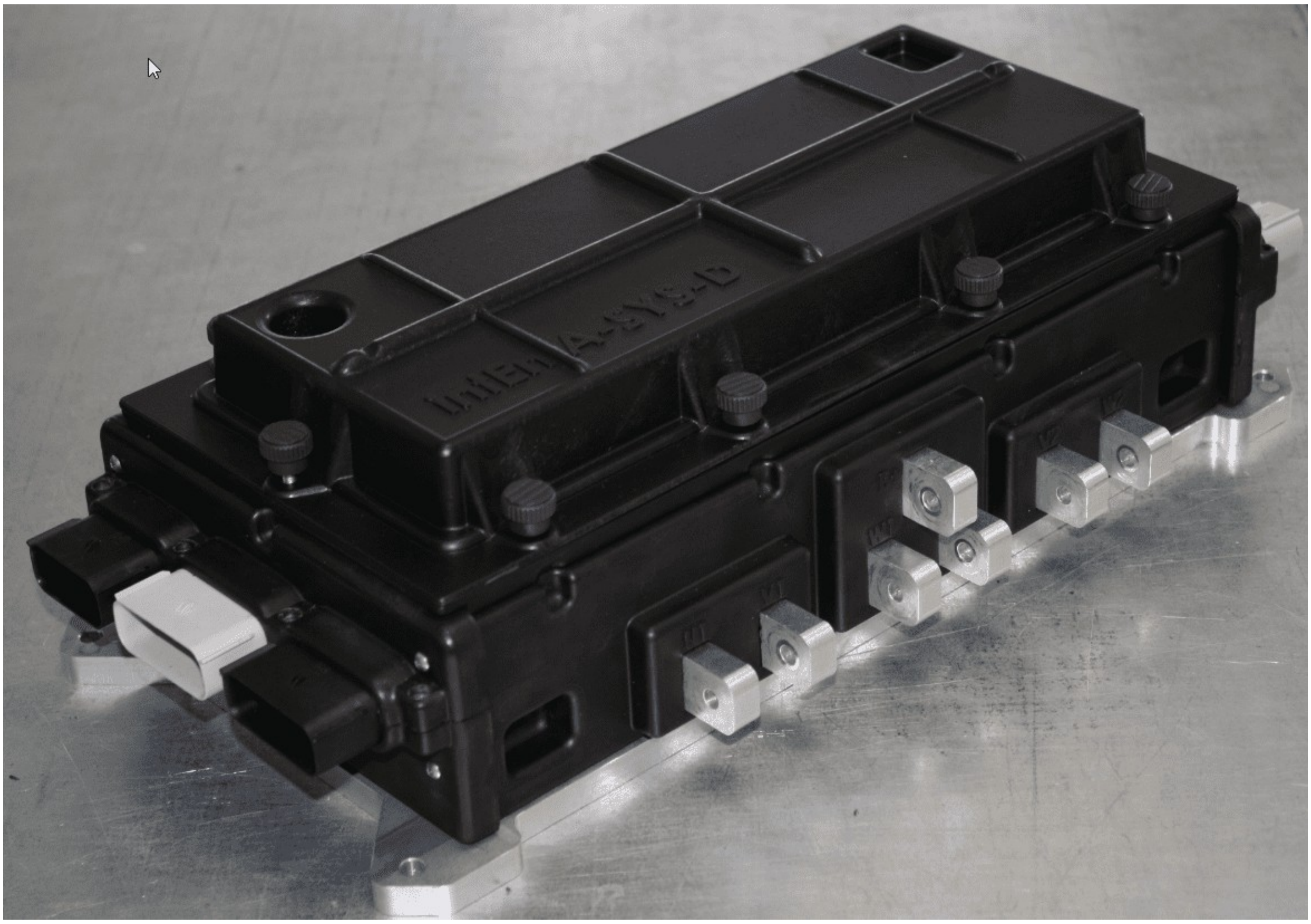
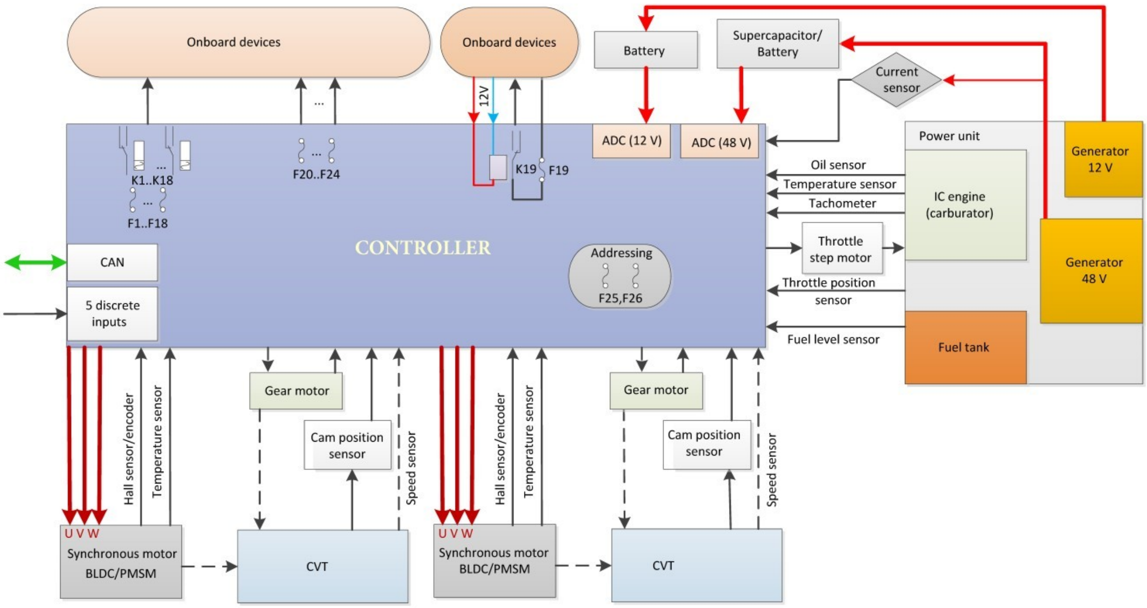
Advanced System Design intEn two-channel hybrid/electric vehicle integrated controller



1 Description

The controller represents an electronic module combining all functions that may be required to create control systems for hybrid vehicles or electric cars. Besides vehicle control systems, the controller can be used in any BLDC/PMSM based systems.

Picture 1 Shows devices attachable to the controller.



Pic. 1 Connected equipment.

The controller can be used for:

– driving two three phase brushless electric motors (PMSM or BLDC) up to 15 kW each with digital (Hall sensor) or analog (encoder) position sensors;
– controlling of two electronic CVTs;
– controlling power module consisting of a carburetor-type IC engine and a generator to provide configured battery voltage;
– managing onboard equipment power with relays;
– collecting and processing sensor data (electric motor and IC engine temperature, IC frequency, electric motorfrequency, wheel velocity, fuel level, generator amperage);
– monitoring discrete signals from devices and sensors with open collector type outputs.

The electric motor control algorithms allow configuring of wheel velocity and of maximum power consumption. Temperature sensors data processing allows controlling of temperature conditions of electric motors and controller to avoid overheating.

The controller allows expanding the electric motor dynamic range by means of an electrically controlled CVT. The CVT mechanism is driven by a brushed motor. Automatic regulation of the CVT gear ratio provides balance between the motor frequency and torque.

The power unit control function ensures optimal battery voltage by means of controlling the ICE throttle.

The onboard equipment power control is performed by means of easily replaceable automobile relays. To prevent short circuits and overcurrent each relay is protected with a fuse. Apart from controlled power outputs there are a few non-controlled outputs also protected with fuses. For the user convenience the system provides automatic fuse integrity check. Aside from controlled relays the controller includes one relay with external control.

Discrete inputs allow connecting and monitoring the condition of discrete sensors. The following sensors have discrete output:

- oil level sensor;
- throttle position sensor;
- engine oil pressure sensor;
- brake liquid sensor;
- service brake sensor;
- handbrake sensor;
- windscreen washer liquid sensor;

The controller is operated through CAN interface. It is recommended to use our front panel controller as board computer to operate the controllers.[1].

[1] [see the Quote attached].

