MOTION TECHNOLOGY

Torque motors series

Torque motors

Handbook

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Record of revisions concerning the torque motors handbook:

Document revisions		
Issue (x)	Date	Modified
Ver A	01.10.04	First version for TMB torque motors family
Ver B	13.09.05	Updated version: - New TML and TMM torques motors - New bridge
Ver C	22.05.07	Updated version: - TML0140 and TML0175 have been removed - Bridge codification modified (refer to §3.3) - New thermal sensor configuration (refer to §6.3) - Redundant option of the IMSPS removed (refer to §7.3) - Thermal protection interface (refer to §7.4) - Handling procedure modified (refer to §8.3.1)
Ver D	30.06.08	Updated version: - New torque motors family: TMK (first three diameters)
Ver E	12.07.10	Updated version: - TMB1220 replaced by TMB1221 - TMK bridges (refer to §3.3.4 and §7.2.1) - Field weakening (refer to §5.5) - Coolant characteristics improved (refer to §6.1.4) - Technical details improved and added (refer to the modification strokes)

Documentation concerning the torque motors series:

- **Torque-Motors-Handbook-VerE** **(Sizing, mechanical & electrical integration guide)**
- Data sheets (Mechanical & electrical specifications, refer to website)

EC conformity

Taking into account that ETEL motors are not considered as a “Partly completed machinery” according to the article 2-g of the Machinery Directive 2006/42/EC and, that ETEL motor bus voltage is below 1500 VDC, ETEL motors are designed, built and tested according to the Low Voltage Directive 2006/95/EC.

Therefore, ETEL S.A. certifies that motors described in the present handbook meet the requirements stated in the Low Voltage Directive 2006/95/EC.

ETEL motors are not allowed to be put into service until the machinery into which they are to be incorporated has been declared in conformity with the requirements of the Machinery Directive 2006/42/EC and the Electromagnetic Compatibility Directive 2004/108/EC.

1. Introduction

1.1 Purpose

This manual explains the use of ETEL's torque motors series (TMB, TML, TMM and TMK families). It provides the customer with the necessary information (specification, installation, interfacing and hardware) to select, integrate, operate and maintain a torque motor.

ETEL's responsibility is limited to the torque motor alone and does not cover the whole user's system. If any malfunction or technical problem arises, for which a solution is not described in this manual, please contact ETEL SA for technical support.

The data specified in this manual is for product description only and may not be guaranteed unless expressly mentioned in a contract.

Remark: The updates between two successive versions are highlighted with a modification stroke in the margin of the manual.

1.2 Safety

1.2.1 Principle

The user must have read and understood this documentation before carrying out any operation on a torque motor. Please contact ETEL or authorized distributors in case of missing information or doubt regarding the installation procedures, safety or any other issue.

	Caution	**ETEL SA disclaims all responsibility to possible industrial accidents and material damages if the procedures & safety instructions described in this manual are not followed.**

1.2.2 Importance of safety instructions

It is compulsory to follow the safety instructions described in this manual (each paragraph includes its own safeties) to avoid injuries and damages to the property and the environment. Similarly, the torque motor must comply with the local regulations, preventive accident measures and environmental protection, which are in force in the country of installation. The recognized technical rules for safe and appropriate working practices should also be followed.
Noncompliance with the safety instructions, legal and technical regulations may lead to injuries and damage to property and environment.

1.2.3 Safety symbols

The safety symbols placed on the hardware or written in the manual must be respected.

Safety symbols		
	Warning	Signals a danger of electrical shock to the operator. **Can be fatal to a person.**
	Caution	Signals a danger for the hardware. Can be destructive for the equipment. A **dangerous condition** for the operator can result from it.
	Caution	The magnetic component (rotor) must not be placed close to metallic parts or other magnetic components. Attraction forces between the rotor and the stator are very high.
	Warning	Indicates possibility of injury to the user (moving parts can crush fingers, hand,...) The component (rotor) must be handled carefully and held far away from metallic parts, stators and other rotors. It indicates powerful magnetic induction, dangerous for the user.
	Warning	Indicates powerful magnetic induction, dangerous for the user. Magnetic induction can cause irreversible heart troubles to people wearing an electrical assistance.

	Caution	Do not approach items which are sensitive to magnetic induction such as watches, credit cards, ...
	Caution	Do not approach ferromagnetic material.
	Caution	Indicates a device sensitive to ESD (**E**lectro**S**tatic **D**ischarges). All necessary precautions against ESD must be taken by the user.

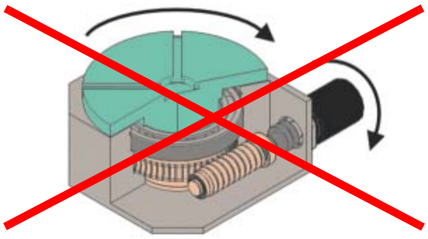
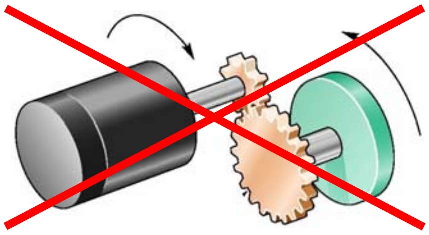
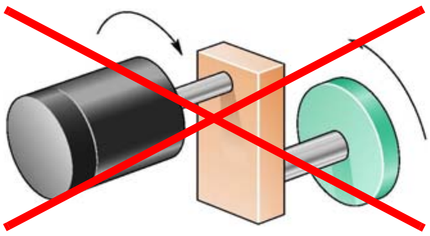
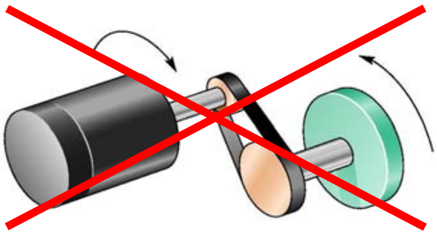
1.2.4 General safety instructions

Please read all safety precautions listed below before handling a torque motor:

General precautions	
	1. Anyone having active implants (pacemakers) or having any other ferromagnetic prosthesis is not qualified to work with these kinds of devices, or to approach them. Keep at a safe distance from the motor!
	2. Electronic devices and measuring equipment may be affected or destroyed by strong magnetic induction. Avoid placing devices with magnetic parts close to computers, monitors and all magnetic data carriers (e.g. disks, credit cards, audio and video tapes, etc). **3.** Warning information such as "**Strong Magnetic induction**" or "**High Magnetic Forces** or **Attraction**" must be visible on the users machine. **4.** According to state-of-the-art medical findings, magnetic induction of less than 5 mT has no effect on the human organism. At a distance of approximately 30 mm (rotor inside the stator), the flux density is less than 3 mT. As the distance from the motor increases, the magnetic induction intensity decreases. **5.** Because of the strong attraction forces, special caution is required in the direct proximity of the rotor (i.e. under 100 mm). Heavy or wide objects made of steel or iron must never be brought close to the rotor by free hand. As magnetic forces are invisible, their effects are generally underestimated close to the rotor. The magnetic attraction forces may start abruptly and can increase up to several thousand Newtons near ferromagnetic objects (steel or iron) of medium size.
	6. Always wear adequate working clothes and protective equipment (e.g. gloves, shoes, etc). when handling a motor. **7.** Assembly and operation must be carried out only by qualified and trained personnel. **8.** In the event of an accident while handling the motor, **always have on hand at least two wedges** (approx. 10°-15°) of solid, non-magnetic material (f.e. aluminum) as well as a non-magnetic hammer (approx. 2-3 kg). In emergency cases, these tools are for separating parts magnetically attached to the rotor in order to free caught limbs (finger, hand, foot). Never place a stator directly on a rotor. **9.** The electrical safety of the torque motor will be ensured only if the electrical installation of the building complies with the national or specific applications domain regulations. **10.** ETEL's torque motors cannot be powered directly from the mains. **11.** Leakage current exceeds 3.5mA in normal operation. **12.** Prevent contact with live parts at any time. **13.** Before working with a torque motor, the power supply must be disconnected. Make sure the machine cannot be switched on unintentionally. **14.** Before switching on the power, the ground wire must be permanently connected to all electrical units. **15.** No third party spare parts must be used without prior approval from ETEL. **16.** Troubleshooting and servicing must be performed only by ETEL's technicians or authorized distributors.
What to do in case of emergency	
	1. Immediately stop the machine. **2.** Switch **OFF** all the power supplies. **3.** Call for First Aid.

2. Technology

In most applications, the direct drive technology offers tremendous benefits compared with the other technologies (worm gear, gear train, reducer, timing belt...). The load is directly coupled to the motor's rotating part, resulting in an efficient and effective gearless construction.

Worm gear	Gear train
	
Reducer	**Timing belt**
	

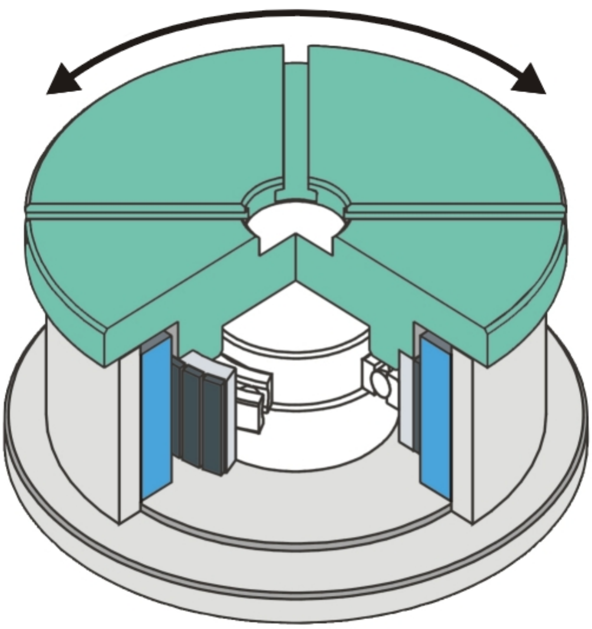
Here are the benefits of the torque motor technology:

REDUCED COST:
The machine's mechanical part count is lowered, and the servo torque motor requires no maintenance.

EXTENDED LIFETIME, RELIABILITY and RIGIDITY:
Torque motors are inherently simple, with an absolute minimum number of moving parts which are not subject to wear.

HIGH ACCURACY AND REPEATABILITY:
The backlash and hysteresis inherent in mechanical transmission elements are suppressed.

HIGH DYNAMIC PERFORMANCE AND HIGH EFFICIENCY:
No energy is used in driving heavy power transmission parts. Direct drive torque motors provide the highest torque-to-inertia ratio where it counts at the load.



3. Motor description

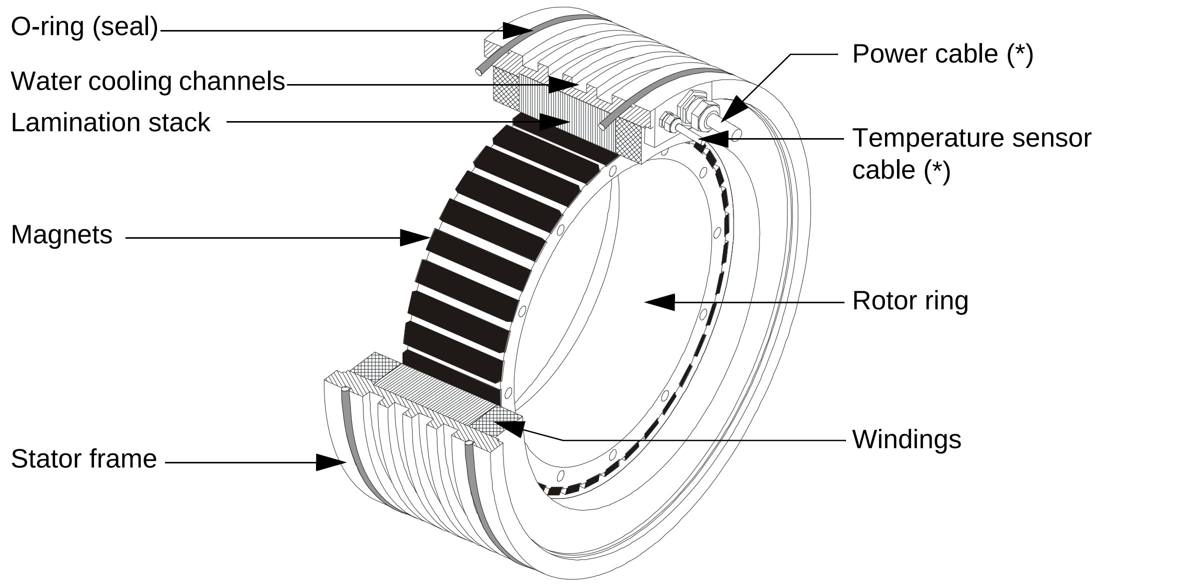
3.1 General view

ETEL's brushless ring torque motors (TMB, TML, TMM and TMK) are frameless and do not include bearings or an encoder. Each torque motor is made up of two independent parts, the rotor and the stator.

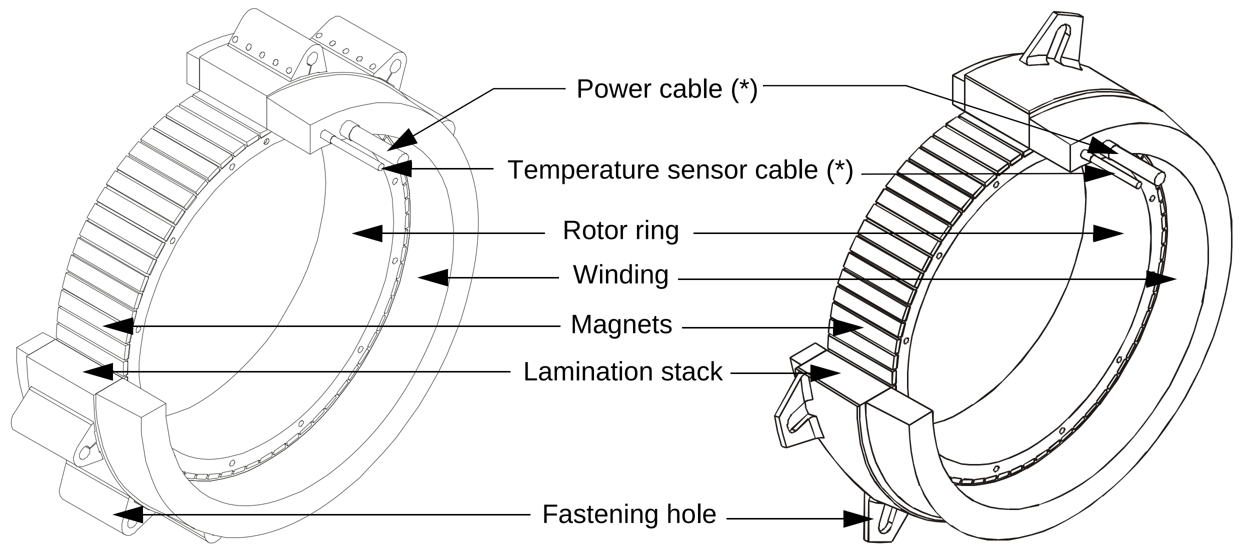
- The stator is the static outer ring of the motor. It is made of steel and includes the lamination stack and the windings. The windings are filled with potting to improve motor thermal behavior and insulation. Phase interconnections are made inside the winding and leads are brought out for the electronic connection. On the TMB and TMK series motors, channels for water cooling are directly machined in the stator frame.
- The rotor is the rotating part of the motor. It is a steel ring with bonded neodymium-iron bore permanent magnets coated with a thin layer of epoxy to protect them from corrosion.

ETEL's patented design provides a remarkably high motor constant Km, compactness and very low thermal resistance. The motor is electrically shielded in order to comply with EMC (ElectroMagnetic Compatibility) standards.

