TM SERIES
IN-LINE TORQUE TRANSDUCERS

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.

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 *see section 2.5 - Protective systems*.

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

QUALIFIED PERSONNEL

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

The TM In-Line Torque Transducer 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 TM 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 meausres 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 Transducer 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 data sheets for Magtrol's TM In-Line Torque Transducers, which describe the units and provide detailed technical characteristics.

Chapter 2: INSTALLATION / CONFIGURATION – Provides information needed for the setup of the TM Transducers in a test system, and their 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 B.I.T.E. (Built-In Test cirEquipement).

Chapter 4: MAINTENANCE, REPAIR & CALIBRATION – Provides information on maintenance, repair and calibration procedures, should the need arise.

Chapter 5: SERVICES INFORMATION - Information, contacts and addresses relative for repair and/or calibration.

SEMANTICS

In this manual, different terminologies may be used to speak about the «TM Series In-Line Torques Transducer». 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; «TM XXX Series», «TM 3XX Series» or «TM Series» are all abreviations for «TM Series In-Line Torque Transducer», etc.

The term «Series» stands for all the products of the series (e.g. TM 3XX Series refers to TM 301 - TM 399).

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.

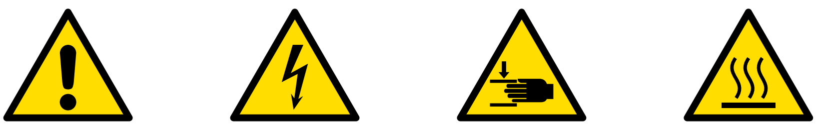
THIS INTRODUCES DIRECTIVES, PROCEDURES, PRECAUTIONARY MEASURES, ETC. WHICH MUST BE EXECUTED OR FOLLOWED WITH THE UTMOST CARE AND ATTENTION, OTHERWISE THE PERSONAL SAFETY OF THE OPERATOR OR THIRD PARTY MAY BE AT RISK. THE READER MUST ABSOLUTELY TAKE NOTE OF THE ACCOMPANYING TEXT, AND ACT UPON IT, BEFORE 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 TM Series In-Line Torque Transducers represent a generation of high-precision torque sensors with integrated electronic processing circuitry developed by Magtrol. The TM Series Transducers are available in three versions: TMB, TM and TMHS; TMB for all standard applications, TM for high-precision applications and TMHS for High-Speed applications.

The TM 3XX Series includes transducers with the following torque ratings: 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, 1 000 N·m, 2 000 N·m, 5 000 N·m and 10 000 N·m.

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

1.2 TM TRANSDUCER RANGE PRESENTATION

All TM Series In-Line Torque Transducers 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.

The upper part of the unit contains the built-in electronics. This part is sealed according to the IP44 standard and offers protection against splashed water. A Souriau connector allows the torque transducer to be connected to an external signal processing unit - such as the Magtrol MODEL 3411 Torque Display - via a special cable assembly.

Fig.1-1 TM 314 & TM 306 | In-Line Torque Transducers

TM Torque Transducers perform the following main functions:

1. Measurement of static and dynamic torque and detection of torque direction.
2. Measurement of the shaft's rotational speed and detection of rotational direction.
3. Self-check.

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 DATASHEET

TM SERIES
IN-LINE TORQUE TRANSDUCERS

FEATURES

- Integrated torque and speed conditioning
- Torque Range: from 0.1 N·m to 10 kN·m (0.07 lb·ft to 7375 lb·ft)
- Accuracy: < 0.1 %
- Overload Capacity: 200 %
- Breaking Limit: > 400 %
- High Speed Applications: up to 50 000 rpm
- Non-Contact (no sliprings)
- No Electronic Components in Rotation
- High Electrical Noise Immunity
- Single DC Power Supply: 20 VDC to 32 VDC
- Immediate Speed Detection
- Adjustable Torque Signal Frequency Pass Band up to 5 kHz
- Built-In Test Function (B.I.T.E.)
- Stainless Steel Shaft
- EMC Susceptibility Conforms to European Standards

Fig. 1: TM 312 & TM 308 In-Line Torque Transducer with smooth shaft

DESCRIPTION

Magtrol's In-Line Torque Transducers provide extremely accurate torque and speed measurement over a very broad range. Each model has an integrated conditioning electronic module providing a 0 VDC to ± 10 VDC torque output and an open collector speed output. Magtrol Torque Transducers are very reliable, providing high overload protection, excellent long term stability and high noise immunity.

All transducer models employ our unique non-contact differential transformer torque measuring technology. This measuring technology offers many benefits, most notably that no electronic components rotate during operation.

To provide customers with several price/performance options, Magtrol offers three torque transducer models: basic model (TMB Series), high accuracy (TM Series) and high speed with high accuracy (TMHS).

Each transducer consists of a hardened stainless steel shaft with smooth, splined or keyway shaft ends, an anodized aluminium housing containing the guide bearings and an electronic measurement conditioner.

The integrated electronic circuit, supplied by single DC voltage, provides torque and speed signals without any additional amplifier. The transducer is a stand-alone measuring chain. Connections are made by means of a 6-pole male connector mounted on the housing. A removable aluminium base (delivered as standard with TM and TMHS models, and as an option for TMB transducers) allows fixed mounting of the transducer.

OPERATING PRINCIPLES

The measuring system, based on the principle of a variable, torque proportional transformer coupling, consists of two concentric cylinders shrunk on the shaft on each side of the shaft's deformation zone, and two concentric coils attached to the housing.

Both cylinders have a circularly disposed coinciding row of slots and rotate with the shaft inside the coils. An alternating current with the frequency of 20 kHz flows through the primary coil. When no torque is applied, the slots on the two cylinders fail to overlap. When torque is applied, the deformation zone undergoes an angular deformation and the slots begin to overlap.

Thus a torque-proportional voltage is on the secondary coil. The conditioning electronic circuit incorporated in the transducer converts the voltage to a nominal torque signal of 0 VDC to ±5 VDC. A low-pass filter (Butterworth / 2nd order), adjustable from 5 kHz to 1 Hz, allows tuning of the torque signal frequency limitation.

An optical sensor reads the speed on a toothed pattern machined directly on the measuring system. The electronic conditioner outputs a frequency signal proportional to the shaft rotational speed. An active circuit compensates the zero and sensitivity temperature drifts within a tolerance of 0.1 % / 10 K.

APPLICATIONS

TM, TMB and TMHS Series Torque Transducers provide dynamic torque and speed measurement of:

- Propellers - aerospace, marine and helicopter
- Windshield wipers, electrical windows, starters, generators and brakes in automobile industry
- Pumps - water and oil
- Reduction gears and gearboxes
- Clutches
- Motorized valves
- Drills, pneumatic tools and other machine tools

SYSTEM CONFIGURATION

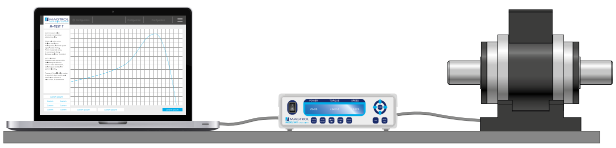


Fig. 2: TM connected with MODEL 3411 Torque Display and a computer with TORQUE Software

ELECTRICAL CONFIGURATION

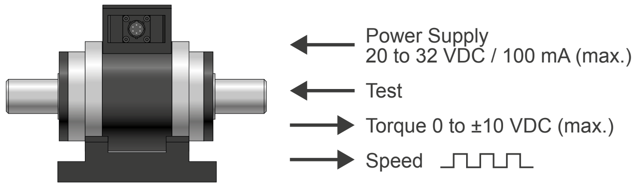


Fig. 3: TM's electrical input and output

SUPPORTED & SUSPENDED INSTALLATIONS

TheTMB Series is dedicated for use in a basic configuration or for low speed applications. The TMB Series ranges from TMB 304 (1 N·m) to TMB 313 (500 N·m). Due to dedicated low speed usage,the TMB Series is **delivered without base mount** however, a base is available as an option.

The TM Series ranges from TM 309 to TM 317 and can also be installed without the base mount in a suspended configuration. This configuration is **only allowed for low speed measurment**. The benefit of this configuration is the use of a single element coupling, creating a shorter drive train.

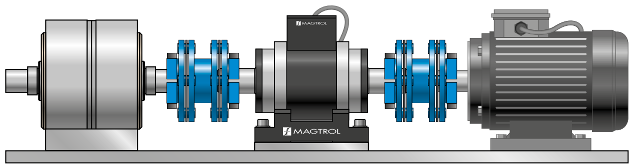


Fig. 4: **Supported installation**
Mandatory for standard and high speed applications

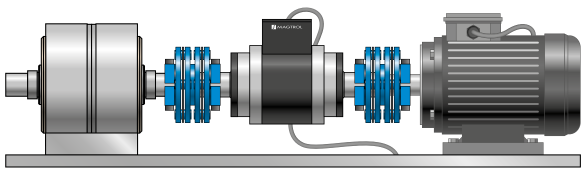


Fig. 5: **Suspended installation for low speed application only**.
Use single element coupling to create a shorter drive train.

SPECIFICATIONS

TORQUE TRANSDUCER RATINGS

<table>
<tr><th rowspan="2">MODEL</th><th colspan="2">Nominal Rated Torque (RT)</th><th colspan="2">TMB Series</th><th colspan="2">TM Series</th><th colspan="2">TMHS Series (High speed)[a)]</th></tr>
<tr><th>N·m</th><th>lb·ft</th><th>Accuracy class</th><th>Max. speed rpm</th><th>Accuracy class</th><th>Max. speed rpm</th><th>Accuracy class</th><th>Max. speed rpm</th></tr>
<tr><td>TM 301</td><td>0.1</td><td>0.07</td><td colspan="2" rowspan="3">N/A</td><td><0.2 %</td><td rowspan="8">20 000</td><td colspan="2" rowspan="2">N/A</td></tr>
<tr><td>TM 302</td><td>0.2</td><td>0.15</td><td rowspan="15"><0.1 %</td></tr>
<tr><td>TM 303</td><td>0.5</td><td>0.37</td><td rowspan="14"><0.1 %</td><td>40 000</td></tr>
<tr><td>TM 304</td><td>1</td><td>0.70</td><td rowspan="10"><0.1 %</td><td rowspan="5">6 000</td><td rowspan="5">50 000</td></tr>
<tr><td>TM 305</td><td>2</td><td>1.50</td></tr>
<tr><td>TM 306</td><td>5</td><td>3.70</td></tr>
<tr><td>TM 307</td><td>10</td><td>7.40</td></tr>
<tr><td>TM 308[e)]</td><td>20</td><td>15</td></tr>
<tr><td>TM 309[e)]</td><td>20</td><td>15</td><td rowspan="5">4 000</td><td rowspan="5">10 000</td><td rowspan="3">32 000</td></tr>
<tr><td>TM 310</td><td>50</td><td>37</td></tr>
<tr><td>TM 311</td><td>100</td><td>74</td></tr>
<tr><td>TM 312</td><td>200</td><td>148</td><td rowspan="2">24 000</td></tr>
<tr><td>TM 313</td><td>500</td><td>369</td></tr>
<tr><td>TM 314</td><td>1 000</td><td>737</td><td colspan="2" rowspan="4">N/A</td><td rowspan="2">7 000</td><td rowspan="2">16 000</td></tr>
<tr><td>TM 315</td><td>2 000</td><td>1 475</td></tr>
<tr><td>TM 316</td><td>5 000</td><td>3 687</td><td rowspan="2">5 000</td><td rowspan="2">12 000</td></tr>
<tr><td>TM 317</td><td>10 000</td><td>7 375</td><td><0.15 %</td><td><0.15 %</td></tr>
</table>