2 Technical parameters

The device has the following technical parameters and features:

Table. 1 Technical parameters

Parameters	**Rating**
Controller supply voltage range	11,5...30 V
Supply current	≤ 0,6 A
Operating temperature range	-40…+55°C
Environmental protection	IP67
CAN baud rate	1 Mbps
CAN differential output voltage (dominant)	1,5…3,0 V
Dimensions:	
-length	417,6 mm
-width	208 mm
-height	120,5 mm

табл. 2. Discrete inputs

Parameter	**Rating**
Maximum switching resistance	500 Ohm
Minimum switching current	2 mA

Table 3. Power outputs

Type	**Max current[1], A**	**Quantity**
Electronically controlled relay	30	4
	20	14
External control relay	20	1
Non-controlled output	-	6

[1] Max current values depend on fuses installed

Table 4. Electric motors and equipment

Parameter	**Rating**
Max motor phase current (pulsed)	500 A
Max current pulse time	30 sec
Max motor current (countinuous)	300 A
Max motor continuous power	15000 W
Battery voltage	48±18 V
Max throttle step motor phase current	2,5A
Throttle step motor phase voltage range	8,2…12 V
Brushed motor supply voltage	U*-1 V
Max brushed motor current	11A
Speed sensors supply voltage	U*-0,7 V
Max speed sensor supply current	100 mA
CVT cam sensor supply voltage range	4,7…5 V
CVT cam sensor input signal range	0…5 V
Hall sensor/encoder supply voltage	4,7…5 V
Hall sensor/encoder max supply current	50 mA
Min Hall sensor switching current	7 mA
Encoder signal input voltage range	0…5 V
Motor temperature sensor resistance range	50…5000 Ohm

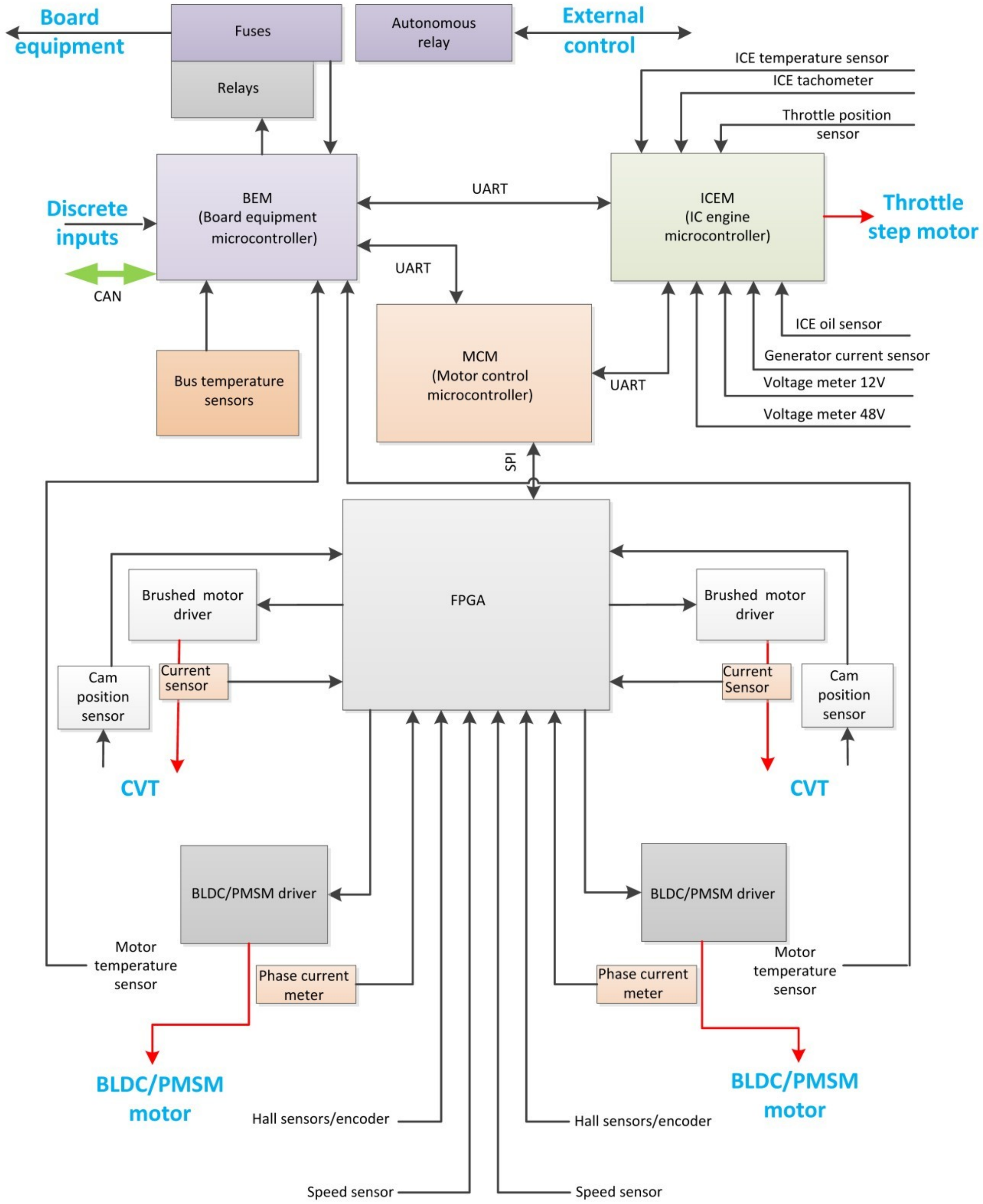
Table 5. IC engine and generator sensors

Parameter	**Rating**
IC engine speed sensor voltage	Up to 25 V
Fuel sensor resistance range	7…350 Ohm
Coolant temperature sensor resistance range	50…5000 Ohm
Generator current sensor supply voltage	9±1 V
Max supply current for generator current sensor	50 mA
Input voltage range for generator current sensor	0…9 V

* U – in-line controller power voltage

3 Controller architecture

Pic. 2 shows controller architecture.



Pic. 2 Controller architecture

The controller includes three microcontrollers connected via UART interface and one FPGA. The electric motors microcontroller is connected with FPGA through SPI interface, with the FPGA being a slave device . Each microcontroller performs its own function.

IC engine microcontroller operates the IC engine and maintains the configured values of battery voltage. Regulation of IC engine frequency and of battery voltage is performed by means of step motor that controls the air throttle position. Opening of the air throttle causes fuel injection increase and engine rpm enlargement while closure of the air throttle gives the opposite effect. The air throttle regulation range is limited by the throttle position sensor. Beside this, the IC engine microcontroller performs monitoring of board and battery voltages, generator current, the IC engine temperature and frequency and discrete signal of ICE oil level.

The board device microcontroller's main function is to provide CAN interface of the controller and to control relays. The board device microcontroller also measures power bus temperature, checks fuse's integrity and discrete input's states.

The motor control microcontroller main function is to manage motors and CVTs. This microcontroller only calculates parameters and sends required data to FPGA. The FPGA performs collecting data from ADCs and generates timing diagrams for synchronous and brushed motors drivers.

4 Connections

The controller has on its body 7 connectors for low-current circuits and power terminals for connecting electric motors and battery voltage. Please, see below the detailed information on the connector types and pin and terminals wiring information.

4.1 Pin definition

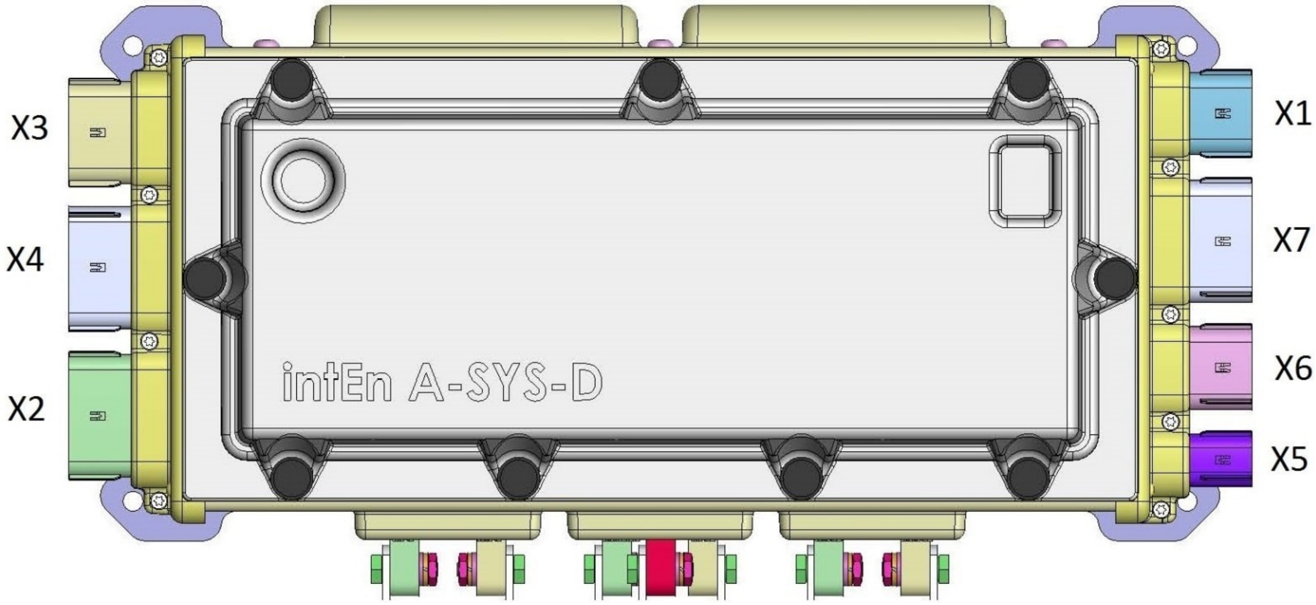


рис. 3 Интерфейс

The controller contains 7 MX150 series connectors produced by Molex. The table below specifies the connectors types and counterparts.