TMB

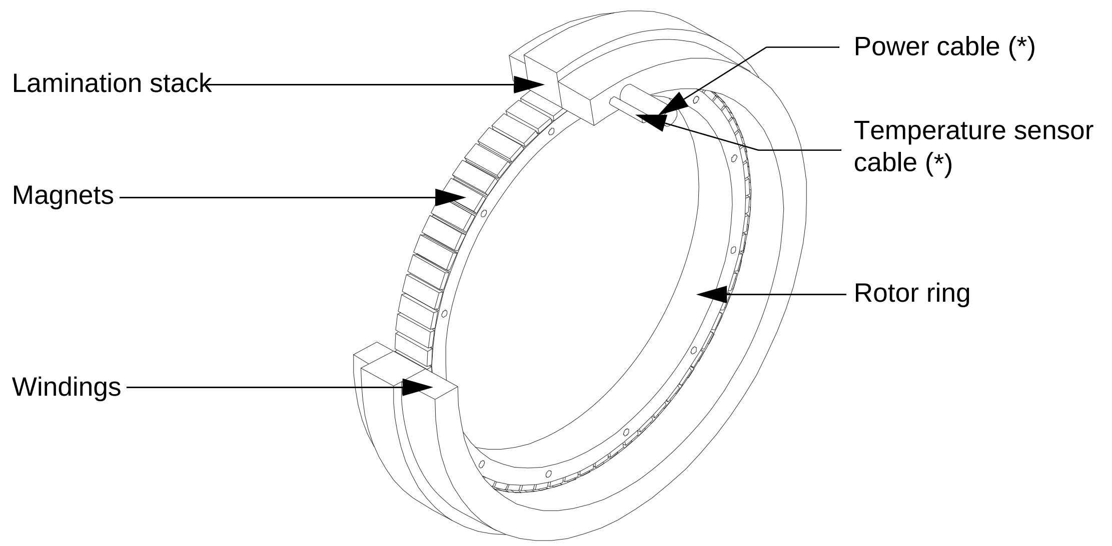


TML

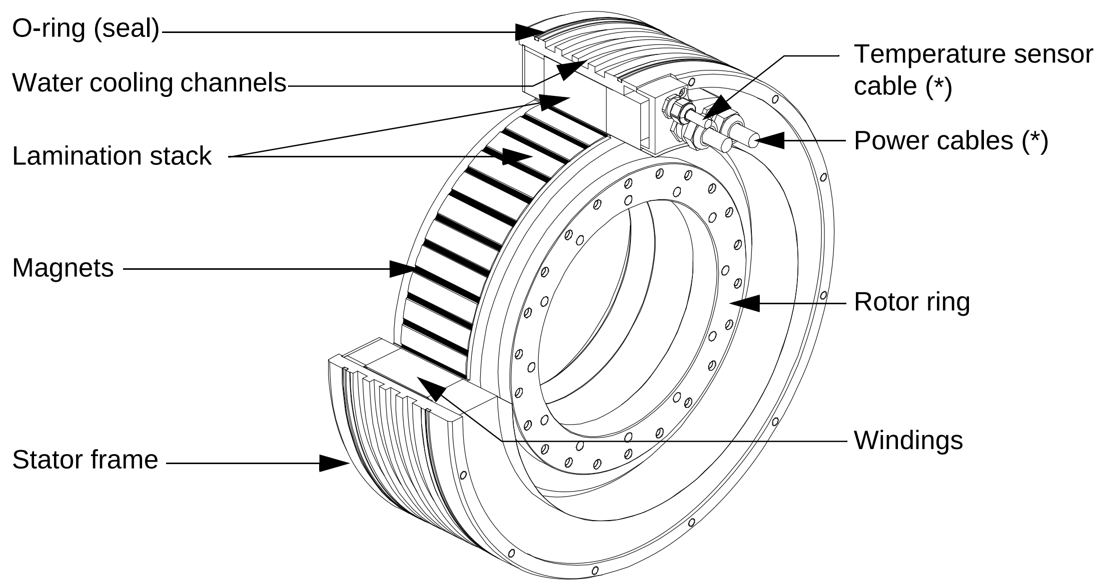


From TML0210 to TML0291 From TML0360 to TML0530

TMM



TMK



(*): Unless specially requested, ETEL's torque motors are delivered with a 2 meter shielded cable and without connectors.

The rotor and the stator of all torque motors (except the stator of the TML and TMM) are protected, during the transport and the storage, by a rust-proofing protection (Corro protect). This protection is guaranteed during 6 months under the condition that the motor remains in its original packaging.

Remark: All the torque motors can be delivered with a bridge holding the rotor and the stator together. The two parts are axially aligned before fastening them with the bridge (refer to §7.2.1 for more information about the bridges).
Refer to §3.2.1 for more information.

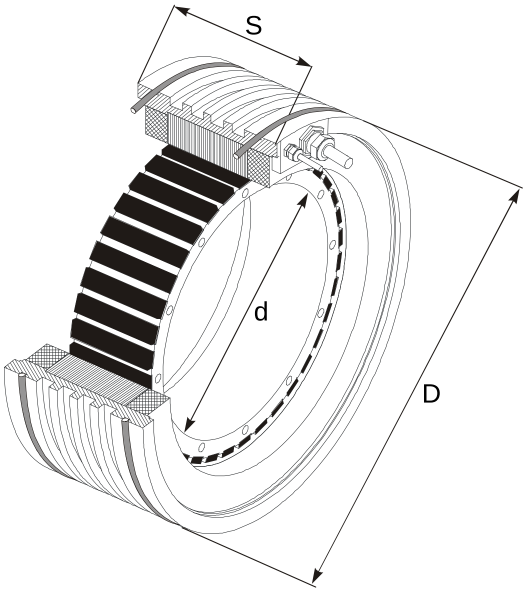
The TMB, TML and TMM motors have the same electromagnetic design which means that their peak torque values are identical. However, their continuous torque values are not the same (higher for TMB motors) because the TMB torque motors are equipped with a cage (higher dissipation surface) surrounding the lamination stack which is not the case for the TML and TMM (cageless). The electromagnetic design of the TMK, which is different from the one of the other motors, produces on average a 30% continuous torque increase. Refer to the corresponding data sheets for more information.

3.2 Motor families

3.2.1 Motor size range

3.2.1.1 TMB family

The TMB torque motor family is made up of 10 different motor diameters with 5 possible widths.



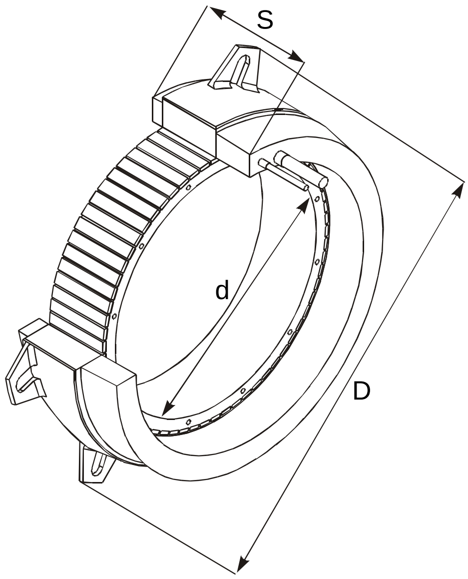
Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TMB0140-030	160	60	70
TMB0140-050	160	60	90
TMB0140-070	160	60	110
TMB0140-100	160	60	140
TMB0140-150	160	60	190
TMB0175-030	198	90	80
TMB0175-050	198	90	100
TMB0175-070	198	90	120
TMB0175-100	198	90	150
TMB0175-150	198	90	200
TMB0210-030	230	140	70
TMB0210-050	230	140	90
TMB0210-070	230	140	110
TMB0210-100	230	140	140
TMB0210-150	230	140	190
TMB0291-030	310	200	80
TMB0291-050	310	200	100
TMB0291-070	310	200	120
TMB0291-100	310	200	150
TMB0291-150	310	200	200
TMB0360-030	385	265	90
TMB0360-050	385	265	110
TMB0360-070	385	265	130
TMB0360-100	385	265	160
TMB0360-150	385	265	210

Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TMB0450-030	485	345	90
TMB0450-050	485	345	110
TMB0450-070	485	345	130
TMB0450-100	485	345	160
TMB0450-150	485	345	210
TMB0530-030	565	420	90
TMB0530-050	565	420	110
TMB0530-070	565	420	130
TMB0530-100	565	420	160
TMB0530-150	565	420	210
TMB0760-030	795	650	110
TMB0760-050	795	650	130
TMB0760-070	795	650	150
TMB0760-100	795	650	180
TMB0760-150	795	650	230
TMB0990-030	1030	870	110
TMB0990-050	1030	870	130
TMB0990-070	1030	870	150
TMB0990-100	1030	870	180
TMB0990-150	1030	870	230
TMB1221-030	1288 & 1290	1070	110
TMB1221-050	1288 & 1290	1070	130
TMB1221-070	1288 & 1290	1070	150
TMB1221-100	1288 & 1290	1070	180
TMB1221-150	1288 & 1290	1070	230

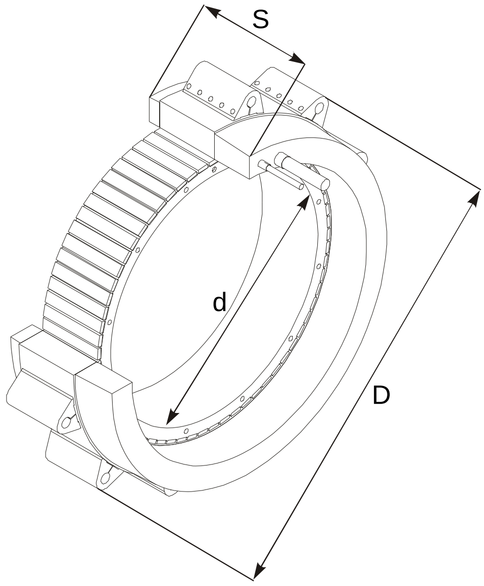
Remark: Refer to the corresponding torque motor data sheet and interface drawing (available on our website) for more information about the motors.

3.2.1.2 *TML family*

The TML torque motor family is *made* up of 5 different motor diameters with 5 possible widths.



From TML0210 to TML0291



From TML0360 to TML0530

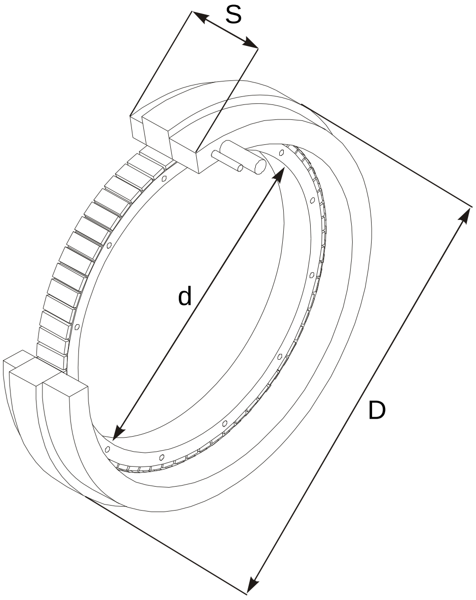
Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TML0210-030	255	140	77.5
TML0210-050	255	140	97.5
TML0210-070	255	140	117.5
TML0210-100	255	140	148
TML0210-150	255	140	198
TML0291-030	335	200	90.5
TML0291-050	335	200	110.5
TML0291-070	335	200	130.5
TML0291-100	335	200	161
TML0291-150	335	200	211
TML0360-030	411	265	90.5
TML0360-050	411	265	110.5
TML0360-070	411	265	130.5
TML0360-100	411	265	161
TML0360-150	411	265	211

Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TML0450-030	502	345	90.5
TML0450-050	502	345	110.5
TML0450-070	502	345	130.5
TML0450-100	502	345	161
TML0450-150	502	345	211
TML0530-030	582	420	90.5
TML0530-050	582	420	110.5
TML0530-070	582	420	130.5
TML0530-100	582	420	161
TML0530-150	582	420	211

Remark: Refer to the corresponding torque motor data sheet and interface drawing (available on our website) for more information about the motors.

3.2.1.3 *TMM family*

The TMM torque motor family is made up of 7 different motor diameters with 5 possible widths.



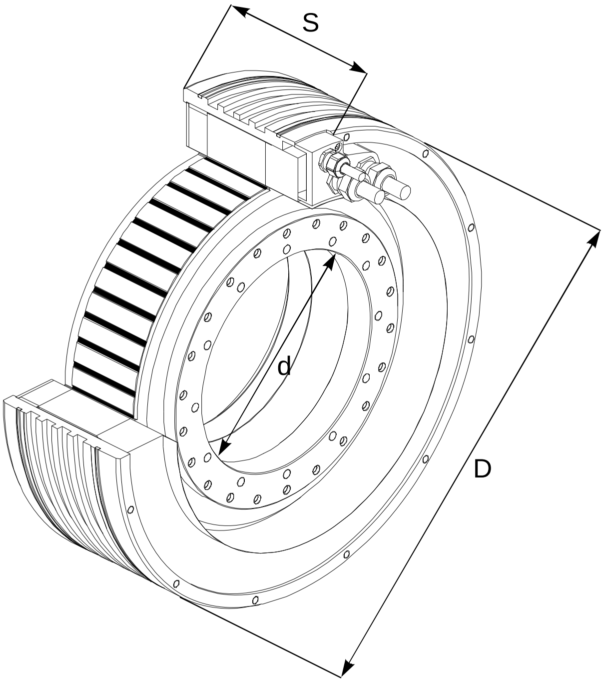
Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TMM0140-030	140	60	75.5
TMM0140-050	140	60	95.5
TMM0140-070	140	60	115.5
TMM0140-100	140	60	146
TMM0140-150	140	60	196
TMM0175-030	175	90	80.5
TMM0175-050	175	90	100.5
TMM0175-070	175	90	120.5
TMM0175-100	175	90	151
TMM0175-150	175	90	201
TMM0210-030	210	140	77.5
TMM0210-050	210	140	97.5
TMM0210-070	210	140	117.5
TMM0210-100	210	140	148
TMM0210-150	210	140	198
TMM0291-030	290	200	90.5
TMM0291-050	290	200	110.5
TMM0291-070	290	200	130.5
TMM0291-100	290	200	161
TMM0291-150	290	200	211

Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TMM0360-030	360	265	90.5
TMM0360-050	360	265	110.5
TMM0360-070	360	265	130.5
TMM0360-100	360	265	161
TMM0360-150	360	265	211
TMM0450-030	450	345	90.5
TMM0450-050	450	345	110.5
TMM0450-070	450	345	130.5
TMM0450-100	450	345	161
TMM0450-150	450	345	211
TMM0530-030	530	420	90.5
TMM0530-050	530	420	110.5
TMM0530-070	530	420	130.5
TMM0530-100	530	420	161
TMM0530-150	530	420	211

Remark: Refer to the corresponding torque motor data sheet and interface drawing (available on our website) for more information about the motors.

3.2.1.4 *TMK family*

The TMK torque motor family is made up of 3 different motor diameters with 4 possible widths.



Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TMK0175-050	198	50	100
TMK0175-070	198	50	120
TMK0175-100	198	50	150
TMK0175-150	198	50	200
TMK0291-050	310	144	100
TMK0291-070	310	144	120
TMK0291-100	310	144	150
TMK0291-150	310	144	200

Motor series	External diameter D [mm]	Internal diameter d [mm]	Stator length S [mm]
TMK0360-050	385	216	110
TMK0360-070	385	216	130
TMK0360-100	385	216	160
TMK0360-150	385	216	210

530
760
990

Remark: Refer to the corresponding torque motor data sheet and interface drawing (available on our website) for more information about the motors.

3.2.2 Motor torque range

Refer to the corresponding booklet of the torque motor data sheets to know the continuous and peak torque values (with and without cooling).

3.3 Ordering information

3.3.1 TMB torque motors

The codification of the TMB torque motors is explained hereafter with an example:

TM	B	0360	-	100	-	3TA	S	-	S	8	2	-	EL

Motor type:
TM = Torque Motor

Family:
B with cooling cage

External diameter of the stator's lamination stack:
(refer to §3.2.1.1 for more information)

Active length in mm:
(refer to §3.2.1.1 for more information)

Winding code:
(refer to §3.3.4 for more information)

Neutral point output:
N = with neutral point
S = without neutral point
(refer to §6.2.3.1 for more information)

Cable output:
S = straight output
E = 90° cable output
(refer to §6.2.2 for more information)

Temperature sensor configuration:
8 = standard configuration
H = used with IMTHP configuration
(refer to §6.3 for more information)

Cable length [m]:
(refer to §6.2 for more information)

Bridge:
NN = no bridge
EL = rigid ETEL's bridge at the opposite side of the output cable
ER = rigid ETEL's bridge on the same side of the output cable
CL = customer's bridge at the opposite side of the output cable
CR = customer's bridge on the same side of the output cable
ML = magnetic ETEL's bridge at the opposite side of the output cable
MR = magnetic ETEL's bridge on the same side of the output cable
(refer to §7.2.1 for more information)

3.3.2 TML torque motors

The codification of the TML torque motors is explained hereafter with an example:

TM	L	0360	-	100	-	3TA	S	-	S	8	2	-	MC

Motor type:
TM = Torque Motor

Family:
L cageless with lugs

External diameter of the stator's lamination stack:
(refer to §3.2.1.2 for more information)

Active length in mm:
(refer to §3.2.1.2 for more information)

Winding code:
(refer to §3.3.4 for more information)

Neutral point output:
N = with neutral point
S = without neutral point
(refer to §6.2.3.1 for more information)

Cable output:
S = straight output
E = 90° cable output
(refer to §6.2.2 for more information)

Temperature sensor configuration:
8 = standard configuration
H = used with IMTHP configuration
(refer to §6.3 for more information)

Cable length [m]:
(refer to §6.2 for more information)

Bridge:
Bridge for **TML0210 to TML0291**
NC = no bridge, fixation of the stator on the same side of the output cable
NO = no bridge, fixation of the stator at the opposite side of the output cable
MC = magnetic ETEL's bridge on the same side of the output cable, fixation of the stator on the same side of the output cable
MO = magnetic ETEL's bridge on the same side of the output cable, fixation of the stator at the opposite side of the output cable
KC = magnetic ETEL's bridge at the opposite side of the output cable, fixation of the stator on the same side of the output cable
KO = magnetic ETEL's bridge at the opposite side of the output cable, fixation of the stator at the opposite side of the output cable
CC = customer's bridge, fixation of the stator on the same side of the output cable
CO = customer's bridge, fixation of the stator at the opposite side of the output cable

Bridge for **TML0360 to TML0530**
NN = no bridge
ML = magnetic ETEL's bridge at the opposite side of the output cable
MR = magnetic ETEL's bridge on the same side of the output cable
CN = customer's bridge
(refer to §7.2.1 for more information)

3.3.3 TMM torque motors

The codification of the TMM torque motors is explained hereafter with an example:

TM	M	0360	-	100	-	3TA	S	-	S	8	2	-	ML

Motor type:
TM = Torque Motor

Family:
M cageless without lug

External diameter of the stator's lamination stack:
(refer to §3.2.1.3 for more information)

Active length in mm:
(refer to §3.2.1.3 for more information)

Winding code:
(refer to §3.3.4 for more information)

Neutral point output:
N = with neutral point
S = without neutral point
(refer to §6.2.3.1 for more information)

Cable output:
S = straight output
E = 90° cable output
(refer to §6.2.2 for more information)

Temperature sensor configuration:
8 = standard configuration
H = used with IMTHP configuration
(refer to §6.3 for more information)

Cable length [m]:
(refer to §6.2 for more information)

Bridge:
NN = no bridge
ML = magnetic ETEL's bridge at the opposite side of the output cable
MR = magnetic ETEL's bridge on the same side of the output cable
CN = customer's bridge
(refer to §7.2.1 for more information)

3.3.4 TMK torque motors

The codification of the TMK torque motors is explained hereafter with an example:

TM	K	0360	-	100	-	3TA	S	-	U	8	2	-	ML

Motor type:
TM = Torque Motor

Family:
K with cooling cage

External diameter of the stator's lamination stack:
(refer to §3.2.1.4 for more information)

Active length in mm:
(refer to §3.2.1.4 for more information)

Winding code:
(refer below for more information)

Neutral point output:
N = with neutral point
S = without neutral point
(refer to §6.2.3.1 for more information)

Cable output:
U = Individual wire output
(refer to §6.2.2 for more information)

Temperature sensor configuration:
8 = standard configuration
H = used with IMTHP configuration
(refer to §6.3 for more information)

Cable length [m]:
(refer to §6.2 for more information)

Bridge:
NN = no bridge
EL = rigid ETEL's bridge at the opposite side of the output cable with rotor shoulder on output cable side
ER = rigid ETEL's bridge on the same side of the output cable with rotor shoulder on output cable side
FL = rigid ETEL's bridge at the opposite side of the output cable with rotor shoulder on the opposite side of the output cable
FR = rigid ETEL's bridge on the same side of the output cable with rotor shoulder on the opposite side of the output cable
ML(*) = magnetic ETEL's bridge at the opposite side of the output cable with rotor shoulder on output cable side (for active length -030 and -050)
MR(*) = magnetic ETEL's bridge on the same side of the output cable with rotor shoulder on output cable side (for active length -030 and -050)
KL(*) = magnetic ETEL's bridge at the opposite side of the output cable with rotor shoulder on the opposite side of the output cable (for active length -030 and -050)
KR(*) = magnetic ETEL's bridge on the same side of the output cable with rotor shoulder on the opposite side of the output cable (for active length -030 and -050)
CN = customer's bridge
(refer to §7.2.1 for more information)

(*): magnetic bridges available only up to diameter 0360 (included).

Here is the description of the type of winding.

- The first digit corresponds to the number of phases: 2 = 2 phases (custom) and 3 = 3 phases (standard)
- The first letter corresponds to the diameter of the copper wire of the coil

Letter	B	C	D	E	F	G	H	I	J	K	L	M
Copper ∅ [mm]	0.1	0.112	0.125	0.14	0.16	0.18	0.2	0.224	0.25	0.28	0.315	0.355

Letter	N	O	P	Q	R	S	T	U	V	W	X	Y
Copper ∅ [mm]	0.4	0.45	0.5	0.56	0.63	0.71	0.8	0.9	1	1.12	1.25	1.32

- The second letter corresponds to the number of electrical sector in parallel

Letter	A	B	C	D	E	F	H	J	L	P	T
Number of electrical sector	1	2	3	4	5	6	8	10	12	16	20

3.3.5 Spike suppressor

The codification of the IMSPS is explained hereafter with an example:

IMSPS	**Product type:**
1	**Number of circuit:** 1 = single circuit
1	**Output cable length:** 1 = 1m 3 = 3m 5 = 5m
1	**Reserved for future option**
X	**Hardware version**

3.3.6 Thermal protection interface

The codification of the IMTHP is explained hereafter with an example:

IMTHP	**Product type:**
1	**Motor type:** 1 = Torque motor (green housing) 2 = LMP linear motor (blue housing)
08	**Time constant:** 08 = compensation of 8s (for torque motor) 12 = compensation of 12s (for LMP linear motor)
-	
1	**Reserved for future option**
1	**Reserved for future option**
1	**Reserved for future option**
X	**Hardware version**

4. Tests and measurement

4.1 High voltage immunity tests

The following electrical tests are performed on each ETEL torque motor prior to shipment:

- A dielectric voltage test with 2500 VAC (according to EN 60034-1 standard). This test verifies the electrical insulation present between two electrical parts of the motor. This test must not be repeated as it can produce wear in the insulation and therefore irreversibly damage the motor. If a second test must be performed, the voltage level should not exceed 80% of the above-mentioned voltage level.

- A partial discharge test.

- An insulation resistance test with 1000 VDC (according to EN 60204-1 standard)

- A surge test (Baker). This test shows a possible winding defect.

Remark: The insulation resistance measured during the test must be at least 10 MΩ.

4.2 Current overload protection

Caution: **In order to protect the motor against overheating, both protection systems below should be implemented!**

- An **over temperature detection** on several of the active motor phases according to the IEC 60034-11 standard.

Risk of motor destruction due to slow reaction of over temperature sensor.
The motors equipped with thermal overload protection devices are protected only against slow thermal variations and not against rapid thermal changes. The motor thermal protection device time constant is about 2 to 4 minutes depending on the type of temperature sensor.

The temperature sensor must not be connected directly to the PELV (Protective Extra Low Voltage) or SELV (Safety Extra Low Voltage) electronic circuit. In case of destruction of the sensor, there is a risk of destruction of the electronic circuit.

Temperature sensors must be galvanically insulated from the electronics (optocoupler, eg).

- A **limitation of the I^2t** value (this feature is included in ETEL's controllers) which is a direct measurement of the energy sent to the motor.

Please refer to the IEC 60204-1 directive «Safety on the machines» for overload protection sizing.

4.3 Mechanical inspection

Prior to delivery, all torque motors undergo the following mechanical inspections:

- Internal and external diameters

- Internal and external circularity tolerance

- Polarity control of the rotor's magnets

5. Motor and power supply selection

5.1 Motor selection

This section describes how to select a torque motor to best match the user's requirements. This procedure applies to ETEL's complete range of torque motors. The motor selection strongly depends on the type of application, for which certain conditions are defined by the user and others might come from technical limitations. The more precisely the application can be described, the more successful the motor sizing will be. Most motors can be sized very easily by looking at the most critical movements and by matching the motors technical specifications with the user's requirements. In some applications a field test may be required to optimize or qualify the selected motor. Please contact ETEL in case you would need a personalized motor sizing.

5.1.1 General procedure

The first step in sizing a motor is to determine the peak and continuous torques (Tp and Tc) as well as the maximum possible speed (n_{max}) required for the application. External forces such as the load, machining, friction and perturbations generate additional torque and then has to be considered for the calculation. Given both Tp and Tc torques, the peak and continuous power dissipations (Pp and Pc) can be estimated. The thermal resistance (Rth) then allows the calculation of the average heat produced by the motor. Under stall conditions (refer to the glossary), it is essential to ensure that the applied load does not exceed the stall torque (Ts), since power dissipation is not equally shared among all three phases. In rare cases, the detent torque (Td) may have an impact on speed stability, especially if the position control regulation bandwidth is limited (ETEL's position controllers eliminate this problem). ETEL's torque motors are available in several winding configurations to fit the user's speed requirements and to match the output voltage and current of the controller. The torque motors 'torque vs. speed' curve identifies the motor's maximum output torque as a function of speed.

Boundary conditions

- Environment (ambient temp., cooling and exchange surfaces)
- Axis configuration (motors in series or parallel)
- Technical limitations (drive power, bandwidth, encoder, bearings, maximum velocity and acceleration)

Technical requirements

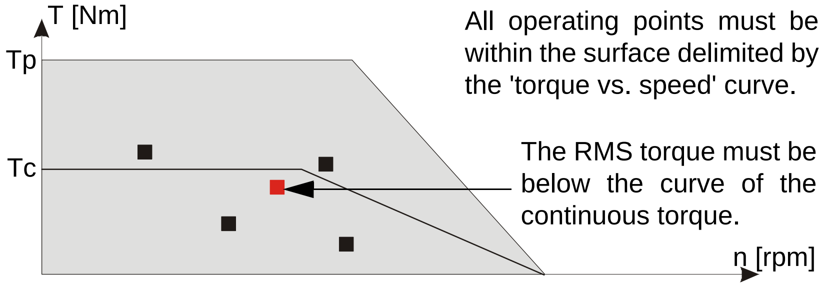
- Duty cycle, machining cycle
- Friction, inertia, dynamic specifications (position loop bandwidth...)

Computation of the diagram "torque vs. time" including

- Maximum torque required by the application
- Continuous torque required by the application
- Operating points defined by Torque = f(rotation speed)

Selection based on the motor data sheet

- Maximum torque
- Continuous torque
- Torque = f(rotation speed)



All boundary conditions are satisfied (temperature, cooling, ...)

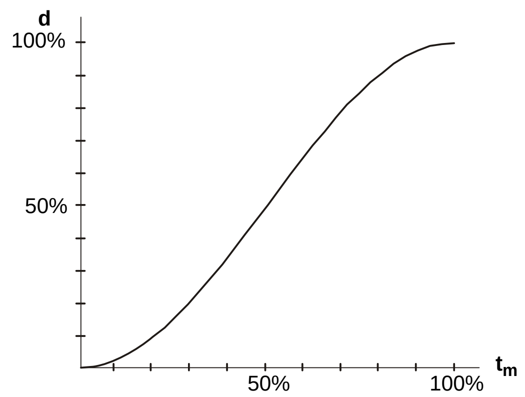
5.1.2 Basic formulas

There are many different types of motion profiles which can provide advantages or result in disadvantages depending on the application requirements. The motion trajectory is mainly characterized by:

- The maximum speed, acceleration and jerk
- The constant speed

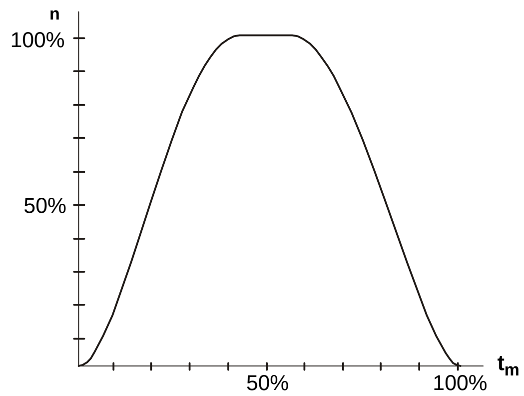
One widely used trajectory profile is the S-curve (represented below). By adapting the value of the parameters α and β (defined below), triangular, full-jerk and trapezoidal profiles can be determined.

Position



d: movement stroke [rad]
t_m: movement time [s]

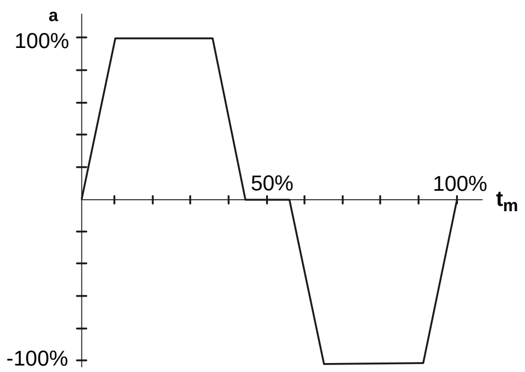
Speed



n_{max}: maximum possible speed [rpm]

$$n_{max} = \frac{2}{1+\beta} \cdot \frac{d}{t_m} \quad \text{(independent of } \alpha\text{)}$$

Acceleration

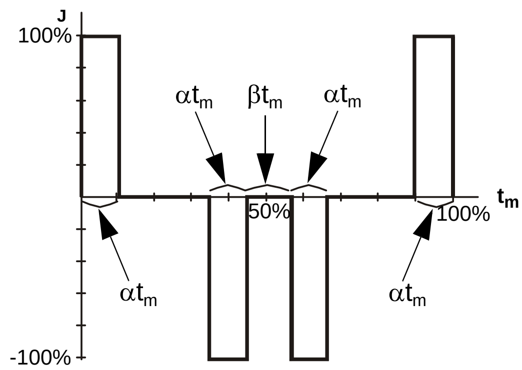


a_{max}: maximum acceleration [rad/s^2]

$$a_{max} = \frac{4}{(1+\beta)(1-2\alpha-\beta)} \cdot \frac{d}{t_m^{\,2}}$$

(dependent of α and β)

Jerk



j_{max}: maximum jerk [rad/s^3]

$$j_{max} = \frac{4}{\alpha(1+\beta)(1-2\alpha-\beta)} \cdot \frac{d}{t_m^{\,3}}$$

αt_m = jerk time
βt_m = time with constant speed

- The RMS value of the acceleration is given by the following formula:

$$a_{RMS} = \sqrt{\frac{1}{t_{max}-t_0}\left(\int_{t_0}^{t_{max}} a^2\right) dt}$$

- The continuous acceleration, which is directly responsible for the increase of the coil temperature, is given by the following formula:

$$a_{cont} = \sqrt{1-\frac{8}{3}\alpha-\beta}\; a_{max}$$

and can be minimized by choosing the appropriate value of α and β

with $\alpha < 16.7\%$ and $\beta = \dfrac{6 - 19\alpha - \sqrt{73\alpha^2 - 66\alpha + 9}}{9}$ or

with $\alpha \geq 16.7\%$ and $\beta = 1 - 4\alpha$

The equations used to calculate the kinematic quantities mentioned above are summarized below:

Characteristics	Values	Units
Speed	$\Omega_{max} = Factor\ \Omega_{max} \cdot \frac{d}{t_m}$	rad/s
Maximum acceleration	$a_{max} = Factor\ \ a_{max} \cdot \frac{d}{t_m{}^2}$	rad/s^2
Continuous acceleration	$a_{cont} = Factor\ \ a_{cont} \cdot \frac{d}{t_m{}^2}$	rad/s^2
Jerk	$j_{max} = Factor\ \ j_{max} \cdot \frac{d}{t_m{}^3}$	rad/s^3

The following chart provides the value of the above-mentioned factors with corresponding values of α and β for use with other motion profiles:

Motion profile	Factor Ω_{max}	Factor a_{max}	Factor a_{cont}	Factor j_{max}	α	β
S-curve	1.59	5.87	4.04	58.73	10.0%	25.9%
Triangular	2.00	4.00	4.00	Infinite	0.0%	0.0%
Full-jerk	2.00	8.00	4.62	32.00	25.0%	0.0%
Trapezoidal	1.33	5.33	3.77	Infinite	0.0%	50.0%
Sine	1.57	4.93	3.49	Infinite		
Modified sine (cam)	1.76	5.53	3.91	69.47		

To have a S-curve motion profile (typical values) with a minimal continuous acceleration, the kinematic quantities become:

$\Omega_{max} = 1.59\frac{d}{t_m}$, $a_{max} = 5.87\frac{d}{t_m{}^2}$ and $a_{cont} = 4.04\frac{d}{t_m{}^2}$ with the typical values: $\alpha = 0.1$ and $\beta = 0.259$

5.1.3 Duty cycle and continuous torque

An application can usually be described by one typical duty cycle composed of motion steps and dwell intervals. In order to define a suitable motor and the corresponding electronics, the peak and continuous currents required for the application need to be computed.
Looking at the steps in a sequential manner, different torque components have to be considered.

Characteristics	Values	Units
Acceleration torque	$T_{acc} = J \times a$	Nm
Friction torque	$T_{friction} = T_{dry} + T_{viscous}$	Nm
External torque	$T_{external} = T_{machining} + \ldots$	Nm
Total torque	$T_{total} = T_{acc} + T_{friction} + T_{external}$	Nm

with: J = Inertia including the motor [kgm^2]
a = Acceleration [rad/s^2]
T_{dry}, $T_{viscous}$ = Dry and viscous friction [Nm]
$T_{machining}$ = Machining torque [Nm]

Remark: The friction is mainly caused by the sealing (bearing). The amount of friction is proportional to the diameter of the bearing. The larger it is, the more friction the system will have.

The resulting maximum and continuous torques over one complete cycle are:

Characteristics	Values	Units
Maximum torque	$T_{max,\ complete\ cycle} = Max(T_{max,i})$	Nm
Continuous torque	$T_{cont,\ complete\ cycle} = \sqrt{\dfrac{\sum_{i=1}^{N} T^2_{cont,\ i} \cdot t_{m,\ i}}{T_{complete\ cycle}}}$	Nm

With: $T_{max,i}$, $T_{cont,i}$ = Torque values for a step
N = Number of steps
$t_{m,i}$ = Step duration
$T_{complete\ cycle}$ = Complete movement time (including dwell time)

Remark: Because of the non-linearity of the torque constant (Kt), it is necessary to use a leeway (≅15%) for the calculation of the continuous torque. In case of high speed, please refer to the torque vs. speed curve or add an additional leeway.

After choosing one possible motor, the operating points defined by the torque vs. speed curve need to be compared to the data sheet of the motor.

