ENGINEERING
TOMORROW

Technical Information

e-Wheel 100

Passive Force Feedback Electric Steering Base Unit

powersolutions.danfoss.com

Revision history

Table of revisions

Date	Changed	Rev
December 2025	Third edition	0103
January 2020	Second Edition: Corrected RPM operating speed	0102
September 2019	First Edition	0101

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Literature References

Purpose of the document

This document describes the technical specifications and features' information of the e-Wheel, applied with Danfoss electro-hydraulic steering valves and steering controller.

References

Literature	Type	Reference number
PVED-CLS	Communication Protocol	L1425546
PVED-CLS	User Manual	L1525062
PVED-CLS	Safety Manual	BC00000331
OSPE Steering valve, SASA Sensor	Technical Information	11068682
EHi Steering Valve	Technical Information	BC00000379

Definitions and Abbreviations

e-Wheel	Electric Steering Wheel Base
SbW	Steer-by-Wire
AgPL	Agricultural Performance Level
SIL	Safety Integrity Level
CAN	Controller Area Network
PL	Performance Level
PVED-CLS	Proportional Valve Digital – Closed Loop - Safety (steering valve controller)
OSPE	Orbital Steering Product – Electro-hydraulic steering valve
EHi	Electro-hydraulic in-line steering valve
EH (Steering)	Electro-hydraulic
Fail Safe	To detect fault, indicate fault to safe state system and revert to a safe condition in the event of a breakdown or malfunction
Fail Operational	To detect fault, indicate fault to safe state system and continue full operation with enough redundancy level
PAE	Product Application Engineering

OEM responsibility

The OEM of a machine or vehicle in which Danfoss products are installed has full responsibility for all consequences that might occur. Danfoss has no responsibility for any consequences, direct or indirect, caused by failures or malfunctions.

- The OEM shall perform a hazard and risk analysis for the target system to analyze if the relevant risks are sufficiently reduced by the integrated safety functions.
- Danfoss has no responsibility for any accidents caused by incorrectly mounted or maintained equipment.
- Danfoss does not assume any responsibility for Danfoss products being incorrectly applied or the system being programmed in a manner that jeopardizes safety.

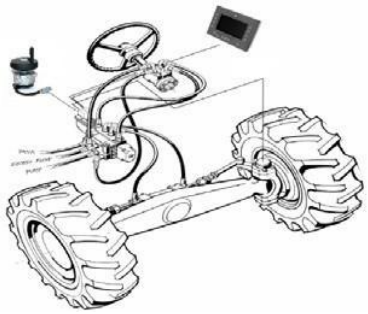
Introduction

e-Wheel 100

Danfoss steering products are used in vehicles where the driver must control high steering forces, reliably, comfortably and with maximum safety.

With the introduction of electro-hydraulic and Steer-by-Wire steering systems, advanced electric steering wheel features—such as variable lock-to-lock ratio, soft-stop, and anti-drift—can now be easily integrated into new vehicles or retrofitted into existing ones.
The primary goal of the electric steering wheel is to deliver a high-quality steering feel, enhancing operator comfort and reducing fatigue. To support this, Danfoss now offers an electric steering input device: **e-Wheel 100.**

Electrohydraulic steering system



'e-Wheel' stands for Electric Steering Wheel. '100' represents the first of the series of Danfoss electric steering input devices. 'e-Wheel 100' is referred to as 'e-Wheel' further in this document. The e-Wheel 100 is a haptic steering input device with passive force-feedback torque. The measured steering angular position and the rate of rotation (RPM) from the e-Wheel are transmitted to a steering valve controller, which determines the preferred steering response.

- The e-Wheel 100 is a 'Plug and Play solution' when interfaced directly to the PVED-CLS steering valve controller (for details see PVED-CLS User Manual), together with the OSPE & EHi electro-hydraulic steering units.
- The communication protocol between the e-Wheel and the steering valve controller is based on the Danfoss proprietary safety CAN protocol (see PVED-CLS Communication Protocol).
- The e-Wheel 100 sub-system with a PVED-CLS supports realizing safe steering solutions designed to meet SIL 2/ PL d/ AgPL d by designing the sub-system to a category 3 architecture (see PVED-CLS Safety Manual).

In applications where an e-Wheel is used as a primary steering input device or an auxiliary steering input device, force-feedback is necessary as the steering is expected to replicate the same functions of conventional mechanically linked steering systems. The absence of hydrostatic enforced feedback may cause the operator to feel disconnected with the vehicle steering controls which may cause over or under steering. To prevent this, the e-Wheel haptic passive force-feedback device mimics the feeling of conventional steering systems.

Features of e-Wheel

- 'Plug and Play' solution with PVED-CLS as steering controller
- SIL Claim limit : 2
- Dual channel redundant CAN bus interface
- High quality steering feel
  - Smooth steering torque control
  - Absence of traditional steering wheel backlash and drift
  - End-Stop feeling when vehicle wheels are steered to end-locks
  - RPM torque for better controllability during Variable Ratio Steering
  - Warning or event signal via steering wheel vibration

Benefits of e-Wheel

- Reduced operator fatigue due to improved ergonomics
- Potential to eliminate steering column
- Cabin design freedom for OEMs
- Better accessibility for operator, flexibility in seat movements and orientation
- Low power consumption
- Compact and robust design
- Easy to install

e-Wheel Safety Functions

1. **Safe Steering Angular Position and Safe Steering Speed:**
   Two Channels of e-Wheel (each channel provides sub-system elements such as the hall effect angle sensors, microprocessor logic blocks, power supply conditioning and protection, CAN transceivers) independently measure angular positions, calculate steering speeds and transmit both steering angular positions and steering speeds onto the CAN bus (safety protocol as per PVED-CLS communication protocol)
2. **Safe Force-Feedback Brake Torque:**
   Applying force-feedback torque by e-Wheel as response to the data received via CAN bus (safety protocol as per PVED-CLS communication protocol). Software in the microprocessors will run various torque algorithms in response to the system inputs, defining the required current for force feedback brake torque of e-Wheel. Both microprocessors within e-Wheel will also carry out independent monitoring of sub-system elements to identify and react to subsystem faults.

