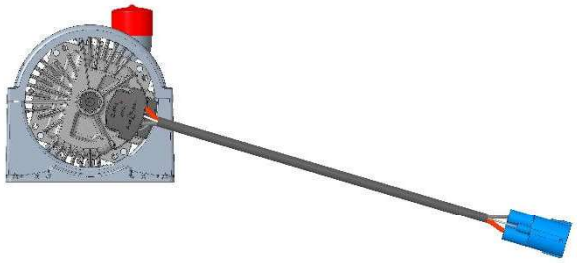
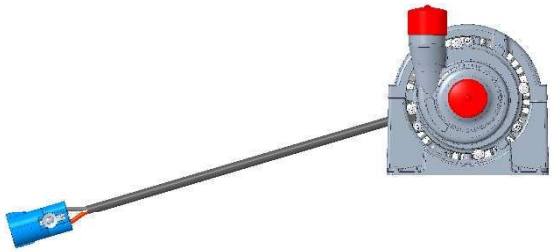
1 General



Nominal voltage: 24 V
Drive family SBL500P

Part number: 30207004

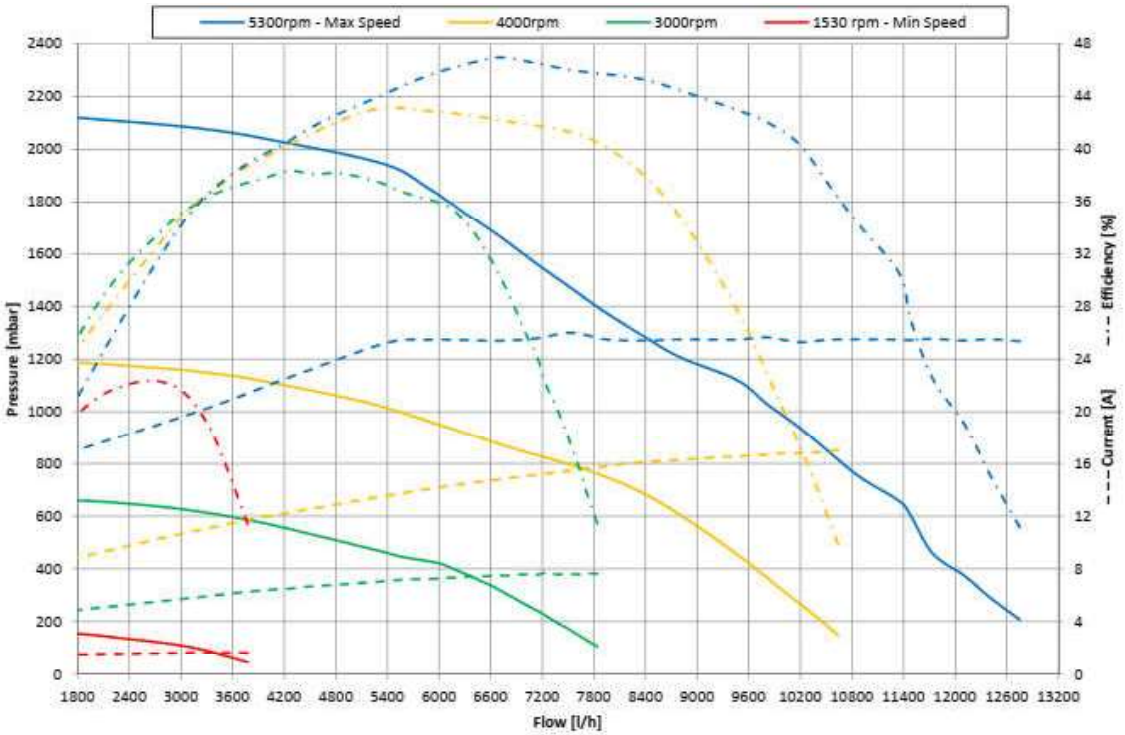


2 Features

Max speed	rpm	5350
Min speed	rpm	1500
Weight	kg	2.8
Operating supply voltage range	V	16.0 .. 32.0 at the Drive connector
Supply voltage to reach max speed	V	26.0 .. 32.0 at the Drive connector
Operating ambient temperature range	°C	-40 .. +120
Operating fluid temperature range	°C	-40 .. +120
Max operating ambient temperature @ max pump speed	°C	+105 (1)
Storage temperature range	°C	-40 .. +125
Lifetime	h	up to 40000 hours depending on mission profile
Time from 0 rpm to max speed	s	17
Load dump protection (Pulse 5a)	V	150V - Pulse peak voltage (U_S) - ISO16750-2:2010
Reverse polarity protection		ISO 16750-1 functional status class C - device fully functional after correcting the polarity
Notes: (1) Few minutes ambient temperature transients do not engage the derating owing to the thermal inertia of the system. Overloads may anticipate derating.		