Table 6 Pin types and counterparts

Ref. des.	Partnumber	Number of positions	Counterpart (replacements)
X1	33482-1201	12	33472-1201 (33472-1206, 33472-1211)
X2	33482-2101	20	33472-2101 (33472-2103, 33472-2104)
X3	33482-1601	16	33472-1601 (33472-1606, 33472-1621)
X4	33482-2102	20	33472-2102 (33472-2105, 33472-2123)
X5	33482-0602	6	33472-0602 (33472-0612, 33472-0617)
X6	33482-1202	12	33472-1202 (33472-1207, 33472-1212)
X7	33482-2102	20	33472-2102 (33472-2090, 33472-2121)

Tale 7 Pin definition of X1

Pin	Net	Type	Description
1	12V	Input	Relay supply voltage (+12V)
2	K1_OUT	Output	K1 relay output
3	K1_OUT	Output	K1 relay output
4	K2_OUT	Output	K2 relay output
5	K2_OUT	Output	K2 relay output
6	K4_OUT	Output	K4 relay output
7	K4_OUT	Output	K4 relay output K
8	12V	Input	Relay supply voltage (+12V)
9	K3_OUT	Output	K3 relay output K3
10	K3_OUT	Output	K3 relay output K3
11	-	-	Not used
12	-	-	Not used

Table 8 Pin definition of X2

Pin	Net	Type	Description
1	12V	Input	Relay supply voltage (+12V)
2	K7_OUT	Output	K7 relay output
3	K8_OUT	Output	K8 relay output
4	12V	Input	Relay supply voltage (+12V)
5	K11_OUT	Output	K11 relay output
6	K12_OUT	Output	K12 relay output
7	12V	Input	Relay supply voltage (+12 voltage)
8	K15_OUT	Output	K15 relay output
9	K16_OUT	Output	K16 relay output
10	12V	Input	Relay supply voltage (+12V)
11	K18_OUT	Output	K18 relay supply
12	F22_OUT	Output	F22 fuse output
13	12V	Input	Relay supply voltage (+12V)
14	F23_OUT	Output	F23 fuse output
15	F24_OUT	Output	F24 fuse output
16	K19_UPR+	Input	Autonomous relay control (+)
17	K19_UPR-	Input	Autonomous relay control (-)
18	K19_NC	Output	Autonomous relay (normally closed contact)
19	K19_NO	Output	Autonomous relay (normally open contact)
20	K19_COM	Input	Autonomous relay (common contact)

Table 9 Pin definition of X3

Pin	Net	Type	Description
1	12V	Input	Relay supply voltage (+12V)
2	K5_OUT	Output	K5 relay output
3	K6_OUT	Output	K6 relay output
4	12V	Input	Relay supply voltage (+12V)
5	K9_OUT	Output	K9 relay output
6	K10_OUT	Output	K10 relay output
7	12V	Input	Relay supply voltage (+12V)
8	K13_OUT	Output	K13 relay output
9	K14_OUT	Output	K14 relay output
10	12V	Input	Relay supply voltage (+12V)
11	K17_OUT	Output	K17 relay output
12	F19_OUT	Output	F19 fuse output
13	12V	Input	Relay supply voltage (+12V)
14	F20_OUT	Output	F20 fuse output
15	F21_OUT	Output	F21 fuse output
16	GEN	Output	Generator excitation (12 V)

Table 10 Pin definition of X4

Pin	Net	Type	Description
1	12V	Input	Supply voltage input
2	DESCR IN0	Input	Throttle position sensor input
3	DESCR IN1	Input	Discrete input 1
4	DESCR IN2	Input	Discrete input 2
5	DESCR IN3	Input	Discrete input 3
6	DESCR IN4	Input	Discrete input 4
7	DESCR IN5	Input	Discrete input 5
8	Temp+	Input	ICE temperature sensor input
9	L-	Analog input	ICE frequency sensor input (-)
10	L GND	Shared	ICE frequency sensor shielding
11	L+	Analog input	ICE frequency sensor input (+)
12	Fuel+	Analog input	Fuel level sensor input
13	Fuel- (GND)	Common	Oil level sensor common
14	9V	Output	Generator current sensor supply
15	Curr sens	Analog input	Generator current sensor input
16	GND	Shared	Generator current sensor common
17	A+	Output	Throttle step motor. Phase A+
18	A-	Output	Throttle step motor. Phase A-
19	B+	Output	Throttle step motor. Phase B+
20	B-	Output	Throttle step motor. Phase B+

Table 11 Pin definition of X5

Pin	Net	Type	Description
1	CAN GND	Common	CAN bus (common)
2	CAN -	Input-output	CAN bus -
3	CAN +	Input-output	CAN bus +
4	CAN +	Input-output	CAN bus +
5	CAN -	Input-output	CAN bus -
6	CAN GND	Commn	CAN bus (common)

Table 12 Pin definition of X6

Pin Connector №	NetConnector marking	Type	Description
1	HALL 5V	Output	Halls sensor supply (5 V)
2	HALL U1/SIN	Input / Analog input	Motor 1 Hall sensor U /encoder sin channel
3	HALL V1/COS	Input / Analog input	Motor 1 Hall sensor V/ encoder cos channel
4	HALL W1	Input	Motor 1 Hall sensor Wchannel
5	Temp M1+	Input	Motor 1 temperature sensor input
6	HALL GND	Common	Hall sensor supply (common)
7	HALL 5V	Output	Hall sensor supply (5 V)
8	HALL U2/SIN	Input / Analog input	Motor 2 Hall sensor U/encoder sin channel
9	HALL V2/COS	Input / Analog input	Motor 2 Hall sensor input V/ encoder cos channel
10	HALL W2	Input	Motor 2 Hall sensor Wchannel
11	Temp M2+	Input	Motor 2 temperature sensor input
12	HALL GND	Common	Hall sensor supply (common)

Tale 13 Pin definition of X7

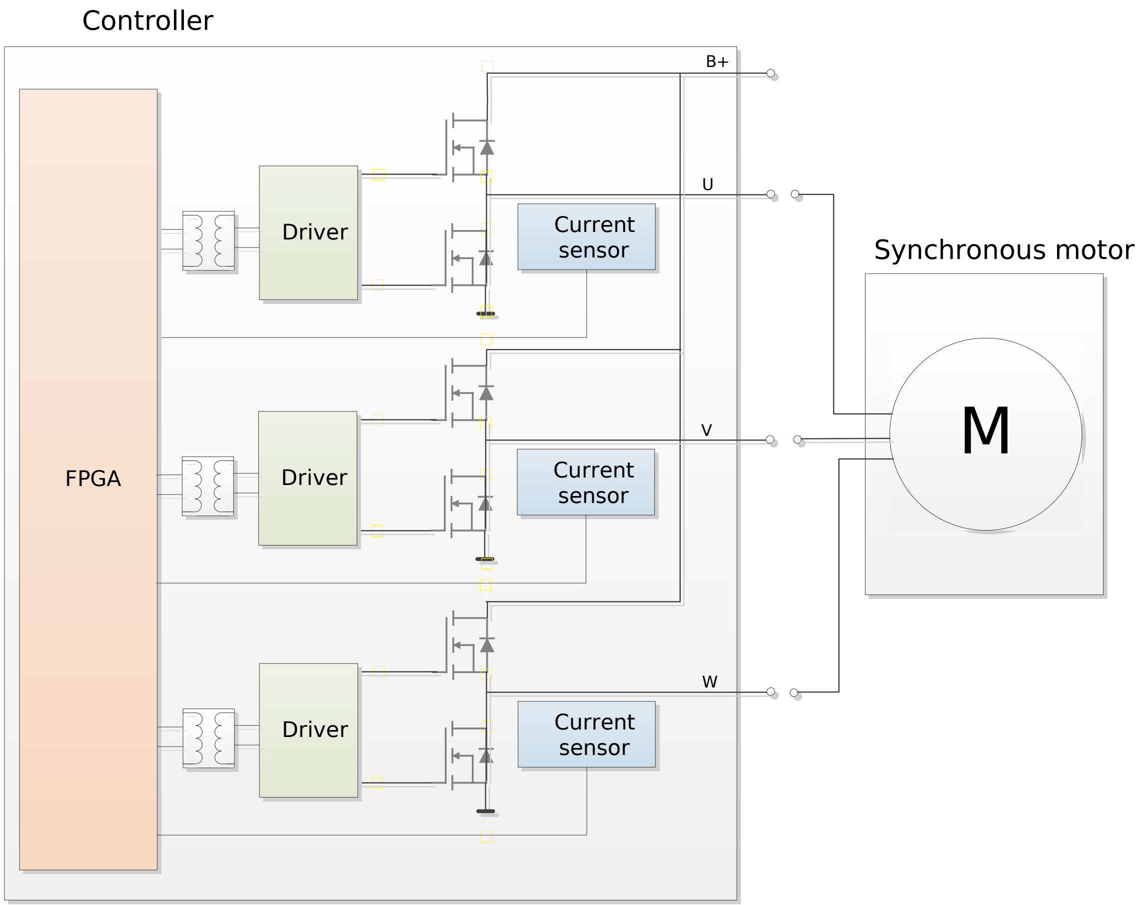
Pin Connector №	NetConnector marking	Type	Description
1	M1+	Output	CVT DC motor 1. Phase +
2	M1-	Output	CVT DC motor 1. Phase -
3	12V	Output	CVT DC motor supply (12 V)
4	M2+	Output	CVT DC motor 2. Phase +
5	M2-	Output	CVT DC motor 2. Phase -
6	L1	Input	CVT speed sensor 1 signal
7	12V_L1	Output	CVT speed sensor 1 supply (12 V)
8	L2	Input	CVT speed sensor 1 signal
9	12V_L2	Output	CVT speed sensor 1 supply (12 V)
10	VAR_5V_1	Output	CVT cam position sensor 1 supply (5 V)
11	VAR_SIG_1	Input	CVT cam position sensor 1 signal
12	VAR_GND_1	Common	CVT cam position sensor 1 supply (common)
13	VAR_5V_2	Output	CVT cam position sensor2 supply (5 V)
14	VAR_SIG_2	Input	CVT cam position sensor 2 signal
15	VAR_GND_2	Common	CVT cam position sensor 2 supply (common)
16	-	-	Not used
17	-	-	Not used
18	-	-	Not used
19	-	-	Not used
20	-	-	Not used