Application Example and Safety Considerations

The e-Wheel supports category 3 architecture and can be integrated into a Danfoss CAT 3 Fail-Safe Steering System with Danfoss EHi / OSPE and PVED-CLS as steering valve controller (refer to EHi / OSPE Technical Information Document). In the example below shown in figure 1, we consider a Fail-Safe steering solution for a Steer-by-Wire (SbW) system:

Components	Description
e-Wheel 100	Primary steering input device
EHi (configuration type 7)	Electro-hydraulic steering unit
PVED-CLS	Steering Valve Controller
WAS	Dual Analogue Wheel Angle sensor
VSP	CAN Vehicle Speed Sensor (Dual Channel)
MMI	Man-Machine Interface as well as a Gateway for primary vehicle speed message (Dual Channel)
MC012	External Controller (as a redundant controller) for secondary vehicle speed message
Vehicle ECU	OEM controller for braking function during any malfunction or events of failure

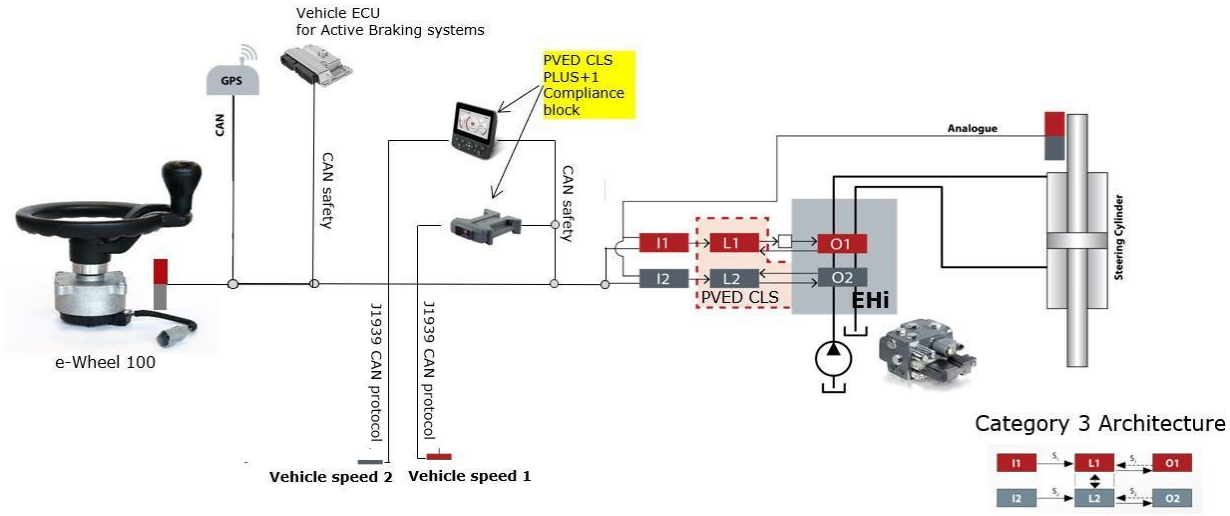


Figure 1 Fail-Safe Steer-by-Wire steering sub-system with e-Wheel

Here, an e-Wheel is the primary steering input device in a vehicle with a Fail-Safe steering system, which transmits the steering angular position and the rate of rotation, via CAN bus, to the steering valve controller. The steering valve controller uses the dual redundant analogue wheel angle sensor inputs, dual redundant vehicle speed messages and dual MMI (display) message, as per the PVED-CLS communication protocol. In this example, the vehicle speed (VSP) message is per standard CAN J1939 protocol. So the VSP messages further need to be converted from the standard CAN protocol to the PVED-CLS communication protocol using PLUS+1 functional block in the two redundant external controllers (Danfoss Display and Danfoss MC-012 Controller). With the above messages along with the e-Wheel inputs, the steering valve controller determines the appropriate steering response.

For vehicles with Fail-Safe SbW steering systems only using an EHi steering valve, manual activated emergency steering will not be possible. Such steering systems must be set up with complete redundancy and limited only for off-road/low risk usage. In case of failures, vehicles must be brought to a defined safe state, for instance by stopping the vehicle or switching to a backup steering system. As shown in figure 1, during a system malfunction or failure event, based on the operational status message from the steering controller and the vehicle speed CAN safety messages from the two plus+1 controllers, the vehicle ECU can signal the vehicle brake systems for deceleration and stopping the vehicle as a safe state response. Vehicle designers must perform hazard and risk analyses to have a "safe vehicle brake" safety function that the steering sub-system can command. To integrate this steering safety concept, category 3 architecture is recommended. Note that the steering controller will not monitor any return status messages from the braking system and no response is to be expected by the steering system related to the status of the braking system.

Different steering wheel sizes

Danfoss offers the e-Wheel 100 **without a physical steering wheel mounted,** shown as per figure 2.
The shaft of the e-Wheel is a 'flat D-shaped' shaft with:

- A maximum axial force of 1500 N
- A bending moment of 50 Nm

Figure 2

The steering wheels to be mounted onto the e-Wheel, must be machined in a way that they accept the 'flat D-shaped' shaft of the e-Wheel, as shown in figure 3.

Figure 3

Below are a few possibilities of different steering wheel sizes that can fit on the shaft of the e-Wheel:

Examples* (*Danfoss does not offer the mounted steering wheels shown, just the base unit).	**Steering wheel sizes to fit on e-Wheel**	**Recommended Torque for corresponding steering wheel size**	**Recommended Part Numbers**
	Mini-steering wheel (~10 cm)	2 Nm	11224128
	Medium and Large size steering wheels (~25-35 cm)	5 Nm	11224129
			

Note:

- Danfoss offers the e-Wheel with 5 Nm and 2 Nm standard variants**. This value represents the maximum torque level during resistance effects, not normal steering.**

e- Wheel Torque Control Algorithms

The passive force- feedback torque is controlled by applying a proportional current, where the current is a function of the control algorithms in the e-Wheel. Force feedback torque will be set based on one control algorithm at a time, determined by the highest value out of all active control algorithms in the e-Wheel at a particular instant. Below is the list of e-Wheel Torque Control Algorithms:

- End-Stop Torque
- Base Torque
- RPM Torque*
- Vehicle Speed Dependent Torque
- Warning Control Torque

*(Note that RPM Torque is not present in the 2 Nm variant).

