors. If the corresponding sensor is used, analog pin is not available for other functions.

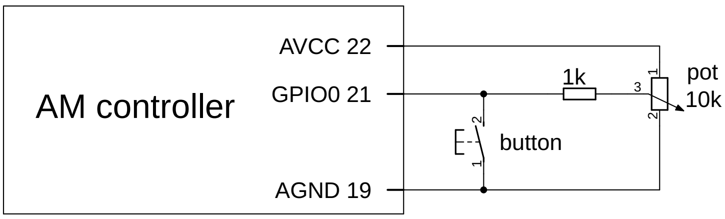


Figure 9.5: Connection of potentiometer and pushbutton to the same GPIO

Table 9.5: Analog input pins

Pin	Name	Description	Direction	Parameters
19	AGND	Analog supply ground, internally connected to BATT−	Power output	0 V, max. 20 mA
20	GPIO1	Analog input 1	Input	0–6 V, max. 10 mA (2) −0.5–6 V, max. 10 mA (3)
21	GPIO0	Analog input 2	Input	
22	AVCC	Analog supply voltage	Power output	5 V, max. 20 mA

Note 1: All pins are related to the pin 19 AGND.
Note 2: Internal resistor disconnected, parameter `/common/ioconf` set to 0 (refer to chapter 12.5.1).
Note 3: Internal resistor connected as pull-up, parameter `/common/ioconf` set to 1 (refer to chapter 12.5.1).

9.7 Digital outputs

The AM controller has two power digital outputs. They are designed to cooperate with the pin 6 VBATSW. This pin is connected to the pin BATT+ when the controller is powered on. Digital outputs are open-drain type. It means that in ON-state the DOUT is connected to the ground of controller, in OFF-state is pin disconnected (floating). The result is that load of the DOUT should be connected between pins DOUT and VBATSW. Example usage of DOUTs are lights on e-bike.

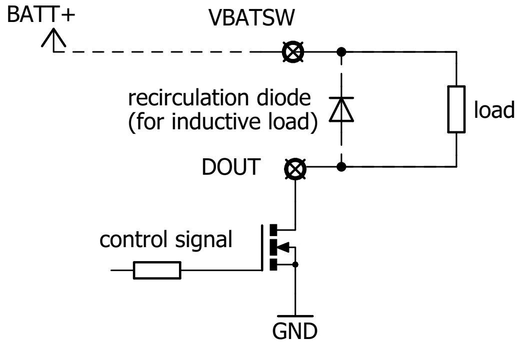


Figure 9.6: Digital output connection – open drain

Connection of open drain outputs is shown in figure 9.6. If the digital output is used for switching inductive load such as contactor, recirculation diode **has to be added** as shown in the figure. Diode is required to protect the board from voltage spikes that result from switching inductive load. Diode should be as close as possible to the AM controller.

Table 9.6: Digital output pins

Pin	**Name**	**Description**	**Direction**	**Parameters, max. range**
6	VBATSW	Internally connected to BATT+ when controller is ON	Power output	0–60 V, max. 1 A
7	GND	Internally connected to BATT−	Power output	0 V, max.1 A
9	DOUT2	Generic digital output	Power output	Open drain, max. 1 A
10	DOUT1			

Note: All pins are related to the pin 7 GND.

Chapter 10: Motor sensors interface

Motor sensors interface of the AM 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 AM 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 AM controller are listed in table **??**. This interface has separated power supply with outputs on pins 15 HALL+5V and 11 HALLGND. Current capability of this power supply is 50 mA. This supply is not galvanically isolated from the battery. Using motor sensors' ground (pin 11 HALLGND) helps to connect all grounds properly without ground loops. Shielding of motor sensors' cable should be also connected to this pin.

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 (default)

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.