4.2 Sensors and devices

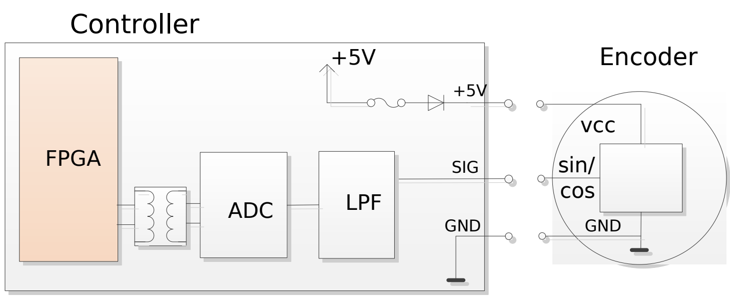
Please, see below the detailed range of devices that may be connected to the controller.

- <u>Electric motors</u>

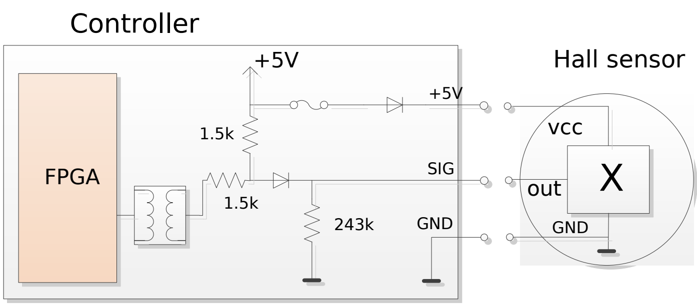
Two BLDC or PMS motors (option is specified when ordering). Electric motors can be controlled by means of Hall sensors or encoders (option is specified when ordering). Motor power control is based on the phase current and battery voltage measurements. Picture 4 represents the structural scheme of synchronous motor driver channel. Pictures 5 and 6 show the motor positioning sensor connection.



Picture 4 Synchronous motors connection



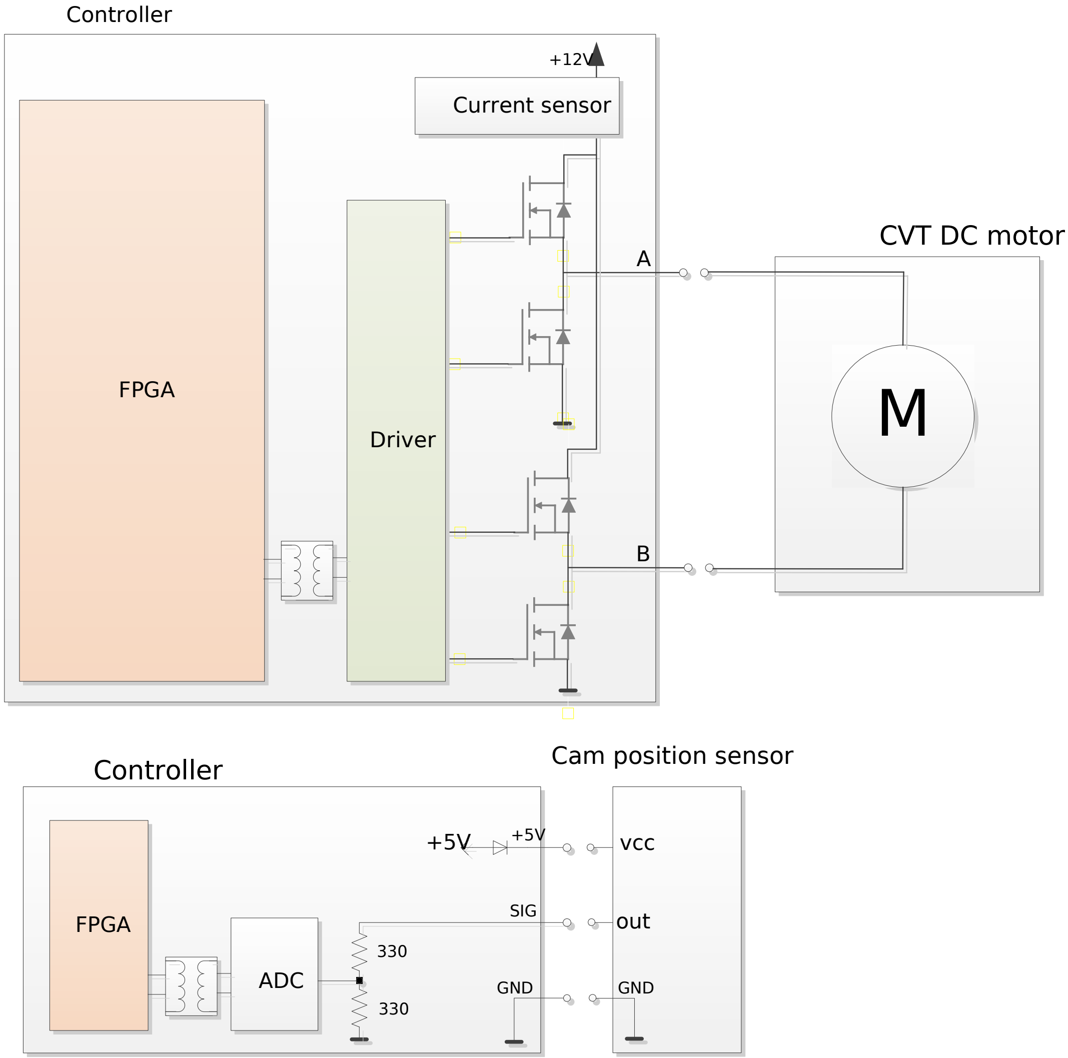
Picture 5 Encoder connection



Picture 6 Hall sensor connection

 [Electronic CVT]

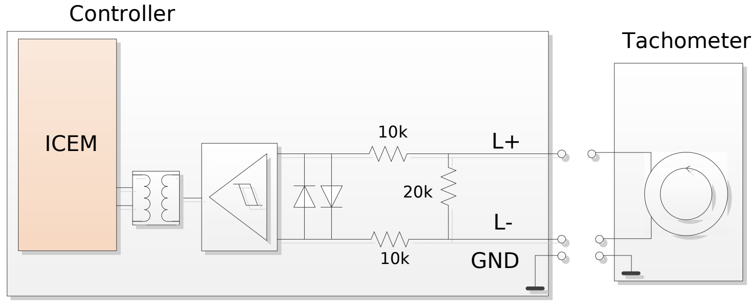
The CVT is used for expanding synchronous motors dynamic range. An electronic CVT is controlled by means of DC brushed motor (CVT DC motor). Taking into account the CVT construction peculiarities, it is necessary to control the cam passing of phase points by means of cam position sensor connected to the corresponding controller input.



Picture 7 Connecting of CVT DC motor and cam position sensor

 [IC engine frequency sensor]

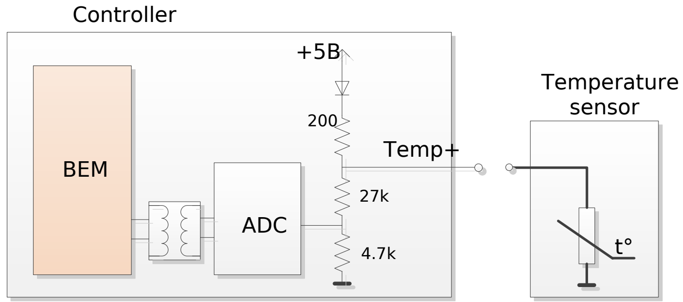
It is necessary to control the IC engine work and to maintain idle speed for no load condition by means of analog tachometer.