Information Flow Block Diagram

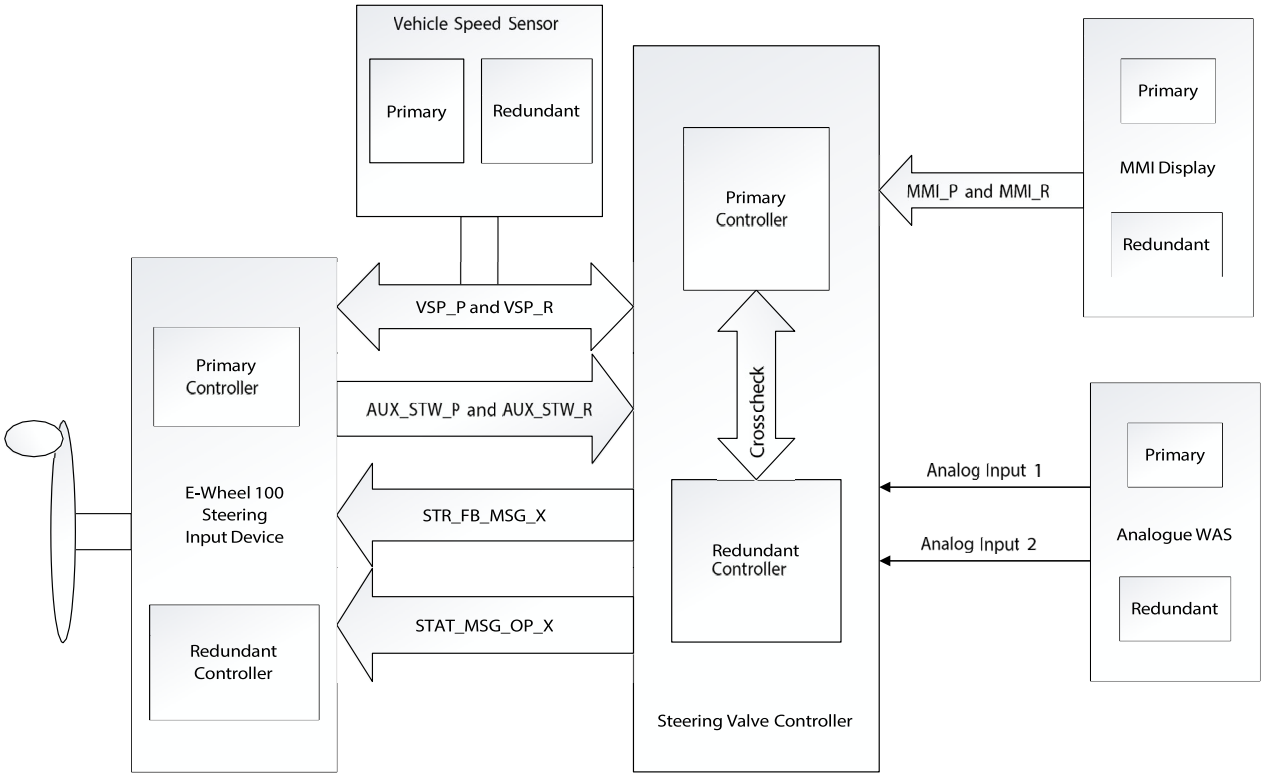


Figure 4 Block diagram for e-Wheel with steering valve controller

The operation between e-Wheel and steering controller in the steering system with the relevant messages from each component is simplified in figure 4. The primary purpose of the e-Wheel is to give steering inputs (steering angle and steering speed); whereas the steering controller defines the steering response based on the data available from all components in the steering sub-system. The messages from each component in figure 4, are per the PVED-CLS communication protocol, specified with the respective annotations (i.e. VSP_P).

Recommendation:

- Since the e-Wheel is a 'Plug and Play solution' with the PVED -CLS, it is recommended to use the PVED-CLS as the steering valve controller for the easiest implementation.
- The Steering Valve Controller's Primary and Redundant Controllers must perform the cross checks to use e-Wheel in a safe way (see the PVED-CLS Safety Manual for more detail).

Graphical Representation of Torque featuring various control algorithms

The control algorithms in e-Wheel, are offered as standard variants with the torque values shown as per figure 5 and figure 6.

