

TS SERIES IN-LINE TORQUE SENSORS USER MANUAL



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SAFETY PRECAUTIONS

**WARNING**

WARNING! IN ORDER TO MINIMIZE RISKS, IT IS OF UTMOST IMPORTANCE TO RESPECT THE CURRENT SAFETY STANDARDS WHEN PLANNING, CONFIGURING AND OPERATING THE TORQUE MEASUREMENT DRIVE TRAIN.

**CAUTION**

CAUTION: OPERATE THE TS SERIES IN-LINE TORQUE SENSOR WITH GREAT CAUTION! THE SENSOR MAY BE IRREVERSIBLY DAMAGED IF IMPACTED MECHANICALLY (FALL), CHEMICALLY (ACIDS) OR THERMALLY (HOT AIR, VAPOR).

1. Make sure that all Magtrol electronic products are earth-grounded, to guarantee personal safety and proper operation.
2. Check line voltage before operating electronic equipment.
3. Make sure that all rotating parts are equipped with appropriate safety guards.

**NOTICE**

Detailed information regarding the safety guards or protective systems can be found in *section - 2.5 Protective systems*.

4. Periodically check all connections and attachments.
5. Always wear protective glasses when working close to rotating elements.
6. Never wear a necktie or baggy clothes when standing close to rotating elements.
7. Never stand too close or bend over the rotating drive chain.

QUALIFIED PERSONNEL

Persons in charge of installing and operating the TS Series In-Line Torque Sensor must have read and understood this user manual, paying extra close attention to all safety-related information.

The TS In-Line Torque Sensor is a high-precision product integrating the most recent measurement techniques. The sensor can give rise to residual dangers if used and manipulated in a non-compliant way by unqualified personnel.

This sensor must be handled by qualified personnel according to the technical requirements and the above-mentioned safety instructions. This is also true when using torque sensor accessories.

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PREFACE

PURPOSE OF THIS MANUAL

This manual contains all the information required for the setup, connection and general use of Magtrol's TS Series In-Line Torque Sensor. To achieve maximum capability and ensure proper use, please read this manual in its entirety before operating the unit. Keep the manual in a safe place for quick reference whenever a question should arise.

WHO SHOULD USE THIS MANUAL

This is written for operators installing a torque transducer as part of a test system that measures the torque on transmission chains. The operator is assumed to have the necessary technical knowledge in electronics and mechanical engineering enabling him to install the In-Line Torque Sensor without risk.

MANUAL ORGANIZATION

This section gives an overview of the structure of the manual and the information contained within it. Some information has been deliberately repeated in different sections of the document to minimize cross-referencing and to facilitate understanding through reiteration.

The structure of the manual is as follows:

- Chapter 1: INTRODUCTION – Contains the technical datasheets for Magtrol's TS In-Line Torque Sensor, which describe the units and provide detailed technical characteristics.
- Chapter 2: INSTALLATION/CONFIGURATION – Provides information needed for the setup of the TS Sensor in a test system, and its integration with Magtrol electronic control units.
- Chapter 3: OPERATING PRINCIPLES – Information pertaining to theory of operation including details about the transducer's architecture, speed conditioning chain and built-in self-test circuit.
- Chapter 4: COMPUTER CONTROLLED OPERATION – How to run a test when the TS Sensor is used with a computer. Includes information on hardware connection and driver installation.
- Chapter 5: USER COMMANDS – How to program the TS Sensor. Includes information on data format, programming and command set.
- Chapter 6: MAINTENANCE, REPAIR & CALIBRATION – Provides information on maintenance, repair and calibration procedures, should the need arise.
- Chapter 7: TROUBLESHOOTING – Provides solutions to common problems encountered during configuration and running of the torque sensors, its accessories or associated products.
- Chapter 8: SERVICE INFORMATION – Information, contacts and addresses relative for repair and/or calibration.

SEMANTICS

In this manual, different terminologies may be used to speak about the «TS Series In-Line Torques Sensor». The primary purpose is to make this user manual useful and easy to read.

Below you will find different terminology used such as: «In-Line Torque Sensor», «Torque Sensor», «Sensor», «In-Line Torque Transducer», «Transducer» or «Torque Transducer» are synonyms; «TS XXX Series», «TS 1XX Series» or «TS Series» are all abbreviations for «TS Series In-Line Torque Sensor», etc.

The term «Series» stands for all the products of the series (e.g. TS 1XX Series refers to TS 100 – TS 199).

CONVENTIONS USED IN THIS MANUAL

The following symbols and type styles may be used in this manual to highlight certain parts of the text:

**NOTICE**

Indicates information considered important but not hazard related.

This is intended to draw the operator's attention to complementary information or advice relating to the subject being treated. It introduces information enabling the correct and optimal function of the product.

**CAUTION**

INDICATES A HAZARDOUS SITUATION THAT, IF NOT AVOIDED, COULD RESULT IN MINOR OR MODERATE INJURY.

THIS IS ALSO USED TO DRAW THE OPERATOR'S ATTENTION TO INFORMATION, DIRECTIVES, PROCEDURES, ETC. WHICH, IF IGNORED, MAY RESULT IN DAMAGE TO THE MATERIAL BEING USED. THE ASSOCIATED TEXT DESCRIBES THE NECESSARY PRECAUTIONS TO TAKE AND THE CONSEQUENCES THAT MAY ARISE IF THESE PRECAUTIONS ARE IGNORED.

**WARNING**

INDICATES A HAZARDOUS SITUATION THAT, IF NOT AVOIDED, COULD RESULT IN DEATH OR SERIOUS INJURY.

THIS INTRODUCES DIRECTIVES, PROCEDURES, PRECAUTIONARY MEASURES, ETC. WHICH MUST BE EXECUTED OR FOLLOWED WITH THE UTMOST CARE AND ATTENTION, OTHERWISE THE PERSONAL SAFETY OF THE OPERATOR OR THIRD PARTY MAY BE AT RISK. THE READER MUST ABSOLUTELY TAKE NOTE OF THE ACCOMPANYING TEXT, AND ACT UPON IT, BEFORE PROCEEDING FURTHER.

**DANGER**

INDICATES A HAZARDOUS SITUATION THAT, IF NOT AVOIDED, WILL RESULT IN DEATH OR SERIOUS INJURY. THE SIGNAL WORD «DANGER» IS TO BE LIMITED TO THE MOST EXTREME SITUATIONS.

THIS INTRODUCES DIRECTIVES, PROCEDURES, PRECAUTIONARY MEASURES, ETC. WHICH MUST BE EXECUTED OR FOLLOWED WITH THE UTMOST CARE AND ATTENTION, OTHERWISE THE PERSONAL SAFETY OF THE OPERATOR OR THIRD PARTY MAY BE AT RISK. THE READER MUST ABSOLUTELY TAKE NOTE OF THE ACCOMPANYING TEXT, AND ACT UPON IT, BEFORE PROCEEDING FURTHER.

The safety symbol may subsequently vary depending on the source of the hazard. Below are examples:



Various safety pictograms according to ISO 7010

1. INTRODUCTION

1.1 GENERAL INFORMATION

The TS Series In-Line Torque Sensor is a generation of high-precision torque sensors with integrated electronic processing circuitry, developed by Magtrol.

The TS Series includes sensors with the following torque ratings: 0.05 N·m, 0.1 N·m, 0.2 N·m, 0.5 N·m, 1 N·m, 2 N·m, 5 N·m, 10 N·m; (20 N·m, 50 N·m, 100 N·m, 200 N·m, 500 N·m are foreseen at short term.)

The TS Series In-Line Sensors, together with Magtrol's TM Series In-Line Torque Transducers and TF Series Torque Flange Sensors, offer a wide range of torque measurement requirements for the most demanding applications.

1.2 TS SENSORS RANGE PRESENTATION

All TS Series In-Line Torque Sensors consist of a torque measuring shaft and built-in signal processing electronics. These elements, along with two sealed bearings having lifelong lubrication, are all contained in an aluminium housing which also supports the shaft. This Sensor is sealed according to the IP 44 standard and offers protection against splashed water.

Magtrol's In-Line TS Series Torque Sensors provide extremely accurate torque and speed measurement. Each model has an integrated conditioning electronic module providing $\pm 5\text{VDC}$ ($\pm 10\text{VDC}$ at 200%) torque output through an 8-pole connector, as well as a USB interface which can be directly connected to a computer.

The TS Sensor is delivered with software allowing easy connection and data acquisition. A speed encoder provides 360 PPR (Pulses Per Revolution) in Tach A, Tach B and Index reference Z (1 PPR). Magtrol torque sensors are very reliable, providing high overload protection, excellent long-term stability and high noise immunity.

TS Series Sensor models are strain gauge-based measuring systems with imbedded telemetry signal transmission. Three LED lights located on the top of the sensor cover allow a visual check of the sensor status by color code (combination of the 3 LEDs). The sensor is powered by 12 to 32 VDC (24 VDC recommended) through its 8-pole connector. TARE & B.I.T.E. (Built-In Test Equipment) can be activated by either software or input from the 8-pole connector.

Available torque ranges from 0.05 N·m to 10 N·m. Higher torque ranges will be available soon.



Fig.1-1 Full size range of TS Series In-Line Torque Sensors

The sensor offers an isolated USB interface in parallel with analog signals. Both signals can be used at the same time; for example, for process control loop through computer via USB and in parallel fast data acquisition from the analog outputs, or an analog fast control loop using USB link to acquire torque speed, angle, etc.

The refresh time of the continuous analog signals is 100 μ s (10 kHz). The analog signal provides a ± 5 VDC output corresponding to the sensor nominal range, allowing 200 % of measuring range (± 10 VDC).

The USB interface is a plug and play function not requiring any programming. It can easily be connected and used together with LabVIEW™ based torque software delivered with the sensor.

The TS Torque Sensor performs the following main functions:

1. Measurement of static and dynamic torque;
2. Measurement of the shaft's rotational speed;
3. Measurement of the angle;
4. Measurement of the mechanical power;
5. Self-check (B.I.T.E. Built-In Test Equipment);
6. TARE.

The transducer's integrated electronic circuitry filters the torque signal and its built-in self-test function checks the operation of the measuring chain. Each transducer also has a built-in temperature compensation circuit. This assures that the accuracy of the measured torque is maintained regardless of operating temperature.

1.3 PRODUCT DESCRIPTION



1.4 DATASHEETS

TS SERIES

IN-LINE TORQUE SENSORS

FEATURES

- Integrated torque, speed and angle conditioning
- Torque range: from 0.05 N·m to 10 N·m
- Integrated speed encoder with index
- Accuracy: <0.1 %
- Overload capacity: 200 %
- Overload limit: 300 %
- Speed range: up to 15 000 rpm
- Torque output: ± 5 VDC (± 10 VDC)
- USB interface & analog connection
- LED operating status control
- Non-contact (no slip rings)
- Single DC power supply: 12-32 VDC



Fig. 1: TS 104 | In-Line Torque Sensor

DESCRIPTION

Magtrol's TS Series In-Line Torque Sensors provide extremely accurate torque and speed measurement. Each model has an integrated conditioning electronic module providing 0 VDC to ± 5 VDC (± 10 VDC) torque output through an 8-pole connector, as well as a USB interface which can be directly connected to a computer. The sensor is delivered with software allowing easy connection and data acquisition. A speed encoder provides 360 PPR (Pulse Per Revolution) in Tach A, Tach B and Index reference Z (1 PPR). Magtrol Torque Sensors are very reliable, providing high overload protection, excellent long-term stability

and high noise immunity. TS Series sensor models are strain gauge-based measuring systems with imbedded telemetry signal transmission. Three LED lights located on the sensor cover allow a visual check of the sensor status by color code (combination of the 3 LEDs). The sensor is powered by 24 VDC (12-32 VDC) through its 8-pole connector. TARE & B.I.T.E. (Built-In Test Equipment) can be activated by either software or input from the 8-pole connector. Available torque ranges from 0.05 N·m to 10 N·m. Higher torque ranges will be available soon.

USB & ANALOG OUTPUT

The sensor offers both an isolated USB interface and an analog output. Both signals can be utilized simultaneously. For example, control loop data can be acquired using a computer via the USB interface while fast data acquisition can be performed using the analog output. In addition torque, speed, and angle data can be acquired using the USB interface while fast control loop data can be acquired using the analog output signals.

The refresh time of the continuous analog signals is 100 μ s (10 kHz). The analog signal provides a 0 to ± 5 VDC output corresponding to the sensor nominal range up to 200 % of measuring range (0 to ± 10 VDC). The USB interface can easily be connected and used with the LabVIEW™ dedicated software delivered with the sensor.

APPLICATIONS

TS Series Torque Sensors provide dynamic torque and speed measurement of:

- Windshield wipers, electric windows, starters, generators and brakes in the automotive industry
- Pumps - water and oil
- Reduction gears and gearboxes
- Clutches
- Motorized valves & actuators
- Drills, pneumatic tools and other machine tools
- Torque & friction measurement in medical devices and the watch industry

INTEGRATED ENCODER

TS Series Torque Sensors integrate a high-end encoder with 360 PPR (Pulses Per Revolution) on 2 distinct signals (Tach A, Tach B) 90° out of phase providing an angular measurement resolution of 0.25°. A third signal offers 1 PPR (Z) providing an angular reference. The sensor body is marked with «Encoder Side» to indicate the encoder location. In low speed applications, where the angular position/accuracy of the test object is important, the encoder side needs to be directly connected to the test object so that the angular measurement is not influenced by the sensor deformation zone.

OPERATING PRINCIPLES

The measuring system is based on strain gauge technology directly applied on the sensor measuring section and connected in Wheatstone full bridge circuit. The strain gauge and its associated front end amplifier are powered by a high frequency power transfer. Under the applied torque, the measuring section will elastically deform providing a strain in the measuring elements. A microprocessor conditions the signal from the amplifier and transfers the measured values to the stator via contactless telemetry data transfer. On board micro-controllers manage all the internal functions, such as power transfer, data collecting and filtering, calibration and set-up, tare and B.I.T.E. (Build-In Test Equipment) functions, as well as the LED operating status control code. The sensor is supplied by 24 VDC (12-32 VDC) from the analog connector. The signal cutoff frequency can be digitally selected and configured in a range from 2 Hz up to 1000 Hz.