Picture 8 Connection of IC engine tachometer

- Temperature sensor

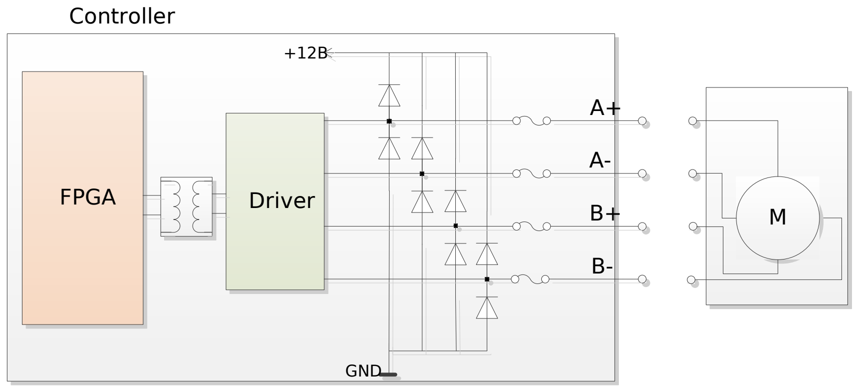
To control the engine and electric motor temperature in the working condition resistive temperature sensors are connected to the controller (see table 5, picture 9)



Picture 9 Connection of resistive temperature sensor

- Throttle stepmotor

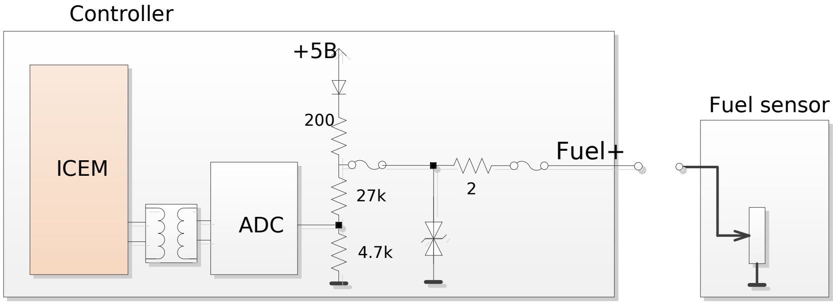
The picture below shows the structure of throttle step motor driver.



Picture 10 Connection of throttle step motor

- Fuel level sensor

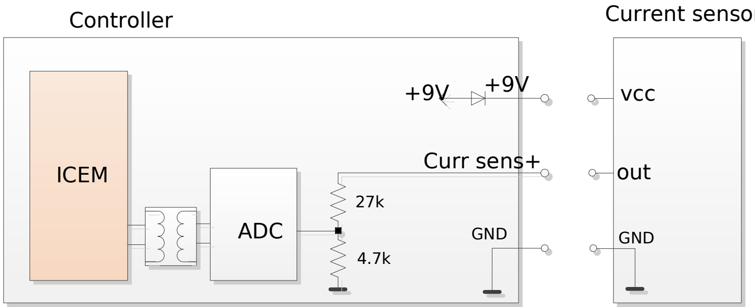
To estimate fuel level a potentiometeric sensor can be connected to the controller. To avoid ignition the spark protection is used. See the sensor connection in the picture below.



Picture 11 Connection of fuel level sensor

- Current sensor

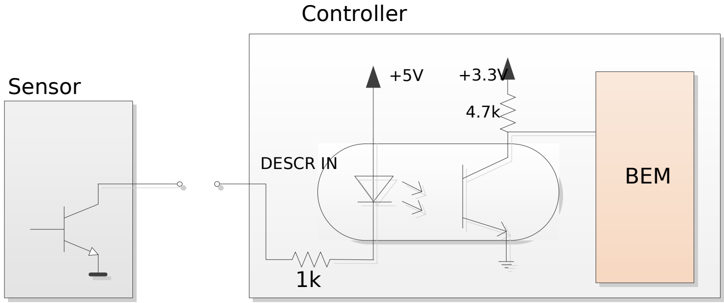
  Generator current is monitored by the current sensor shown in the picture below.



Picture 12 Connection of generator current sensor

- Discrete inputs

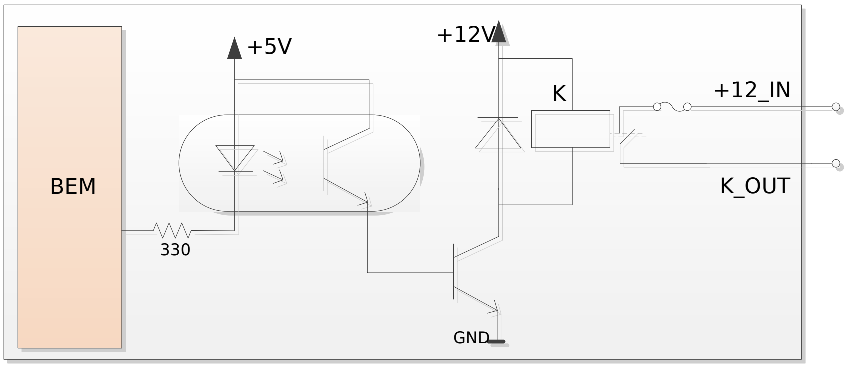
Discrete inputs serve for connection of sensors with “open collector” type outputs. The structural scheme of input is shown in the picture 13. Input and output parameters of sensors connected to the system are specified in table 2.



Picture 13 Open collector output and discrete input

- Board equipment

  A set of relays and fuses is provided to control power supply of the onboard equipment. Controller includes two types of relays(see table 2). For high loads (driving beams) high current relays are recommended



