

LORD TFD[®] Steering Units

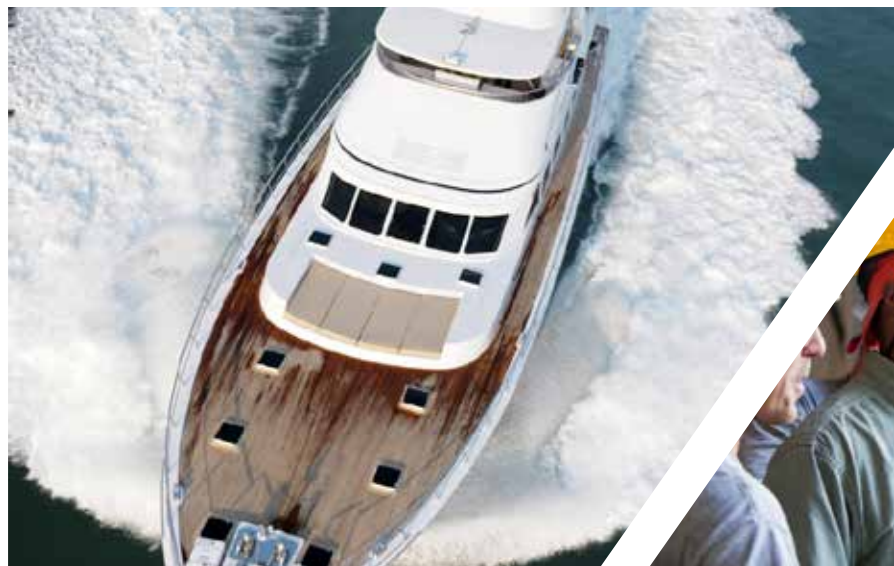
FOR STEER-BY-WIRE SYSTEMS



Steer-by-Wire Systems in Industrial and Off-Highway Equipment



Electro-hydraulic and fully-electric Steer-by-Wire (SbW) systems are gaining favor over traditional mechanical and hydraulic steering systems. Vehicles with SbW systems tend to consume less energy, which reduces the cost of ownership and improves environmental impact. In SbW systems there is no mechanical connection between the steering wheel and road wheels, which has challenged OEMs in providing the operator with a high quality steering feel. In response to this challenge LORD offers a line of Tactile Feedback Device (TFD) steering units.



WHAT IS A TFD STEERING UNIT?

The TFD steering unit is a key component of fully-electric and electro-hydraulic SbW systems. These devices provide an integrated solution that combines bearing support, steering position sensing, communication and continuously variable resistive steering torque, all to deliver high-fidelity tactile feedback and maximum control to the operator.

LORD Corporation has been a pioneer of SbW steering units since 1999, when the first device began production in a forklift truck application. The LORD TFD steering unit is maintenance-free and will never require inspection or adjustment during its expected service life. There are very few moving parts in the design, which greatly enhances durability. With more than 400,000 devices in service today, LORD Corporation has a long history of providing reliable and safe devices for industrial and off-highway equipment.



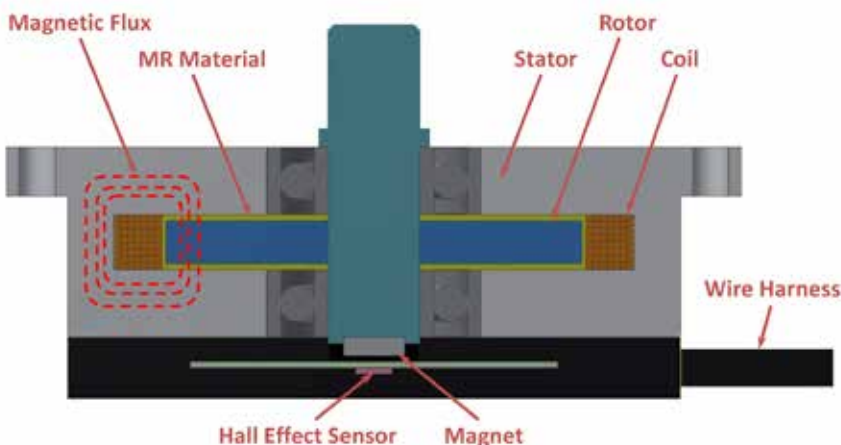
HOW DOES A TFD STEERING UNIT WORK?

