Zubax AmpDrive AD0505C & AD0505D Datasheet

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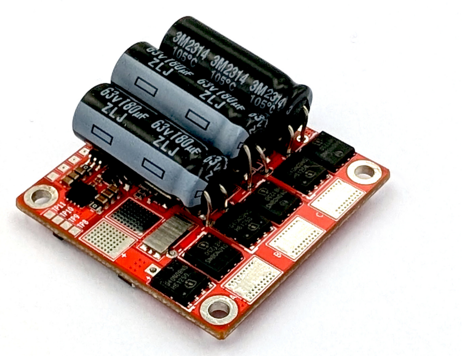
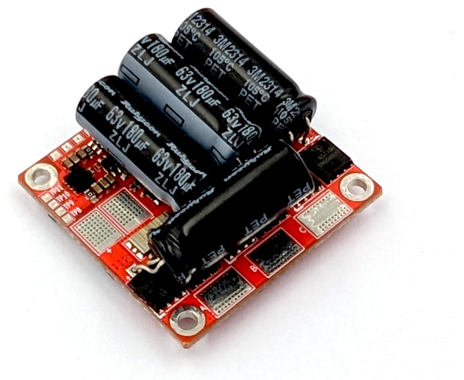
Zubax AmpDrive **AD0505** is an industry-leading high-reliability FOC ESC based on the Telega motor control technology. AD0505 is designed for use in propulsion systems of light unmanned aerial vehicles (UAV) of all types (multirotors, fixed-wing, VTOL, etc.), unmanned underwater vehicles (UUV) and unmanned surface vehicles (USV), and is compatible with almost all PMSM and BLDC motors.

The advanced vector control algorithms implemented in Telega make it one of the most energy-efficient sensorless ESCs on the market.

Features

- Up to 1200 W of continuous power output in a compact form-factor
- 13–51 V input voltage range (4–12S $LiCoO_2$ battery)
- Based on Zubax Telega[1] — industry-leading energy efficient motor control technology:
  - Energy-efficient sensorless field-oriented control (FOC)
  - Regenerative braking and active freewheeling
  - Self-diagnostics and health status reporting
  - Various control modes: torque, velocity, position, etc.
  - Highly configurable, wide range of tunable parameters
- External motor temperature sensor support
- Software-controllable 5 V BEC (some models)
- Firmware updatable in-field via CAN
- No soldering required for installation or use
- Compact board-level and IP69 enclosed versions available
- Flexible interfaces:
  - CAN bus interface:
    - Cyphal/CAN or DroneCAN protocol
    - Dual redundancy for fault tolerance (some models)
  - Standard RCPWM input
  - Motor thermistor port





Applications

- UAV propeller and fan drives
- Pump and propeller drives for UUVs and USVs
- Fuel pump drives for gas turbine engines

[1] https://telega.zubax.com

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1 Overview

Zubax AmpDrive AD0505 is a highly reliable, industry-leading FOC ESC based on the Zubax Telega motor control technology designed for use in the propulsion systems of various unmanned vehicles and as a fuel pump drive in gas turbine engines. AD0505 is one of the most energy-efficient sensorless PMSM/BLDC controllers available on the market.

For information on operating and tuning the device, please refer to the Telega Reference Manual at `https://telega.zubax.com`. For help with tuning, please reach out at `https://forum.zubax.com`.

1.1 Quality assurance

Every manufactured device undergoes an automated hardware verification process, the test logs of which can be viewed at `http://device.zubax.com/device_info`. To facilitate traceability and reduce the risk of counterfeits, every manufactured device stores a strong digital signature to identify its origin.

Additional information about product quality is available upon request from `support@zubax.com`.

1.2 Models

The model comparison table 1.1 uses the following notation:

- IP — ingress protection code.
- P_{dc} — continuous electrical power limit; includes the auxiliary power output, if applicable.
- i_{dc} — continuous DC link current limit.
- i_{abc} — continuous phase current amplitude limit.
- $i_{abc\text{-peak}}$ — peak phase current amplitude; duration limited by temperature.
- CAN — number of CAN bus interfaces: single or doubly-redundant. The secondary CAN bus shall be disabled if not used.
- BEC — auxiliary power output, also known as the battery elimination circuit; i.e., the low-voltage power supply output for external electronics.
- t_{oper} — device operating temperature.