Picture 14 Connection of board equipment to the controller relay

4.3 Power terminals

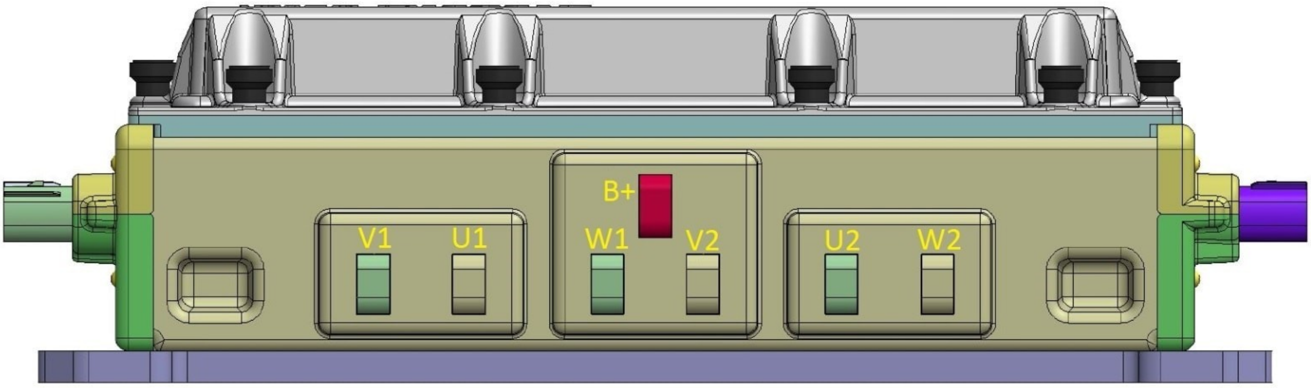
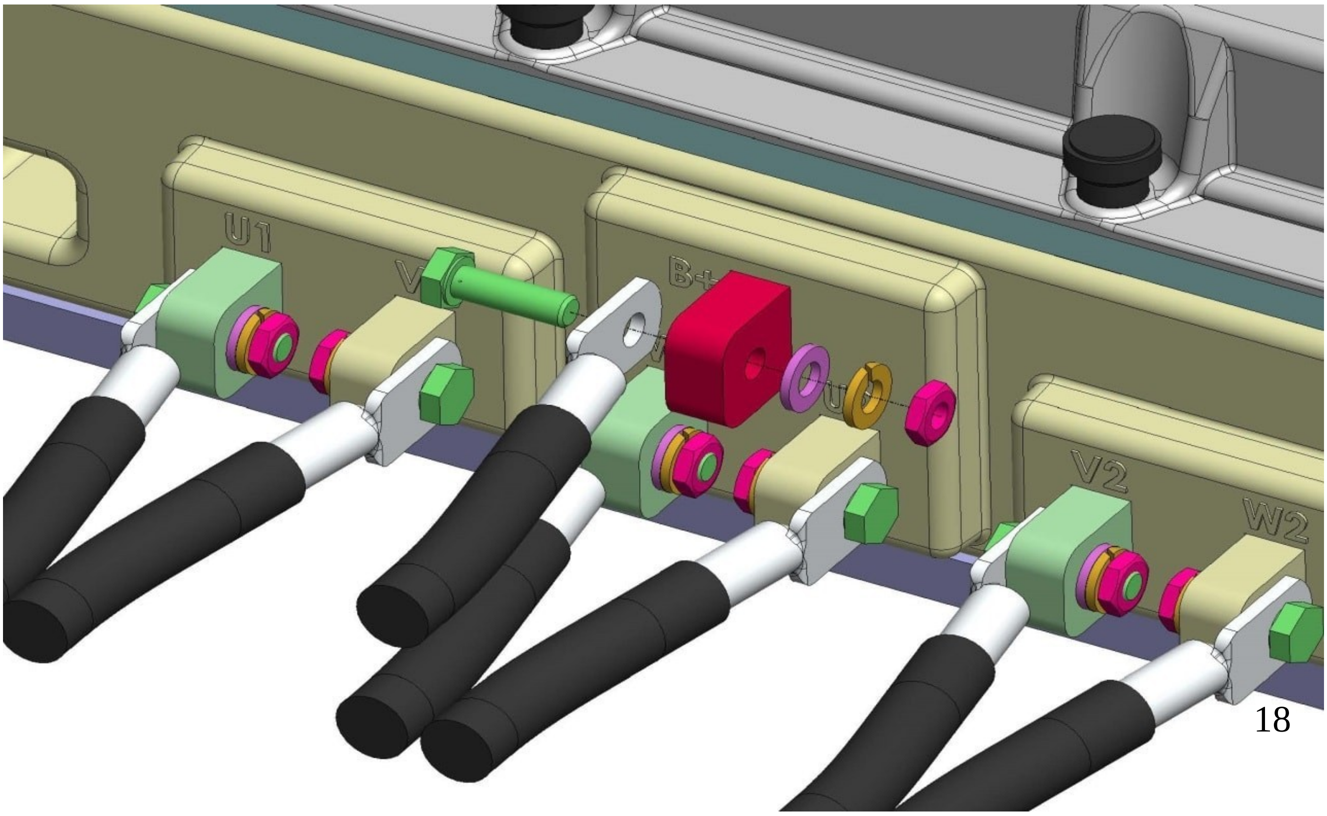
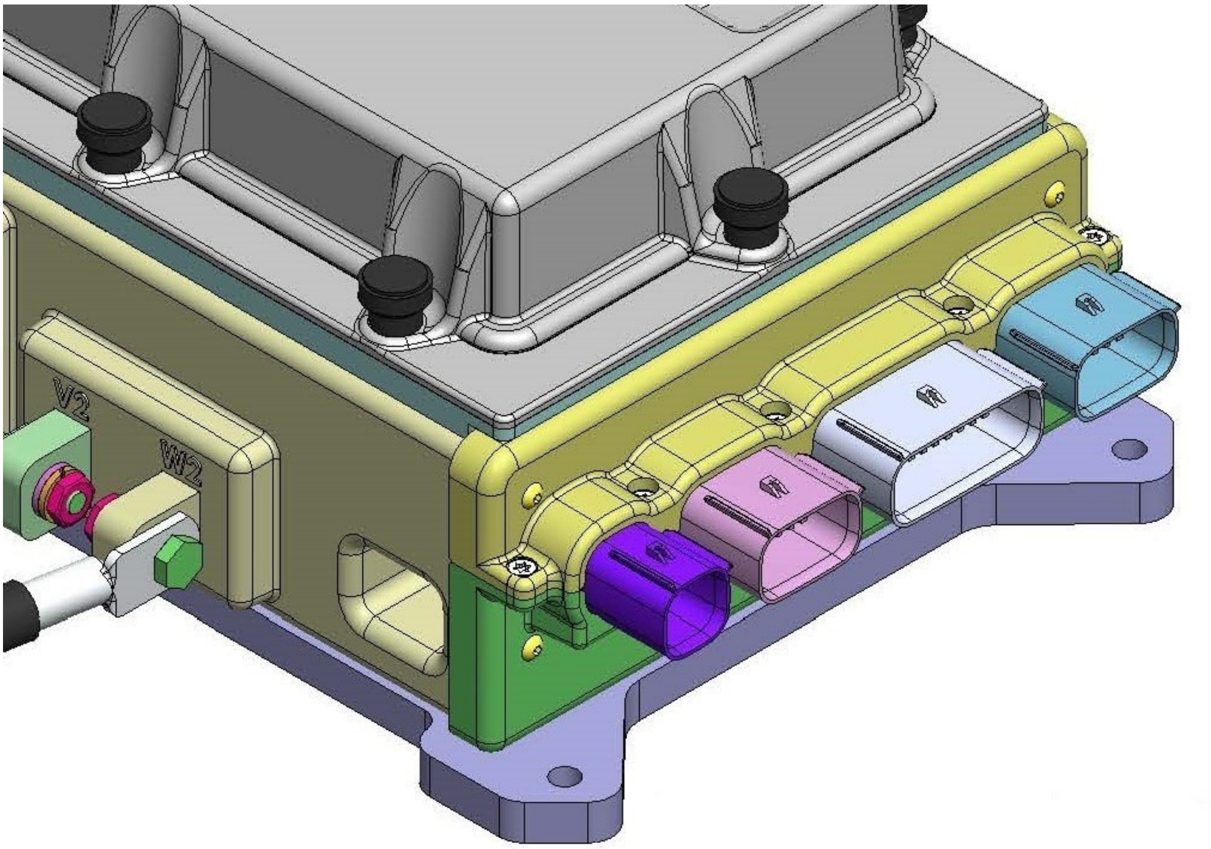


рис. 15 Power terminals view

Phases of motor 1 and 2 should be connected to terminals U1, V1, W1 and U2, V2, W2 respectively . Terminal B+ serves as a common battery power supply input for both electric motors. Power supply and motor phases are connected to power terminals by means of bolt-nut connection. (pic.16).





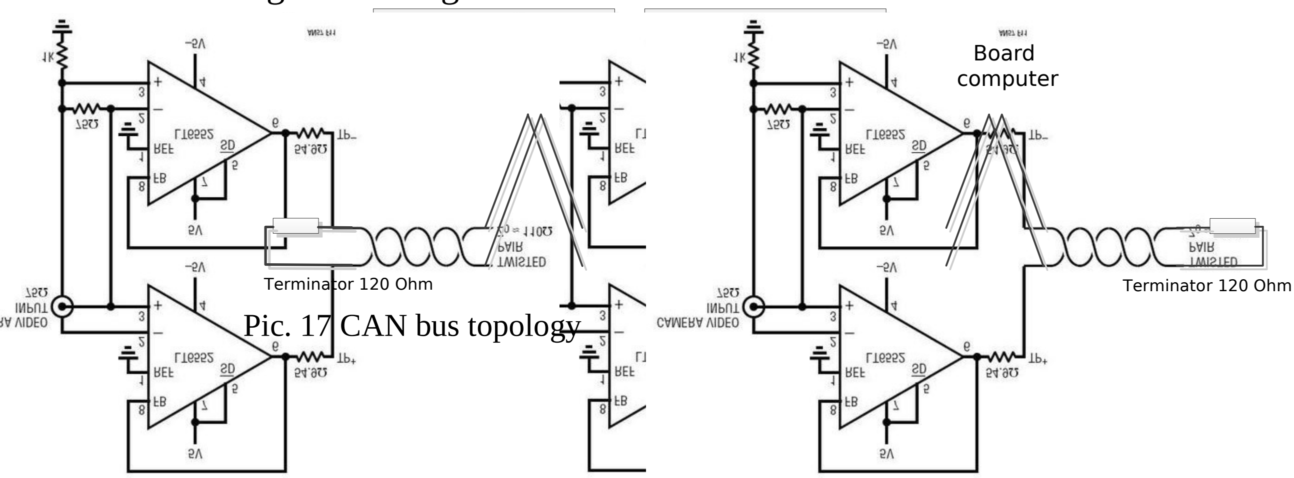
Pic. 16 Connection of power terminals

The controller bed plate is used for commutating board voltage source and battery common terminals. The bed plate also serves as a heat sink. To normalize thermal condition of the in-line controller the bed plate should be installed onto a heatsink or any other massive element of the construction to provide heat dissipation.

4.4 CAN interface

Digital serial interface CAN is used for managing the controller and monitoring the system parameters. The controller and the board computer are connected via differential line with thelinear bus topology. Data transfer is performed in the form of frames fully compatible with CAN2.0A standard.

The controllers have two CAN line inputs in X5 connector (see table 11) for connecting them in a ‘daisy chain’ arrangement(pic. 17). The controller address is configured through address fuses..