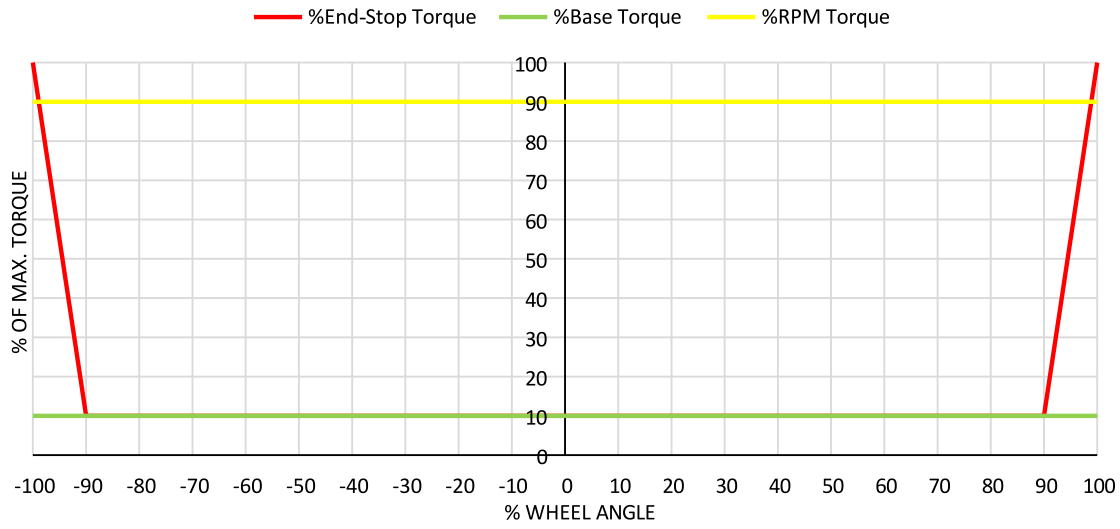


Figure 5 Torque Control Algorithms for 5 Nm

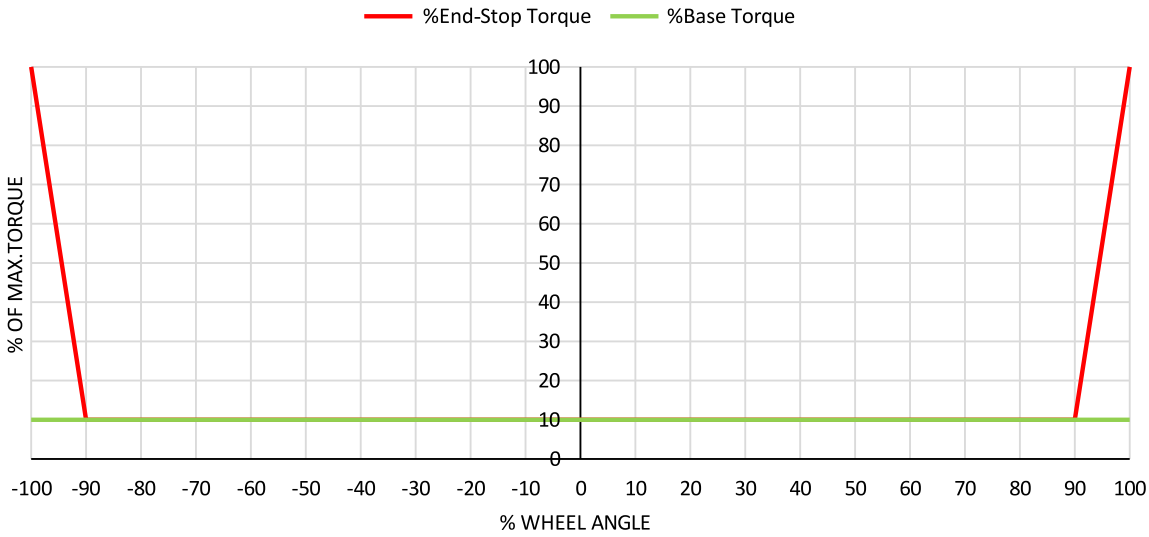


Figure 6 Torque Control Algorithms for 2 Nm

In the above figures 5 and 6 respectively,

- ±100 % wheel angle shall correspond to maximum wheel angles for right and left end stop.
- Figure 5 represents for e-Wheel with 5 Nm as 100 % of the maximum operating torque and figure 6 represents for e-Wheel with 2 Nm as 100 % of the maximum operating torque.
- The RPM torque in both above graphs depict that it can be experienced irrespective of the wheel angle position,

depending upon the allowable RPM at a corresponding steering lock to lock ratio from steering controller. Figure 5 shows, the maximum RPM torque for 5Nm is defined for 90 % of the maximum operating torque; whereas figure 6 shows RPM torque for 2Nm is defined for 60 % of the maximum operating torque.

End-Stop Torque Control

Wheel angle sensors close the feedback loop with the steering controller, ensuring the vehicle wheels match steering commands. During operation, the steering controller transmits the estimated wheel angle values as a feedback message over the CAN bus to the e-Wheel, see Figure 4. Based on this message, the e-Wheel detects the wheel angle values and determines the force feedback torque. As shown in figures 5 and 6, the End-Stop control algorithm increases linearly from 90 % to 100 % wheel angle and provides maximum operating torque (torque of 5Nm or 2Nm based on the chosen e-Wheel variant) at 100 % wheel angle. Thus, the operator experiences the End- Stop torque feedback when the vehicle wheels reach the maximum wheel angle limits. When the operator changes direction to steer away from the end stop towards neutral, the torque drops back to the base torque.

Base Torque Control

The background torque for normal steering, excluding end-stop conditions, is the base torque control. This torque is smooth and persistent throughout the middle of the steering wheel angle range, as shown in figures 5 and 6, as 10 % of the maximum operating torque.

RPM Torque Control

RPM torque control is the application of a resistance torque when an operator starts to reach a higher steering wheel RPM than a particular lock to lock ratio is configured for. The lock-to-lock configuration is provided in the feedback message from the steering valve controller to the e-Wheel.

For different lock-to-lock values, the Max Allowable steering speed (RPM) is:

Lock-to-Lock	Maximum Allowable steering speed (RPM)
1	25
2	50
3	75
4	100
5	125
6	150
7	175
8	200

Figure 7 shows the amount of torque requested (as a percentage of maximum allowable torque) as the operator approaches the maximum allowable RPM (scaled to 1200 internal resolution) for the respective lock-to-lock ratio. The torque brake in the e-Wheel is applied by the algorithm to attempt to limit the operator's steering speed so that the steering speeds in the previous table are not far exceeded. Figure 7 shows the maximum RPM torque is limited to 90 % of maximum operating torque of 5 Nm. This is applicable for medium to large diameter steering wheel applications using the 5 Nm variant.

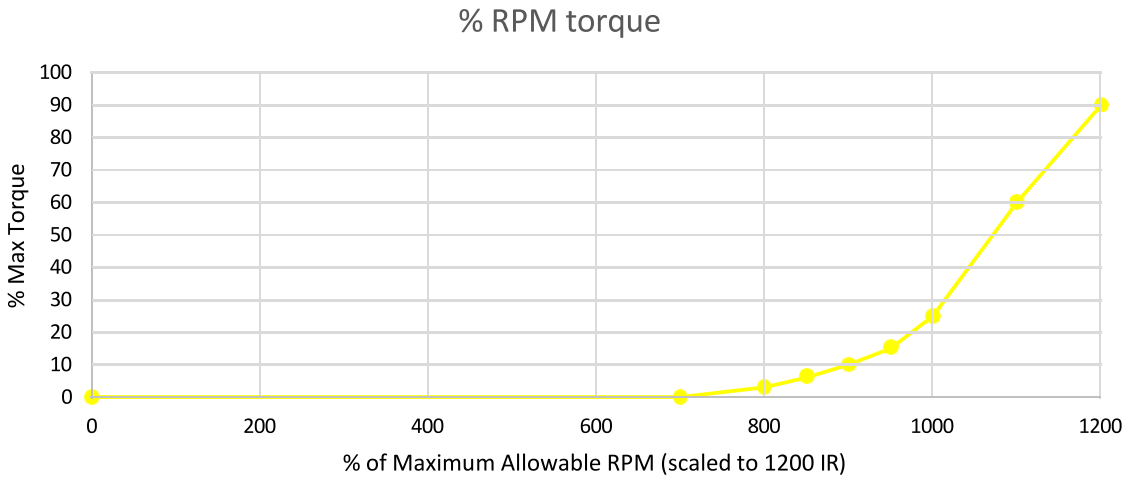


Figure 7 RPM torque for e-Wheel with 5 Nm

Warning Control Torque

In case of CAN message errors, power/ground short circuits, or other failure modes, the e-Wheel will provide relevant error codes in its output message which will trigger the steering controller to a safe state mode. In these error conditions the e-Wheel will provide a warning feedback signal to the operator by producing a vibrational sensation through the steering wheel called Warning Torque. Warning torque will also be present when the Operational Status Message (STAT_MSG_OP_X from figure 4) indicates an operation state where the e-Wheel device is not allowed to be active. (The e-Wheel will be set up as either an STW or AUX device – see the PVED-CLS User Manual for instruction on how to select the e-Wheel device type in the PVED-CLS parameters).