MECHANICAL CHARACTERISTICS

<table>
<tr><th rowspan="2">MODEL</th><th colspan="2">NOMINAL RATED TORQUE (RT)</th><th colspan="2">TORSIONAL STIFFNESS</th><th colspan="2">MOMENT OF INERTIA</th><th colspan="2">WEIGHT[b)]</th><th colspan="3">SHAFT ENDS</th><th colspan="2">BASE MOUNT</th></tr>
<tr><th>N·m</th><th>lb·ft</th><th>N·m / rad</th><th>lb·ft</th><th>kg·m²</th><th>lb·ft·s²</th><th>kg</th><th>lb</th><th>Smooth</th><th>Splined</th><th>Keyway</th><th>TM / TMHS</th><th>TMB</th></tr>
<tr><td>TM 301</td><td>0.1</td><td>0.07</td><td>29</td><td>21</td><td>2.50×10^{-5}</td><td>1.84×10^{-5}</td><td>1.1</td><td>2.43</td><td>X</td><td>-</td><td>-</td><td></td><td></td></tr>
<tr><td>TM 302</td><td>0.2</td><td>0.15</td><td>29</td><td>21</td><td>2.50×10^{-5}</td><td>1.84×10^{-5}</td><td>1.1</td><td>2.43</td><td>X</td><td>-</td><td>-</td><td></td><td></td></tr>
<tr><td>TM 303</td><td>0.5</td><td>0.37</td><td>66</td><td>48</td><td>2.55×10^{-5}</td><td>1.88×10^{-5}</td><td>1.1</td><td>2.43</td><td>X</td><td>-</td><td>-</td><td></td><td></td></tr>
<tr><td>TM 304</td><td>1</td><td>0.70</td><td>145</td><td>107</td><td>2.82×10^{-5}</td><td>2.07×10^{-5}</td><td>1.2</td><td>2.65</td><td>X</td><td>-[c)]</td><td>-[c)]</td><td colspan="2" rowspan="5">integrated</td></tr>
<tr><td>TM 305</td><td>2</td><td>1.50</td><td>290</td><td>214</td><td>2.91×10^{-5}</td><td>2.14×10^{-5}</td><td>1.2</td><td>2.65</td><td>X</td><td>-[c)]</td><td>-[c)]</td></tr>
<tr><td>TM 306</td><td>5</td><td>3.70</td><td>725</td><td>535</td><td>3.08×10^{-5}</td><td>2.27×10^{-5}</td><td>1.2</td><td>2.65</td><td>X</td><td>-[c)]</td><td>-[c)]</td></tr>
<tr><td>TM 307</td><td>10</td><td>7.40</td><td>1 450</td><td>1 069</td><td>2.63×10^{-5}</td><td>1.94×10^{-5}</td><td>1.2</td><td>2.65</td><td>X</td><td>-[c)]</td><td>-[c)]</td></tr>
<tr><td>TM 308[e)]</td><td>20</td><td>15</td><td>2 900</td><td>2 139</td><td>2.66×10^{-5}</td><td>1.96×10^{-5}</td><td>1.2</td><td>2.65</td><td>X</td><td>-[c)]</td><td>-[c)]</td></tr>
<tr><td>TM 309[e)]</td><td>20</td><td>15</td><td>2 400</td><td>1 770</td><td>1.49×10^{-4}</td><td>1.03×10^{-4}</td><td>2.5</td><td>5.51</td><td>X</td><td>-[c)]</td><td>-[c)]</td><td rowspan="9">included</td><td rowspan="5">optional</td></tr>
<tr><td>TM 310</td><td>50</td><td>37</td><td>5 700</td><td>4 204</td><td>1.52×10^{-4}</td><td>1.12×10^{-4}</td><td>2.5</td><td>5.51</td><td>X</td><td>-[c)]</td><td>-[c)]</td></tr>
<tr><td>TM 311</td><td>100</td><td>74</td><td>11 400</td><td>8 408</td><td>1.55×10^{-4}</td><td>1.14×10^{-4}</td><td>2.5</td><td>5.51</td><td>X</td><td>-[c)]</td><td>-[c)]</td></tr>
<tr><td>TM 312</td><td>200</td><td>148</td><td>38 200</td><td>28 200</td><td>4.85×10^{-4}</td><td>3.57×10^{-4}</td><td>4.1</td><td>9.04</td><td>X</td><td>X[d)]</td><td>-[c)]</td></tr>
<tr><td>TM 313</td><td>500</td><td>369</td><td>95 800</td><td>70 700</td><td>5.16×10^{-4}</td><td>3.80×10^{-4}</td><td>4.4</td><td>9.70</td><td>X</td><td>X[d)]</td><td>-[c)]</td></tr>
<tr><td>TM 314</td><td>1 000</td><td>737</td><td>3.28×10^{5}</td><td>2.419×10^{6}</td><td>3.01×10^{-3}</td><td>2.21×10^{-3}</td><td>9.9</td><td>21.80</td><td>-</td><td>X[d)]</td><td>X</td><td></td></tr>
<tr><td>TM 315</td><td>2 000</td><td>1 475</td><td>6.56×10^{5}</td><td>4.838×10^{6}</td><td>3.30×10^{-3}</td><td>2.43×10^{-3}</td><td>10.8</td><td>23.80</td><td>-</td><td>X[d)]</td><td>X</td><td></td></tr>
<tr><td>TM 316</td><td>5 000</td><td>3 687</td><td>1.94×10^{6}</td><td>1.4×10^{7}</td><td>9.95×10^{-3}</td><td>7.32×10^{-3}</td><td>20.0</td><td>44.10</td><td>-</td><td>X[d)]</td><td>-[c)]</td><td></td></tr>
<tr><td>TM 317</td><td>10 000</td><td>7 375</td><td>2.26×10^{6}</td><td>1.7×10^{7}</td><td>1.18×10^{-2}</td><td>8.66×10^{-3}</td><td>22.3</td><td>49.20</td><td>-</td><td>X[d)]</td><td>-</td><td></td></tr>
</table>

a) Higher speed versions available for some models

b) The weight for the TM, TMHS or specifically TMB, ordered without the foot mount is slightly lower. Weight is given for the heavier version (shaft end) of TM. Effective weight depending on the model is available on request

c) Versions available on request

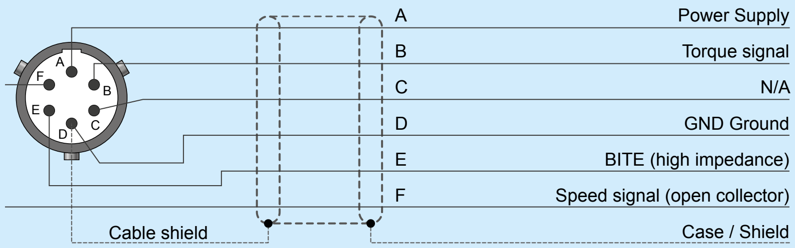
d) Magtrol recommends using adapation flanges (available on request)

e) For 20 Nm, Model TM 309 is recommended

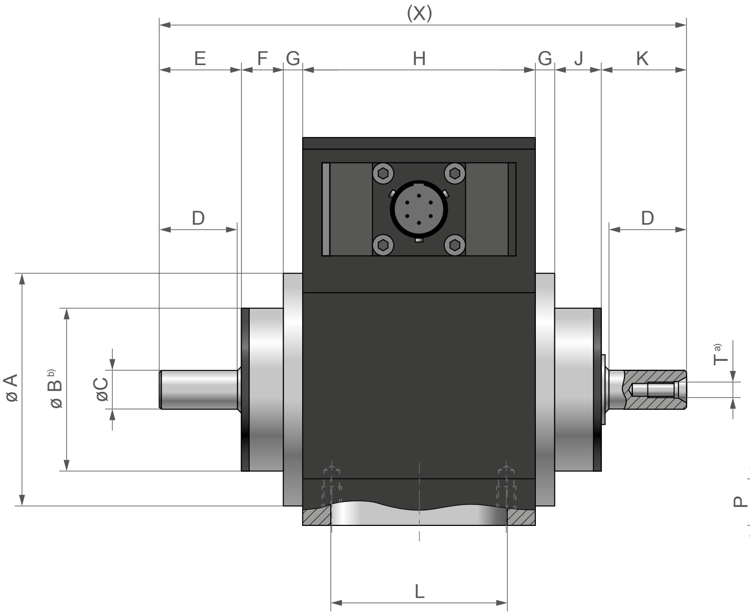
SPECIFICATIONS

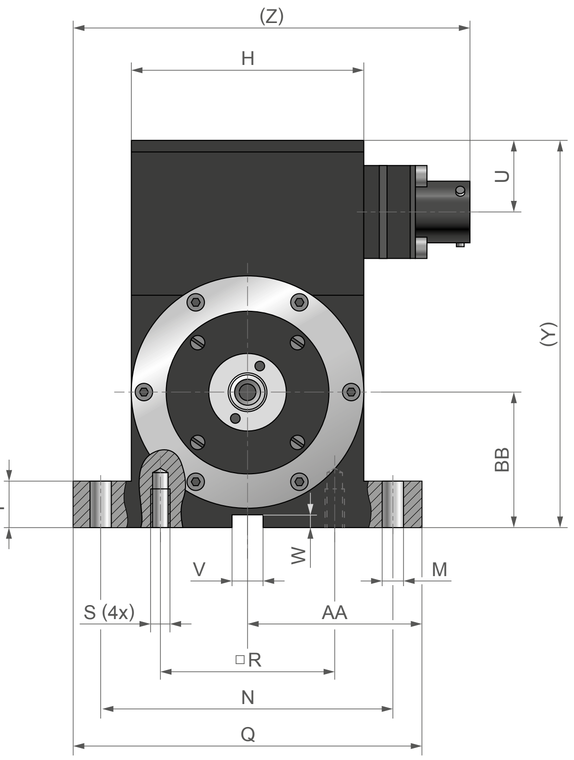
STANDARD VERSION	TM Series	TMHS Series	TMB Series
TORQUE MEASUREMENT			
Maximum Dynamic Torque Peak Value (Overload Capacity)	0 % to ±200 % of RT		
Maximum Dynamic Torque (Measuring Overload Limit with possible 0 deviation)	0 % to ±400 % of RT (±200 % for TM 317)		
Combined Error of Linearity and Hysteresis to 100 % of RT	<±0.1 % of RT (<±0.15 % for TM 317)		<±0.1 % of RT
Combined Error of Linearity and Hysteresis from 100 % to 200 % of RT	<±0.15 % of RT (<±0.2 % for TM 317)		<±0.15 % of measured value
Influence of Speed on Zero Torque Signal	<±0.01 % of RT / 1 000 rpm		<±0.02 % of RT / 1 000 rpm
SPEED MEASUREMENT			
Rated range of use	1 rpm to 50 000 rpm (see « Torque Transducer Ratings » section)		
Number of teeth	60 Z		
Minimum speed detection	1 rpm		
ENVIRONMENT & MECHANICAL CHARACTERISTICS			
Operating Temperature	-40 °C to +85 °C		
Storage Temperature	-40 °C to +100 °C		
Temperature Influence on Zero / on Sensitivity: · In Compensated Range +10° C to +60° C · In Compensated Range -25° C to +80° C	 <±0.1 % of RT / 10K <±0.2 % of RT / 10K		 <±0.2 % of RT / 10K <±0.4 % of RT / 10K
Long-term Stability of Sensitivity	<±0.05 % of RT / year		<±0.1 % of RT / year
Mechanical Shock	according to IEC 68.2.27 / Class D3		
Vibration	according to IEC 68.2.6 / Class D3		
Protection class	IP 44		
EMC / EMI compatibility	IEC 61326-1 / IEC 61321-2-3		
Balancing Quality	G1 according to ISO 1940		G2.5 according to ISO 1940
ELECTRICAL CHARACTERISTICS			
Power supply (max. voltage / current)	20 VDC to 32 VDC / 100 mA		
Torque output (rated / max.)	±5 VDC / ±10 VDC		
Filter Cutoff (frequency)	5 000, 2 500, 1 000, 500, 200, 100, 40, 20, 10 ,5, 2, 1 Hz		
Speed output (frequency)	open collector (15 Ω in series), max. 30 VDC, protected against short circuits		
ELECTRICAL CONNECTION			
Output connector	Axial connector Souriau 851 02 E 10 6P 50 29		
Connection cable assembly	Option		
Wiring diagram	(see diagram below)		

Wiring diagram



TM 301-308 (SMOOTH SHAFT) DIMENSIONS





a) Center according to:
ISO 6411 - A1 / 2.12 (for TM 301-303)
DIN 332 - D M4 (for TM 304-308)

b) Centering seat

CAUTION: MAGTROL has redesigned the fixation for its small torque transducers (TM 301-308). The new housing allows installation of the torque transducer from the bottom as before, but also allows installation from the top. It also integrates a centering key underneath its housing. The old fastening system (from the bottom only) is still available as an alternative option.