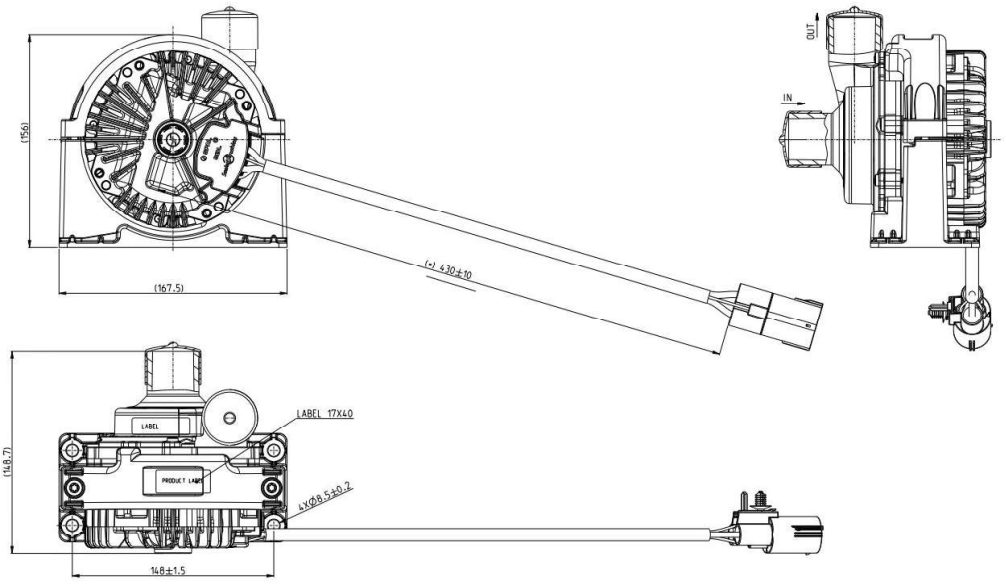
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3 Performance at maximum speed



Ethylene Glycol / Water mixture 60:40 ratio by volume – Density 1,08kg / l – Test bench compliant to ISO9906
TAMB = 20 °C ± 5 °C - UB = 26.0 V at the Drive connector

4 Mechanical data

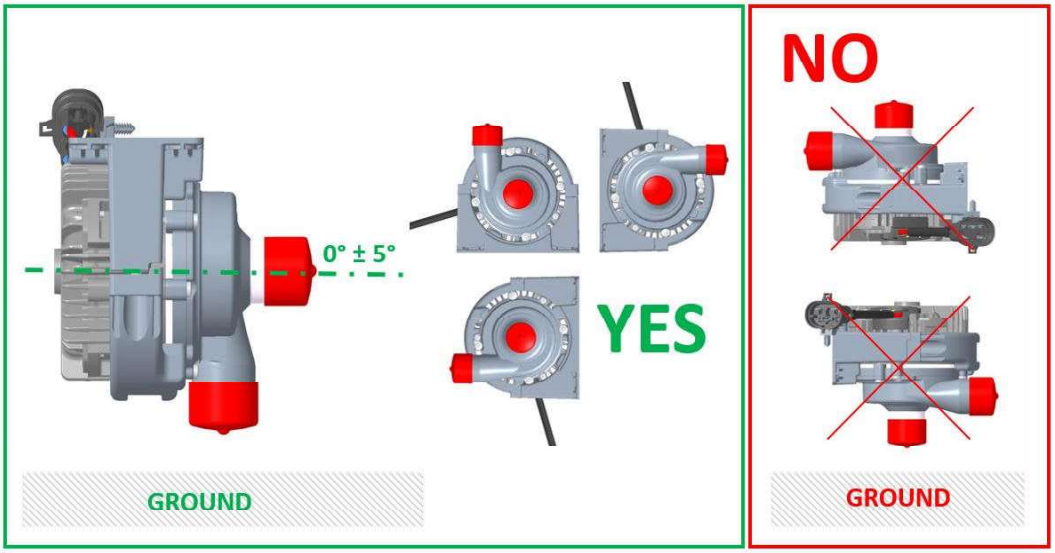


The pump must be assembled on a flat and regular surface.
Fixing recommendation:use M6 bolts with washer _n_12-18mm for fixing.
Nominal tightening torque Max 5 Nm.
Nominal torque defined for brand new, clean and lubrificant-free bolts.
MAX ALLOWABLE APPLICATION FLATNESS ±1mm