The relation between the DC electrical power and the AC electrical power is described by the drive power transfer equation introduced in the Telega Reference Manual:

$$P_{\text{dc}} = u_{\text{dc}}\, i_{\text{dc}} \approx \frac{3}{2}\left(u_q\, i_q + u_d\, i_d\right) \approx \omega\tau = P_{\text{mechanical}}$$

AD0505 model	Form-factor	P_{dc} watt	i_{dc} ampere	i_{abc} ampere	$i_{abc\text{-peak}}$ ampere	Mass gram	$L \times W \times H$ millimeter	IP	t_{oper} °C	CAN	RCPWM	BEC
AD0505C0	bare PCB	850[a]	32	37[a]	50	13	35 × 35 × 15	IP00	-40 – +85	1	yes	no
AD0505C0Z	bare PCB	1200[a]	40	45[a]	50	15	35 × 35 × 15	IP00	-40 – +105	1	yes	no
AD0505C2	aluminum enclosure	850	32	37	50	TBD	37 × 37 × 20	IP69	-40 – +85	1	yes	no
AD0505C2Z	aluminum enclosure	1200	40	45	50	TBD	37 × 37 × 20	IP69	-40 – +105	1	yes	no
AD0505D0	bare PCB	850[a]	32	37[a]	50	13	35 × 35 × 15	IP00	-40 – +85	2	yes	yes
AD0505D0Z	bare PCB	1200[a]	40	45[a]	50	15	35 × 35 × 15	IP00	-40 – +105	2	yes	yes
AD0505D2	aluminum enclosure	850	32	37	50	TBD	37 × 37 × 20	IP69	-40 – +85	2	yes	yes
AD0505D2Z	aluminum enclosure	1200	40	45	50	TBD	37 × 37 × 20	IP69	-40 – +105	2	yes	yes

Table 1.1: Characteristics per model

[a] Requires an external heat sink. Assuming the junction-to-environment thermal impedance is not higher than in the aluminum enclosure models; otherwise, the power is limited by temperature. Refer to section 1.6.1.

1.3 Absolute maximum ratings

Stresses that exceed the limits specified in this section may cause permanent damage to the device. Proper operation of the device within the limits specified in this section should not be assumed.

Symbol	Parameter	Min	Max	Unit
u_{dc}	Supply voltage	-0.3	+56	V
$P_{\text{dc-peak}}$	Peak DC power		2000	W
i_{abc}	Phase current amplitude	-53	+53	A
t_{oper}	Operating temperature (device)	-40	+105	°C
	Aux pin input voltage	-0.3	+7	V
	CAN H/L input voltage	-58	+58	V

Table 1.2: Absolute maximum ratings

1.4 Environmental conditions

Refer to table 1.1 for model-specific parameters.

Bare PCB models do not permit condensation. IP69 models are protected against close-range high-pressure, high-temperature spray downs, and continuous immersion in water up to 1 m.

For the operating temperature, refer to table 1.1.

Parameter	Note	Min	Max	Unit
Storage temperature (ambient)		-40	50	°C

Table 1.3: Environmental conditions

1.5 Reliability and safety

Contact Zubax Robotics for additional information about reliability and safety.

Parameter	Typ	Unit
Replacement life	8	year
Operational service life	10 000	hour
Mean time to failure (MTTF)	150 000	hour

Table 1.4: Reliability characteristics

1.6 Mechanical characteristics

Refer to table 1.1 for model-specific parameters.

In bare PCB models, some of the mounting holes are grounded via large-valued resistors as shown in the mechanical drawing to prevent static charge buildup. Aluminum enclosure models are similarly equipped with high-resistance electrical connection between the enclosure and the DC power ground.