NOTE: Dimensions are the same for every series (TM, TMHS). Original dimensions are in metric units. Dimensions converted to imperial units have been rounded up to 3 or 4 decimal places.

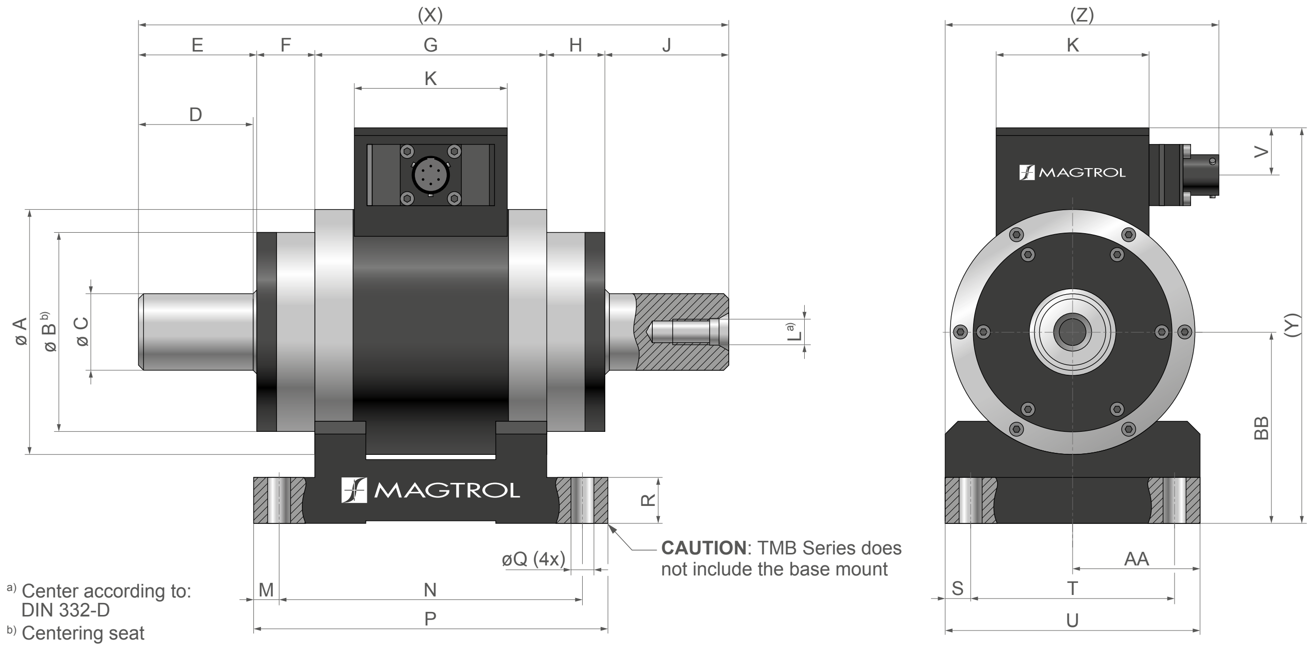
MODEL	Units	ø A	ø B	ø C	D	E	F	G	H	J	K	L	M	N
TM 301 - 303	mm	60	42g6	6h6	12	13.2	7.8	5	60	9	14	45.5	5.5	75
	in	2.362	1.6533 1.6526	0.2362 0.2359	0.472	0.520	0.307	0.197	2.362	0.354	0.551	1.791	0.217	2.953
TM 304 - 308	mm	60	42g6	10h6	20	21.2	10.8	5	60	12	22	45.5	5.5	75
	in	2.362	1.6533 1.6526	0.3937 0.3933	0.787	0.835	0.425	0.197	2.362	0.472	0.866	1.791	0.217	2.953

MODEL	Units	P	Q	□ R	S	T a)	U	V	W	X	Y	Z	AA	BB
TM 301 - 303	mm	12	90	45	M5 x 10	ø 1	18.5	8H9	3.3	114	100	101	$45\left(^{\ 0}_{-0.1}\right)$	$35\left(^{\ 0}_{-0.1}\right)$
	in	0.472	3.543	1.772	M5 x 10	ø 1	0.728	0.3164 0.3149	0.13	4.488	3.937	3.976	1.7717 1.7677	1.3780 1.3740
TM 304 - 308	mm	12	90	45	M5 x 10	M4	18.5	8H9	3.3	136	100	101	$45\left(^{\ 0}_{-0.1}\right)$	$35\left(^{\ 0}_{-0.1}\right)$
	in	0.472	3.543	1.772	M5 x 10	M4	0.728	0.3164 0.3149	0.13	5.354	3.937	3.976	1.7717 1.7677	1.3780 1.3740

a) Center according to DIN 6411-A or DIN 332-D

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

TM 309-313 (SMOOTH SHAFT) DIMENSIONS



NOTE: Dimensions are the same for every series (TM, TMHS and TMB). Original dimensions are in metric units. Dimensions converted to imperial units have been rounded up to 3 or 4 decimal places.

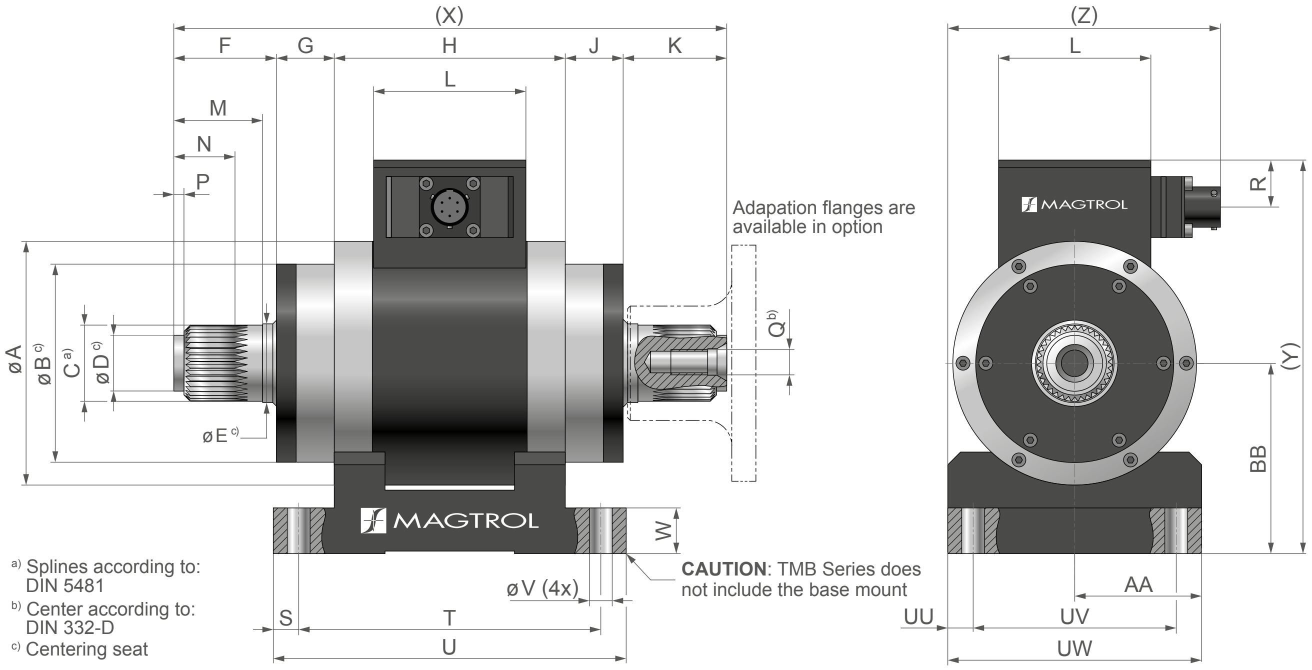
MODEL	Units	ø A	ø B	ø C	D	E	F	G	H	J	K	L a)	M	N
TM 309	mm	82g6	64	20h6	25	26.2	16.8	86	15	26.4	60		10	110
	in	3.2283 3.2270	2.52	0.7874 0.7869	0.984	1.031	0.661	3.386	0.591	1.039	2.362		0.394	4.331
TM 310	mm	82g6	64	20h6	35	36.2	16.8	86	15	36.4	60	M6	10	110
	in	3.2283 3.2270	2.52	0.7874 0.7869	1.378	1.425	0.661	3.386	0.591	1.433	2.362		0.394	4.331
TM 311	mm	82g6	64	20h6	40	41.2	16.8	86	15	41.4	60		10	110
	in	3.2283 3.2270	2.52	0.7874 0.7869	1.575	1.662	0.661	3.386	0.591	1.630	2.362		0.394	4.331
TM 312	mm	96g6	78	30h6	45	46.4	22.8	91	21	46.8	60		10	119
	in	3.7791 3.7782	3.071	1.1811 1.1806	1.772	1.827	0.898	3.583	0.827	1.842	2.362	M10	0.394	4.685
TM 313	mm	96g6	78	30h6	55	56.4	22.8	91	21	56.8	60		10	119
	in	3.7791 3.7782	3.071	1.1811 1.1806	2.165	2.220	0.898	3.583	0.827	2.236	2.362		0.34	4.685

MODEL	Units	P	ø Q	R	S	T	U	V	X	Y	Z	AA	BB
TM 309	mm	130	6.6	12	8	74	90	18.5	170.4	134	90	45	$60\,(^{0}_{-0.05})$
	in	5.118	0.260	0.472	0.315	2.913	3.543	0.728	6.709	5.276	3.543	1.772	2.3622 2.3603
TM 310	mm	130	6.6	12	8	74	90	18.5	190.4	134	90	45	$60\,(^{0}_{-0.05})$
	in	5.118	0.260	0.472	0.315	2.913	3.543	0.728	7.496	5.276	3.543	1.772	2.3622 2.3603
TM 311	mm	130	6.6	12	8	74	90	18.5	200.4	134	90	45	$60\,(^{0}_{-0.05})$
	in	5.118	0.260	0.472	0.315	2.913	3.543	0.728	7.890	5.276	3.543	1.722	2.3622 2.3603
TM 312	mm	139	9	18	10	80	100	18.5	228.0	155	100	50	$75\,(^{0}_{-0.05})$
	in	5.472	0.354	0.709	0.394	3.150	3.937	0.728	8.976	6.102	3.937	1.967	2.9527 2.9508
TM 313	mm	139	9	18	10	80	100	18.5	248.0	155	100	50	$75\,(^{0}_{-0.05})$
	in	5.472	0.354	0.709	0.394	3.150	3.937	0.728	9.764	6.102	3.937	1.967	2.9527 2.9508

a) Center according to DIN 332-D

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

TM 312-313 (SPLINED SHAFT) DIMENSIONS



NOTE: Dimensions are the same for every series (TM, TMHS and TMB). Original dimensions are in metric units. Dimensions converted to imperial units have been rounded up to 3 or 4 decimal places.