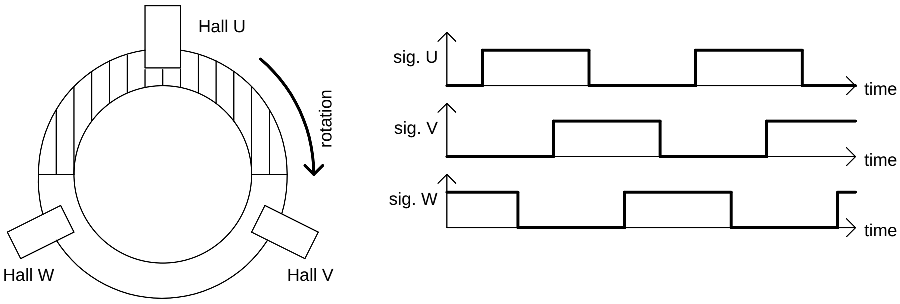


Figure 10.1: Example of UVW commutation signals

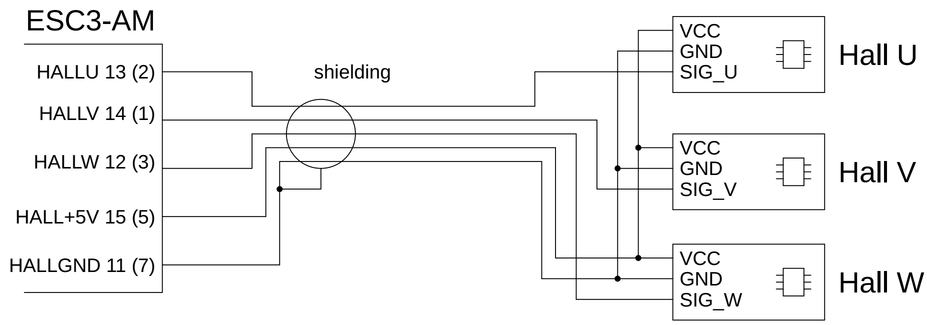


Figure 10.2: Connection of UVW commutation signal to the controller

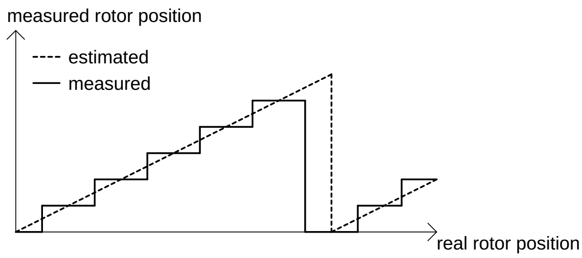


Figure 10.3: Rotor position estimation from UVW commuation signal

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 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