eWheel 100 Response				
Value (Hex)	Current Operation state	Warning Control Brake Request	Rate, CRC, Seq Error & validity checking	Lock -Out Flags
0x00	On-Road	Yes	No Error Check	N/A(2)
0x10	Off-Road Reaction	Yes	No Error Check	N/A(2)
0x11	Off-Road Non-reaction	Yes	No Error Check	N/A(2)
0x20	STW Program 1	Only if errors present or eWheel input device is not STW	Check for Errors	STW device lockout flags only
0x21	STW Program 2	Only if errors present or eWheel input device is not STW	Check for Errors	
0x22	STW Program 3	Only if errors present or eWheel input device is not STW	Check for Errors	
0x23	STW Program 4	Only if errors present or eWheel input device is not STW	Check for Errors	
0x24	STW Program 5	Only if errors present or eWheel input device is not STW	Check for Errors	
0x30	AUX Program 1	Only if errors present or eWheel input device is not AUX	Check for Errors	AUX device lockout flags only
0x31	AUX Program 2	Only if errors present or eWheel input device is not AUX	Check for Errors	
0x32	AUX Program 3	Only if errors present or eWheel input device is not AUX	Check for Errors	
0x33	AUX Program 4	Only if errors present or eWheel input device is not AUX	Check for Errors	
0x34	AUX Program 5	Only if errors present or eWheel input device is not AUX	Check for Errors	
0x40	GPS Steering	No	No Error Check	AUX device lockout flags only(1)
0x41	GPS 2 Steering	No	No Error Check	AUX device lockout flags only(1)
0xD0	Off-Road Safety-Check	Yes	No Error Check	N/A(2)
0xE0	Service mode – Direct Output Control	Yes	No Error Check	N/A(2)
0xE1	Service mode – Wheel angle sensor calibration	No	No Error Check	Ignore
0xE2	Service mode – Spool calibration	No	No Error Check	Ignore
0xE3	Service mode – Joystick calibration	Yes	No Error Check	N/A(2)
0xF0	Initialization	Yes	No Error Check	N/A(2)
0xF1	Safe Degraded Mode	No	Check for Errors in Operational Status Msg Only	Ignore
0xFF	Safe State	Yes	No Error Check	N/A(2)
	powering on with no CLS messages	Yes	No Error Check	N/A(2)

(1): Lock out flags have no effect when input device is STW. When input device is AUX, respond to AUX stg device lockout only. When the auxiliary device is moved, the steering controller will kick it out of GPS operational state into appropriate AUX programs.
(2): N/A here since warning control issued due to current operational state.

Vehicle Speed Torque Control

This is a subtle torque effect designed to eliminate vehicle resonances entering the e-Wheel by providing gradually increasing torque dependency on vehicle speed.

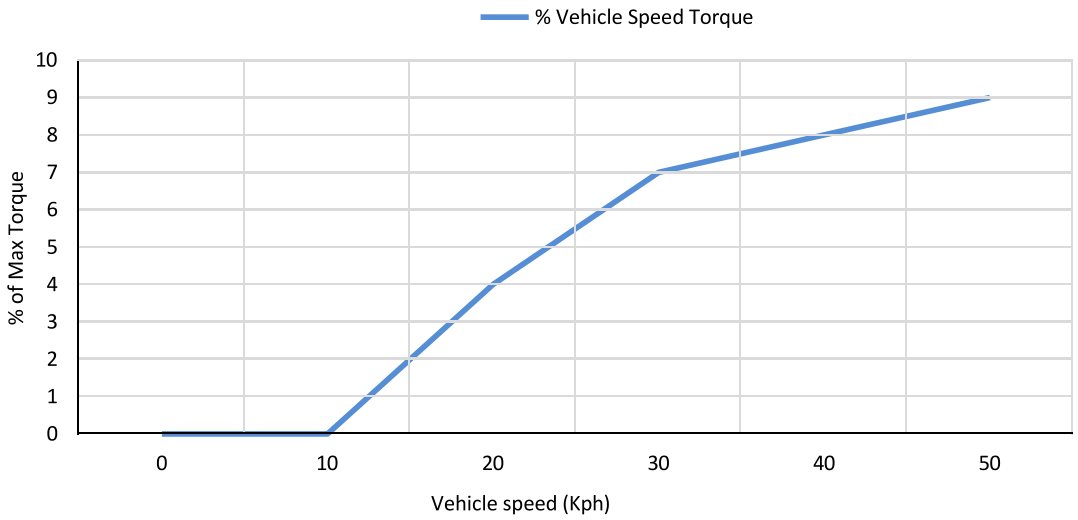


Figure 9 Vehicle Speed Torque

Technical Data

Mechanical characteristics

Description	Value
Rated Torque	5.5 Nm Nominal (100 % command)
Off-State Torque	<0.5 Nm (0% command)
Operating Speed	300 RPM maximum
Max Axial Force	1500 N
Max Bending Moment	50 Nm
Shaft Type	D shaped
Rotating Angle	360°, without mechanical stop
Weight	1.5kg

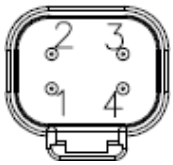
Electrical characteristics

Description	Value
Supply Voltage	12 VDC or 24 VDC (9-36 V), single common power
Coil Resistance	10 Ω nominal
Maximum Power Dissipated	15 Watts
Cable	20 AWG x 4 conductors (Sealed cable with single connector withstands cable pull load maximum 100 N)

CAN (Controller Area Network)

Description	Value
Standard	CAN 2.0B
Channels	Two
Baud Rate	250k Baud

Connector type and Pin Configuration



Connector	DEUTSCH DT 04-4P*

*Mating part to be bought externally

PIN	Wire Color	Function
1	White	CAN-H
2	Blue	CAN-L
3	Red	V+
4	Black	V-

Environmental characteristics

Description	Value
Operating Temperature	-40 °C to 85 °C
Storage Temperature	-40 °C to 95 °C
Ingress Protection (IP) rating	IP66
Environmental Testing Std.	ISO 16750-4 §5.1 per IEC 60068-2

Functional Safety

Description	e-Wheel Sensor Safety Specification	e-Wheel Brake Safety Specification
Performance Level (EN 13849-1: 2015)	PLd	PLd
Hardware Fault Tolerance (HFT)	1 (1)	1
System	Fail Safe	Fail Safe
Safety Element Classification (IEC 62061)	Type B	Type B
Probability of Dangerous Failures (PFHDssD) (IEC 62061 : 2005)	1.597×10^{-8}	5.289×10^{-9}
Safe Failure Fraction (SFF)	98.72%	99.25%
SIL Claim Limit (IEC 62061:2005)	2	2
Architecture (ISO 13849)	Category 3	Category 3
DC	High (2)	High
Proof Test Interval / Mission Time	20 years	20 Years
MTTFd per channel (ISO 13849 Table K.1)	150 years	180 years
CCF factor (IEC 62061)	5 %	5 %

Notes:

(1) The sensor sub-system is redundant. If one channel fails, the other channel continues transmitting data. However, the steering controller can no longer perform diagnostics and a system safe state shall be reached. The system integrator must ensure sufficient diagnostics; please refer to the Block Diagram in figure 4.