SYSTEM STATUS INDICATORS

A color code is given by the activation of 3 LEDs lights (Yellow, Green, Red) located on the top cover of the sensor. This color code continuously communicates the operating status of the sensor, such as measuring status, tare functions, offset value, B.I.T.E. (Built-In Test Equipment) and overload.



ELECTRICAL CONFIGURATION

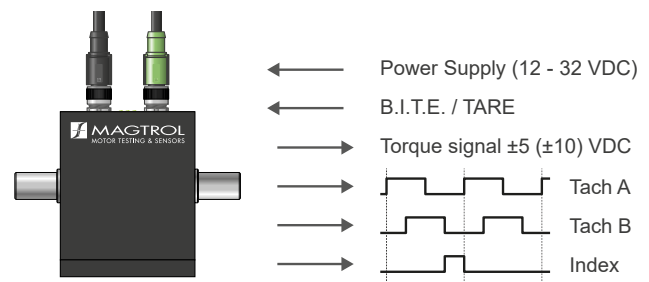


Fig. 2: TS Series Torque Sensor electrical input and output

SUPPORTED & SUSPENDED INSTALLATIONS

The device can be used in both supported and suspended configurations. Supported configuration is recommended for the majority of applications (mandatory for high speed testing).

The TS Series can be installed without the base mount in a suspended configuration. The benefit of this configuration is the use of a single element coupling creating a shorter drive

train. This configuration is **only applicable for low speed measurement**.

CAUTION: TS 100-102 cannot be used in suspended installation as the weight of the sensor will degrade the accuracy of the measurement due to radial forces.

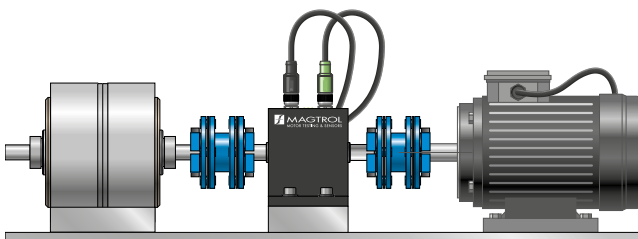


Fig. 3: **Supported installation**
Mandatory for standard and high speed applications.

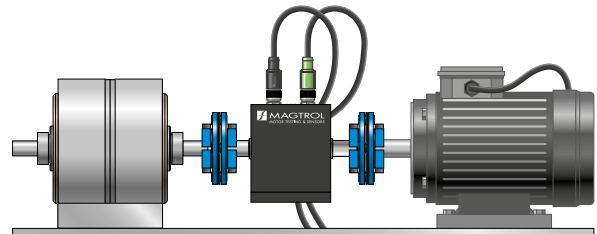


Fig. 4: **Suspended installation for low speed applications only.**
A single element coupling can be used to create a shorter drive train. This specific configuration cannot be used for TS 100-102.

SYSTEM CONFIGURATIONS

The TS Series Torque Sensor can be connected in various configurations. It can be used independently (via an external power supply) or in combination with other Magtrol devices (e.g. DSP 7000 - High-Speed Dynamometer Controller, MODEL 3411 - Torque Display,...). The sensors can be

used with Magtrol software, such as M-TEST or TORQUE (included), to allow the data to be acquired and displayed. The double signal output, analog and USB, can be used simultaneously. For example, one channel for data acquisition and the other one for closed loop control of a drive line.

USB CONNECTION

When a TS Series Torque Sensor is used solely with a USB connection, it must be supplied (12-32VDC) through its analog connection.

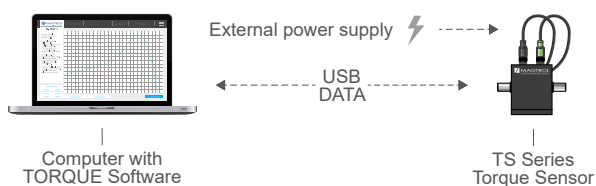


Fig. 5: TS Torque Sensor USB only configuration

ANALOG WITH DYNAMOMETER CONTROLLER

In this configuration the power supply to the sensor is provided by the dynamometer controller. The DSP 7000 is a high speed programmable dynamometer controller. The analog only connection is used and data acquisition is supplied through a computer with M-TEST software.

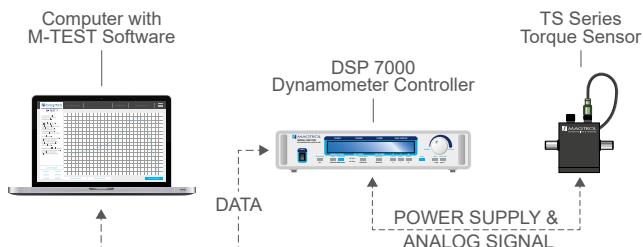


Fig. 6: TS Torque Sensor analog configuration connected to and power supplied by the DSP 7000.

ANALOG & USB WITH TORQUE DISPLAY

In this configuration the power supply to the Sensor is provided by the torque display. The MODEL 3411 is a torque/speed/power display. The TS Torque Sensor's USB connection to the computer supplies data acquisition using TORQUE Software.

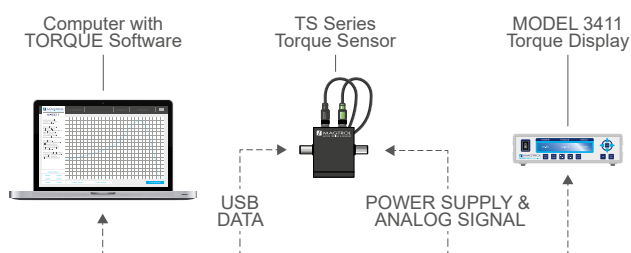


Fig. 7: TS Sensor configuration with MODEL 3411 Torque Display

SPECIFICATIONS

MECHANICAL CHARACTERISTICS							
MODEL	NOMINAL RATED TORQUE (RT)	SHAFT DIAMETER	MAX SPEED	TORSIONAL STIFFNESS	MOMENT OF INERTIA	ANGULAR DEFORMATION	WEIGHT
	N·m	mm	rpm	N·m / rad	kg·m ²	Degree	Kg
TS 100	0.05	6	15 000	19	1.96 x 10 ⁻⁶	0.15	0.5
TS 101	0.1			50	1.97 x 10 ⁻⁶	0.31	
TS 102	0.2					0.23	
TS 103	0.5			160	0.18		
TS 104	1	8		330	2.19 x 10 ⁻⁶	0.17	0.65
TS 105	2				2.19 x 10 ⁻⁶	0.34	
TS 106	5			680	2.23 x 10 ⁻⁶	0.42	
TS 107	10	9		1 260	2.34 x 10 ⁻⁶	0.46	0.7
TS 109 ^{a)}	20	18	8 000	3 600	N/D	0.32	1.1
TS 110 ^{a)}	50			7 380	N/D	0.39	
TS 111 ^{a)}	100			9 627	N/D	0.60	
TS 112 ^{a)}	200	32	6 000	38 800	N/D	0.45	1.7
TS 113 ^{a)}	500			62 840	N/D	0.46	

TORQUE MEASUREMENT	
Maximum Dynamic Torque Peak Value	200 % of RT
Maximum Static Torque Without Damage	300 % of RT
Resolution at RT	11 000 points
Sampling Frequency	16 bits at 10 000 sample/second
Combined Error of Linearity and Hysteresis	< 0.1 % of RT ^{c)}
Noise Spectral Density	2 ppm of RT / √ Hz typical ^{b,c)}
Speed Influence on Zero Torque	< 0.015 % / 1 000 rpm ^{d)}
Power Supply Change Sensitivity ^{e)}	< 50 (ppm of RT / V)

USB SPEED & ANGLE MEASUREMENT	
Speed & Angle Measurement	Based on 360 pulses, 2 signals, 90° phase shift (quadrature X4) + Index Optical Encoder
Computed Speed Accuracy (USB Output)	< ±0.05% ^{f)}
Angle Resolution (USB)	0.25°
Accuracy	±0.25° over 360°.
Thermal drift	< 50 ppm over temperature range

a) These models are currently under development

b) Corresponds to <0.05% of RT, peak to peak over the entire 1 kHz bandwidth

c) For TS 100 (0.05 N·m) this parameter is degraded by a factor of 2.
Applicable to both analog and USB output

d) For TS 100 (0.05 N·m) and TS 101 (0.1 N·m) this parameter is degraded by a factor of 2.

e) Torque output change due to power supply change

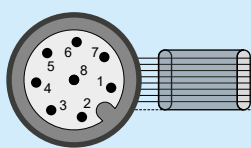
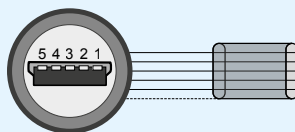
f) Constant speed and based on the last 360 pulses

SPECIFICATIONS

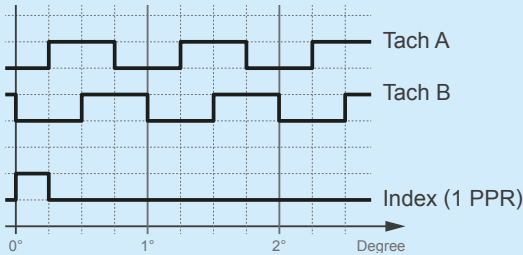
ENVIRONMENT & CERTIFICATIONS

Storage Temperature	-40 °C to +85 °C
Operating Temperature	-25 °C to +80 °C
Temperature Influence on Zero / Sensitivity	< ±0.1 % / 10 °C for the range -25 °C to +80 °C ^{a)}
Mechanical Shock	IEC 60068-2-27:2008 / Class C3
Vibration Sinusoidal	IEC 60068-2-6:2007 / Class C3
Protection Class	IP44 (DIN EN 60529)
EMC / EMI Compatibility	IEC 61326-1 / IEC 61321-2-3
Balancing Quality	G2.5 according to ISO 1940
Safety Standard	ISO 13849 / EN 62061
Low voltage	IEC 61010-1

ELECTRICAL CHARACTERISTICS & CONNECTIONS

Power Supply (voltage range / max. power)	12 to 32VDC / < 2.2W (24VDC recommended)																		
Analog Torque Output (rated / max.)	±5V / ±10V (max. output current 2mA)																		
Torque Signal Bandwidth (-3dB) controlled by USB command.	2 Hz / 5 Hz / 10 Hz / 20 Hz / 50 Hz / 100 Hz / 1000 Hz (50 Hz is factory default)																		
Wiring diagram (Analog)	<div></div> <table><tr><td>1 - White</td><td>Tach B</td></tr><tr><td>2 - Brown</td><td>Tach A</td></tr><tr><td>3 - Green</td><td>Index (1 pulse / rev)</td></tr><tr><td>4 - Yellow</td><td>B.I.T.E. / TARE</td></tr><tr><td>5 - Grey</td><td>Torque Ground 0V</td></tr><tr><td>6 - Pink</td><td>Torque Signal ±5 (±10) VDC</td></tr><tr><td>7 - Blue</td><td>Power Supply Ground</td></tr><tr><td>8 - Red</td><td>Power Supply 12-32 VDC</td></tr><tr><td>Case / Shield ^{b)}</td><td>Case / Shield ^{b)}</td></tr></table>	1 - White	Tach B	2 - Brown	Tach A	3 - Green	Index (1 pulse / rev)	4 - Yellow	B.I.T.E. / TARE	5 - Grey	Torque Ground 0V	6 - Pink	Torque Signal ±5 (±10) VDC	7 - Blue	Power Supply Ground	8 - Red	Power Supply 12-32 VDC	Case / Shield ^{b)}	Case / Shield ^{b)}
1 - White	Tach B																		
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7 - Blue	Power Supply Ground																		
8 - Red	Power Supply 12-32 VDC																		
Case / Shield ^{b)}	Case / Shield ^{b)}																		
Wiring diagram (USB)	<div></div> <table><tr><td>1</td><td>+ 5V</td></tr><tr><td>2</td><td>Data -</td></tr><tr><td>3</td><td>Data +</td></tr><tr><td>4</td><td>n.c</td></tr><tr><td>5</td><td>GND</td></tr></table> <p>USB - Mini B</p>	1	+ 5V	2	Data -	3	Data +	4	n.c	5	GND								
1	+ 5V																		
2	Data -																		
3	Data +																		
4	n.c																		
5	GND																		

ANALOG INPUT AND OUTPUT SIGNALS

Tach Outputs & Index	<p>Tach A + B, 360 PPR, 100 kHz max. frequency, Index 1 PPR ^{c,d)}</p>  <p>TTL, max. output current 5 mA</p>
B.I.T.E. (Built-In Test Equipment)	B.I.T.E. Input pin grounded for more than 1 s allows +60 % FSD shift at the O/P for 5 s (refer to manual for more information)
TARE	TARE Input pin pulled up to 12 V min. / 32 V max. for more than 1 s enables a TARE function in the sensor. Depending on how long voltage is applied, the TARE is either saved or dismissed.