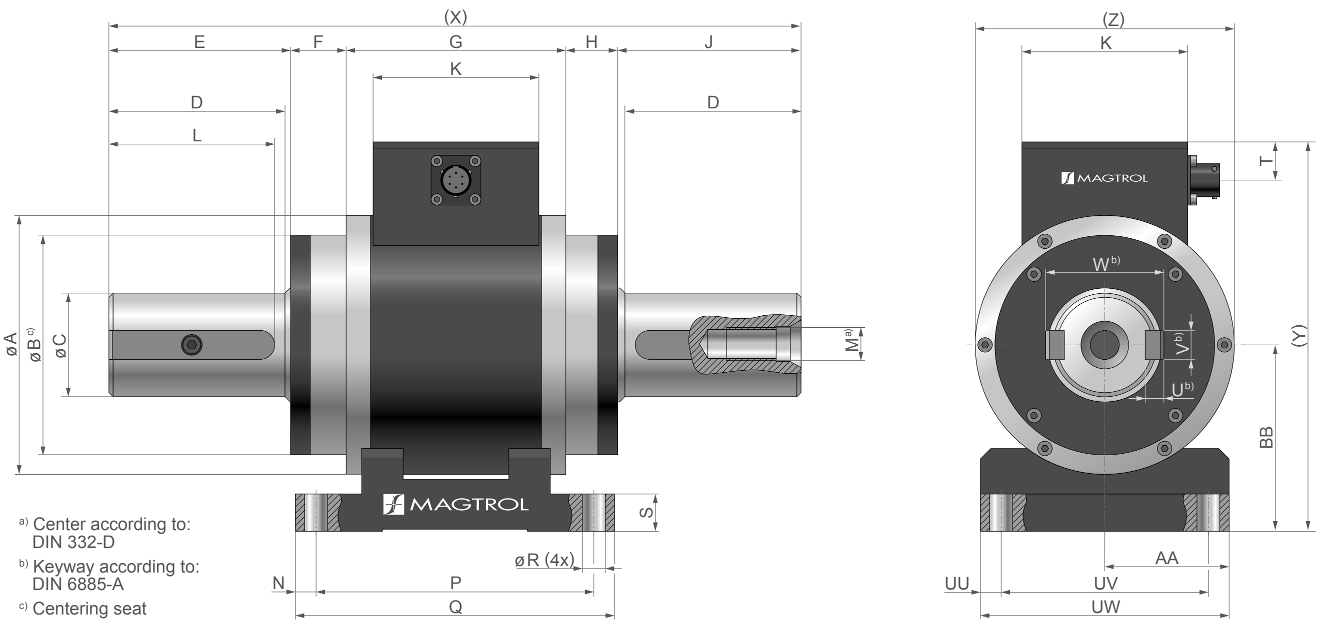
MODEL	Units	ø A	ø B	ø C a)	ø D	ø E	F	G	H	J	K	L	M	N	P	Q b)
TM 312	mm	96g6	78	26x30	22h6	31h6	40.4	22.8	91	21	40.8	60	35	24	4	M10
	in	3.7791 3.7782	3.071	26x30	0.8661 0.8656	1.2205 1.2198	1.591	0.898	3.583	0.827	1.606	2.362	1.378	0.945	0.157	M10
TM 313	mm	96g6	78	26x30	22h6	31h6	52.4	22.8	91	21	52.8	60	47	36	4	M10
	in	3.7791 3.7782	3.071	26x30	0.8661 0.8656	1.2205 1.2198	2.063	0.898	3.583	0.827	2.079	2.360	1.850	1.417	0.157	M10

MODEL	Units	R	S	T	U	ø V	W	UU	UV	UW	X	Y	Z	AA	BB
TM 312	mm	18.5	10	119	139	9	18	10	80	100	216	155	107	50	75 $(^{0}_{-0.05})$
	in	0.728	0.394	4.685	5.472	0.354	0.709	0.394	3.15	3.937	8.504	6.102	4.213	1.969	2.9527 2.9508
TM 313	mm	18.5	10	119	139	9	18	10	80	100	240	155	107	50	75 $(^{0}_{-0.05})$
	in	0.728	0.394	4.685	5.472	0.354	0.709	0.394	3.15	3.937	9.449	6.102	4.213	1.969	2.9527 2.9508

a) Splines according to DIN 5481
b) Center according to DIN 332-D

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

TM 314-315 (KEYWAY SHAFT) DIMENSIONS



NOTE: Dimensions are the same for every series (TM and TMHS). Original dimensions are in metric units. Dimensions converted to imperial units have been rounded up to 3 or 4 decimal places.

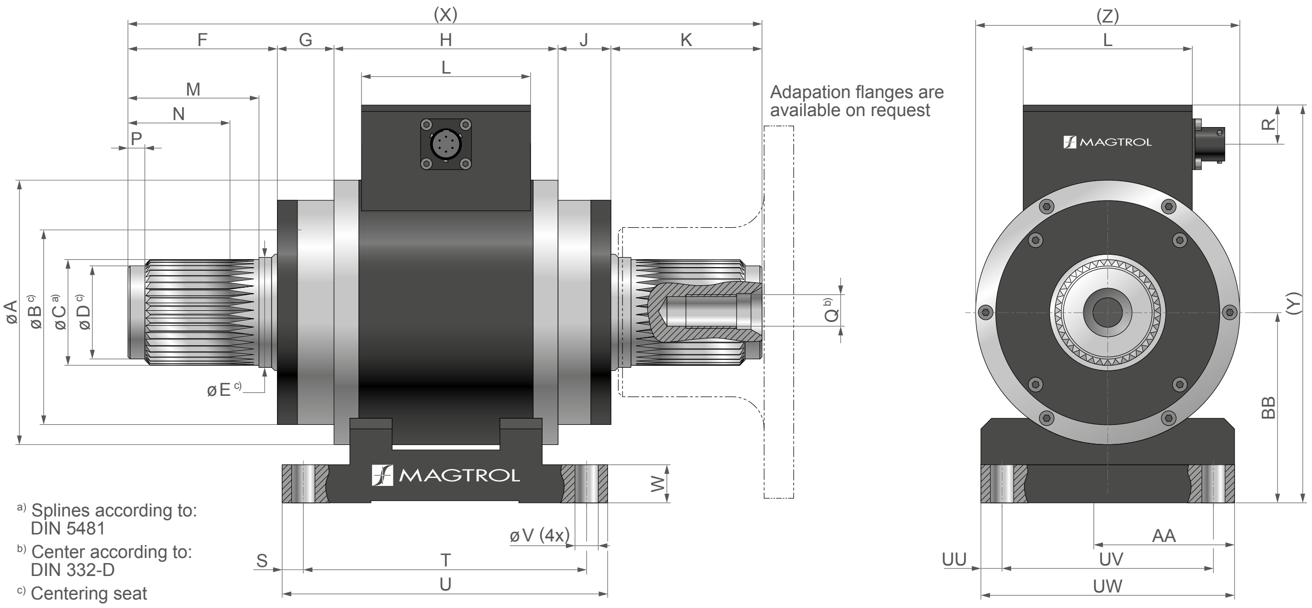
MODEL	Units	øA	øB	øC	D	E	F	G	H	J	K	L	M a)	N	P	Q
TM314	mm	125g6	106	50h6	65	67.7	26.8	106	25	68.5	80	60	M16	10	134	154
	in	4.9207 4.9197	4.173	1.9685 1.9679	2.559	2.665	1.055	4.173	0.984	2.697	3.150	2.362		0.394	5.276	6.063
TM315	mm	125g6	106	50h6	85	87.7	26.8	106	25	88.5	80	80		10	134	154
	in	4.9207 4.9197	4.173	1.9685 1.9679	3.346	3.453	1.055	4.173	0.984	3.484	3.150	3.150		0.394	5.276	6.063

MODEL	Units	øR	S	T	UU	UV	UW	U b)	V b)	W b)	X	Y	Z	AA	BB
TM314	mm	11	18	18.5	10	100	120	9h11	14h9	57	294	187.5	125	60	$90\,(^{0}_{-0.05})$
	in	0.433	0.709	0.728	0.394	3.937	4.724	0.3543 0.3508	0.5512 0.5495	2.244	11.575	7.382	4.921	2.362	3.5433 3.5414
TM315	mm	11	18	18.5	10	100	120	9h11	14h9	57	334	187.5	125	60	$90\,(^{0}_{-0.05})$
	in	0.433	0.709	0.728	0.394	3.937	4.724	0.3543 0.3508	0.5512 0.5495	2.244	13.150	7.382	4.921	2.362	3.5433 3.5414

a) Center according to DIN 332-D
b) Keyway according to DIN 6885-A

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

TM 314-317 (SPLINED SHAFT) DIMENSIONS



NOTE: Dimensions are the same for every series (TM and TMHS). Original dimensions are in metric units. Dimensions converted to imperial units have been rounded up to 3 or 4 decimal places.

MODEL	Units	øA	øB	øC a)	øD	øE	F	G	H	J	K	L	M	N	P	øQ b)
TM314	mm	125g6	106	45x50	44h6	52h6	50.7	26.8	106	25	51.5	80	42	28	8	M16
	in	4.9207 4.9197	4.173	45x50	1.7323 1.7317	2.0472 2.0465	1.996	1.055	4.173	0.984	2.028	3.150	1.654	1.102	0.315	
TM315	mm	125g6	106	45x50	44h6	52h6	70.7	26.8	106	25	71.5	80	62	48	8	
	in	4.9207 4.9197	4.173	45x50	1.7323 1.7317	2.0472 2.0465	2.784	1.055	4.173	0.984	2.815	3.150	2.441	1.890	0.315	
TM316	mm	155g6	135	60x65	55h6	70h6	82.7	25.8	124	24	83.5	80	70	50	8	M20
	in	6.1018 6.1008	5.315	60x65	2.1654 2.1646	2.7559 2.7552	3.256	1.016	4.882	0.945	3.287	3.150	2.756	1.968	0.315	
TM317	mm	155g6	135	65x70	60h6	72h6	107.7	25.8	124	24	108.5	80	95	80	8	
	in	6.1018 6.1008	5.315	65x70	2.3622 2.3615	2.8346 2.8339	4.240	1.016	4.882	0.945	4.272	3.150	3.740	3.150	0.315	

MODEL	Units	R	S	T	U	øV	W	UU	UV	UW	X	Y	Z	AA	BB
TM314	mm	18.5	10	134	154	11	18	10	100	120	260	187.5	125	60	90 ($^{0}_{-0.05}$)
	in	0.728	0.394	5.276	6.063	0.433	0.709	0.394	3.937	4.724	10.236	7.382	4.921	2.362	3.5433 3.5414
TM315	mm	18.5	10	134	154	11	18	10	100	120	300	187.5	125	60	90 ($^{0}_{-0.05}$)
	in	0.728	0.394	5.276	6.063	0.433	0.709	0.394	3.937	4.724	11.811	7.382	4.921	2.362	3.5433 3.5414
TM316	mm	18.5	10	150	170	11	18	10	140	160	340	217.5	160	80	105 ($^{0}_{-0.05}$)
	in	0.728	0.394	5.905	6.693	0.433	0.709	0.394	5.512	6.299	13.386	8.563	6.299	3.149	4.1338 4.1319
TM317	mm	18.5	10	150	170	11	18	10	140	160	390	217.5	160	80	105 ($^{0}_{-0.05}$)
	in	0.728	0.394	5.905	6.693	0.433	0.709	0.394	5.512	6.299	15.354	8.563	6.299	3.149	4.1338 4.1319

a) Splines according to DIN 5481
b) Center according to DIN 332-D

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

SYSTEM OPTIONS AND ACCESSORIES

COUPLINGS

When Magtrol TMB, TM and TMHS Series Torque Transducers are to be mounted in a drive train, double-element miniature couplings are the ideal complement, 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

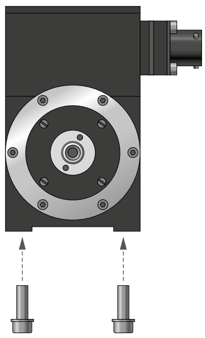
The higher the speed of the application, the more care is required in selecting the coupling and assembling (alignment and balancing) the drive train configuration. Magtrol provides a wide range of couplings suitable for torque measurement applications and can assist you in choosing the right coupling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

Fig. 6: BKC Series Metal Bellows Coupling

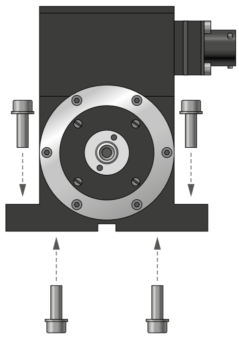
Fig. 7: MIC Series Miniature coupling

FIXATION FOR TM 301-308

MAGTROL has redesigned the mounting system for its small torque transducers (TM 301-308). The new mounting base allows not only installation of the torque transducers from below as before, but also installation from the top. It also integrates a centering key underneath its housing. The old fastening system (from below only) is still available as an alternative.