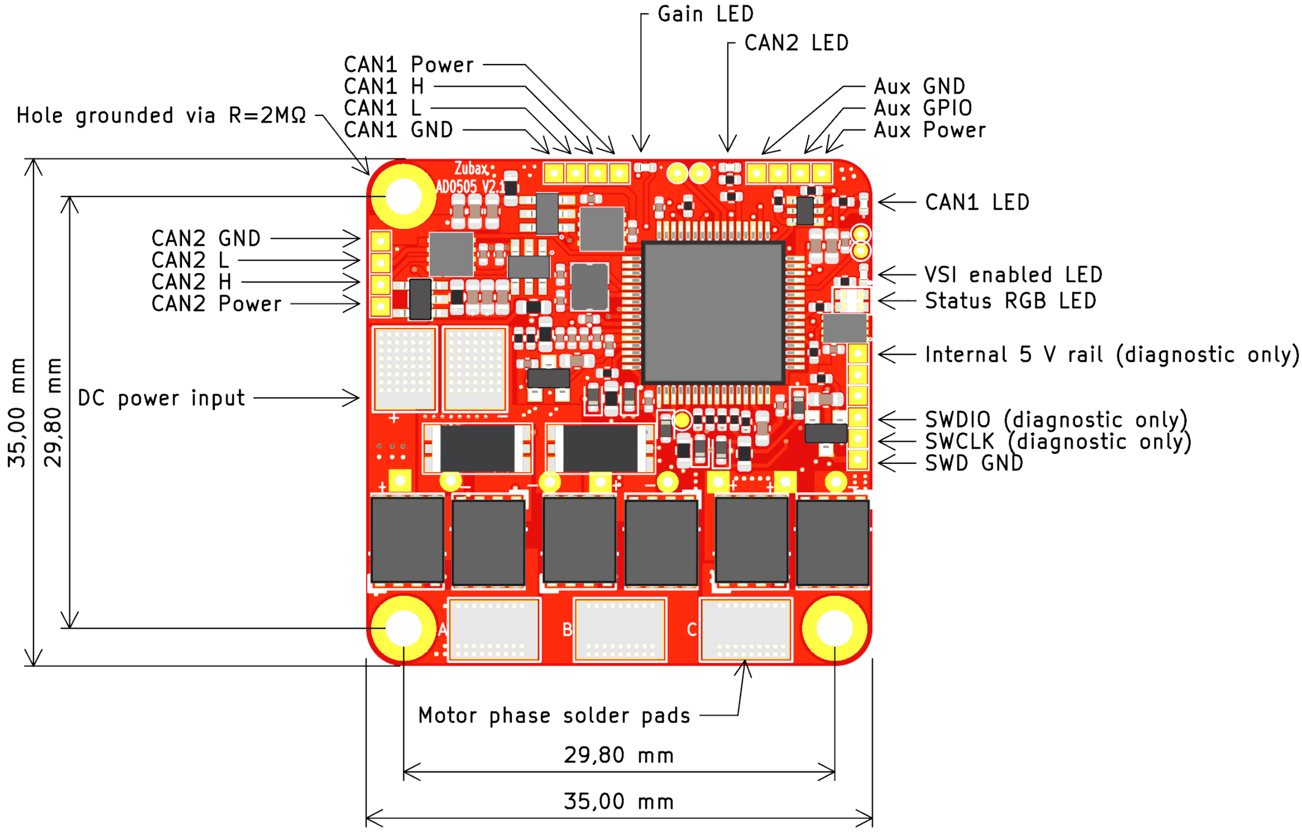
All dimensions are given in millimeters.

1.6.1 Thermal interface

The power limit specified in table 1.1 for the board-level models (devoid of a heatsink) is based on the assumption that the junction-to-environment thermal impedance is not higher than in the aluminum enclosure models; otherwise, the power is limited by temperature. Therefore, to achieve the maximum power specified in the table, the end application should provide an adequate thermal interface between the PCB and the external heatsink. Usage without the heatsink is possible at a reduced power level.

The aluminum enclosure models require forced air or liquid cooling of the enclosure to achieve the maximum power.