5.1.4 Power dissipation

One additional topic to complete the motor sizing concerns the power dissipation which might be critical in some applications, specially where the temperature increase can have an impact on the machine performance. Given the maximum and continuous torques and the non-linear curve (T, I), which is specific to each motor, the corresponding currents (I_p, I_c) can be estimated. The equations applying to the dissipated power are as follows:

Characteristics	Values	Units
Electrical resistance at θ_c	$R_c = R_{20} \cdot (1 + (0.00392 \cdot (\theta_c - 20)))$	Ω
Peak power at operating point at θ_c	$P_p = \frac{3}{2} \cdot R_c \cdot I_p^2$	W
Continuous power at θ_c	$P_c = \frac{3}{2} \cdot R_c \cdot I_c^2$	W
Continuous coil temperature (*)	$\theta_c = \theta_{amb} + P_c \cdot R_{th}$	°C

(*): refer to §6.1.5 for more information.

With P_p = Peak power dissipation [W]
P_c = Continuous power dissipation [W]
R_c = Resistance between phases at θ_c [Ω]
R_{20} = Electrical resistance at 20°C [Ω]
I_p = Peak current [A_{RMS}]
I_c = Continuous current [A_{RMS}]
θ_c = Continuous coil temperature [°C]
θ_{amb} = Ambient temperature [°C]
R_{th} = Thermal resistance [K/W]

5.1.5 Controller specification

The required bus voltage is calculated by computing the following values (values given without field weakening).

Characteristics	Values	Units
Voltage due to resistance	$U_r = \frac{R}{2} \cdot i$	V
Voltage due to rotation speed	$U_{BEMF} = \frac{K_u}{\sqrt{3}} \cdot \Omega$	V
Voltage due to inductance	$U_L = (2\pi \cdot f) \cdot \frac{L1}{2} \cdot i$ with $f = \frac{\Omega}{2\pi} \cdot p$	V
Bus voltage	$U_{bus} = \sqrt{(U_r + U_{BEMF})^2 + U_L{}^2} \cdot \sqrt{6}$	VDC

With R = Electrical resistance [Ω] (terminal to terminal value)
L1 = Electrical inductance [H] (terminal to terminal value)
i = Current [A_{RMS}]
K_u = Back EMF constant [V_{RMS}/(rad/s)] (terminal to terminal value)
Ω = Angular speed [rad/s]
p = Number of poles pairs

In addition to the voltage, the controller must be able to meet the motor's current requirements. A variety of motor windings are available to accommodate a wide range of torque and speed combinations.

Operating modes

There are many categories among the various rotary applications. Refer to IEC 60034.1 standard for more information. Each of them can be approached in different ways:

- Mode S1: For applications running continuously like a printing machine, the continuous torque is required to compensate friction and to ensure the specified rotation speed is maintained. After reaching the operating rotation speed, the motor temperature is well-defined.
- Mode S2: Applications with long dwell time periods and almost no continuous thrust have no cooling issue. Therefore, the sealing friction and peak torques due to acceleration and machining thrust are the most significant values to be considered.
- Mode S8: High production rate typically requires machines with reduced flexibility and repetitive production cycles. Each machine part is optimized and tailored around the manufactured products. Clear specifications describe the application. In addition to the environment, the axis configuration and the technical limitations are given, along with the duty and machining cycles.
- Mode S9: In general, the machine-tool builders can not accurately predict the specific details of the parts their users are going to manufacture. However, based on their experience, they are capable of designing new generations of machines to obtain certain technical performance in terms of velocity, acceleration and torques. In this case, the motor sizing is usually an iterative process between the user and the motor supplier until the most suitable motor is selected.

Remark: All the torque motors can be stopped (emergency shutdown) by shorting the phases. The duration of the braking depends on the initial speed and total inertia of the motor. The braking time can be optimized by adding a brake resistor. Contact ETEL to have the braking time value relating to an application.

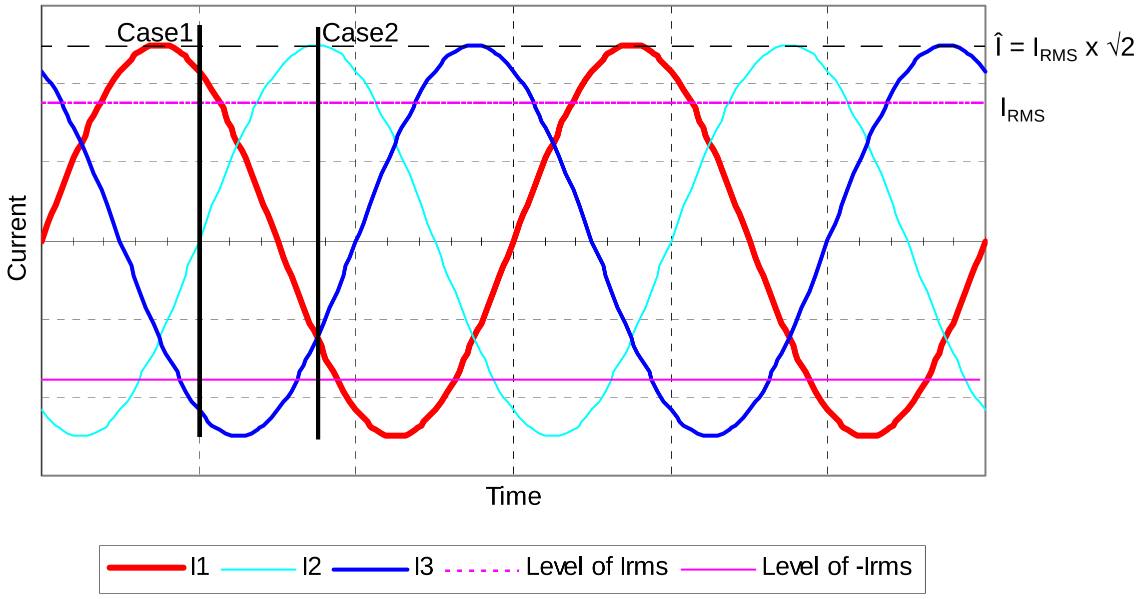
5.2 Stall conditions

A torque motor works in stall conditions when the electrical frequency is ≤ 1Hz. The electrical frequency [Hz] is given by the following formula:

$$Frequency = \frac{n \cdot p}{60}$$

with: n = speed [rpm]
p = number of poles pairs

Here is a graph of the current in a three-phase motor.



The continuous current [A_{RMS}] in the data sheet is given for a coil temperature of 130°C. The peak value of the current signals (Î) shown above is higher than the value given in the data sheet (RMS value). If the rotation speed is equal or lower than the stall speed (n_s) given in the corresponding data sheet, we always have (as shown in the graph) 1 or 2 phases with a current higher than the I_{RMS} value. To avoid damage to the motor, the stall current (refer to §13. for definition) given in the data sheets in RMS value must be reduced.

The two cases (case 1 and case 2) mentioned on the graph represent two examples of overcurrent in one or two phases:

- Case 1: overcurrent in **two phases**

$$|I1| = |I3| = \frac{\sqrt{3}}{2} \cdot I_{RMS} > Ic_{data\ sheet}$$

and I2 = 0A

- Case 2: overcurrent in **one phase**

$$|I1| = |I3| = \frac{1}{2} \cdot \hat{I} = \frac{\sqrt{2}}{2} \cdot I_{RMS} < Ic_{data\ sheet}$$

$$I2 = \hat{I} = \sqrt{2} \cdot I_{RMS} > Ic_{data\ sheet}$$

5.3 Power supply selection

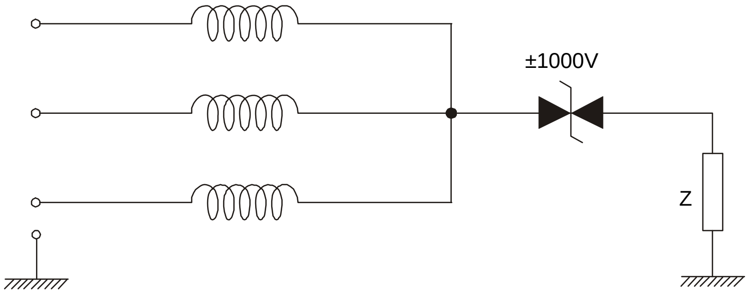
To select a power supply, the continuous current, peak current and bus voltage are taken into account. In addition, the resonance effect which can be induced in motors by some drive systems must be considered.

Motors are manufactured with several individual coils in series. Each one of these coils has an inductance in series and a stray capacitance to earth. The LC network obtained possesses a resonant frequency, like a mechanical system with a flexible beam fixed at one end. When the beam fixation system vibrates, these vibrations are transmitted through the beam. At very low frequencies, the other end of the beam moves with the same amplitude as the fixed side. At very high frequencies, it does not move at all. But somewhere in the middle, there exists a resonant frequency where the loose end of the beam vibrates with an amplitude which can be much greater than the amplitude of the vibrations applied to the fixed end.

The same behavior occurs in motors, when an electrical oscillation is applied to the phase inputs (in particular the PWM frequency). The neutral point of the motor can oscillate with very high amplitudes with respect to earth, and the insulation can be damaged as a consequence of these oscillations. This phenomenon is more pronounced in motors with a large number of poles (such as torque motors).

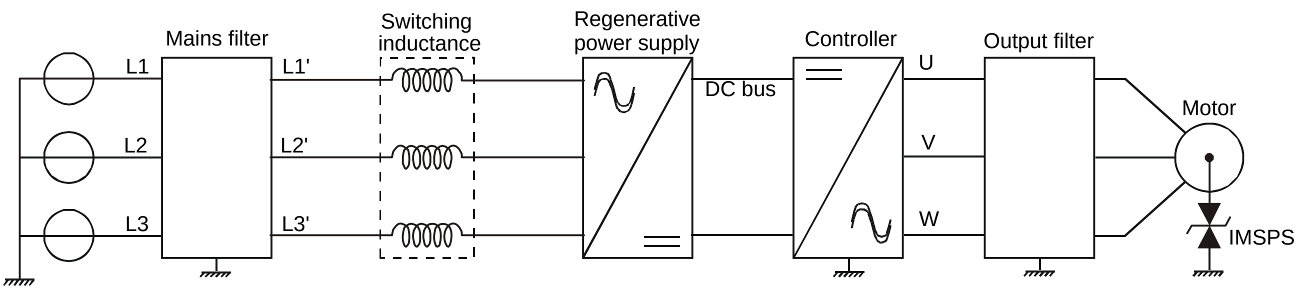
Using the IMSPS module

The solution prescribed by the electronics manufacturer should be installed to prevent damage to the insulation related to the phenomenon described above. When this solution is inadequate, it is then compulsory to insert between the neutral point of the motor and the earth a module (called IMSPS) based on spike suppressors that clips the over-voltages that occur (refer to §7.3 for more information about the IMSPS). Current starts flowing through the spike suppressors when the voltage is greater than ±1000V. To prevent a short-circuit to earth, an impedance containing a Y capacitor is inserted in series. The voltage on these capacitors increases when current flows through them, which means that the voltage on the IMSPS module can reach about ±1100V after a strong current pulse.



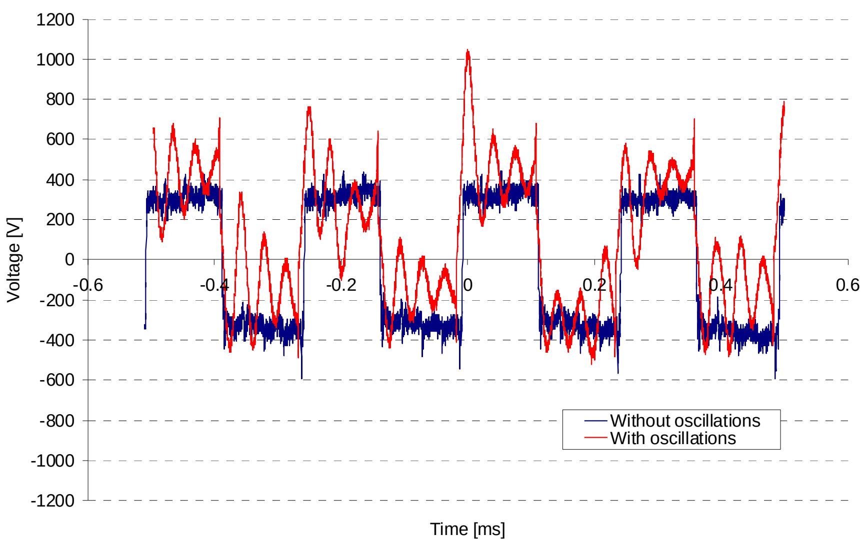
Supply voltage

A typical drive system is illustrated in the following figure:



In the ideal case, the 600VDC bus voltage generated by the regenerative power supply should lie between -300V and +300V with respect to earth. Unfortunately, in some configurations, the voltage between the bus bars and earth can oscillate and high voltage spikes are transmitted to the motor.

The following figure shows two examples of voltages that have been measured on motor phase inputs. One voltage switches between -300VDC and +300VDC and no oscillations are visible. Oscillations up to +1000V are however visible on the second curve.



These oscillations between the bus voltage and earth are system dependant. By experience, a system with few axes connected to the bus voltage is less liable to have disturbing oscillations on the bus, but for example in a large machine tool with many axes and several spindles, the oscillations can reach high amplitudes. If the frequency of these oscillations is close to the resonant frequency of the motor, it can lead to over-voltage failures on the neutral point.

There exists a second situation that can lead to an over-voltage failure. The case where the PWM frequency of the controller happens to correspond to the resonant frequency of the motor. In this case, the fundamental harmonic of the PWM frequency is directly exciting the resonant frequency of the motor, and very high voltages are thus obtained on the neutral point. Also, as the PWM voltage is a square wave, it contains odd harmonics (1, 3, 5, 7, etc.) that can also excite the motor resonance. Fortunately, these harmonics have a smaller amplitude that the fundamental.

In conclusion, to prevent any failure from occurring, two elements must be considered: the oscillations between the bus voltage and earth and the PWM frequency. If both elements above do not enter into resonance with the motor, then there is no risk for the motor.

Drive system analysis

To establish whether there exists any risk of causing an over-voltage on the motor neutral point, the following inputs must be considered:

=> The PWM frequency of the controller
=> The presence (or not) of oscillations of the bus voltages with respect to earth
=> The resonance characteristics of the motor
=> Passive or regenerative power supply
=> Floating or clamped DC bus

These inputs are analyzed using graphs developed in-house in which every drive configuration can be classified in three areas:

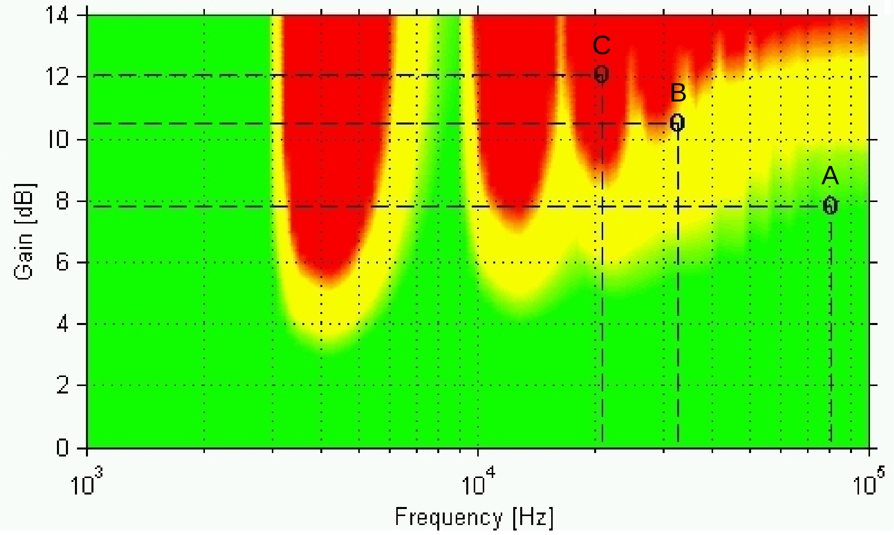
=> In green area: no risk is present.
=> In yellow area: install the solution recommended by the electronics' manufacturer so that electrical system oscillations are dampened. Perform a measurement on the neutral point voltage. If the peak voltage exceeds the prescribed value, the IMSPS module must be connected.
=> In red area: each case must be analyzed individually to find solutions. The solution recommended by the electronics' manufacturer must be installed as well as the IMSPS module.

If the configuration of the system changes (e.g. an extra axis is added to the system), it may considerably modify the oscillations of the bus voltages with respect to earth! A security margin is therefore necessary in systems with variable configurations.

In the following example, the effect on 3 different motors of the same drive system is considered:

Motor	Resonant frequency [kHz]	Resonance amplitude [dB]
Motor A	80.3	7.8
Motor B	32.5	10.5
Motor C	20.8	12.1

The drive system comprises a 600VDC controller working at 4kHz PWM frequency, and “standard” oscillations of the bus voltages with respect to earth. The three motors are located in the graph:



- The first motor (A) operates in the green area, so no further action needs to be taken.
- The second motor (B) operates in the yellow area, so install the solution recommended by the electronics’ manufacturer so that electrical system oscillations are dampened. Perform a measurement on the neutral point voltage. If the peak voltage exceeds the prescribed value, the IMSPS module must be connected.
- The third motor (C) operates in the red area, so an analysis is required. The solution recommended by the electronics’ manufacturer must be installed as well as the IMSPS module. ETEL can provide extensive know-how for every critical situation.