Old housing (fastening from bottom only)



New housing (fastening from top and bottom)

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. 8: TSB «Torque Speed Box»

TORQUE TRANSDUCER DISPLAYS

Magtrol offers the MODEL 3411 Torque Display which supplies the power to any TM / TMHS / TMB 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
- Torque and speed outputs
- Closed-box calibration
- Includes Magtrol's Torque 7 Software

Fig. 9: MODEL 3411 Torque Display

«TORQUE» SOFTWARE

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

SYSTEM OPTIONS AND ACCESSORIES

CABLE ASSEMBLY

ORDERING NUMBER	ER 1	_ _	/ 0	_

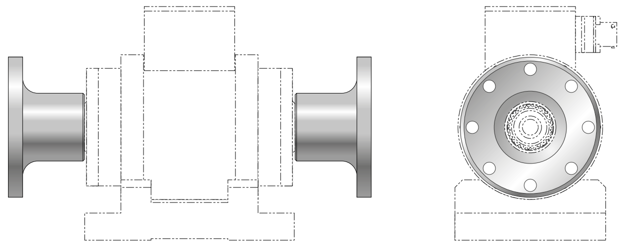
07 : Pigtail wires
13 : 14 Pin connector [a]

1 : Cable length 5 m
2 : Cable length 10 m
3 : Cable length 20 m

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

FLANGES OPTION (for splined shaft)

Adaptation flanges are optional for torque transducers with splined shaft ends. Magtrol flanges are recommended because they are specially designed for Magtrol Torque Transducers.

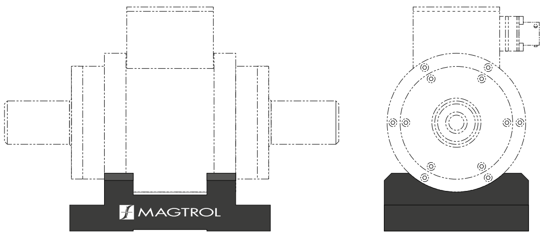


ORDERING NUMBER	FTM 2	_ _

12, 13, ... , 17 : according to TM model

BASE MOUNT OPTION (for TMB Series)

TMB Series Transducers are delivered without base mount.



TMB 309 - 311	PTM 310
TMB 312 - 313	PTM 312

COUNTER CONNECTOR

Axial connector	Souriau 851 06 JC 10 6S 5029
90° connector	Souriau 851 08 EC 10 6S 50

ORDERING INFORMATION

ORDERING NUMBER	TM	_	3	_ _	/ X	_	X

HS : high-speed version (TM 303 - TM 317)
B : basic version (TM 304 - TM 313)

01, 02, ... , 17 : Model TM

1 : Smooth shaft (TM 309 - 313)
2 : Splined shaft (TM 312 - 317)
3 : Keyway shaft (TM 314 - 315)
5 : Smooth shaft (TM 301 - 308) [a]

a) This model is still available with narrow body (fixation from bottom only). (please see options and accessories section)

Example: TM 312 In-line Torque Transducer high speed version with splined shaft would be ordered as : **TMHS 312/X2X**.

2. INSTALLATION / CONFIGURATION

2.1 MOUNTING POSSIBILITIES

Magtrol TM Series Torque In-Line Torque Transducers must, above all, be considered precision measuring instruments and not torque transmission components. The transducer model and the alignment precision highly influence the measuring precision as well as the operating life of the transducer, especially of the bearings and couplings.

There are two different ways of mounting TM Torque Transducers: suspended and supported installation.

2.1.1 SUSPENDED INSTALLATION

Both the measuring shaft and torque transducer housing are supported by the driving and driven machine shafts via couplings (*see Fig.2-1*). In this configuration, couplings offering only one degree of freedom are adequate to avoid a hyperstatic mounting.

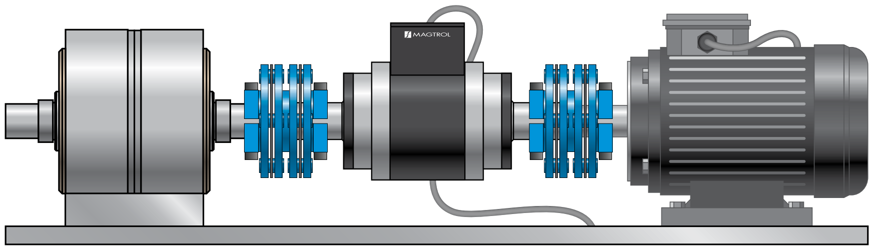


Fig.2-1 Suspended Installation

2.1.1.1 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).

2.1.1.2 DISADVANTAGES

- Increase of radial play as the torque transducer is not directly fixed to the test bench. Consequently, the critical speed is lower than with a supported installation.

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

2.1.2 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.2-2*). Here, couplings with two degrees of freedom must be used in order to avoid hyperstatic mountings.

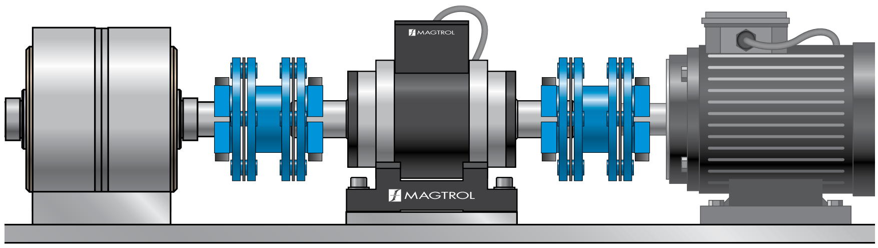


Fig.2-2 Supported Installation

2.1.2.1 ADVANTAGES

- Increased critical speed due to less shaft bending.

2.1.2.2 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.

High-performance couplings can be realized by mounting flanges directly onto a splined torque transducer shaft. (Not available on all models.)

2.1.3 TM / TMB IN VERTICAL INSTALLATION

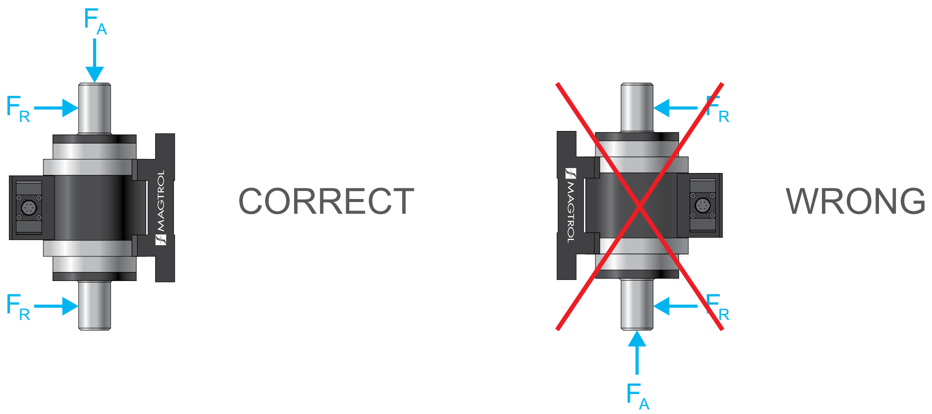
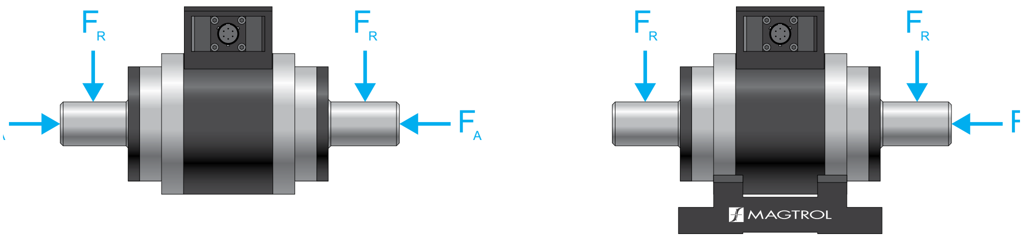


Fig.2-3 Vertical installation

CAUTION PLEASE *SEE SECTION 2.2 - PARASITIC FORCES* OF THIS MANUALS TO UNDERSTAND THE MAXIMUM ACCEPTABLE F_A FORCE!.

2.2 PARASITIC FORCES

Incorrectly mounted torque transducers can generate parasitic forces on the measuring shaft in radial (F_R) and axial direction (F_A) (*see Fig.2-4*).



Suspended installation Supported installation

Fig.2-4 Parasitic Forces

2.2.1 RADIAL FORCES (BENDING)

Radial forces (F_R *see Fig.2-4*) 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 TMB, TM and TMHS Series torque transducer shafts in suspended and supported installations.

MODEL	F_R max. (Suspended installations)	F_R max. (Supported installations)	
		TM / TMB [a)]	TMHS
	N	N	N
TM 301	[b)]	8	N/A
TM 302	[b)]	16	
TM 303	[b)]	25	25
TM 304	20	50	50
TM 305	40	80	80
TM 306	70	120	120
TM 307	60	120	
TM 308	80	160	
TM 309	60	150	150
TM 310	120	300	280
TM 311	200	410	
TM 312	300	570	420
TM 313	500	550	410
TM 314	800	900	680
TM 315	1 100	850	640
TM 316	2 200	1 460	1 090
TM 317		1 300	980

d) If available (*see section 1.3-Fiche technique*)

e) Suspended installation is not recommended for these models

2.2.2 AXIAL FORCES (THRUST)

In suspended installations, pure thrust forces (F_A *see Fig.2-4*) have practically no effect on the measurement results, as they do not provoke 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 maximal axial forces F_A allowed for TMB, TM and TMHS Series transducer shafts in suspended and supported installations.

MODEL	F_A max. (Suspended installations)	F_A max. (Supported installations)
	N	N
TM 301	600	35
TM 302		
TM 303	1 000	
TM 304	1 100	100
TM 305	1 500	
TM 306	2 500	
TM 307	3 500	
TM 308	4 000	
TM 309	4 500	120
TM 310	6 000	
TM 311	10 000	
TM 312	20 000	150
TM 313	30 000	
TM 314	60 000	200
TM 315	80 000	
TM 316	150 000	
TM 317		

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.