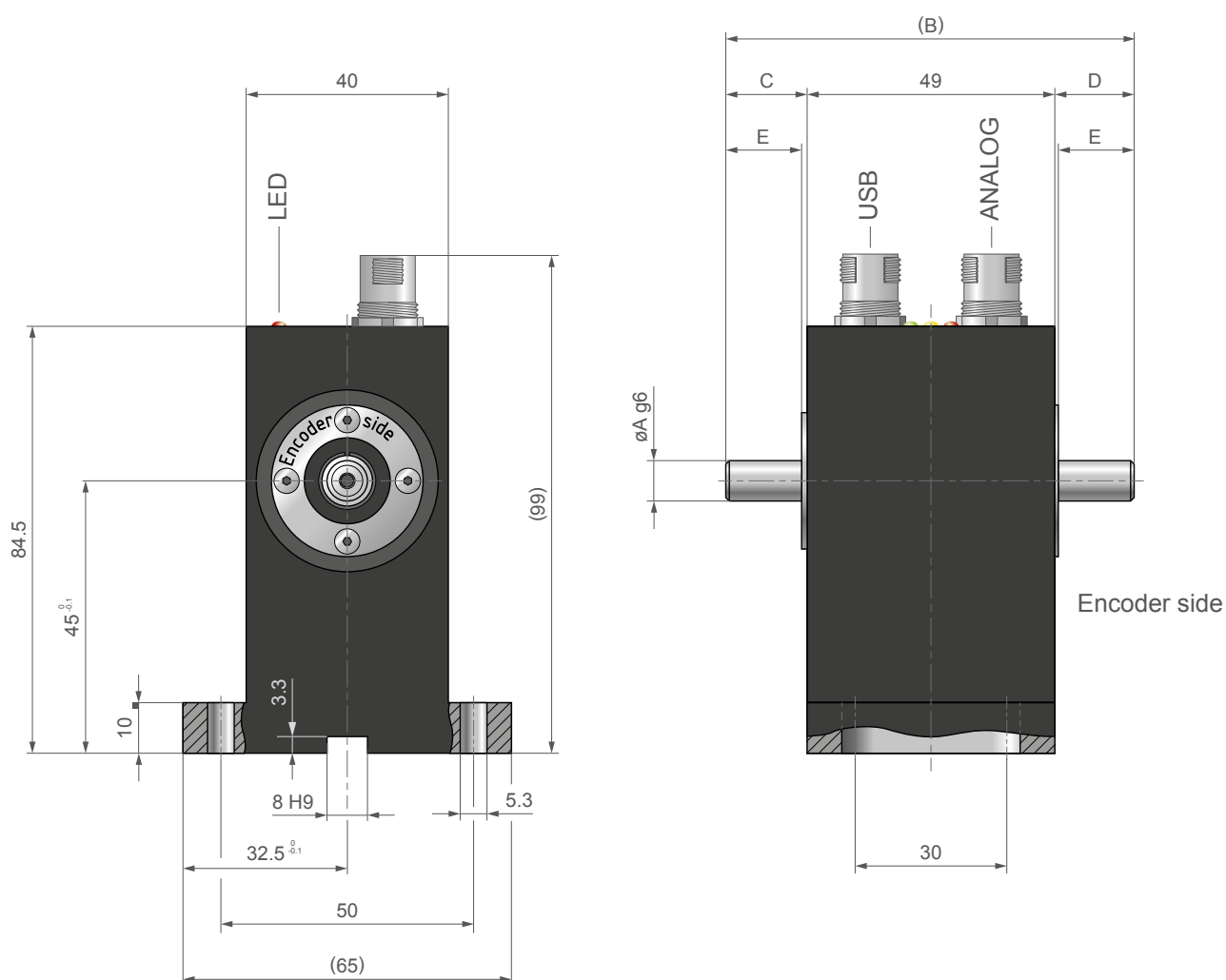
a) For TS 100 (0.05 N·m) this parameter is degraded by a factor of 2.
Applicable to both analog and USB output

b) Cable shield connected to GND at user side

c) PPR means Pulse Per Revolution

d) Available with 5000 PPR (speed limit 1000 rpm)

TS 100-107 DIMENSIONS

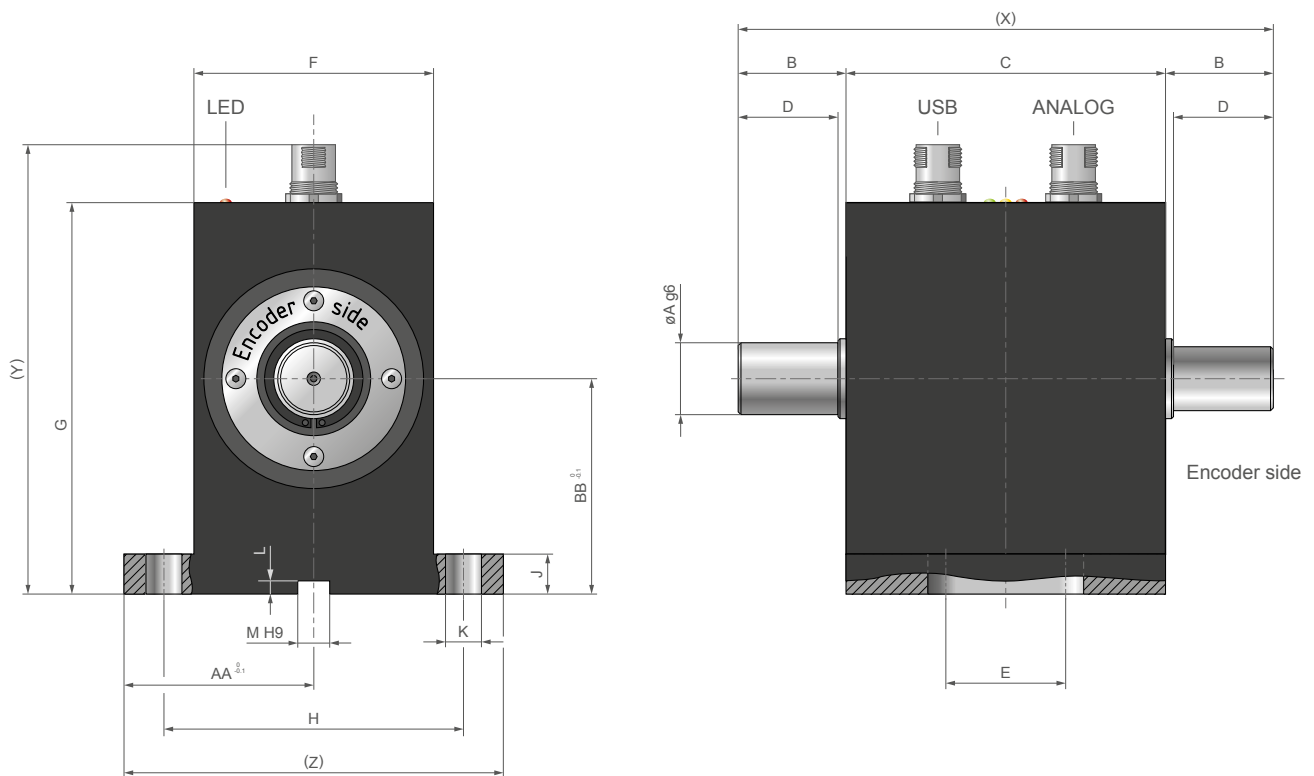


NOTE: All values are in metric units. Dimensions are in millimeters.

MODEL	TORQUE [N·m]	$\varnothing A$ g6	B	C	D	E
TS100	0.05	6	80.8	16.1	15.7	15
TS101	0.1					
TS102	0.2					
TS103	0.5	8	85	18.2	17.8	17.1
TS104	1					
TS105	2					
TS106	5	9	90.8	21.1	20.7	20
TS107	10					

NOTE: 3D STEP files of most of our products are available on our website: www.magtrol.com ; other files are available on request.

TS 109-113 DIMENSIONS



NOTE: All values are in metric units. Dimensions are in millimeters.

MODEL	TORQUE [N·m]	ØA	B	C	D	E	F	G	H
TS 109 ^{a)}	20	18 g6	27	80	25	30	60	98	75
TS 110 ^{a)}	50		38		36				
TS 111 ^{a)}	100		43.5		42.75				
TS 112 ^{a)}	200	32 g6	43.5	110	42.75	80	95	135	125
TS 113 ^{a)}	500								

MODEL	J	K	L	M	AA	BB	X	Y	Z
TS 109 ^{a)}	10	9	3.3	8 H9	47.5 ^(0/-0.1)	45 ^(0/-0.1)	134	112.5	95
TS 110 ^{a)}							156		
TS 111 ^{a)}									
TS 112 ^{a)}	20	10.5	4.1	10 H9	75 ^(0/-0.1)	65 ^(0/-0.1)	197	147.5	150
TS 113 ^{a)}									

a) **Notice:** These models are currently under development (subject to change)

NOTE: 3D STFP files of most of our products are available on our website: www.mactrol.com - other files are available on request

SYSTEM OPTIONS AND ACCESSORIES

COUPLINGS

When Magtrol TS Series Torque Sensors are mounted in a drive train, double-element miniature couplings are ideal, although single-element couplings can be used for low speed applications. The criteria for selecting appropriate couplings for torque measurement is as follows:

- High torsional spring rate: Ensures a high torsional stiffness and angular precision
- Clamping quality (should be self-centering and of adequate strength)
- Speed range
- Balancing quality (according to speed range)
- Alignment capability

The higher the speed of the application the more care is required in selecting the coupling and assembling (alignment and balancing) the drive train configuration. Magtrol provides a wide range of couplings suitable for torque measurement applications and can assist you in choosing the right coupling for your transducer.



Fig. 8: MIC Series
Miniature coupling

TORQUE SPEED BOX

Magtrol's TSB Torque Speed Box allows data acquisition from two torque transducers simultaneously and provides the torque's analog signal output and speed's TTL signal output.



Fig. 9: TSB | Torque Speed Box

TORQUE «SOFTWARE»

Magtrol's TORQUE Software is an easy-to-use LabVIEW™ executable program used to automatically collect torque, speed, mechanical power and angle data. This data can be printed, displayed graphically or quickly saved as a Microsoft® Excel spreadsheet. Standard features of TORQUE include: multi-axis graphing, measured parameter vs. time, adjustable sampling rates and multi-language display.

TORQUE DISPLAY

Magtrol offers the MODEL 3411 - Torque Display which supplies power to any TS/TM/TMHS/TMB Sensor/Transducer and displays torque, speed and mechanical power. Features include:

- Adjustable English, Metric and SI torque units
- Large, easy-to-read vacuum fluorescent display
- Built-in self-diagnostic tests (B.I.T.E.)
- Overload indication
- Tare function
- USB & Ethernet interface
- 2 BNC back panel outputs: torque (analog raw sensor signal) & speed (TTL or analog)
- Closed-box calibration
- Includes Magtrol's TORQUE Software



Fig. 10: MODEL 3411 | Torque Display

HIGH-SPEED DYNAMOMETER CONTROLLER

Magtrol's DSP7000 High-Speed Programmable Dynamometer Controller employs state-of-the-art digital signal processing technology to provide superior motor testing capabilities. Designed for use with any Magtrol Hysteresis, Eddy-Current or Powder Brake Dynamometer, Magtrol In-Line Torque Transducer/Sensor or auxiliary instrument, the DSP7000 can provide complete PC control via USB interface or IEEE-488 optional. Standard Features:

- DSP7001 Single Channel: Easy to use plug & play solution
- DSP7002 Dual Channel: Enables the support of two testing instruments with independent or tandem configurations and two fully independent control loops
- Built-in Alarm System
- Speed & Torque closed loop Operating Modes
- Programmable Digital PID Values
- Built-in Current-Regulated Supply
- Adjustable Torque Units.



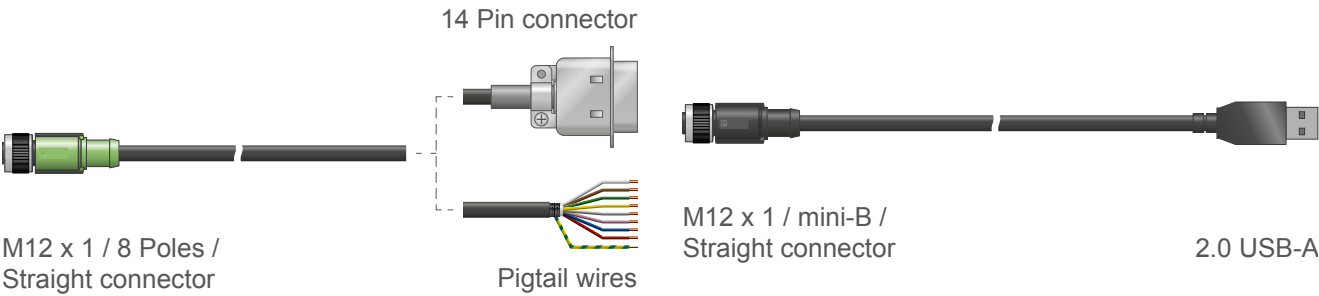
Fig. 11: DSP7000 | High-Speed Dynamometer Controller

SYSTEM OPTIONS AND ACCESSORIES

CABLE ASSEMBLIES (ANALOG & POWER SUPPLY / USB)

Each TS Series Torque Sensor is delivered with a 3 meter cable for supply and analog signals (M12 straight connector and Pigtail wires) as well as a 2 meter USB cable (M12 mini-B / 2.0 USB-A).

Other lengths and cable configurations (e.g. with a 14 Pin connector for use with Model 3411 Torque Display or DSP 7000 Dynamometer Controller) are available on request.



ORDERING NUMBER	ER 12	-	/ 0	-	1
0 : Pigtail wires					
1 : 14 Pin connector ^{a)}					
1 : Cable length 5 m					
2 : Cable length 10 m					
3 : Cable length 20 m					
4 : Cable length 3 m					

ORDERING NUMBER	957-11-07-251	-
3 : Cable length 2 m		
4 : Cable length 5 m		

a) For use with 3411 Torque Display or DSP7000 Controller

ORDERING INFORMATION

ORDERING NUMBER	TS 1	--	/ XX
01, 02, ... , 13 : Model TS			

Example: TS 109 In-line Torque Sensor would be ordered as : TS 109/XX.

2. INSTALLATION / CONFIGURATION



CAUTION

IN HORIZONTAL POSITION, THE TS SENSOR HAS NO SPECIFIC MOUNTING DIRECTION. THE DEVICE UNDER TEST (DUT) WILL DETERMINE THE MOUNTING DIRECTION.

THE ENCODER SIDE OF THE TS SENSOR MUST BE CONNECTED TO THE DUT TO OBTAIN ACCURATE POSITION DATA WITH RESPECT TO TORQUE MEASUREMENT. THIS CAN BE THE ENGINE OR THE GEARBOX (WHEN THE LATTER IS THE DUT).

THE POSITION OF THE ENCODER IS ENGRAVED ON THE SENSOR; IT ALSO CORRESPONDS TO THE SIDE OF THE ANALOG CONNECTION (GREEN CONNECTOR).

2.1 MOUNTING POSSIBILITIES

Magtrol's TS Series In-Line Torque Sensors should be considered primarily as precision measuring instruments and not as torque transmission components. The model of the sensor and the accuracy of its drive train alignment strongly influence the measurement accuracy and lifetime of the sensor, especially of the bearings.



WARNING

IT IS CRITICAL TO USE A COUPLING DESIGNED FOR YOUR ASSEMBLY (e.g. FLEXIBLE COUPLINGS). NEVER MAKE A RIGID ASSEMBLY !

Magtrol provides a wide range of couplings suitable for torque measurement applications and can assist you in choosing the right coupling for your transducer. Please contact our technical service.

There are two main ways to mount the TS torque sensor: **supported** (mandatory for standard and high speed applications) or **suspended** (for low speed applications only).