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5 Installation

5.1 Orientation



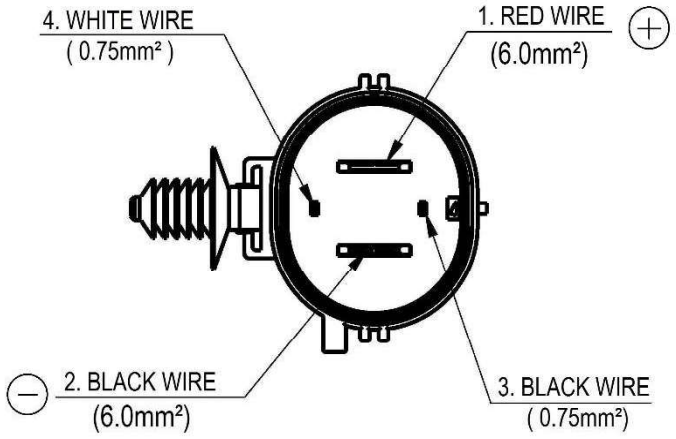
Pump inlet (as the rotational axe) must be oriented parallel to the ground with a tolerance of ±5°, if thiss condition is satisfied pump outlet can be oriented in any orientation. Pump inlet can't be orientedd perpendicular to the ground

5.2 Filling

Pump filling must be performed in a debris-free and clean environment.

Fluids must be compliant with ASTM D6210-10 or ASTM D3306.

6 Connector and wires



Connector : YAZAKI HYBRID (USCAR-2 compliant) - Part number: 7282-8497-90				
Identification (*)	+D	-D	FO	PWM / E
Pin number	1	2	3	4
Wire Color	Red	Black	Black	White
Sealing p/n	7158-3035	7158-3035	7158-3031-90	7158-3031-90
Pin p/n	7114-3250	7114-3250	7114-4103-02	7114-4103-02
Section [mm²]	6.0	6.0	0.75	0.75

For abbreviations see chapter **8.2 Drive pin functions**

NOTE: Never handle the pump module via the cable harness

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Further Features

Compliance		ECE Reg. 10-04 and updates - Automotive EMC directive
		2002/95/EC RoHS - Hazardous Substances
		2000/53/EC and updates - End-of Life Vehicle
Ingress Protection		IP 68 and IP6K9K design
Allowed power supply max ripple	rms	1 % - contact SPAL for special needs
Fuse protection		An automotive fuse according ISO8820 must be chosen and used by the customer in the application wire harness. Each drive must be protected by the unique proper fuse (e.g. in case of double pump modules, two fuses are needed)

7 Measurement conditions

The below conditions are assumed:

- T_{AMB} = 20 °C ± 5 °C and
- Supply voltage **UB** = 26.0 V at the **Drive** connector

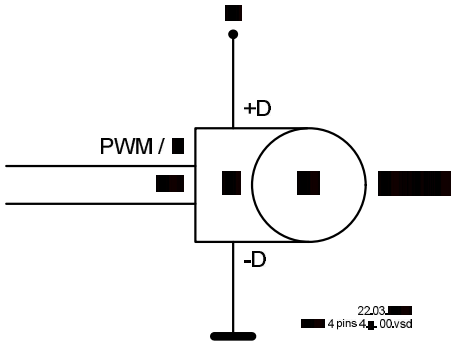
unless otherwise specified.

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8 Hardware functions

8.1 Drive diagram

The Drive diagram is shown below.



E stands for integrated electronics. M stands for motor. Drive stands for motor with axial integrated electronics.