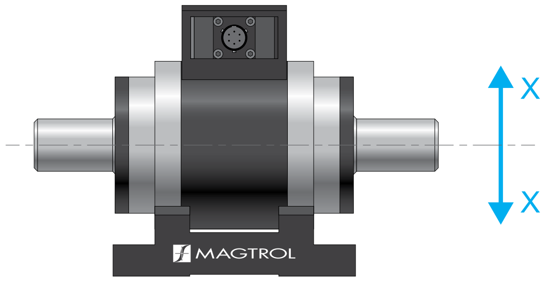


Fig.2-5 Radial displacement

2.3.1 PERMITTED VIBRATIONS ON MEASURING SHAFT

The periodic displacement of the measuring shaft generates vibrations. These vibrations express themselves in either speed (in m/s) or acceleration (in m/s^2 or g)

NOTICE «g» is normally used as a unit for acceleration. It represents the Earth's acceleration of $9.81\ m/s^2$, often rounded up to $10\ m/s^2$.

Both of these parameters depend on the radial displacement and the speed of the shaft. The formulas used to calculate this speed and acceleration are as follows:

Speed: $v = 2 \cdot \pi \cdot n \cdot x$ [m/s]

Acceleration: $a = 4 \cdot \pi^2 \cdot n^2 \cdot x$ [m/s^2]

"x" represents radial displacement, expressed in meters (*see Fig.2-5*)
"n" represents rotational speed, in s^{-1}

The vibratory acceleration of the above is illustrated with the following graph (*see Fig.2-6*)

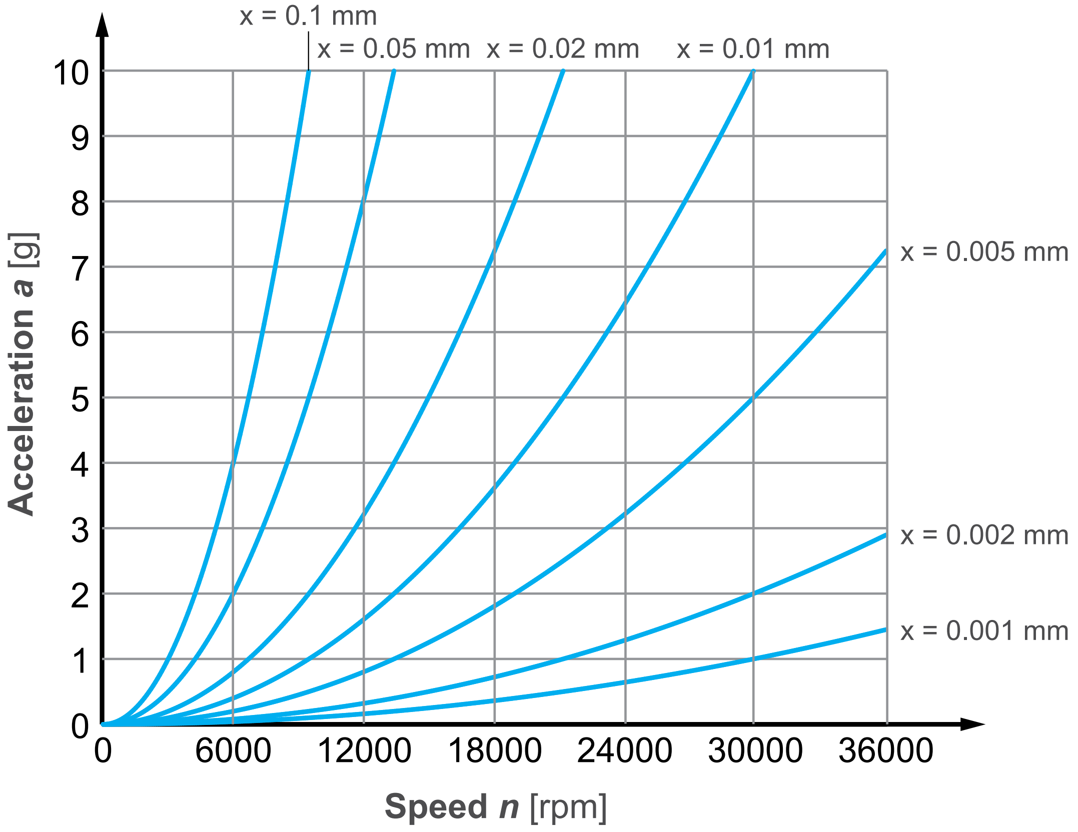


Fig.2-6 Vibratory Acceleration (as a result of radial displacement and rotational speed)

Magtrol TM Series Torque Transducers have been tested by under the following conditions:

2.3.1.1 RANDOM VIBRATION

- Power spectral density of 0.05 g^2 / Hz between 20 Hz and 500 Hz
- 90 minutes of vibration applied along each of the 3 axes (x, y, z)

2.3.1.2 SINUSOIDAL VIBRATION

- Sweep between 10 Hz and 500 Hz at a rate of 1 octave per minute
- From 10 Hz to 60 Hz: 0.35 mm peak-to-peak amplitude
- From 60 Hz to 500 Hz: 5 g peak-to-peak amplitude
- Cycle performed for 90 minutes along each of the 3 axes (x, y, z)

NOTICE The vibratory level as defined (*see section 2.3.1.2 - Sinusoidal Vibration*), should not be exceeded on a regular basis.

2.3.2 TORQUE SIGNAL CONDITIONING ELECTRONIC CIRCUIT

The TM Series Torque Transducer is fitted with a measuring signal conditioning electronic circuit. This conditioning chain is based on a carrier frequency system containing a synchronous demodulator and a second-order Butterworth-type low-pass filter. The filter's cut-off frequency is adjusted by micro-switches (SW1 to SW12) that are accessible by removing the cover of the transducer's builtin electronics (*see Fig.2-7*). The various setting possibilities are indicated on a label affixed to the back of this cover.

Some applications may warrant fine adjustment of the torque transducer zero point. To activate the offset adjustment potentiometer, simply positioning the SW12 micro-switch to ON. A full-scale zero adjustment of ±10% equivalent to ±0.5V can then be carried out by the potentiometer. With the SW12 micro-switch to OFF, the default settings are used.

NOTICE There are no functions allocated to the SW11 micro-switch.

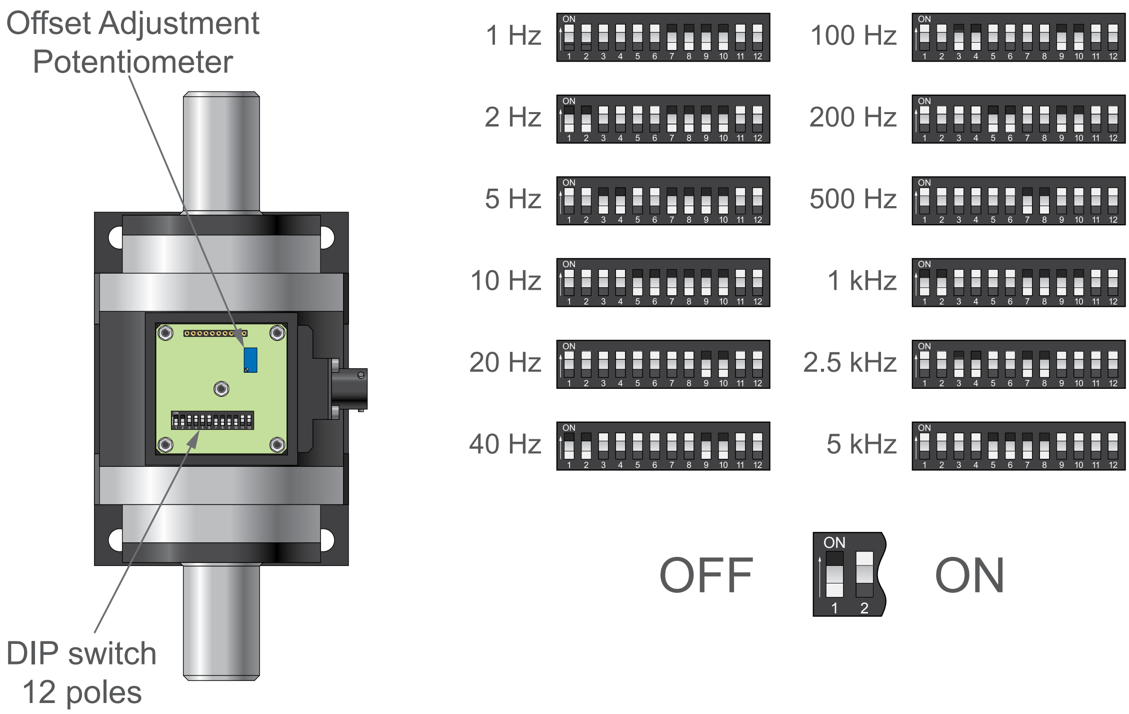


Fig.2-7 SW1 – SW12 Micro-switches and Offset Adjustment Potentiometer

2.4 MOUNTING LIMITS

Magtrol torque sensors have been designed to accept a decent reserve for measurement over the nominal torque. They can measure up to 200% of their rated torque. It is however important not to overpassed this limit to avoid plastic deformation and permanent deterioration of the sensor's performances.

By sensor with very low nominal value, the installation and in particular the couplings tightening should be done with care in order not to overload the sensor

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 TM Series Torque Transducers 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.

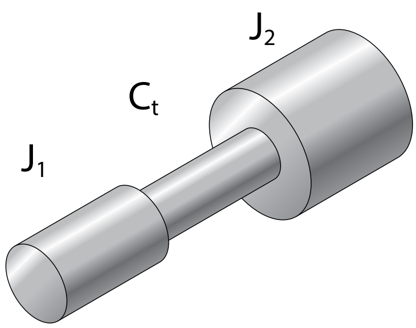


Fig.2-8 Simplified Drive Train Model

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

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) [kgm^2]

J_2 Moment of inertia (driven machine + coupling + ½ of the measuring shaft) [kgm^2]

NOTICE The natural torsional frequency of the drive train is lower due to the presence of the TM Torque Transducer. The system's own natural frequency must then be recalculated to determine the influence of the TM 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 data sheets (*see section 1.3 - Datasheet*). 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 data sheet. 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.

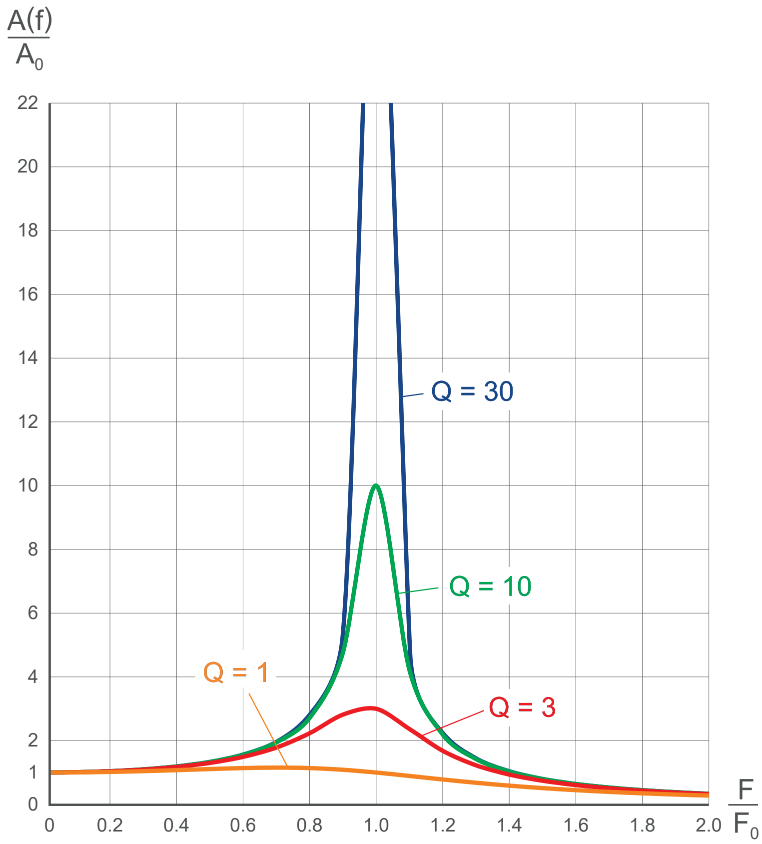


Fig.2-9 Frequency Response Graph

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. Consequentially, the frequency of the drive train torsional oscillations should be less than ~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 lists the natural frequency of each TM Torque Transducer.