The geometry of the thermal interface of the PCB is given in figure 1.3. The heatsink and the PCB should be separated by a 0.5 mm thermal pad. Contact Zubax Robotics for additional guidance on the thermal interface design.

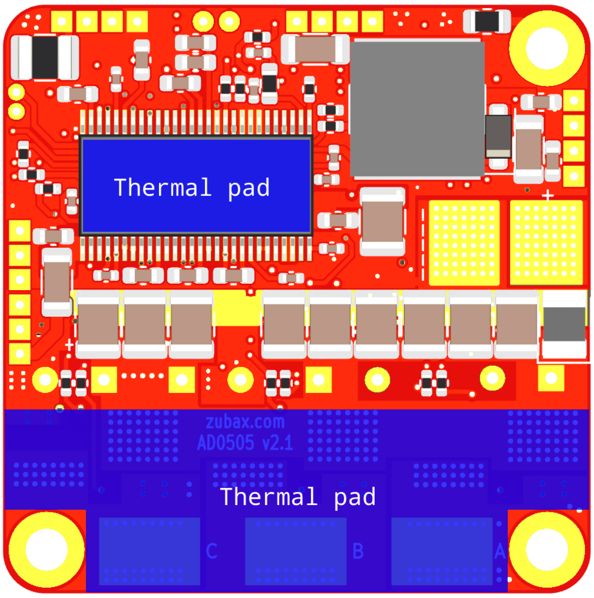


Electrolytic buffer capacitors not shown.

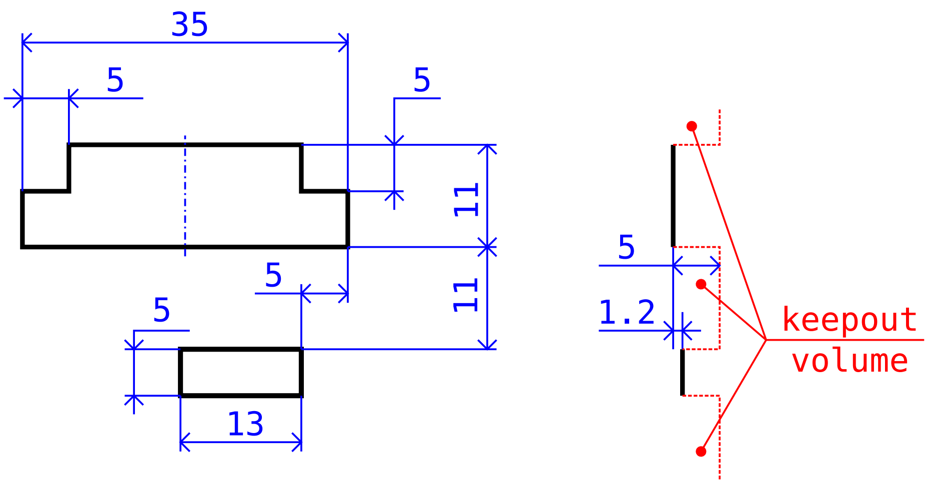
Figure 1.1: Drawing of AD0505C0, AD0505C0Z, AD0505D0, AD0505D0Z

TBD

Figure 1.2: Drawing of AD0505C2, AD0505C2Z, AD0505D2, AD0505D2Z



Bottom side PCB view.



Bottom side PCB view.

Figure 1.3: PCB thermal interface geometry

2 Functional description

The description of the motor control functions of the device is provided in the Telega reference manual. This document focuses on the hardware-related aspects of the device only. Refer to table 1.1 for model-specific parameters.

2.1 Power supply and voltage source inverter (VSI)

In bare PCB models, the DC power supply and the motor phase wires are soldered directly to the PCB pads. The pads are provided on both sides of the PCB for convenience, enabling wire soldering on either side.

In the aluminum enclosure models, the DC power is supplied via exposed copper wires, and the motor phases are connected to the female board-mounted 3.5 mm vertical bullet connectors.

The VSI is equipped with phase current sensor amplifiers with two gain levels managed by the automatic gain control (AGC) algorithm.