2.1.1 SUPPORTED INSTALLATION

The measuring shaft is supported by the torque sensor housing, which itself is fixed to the test bench frame by means of a support unit (see Fig.2-1). Here, couplings with two degrees of freedom must be used in order to avoid over constrained mountings.

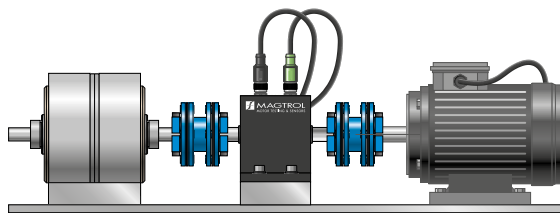


Fig.2-1 Supported installation. Mandatory for standard and high speed applications

2.1.1.1 ADVANTAGES

- Increased critical speed due to less shaft bending.
- Allows the use of the angular information thanks to the rigid case mounting

2.1.1.2 DISADVANTAGES

- Longer overall length of the test bench due to the use of double-element couplings.
- Increased price due to the higher price of double-element couplings.



NOTICE

Supported installations are required when larger misalignments between the different elements of the system are a possibility, as well as with high rotational speeds.

2.1.2 SUSPENDED INSTALLATION

Both the measuring shaft and torque transducer housing are supported by the driving and driven machine shafts via couplings (see Fig.2-2). In this configuration, couplings offering only one degree of freedom are adequate to avoid an over constrained mounting.

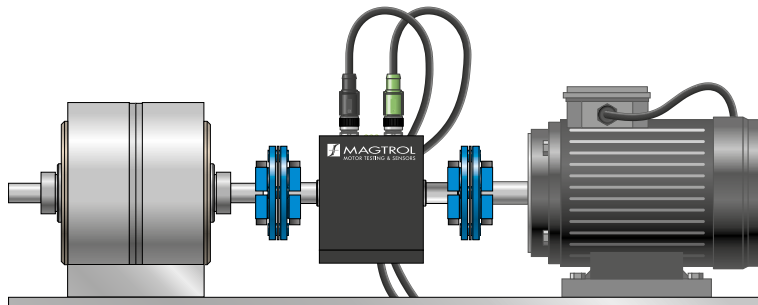


Fig.2-2 Suspended installation for low speed application only.
Use single element coupling to create a shorter drive train.

2.1.2.1 ADVANTAGES

- Single-element couplings are less expensive than double-element couplings.
- Shorter drive train leading to a higher torsional resonance frequency (as compared to double-element couplings).

2.1.2.2 DISADVANTAGES

- Increase of radial play as the torque sensor is not directly fixed to the test bench. Consequently, the critical speed is lower than with a supported installation.
- Angular and speed measurement might be drastically degraded.



NOTICE

The low friction torque generated by the bearings, as well as the weight of the built-in electronic housing and its cable, results in only the shaft being driven by the rotating system.

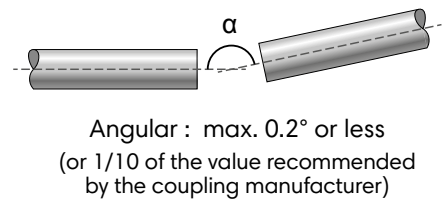
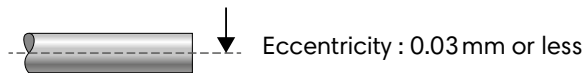
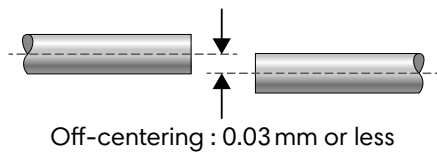


CAUTION

TS 100-102 CANNOT BE USED IN SUSPENDED INSTALLATION AS THE WEIGHT OF THE SENSOR WILL DEGRADE THE ACCURACY OF THE MEASUREMENTS DUE TO RADIAL FORCES.

2.1.3 INSTALLATION PRECAUTIONS

ALIGNMENT: Be careful to install with an accuracy equal to or less than the following permissible installation errors.



STARTING & STOPPING CONDITIONS: Ensure that the torque applied to the sensor never exceeds the product specifications when the system is started and/or stopped.

2.1.4 VERTICAL INSTALLATION

The vertical Installation is allowed with respect of all cautions warning listed in this manual....

**CAUTION**

PLEASE REFER TO *SECTION 2.2 PARASITIC FORCES* OF THIS MANUALS FOR THE MAXIMUM ACCEPTABLE F_a FORCE!

2.2 PARASITIC FORCES

Incorrectly mounted the TS Sensor can generate parasitic forces on the measuring shaft in radial (F_r) and axial (F_a) directions (see Fig.2-3).

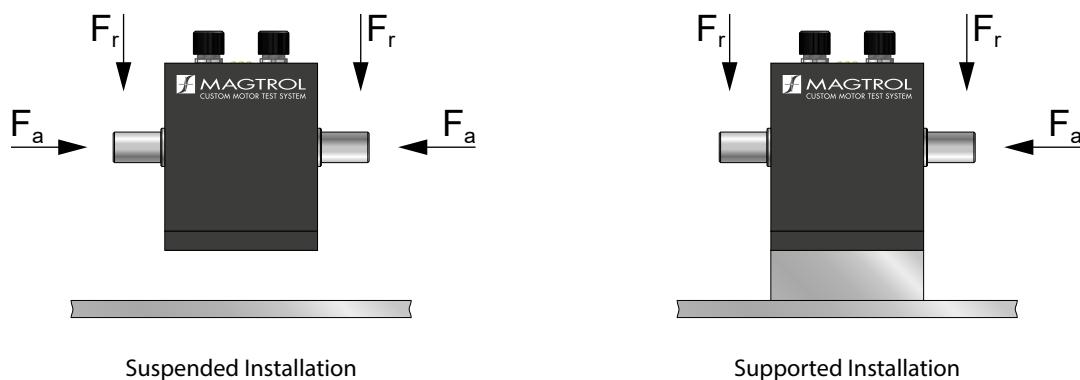


Fig.2-3 Parasitic forces diagrams

2.2.1 RADIAL FORCES (BENDING)

Radial forces (F_r in Fig.2-3) generate a bending momentum in the measuring shaft resulting in displacement of its center of gravity. This disequilibrium will load the shaft periodically with a frequency proportional to the speed of rotation. This effect is particularly noticeable at high speeds.



CAUTION

IN EXTREME CASES, A HIGH BENDING FORCE MAY CAUSE PERMANENT DEFORMATION OF THE MEASURING SHAFT, LEADING TO FALSE MEASURING RESULTS.

The following table lists the maximum radial forces (F_r) allowed for TS Series Torque Sensor shafts in suspended and supported installations.

MODEL	F_r max. (suspended installations) [N]	F_r max. (supported installations) [N]
TS 100	- a)	N/A
TS 101	- a)	N/A
TS 102	- a)	N/A
TS 103	- a)	25
TS 104	20	50
TS 105	40	80
TS 106	70	120
TS 107	60	120

a) Suspended installation is not recommended for these models.

Fig.2-4 Table of maximum radial forces allowed

2.2.2 AXIAL FORCES (THRUST)

In suspended installations, pure thrust forces (F_a in Fig.2-3) have practically no effect on the measurement results, as they do not cause any deformation of the shaft that could influence the measurement.

In supported installations, axial thrust forces produce a strain on the bearings. This leads to premature wear of the bearings and an increase of the residual torque. In this case, the maximum allowed axial force for the transducer is lower than the allowed force in the case of suspended installation.



NOTICE

It is important to avoid the simultaneous application of radial and axial forces on the measuring shaft of a transducer, especially with supported installations.

The following table lists the maximum axial forces (F_a) allowed for TS Series Sensor shafts in suspended and supported installations.

MODEL	F_a max. (suspended installations) [N]	F_a max. (supported installations) [N]
TS 100	300	17
TS 101	600	35
TS 102	600	35
TS 103	1 000	35
TS 104	1 100	100
TS 105	1 500	100
TS 106	2 500	100
TS 107	3 500	100

Fig.2-5 Table of maximum axial forces allowed

2.3 MEASURING SHAFT VIBRATIONS

The presence of radial misalignment in the configuration will give rise to periodic radial displacement of the torque measuring shaft. This, in turn, will induce parasitic vibrations influencing the torque measuring signal.



Fig.2-6 Diagram of radial displacements

Magtrol TS Series Torque Sensors have been tested by under the following conditions:

2.3.1 VIBRATIONS

As a general rule, the vibration level applied to the TS Series Sensor should not exceed 2.7 mm/s RMS for proper operation. This level is according to ISO 10816 Class II / Category B

SPEED [rpm]	RADIAL DISPLACEMENT [mm p-p]	RADIAL ACCELERATION [g]
100	4.581	0.003
500	0.916	0.014
1000	0.458	0.029
2000	0.229	0.058
3000	0.153	0.086
4000	0.115	0.115
5000	0.092	0.144
6000	0.076	0.173
7000	0.065	0.202
8000	0.057	0.231
9000	0.051	0.259
10000	0.046	0.288
11000	0.042	0.317
12000	0.038	0.346
13000	0.035	0.375
14000	0.033	0.404
15000	0.031	0.432

Fig.2-7 Table of allowed vibrations

2.4 MOUNTING LIMITS

During static measurements, the nominal torque may be surpassed in order to reach the plastic deformation torque limit. When exceeding the nominal torque, any extraneous loads such as axial, shearing and bending forces must be avoided.

2.4.1 DYNAMIC TORQUE

Static and dynamic measurements differ from one another by the evolution of torque over time. A constant torque produces static measurements, whereas varying torques can only be determined by dynamic measurement.

Magtrol TS Series Torque Sensors are designed for the measurement of both static and dynamic torque, without the need for recalibration.

2.4.2 NATURAL FREQUENCY OF DRIVE TRAIN

In order to determine the dynamic torque and frequency response, and to prevent any damage to the system, it is necessary to calculate the natural frequency of the drive train torsional oscillations. In this system, however, the deformation area of the measuring flange is the weakest link in the rotating measuring chain and is subject to torsional vibrations.

In practice, this situation can generate rather complex relations which require demanding calculations. This may be, for instance, the case for the physical model in which the drive chain is a combination of torsion springs with intermediate flywheel masses. However, the following simplified model of a drive chain (see Fig.2-8) can often be used.



NOTICE

For a detailed analysis of dynamic response, publications on structural mechanics should be consulted.

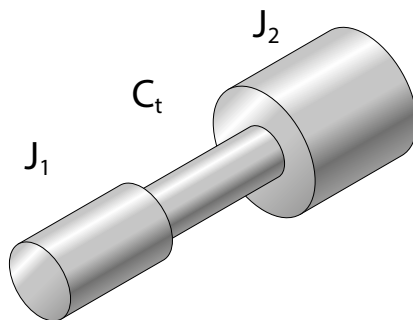


Fig.2-8 Simplified Drive Train Model

$$F_0 = \frac{1}{2\pi} \sqrt{C_t \frac{J_1 + J_2}{J_1 \cdot J_2}}$$

F_0 Natural frequency of system [Hz]

C_t Measuring shaft torsional stiffness [Nm/rad]

J_1 Moment of inertia (driving machine + coupling + ½ of the measuring shaft) [kgm²]

J_2 Moment of inertia (driven machine + coupling + ½ of the measuring shaft) [kgm²]

**NOTICE**

The natural torsional frequency of the drive train is lower due to the presence of the TS Torque Transducer. The system's own natural frequency must then be recalculated to determine the influence of the TS Transducer.

The torsional spring consists only of the deformation zone of the measuring shaft. The torsional stiffness values (C_t) are indicated in the technical datasheets (see section 1.4 DATASHEETS). (J_1) and (J_2) are the two moments of inertia acting on each side of the deformation zone. They can be calculated by adding the moments of inertia of each individual element. The moment of inertia of the measuring shaft is also indicated in the datasheet. Consult with the suppliers of the couplings, driving element(s) and driven element(s) in order to obtain the inertia ratings of these drive train components.

The natural torsional frequency (F_0) determines the following:

- the frequency response of the torque measuring system
- whether or not rapid variations in torque can be accurately sensed
- whether or not the torque signal is amplified or attenuated by the dynamics of the drive train

The transfer response is plotted (see Fig.2-9) for various quality factor values (Q), which are dependent upon the amount of damping in the torsional system. The graph charts the factor by which the torque will be amplified, depending on the frequency of the torsional oscillations.

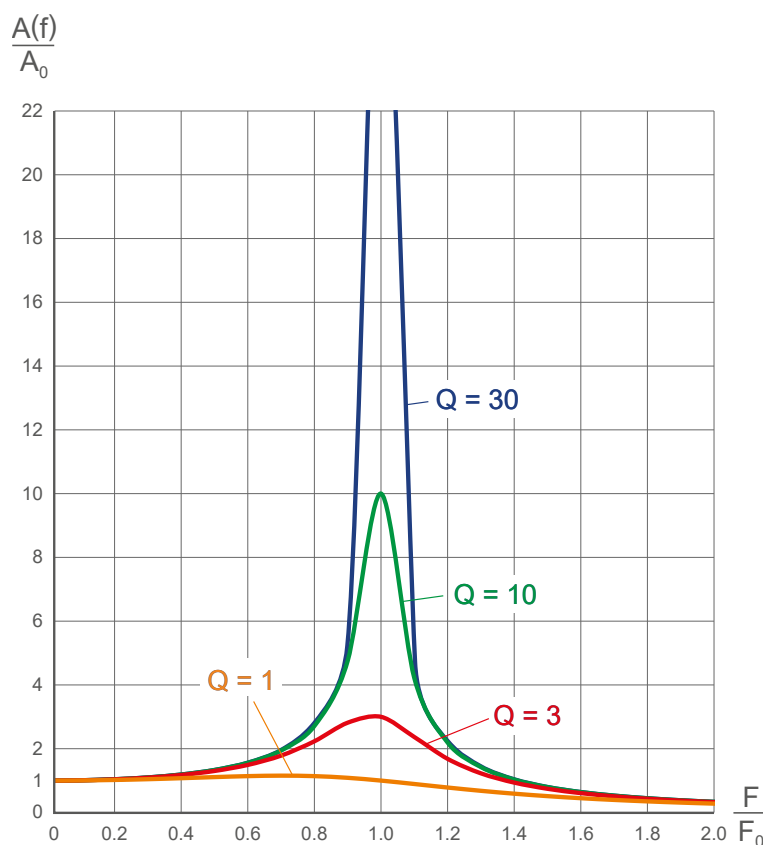


Fig.2-9 Frequency response graph

**NOTICE**

The system should be configured and operated in a manner so that the natural frequency is avoided in everyday operation. The transfer function should be as close to 1 as possible.