MODEL	Natural Torsional Frequency Hz
TM 301	N/A
TM 302	171
TM 303	255
TM 304	355
TM 305	476
TM 306	665
TM 307	903
TM 308	1 058
TM 309	613
TM 310	879
TM 311	1 096
TM 312 TM 312/X2X (Splined shaft)	1 168 1 150
TM 313 TM 313/X2X (Splined shaft)	1 405 1 338
TM 314 TM 314/X2X (Splined shaft)	1 227 1 269
TM 315 TM 315/X2X (Splined shaft)	1 302 1 334
TM 316	1 219
TM 317	1 212

NOTICE All three versions (TMB, TM and TMHS) of each model are equipped with the same measuring shaft.

2.4.4 MAXIMUM DYNAMIC AMPLITUDE

The dynamic peak-to-peak amplitude must not exceed 200 % of the nominal torque of the TM Transducer. This is even true with alternating loads. This amplitude must remain within a range of -200 % $M_{nominal}$ and +200 % $M_{nominal}$ (*see Fig.2-10*).

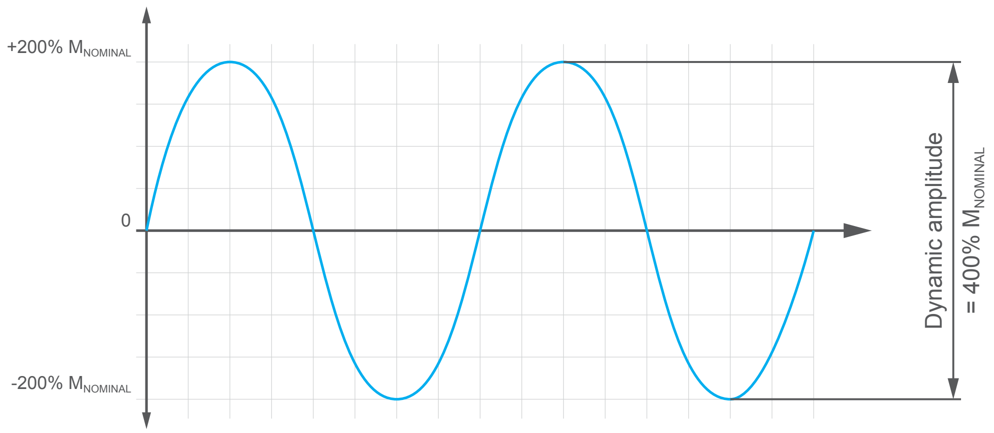


Fig.2-10 Admissible Dynamic Load

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.

WARNING THE ASSEMBLY AND INSTALLATION OF THE SYSTEMS MUST COMPLY WITH MACHINE SAFETY STANDARDS (ISO 12100 OR SIMILAR APPLICABLE STANDARDS).

Below is an example of a protective system (*see Fig.2-11 to Fig.2-13*). All parts of the bench are accessible, but the covers prevent any risk to the user when closed.

Fig.2-12 Turnkey customized test bench with retractable guard.

Fig.2-11 Test bench with fixed and movable metal guard with safety switch.

Fig.2-13 Custom motor test system with control rack and full safety protection all around the test table.

2.6 ELECTRONIC SIGNAL PROCESSING

Magtrol offers electronic processing units that collect signals from its transducers and displays them on an LCD screen. These units have also been designed for digital processing of the measured values.

2.6.1 MODEL 3411 - TORQUE DISPLAY

The MODEL 3411 - Torque Display processes the torque and speed signals, displays the measured torque and speed values, and displays 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 with each MODEL 3411 - Torque Display.

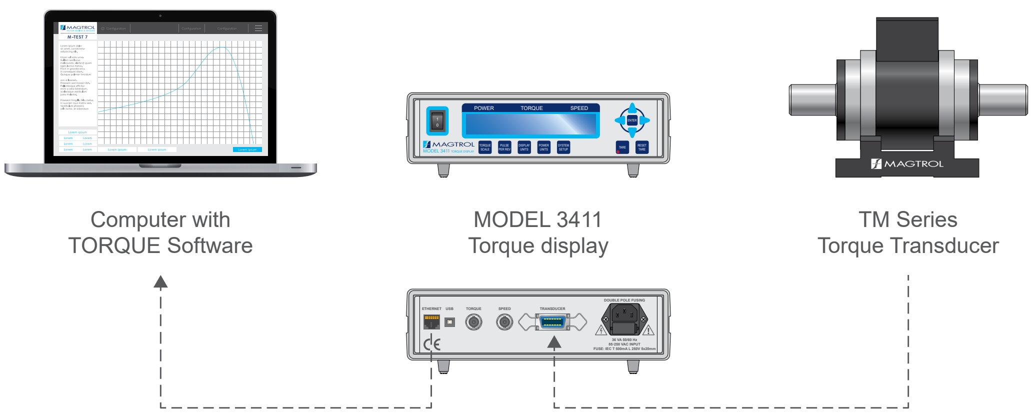


Fig.2-15 PC-Based System Configuration with MODEL 3411 - Torque Display

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).

2.6.2 DSP 7000 - HIGH-SPEED 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 TM Series In-Line Torque Transducers, with TS Series Torque Sensor and is also designed to work with any Magtrol HD, WB, PB or TANDEM Dynamometer. Therefore, any Magtrol Ddynamometer can be used in conjunction with any TM Transducer with both being controlled by the same unit.

Fig.2-16 DSP 7000 | High-Speed 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 HD Series Dynamometer and TM Series Torque Transducer are used in conjunction with a DSP 7000 Programmable Dynamometer Controller

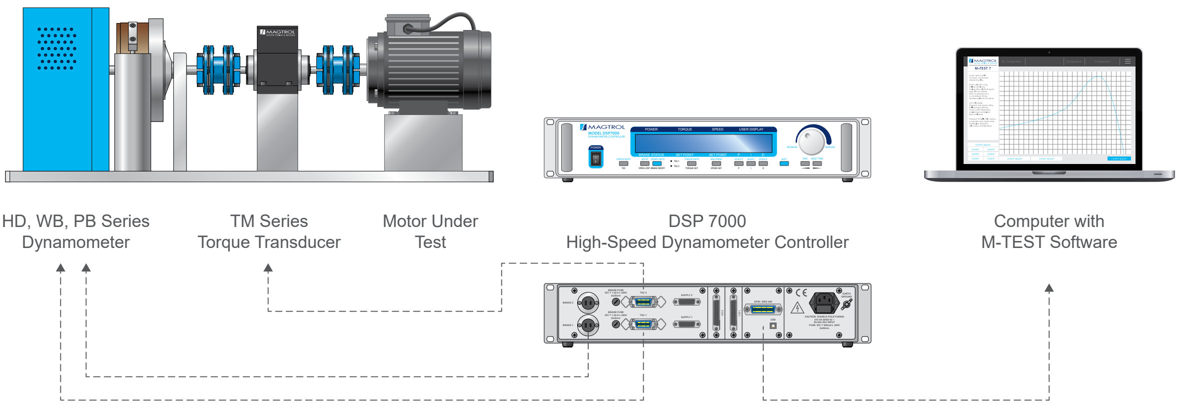


Fig.2-17 Computer-Based System Configuration with Model DSP 7000 Dynamometer Controller

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.

2.7 ELECTRICAL CONNECTIONS

NOTICE The connecting cable assembly (ER 113-0X) consists of a cable with 4 shielded twisted pairs of wires to connect the torque transducer to its signal processing electronic unit. This assembly must be ordered separately.

Connecting the TM In-Line Torque Transducer is extremely simple. Having installed the drive train, only one electrical cable needs to be connected for the system to be operational.

2.7.1 GROUNDING

CAUTION BEFORE CONNECTING THE TM TORQUE TRANSDUCER TO THE SIGNAL PROCESSING UNIT, THE TRANSDUCER'S HOUSING MUST FIRST BE EARTHGROUNDED

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

With supported torque transducer installations, the support connects the transducer with the test bench grounding. On suspended installations, a special wire needs to be drawn from the transducer's housing to the common ground (*see Fig.2-18*).

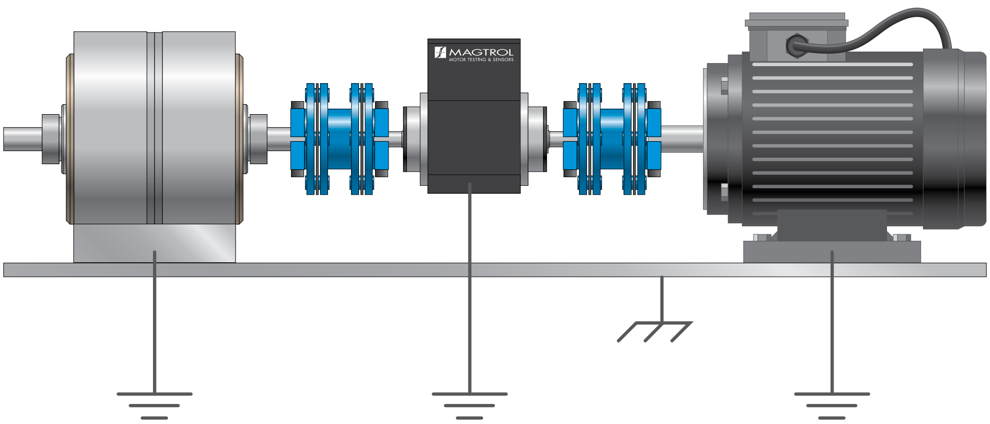
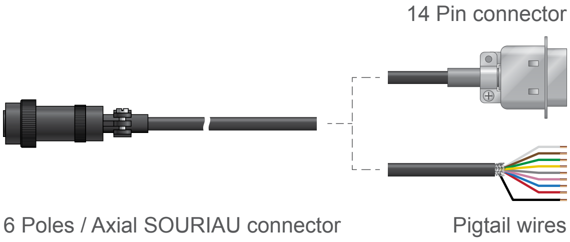


Fig.2-18 Common Grounding.

2.7.2 CONNECTING CABLE

The connecting cable to the selected signal processing unit is fitted with a 6-pin connector on the transducer side and a 14-pin connector on the side of the signal processing unit or pigtail wires for cutomized connection (*see Fig.2-19 and Fig.2-20*).



ORDERING NUMBER	ER 1	_	/ 0	_
07 : Pigtail wires **13** : 14-pin connector [a]		●		
1 : Cable length 5 m **2** : Cable length 10 m **3** : Cable length 20 m				●

a) For use with 3411 Torque Display or DSP7000 Controller

2.7.3 CABLE ASSEMBLY ER107 (PIGTAIL WIRES)

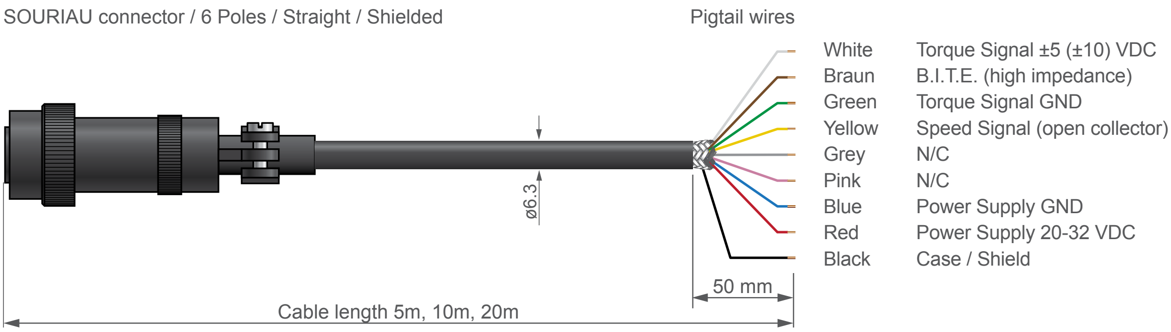


Fig.2-19 Cable ER107 - Pin Configuration

The connection cable to the signal processing unit is fitted with a 6-pole axial connector for connection to the TM Torque Sensor and, on the opposite side, with free ends for connection as required.