Parameter	Note	Min	Typ	Max	Unit
Supply voltage		13		51	V
Idle power consumption			0.5		W
Switching dead time	hardware-regulated	50	100		ns
Temperature measurement range		-55		125	°C
Temperature measurement error		-6		6	°C
Switch on-state resistance			3.4	4	mΩ
Ceramic buffer capacitance	excluding electrolytic		42		μF

Table 2.1: Power supply and voltage source inverter (VSI) characteristics

2.1.1 Buffer capacitance and DC voltage ripple

The switching-induced peak-to-peak DC voltage ripple should not exceed 1.5 V or 5% of the DC bus voltage, whichever is greater, to avoid stability hazards, overheating, excessive energy loss, and the risk of electromagnetic interference. To manage the ripple, the motor controller is equipped with DC link buffer capacitance that is sufficient for most applications with low-impedance power supply networks.

If the controller is powered via long leads or from a high-impedance power supply network, additional capacitance may need to be introduced next to the device to manage the voltage ripple. Refer to the Telega Reference Manual for additional information on the subject.

2.1.2 Regenerative braking

While braking, the device transfers energy from the motor to the power supply network in a process known as regenerative braking. If the resistance of the power supply network is high, the regenerative energy transfer may lead to the supply voltage increasing beyond the device's safe operating limits.

The internal resistance of traction batteries is generally sufficiently low to ensure safe absorption of the recovered energy. Problems may arise if the device is powered by a source where the input impedance is high, such as a laboratory power supply, for instance. In this case, it is advised to use an electronic load or a large capacitor connected in parallel with the power supply as protection against overvoltage.

2.2 Communication interfaces

For the connector placement, please refer to 1.6.

2.2.1 CAN bus

The device is equipped with a single (AD0505C) or doubly-redundant (AD0505D) ISO 11898-2 CAN 2.0B interface. Termination resistors are not included. An external CAN bus splitter or T-connector is required, which are available from Zubax Robotics as well as other vendors.

The secondary CAN bus interface (CAN2) can only be used with redundant CAN bus configurations. With non-redundant CAN bus configurations, only the primary CAN bus connectors (CAN1) should be used with the secondary CAN2 bus connectors being left unconnected.

The device does not consume power from the CAN bus. BEC-enabled configurations can deliver the power to the CAN bus via the CAN bus connectors if the software is configured accordingly.

Parameter	Min	Typ	Max	Unit
Bit rate	125		1000	Kbps
Differential output voltage, dominant	1.5		5.1	V
Bus power rail voltage	-0.1	5.0	5.5	V
Inter-connector current pass-through	-1		1	A
Contact pair resistance		30	50	mΩ

Table 2.2: CAN bus interface characteristics

Pin no.	Type	Function	Comment
1	Power	Auxiliary power output	Section 2.3
2	Input/output	CAN high	
3	Input/output	CAN low	
4	Ground	Ground	

Table 2.3: CAN bus connector pinout (except bare PCB models)

2.2.2 Auxiliary I/O

AD0505 is equipped with an Auxiliary I/O interface. This interface can be used to supply RCPWM control signal, voltage level control, motor temperature measurement, and other auxiliary functions. Refer to the Telega Reference Manual for detailed information on the Auxiliary I/O interface.