Chapter 11: Pinouts

11.1 Board pinout

Figure 11.1: Board pinout – top side

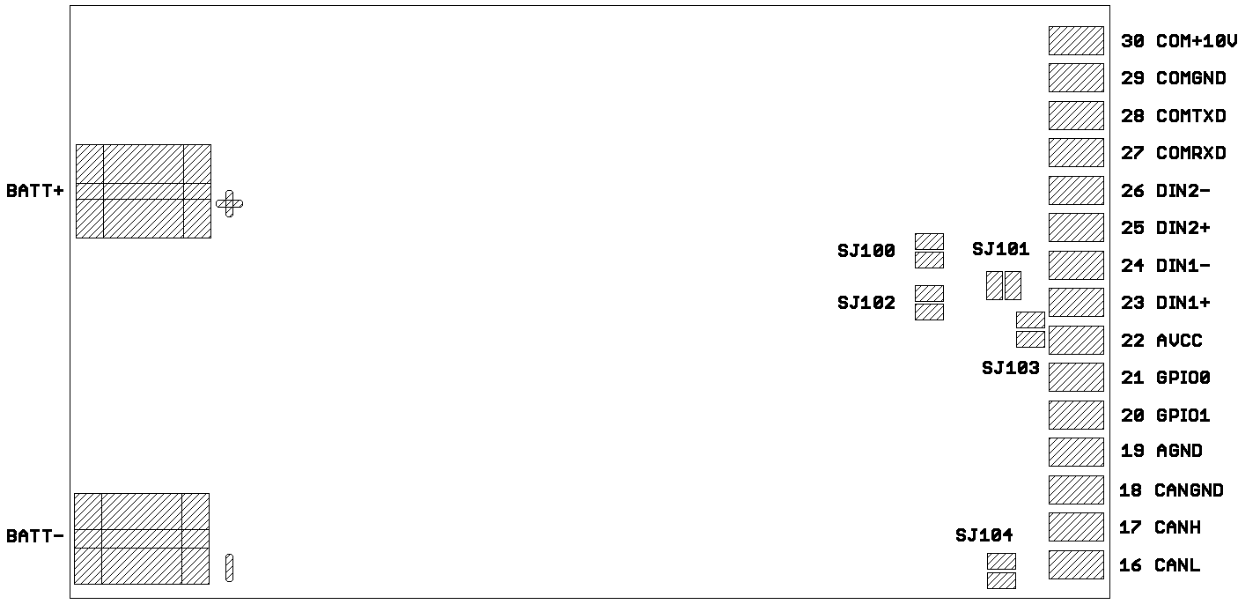


Figure 11.2: Board pinout – bottom side

11.2 Pin list & overview

Table 11.1: AM controller pin list

Pin	Name	Description	Direction
1	USB+5V	USB 5V	Power input
2	USBGND	USB ground, internally connected to BATT−	Power input
3	USBDM	USB data −	I/O
4	USBDP	USB data +	I/O
5	KEY	Internally connected to BATT+	Power output
6	VBATSW	Internally connected to BATT+ when controller is ON	Power output
7	GND	Internally connected to BATT−	Power output
8	POWER	Controller ON/OFF input, active high	Input
9	DOUT2	Generic digital output	Output
10	DOUT1	Generic digital output	Output
11	HALLGND	Hall sensors supply ground	Power output
12	HALLW	Hall sensor B	I/O
13	HALLU	Hall sensor C	I/O
14	HALLV	Hall sensor A	I/O
15	HALL+5V	Hall sensors supply voltage	Power output
16	CANL	CAN Bus LOW	I/O
17	CANH	CAN Bus HIGH	I/O
18	CANGND	CAN Bus ground	Power output
19	AGND	Analog supply ground	Power output
20	GPIO1	Analog input 1	Input
21	GPIO0	Analog input 2	Input
22	AVCC	Analog supply voltage	Power output
23	DIN1+	Digital input 1 +	Input
24	DIN1−	Digital input 1−	Input
25	DIN2+	Digital input 2 +	Input
26	DIN2−	Digital input 2−	Input
27	COMRXD	UART RX	Input
28	COMTXD	UART TX	Output
29	COMGND	UART ground	Power output
30	COM+10V	UART supply 10 V	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 11.2: USB connector

JST JWPF 4-pin male JM4_USB	**Connector pin**	**Wire color**	**AM pin**	**Function**
	1	● **white**	04 USBDP	USB data+
	2	● **green**	03 USBDM	USB data-
	3	● **black**	02 USBGND	USB ground
	4	● **red**	01 USB+5V	USB 5 V supply

Table 11.3: Power connector

JST JWPF 3-pin female JF3_PWR	**Connector pin**	**Wire color**	**AM pin**	**Function**
	1	● **brown**	05 KEY	Supply in/out
	2	● **yellow**	08 POWER	Power control input
	3	● **black**	07 GND	Ground

Table 11.4: Digital OUT1 connector

JST JWPF 2-pin female JF2_DO1	**Connector pin**	**Wire color**	**AM pin**	**Function**
	1	● **brown**	06 VBATSW	Switched battery output
	2	● **green**	10 DOUT1	Open-drain output

Table 11.5: Digital OUT2 connector

JST JWPF 2-pin female JF2_DO2	**Connector pin**	**Wire color**	**AM pin**	**Function**
	1	● **brown**	06 VBATSW	Switched battery output
	2	● **blue**	09 DOUT2	Open-drain output

Table 11.6: UART COM connector (10 V variant)