The TFD steering unit is typically mounted below the vehicle's steering wheel. As the operator turns the steering wheel, the hall-effect steering sensor detects and transmits the steering position to the vehicle steering controller. The steering controller uses information from a variety of vehicle inputs to determine the preferred steering response.

The steering response can be programmed for partial or multiple rotations, to be speed sensitive, and to generate end-stop control, position detents and more. Integration with other devices and technologies, such as electric motors, GPS and vision systems, can provide sophisticated hybrid steering control.



These devices provide an integrated solution for electric and electro-hydraulic Steer-by-Wire systems.



Torque feedback to the operator is generated through our proprietary “Direct Shear Mode” design, in which a rotor attached to a shaft shears magnetically responsive (MR) material against a fixed stator. As the current commanded by the vehicle steering controller to the TFD steering unit changes, a low-power (0-1 amp) coil generates a magnetic field that instantaneously changes the properties of the MR material and the subsequent torque feedback.

With torque feedback independent of speed and temperature, a wide variety of applications can benefit from the smooth and quiet steering feel.

BENEFITS OF LORD TFD STEERING UNITS

IMPROVED STEERING FEEDBACK PERFORMANCE

- PROGRAMMABLE RESISTIVE STEERING FEEDBACK BASED ON EQUIPMENT OPERATING CONDITIONS
- SMOOTH STEERING TORQUE INDEPENDENT OF VEHICLE SPEED AND TEMPERATURE
 - NO “STICK SLIP” AT LOW SPEEDS (COMMON WITH FRICTION BRAKES)
 - NO ELECTRIC MOTOR “COGGING” FEEL
- INCREASED EASE OF OFF-ROAD MANEUVERABILITY
- IMPROVED ACCURACY AT ON-ROAD SPEEDS
- LOW POWER CONSUMPTION
- FAST RESPONSE TIME

RELIABLE CONTROL SIGNALS

- MULTIPLE NON-CONTACT SENSOR CONFIGURATIONS (2, 3 OR 4 OUTPUTS)
- ANALOG (V) AND/OR DIGITAL (PWM) OUTPUTS
- PROTECTED FROM EMC
- SIL2/3 SAFETY RATING

INCREASED DESIGN FLEXIBILITY

- EXTENSIVE PORTFOLIO OF STANDARD AND CUSTOMIZED SOLUTIONS
- ROBUST, EASY-TO-INSTALL, COMPACT DESIGN
- IMPROVED STEERING ERGONOMICS FOR THE OPERATOR
- NO REQUIRED MAINTENANCE

Current Applications: Industrial Lift Trucks, Agriculture &

Construction Equipment, Electric Vehicles, Marine

TFD Steering Unit Product Portfolio

LORD Corporation has a diverse portfolio of TFD steering units to satisfy a variety of customer requirements. Our portfolio includes devices capable of producing resistive steering torque ranging from 5Nm to 20Nm.

5NM DEVICES

The adoption of smaller steering wheels has increased as many industrial and off-highway Equipment OEMs consider more innovative and flexible steering interfaces. To meet the various needs of these applications, LORD has developed a standard product line of 5Nm devices which include the following features:

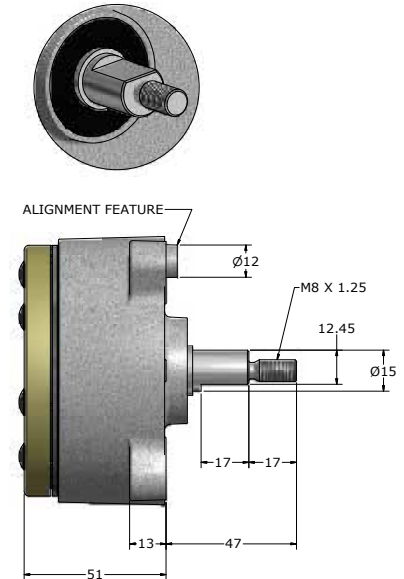
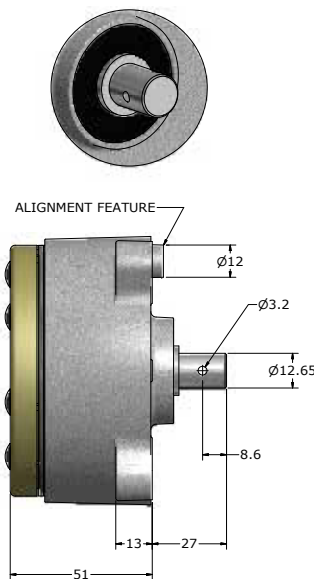
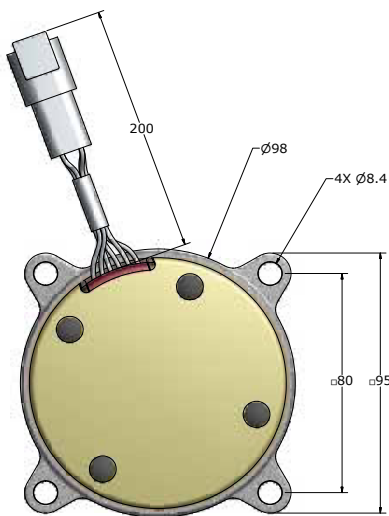
- 2-channel dual-redundant, non-contact, Hall effect steering sensor
- Sensor output (three options)
 - Standard digital (PWM) multi-rotational code
 - Analog code suitable for controllers with limited digital I/O
 - Analog multi-rotational code with no discontinuities in the signal
- Shaft connection (two options)
 - Flat
 - Cross-drilled
- Deutsch DTM04-6P connector
- 20 AWG wire
- 200mm cable length
- 10 Ohm coil