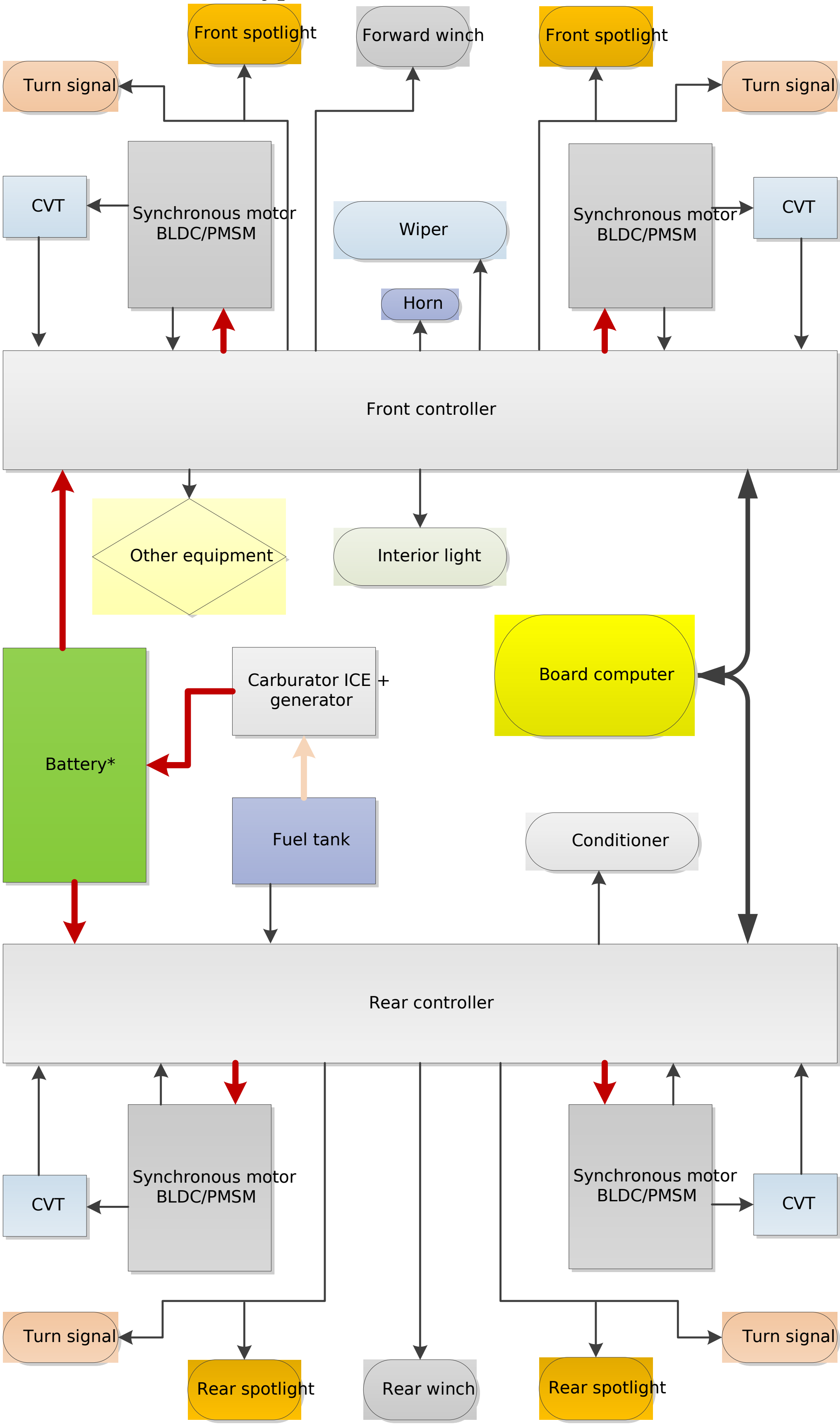


Pic. 17 CAN bus topology

5 Possible applications

5.1 Typical application

Picture 18 shows typical structure of all-wheel drive vehicle control system.

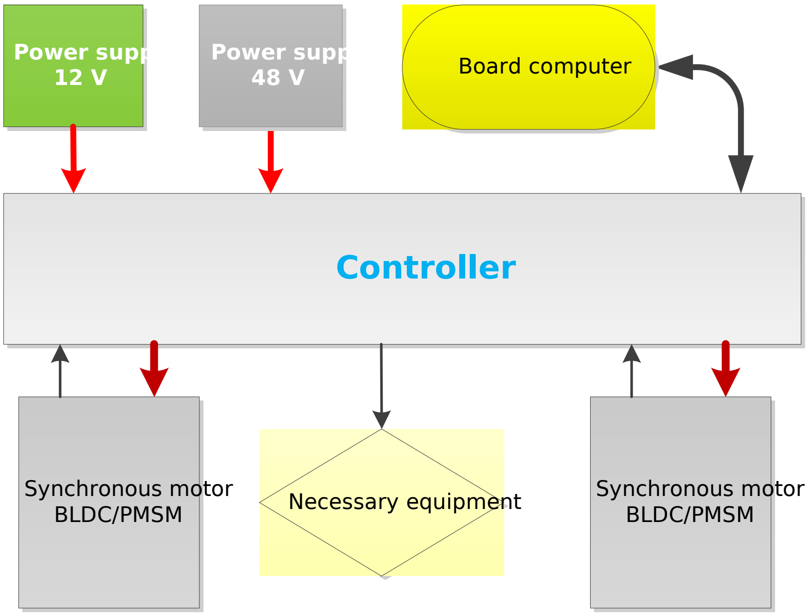


Pic. 18 Possible arrangement scheme

* To buffer the generator voltage it is recommended to use an supercapacitor with 20F capacity.

The scheme below shows two controllers – the front and the rear controllers which are identical in the functions performed.