8.2 Drive pin functions

The electrical Drive interface consists of 4 pins:
Power pins:

- supply voltage plus: +D
- supply voltage minus: -D

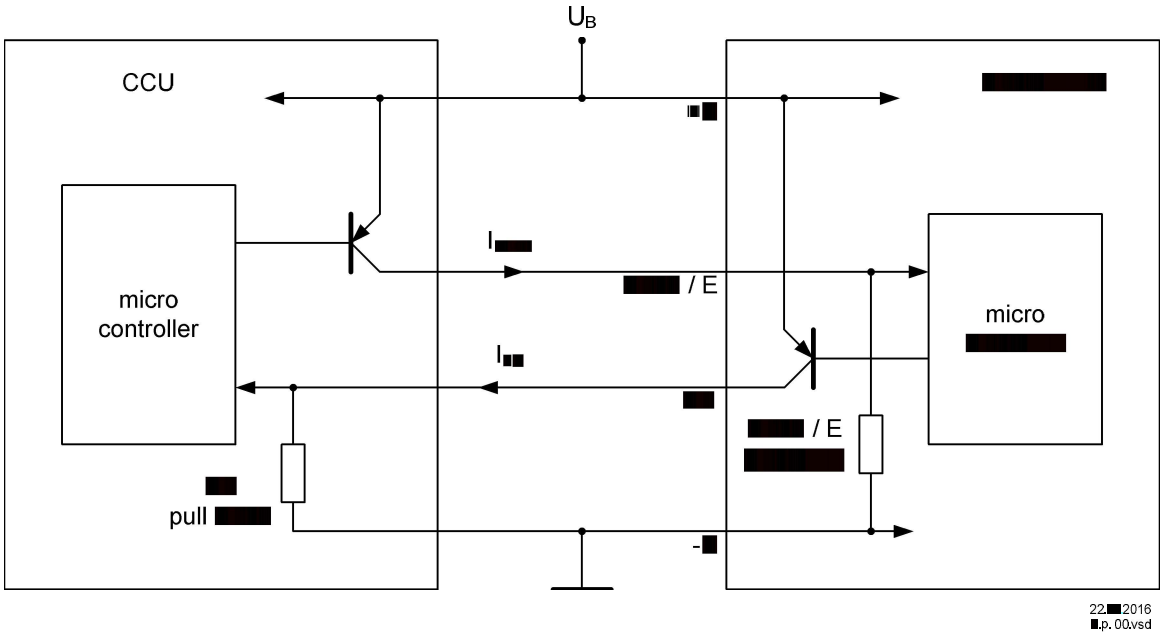
Signal pins:

1. Input: digital PWM input / active high: PWM / E
2. Output: feedback output / active high: FO

The signal pin PWM / E is used to control the Drive mode, it is the control input.
The signal pin FO is used to notify the Drive status.

9 Drive interface

The Drive interface, i.e. the connections between the CCU (Custom Control Unit) and the Drive, is depicted in the following picture.



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The CCU electronics and the Drive electronics are connected via two unidirectional lines.

The PWM signal for the input PWM / E comes from the CCU electronics and uses a pull down resistor (PWM / E pull down) located in the Drive electronics to determine the recessive level.
This pull down resistor is connected to the supply voltage minus: -D / GND.
The dominant level on the input PWM / E is high level, provided by the switching to plus stage depicted in above Figure as a bipolar pnp transistor in the CCU.

The output FO comes from the Drive electronics and uses a pull down resistor (FO pull down) located in the CCU electronics.
The dominant level on output FO is high level, provided by the switching to high stage depicted Figure above as a bipolar pnp transistor in the Drive.

10 Interface hardware for Digital control: pin PWM / E

The input PWM / E is used to wake up the Drive from Quiescent current mode. Any PWM duty cycle that guarantees a pulse going to the dominant level for more than T_{wakeup} will wake up the Drive electronics.

Parameters	Min	Typical	Max	Unit	Denomination
PWM / E frequency range	50	100	500	Hz	f_{PWM} 1)
PWM / E duty cycle range	0		100	%	dc_{min} .. dc_{max}
PWM / E high level voltage	13			V	U_{PWMH}
PWM / E low level voltage			5.5	V	U_{PWML}
PWM / E resolution		1		%	dc_{resol}
PWM / E accuracy		1		%	dc_{accu}
PWM / E current	-10%	4.9	+10%	mA	I_{PWM}
PWM / E leakage (quiescent) current			500	µA	
PWM / E wake up voltage	9			V	U_{PWMWU}
PWM / E wakeup pulse	150			µs	T_{wakeup}
PWM pull up		5.3		kΩ	

1): the PWM thresholds consider a temperature range of -40 °C to 130 °C in the electronics
2): the activation level U_{PWMact} considers a temperature range of -40 °C to 130 °C in the electronics
3): for SPAL production line internal reasons there is a test mode implemented which is activated at a PWM frequency range from 1400 Hz to 1600 Hz with dedicated duty cycles for various test modes.
The application must not use this frequency range!