5.3.1 Controller power

Peak voltages and dV/dt gradients generated by the power supply must not exceed the values below:

- 300 VDC controllers: 750 Vp (phase to ground), voltage gradient: 8 kV/µs.
- 600 or 750 VDC controllers: 1000 Vp maximum (at the PWM frequency) and spikes up to 1400 V (earth to peak and for a few µs) and a voltage gradient: 11 kV/µs.

If the length of the cable between the controller and the motor is longer than 10 m, it is necessary to measure voltages at the motor terminals to ensure they are lower than specified above. If the measured value is greater, a dV/dt filter must be inserted between the controller and the motor for protection.

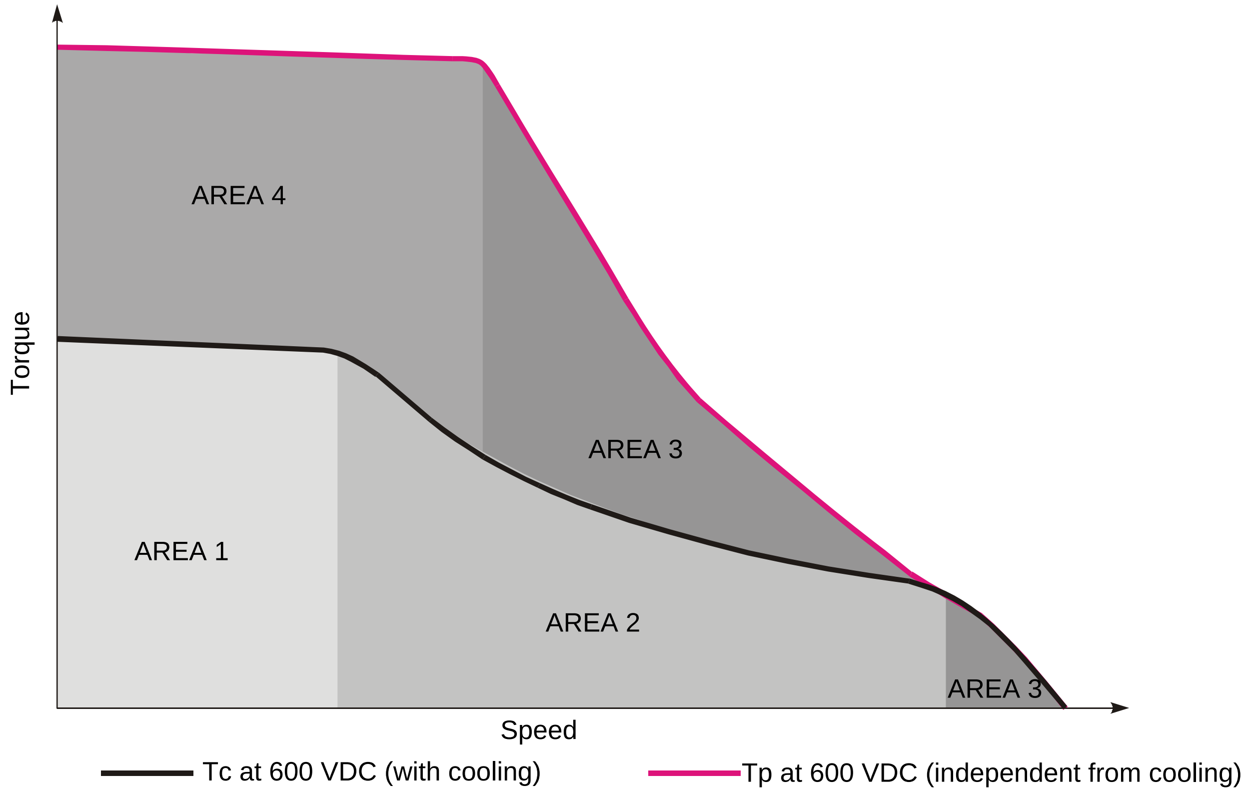
5.4 Torque vs. speed curve

Each torque motor's data sheet includes the corresponding torque vs. speed profile. Here is an example of this profile which depends on several parameters:

- Motor type (resistance, inductance, motor constant (Ku), power dissipation of the motor)
- DC bus voltage level

A torque vs. speed curve is typically calculated with:

- DC bus voltage = 300 VDC or 600 VDC
- Winding temperature = 130°C (266°F)
- Cooling temperature (at the cooling inlet) = 20°C (68°F)



The continuous duty zone is made up of three areas (delimited by black line):

- Area 1: area bounded by the thermal limit of the stator (thermal protection of the stator)
- Area 2: area bounded to area 1 plus the thermal limit of the rotor as well (protection against the demagnetization of the magnets)
- Area 3: area bounded to area 1, plus area 2, plus the limit of the DC bus voltage

The intermittent duty zone is made up of one area (delimited by red line):

- Area 4: area bounded only by the current before demagnetization of the magnets

Remark: As the torque and the speed are higher for the TMK with flux weakening, the difference with the above mentioned torque/speed curve is that both areas 3 are larger.

5.5 Field weakening

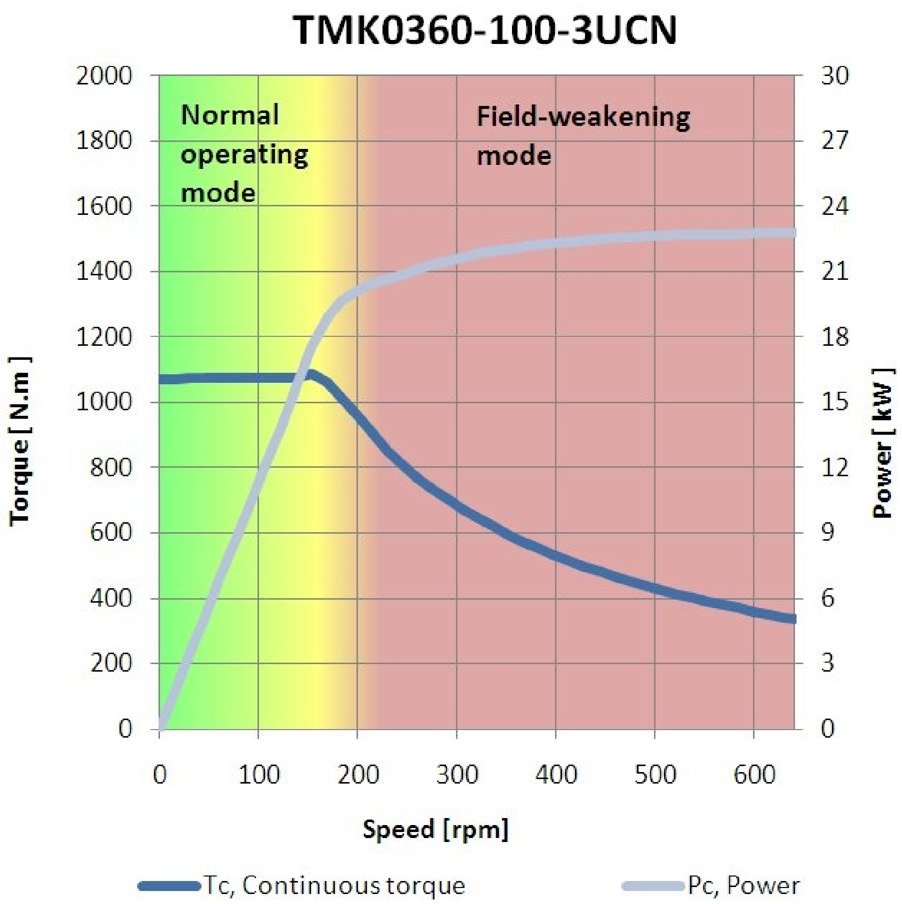
Field weakening is a control strategy used in order to extend the operating speed of a permanent magnet synchronous motor. At low speed, field-weakening is not active and torque is kept constant up to the nominal speed (power is proportional to speed). Field-weakening is activated beyond the nominal speed. The power being limited, torque is decreased in order to achieve higher speed (constant power operation).

Only the TMK motors are compliant with field-weakening operation. Moreover, water cooling is mandatory to operate with field-weakening.

The absolute speed limit is defined in each TMK motor datasheet. This speed is based on a safety criterion in case of power failure when operating with field-weakening. Due to the high speed operation, the B-EMF voltage present on the motor terminals in case of power failure can reach thousands of volts. The TMK maximum speed is defined in such a way that this overvoltage in case of power failure does not exceed 2000VAC. The customer's motor supply system has to be designed accordingly to this operating mode. In particular, a safety relay need to be foreseen to create a short-circuit of the motor phases in case of failure.

Operation beyond datasheet specified maximum speed can lead to serious damages in the customer’s electrical system.

Example:



6. Motor configuration

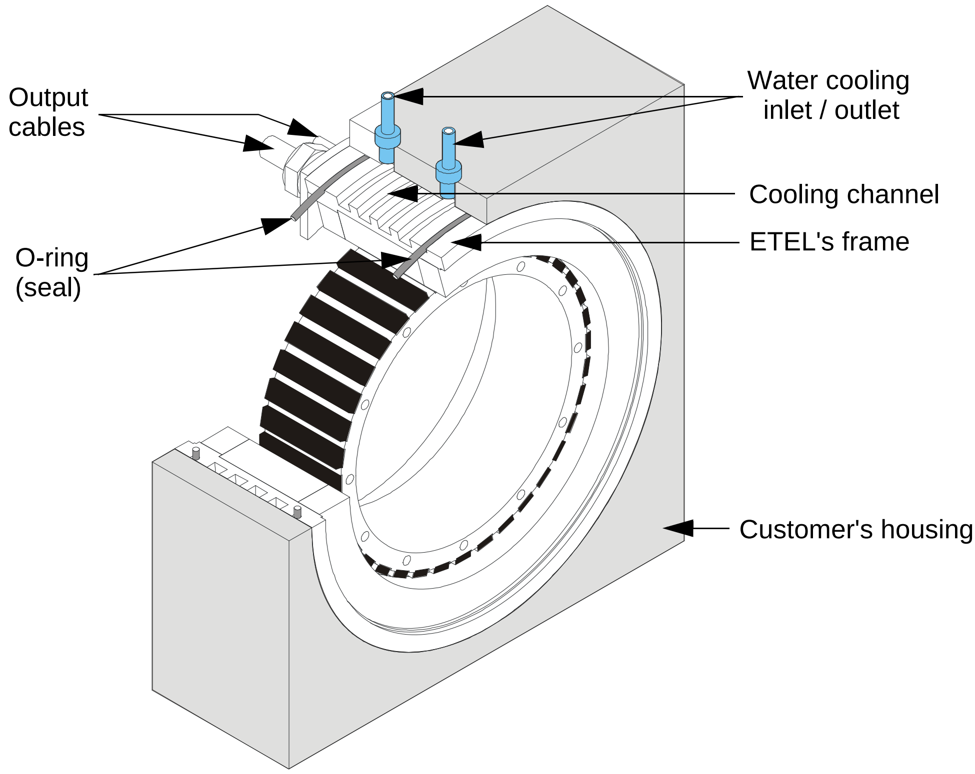
6.1 Motor cooling

The TMB and TMK torques motor can be cooled either by free air convection or water. The cooling channels machined in the frame of the stator enable the water circulation to dissipate the heat that results from power losses in the windings. Dissipation of the heat allows the motor to maintain a higher continuous torque than an uncooled motor. The cooling channels are sealed in the user's housing with two O-rings (seal).

Remark: The coolant inlet and outlet are fixed to the customer's housing. The design of the cooling system and interface is under the customer's responsibility.
The rotor and the stator are made of steel.
It is recommended to grease the two O-rings with an ordinary lubricant to improve the tightness (for example: grease Castrol OLIT 2 EP, Lithium grease DIVINOL Fett LT1, part.No. 22010).

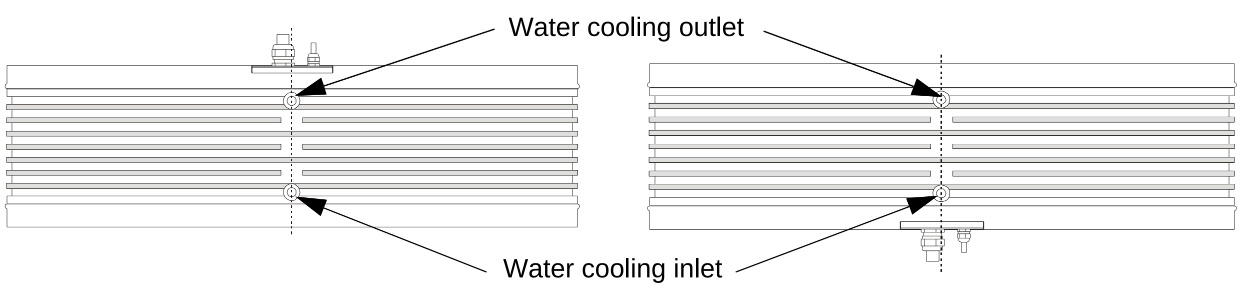
Be careful not to twist the O-rings to avoid leakages.

Refer to the respective torque motor data sheet for the minimum water flow (qw) required and the pressure drop at qw.

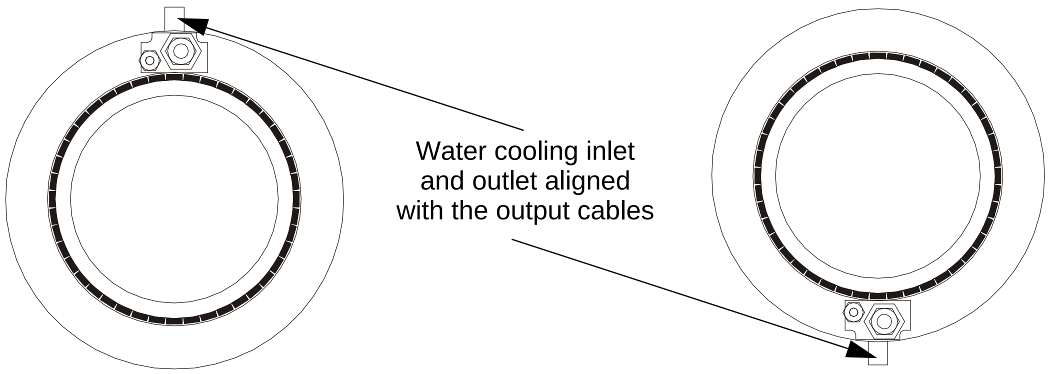


Due to machining of the cooling channels, **the water cooling inlet and outlet must be aligned with the output cables (strain relief)** to guarantee proper cooling (otherwise a part of the motor may be not cooled enough).

- If the torque motor is mounted horizontally (upside down or not) it is strongly recommended to connect the water cooling inlet at the bottom of the motor and the outlet at the top of it, as shown below.

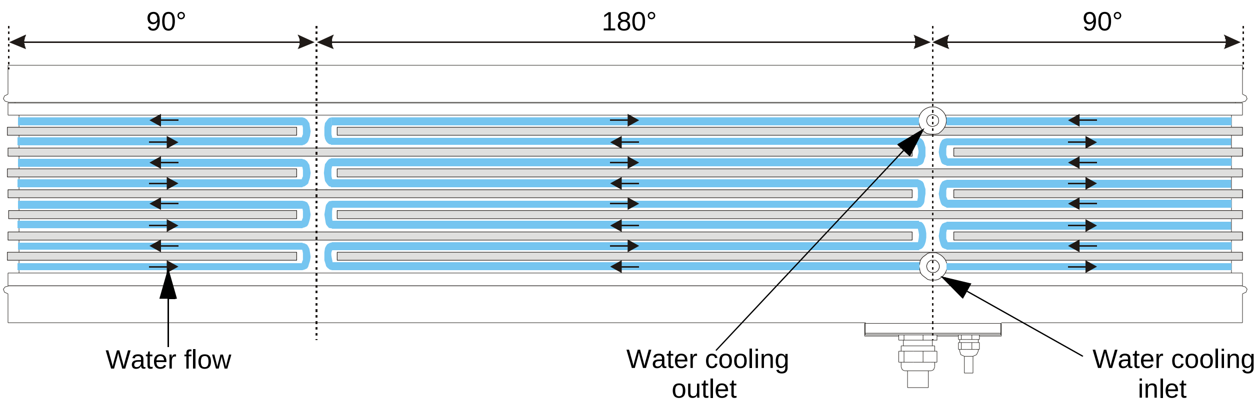


- If the torque motor is mounted vertically (upside down or not) there is no recommended positioning of the water cooling inlet and outlet (as long as they remain aligned with the cable output), as shown below.



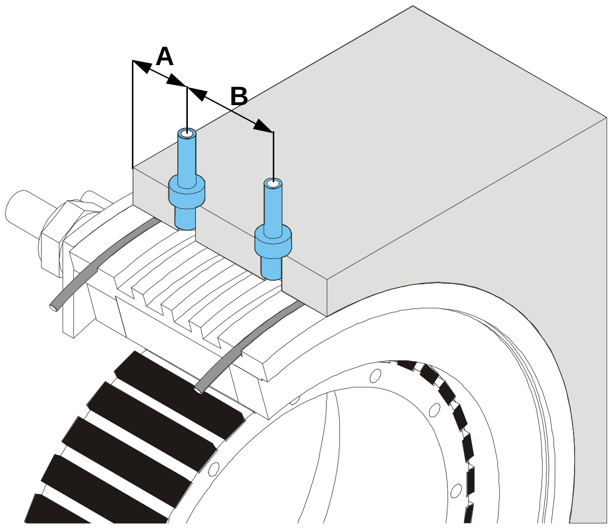
Remark: If the torque motor is mobile in the customer's system, the cooling must be activated (cooling channel full) before powering on the motor.