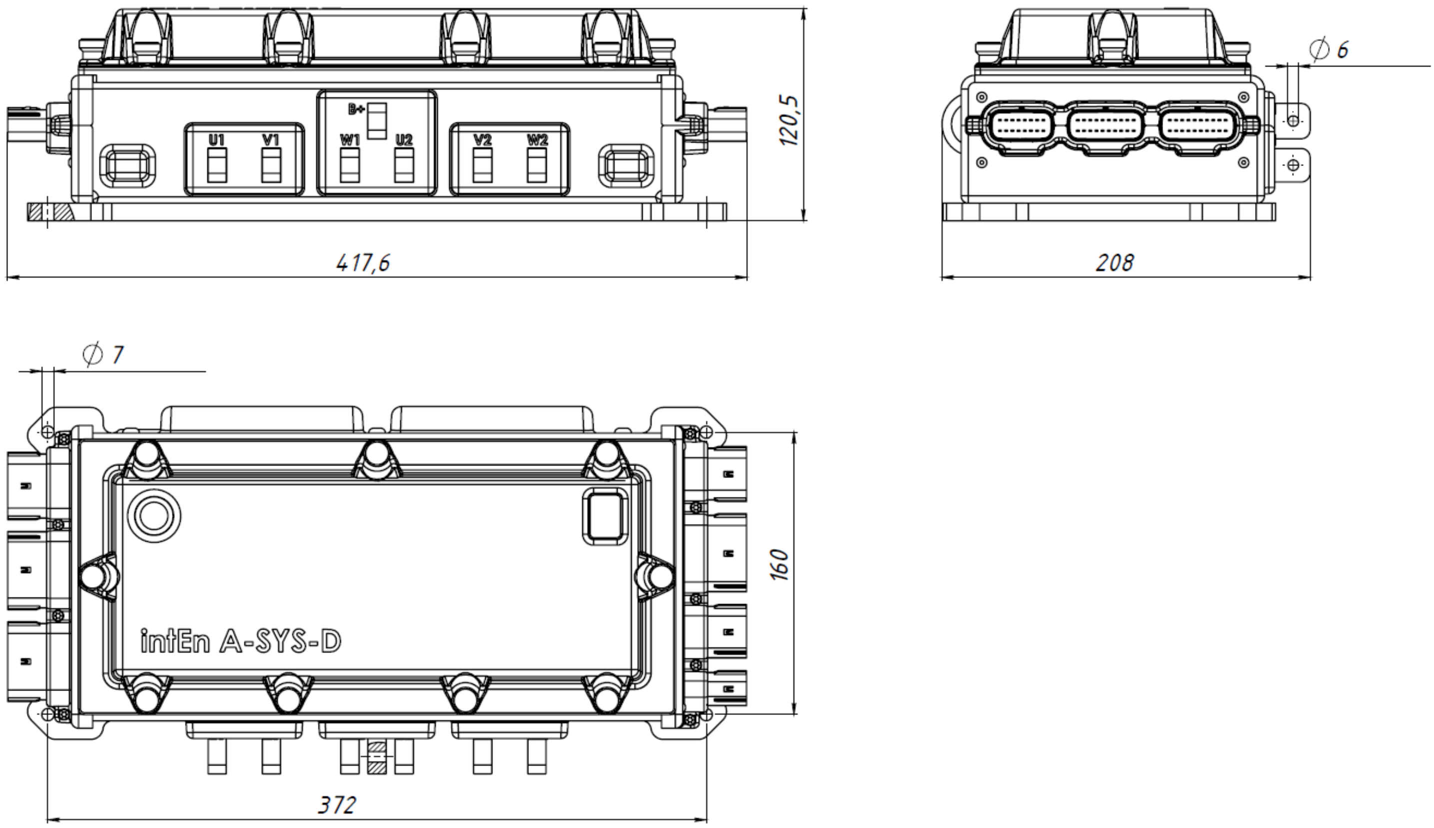
5.2 Minimal configuration



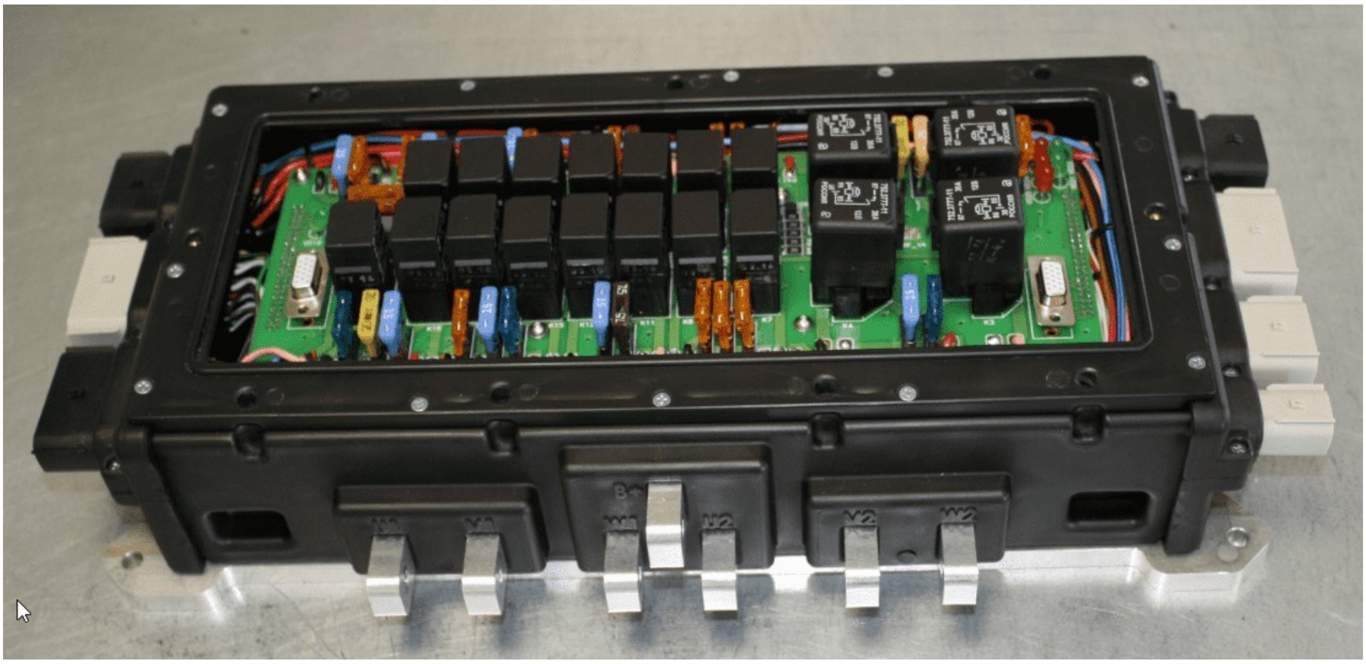
Pic. 19 Application of controller for the minimal configuration

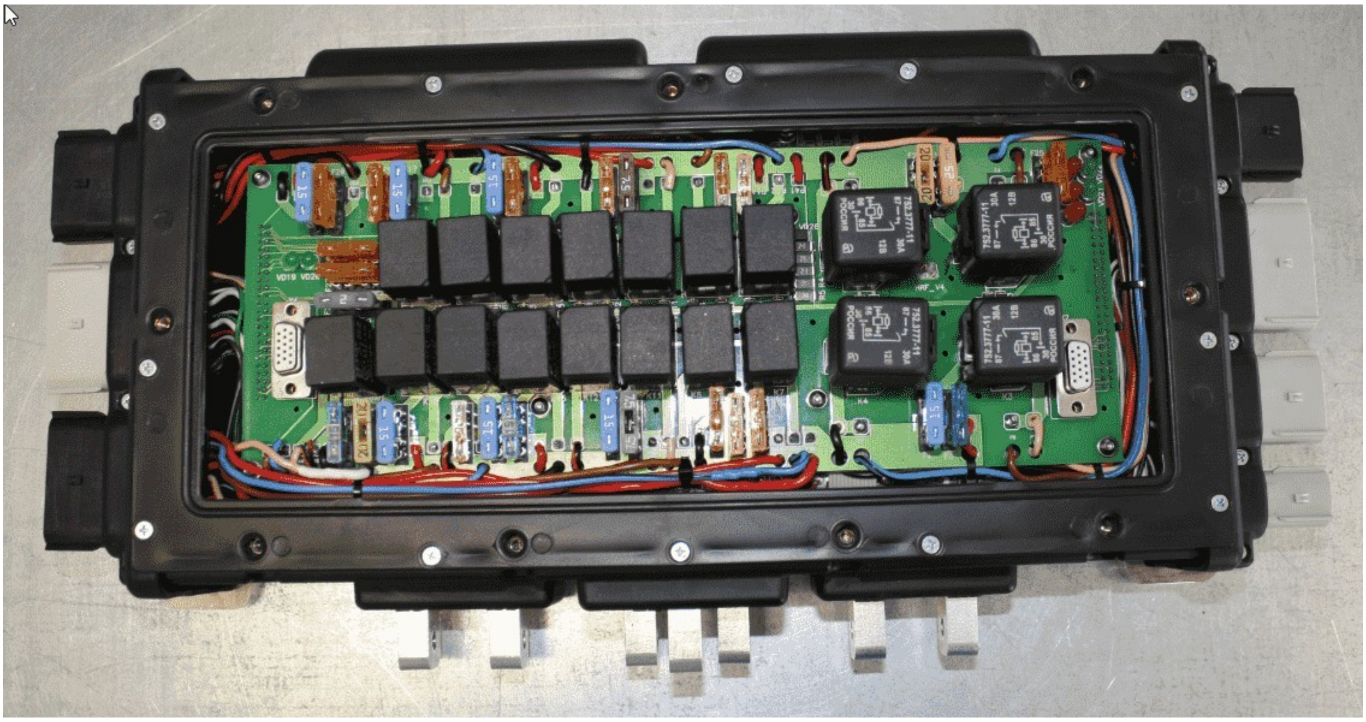
Picture 19 represents minimal equipment configuration with one controller and two synchronous motors. The controller is connected to the power supply giving the necessary voltage for the controller and the motors. The controller is operated via a board computer.

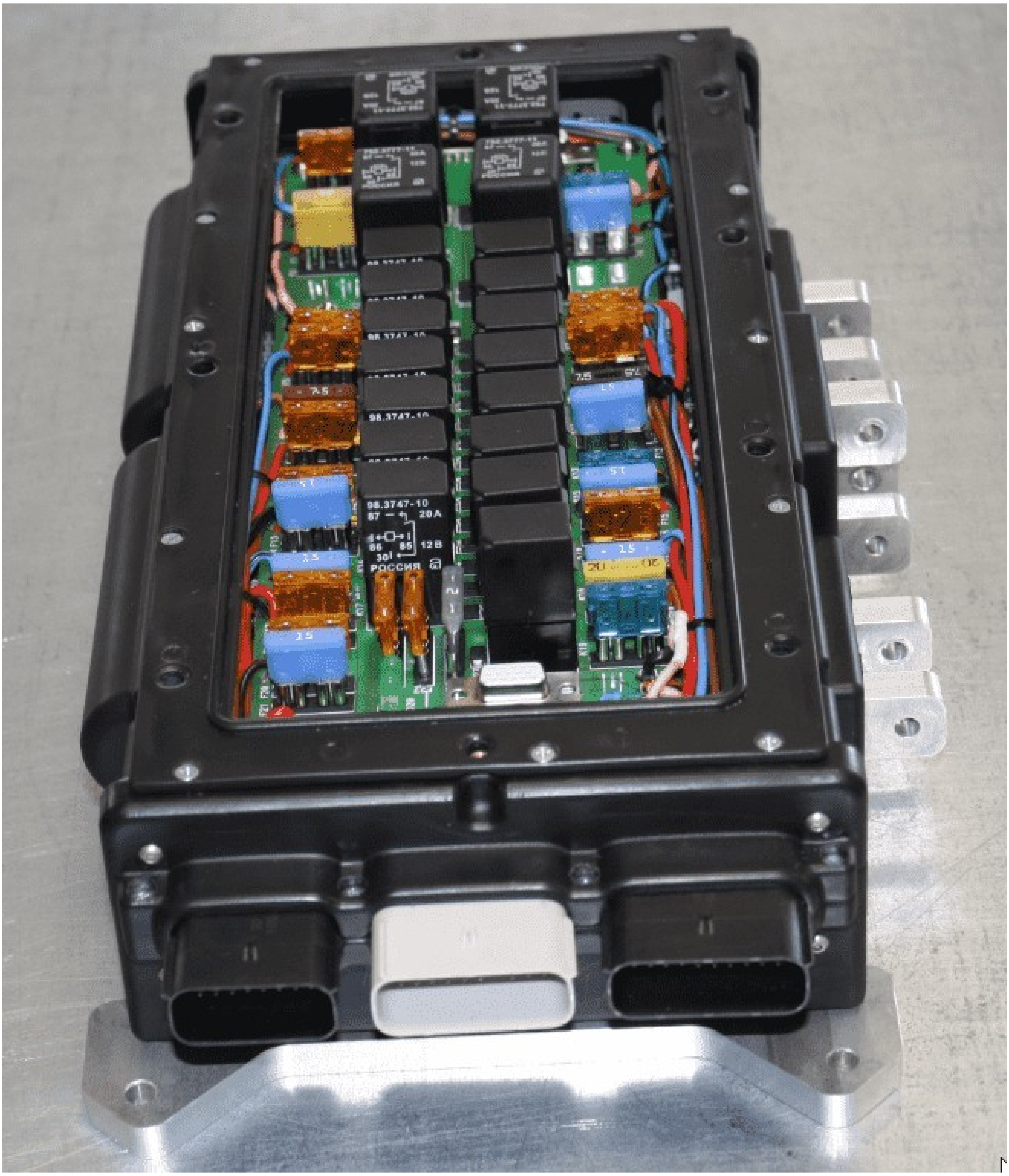
6 Dimensions



7 Appearance



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