Consequently, the frequency of the drive train torsional oscillations should be less than $\sim 0.5 F_0$.

2.4.3 NATURAL MEASURING SHAFT TORSIONAL FREQUENCY

The natural torsional frequency of the measuring shaft corresponds to the frequency at which a torsional resonance may occur.

The following table (see Fig.2-10) lists the inertia of each side and the stiffness of each TS Torque Transducer. Based on the value of the inertias attached at both sides, the user is able to compute the natural torsional frequency.

MODEL	MEASURING RANGE [Nm]	STIFFNESS [Nm/rad]	INERTIA ENCODER SIDE [kgm ²]	INERTIA OPPOSITE SIDE [kgm ²]	INERTIA TOTAL [kgm ²]
TS100	0.05	19	0.198×10^{-6}	1.76×10^{-6}	1.96×10^{-6}
TS101	0.1	19	0.198×10^{-6}	1.76×10^{-6}	1.96×10^{-6}
TS102	0.2	50	0.199×10^{-6}	1.76×10^{-6}	1.97×10^{-6}
TS103	0.5	159	0.202×10^{-6}	1.76×10^{-6}	1.97×10^{-6}
TS104	1	333	0.301×10^{-6}	1.89×10^{-6}	2.19×10^{-6}
TS105	2	333	0.301×10^{-6}	1.89×10^{-6}	2.19×10^{-6}
TS106	5	684	0.318×10^{-6}	1.91×10^{-6}	2.23×10^{-6}
TS107	10	1257	0.370×10^{-6}	1.97×10^{-6}	2.34×10^{-6}

Fig.2-10 Table of natural torsional frequency

2.4.4 MAXIMUM DYNAMIC AMPLITUDE

The dynamic peak-to-peak amplitude must not exceed 200% of the nominal torque of the TS Sensor. This is even true with alternating loads. This amplitude must remain within a range of $-200\% M_{\text{nominal}}$ and $+200\% M_{\text{nominal}}$ as shown below (see Fig.2-11).

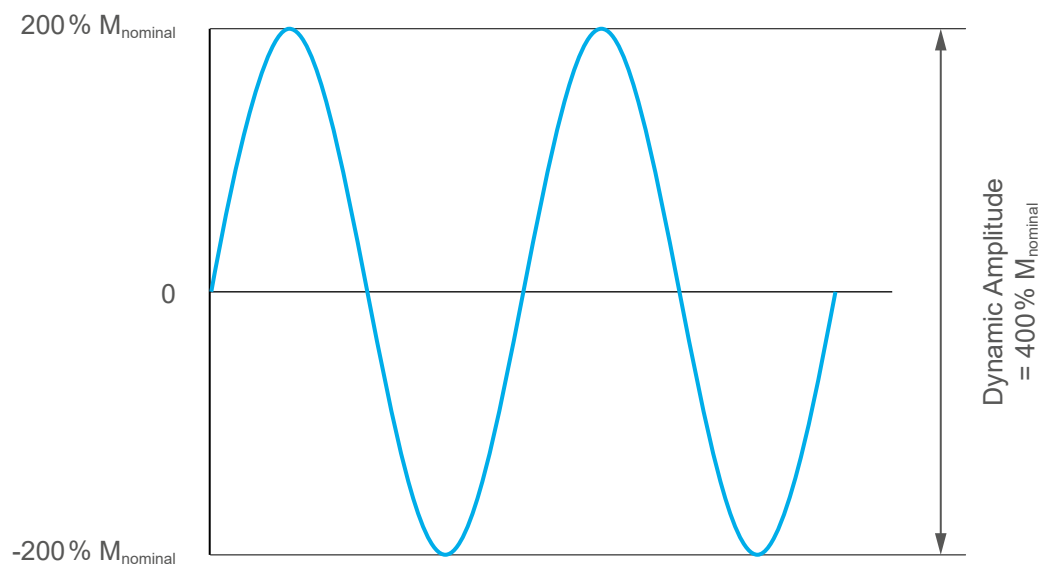


Fig.2-11 Admissible dynamic load

2.5 PROTECTIVE SYSTEMS

**WARNING**

ALL ROTATING PARTS MUST BE FITTED WITH A PROTECTIVE SYSTEM TO ENSURE THAT THE USER, AS WELL AS ALL OTHER SURROUNDING PEOPLE AND OBJECTS, WILL NOT BE INJURED OR DAMAGED AS A RESULT OF THE DRIVE ELEMENT BECOMING BLOCKED, A TORQUE OVERLOAD, OR ANY OTHER POTENTIAL PROBLEM.

The following precautions concerning protective equipment of the drive train must be observed:

- Protective elements must prevent access to moving parts (during test).
- Protective elements must cover all parts which can cause crushing or cutting, and protect against projections of parts having become loose.
- Avoid attaching protective elements to rotating parts.
- Keep protective elements at a sufficient distance away from rotating parts.

Below is an example of a protective system (see Fig.2-12). All parts of the bench are accessible, but the covers prevent any risk to the user when closed.

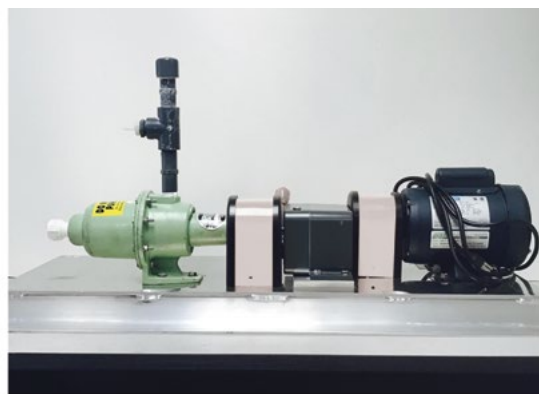


Fig.2-12 Examples of protective systems

2.6 ELECTRONIC SIGNAL PROCESSING

Magtrol offers electronic processing units that collect signals from its TS Sensor and displays them on a digital readout. These units have also been designed for digital processing of the measured values.

The TS Series Torque Sensor can be connected in various configurations. It can be used independently (via an external power supply) or in combination with other MAGTROL devices (e.g. DSP 7000 High-Speed Dynamometer Controller, MODEL 3411 Torque Display,...). The sensors can be used with Magtrol software, such as M-TEST or TORQUE (included), to allow the data to be acquired and displayed. The double signal output, analog and USB; can be used simultaneously. For example, one channel for data acquisition and the other one for closed loop control of a drive line.

2.6.1 USB CONNECTION

When a TS Series Torque Sensor is used solely with a USB connection, it must be supplied with 12-32 VDC through its analog connection.

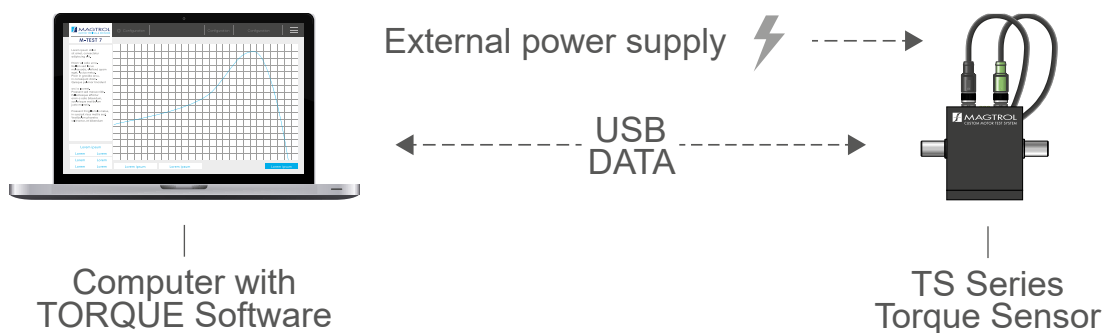


Fig.2-13 TS Torque Sensor in USB only configuration



NOTICE

The TS Series sensors can easily be powered by Magtrol power supplies, such as the MODEL 3411 Torque Display, DSP 7000 High-Speed dynamometer controller or TSB Torque Speed Box or with all types of power supplies capable of supplying a voltage of 12-32 VDC.

2.6.2 MODEL 3411 | TORQUE DISPLAY

The MODEL 3411 Torque Display processes the torque and speed signals, displays the measured torque and speed values, and the calculated power value.



Fig.2-14 MODEL 3411 | Torque Display

With its USB interface, data can be sent to a computer for processing with the LabVIEW™-based TORQUE Software that is supplied.

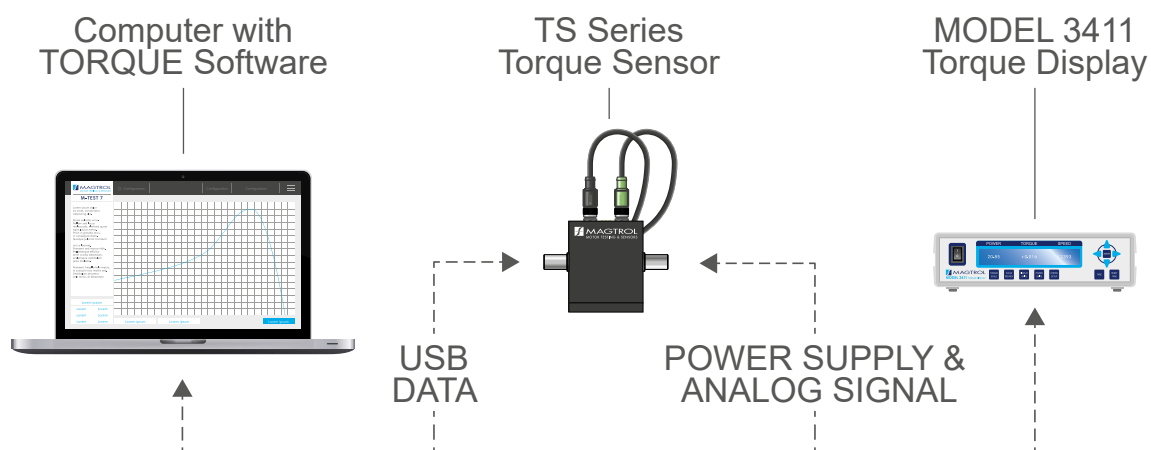


Fig.2-15 Computer-based system configuration with MODEL 3411 Torque display



NOTICE

For additional information regarding the operation of the MODEL 3411 Torque display, refer to the corresponding user's manual (available online at www.magtrol.com).

2.6.3 DSP 7000 | PROGRAMMABLE DYNAMOMETER CONTROLLER

Magtrol's DSP 7000 Programmable Dynamometer Controller employs state-of-the-art Digital Signal Processing technology to provide superior testing capabilities. The DSP 7000 is compatible with all TS Series In-Line Torque Sensors and is also designed to work with any Magtrol HD, HD5, WB or PB Dynamometer. Therefore, any Magtrol dynamometer can be used in conjunction with any TS Sensor with both being controlled by the same unit.



Fig.2-16 DSP 7000 | Programmable Dynamometer Controller

Complete computer control of the test system can be attained via USB interface, optionally GPIB IEEE-488 or RS-232, and Magtrol's M-TEST Software. This LabVIEW™-based program is equipped with ramp, curve and manual testing capabilities to help determine the performance characteristics of a motor under test, and also provides pass/fail testing for production line and inspection applications.

Below is an example of a system configuration in which a Magtrol WB/PB Series Dynamometer and TS Series Torque Transducer are used in conjunction with a DSP 7000 Programmable Dynamometer Controller.

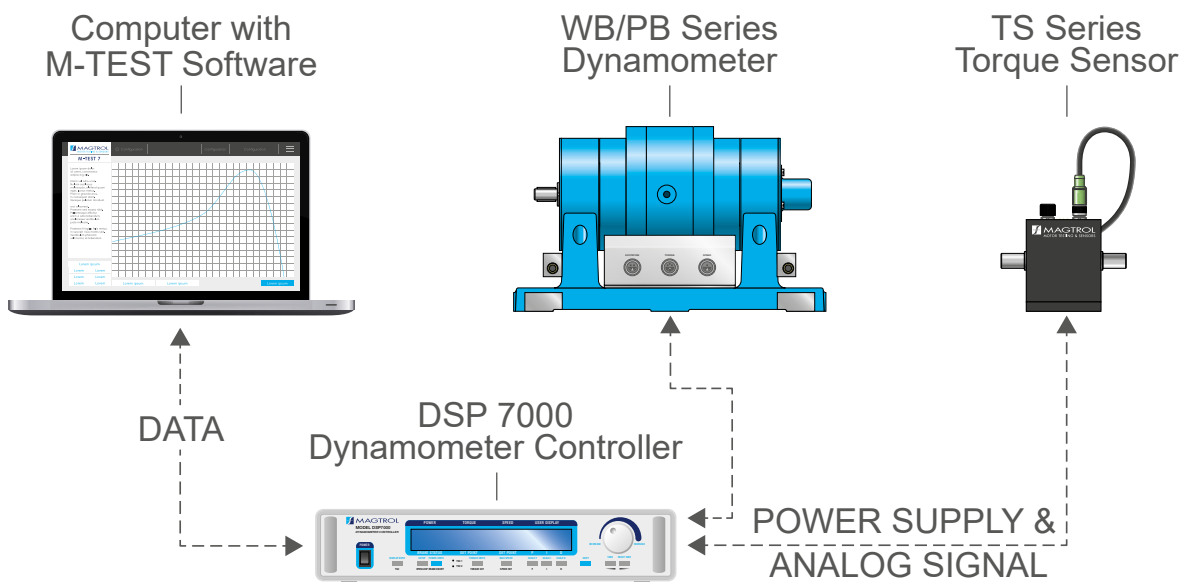


Fig.2-17 Computer-based system configuration with DSP 7000 Dynamometer Controller



NOTICE

For more system configuration possibilities, and detailed information regarding the operation of the DSP 7000 Dynamometer Controller, please refer to the corresponding user manual (available online at www.magtrol.com).