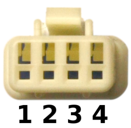
JST JWPF 4-pin female JF4_UARTCOM10	**Connector pin**	**Wire color**	**AM pin**	**Function**
	1	● **black**	29 COMGND	Communication ground
	2	● **white**	28 COMTXD	UART TX
	3	● **blue**	27 COMRXD	UART RX
	4	● **orange**	30 COM+10V	+10 V output

Table 11.7: Control IO 1 (analog) connector

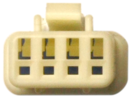
JST JWPF 4-pin female JF4_CNTRL1	**Connector pin**	**Wire color**	**AM pin**	**Function**
 1 2 3 4	1	● **black**	19 AGND	Analog ground
	2	● **blue**	20 GPIO1	Analog input (brake)
	3	● **green**	21 GPIO0	Analog input (throttle)
	4	● **red**	22 AVCC	Analog supply

Table 11.8: CAN connector

JST JWPF 3-pin male JM3_CAN	**Connector pin**	**Wire color**	**AM pin**	**Function**
 3 2 1	1	● **black**	18 CANGND	Communication ground
	2	● **yellow**	17 CANH	CAN high
	3	● **green**	16 CANL	CAN low

Table 11.9: PAS connector

JST JWPF 3-pin male JM3_PAS	**Connector pin**	**Wire color**	**AM pin**	**Function**
 3 2 1	1	● **black**	19 AGND	Analog ground
	2	● **yellow**	24 DIN1−	PAS signal
	3	● **red**	23 DIN1+	PAS supply

Table 11.10: Digital IN1 connector

JST JWPF 2-pin male JM2_DI1	**Connector pin**	**Wire color**	**AM pin**	**Function**
2  1	1	● **green**	24 DIN1−	Diff signal−
	2	● **orange**	23 DIN1+	Diff signal+
	1	● **green**	07 GND	Ground
	2	● **orange**	24 DIN1−	Signal+ (pull-up)
	1	● **green**	23 DIN1+	Signal− (pull-down)
	2	● **orange**	22 AVCC	Analog supply

Table 11.11: Digital IN2 connector

JST JWPF 2-pin male JM2_DI2	**Connector pin**	**Wire color**	**AM pin**	**Function**
2  1	1	● **blue**	26 DIN2−	Diff signal−
	2	● **orange**	25 DIN2+	Diff signal+
	1	● **blue**	07 GND	Ground
	2	● **orange**	26 DIN2−	Signal+ (pull-up)
	1	● **blue**	25 DIN2+	Signal− (pull-down)
	2	● **orange**	22 AVCC	Analog supply

Table 11.12: Motor sensors connector – *Motor sensors variant* ***h***

JST JWPF 8-pin male JM8_MSENS_H	**Connector pin**	**Wire color**	**AM pin**	**Function**
	1	● **green**	14 HALLV	Hall V signal
	2	● **blue**	13 HALLU	Hall U signal
	3	● **yellow**	12 HALLW	Hall W signal
	4		not connected	
	5	● **red**	15 HALL+5V	Hall supply
	6		not connected	
	7	● **black**	11 HALLGND	Ground
	8		not connected	

11.3.2 HIGO e-bike combined wiring connector (variant H)

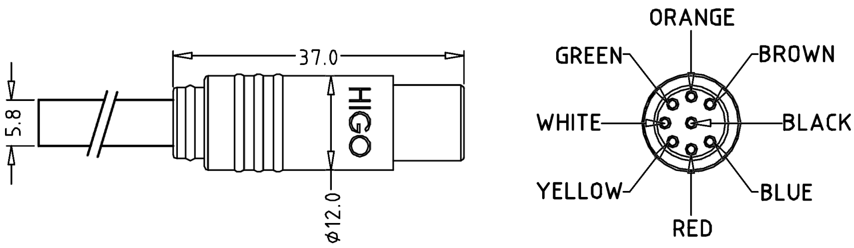


Figure 11.3: Combined wiring connector – Higo Z812AM P

Table 11.13: Combined wiring connector pinout – Higo Z812AM P

Connector pin	**AM pin**	**Function**
● BLUE	21 GPIO0	Accelerator input
● RED	22 AVCC	Power for accelerate / brake controls
● YELLOW	28 COMRXD	Display communication
● WHITE	20 GPIO1	Brake input
● GREEN	29 COMTXD	Display communication
● ORANGE	8 POWER	Activation input
● BROWN	5 KEY	Power output to switch
● BLACK	7 GND	Ground