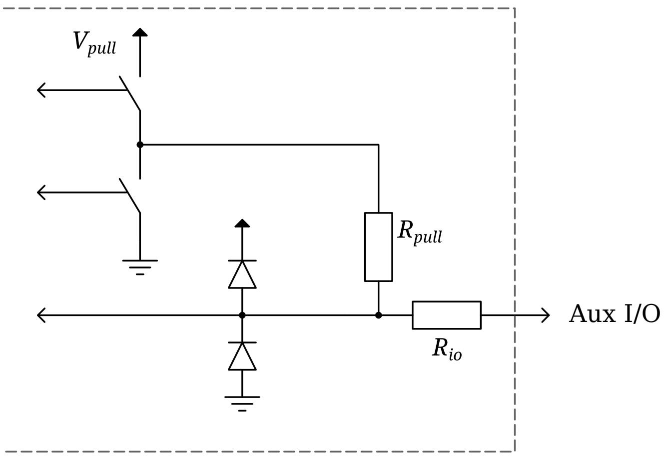


Figure 2.1: Auxiliary I/O interface schematic

Symbol	Parameter	Note	Min	Typ	Max	Unit
	Low-level input voltage		-0.3	0	1.6	V
	High-level input voltage		2.1	3.3	5.5	V
	Low-level output voltage	no load	0	0	0.5	V
	High-level output voltage	no load	2.8	3.3	3.4	V
	Source/sink output current		-10		10	mA
	RCPWM input pull down resistance	iff RCPWM is enabled	15000	20000	25000	Ω
R_{pull}	Strong pull resistance		980	1000	1020	Ω
V_{pull}	Strong pull voltage		3.2	3.3	3.4	V
R_{io}	Auxiliary pin series resistance		196	200	204	Ω

Table 2.4: Auxiliary I/O characteristics

Wire color	Type	Function	Comment
black or brown	Ground	Ground	
red	Power	Auxiliary power output	Section 2.3
white, yellow, or orange	Input/output	Auxiliary GPIO	

Table 2.5: Auxiliary I/O pinout (except bare PCB models)

2.3 Auxiliary power output (BEC)

AD0505D features a software-controllable auxiliary low-voltage power output (BEC) that can be used to power external low-power devices (e.g. camera, GNSS module, flight controller, etc.) via the CAN bus interface connectors and/or the Auxiliary interface connector. Each output is protected from reverse current flow with ideal diodes so that the device is not back-powered from the bus if the main power is disconnected.

CAN1 is equipped with a dedicated ideal diode and current limiter, while CAN2 shares its power output with the Auxiliary interface connector via a separate self-recovery PTC fuse. The PTC fuse may contribute an additional voltage drop under load.

Multiple controllers connected to the same CAN bus will share the load, which provides fault tolerance and an increase in the total available power to other CAN nodes.

Refer to the Telega Reference Manual for further information on configuring this feature.

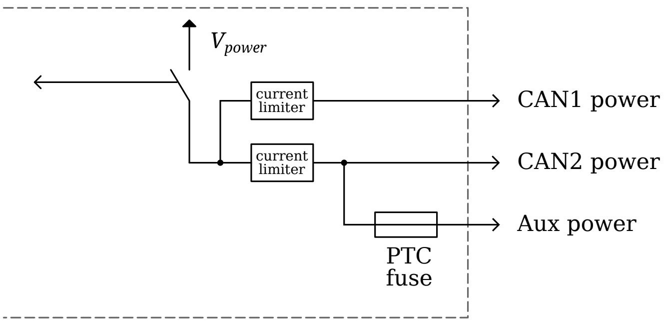


Figure 2.2: Auxiliary power output (BEC) schematic

Symbol	Parameter	Note	Min	Typ	Max	Unit
V_{power}	Constant voltage (CV) output	no load	4.9	5	5.2	V
	Constant current (CC) output		0.5	0.85	1.1	A
	Continuous total load current				0.25	A
	PTC fuse trip level		0.25		1.0	A
	Voltage ripple				100	$mV_{p\text{-}p}$
	CV/CC mode switch delay			2		μs

Table 2.6: Auxiliary power output (BEC) characteristics

2.4 LED indication

The device is equipped with LED indicators that communicate the status of the hardware and software. For their placement, refer to 1.6.

2.4.1 CAN LED indicators

The CAN1 and CAN2 LEDs indicate network traffic through the CAN interfaces.

2.4.2 VSI-enabled LED

The VSI-enabled LED indicates that the power stage is armed.

2.4.3 Gain LED

The Gain LED reflects the status of the AGC of the phase current measurement circuitry. When the LED is on, the gain is low (high power operation); when off, it is high (low power operation).

2.4.4 Status RGB LED

The Status RGB LED indicates the current state of the device control logic. Refer to the Telega Reference Manual for a detailed description of the LED states.