5NM PRODUCT SPECIFICATIONS

Category	Specification
Product Weight	1.3 kg (2.9 lbs)
Rated Torque @ 1A	5 Nm nominal (3.7 lb-ft)
Off-State Torque @ 0A	<0.5 Nm (<0.4 lb-ft)
Operating Speed	180 rpm max
Operating Temperature	-35 °C to +80 °C (-31 °F to +176 °F)
Axial Force Limit	1500 N max (337 lbf)
Bending Moment Limit	50 Nm max (36.9 lb-ft)
Current Control	12 VDC
Coil Resistance	10 Ω nominal
Current (max)	1.5 A peak
Current (continuous)	1.0 A
Sensor Resolution	12 bit
Sensor Linearity	+/- 1.2% Full Scale
Environmental Protection	IP66

CROSS DRILLED SHAFT

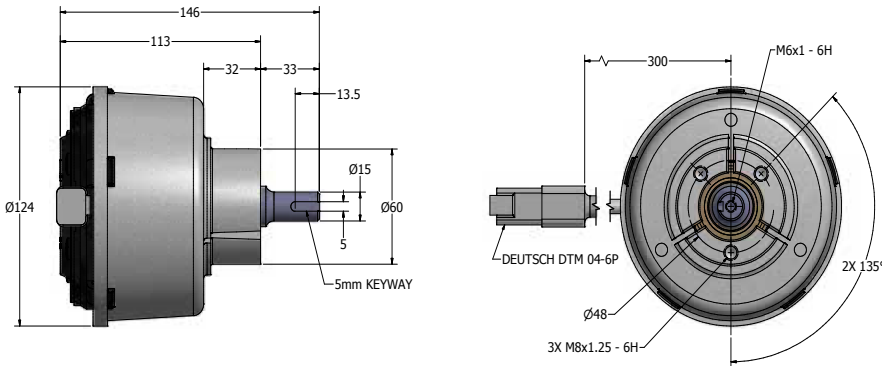
FLAT SHAFT



*DIMENSIONS ARE IN MILLIMETERS

12NM DEVICES

For applications with larger steering wheels, LORD has a standard 12Nm TFD steering unit to accommodate the higher steering torque.