11 FO Feedback Output / Active high

Parameters	Min	Typical	Max	Unit	Denomination
FO voltage	U_B – 2 V		U_B	V	U_{FO}
FO current			50	mA	I_{FO}

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12 Software functions

12.1 Drive modes

The Drive has different working modes related mainly to the Drive current consumption:

1. Quiescent current mode
2. Electronics active mode
3. Run mode
4. Failure mode

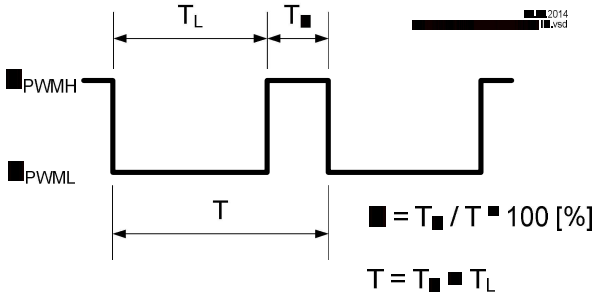
The Drive mode changes accordingly to the control input duty cycle on pin PWM / E.

No.	Drive mode	Current consumption	Drive speed	FO
1	Quiescent current mode	< 200 µA	0	Recessive
2	Electronics active mode	< 40 mA	0	Recessive
3	Run mode	depending on the requested speed and on the load	depending on the PWM duty cycle	Recessive
4	Failure mode	< 40 mA	depending on the failure	Dominant

The Quiescent current mode is entered when the pin PWM / E is on 0 % duty cycle (recessive level). The time to go into Quiescent current mode depends on the actual PWM base frequency and the number of samples for the plausibility check (see chapter 12.3). Additionally 2 s are waited after the detection of the absence of the PWM signal before finally going into Quiescent current mode.
The Electronics active mode is entered with any PWM duty cycle value between 0 % and < 100 % if the condition from chapter 10 is fulfilled (T_{wakeup}).
The Run mode is entered if the PWM duty cycle on pin PWM / E has a value where the Drive is asked to run (see chapter 12.2)
The Failure mode is entered in case of failures of the Drive (see chapter 12.4).

12.2 Digital control: transfer function PWM input

The transfer function PWM input is the relation between the Drive speed and the duty cycle on the pin digital PWM input / active high: PWM / E.



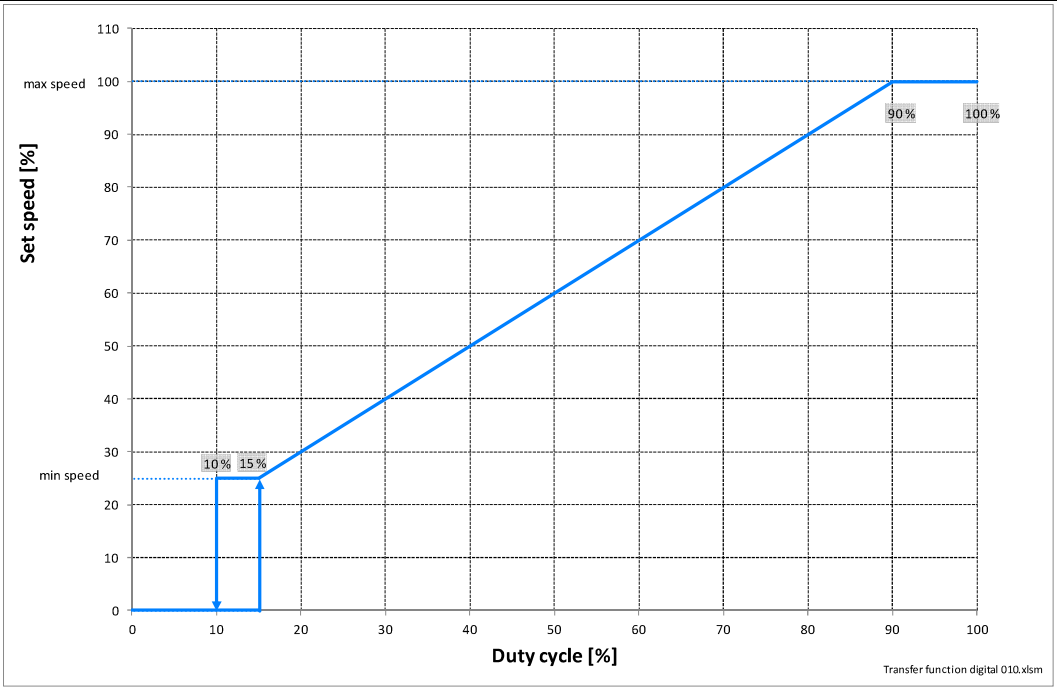
It is called ”positive logic duty cycle definition”.