Here is the representation of the water flow inside the housing of the stator. The cooling channel is designed to equally cool both half of the motor as shown in the following drawing.



6.1.1 Water cooling information

The following chart defines the distance A between the edge of the motor and the inlet/outlet, and the distance B between the inlet and the outlet as shown in the following drawing:

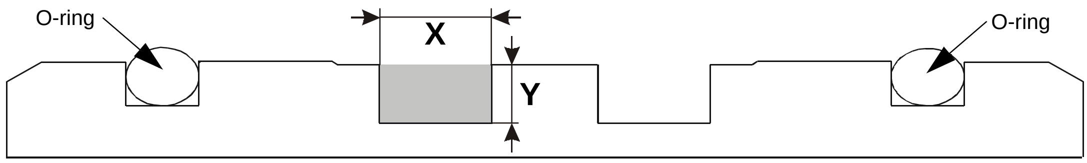


A	B				
	20	40	60	90	140
25	TMB0140-030	TMB0140-050	TMB0140-070	TMB0140-100	TMB0140-150
30	TMB0175-030	TM#0175-050	TM#0175-070	TM#0175-100	TM#0175-150
25	TMB0210-030	TMB0210-050	TMB0210-070	TMB0210-100	TMB0210-150
35	TMB0291-030	TM#0291-050	TM#0291-070	TM#0291-100	TM#0291-150
35	TMB0360-030	TM#0360-050	TM#0360-070	TM#0360-100	TM#0360-150
43	TMB0450-030	TMB0450-050	TMB0450-070	TMB0450-100	TMB0450-150
35	TMB0530-030	TMB0530-050	TMB0530-070	TMB0530-100	TMB0530-150
45	TMB0760-030	TMB0760-050	TMB0760-070	TMB0760-100	TMB0760-150
45	TMB0990-030	TMB0990-050	TMB0990-070	TMB0990-100	TMB0990-150
45	TMB1221-030	TMB1221-050	TMB1221-070	TMB1221-100	TMB1221-150

TM# means either TMB or TMK

6.1.2 Water cooling channel section

The following chart provides the nominal values of the water cooling channel sections according to the type of torque motors:



Motor series	X [mm]	Y [mm]	Inlet and outlet's internal diameter [mm]
TMB0140 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	8
TMB0175 - 030	8	5	8
TMB0175 TMK0175 - 050 - 070 - 100 - 150	8 9 8 9	5 5 5 5	8
TMB0210 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	8
TMB0291 - 030			
TMB0291 TMK0291 - 050 - 070 - 100 - 150	8 9 8 9	4 4 4 4	8
TMB0360 - 030			
TMB0360 - 050 - 070 - 100 - 150	8 9 8 9	5 5 5 5	8

Motor series	X [mm]	Y [mm]	Inlet and outlet's internal diameter [mm]
TMB0450 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	8
TMB0530 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	10
TMB0760 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	10
TMB0990 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	10
TMB1221 - 030 - 050 - 070 - 100 - 150	8 8 9 8 9	5 5 5 5 5	10

Remark: The above-mentioned water cooling inlet and outlet sections must have the following internal diameter to guarantee the minimum water flow given in the data sheets.
The maximum pressure that can be applied to ETEL's torque motors is 10 bars.

6.1.3 O-ring characteristics

The following chart defines the O-ring characteristics for each TMB and TMK series torque motor.

Motor series	O-ring type	O-ring cross section [mm]	O-ring internal diameter [mm]
TMB0140	FPM 75 (molded, one piece)	2.5 ±0.1	153 ±1.2
TMB or TMK0175	FPM 75 (molded, one piece)	2.5 ±0.1	190 ±1.6
TMB0210	FPM 75 (molded, one piece)	2.5 ±0.1	222 ±1.8
TMB or TMK0291	FPM 75 (molded, one piece)	2.5 ±0.1	300 ±2.4
TMB or TMK0360	FPM 75 (molded, one piece)	4 ±0.1	371 ±2.8
TMB0450	FPM 75 (molded, one piece)	4 ±0.1	469 ±3.6
TMB0530	FPM 75 (molded, one piece)	4 ±0.1	548 ±4
TMB0760	FPM 75 (molded, one piece)	4 ±0.1	773 ±4.8
TMB0990	FPM 75 (molded, one piece)	4 ±0.1	1003 ±5
TMB1221	FPM 75 (molded, one piece)	4 ±0.1	1229 ±6.1

Remark: It is recommended to grease the two O-rings (four for the TMB1221) with an ordinary lubricant to improve the tightness (for example: grease Castrol OLIT 2 EP, Lithium grease DIVINOL Fett LT1, part.No. 22010).

6.1.4 Coolant characteristics

The values given in the data sheets are based on the use of water as the coolant with a coefficient of 2000 W/m^{2}K. These values may not be valid if another type of coolant is used. Damage caused by the use of another coolant is under the customer's responsibility. The use of tap water is not recommended as calcareous deposits can obstruct the cooling channels and reduce the efficiency of the cooling system, like any dirty water. To respect the water flow, pressure and dissipation, it is advisable to use water with rustproof and antifreeze additives. The coolant must not contain products that are dangerous to the environment (according to WGK standard) and must be compatible with the O-rings material as well as with the machine housing & stator material (steel ST52-3 or 1.0570). To avoid possible pollution, it is recommended to use a filter. The maximum allowed particle size is 100 μm.the machine housing & stator material (steel ST52-3 or 1.0570).

Here are coolant examples:

Manufacturer	Product name	Recommended dilution into water
BASF	Glythermin P44	25% to 75%
	Glysantin protect plus / G48	33% to 50%
	Glysantin Alu protect premium	30% to 50%
	Glythermin NF	20% to 58%
	Glythermin G48	33% to 50%
Shell	GlycoShell longlife Concentrate	50%
Blaser Swisslube	Denaturated antifreeze art04860	>25%
BP	Antifrost NT	35% to 40%
TYFO	Tyfocor L	25% to 75%

Remark: The water hardness should be around 20°dh (around 3.3mmol/l) and the pH of the dilution water between 6.0 and 8.5. Demineralized water can also be used.

The maintenance of the coolant (refer to the manufacturer characteristics) must be respected (minimum an annual service). It is necessary to maintain a slightly alkaline pH (it should remain > 6ml HCl) as the degradation of certain products can induce acidity. Furthermore, a totally closed circuit is recommended. Contact between coolant liquid and air must be avoided.

6.1.5 Thermal behavior

To supply mechanical power, the motor generates copper losses (P_c) (Joule effect) in the coils of the stator and iron losses (P_{Fe}) in the stator and the rotor.

The copper losses are:

$$P_c = \frac{3}{2} \cdot R_{20} \cdot (1 + (0.00392 \cdot (\theta_c - 20))) \cdot I_c^2$$

with: P_c = copper losses [W] at the coil temperature θ_c [°C]
R_{20} = electrical resistance [Ohm], terminal to terminal, at a coil temperature of 20°C
Ic = continuous current [A_{RMS}] at the coil temperature θ_c [°C] (with or without water cooling)
θ_c = coil temperature [°C] (130°C in torque motor's data sheets)

The iron losses are mainly generated by eddy currents and are dependant on the square of the frequency. The iron losses can be significant at high frequency (high speed operation).

$$P_{Fe} \sim f^2$$

with: P_{Fe} = iron losses [W]
f = electrical frequency [Hz]

$$f = \frac{n \cdot p}{60}$$

with: n = speed [rpm]
p = number of poles pairs

The thermal losses are transferred by conduction inside the motor from the winding to the housing and by convection from the housing to the water. In case there is no water cooling used, the heat losses are then transferred to the air by convection and radiation and also by conduction to the customer interface. As the TMB torque motors can be cooled with water or free air, make sure to use the correct values in the data sheets. The coil temperature must not exceed 130°C. With water cooling, the temperature of the interface corresponds to the average temperature of the water but without water cooling, the temperature of the interface is close to the coil temperature.

6.1.5.1 Continuous operating conditions

The stabilized temperature is proportional to the dissipated losses. At low speed, the iron losses can be ignored. The copper losses (P_c) given in the data sheets correspond to a coil temperature of 130°C and a continuous torque (T_c). If a continuous torque (T_x) is lower than T_c, the stabilized temperature can be given by the following formula:

$$\theta_x = \theta_{amb} + \left(\frac{T_x}{T_c}\right)^2 \cdot (\theta_c - 20)$$

with: θ_x = stable coil temperature [°C]
T_x = continuous torque [Nm] for a balanced coil temperature θ_x
T_c = continuous torque [Nm] for a coil temperature θ_c
θ_{amb} = ambient temperature [°C]

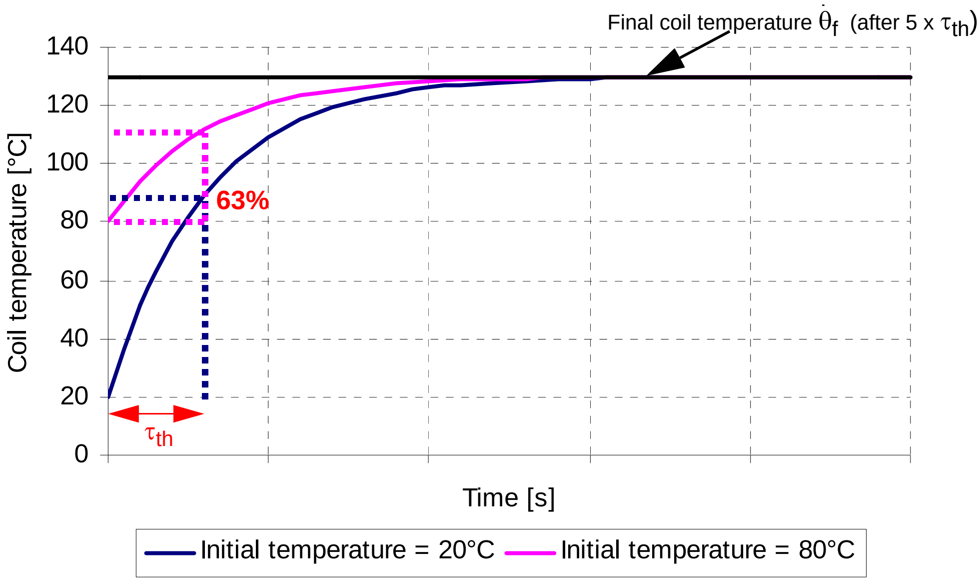
At higher speed, the stabilized temperature depends on the copper losses at the stator and iron losses at the stator and rotor. Refer to the torque/speed curve on the data sheet corresponding to the motor (as well as §5.4).

6.1.5.2 Transient operating conditions

In variable thermal conditions, the motor temperature depends on its thermal constant τ_{th} given below. The thermal time constant corresponds to the time required for a motor to reach 63% of the final temperature after a local step. In transient conditions, the temperature is given by the following formula:

$$\theta(t) = \theta_i + (\theta_f - \theta_i) \cdot \left(1 - e^{\frac{-t}{\tau_{th}}}\right)$$

with: $\theta(t)$ = temperature [°C] vs. time
θ_i = initial coil temperature [°C]
θ_f = final coil temperature [°C] (stabilized value)
τ_{th} = thermal time constant [s]



Remark: Refer to the corresponding data sheets to know the thermal time constant. For the TMB and TMK motors, the values in the data sheets are given for a water surface convection of 2000 W/m²K for the water channel. The use of a coolant with a surface coefficient different from 2000 W/m²K will result in a change in thermal time constant and cooling efficiency. If only air cooling is used, the thermal time constant will be much higher than noted above and its value will be dependent on the design of the customer's system.

The theoretical final temperature θ_f estimated in continuous operating mode can be given by the following formula:

$$\theta_f = \theta_{amb} + \left(\left(\frac{I_x}{I_c}\right)^2\right) \cdot (\theta_c - 20)$$

with: I_x = current [A_{RMS}] sent to the motor
Ic = continuous current [A_{RMS}] for the coil temperature θ_c (value given in the data sheet with or without water cooling).

θ_f is a theoretical value and has no limit (can be higher than 130°C). This theoretical value allows the user to determine the maximum time that the I_x current can be applied:

- If $I_x \leq I_c$

I_x can be applied indefinitely and θ_f is given by the above-mentioned formula. Without water cooling, the thermal time constant is bigger. A fixed value cannot be given here as the result strongly depends on the customer's construction.

- If $I_x > 2I_c$, the following formula must be used to take the adiabatic heating of the copper into account:

$$t = \frac{125 \cdot d^4 \cdot N^2 \cdot \Delta\theta}{(1 + 0.00392 \cdot \Delta\theta) \cdot (I_x)^2}$$

with: $\Delta\theta$ = temperature difference: maximum copper temperature - initial copper temperature = 130 - θ_i
d = copper wire diameter [mm] (refer to §3.3.4 for more information)
N = number of electrical sectors (refer to §3.3.4 for more information)
t = time [s] while the I_x current is applied

Example:

Example with a TMB0140-030-3RBS and with:

$I_x = 15\ A_{RMS}$
$I_c = 5.8\ A_{RMS}$
$\theta_i = 20°C$, initial coil temperature
d = 0.63 mm (refer to §3.3.4 for more information)
N = 2 (refer to §3.3.4 for more information)

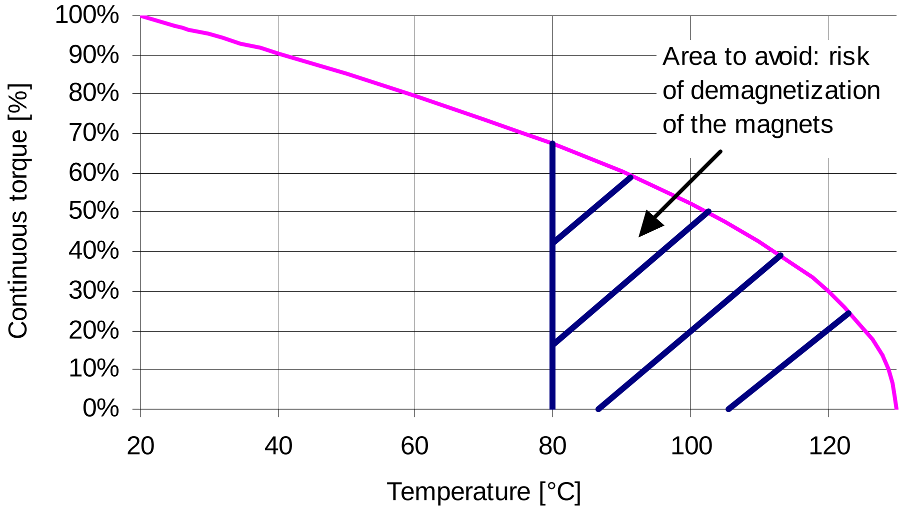
$\Delta\theta = 110°C$ and then the maximum time that I_x can be applied is:

$$t = \frac{125 \cdot 0.63^4 \cdot 2^2 \cdot 110}{(1 + 0.00392 \cdot 110) \cdot 15^2} = 26.9s$$

With $\theta i = 80°C$, the result is t = 14.63s

6.1.5.3 *Continuous torque vs. temperature*

The values of the continuous torque in the data sheet are given for an ambient (or water) temperature of 20°C and a coil temperature of 130°C. A different temperature will have a direct effect on the continuous torque. The following graph represents the variation of the continuous torque vs. temperature (ambient temperature for free air convection and inlet temperature with a constant flow rate for water cooling) and for a maximum coil temperature of 130°C.



According to §6.1.5.1:

$$\frac{130 - \theta_{amb}}{\theta_c - 20} = \frac{T_x^2}{T_c^2} \quad \text{then} \quad T_x = T_c \sqrt{\frac{130 - \theta_{amb}}{\theta_c - 20}} = f(\theta_{amb})$$

6.1.6 Cooling system design

The customer is responsible for the design of the cooling system and connection to the motor of the coolant inlet and outlet. If the continuous torque given in the data sheet is never reached, the cooling system can be optimized (lower flow rate,...) while keeping a coil temperature of 130°C and a water temperature difference ΔTw of 5°C or 10°C depending on the motor size (refer to the corresponding data sheet).