NOTE The B.I.T.E. test function is only active when the input (brown) is grounded.

2.7.4 CABLE ASSEMBLY ER113 (14-PIN CONNECTOR)

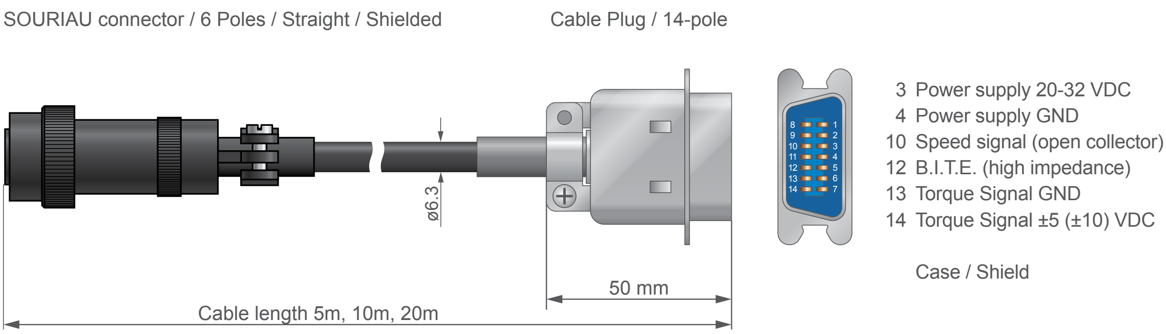


Fig.2-20 Cable ER113 - Pin Configuration

The connection cable to the signal processing unit is equipped with a 6-pole axial connector for connection to the TM torquemeter and, on the opposite side, a 14-pole connector for connection to the signal processing unit (MODEL3411, DSP7000,...).

NOTE The B.I.T.E. test function is only active when the pin n°12 is grounded.

2.7.5 CONNECTION TO NON-MAGTROL ELECTRONICS

To connect the Torque Transducer to electronic devices not manufactured by Magtrol, refer to the connection diagram below (*see Fig.2-21*).

A Differential Amplifier is required for elimination of potential DC voltage developing in the 0 V leg (0 V_{AL}). 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.

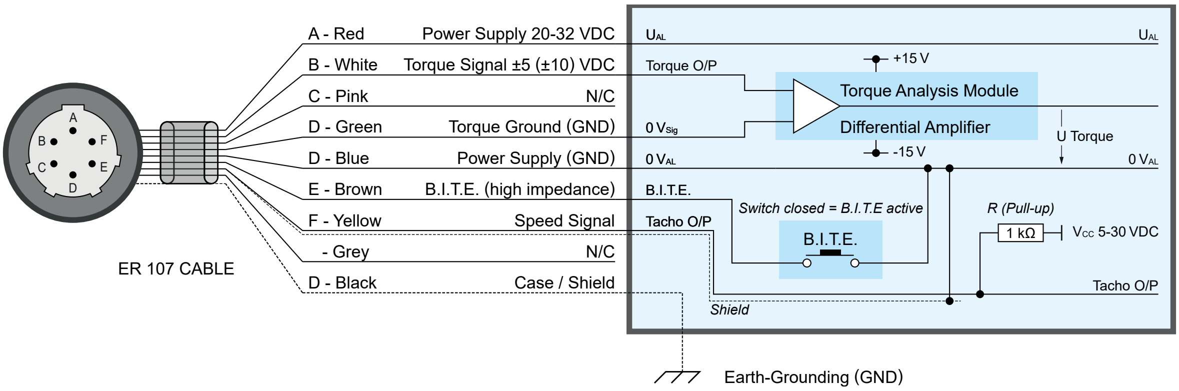


Fig.2-21 Wiring Diagram for Connection to Non-Magtrol Electronics

2.7.5.1 PULL-UP RESISTANCE

A pull-up resistor must be incorporated into the circuit. Pull-up resistance should be set to the following, dependent upon the V_{CC} of the application.

V_{CC}	Pull-up resistance
5 V DC	1 kΩ
20 - 32 V DC	4.7 kΩ

NOTE If the electronics used for speed measurement already has its own internal pull-up resistor, make sure the setting is in accordance with the table above.

2.7.5.2 TACHOMETER SIGNAL CONTAINMENT SHIELD

Magtrol recommends isolating the «Tacho» signal from other signals by using a separate shielded wire to minimize the noise of the «Tacho» signal that can be injected on the «Torque» signal.

Alternatively, Magtrol recommends using ER107 or ER113 cable (*voir Fig.2-22*).

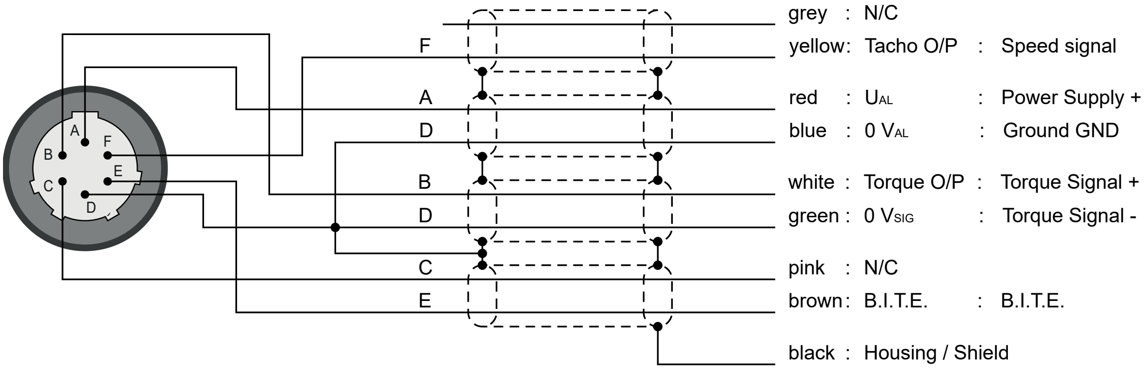


Fig.2-22 ER107 - Cable connection diagrams

3. OPERATING PRINCIPLES

The TM Series In-Line Torque Transducer can be defined as an inductive transducer operating on the basis of a differential voltage transformer having a variable coupling factor.

3.1 TORQUE TRANSDUCER ARCHITECTURE

The part of the transducer effectively measuring the torque is composed of three elements: a shaft with a deformation zone, a pair of coils and two metallic cylinders.

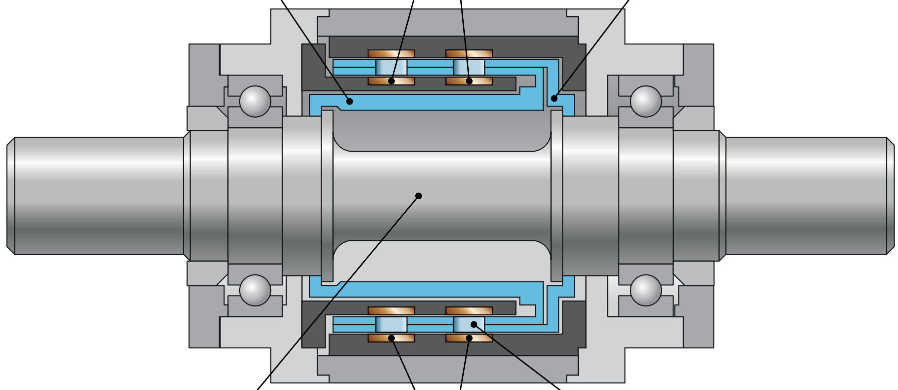


Fig.3-1 TM Torque Transducer Principal Elements

The primary and secondary coil composing the differential transformer are separated by two concentric aluminum cylinders. These cylinders are connected to the torque measuring shaft—the external cylinder on one side of the deformation zone and the internal cylinder on the opposite side. Both cylinders have two series of slots on their surface. When there is no torque being applied to the measuring shaft, the slots in both cylinders fail to overlap. Because the cylinders are non-magnetic, there is total screening and differential induction cannot be generated between the primary and secondary coil.

As torque is applied to the shaft, the deformation zone undergoes increasing angular deformation. As torque is sensed, the overlap between the slots increases creating an opening for the induction flux. The amount of differential induction is proportional to the applied torque. In this way, when the primary coil is excited by a sinusoidal voltage, the secondary coil produces a voltage whose magnitude is dependent on the applied torque.

3.1.1 DIFFERENTIAL TRANSFORMER

The primary coil of the transformer consists of two equal windings mounted in series. It is excited by an alternative current having a frequency of 20 kHz which is generated by the transducer's built-in electronics. In addition, a constant current is supplied to the primary coil in order to determine the temperature of the entire measuring unit and to compensate the temperature signal.

The secondary coil consists of two windings in phase opposition. This determines the spacing between the cylinder slots and produces a torque-proportional dynamic voltage signal.

3.2 SPEED CONDITIONING CHAIN

A speed transducer is incorporated into the torque transducer housing in order to measure the rotational speed of the measuring shaft. This optical transducer is mounted facing a toothed part of the rotor and produces 60 pulses per revolution.

3.3 BUILT-IN SELF-TEST CIRCUIT (B.I.T.E.)

The torque transducer's connector has a pin allocated for activating a test signal. When this pin is held low (logic 0), a test signal equivalent to +5 V DC is activated which superimposes itself to the torque measuring signal. Therefore, this self-test may be carried out at while the transducer is in use. The signal is supplied by the control electronics.

The self-test circuit checks the correct functioning of the torque signal conditioning unit. This function, however, does not in any way obviate the need for a static calibration of the transducer.

4. MAINTENANCE, REPAIR & CALIBRATION

4.1 MAINTENANCE

Magtrol TM Series In-Line Torque Transducer 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 TM 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.**

4.2 REPAIR

In case of a defect, please see chapter *see chapter SERVICES 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 *see chapter SERVICES INFORMATION* of this manual.

4.3 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.

4.4 PACKAGING

The TM 301 to TM 308 are delivered with specific packaging designed to store the sensor while not in use as well as to return the sensor to Magtrol for annual calibration. **For this one, please keep the packaging!**

REVISIONS TO THIS MANUAL

The contents of this manual are subject to change without prior notice.

To ensure that you have the latest version, compare the issue date (on the back of this manual) with the last updated document available on our website.

The table of revisions below lists the significant updates that have been made.

REVISION DATES

DATE	EDITION	CHANGE	SECTION(S)
Dec. 2020	2nd Edition - rev. A	Updated all informations concerning the new TM Series; Global update regarding the continuous updates; Global reorganization and new design for the manual	All
May 2017	1st Edition - rev. H	New TM Series data sheet was added.	1.3
June 2011	1st Edition - rev. G	Accuracy update for TMB 301 to 313	1.3.1, 1.3.2
May 2011	1st Edition - rev. F	Overload limit updated	1.3.1, 1.3.2, 1.3.3
Oct. 2010	1st Edition - rev. E	Added information regarding vertical installation of a TM/TMB	2.1.3
July 2009	1st Edition - rev. D	Added information regarding connection to an differential amplifier	2.7.3
Sept. 2008	1st Edition - rev. C	Updated: Figure 2–3 Parastic Forces	2.2
Dec. 2007	1st Edition - rev. B	New transducer model: TM 309	1.3.2, 2.2.1, 2.2.2, 2.4.3
Oct. 2007	1st Edition - rev. A	Added information regarding connection to non-Magtrol electronics.	2.7.3

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