Considering this definition,

- continuous low voltage is 0 % duty cycle (recessive level)
- continuous high voltage is 100 % duty cycle (dominant level)

Based on this duty cycle definition the transfer function PWM input is shown in the following figure.

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12.3 Drive speed set point with Digital control

The PWM signal on the control input PWM / E is measured by the Drive electronics. For improving noise to signal ratio the PWM signal becomes only valid and is only used to set the speed of the Drive when a sufficient number of consecutive duty cycle measurements are equal.
This plausibility test slightly delays the response to the change of the duty cycle PWM value. This delay is in the range of 0.2 s or less.

12.4 Drive mode Failure modes

There are the following cases where the Drive will go into Failure mode and stop the Drive:

Failure modes	Handling of the failure	Notification
Drive blocked	In case of detection of a rotor locked the following strategy is used: a delay of 5 s till the next start attempt is introduced. If this start attempt fails again a delay increased by further 5 s till the next start attempt is introduced. This delay increase is repeated till the delay between the attempts is 25 s. Then this delay is kept for ever as long a valid PWM duty cycle is detected which asks the Drive to run	FO set to dominant level after 5 restarting attempts
Drive overloaded	Pump speed is reduced in case of overload detection by means of current draw measurement.	FO set to recessive level
Dry Run	The pump can detect a dry condition (no circulating fluid): the drive will run in Dry-run condition for 20 s. Then, the Drive will be halted (and Dry-run error will be set). A new startup will be performed after 15 s.	FO set to dominant level
Over current	The Drive will stop if the over current safety threshold is reached.	FO set to dominant level
Drive overheated	Pump speed is reduced in case of overheating detection (derating). Over the max operating temperature, the Drive will stop.	Over the max operating temperature FO is set to dominant level
Under and Over voltage	If the supply voltage is outside the specified range the Drive will stop.	FO set to recessive level
Internal Drive failure	The Drive will stop if a failure is detected during the startup self check procedure.	FO set to dominant level

In all cases the Drive tries to recover from failures when a valid PWM signal is detected which asks the Drive to run.

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13 Units of measurements

Unit		Physical Quantity	Prefix	Dimension	
%	percent	Proportionality	M	10^{6}	mega
Ω	Ohm	Electrical Resistance	k	10^{3}	kilo
°C	degree Celsius	Temperature	m	10^{-3}	milli
A	Ampere	Current	µ	10^{-6}	micro
h	hours	Time	n	10^{-9}	nano
dBA	deciBel (A-weighting)	Sound pressure level	p	10^{-12}	pico
Hz	Hertz	Frequency			
min	minute	Time			
Pa	Pascal	Pressure			
rpm	Revolutions per minute	Rotation frequency			
s	second	Time			
V	Volt	Voltage			
W	Watt	Power			

Table 1: Units and acronyms

Key Word	Description
AMPL_IN	Amplitude PWM input signal
CCU	Custom Control Unit
Drive	Motor with axially integrated electronics
IGN	Ignition (KL15)
PWM	Pulse Width Modulation
R_i	Input Resistance
SBL	Sealed brushless
T	Temperature
T_{AMB}	Ambient Temperature
U_B	Supply voltage
U_n	Nominal supply Voltage
rms	root mean square

14 Document change history

Initial document author: document author
Latest revision: 000

Document author	Date	Revision	Comment
SPAL team	08/11/2021	000	Initial Version.
SPAL team	03/12/2021	001	orthographic errors
SPAL team	08/03/2022	002	§9.2 updated
SPAL team	29/08/2022	003	§7 and §13.1 updated
SPAL team	11/10/2023	004	§5.1 and §3 updated

Table 2: Document change history

Document status: released

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