2.7 ELECTRICAL CONNECTIONS

**NOTICE**

For more information on connecting cable assemblies, please refer to the datasheet.

Connecting the TS Series Torque Sensor is extremely simple.

Having installed the drive train, connect the 8-pole electrical cable for the system to be operational.

If a computer with a LabVIEW™ application is used, connect the USB to the computer.

2.7.1 GROUNDING

**CAUTION**

BEFORE CONNECTING THE TS TORQUE SENSOR TO THE SIGNAL PROCESSING UNIT, THE SENSOR'S HOUSING MUST BE EARTH-GROUNDED.

The torque sensor, test bench, driving machine and driven machine must be commonly grounded.

In supported torque sensor installations, the support connects the transducer with the test bench grounding.

In suspended installations, a special wire needs to be drawn from the sensor's housing to the common earth-ground (see Fig.2-18).

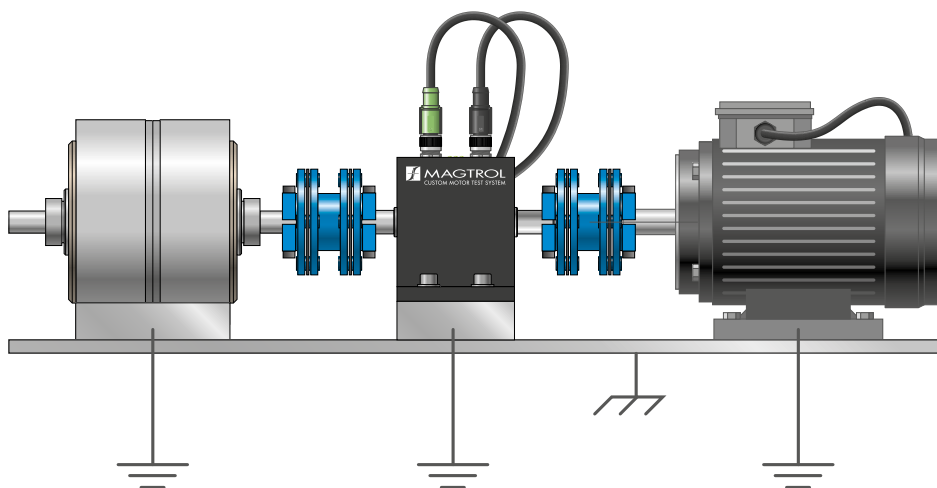
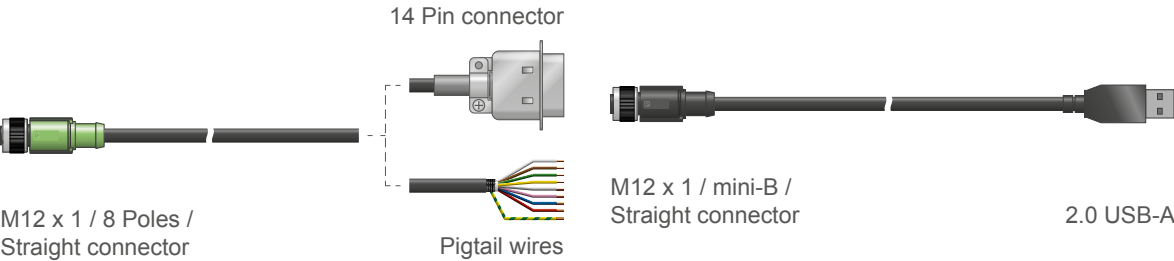


Fig.2-18 Common earth-grounding

2.7.2 CABLE ASSEMBLIES (ANALOG & USB)

Each TS Series Torque Sensor is delivered with a 3 meter cable for supply and analog signals (M12 straight connector and Pigtail wires) as well as a 2 meter USB cable (M12 x 1 mini-B / 2.0 USB-A).

Other lengths and cable configurations (e.g. with a 14-pin connector for use with MODEL 3411 Torque Display or DSP 7000 Dynamometer Controller) are available on request.



ORDERING NUMBER	ER 12	-	/ 0	-	1
0 : Pigtail wires					
1 : 14-pin connector ^{a)}					
1 : Cable length 5m					
2 : Cable length 10m					
3 : Cable length 20m					
4 : Cable length 3m					

a) For use with 3411 Torque Display or DSP 7000 Controller

ORDERING NUMBER	957-11-07-251	-
3 : Cable length 2m		
4 : Cable length 5m		

2.7.3 CABLE ASSEMBLY ER 120 (PIGTAIL WIRES)

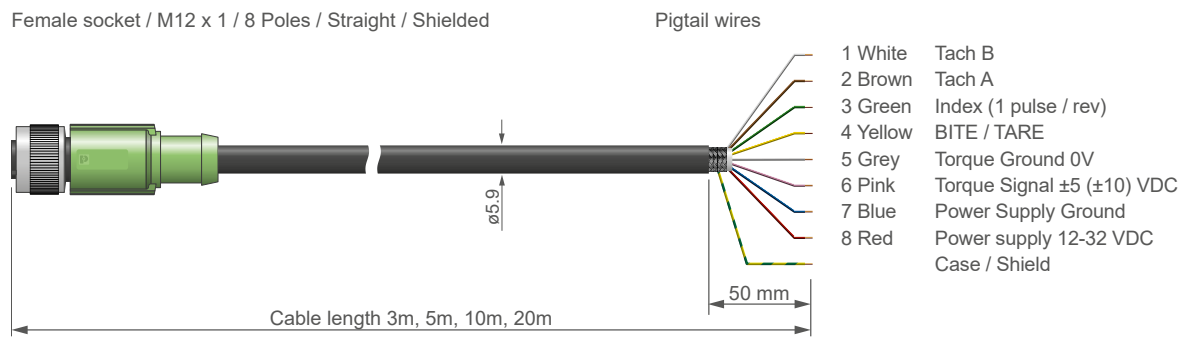


Fig.2-19 Cable ER 120 Pin Configuration

The connecting cable to the signal processing unit is fitted with a M12 x 1 / 8-pole connector on the transducer side and a user's connector on the side of the signal processing unit.



NOTICE

The B.I.T.E. test function is only active when the input is grounded.

The TARE function is only active when the input is pulled up to power supply (12-32V).

2.7.4 CABLE ASSEMBLY ER 121 (14-PIN CONNECTOR)

For use with MODEL 3411 & DSP 7000.

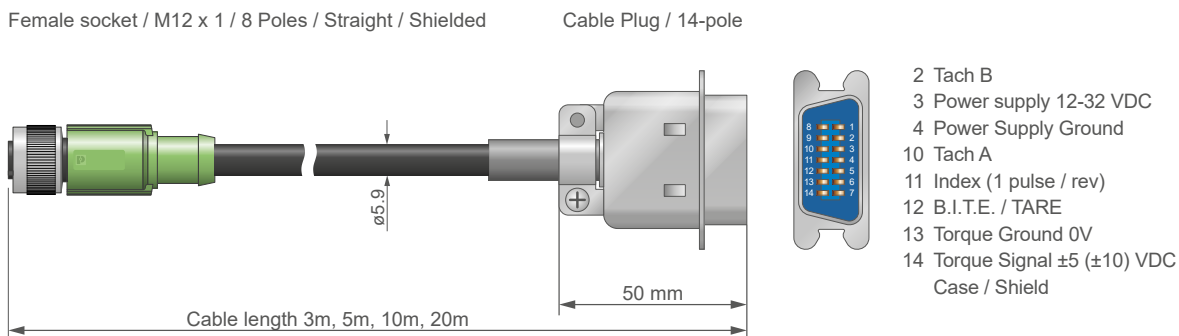


Fig.2-20 Cable ER 121 Pin Configuration

The connecting cable to the signal processing unit is fitted with a M12 x 1 / 8-pole connector on the transducer side and a 14-pin connector on the side of the signal processing unit.



NOTICE

The B.I.T.E. test function is only active when the input is grounded.

The TARE function is only active when the input is pulled up to power supply (12-32 V).

2.7.5 CONNECTION TO NON-MAGTROL MONITORING EQUIPMENT

To connect the torque transducer to electronic devices not manufactured by Magtrol, please refer to the following connection diagram (see Fig.2-21).

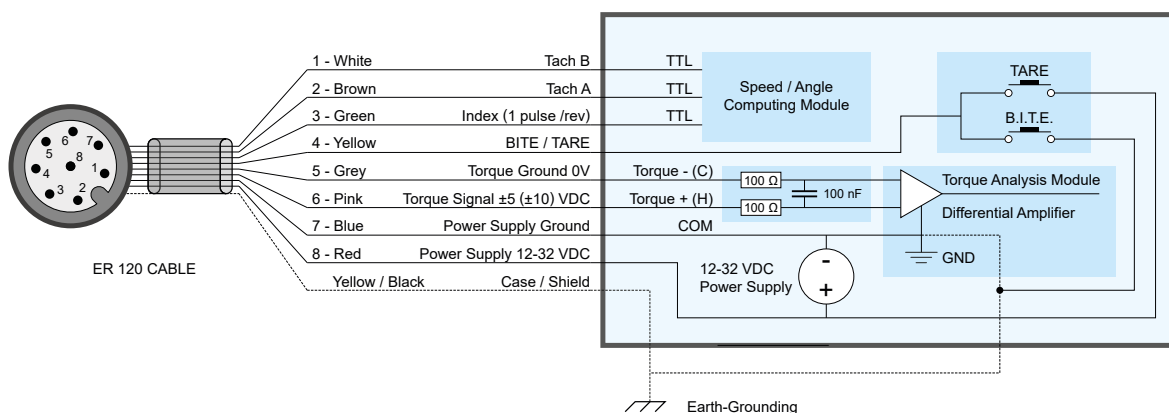


Fig.2-21 Wiring diagram for connection to non-Magtrol electronics

- A differential amplifier is required for elimination of potential DC voltage developing in the COM leg (0V). If there is no differential amplifier, a zero shift of the torque signal will occur depending on the resistance and the length of the cable.
- A $100\Omega + 100\text{nF} + 100\Omega$ input filter might be required to cancel the noise due to the TTL Tach signals. Nevertheless, this noise has no impact on the accuracy of the torque signal in the DC-1 kHz band of interest. This filter is only required when a measurement of the torque signal is performed with an oscilloscope.

2.7.6 CONNECTION TO A COMPUTER

In addition to any monitoring equipment, the TS Sensor can be used as a USB device for various purposes. The sensor offers both an isolated USB interface and an analog output.

Both analog and USB signals can be used simultaneously. For example, control loop data can be acquired using a computer via the USB interface, while fast data acquisition can be performed using the analog output, or torque, speed, and angle data can be acquired using the USB interface while fast control loop data can be acquired using the analog output signals.

The refresh time of the continuous analog signals is $100\mu\text{s}$ (10 kHz). The analog signal provides a $\pm 5\text{VDC}$ output corresponding to the sensor nominal range, allowing 200% of measuring range ($\pm 10\text{VDC}$).

The USB interface is plug and play not requiring any programming. It can easily be connected and used with the LabVIEW™ based TORQUE Software delivered with the sensor.



CAUTION

THE SENSOR IS NOT POWER BY THE USB. THE USE OF THE USB CONNECTION IMPLIES THE TS SENSOR MUST BE POWERED USING THE 8-POLE CONNECTOR AS SHOWN ABOVE.

3. OPERATING PRINCIPLES

The measuring system is based on strain gauges bonded to the sensor measuring section and connected in Wheatstone full bridge circuit. The strain gauges and its associated front-end amplifier are powered by a high frequency power transfer. Under an applied torque, the measuring section will elastically deform providing a strain in the measuring elements. A microprocessor conditions the signal from the amplifier and transfers the measured values to the stator via contactless telemetry data transfer. On board microcontrollers manage all the internal functions, such as power transfer, data collecting and filtering, calibration and set-up, TARE and B.I.T.E. (Build-In Test Equipement) functions, as well as the LED operating status control code. The sensor has to be supplied by a 12 to 32 VDC (24 VDC recommended) from the analog connector. The signal cutoff frequency can be digitally selected and configured in a range from 2 to 1000 Hz (50 Hz is factory default).

3.1 TORQUE TRANSDUCER ARCHITECTURE

The part of the transducer measuring the torque is composed of three elements: a shaft with a deformation zone equipped with strain gauges, a Rotating PCB with Amplifier and Telemetry, and a vertical PCB transferring the HF Power and receiving the Data.

Horizontal Static boards include power supplies, micro-controllers, USB, Encoder and D/A converter.

3.2 SPEED CONDITIONING CHAIN

An encoder is incorporated into the torque transducer housing in order to measure the rotational speed and the angle of the measuring shaft. The toothed part of the rotor produces 360 PPR (Pulses Per Revolution).

3.3 BUILT-IN SELF-TEST B.I.T.E. & TARE

The torque transducer's 8-pole connector has its Pin 4 allocated for activating either the test signal B.I.T.E. when grounded or the TARE when pulled up to the + 24V Power Supply line.

3.3.1 B.I.T.E. SEQUENCE DESCRIPTION

The B.I.T.E. (Built-In Test Equipment) takes place at either «System Power Up» **OR** B.I.T.E. 8-pole (external line when pulled low for at least 1s) **OR** B.I.T.E. USB.

The stator will turn ON power to the rotor. The first 5.5s of information will be used for rotor voltage measurement. Notice during this time, the «Analog output» and USB are set to zero.

After 5.5s, the signal from the rotor is available to the analog output and USB.

The B.I.T.E. signal is available on both the analog voltage output and USB in Newton-meters. The B.I.T.E. level is about 60% of Rated Torque (RT). It is in addition to the torque applied to the sensor. The B.I.T.E. sequence is usually performed when no torque is applied.