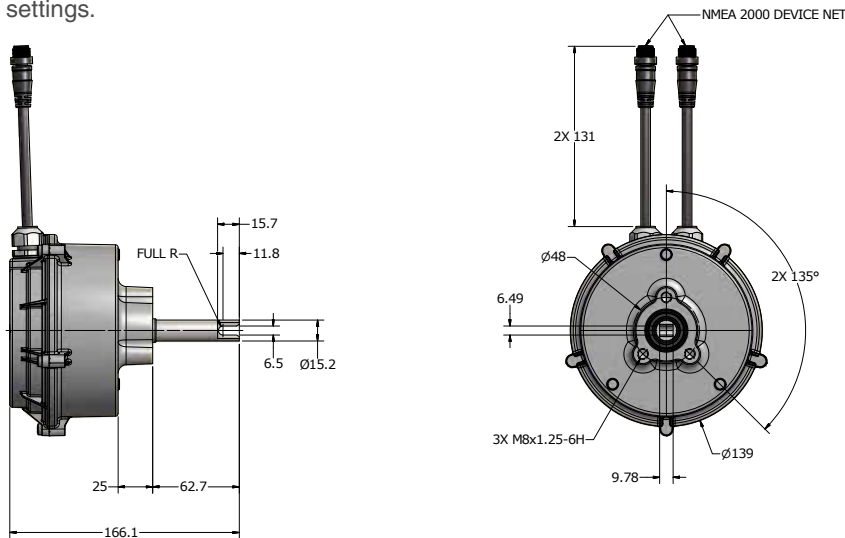
*DIMENSIONS ARE IN MILLIMETERS

12NM PRODUCT SPECIFICATIONS

Category	Specification
Product Weight	2.7 kg (6.0 lbs)
Rated Torque @ 0.8A	10 Nm nominal (7.4 lb-ft)
Off-State Torque @ 0A	<1.0 Nm (<0.75 lb-ft)
Operating Speed	120 rpm max
Operating Temperature	-35 °C to +80 °C (-31 °F to +176 °F)
Axial Force Limit	1500 N max (337 lbf)
Bending Moment Limit	50 Nm max (36.9 lb-ft)
Current Control	12 VDC
Coil Resistance	11 Ω nominal
Current (max)	1.5 A peak
Current (continuous)	1.0 A
Sensor Resolution	12 bit
Sensor Linearity	+/- 1.2% Full Scale
Environmental Protection	IP66

20NM DEVICES

For applications requiring maximum steering torque, LORD offers a 20Nm TFD steering unit. The 20Nm TFD contains an integrated controller which uses inputs from the CAN-bus, allowing for highly tunable steering settings.



20NM PRODUCT SPECIFICATIONS

Category	Specification
Rated torque at 100% command	20 Nm nominal (14.8 lb-ft)
Off-state torque at 0% command	<1.0 Nm (<0.75 lb-ft)
Operating speed	120 rpm maximum
Product weight	3.3 kg (7.3 lbs)
Supply voltage	9-36 VDC
System power draw (continuous)	2.6 W
System power draw (at 100% current command)	17 W
CAN	Two independent CAN 2.0B transceivers (29-bit identifiers), 250 kBaud
Sensor type	Absolute, non-contact, Hall effect
Sensor resolution	14-bit
Cable connection	Dual NMEA 2000 DeviceNet
Shaft connection	Compatible with U-Flex X52 tilt mechanism
Installation orientation	Vertical (shaft up) to horizontal (-10°)
Axial force limit	1500 N max (337 lbf)
Operating temperature	-15 °C to 85 °C (5 °F to 185 °F)
Environmental protection	IP67, 1000-hr salt fog
Safety rating	SIL2 design intent

CUSTOMIZED SOLUTIONS

LORD also designs and manufactures various customized devices, which are tuned to specific customer requirements. These designs may include the following unique features:

- Quad-Redundant steering sensors
- Housings
- Shaft connections
- Cable connections and length
- Coil resistance
- Sensor outputs
- CAN-bus enabled devices



CAN-BUS COMMUNICATION

We have integrated CAN capability into our TFD steering unit product line, enabling more sophisticated steering algorithms using various vehicle inputs. Working closely with an OEM, LORD can use CAN-bus communication to enhance the steering feel of a vehicle in ways not possible with previous technology.

CAN-BUS SPECIFICATIONS

Category	Specification
Version	2.0 B
Transceiver Type	High Speed
Speed	250 kbit/sec (programmable)
Message ID Size	11 or 29 bits
Message Output Rate	50 ms (programmable) 10 - 100ms



Steering wheel and stand shown above are for demonstration purposes only. Please contact LORD to schedule a demonstration of one of our TFD devices.

Values stated in this brochure represent typical values, as not all tests are run on each lot of material produced. For formalized product specification regarding specific product end uses, contact the Customer Support Center.

Information provided herein is based upon tests believed to be reliable. In as much as LORD Corporation has no control over the manner in which others may use this information, it does not guarantee the results to be obtained. In addition, LORD Corporation does not guarantee the performance of the product or the results obtained from the use of the product or this information where the product has been repackaged by any third party, including but not limited to any product end-user. Nor does the company make any express or implied warranty of merchantability or fitness for a particular purpose concerning the effects or results of such use.

LORD provides valuable expertise in adhesives and coatings, vibration and motion control, and magnetically responsive technologies. Our people work in collaboration with our customers to help them increase the value of their products. Innovative and responsive in an ever-changing marketplace, we are focused on providing solutions for our customers worldwide ... Ask Us How.

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