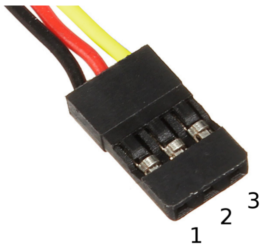
Not all functions of the AM controller can be covered by HIGO connectors. Some functions can be added by JST JWPF connector. Usually USB, PAS sensor and lights are used on e-bikes in addition. Refer to chapter 3 for more information about available variants and their ordering codes.

11.3.3 Other supported connectors (variant E)

This section describes connection of connectors other than JST JWPF or HIGO, that can be also used for the AM controller. Connectors listed in this section is supported, but they are not preffered. Usage of JST JWPF connectors is recommended.

RC servo plug connector

Table 11.14: RC servo plug connector

2.54 mm 3-pin female	Connector pin	Wire color	AM controller pin and number
	1	● **black**	26 DIN2−
	2	● **red**	not connected
	3	● **yellow**	25 DIN2+

11.4 Power connectors pinout

11.4.1 Amass XT60, MT60 (variant A)

Figure 11.4: Battery connector pinout – Amass XT60 male

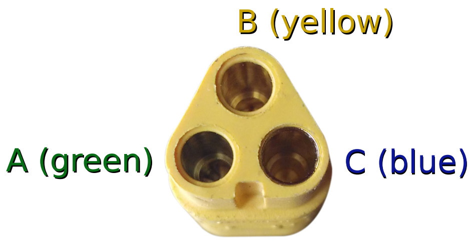


Figure 11.5: Motor connector pinout – Amass MT60 female

11.4.2 HIGO e-bike motor connector (variant H)

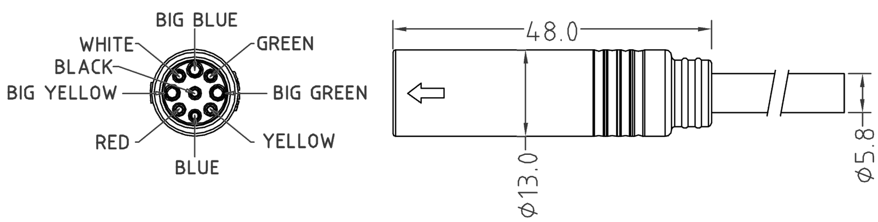


Figure 11.6: Motor connector – Higo Z910AM P

Table 11.15: Motor connector pinout – Higo Z910AM P

Connector pin	AM pin	Function
• BIG YELLOW	B	Motor phase B
• WHITE	26 DIN2−	Speed sensor
• BIG BLUE	C	Motor phase C
• GREEN	14 HALLV	Hall sensor A
• BIG GREEN	A	Motor phase A
• YELLOW	12 HALLW	Hall sensor C
• BLUE	13 HALLU	Hall sensor B
• RED	15 HALL+5V	Hall sensors power
• BLACK	11 HALLGND	Hall sensors ground

11.4.3 Bare wires and cable lugs (variants W, 5 and 6)

Connection of power wire is determined by its color (or color of shrinking tube located on the wire). It applies for assembly variants with bare wires and cable lugs, where the color is the only possible mean, how to determine function of wire. Colors of wires are assigned as follows:

- black – battery +
- red – battery −
- • / • green or brown – motor phase A
- yellow – motor phase B
- blue – motor phase C

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.