Graphically, its sequence can be represented as follows :

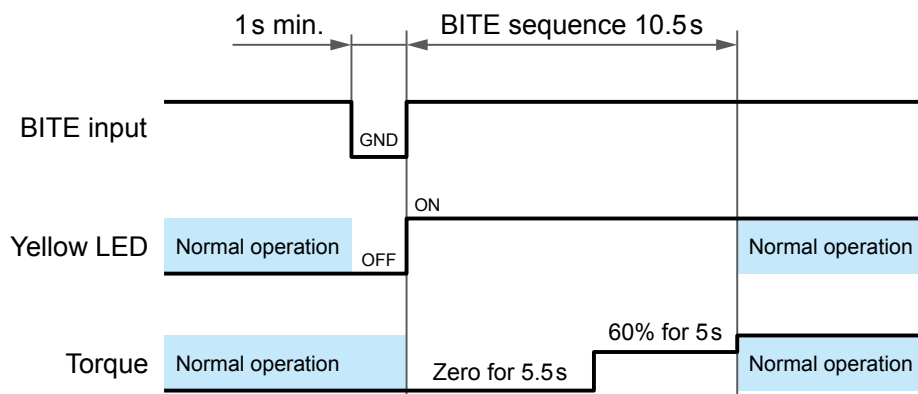


Fig.3-22 B.I.T.E. Sequence description

B.I.T.E. Sequence description

- B.I.T.E. (external line) is pulled low for at least 1 second. All LEDs will go OFF ;
- Unit is still operating normally ;
- B.I.T.E. (external line) is released.

Then :

- Upon System Power up **OR** B.I.T.E. line activity **OR** B.I.T.E. command ;
- **YELLOW** LED comes solid ON ;
- Stator will turn OFF (or hold off) power to rotor for 0.5 seconds ;
- Stator will turn ON power to rotor ;
- Information will start coming in from rotor ;
- The first 5 seconds of information will be used for «Rotor Voltage measurement». Note: during this time the DAC and USB report ZERO ;
- After 5 seconds, the signal from the rotor is released to be sent to the DAC and USB ;
- The B.I.T.E. signal is available on the 8-pole Output and USB for 5 seconds at $5.5\text{ s} < t < 10.5\text{ s}$ after B.I.T.E. line is released.

3.4 TARE SEQUENCE DESCRIPTION

3.4.1 TARE - STATUS DESCRIPTION

TARE (external line) is pulled up to + 24 V line :

1. Activate and hold **TARE** < 1.0 s then ignore ;
2. Activate and hold **TARE** > 1.0 s - 3.0 s then the value is stored in **RAM memory** which will be reset to factory offset the next time the power is turned on ;
3. Activate and hold **TARE** > 3.0 s - 6.0 s then the value is stored in the NVM (Non-Volatile Memory), then it will be saved when the power is turned off ;
4. Activate and hold **TARE** > 6.0 s then the value in NVM is RESET.

3.4.2 TARE - DESCRIPTION OF LED BEHAVIOR

When **TARE** is pressed, all three LEDs turn OFF :

- After 1 s, **YELLOW** turns ON ;
- After 4 s, **YELLOW** and **GREEN** turn ON ;
- After 6 s, **YELLOW**, **GREEN** and **RED** turn ON.



NOTICE

A TARE push button is also available from the cover if required.

Remove the screw located at the opposite side of the Yellow LED, press the button using a pointed end object (e.g. a paper clip).

The sequence above remains valid.

3.5 LED OVERVIEW OF DEVICE STATUS

A color code is given by the activation of 3 LED lights (Yellow, Green, Red) located on the top of the sensor. This color code continuously communicates the operating status of the sensor, such as measuring status, TARE activation type, B.I.T.E. (Built-In Test Equipment) and overload.

RED LED	
Flashing SLOW	Torque reading is above 100 %
Flashing FAST	Torque reading is above 150 %
Solid	Sensor failure; return to factory for repair
YELLOW LED	
Flashing FAST	TARE is in NVM
Flashing SLOW	TARE is in RAM
Solid	B.I.T.E. is active
GREEN LED	
Flashing SLOW	Torque reading is below 10 %
Solid	Torque reading is above 10 %

Fig.3-23 LED Status overview

4. COMPUTER CONTROLLED OPERATION

4.1 USB INTERFACE SPECIFICATIONS

Electrical and mechanical specifications (complies with USB Rev. 2.0):

- Connector: type mini B connector (receptacle)
- Power supply: TS Sensor is not powered by USB cable. Requires 8-pole connection.
- System requirements: computer with a USB port, Windows® 10 (32-bit or 64-bit) or Windows® 7 SP1 or later (32-bit or 64-bit).

The TS Torque Sensor can be interfaced to a personal computer using USB.

The method used is a set of Mag.NET commands, which are fully described in the next chapter. Mag.NET commands are human readable ASCII text strings which may be sent to the TS Torque Sensor using USB. Any program which can open a connection to the TS Torque Sensor via USB can control the unit using Mag.NET commands. This includes: Hyper-terminal, TeraTerm, and Putty; as well as custom programs written in LabVIEW™, Java, and C.

TORQUE Software is a LabVIEW™ program written by Magtrol which can interface with the TS Torque Sensor.

Notice that TS Torque Sensor is a composite device, meaning that it offers more than one USB interface to your computer.

The first device is a Communications Device Class (CDC), also known as a virtual COM port. This interface allows the USB to act as a legacy RS-232 device, and permits you to use software such as HyperTerminal to control the TS Sensor. The second interface is a USB Test and Measurement device. Drivers for this interface may already be installed on your computer. They are included as part of the TORQUE Software.

TORQUE Software installations also include a version of compatible drivers to use with a Test and Measurement Class (USB TMC) interface.

4.2 DRIVER INSTALLATION

1. Connect the TS Torque Sensor to any available USB port on your personal computer using the provided USB cable. Once the sensor is connected, your computer will automatically begin searching for the appropriate drivers to use.



Fig.4-1 Notification pop-up window - Installing the driver

2. Click on the **notification pop-up window** depicted below will show which drivers did not install successfully.

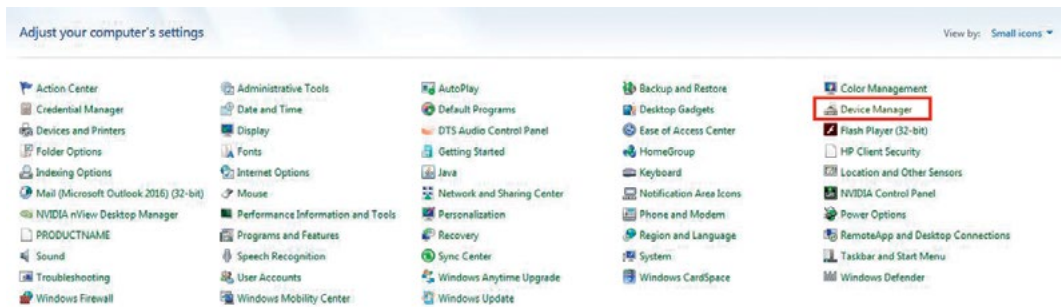


Fig.4-2 Notification pop-up window - Issue(s) with the driver installation

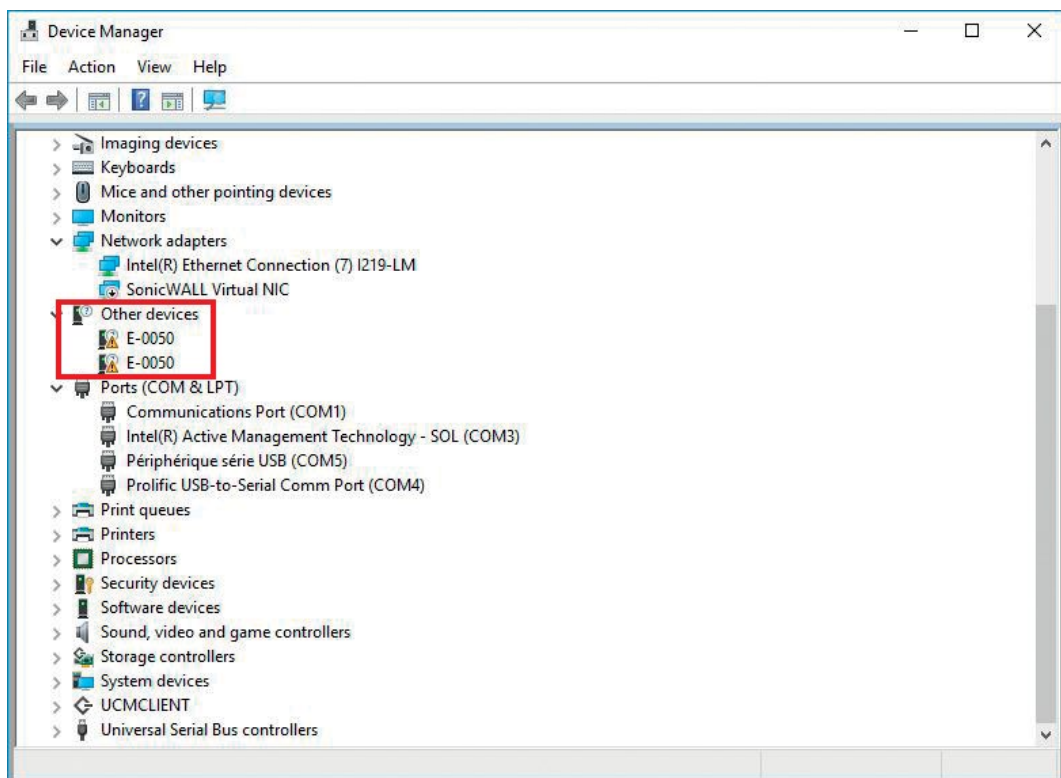
3. Obtain drivers install file torque TS Torque Sensor.

The drivers for the USB Communications Device Class (COM port) can be found on the TORQUE Software installation USB stick included with your TS Torque Sensor.

1. Open **Windows Control Panel**, choose the **Start menu** and then open the **Control panel** ;
2. Once open, if the **Control panel** isn't displaying the small icons, change the view to do so ;

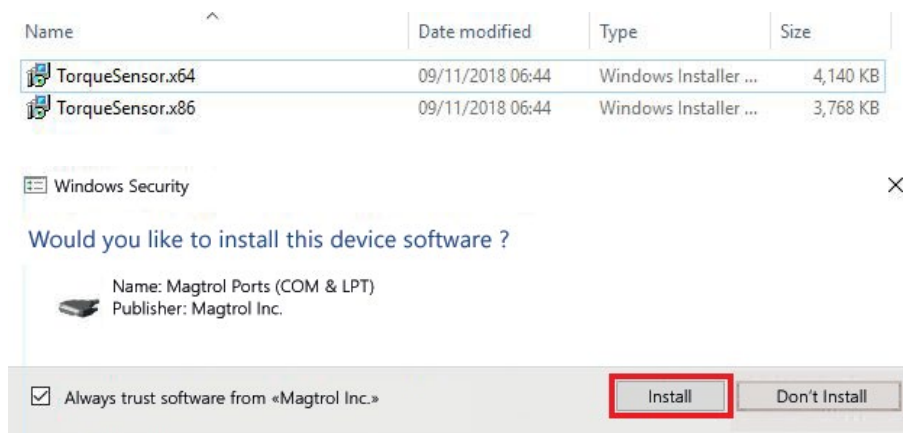


3. Open **Windows Device Manager** ;



In **Other devices**, the TS Sensor is detected but driver is not found ;

4. Depending on your OS (32-bit or 64-bit), install the corresponding driver ;



Select **Install**.

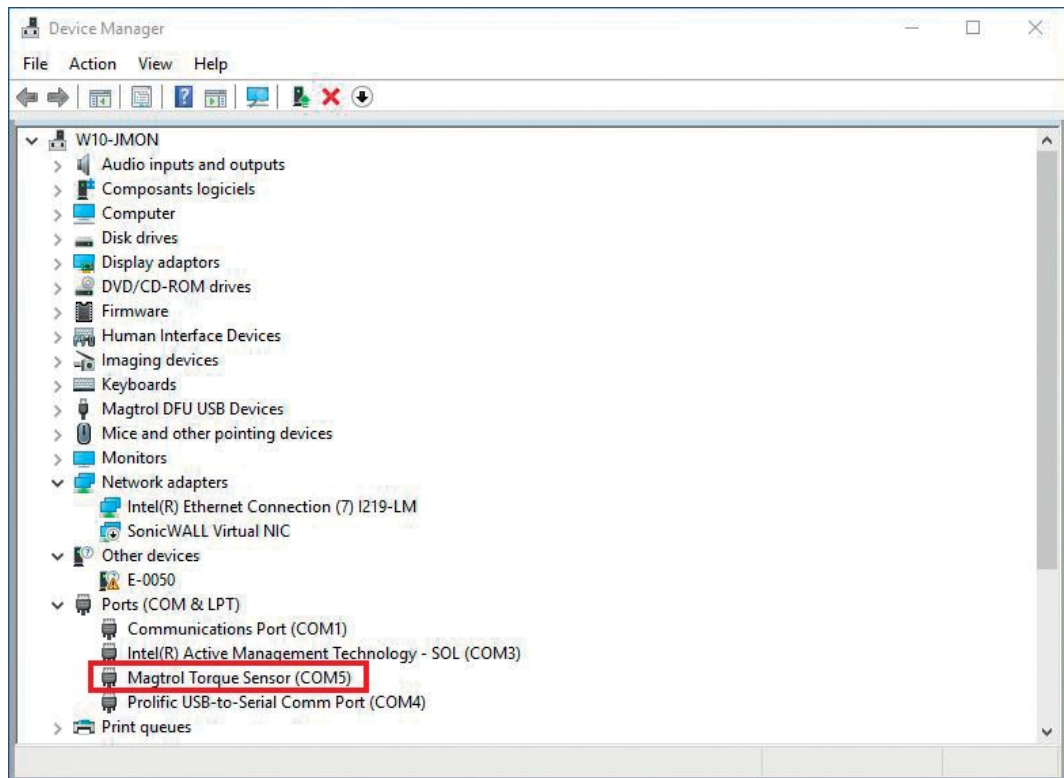


Fig.4-3 In example above, the TS Sensor is correctly installed on COM5

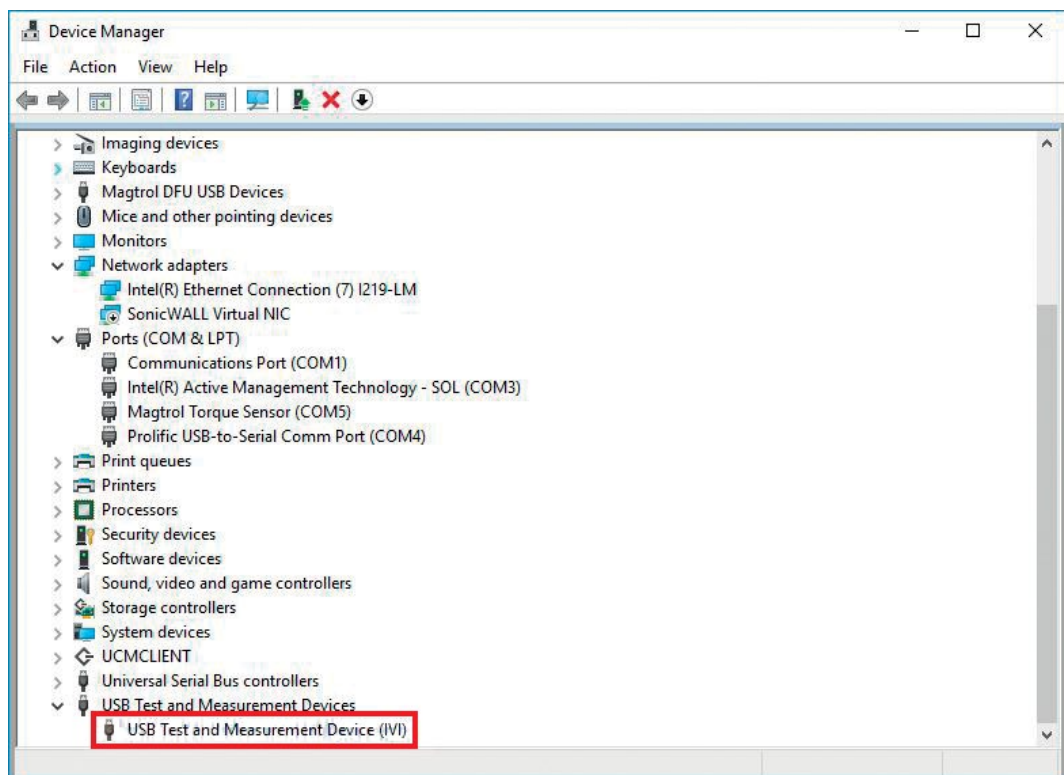


Fig.4-4 This picture shows when the USB TMC is correctly detected after installing the TORQUE Software package.