Here are the formulas to adjust the cooling according to the dissipated power of the motor:

- Dissipated power (Pc_{user}) with respect to the user's continuous torque (Tc_{user})

$$Pc_{user} = \frac{Pc_{data\ sheet}}{\left(\frac{Tc_{data\ sheet}}{Tc_{user}}\right)^2}$$

with: Tc in [Nm] and Pc in [W]

- Flow rate (qw_{user}) (with a coil temperature of 130°C) with respect to the water temperature difference ΔTw_{user}

$$qw_{user} = 0.0143 \cdot \frac{Pc_{user}}{\Delta Tw_{user}}$$

- Pressure drop (ΔP_{user}) with respect to the water flow (qw)

$$\Delta P_{user} = \Delta P_{data\ sheet} \cdot \frac{qw_{user}}{qw_{data\ sheet}}$$

Example:

The goal is to optimize the cooling system for a TMB0360-070 working at a continuous torque of 240 Nm with a coil temperature of 130°C and a ΔTw = 5°C.

$$Pc_{user} = \frac{Pc_{data\ sheet}}{\left(\frac{Tc_{data\ sheet}}{Tc_{user}}\right)^2} = \frac{3530}{\left(\frac{534}{240}\right)^2} = 713W$$

$$Fw_{user} = 0.0143 \cdot \frac{Pc_{user}}{\Delta Tw_{user}} = 0.0143 \cdot \frac{713}{5} = 2.04 l/min$$

then $$\Delta P_{user} = \Delta P_{data\ sheet} \cdot \frac{Fw_{user}}{Fw_{data\ sheet}} = 0.44 \cdot \frac{2.04}{10.1} = 0.09 bar$$

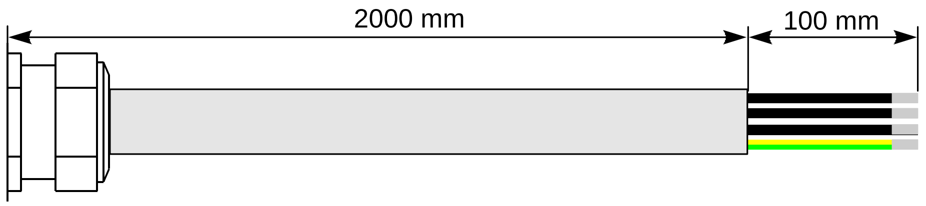
The following chart summarizes the difference between the standard operating conditions and the user's operating conditions.

Characteristics (with water cooling)	Standard operating conditions	User's operating conditions
Continuous torque Tc	534 Nm	240 Nm
Continuous power dissipation Pc	3530 W	758 W
Water temperature difference ΔTw	5	5
Water flow qw	10.1 l/min	2.04 l/min
Pressure drop Δp	0.44 bar	0.09 bar

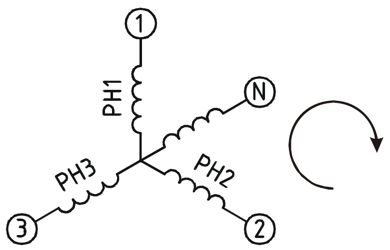
6.2 Motor cable

6.2.1 Cable description

The standard length of the temperature and power cable of ETEL's torque motors is 2m (+ 100mm of bare conductors). The cables do not include connectors. Custom lengths (up to 8m in 1m increments) are also available. Each single wire is crimped with a terminal lug.



Here is the function corresponding to the colors of the motor cables:

Color and wire number	Function	Drawing
Black wire with number 1 or U	Phase 1 (PH1)	
Black wire with number 2 or V	Phase 2 (PH2)	
Black wire with number 3 or W	Phase 3 (PH3)	
Yellow and green wire	Ground (GND)	
Black wire with number Br1 or 5 or white cable	Neutral point wire	
Black wire with number Br2 or 6 or black wire without label	None(*)	

(*): This wire is automatically present when the neutral point wire (which is an option) is added in the motor as it is a 2 x 1 or 2 x 1.5 mm^2 cable.

Remark: The number of wires depends on the motor type. Refer to §6.2.3 for additional information about the type of cable.
If the neutral point wire is present, this wire must be carefully insulated or connected to an IMSPS (refer to §7.3). Depending on the machine setup (controller, switching frequency, motor, cable length), voltage spikes up to 1400V may occur on the neutral point.
ETEL advises not to use the cable of the torque motors in a cable chain as it is considered as a wear component.

6.2.2 Cable output

The torque motors include two types of cable:

- The power cable: depending on the kind of torque motor, this cable is provided with a straight or a 90° output and there is one or several power cables.

- The temperature sensor cable: this cable is always provided with a straight output.

The strain relief dimensions for the most common torque motors windings are given in the corresponding **'Interface drawing'** (available on our website).

6.2.3 Cable type

6.2.3.1 Power cable

The wire section and the power cable diameter for the most common torque motors windings are given in the corresponding **'Interface drawing'** (available on our website).

The power cable diameters are nominal values given by the cable manufacturer. The dimensions can be modified without prior notice.
Two types of cable are used for the power cable of the torque motors:

- Olflex-servo-FD 790 CP cable from Lappkabel (UL and CE certified).
- Superflex-plus (C) PUR combi 0.6/1kV Desina from Lütze (UL and CE certified).
- Chainflex (CF310 or FF900) from Igus (UL and CE certified).

Wire section [mm^2]	1 x 6	1 x 16	4 x 1.5	4 x 2.5	4 x 4	4 x 6	4 x 10	4 x 16	4 x 1.5 + 2 x 1.5	4 x 2.5 + 2 x 1.5	4 x 4 + 2 x 1	4 x 6 + 2 x 1	4 x 10 + 2 x 1	4 x 16 + 2 x 1.5
American Wire Gauge (AWG)	**AWG9**	**AWG5**	**AWG15**	**AWG13**	**AWG11**	**AWG9**	**AWG7**	**AWG5**	**AWG15 + AWG15**	**AWG13 + AWG15**	**AWG11 + AWG17**	**AWG19 + AWG17**	**AWG7 + AWG17**	**AWG5 + AWG15**
Olflex-servo-FD			X	X	X	X	X	X			X	X	X	
Superflex-plus									X	X				X
Chainflex	X	X												

Remark: (+ 2 x 1) or (+ 2 x 1.5) mentioned on the 'Wiring drawing' means that the corresponding motor is delivered with a neutral point wire output (black wire with number Br1 or black wire with number 5 or white cable) and the IMSPS (Interface Motor SPike Suppressor) can be used (refer to §7.3). A second wire (black wire with number Br2 or black wire with number 6 or black wire without label) must be connected to the ground as it is not connected inside the motor. Refer to §7.3.4 and §9.8.2 for more information about the connection.
Both cables are shielded. The shield is always internally connected to the strain relief. **It is strictly forbidden to disconnect the power cable from the strain relief.** The other end of the cable is delivered **without a connector.**
The cables are chosen according to EN 60204-1 standard (installation mode: E)
For more information about the cables, refer to the 'Interface winding drawing' corresponding to your torque motor.

6.2.3.2 Temperature sensor cable

The wire section and the diameter of the temperature sensor cable for the torque motors are given in the corresponding **'Interface drawing'** (available on our website).

Wire section [mm^2]	American Wire Gauge
7 x 0.25	AWG23
10 x 0.25	AWG23

The temperature sensor cable diameters are nominal values given by the cable manufacturer. The dimensions can be modified without prior notice.

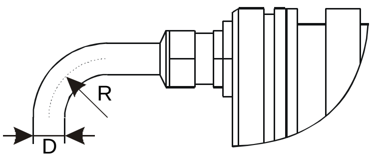
Only one type of cable is used for the temperature sensor cable of the torque motors: Superflex Tronic (C) PUR from Lütze (UL and CE certified).

Remark: The temperature sensor cable is shielded. The shield is always internally connected to the strain relief. **It is strictly forbidden to disconnect the temperature sensor cable from the strain relief. The other end of the cable is delivered without a connector.**

For more information about the cables, refer to the 'Interface drawing' corresponding to your torque motor.

6.2.4 Cable bend radius

The following table provides the minimum bend radius for fixed and moving power and temperature sensor cables. **These values must be respected to avoid damaging cables.**

Characteristics	Representation	Power cable			Temperature sensor cable
		Olflex-servo-FD	Superflex plus	Chainflex	Superflex Tronic
Minimum bend radius for fixed cable		R = 4 x D	R = 6 x D	R = 4 x D	R = 6 x D
Minimum bend radius for moving cable		R = 12 x D	R = 10 x D	R = 7.5 x D	R = 12 x D

6.2.5 Power cable resistance

The following table provides nominal resistance values for torque motor power cables as a function of length.

Cable length [m]	1	2	3	4	5	6	7	8
Section [mm^2]	Additional resistance between 2 phases [Ω]							
0.25(*)	0.136	0.272	0.408	0.544	0.68	0.816	0.952	1.088
1.0	0.034	0.068	0.102	0.136	0.170	0.204	0.238	0.272
1.5	0,0226	0,0452	0,0678	0,0904	0,113	0,1356	0,1582	0,1808
2.5	0,0136	0,0272	0,0408	0,0544	0,068	0,0816	0,0952	0,1088
4.0	0,0085	0,017	0,0255	0,034	0,0425	0,051	0,0595	0,068
6.0	0,00566	0,01132	0,01698	0,02264	0,0283	0,03396	0,03962	0,04528
10	0,0034	0,0068	0,0102	0,0136	0,017	0,0204	0,0238	0,0272
16	0,00212	0,00424	0,00636	0,00848	0,0106	0,01272	0,01484	0,01696

(*): for temperature sensor only

These constants are given at 20°C. They have to be added to the resistance value of the motor given in the data sheets.

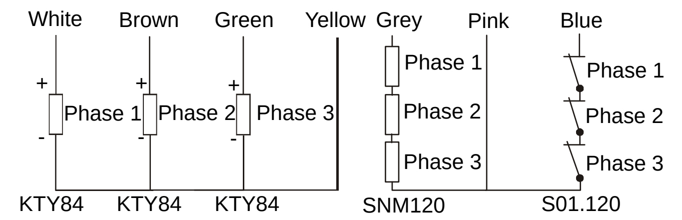
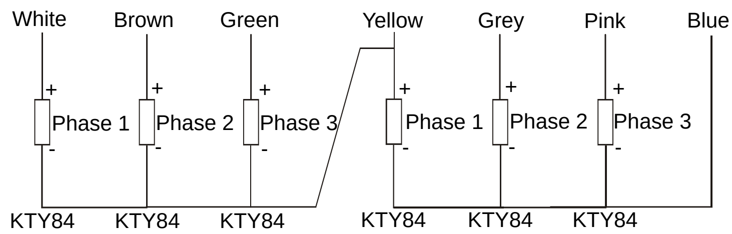
6.3 Temperature sensor

	Caution	ETEL SA disclaims all responsibility to possible industrial accidents and material damages if the temperature sensors are not plugged.

6.3.1 Thermal protection configurations

All torque motors families are delivered with three integrated temperature sensors. Each phase of the motor is connected to one of the three temperature sensors mounted in series. The KTY sensor allows the user to monitor the variation in temperature inside the motor while SNM and S01 act like a switch.

Here is the temperature sensor configurations in the torque motors:

<table>
<tr><th>Motors family</th><th>Temperature sensor configuration</th><th>Temperature sensor wiring</th></tr>
<tr><td rowspan="2">TMB
TML
TMM
TMK</td><td>Configuration 8
(TMB.....-#8#-##)
(TML.....-#8#-##)
(TMM.....-#8#-##)
(TMK.....-#8#-##)</td><td>
</td></tr>
<tr><td>Configuration H
(TMB.....-#H#-##)
(TML.....-#H#-##)
(TMM.....-#H#-##)
(TMK.....-#H#-##)
Strongly recommended for motors using the IMTHP</td><td>
</td></tr>
</table>

6.3.2 Thermal protection characteristics

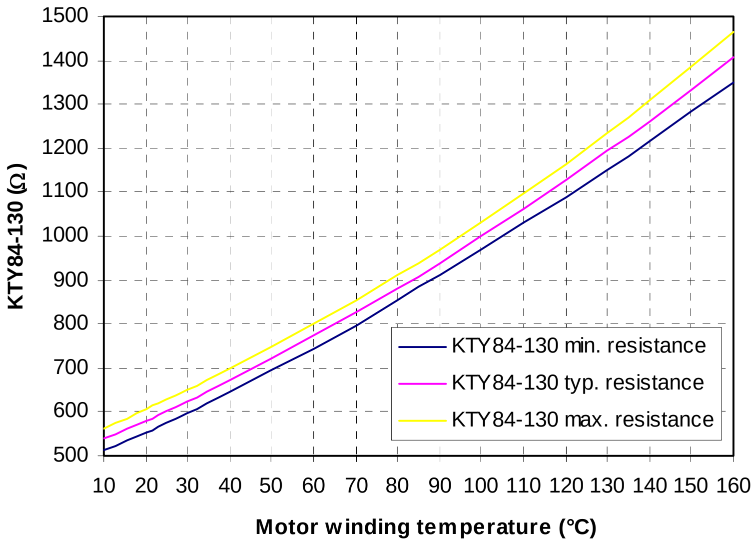
Here are the characteristics of the different thermal protections.

KTY84-130

The KTY84-130 is a silicon temperature sensor that outputs a value of resistance which corresponds to the temperature of the coil in the torque motor.

Caution: **KTY84** sensors are **sensitive to ElectroStatic Discharge (ESD)**. They are shipped with their cable ends protected by insulating sleeves. To connect these sensors, all necessary precautions against ESD must be taken by the user (ESD protected area, grounded wristband (to the housing for example),...).

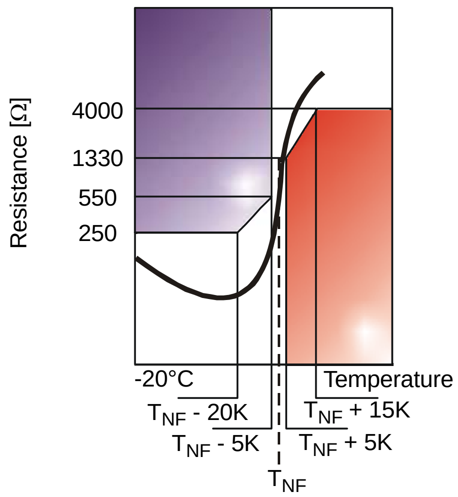
Parameters	Values
Resistance at 20°C	$555\Omega \leq x \leq 607\Omega$
Resistance at 100°C	$970\Omega \leq x \leq 1030\Omega$
Continuous current at 100°C	2mA



SNM.120

The SNM.120 is a thermistor that outputs a value of resistance as a function of coil temperature. The output resistance changes sharply in the region of the nominal response temperature (T_{NF}) of 120°C.

Parameters	Values
Resistance in the temperature range -20°C up to T_{NF}-20K	$20\Omega \leq x \leq 250\Omega$
Resistance at T_{NF}-5K	$\leq 550\Omega$
Resistance at T_{NF}+5K	$\geq 1330\Omega$
Resistance at T_{NF}+15K	$\geq 4000\Omega$



Remark: When there are 3 SNM.120 in series, the controller must NOT trigger at a value lower than three time the resistance value given at ambient temperature.

S01.120

The S01.120 is a fast response temperature limit switch with a trip temperature of 120°C.

6.4 Mechanical interface

6.4.1 Fastening holes

The following chart gives the type and quantity of fastening holes as well as the friction coefficient and maximum tightening torque to be applied on each torque motors family.

6.4.1.1 TMB family

For a given TMB motor series, there is the same quantity and type of holes in both rotor and stator. The tightening torque given in the following chart must be applied to the rotor and the stator.

Motor series	Type & quantity of holes	Nominal tightening torque [Nm]
TMB0140-030 TMB0140-050 TMB0140-070	M5 x 10 (8x)	5.8
TMB0140-100 TMB0140-150	M5 x 10 (16x)(*)	5.8
TMB0175-030 TMB0175-050 TMB0175-070	M5 x 10 (8x)	5.8
TMB0175-100 TMB0175-150	M5 x 10 (16x)(*)	5.8
TMB0210-030 TMB0210-050 TMB0210-070	M5 x 10 (12x)	5.8
TMB0210-100 TMB0210-150	M5 x 10 (24x)(*)	5.8
TMB0291-030 TMB0291-050 TMB0291-070	M5 x 10 (12x)	5.8
TMB0291-100 TMB0291-150	M5 x 10 (24x)(*)	5.8

Motor series	Type & quantity of holes	Nominal tightening torque [Nm]
TMB0360-030 TMB0360-050 TMB0360-070	M6 x 10 (12x)	10
TMB0360-100 TMB0360-150	M6 x 10 (24x)(*)	10
TMB0450-030 TMB0450-050 TMB0450-070	M8 x 12 (12x)	24
TMB0450-100 TMB0450-150	M8 x 12 (24x)(*)	24
TMB0530-030 TMB0530-050 TMB0530-070	M8 x 12 (12x)	24
TMB0530-100 TMB0530-150	M8 x 12 (24x)(*)	24

Motor series	Type & quantity of holes	Nominal tightening torque [Nm]
TMB0760-030 TMB0760-050 TMB0760-070	M8 x 15 (16x)	24
TMB0760-100 TMB0760-150	M8 x 15 (32x)(*)	24
TMB0990-030 TMB0990-050 TMB0990-070 TMB0990-100	M10 x 20 (24x)	48
TMB0990-150	M10 x 20 (48x)(*)	48
TMB1221-030 TMB1221-050 TMB1221-070 TMB1221-100	M10 x 20 (24x)	48
TMB1221-150	M10 x 20 (48x)(*)	48

Remark: The minimum quality of the screw must be 8.8.
(*): Due to the presence of the strain relief on the stator and the locating pin on the rotor, these two sides have one hole less than the above-mentioned value.

6.4.1.2 TML family

The tightening torques given in the following chart must be applied to the lugs of the TML's stator. The type and quantity of holes as well as the tightening torque which must be applied to the rotor of the TML is identical to the one of the TMB given in §6.4.1.1.