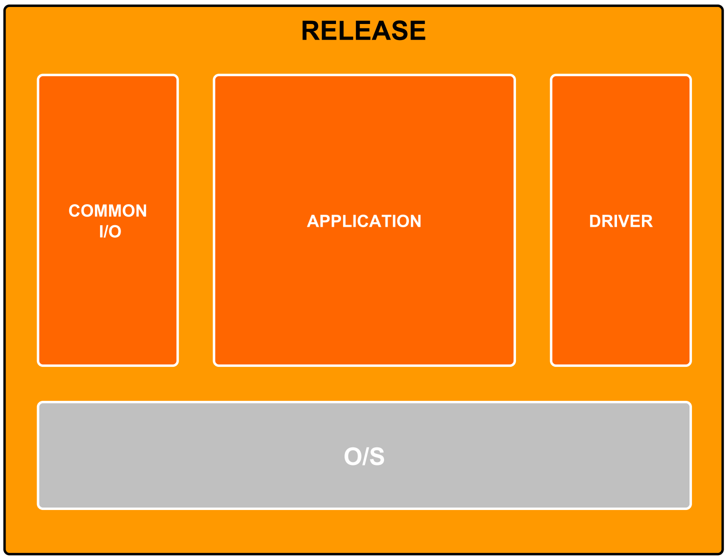


Figure 12.1: Block structure of release

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 AM controller is number **10**.

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. AM contoroller has no dedicated termistor input, this object is reserved.

12.3.2 Rthermistor

`Rthermistor (float) [Ω]`
Thermistor resistance in ohms. AM contoroller has no dedicated termistor input, this object is reserved for future use.

12.3.3 gpio0, gpio1

`gpio0 (int16) [mV]`
`gpio1 (int16) [mV]`
Value on pin 20 GPIO1 or 21 GPIO0 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 gdin1, gdin2

`gdin1 (int8)`
`gdin2 (int8)`
Representation of digital state of pin 20 GPIO1 or 21 GPIO0. 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)
2	$> 1.6\,V$	$> 2.8\,V$	tbd
0	$< 1.6\,V$	$0.2\,V < V_{gdin} < 2.8\,V$	tbd
−1	not defined	$< 0.2\,V$	tbd

12.3.5 din1, din2

`din1 (int8)`
`din2 (int8)`
Representation of differential state between pins 23 DIN1+ (25 DIN2+) and 24 DIN1− (26 DIN2−). If voltage on pin DIN1+ is more than 2 V higer than voltage on pin DIN1−, value of this variable is 1, in other cases value is 0. If DIN1 (DIN2) input is configured as pull-up, logic HIGH is when pin DIN1− (DIN2−) is connected to the ground. If DIN1 (DIN2) input is configured as pull-down, logic HIGH is when pin DIN1+ (DIN2+) is connected to 5 V.

12.3.6 dout1, dout2

`dout1 (int8)`
`dout2 (int8)`
DOUT1 (DOUT2) 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` (or `dout2`) state is 1. When pin is in OFF-state, it is disconnected (floating) and value of the `dout1` (or `dout2`) state is 0.

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`	21	GPIO0
9	0x09	`gpio1`	20	GPIO1
16	0x10	`gdin0`	21	GPIO0
17	0x11	`gdin1`	20	GPIO1
32	0x20	`din1`	23	DIN1+, 24 DIN1−
33	0x21	`din2`	25	DIN2+, 26 DIN2−
48	0x30	`ch1`	23	DIN1+, 24 DIN1−
49	0x31	`ch2`	25	DIN2+, 26 DIN2−
72	0x48	`Vthermistor`		
73	0x49	`Rthermistor`		
128	0x80	`dout1`	10	DOUT1
129	0x81	`dout2`	9	DOUT2

12.5 Configuration of hardware inputs and outputs

In this section are described parameters that configures hardware inputs and outputs. They are located in directory `/common`.

12.5.1 ioconf0, ioconf1

`ioconf0 (uint8)`
`ioconf1 (uint8)`
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 `gpio0` (`gpio1`) is length of pulse in microseconds
- 64 – pulse length measure, value of `gpio0` (`gpio1`) is length of pulse in miliseconds

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 8, especially to section 8.2 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-SC 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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