(2) Reaching a DC= High, depends on a correctly working diagnostic function in the steering controller. (Refer to the PVED-CLS Safety Manual.)

Communication Protocol

The below table shows how the steering controller shall be parameterized in order to correctly send main and redundant sensor CAN messages. In the PVED-CLS documentation, the e-Wheel will be able to function as an STW or AUX device. (Refer to the PVED-CLS User Manual and Communication Protocol found in the firmware release package for further details).

Messages sent by e-Wheel to Steering Controller: (IDs from e-Wheel are fixed).			
Sensor message	**Default Message ID**	**Main Controller Parameters to Map in PVED-CLS**	**Safety Controller Parameters to Map in PVED-CLS**
e-Wheel Primary	0x0CFF144F	P3299 = AUX PGN P3296 = STW/SASA PGN P3321 = AUX Source ID P3319 = STW/SASA Source ID	
e-Wheel Redundant	0x0CFF154F		P3299 = AUX PGN P3296 = STW/SASA PGN P3321 = AUX Source ID P3319 = STW/SASA Source ID
Messages sent by Steering Controller (PVED-CLS) to e-Wheel: (IDs must match these values).			
Steering Feedback: Primary Redundant	0xCFF1813 0xCFF185A	P3297 = 0x13	P3297= 0x5A
Operation Status: Primary Redundant	0x18FF2013 0x18FF205A	P3297 = 0x13	P3297= 0x5A
Vehicle Speed sent to e-Wheel and Steering Controller (PVED-CLS): (IDs must match these values).			
Vehicle Speed - Primary	0xCFF40FB	P3294=0xFB P3318 =0x40	
Vehicle Speed - Redundant	0xCFF41FB		P3294 = 0xFB P3318 = 0x41
Sensor CAN Messages to PVED-CLS Steering Controller: (Not applicable when a PVED-CLS is not used).			
Wheel Angle Sensor- Primary	0x0CFF12FA	P3298 = 0xFA P3320 = 0x12	
Wheel Angle Sensor- Redundant	0x0CFF13FA		P3298 = 0xFA P3320 = 0x13
Man Machine Interface Primary	0x0CEF13FC	P3295=0xFC P3297 =0x13	
Man Machine Interface Secondary	0x0CEF5AFC		P3295 = 0xFC P3297 = 0x5A

Messages sent by e-Wheel to Steering Controller

[AUX_STW_P and AUX_STW_R or STW_P and STW_R per PVED-CLS Communication Protocol]

This message transmits angle, velocity, and fault information from the e-Wheel.

Priority: 3
Nominal Transmission rate: 50 ms
Sent by: e-Wheel
Send to: PVED-CLS Steering controller

Bytes	Encoding	Value/Range	Description
1..2	U16	0..4095 4096..65535	Steering angle 1 relative to the 0-index point [AUX_STW_pos_P]: Steering angle in [360 / 4096 degree] steps, where: 0 corresponds to 0 degrees, 4095 corresponds to 359.912 degrees **Note:** the steering angle rolls over from 4095 to 0 for clockwise activation and from 0 to 4095 for counterclockwise activation Information not available
3..4	U16	0..40960 40961..65535	Steering angle velocity [AUX_STW_velocity_P]: Steering angle velocity (offset -20480) in [30 / 20480 RPM] steps, where 0 corresponds to -300 RPM (300 RPM counterclockwise) 20480 corresponds to 0 RPM 40960 corresponds to 300 RPM (300 RPM clockwise) Information not available
5	-	All 1	Reserved
6	Bits 8..16	0 1 2 3 4 5 6 7 8..13 14 15	Error codes [AUX_STW_error_code_P]: Reserved Sensor chip error Steering angle failure CAN input message failure Power failure CPU failure Memory failure Force feedback failure Reserved Temperature warning No Error
	Bits 4..1	0..15	Sequence number [AUX_STW_Seq_P], incremented by 1 in each AUX primary message Rolls over from 15 to 0
7..8	U16	0..65535	CRC16 for data bytes 1..6 [AUX_STW_CRC_P]: Polynomial: 0xC86C

Note:

- The above messages should be dual messages for both Primary and Redundant controllers.

Vehicle Speed Message from Vehicle CAN bus to both e-Wheel and Steering Controller:

[VSP_P and VSP_R per PVED-CLS Communication Protocol]

This message contains information from the steering controller to the e-wheel

Nominal Transmission: 100 ms
Priority: 3
Sent by: Vehicle Speed Sensor
Send to: e-Wheel

Bytes	Encoding	Value/Range	Description
1	U8	All 1	Reserved
2	Bits 8..7	00 01 10 11	Direction Indication [VSP_Dir_P]: Forward Reverse Error Condition Information not available
	Bits 6..1	All 1	Reserved
3..4	U16	0..64255 64256..65535	Vehicle speed [VSP_Speed_P]: Measured vehicle speed in [1/256 kmph] Information not available
5	-	All 1	Reserved
6	Bits 8..5	All 1	Reserved
	Bits 4..1	0..15	Sequence number [VSP_Seq_P], incremented by 1 in each VSP primary message Rolls over from 15 to 0
7..8	U16	0..65535	CRC16 for data bytes 1..6 [VSP_CRC_P]: Polynomial: 0xC86C

Vehicle Speed

This parameter specifies the vehicle speed, measured in (1/256 kph).

Sequence number

This parameter is an internal counter that runs from 0 – 15 and then loops back. It is used by the e- Wheel to check for validity of the incoming message.

Note:

- The above messages should be dual messages for both Primary and Redundant controllers.