4.3 UPDATE FIRMWARE

It is now possible to remotely update the TS Torque Sensor's firmware via the web interface.

Just select the update file and click the change firmware button. The change firmware button will not be enabled until a valid update file has been selected.

Once the update process has completed the TS Torque Sensor will reboot with the latest version of the firmware installed.

5. USER COMMANDS

5.1 USB COMMUNICATION DEVICE CLASS CONNECTION

You may connect to the TS Torque Sensor using Hyper-terminal, Tera-Term, Putty or any custom program which can open a virtual COM port. The following are the valid communication parameters for the USB CDC via RS-232 connection:

- No parity
- 1 Stop bit
- 921 600 Baud rate
- 8 Data Bits
- No protocol

5.2 USB TEST AND MEASUREMENT CLASS CONNECTION

If you have LabVIEW™ installed on your computer, you may use the NI-VISA™ (National Instrument - Virtual Instrument Software Architecture) to connect to your TS Torque Sensor. NI-VISA™ is a separate program written by National Instruments™ designed to test communication with any NI-VISA™ compliant instrument. By implementing the Test and Measurement Class Specification (USB TMC), the TS Torque Sensor is now NI-VISA™ compliant.

It is possible to write custom LabVIEW™ programs using NI-VISA™ control blocks to connect the TS Sensor.

You must know the NI-VISA™ instrument descriptor of the TS Torque Sensor to do so. The instrument descriptor will follow this format:

- USB[board]:: manufacturer ID:: model code:: serial number[:: USB interface number]:: INSTR

For the TS Torque Sensor it will appear as:

- USB0::0xxxxx::0xxxxx::[units serial number]::INSTR

5.3 GENERAL GUIDES

1. Any command or argument must be in uppercase letters;
2. In commands with an argument, a space must be placed between the command and the argument;
3. If one command, needs more than one argument, use a comma to separate the arguments;
4. It is recommended to add a 50ms software delay between query or sent command for CONFIGURE command. The MEASUR command use 2 ms;
5. Carriage Return (ASCII 13) and Line Feed (ASCII 10) characters must be used with the COMx port (CDC). No specific end of message character must be use with the USB port (USB TMC).

5.3.1 EXAMPLES OF COMMANDS

Example is in CDC format (COMx), don't include <cr><lf> if using USB port TMC

EXAMPLES OF COMMANDS	
CONF:FILTER 5<cr><lf>	To set torque filter at 50 Hz <i>Return</i> : « OK<cr><lf> » (if the processing is correct)
CONF:FILTER ?<cr><lf>	To get torque filter <i>Return</i> : « 5<cr><lf> »
CONF:MEAS TORQUE,SPEED,POWER<cr><lf>	To set the list and order of parameter reading.
CONF:MEAS ?<cr><lf>	To get the list of parameters <i>Return</i> : « TORQUE,SPEED,POWER<cr><lf> »
MEAS:CONF <cr><lf>	To get the data string parameter <i>Return</i> : « 0.052,200.0,1.089<cr><lf> »

5.4 MAG.NET COMMANDS

5.4.1 SYSTEM COMMAND

*IDN?	
*IDN?	<p><i>Return</i> : « Magtrol, TS1YY, X-XXXX, SR, RR » (Magtrol identification and revisions)</p> <p>YY = the size (01, 02, 03, ..., 13)</p> <p>X-XXXX = serial number of the assembly</p> <p>SR = revision Stator firmware</p> <p>RR = revision Rotor firmware</p> <p><i>Example</i> : Magtrol,TS104,A-1234,B0,C0</p> <p><i>Note</i> : Rotor REV of -- = no communication with rotor Stator REV of -- = default after bootloader is installed</p>

5.4.2 FUNCTION COMMAND (FUNC:)

FUNC:	
BITE	Activates B.I.T.E. (Built In Test Equipment) signal for 5 seconds
QUADRESET	INDEX Reset to 0 the quadrature encoder position counter at next index
	ZERO Reset to 0 the quadrature encoder position counter at current position
TARE	RESET Remove tare and return system to calibrated zero
	SAVE Set and save current torque value as the tare value
	SET Set current torque value as the tare value

5.4.3 CONFIGURATION COMMAND (CONF:)

CONF:	
FILTER	<p>Set torque filter -3dB frequency</p> <p>0 = 1.5 kHz</p> <p>1 = 2 Hz</p> <p>2 = 5 Hz</p> <p>3 = 10 Hz</p> <p>4 = 20 Hz</p> <p>5 = 50 Hz (default)</p> <p>6 = 100 Hz</p> <p><i>Return</i> : «OK»</p>
FILTER ?	<p>Get torque filter -3dB frequency</p> <p><i>Return</i> : «0 1 2 3 4 5 6»</p>
GATETIME	<p>Set Gate time for gated speed measurement</p> <p>1 = 0.2 seconds</p> <p>2 = 0.5 seconds</p> <p>3 = 1.0 seconds (default)</p> <p>4 = 2.0 seconds</p> <p>5 = 5.0 seconds</p> <p><i>Return</i> : «OK»</p>
GATETIME ?	<p>Get Gate time for gated speed measurement</p> <p><i>Return</i> : «1 2 3 4 5»</p>
INVERT	<p>Set Inverted Torque signal</p> <p>0 = Non Inverted (default value)</p> <p>1 = Inverted</p> <p><i>Return</i> : «OK»</p>
INVERT ?	<p>Get Inverted Torque signal</p> <p><i>Return</i> : «0 1»</p>

CONF:	
MEAS <string>,<string>, ...	Configures / orders how user wants to see data when using MEAS:CONF command Values for <string> are: TORQUE SPEED POWER QUADPOS Choose 1 to n parameters in any order. <i>Return</i> : « CONFIGURED »
MEAS ?	Get values configured <i>Return</i> : the list order of parameter« TORQUE,SPEED,POWER,QUADPOS »
POWER	Set Power output unit 0 = hp 1 = W (default) 2 = kW <i>Return</i> : « OK »
POWER ?	Gets Power output unit <i>Return</i> : « 0 1 2 »
QUADOUT	Set output in degrees or count 0 = Output 0 to 360 1 = Output 0 to 65536 <i>Return</i> : « OK » If reset of encoder is anticipated do this command before the reset.
QUADOUT ?	Get output in degrees or count <i>Return</i> : « 0 1 »
SPEED	Set SPEED calculation method 0 = Delta T (average of last 360 Delta T) (default) 1 = Delta T (average of last 12 Delta T) 2 = Gated (slow – determined by gate setting) 3 = SUM (SUM and average of 360 pulses calculated once every 360 pulses) <i>Return</i> : « OK »
SPEED ?	Get SPEED calculation method <i>Return</i> : « 0 1 2 3 »

5.4.4 MEASURE COMMAND (MEAS:)

MEAS:	
CONF	<i>Return</i> : CONFIGURED data string. Format <float,float, ...> The order and number of values returned are dependent on CONF:MEAS command
POWER	<i>Return</i> : POWER data string. Format <float>
QUADPOS	<i>Return</i> : Quadrature position. Format <float> Quadrature position value returned dependent on CONF:QUADOUT x.xx = 0.00, 0.25, 0.50, 0.75, ... xxxxx = 0 to 65536
SPEED	<i>Return</i> : SPEED data string. Format <float>
TORQUE	<i>Return</i> : TORQUE data string. Format <float>

6. MAINTENANCE, REPAIR & CALIBRATION

6.1 MAINTENANCE

Magtrol TS Series In-Line Torque Sensors are virtually maintenance-free. This is due to the following aspects of their construction:

- Lifelong lubrication of the bearings.
- Transmission of the torque signal from the rotating measuring elements to the signal processing electronics by a process of induction rather than by using slip rings. This eliminates mechanical wear.

However, it may be necessary to change the bearings after extended use. The theoretical lifetime of the bearings is **5 000** hours and Magtrol recommends that the bearings be replaced after this time. Bearings should be replaced as soon as they start showing signs of wear. Higher wear occurs when the transducer is operated outside its optimal working conditions. This is especially true when the transducer is operated at excessive rotational speeds, which results in the generation of axial and radial forces on the bearings.



CAUTION

THE USER MUST NOT ATTEMPT TO CHANGE OR REPAIR THE BEARINGS OR ANY OTHER COMPONENTS HIMSELF. FOR ALL MAINTENANCE OR REPAIR OPERATIONS, PLEASE RETURN THE SENSOR TO MAGTROL.

SIMILARLY, THE USER SHOULD NOT ATTEMPT TO CARRY OUT REVISIONS OR REPAIRS OF ANY KIND ON THE MECHANICAL OR ELECTRONIC COMPONENTS MAKING UP THE TRANSDUCER. IF A PROBLEM IS SUSPECTED, MAGTROL SHOULD BE CONTACTED SO THAT ARRANGEMENTS CAN BE MADE TO PERFORM ANY REPAIRS IN THE FACTORY.

FAILURE TO COMPLY MAY RESULT IN SERIOUS DAMAGE TO THE TRANSDUCER OR MAY INVALIDATE THE WARRANTY.



NOTICE

The TS Torque Sensor **housing is sealed**. If there is any evidence that the housing has been opened and unauthorized modifications have been attempted, **the warranty will be invalidated**.

6.2 REPAIR

In case of a defect, please *see chapter 8 SERVICE INFORMATION* of this manual. Whether you are directed to ship your equipment back to MAGTROL INC. in the United States or MAGTROL S.A. in Switzerland, it is very important to include the following information with your return shipment:

1. Model number, part number, serial number, order number and date of acquisition
2. Description of the defect and the conditions in which it appeared
3. Description of the test bench (drawing, photographs, sketches, etc.)
4. Description of the tested object (drawing, photographs, sketches, etc.)
5. Description of the test cycle



CAUTION

MAINTENANCE MUST BE PERFORMED BY MAGTROL IN ORDER TO GUARANTEE FUTURE MEASURING ACCURACY.

To allow MAGTROL to complete the work in the best possible time, carefully pack the torque transducer and follow the procedure outlined in the rear of this manual under Service Information.

6.3 CALIBRATION

To ensure correct operation of the sensor and long-term measurement consistency, it is recommended to calibrate the sensor regularly. Magtrol recommends a factory calibration (e.g. in Magtrol's ISO 17025 accredited laboratory) **every 12 months**.

Returning the sensor directly to the Magtrol factory is both advantageous and economical. We can guarantee a dedicated calibration for the sensor performed by one of our specialists. In addition, any wear and tear requiring maintenance will be immediately taken care of by our after-sales service team.

6.4 PACKAGING

The sensor is delivered with packaging designed to store the sensor while not in use as well as to return the sensor to Magtrol for annual calibration. Please keep the packaging!

7. TROUBLESHOOTING

PROBLEM	REASON	SOLUTION	REF
COMx port is not listed	The driver is not correctly installed	Install the driver	4.2
Returned data indicates: ERR:SYNTAX	Command does not match the unit's programmed set of instructions	Use correct command and format	5
Returned data indicates: ERR:NO COMMAND GROUP	Command is incomplete	Use correct command and format	5
No returned data after sending query	In CDC communication, all commands require termination characters \r\n	Correct the format of command	5.3
Mechanical power reads much higher or lower than expected	Power units is incorrect	Set correct power output unit	5.4.3
No USB communication	Setup error and/or hardware fault	Check : <ul style="list-style-type: none"> ▪ Cable attachment from Torque Sensor to USB interface port of computer ▪ Power supply on the 8P connector 	2.7
Torque signal is not at zero when no torque is applied	Sensor has been Tared	Reset TARE	3.4 5.4.2
	Sensor has been overloaded	Send for repair	8
B.I.T.E incorrect value	Sensor has been Tared or torque is still applied	Reset TARE or remove applied torque	3.4 5.4.2
	Sensor has been overloaded	Send for repair	8
Returned data shows inconsistency	Wrong configuration	Use correct CONFIGURATION command set	5.4
RED LED Solid	Defective Sensor	Send for repair	8

REVISIONS TO THIS MANUAL

The contents of this manual are subject to change without prior notice. Should revisions be necessary, updates to all Magtrol user's manuals can be found at Magtrol's website at <http://www.magtrol.com/support/manuals>.

Please compare the date of this manual with the revision date on the web site, then refer to the manual's table of revisions for any changes/updates that have been made since this edition.

REVISION DATES

DATE	EDITION	CHANGE	SECTION(S)
Sep. 2019	1 st Edition - rev. A	Original document	All