Messages sent by Steering Controller (PVED-CLS) to e-Wheel:

Steering Feedback Message [STR_FB_MSG_X per PVED-CLS Communication Protocol]

This message contains information from the steering controller to the e-Wheel, including control commands and relevant system level information.
Priority: 3
Nominal Transmission: 50 ms
Sent by: Steering controller
Send to: e-Wheel

Bytes	Encoding	Value/Range	Description
1..2	U16	0..2000 2001..65535	Estimated EH-Flow [STR_FB_Est_flow_X]: Flow (-1000 offset) in [0.1%], where: 0 corresponds to 100.0% Flow to the left, 1000 is the neutral position (0.0%) and 2000 corresponds to 100.0% Flow to the right Information not available
3..4	U16	0..2000 2001..65535	Estimated Wheel angle [STR_FB_Est_WA_X]: Wheel angle (-1000 offset) in [0.1%], where 0 corresponds to the left most position (-100,0%), 1000 is the neutral position and (0,0%) 2000 corresponds to the right most position (100,0%) Information not available
5	U8	 0 1..80 81..254 255	Number of desired steering wheel revolutions lock to lock [STR_FB_STW_L2L_X]: Reserved Steering revolutions in [0.1 Rev], where 1 corresponds to 0.1 steering wheel revolutions lock to lock 80 corresponds to 8 steering wheel revolutions lock to lock Reserved Information not available
6	Bits 8..5	All 1	Reserved
	Bits 4..1	 0..15	Sequence number [STR_FB_Seq_X], incremented by 1 in each Steering feedback message Rolls over from 15 to 0
7..8	U16	0..65535	CRC16 for data bytes 1..6 [STR_FB_CRC_X]: Polynomial: 0xC86C

Note:

- The above messages are dual messages from both Primary and Redundant controllers.

Operational Status message [STAT_MSG_OP_X per PVED-CLS Communication Protocol]

This message contains information from the steering controller to the e-Wheel.

Priority: 6

Nominal Transmission: 100 ms
Sent by: Steering controller
Send to: e-Wheel

Bytes	Encoding	Value/Range	Description
1	U8		Current Operation state [OperationState_X]:
		0x00	On-Road
		0x10	Off-Road Reaction
		0x11	Off-Road Non-reaction
		0x20	STW Program 1
		0x21	STW Program 2
		0x22	STW Program 3
		0x23	STW Program 4
		0x24	STW Program 5
		0x30	AUX Program 1
		0x31	AUX Program 2
		0x32	AUX Program 3
		0x33	AUX Program 4
		0x34	AUX Program 5
		0x40	GPS Steering
		0x41	GPS 2 Steering
		0xD0	Off-Road Safety-Check
		0xE0	Service mode – Direct Output Control
		0xE1	Service mode – Wheel angle sensor calibration
		0xE2	Service mode – Spool calibration
		0xE3	Service mode – Joystick calibration
		0xF0	Initialization
		0xF1	Safe Degraded Mode
		0xFF	Safe State
2	Bits 8..7		Lock-out status for steering device changes [Lockout_device_change_X]:
		00	Steering device changes allowed
		01	Steering device changes prohibited
		10	Error condition
		11	Information not available
	Bits 6..5		Lock-out status for STW/AUX program changes [Lockout_program_change_X]:
		00	Program changes allowed
		01	Program changes prohibited
		10	Error condition
		11	Information not available

	Bits 4..3		Lock-out status for EH-steering functionality [Lockout_EH_steering_X]:
		00	EH-Steering functionality allowed
		01	EH-Steering functionality prohibited by an external switch
		10	Error condition
		11	Information not available
	Bits 2..1		AUX Steering device lockout status [Lockout_AUX_X]:
		00	AUX device steering allowed
		01	AUX device steering prohibited
		10	Error condition
		11	Information not available
3	Bits 8..7		GPS receiver selection and lockout status [Lockout_GPS_X]:
		00	No GPS receiver selected (GPS steering prohibited)
		01	GPS Steering selected
		10	GPS 2 Steering selected
		11	Reserved
	Bits 6..5	00 01 10 11	STW device lockout status [Lockout_STW_X]: STW device steering allowed STW device steering prohibited Error condition Information not available
	Bits 4..1	All 1	Reserved
4	U&#		Service mode state [Service_mode_state_X]:
		0x00	Direct output control reset
		0x01	Direct output control active
		0x02..0x0F	Reserved
		0x10	WAS calibration Reset
		0x11	WAS calibration in progress
		0x12..0x1C	Reserved
		0x1D	WAS calibration counter update
		0x1E	WAS calibration failure
		0x1F	WAS calibration complete
		0x20	Spool calibration reset
		0x21	Spool calibration inactive
		0x22	Spool calibration getting armed
		0x23	Spool calibration armed
		0x24	Spool calibration in progress
		0x25	Spool parameters plausibility check
		0x26	Spool parameters ready to update
		0x27	Spool parameters update
		0x28..0x2C	Reserved
		0x2D	Spool calibration counter update
		0x2E	Spool calibration failure
		0x2F	Spool calibration complete
		0x30	Joystick calibration Reset
		0x31	Joystick calibration in progress

		0x32..0x3C	Reserved
		0x3D	Joystick calibration counter update
		0x3E	Joystick calibration failure
		0x3F	Joystick calibration complete
		0x40..0xFC	Reserved
		0xFD	No analog joystick configured
		0xFE	No wheel angle sensor configured
		0xFF	Information not available (Operation state other than service mode)
5	Bits 8..7		Steering Device Selected in Safe degraded mode [Str_Device_Sel_X]
		00	STW Selected
		01	AUX Mini Wheel Selected
		10	AUX Joystick Selected
		11	Device not selected
	Bits 6..5		eWheel Input device type [eWheel_Type_X]
		00	STW
		01	AUX
		10	Reserved
		11	Information Not available (Non-SBW configuration)
	Bits 4..1	All 1	Reserved
6	Bits 8..5	All 1	Reserved
	Bits 4..1	0..15	Sequence number [OperationState_Seq_X]: Incremented by 1 in each Operation status message. Rolls over from 15 to 0
7..8	U16	0..65535	CRC16 for data bytes 1..6 [OperationState_CRC_X]: Polynomial: 0xC86C

Note

- The above messages (Steering Feedback and Operation Status) are dual messages from both Primary and Redundant controllers

Operation without a PVED-CLS

Example of the required messages to operate e-Wheel with base torque without a PVED-CLS:

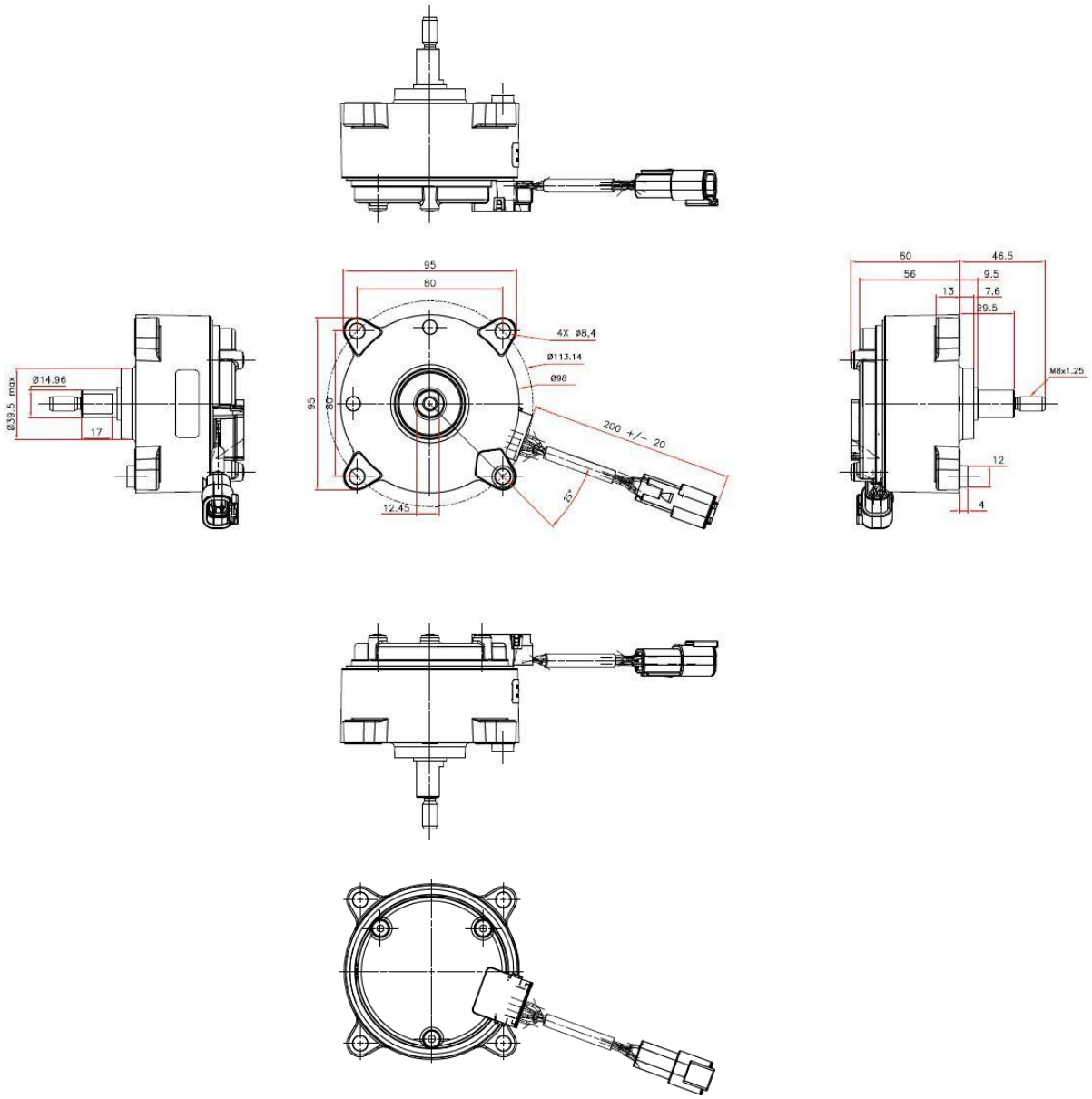
Message Name	Transmission Rate (ms)*	Message ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Steering Feedback (Main)	50	0x0CFF1813	E8	03	E8	03	28	FB	E8	F8
Steering Feedback (Safety)	50	0x0CFF185A	E8	03	E8	03	28	FB	E8	F8
Operation Status (Main)	100	0x18FF2013	30	0C	8F	FF	FF	F8	20	75
Operation Status (Safety)	100	0x18FF205A	30	0C	8F	FF	FF	F8	20	75
Vehicle Speed (Primary)	100	0xCFF40FB	FF	3F	00	00	FF	FB	00	BC
Vehicle Speed (Redundant)	100	0xCFF41FB	FF	3F	00	00	FF	FB	00	BC

Notes

- For torque effects, use the Operation Status message for Warning Torque or Steering Feedback message for End-Stop and RPM Torque as described in the section "e-Wheel Torque Control Algorithms".
- Message sequence counter and CRC must function for VSP, Steering Feedback, and Operation Status messages as per J1939 format for bytes 6, 7, & 8.
- *Nominal Transmission rate "x" given, tolerance is 1.5x

Installations

Dimensions



Instructions

- To be installed such that shaft is between vertical axis and -10° from horizontal axis
- Avoid misalignment that causes excessive radial or axial load

Variant and ordering specifications

e-Wheel MMC

Example only

e-Wheel 100 [1]	CAN[2]	5[3]	ES[4]	BS[5]	RPM[6]	Reserved[7]	VSP[8]	D[9]	Package[10]

[1] e-Wheel 100 base

[2] Communication channel

[3] Maximum Operating Torque (Nm)

[4] End Stop Torque (Nm)

[5] Base Torque (Nm)

[6] RPM Torque (Nm)

[7] Reserved

[8] Vehicle Speed Torque (Nm)

[9] Connector Type

[10] Package

Code Numbers

Code numbers for catalog versions with specifications:

Code No.	**Configuration No.**	**MMC Specifications according to above description format**								
11224128	Type 1	CAN	2	ES	BS	N	-	VSP	D	S
11224129	Type 2	CAN	5	ES	BS	RPM	-	VSP	D	S

Variants codes for e-Wheel MMC

1) e-Wheel 100 base

e-Wheel	Electric Steering Wheel Base
Code	e-Wheel 100

2) Communication Channel

Type	Digital
Code	CAN

3) Maximum Operating Torque (Nm)

Maximum Operating Torque	5 Nm	2 Nm
Code	5	2

4) End Stop Torque (Nm)

EndStop Torque	Included	Not Included
Code	ES	N

5) Base Torque (Nm)

Base Torque	Included	Not Included
Code	BS	N

6) RPM (Nm)

RPM Torque	Included	Not Included
Code	RPM	N

7) Reserved

8) Vehicle Speed Torque (Nm)

VSP Torque	Included	Not Included
Code	VSP	N

9) Connector Type

Type, Connector	Deutsch DT, one 4 pin
Code	D

10) Package

Package	Single	Multiple
Code	S	M

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