Motor series	∅ & quantity of holes	Nominal tightening torque [Nm]
TML0210-xxx	∅9 (12x)	15
TML0291-xxx	∅9 (12x)	15
TML0360-030 TML0360-050 TML0360-070	∅11 (6x)	28
TML0360-100 TML0360-150	∅11 (12x)	28

Motor series	∅ & quantity of holes	Nominal tightening torque [Nm]
TML0450-030 TML0450-050 TML0450-070	∅11 (8x)	28
TML0450-100 TML0450-150	∅11 (16x)	28
TML0530-030 TML0530-050 TML0530-070	∅11 (8x)	28
TML0530-100 TML0530-150	∅11 (16x)	28

Remark: The minimum quality of the screw must be 8.8.

6.4.1.3 *TMM family*

The stator of the TMM torque motors does not include any fastening hole. Refer to §9.6.8 for more information about the assembly of the TMM torque motors. The type and quantity of holes as well as the tightening torque which must be applied to the rotor of the TMM is identical to the one of the TMB given in §6.4.1.1.

6.4.1.4 *TMK family*

The tightening torques given in the following chart must be applied to the rotor. The type and quantity of holes as well as the tightening torque which must be applied to the stator of the TMK is identical to the one of the TMB given in §6.4.1.1.

Motor series	Type & quantity of holes	Nominal tightening torque [Nm]
TMK0175-050 TMK0175-070	M6 x 14 (6x)(*)	16.5
TMK0175-100 TMK0175-150	M6 x 14 (12x)(*)	16.5

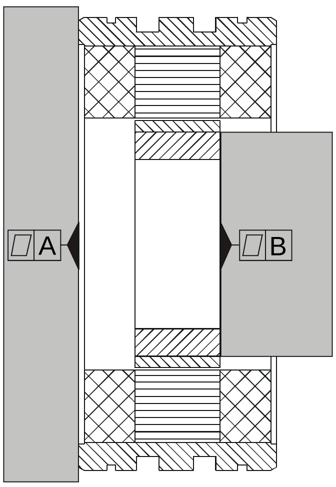
Motor series	Type & quantity of holes	Nominal tightening torque [Nm]
TMK0291-050 TMK0291-070	M6 x 12 (12x)	16.5
TMK0291-100 TMK0291-150	M6 x 12 (24x)	16.5

Motor series	Type & quantity of holes	Nominal tightening torque [Nm]
TMK0360-050 TMK0360-070	M6 x 12 (12x)	16.5
TMK0360-100 TMK0360-150	M6 x 12 (24x)	16.5

Remark: The minimum quality of the screw must be 12.9.
(*): The fastening holes on the rotor of the TMK0175 are present on one side **ONLY**.

6.4.2 Flatness

The flatness requirement, recommended by ETEL, for the user structure interfacing to the torque motor should comply with the following values:



Motor series	A [mm]	B [mm]
TM#0140	0.05	0.05
TM#0175	0.05	0.05
TM#0210	0.1	0.1
TM#0291	0.1	0.1
TM#0360	0.1	0.1
TM#0450	0.15	0.15
TM#0530	0.15	0.15
TMB0760	0.2	0.2
TMB0990	0.2	0.2
TMB1221	0.2	0.2

6.5 Environmental rating

The class of protection of the torque motors are defined by the International Protection degree called IP degree. It is made up of two numbers:

- the first one represents the protection against penetration by foreign bodies and dust.
- the second one represents the protection against penetration by water.

According to IEC 60034-5 standard, all ETEL's torque motors have the following class of protection: **IP60** for the stator and **IP00** for the rotor.

	Caution	**The torque motors must be used in an environment respecting the class of protection of these motors**

The torque motors have a thermal class F according to IEC 60085 standard.

7. Associated components

7.1 Key components

To achieve optimum performance from a direct drive motor it must be built to the necessary standards of precision and stiffness as part of a complete direct drive solution. In addition to the motor, the key components of a direct drive system are the electronics, the encoder and the bearings.

7.1.1 Encoder

The encoder choice is application specific, therefore only general advice can be given by ETEL, however, high-precision, high-resolution feedback is essential for achieving optimum performance of a direct drive. Direct coupling of the load to the controller improves accuracy but the highest performance can only be achieved with the appropriate selection of the feedback device. This requires an optical absolute or incremental encoder with high line counts. A rough estimate to achieve good performances is 100 lines per pole. To achieve very high accuracy this value must be increased. Very high speed applications may require a lower line count to limit signal frequency. When combined with the interpolation capability of the electronics, resolutions of less than 1 arc-sec can be achieved.

7.1.2 Bearing

The bearing choice is application specific, therefore only general advice can be given by ETEL. Bearing selection is dependant on a system's dynamic load and accuracy requirements. Applications that require high stability, accuracy and repeatability will typically utilize high stiffness bearings to meet their performance needs. Mechanical bearings are often the only wear-prone components in a direct drive based system (refer to §9.6 for more information). The most commonly used bearings are:

- Deep groove ball bearing: high speed capability, high precision and low cost
- Angular contact ball bearing: high speed capability, suitable for combined loads (axial & radial) and high precision.
- Cross roller bearing: suitable for combined loads, high stiffness, high precision, assembly with one single bearing.
- Axial-radial roller bearing: very high stiffness, suitable for combined load and high precision.

7.1.3 Electronics

The highest level of torque motor performance is achieved when integrated with a fully digital controller with high loop bandwidth like the ETEL AccurET series position controllers.
The working principles of the electronic control system of a direct drive motor are similar to that for a classical brushless servomotor. In the case of direct drive, there is no mechanical transmission to reduce motion amplitude and the speed and position feedback resolution do not benefit from the transmission multiplication factor. Apart from this, the inertia is much smaller reducing the filtering effect at constant speed.

The key factors to take into account when selecting a direct drive controller are as follows:

- Fully digital control loop (current, speed and position loops).
- Direct sine commutation through encoder signals (eliminates need for Hall sensors).
- High current and position loop bandwidths (typically > 2 kHz and > 100 Hz respectively).
- High encoder interpolation factor to ensure adequate speed and position resolution (typically > 256 times) and high bandwidth (typically > 250 kHz).
- Advanced servo algorithms (PID with feedforward, state space and RST regulators, observers, notch filters etc.).
- Capability to compensate cogging torque, torque ripple, stick-slip and other system defaults.
- Temperature sensor management.

ETEL's torque motors have been successfully integrated with most major brands of servo controllers and CNC including: Heidenhain, Siemens, Fanuc, Bosch, Indramat, Kollmorgen and Num (Schneider Electric).

7.2 Accessories

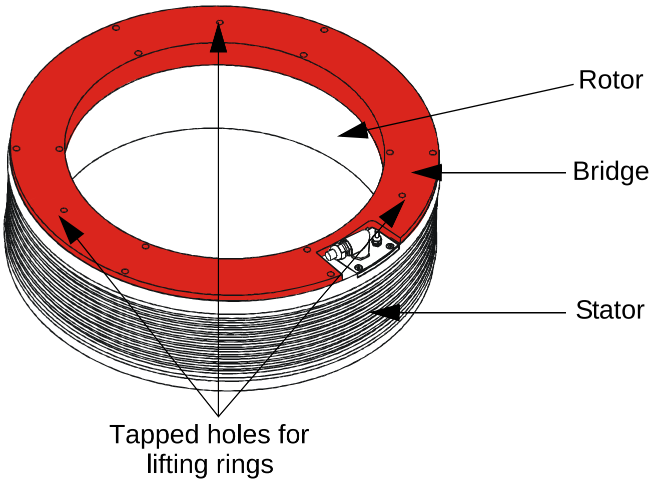
7.2.1 Bridges

ETEL's torque motor mounting bridge is used to maintain axial alignment of the rotor and the stator. The bridge, available on request, simplifies handling and installation of the motor. Three different types of bridge can be used.

- **Ring bridge**

This bridge, made up of aluminum, can be used only with TMB and TMK torque motors family. It can be mounted on either side of the motor. If the motor is delivered with a bridge, it must be removed **only** when the motor has been correctly installed in the customer's machine and **before** starting up this machine (refer to §9.6.2 for more information).

Ring bridge

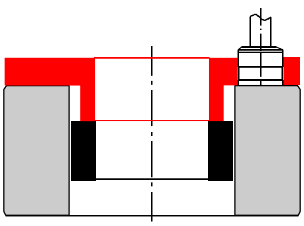
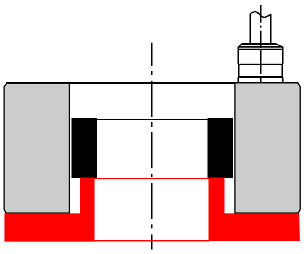


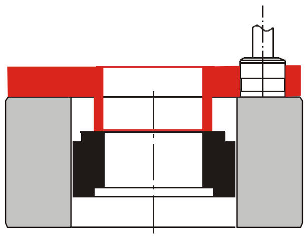
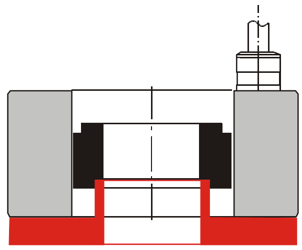
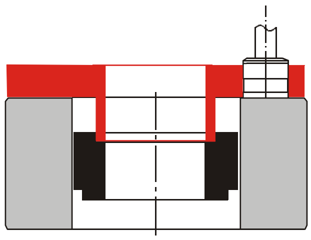
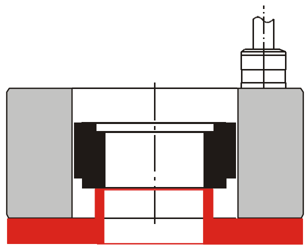
The following chart identifies the type and depth of the tapped interface holes in the ring bridges.

Motor series	TMB0140	TMx0175	TMB0210	TMx0291	TMx0360	TMB0450	TMB0530	TMB0760	TMB0990	TMB1221
Screw type	M8	M10	M10	M10	M10	M10	M10	M10	M10	M10
Thread depth	12.5 mm	12.5 mm	12.5 mm	12 mm	15 mm	15 mm	15 mm	15 mm	20 mm	20 mm

Remark: Be aware of the thread depth when using a lifting ring. When fixing it, it can touch and then damage the motor if the tapping depth of the lifting ring is much longer than the one of the bridge mentioned above.

Here are the configurations of this bridge mentioned in §3.3:

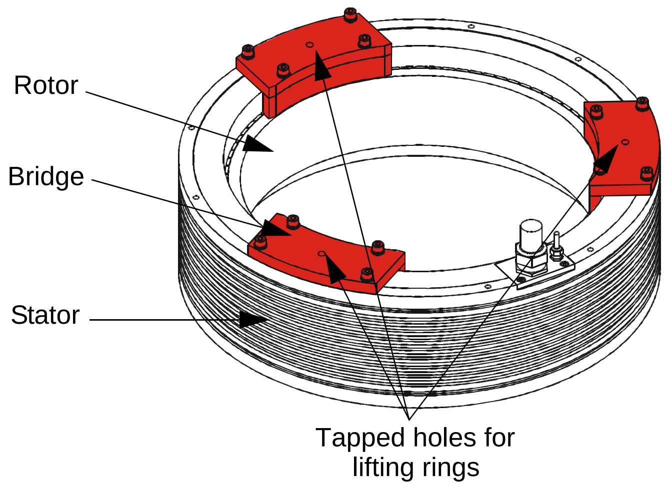
TMB####-###-####-###-ER	**TMB####-###-####-###-EL**
	

TMK####-100-####-###-ER & TMK####-150-####-###-ER	TMK####-100-####-###-EL & TMK####-150-####-###-EL
	
TMK####-100-####-###-FR & TMK####-150-####-###-FR	**TMK####-100-####-###-FL & TMK####-150-####-###-FL**
	

- **Segmented bridges**

This bridge, made up of aluminum, can be used only with TMB0360 to TMB1221 torque motors family. They can be mounted on either side of the motor. If the motor is delivered with a bridge, it must be removed **only** when the motor has been correctly installed in the customer's machine and **before** starting up this machine (refer to §9.6.2 for more information).

Segmented bridge



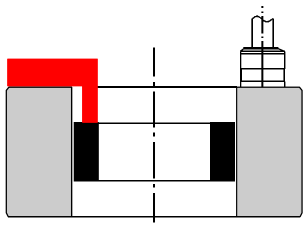
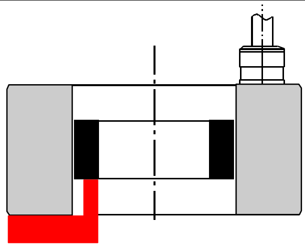
Remark: The segmented bridge is made up of 3 pieces for TMB0360 to TMB0530, 4 pieces for TMB0760 and 6 pieces for TMB0990 and TMB1221 motors.

The following chart identifies the type and depth of the tapped interface holes in the segmented bridges.

Motor series	TMB0140	TMx0175	TMB0210	TMx0291	TMx0360	TMB0450	TMB0530	TMB0760	TMB0990	TMB1221
Screw type	M8	M10	M10	M10	M10	M10	M10	M10	M10	M10
Thread depth	12.5 mm	12.5 mm	12.5 mm	12 mm	15 mm	15 mm	15 mm	15 mm	20 mm	20 mm

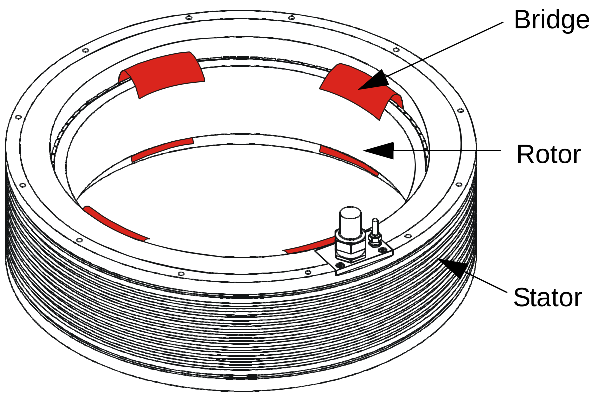
Remark: Be aware of the thread depth when using a lifting ring. When fixing it, it can touch and then damage the motor if the tapping depth of the lifting ring is much longer than the one of the bridge mentioned above.

Here are the configurations of this bridge mentioned in §3.3:

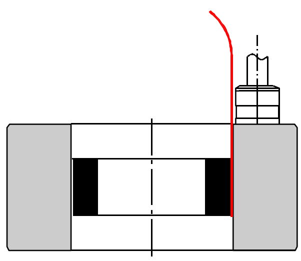
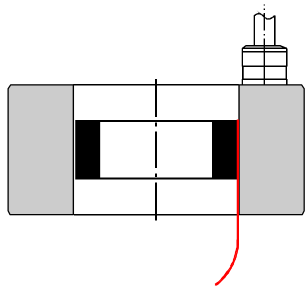
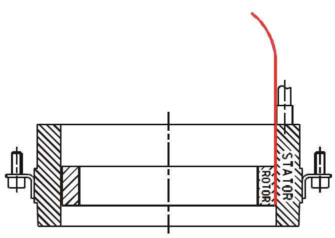
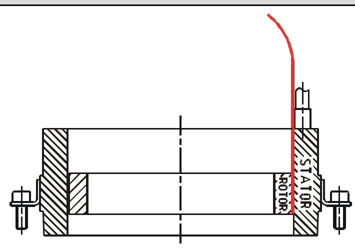
TMB####-###-####-###-ER	TMB####-###-####-###-EL
	

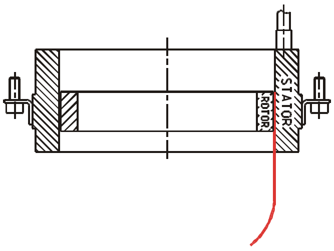
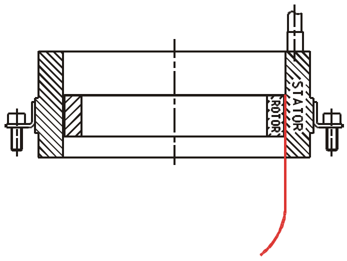
- **Magnetic bridge**

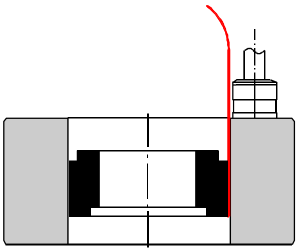
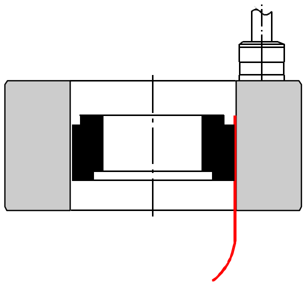
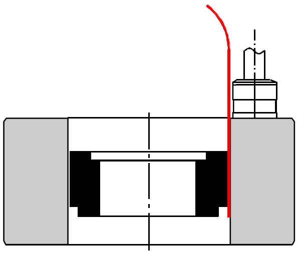
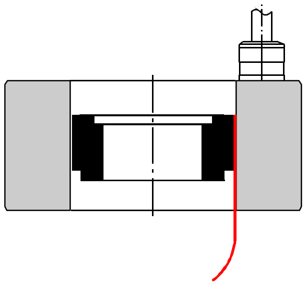
This bridge, made up of magnetic sheets, can be used with any torque motors family. It is wedged in the air gap of the motor in which the rotor and the stator are maintained together thanks to the attraction force of the magnets. It can be mounted on either side of the motor. **However, the use of this bridge requires an adaptation of the customer's interface (refer to §9.6.7).**

Magnetic bridge


Here are the configurations of this bridge mentioned in §3.3:

TMB & TMM####-###-####-###-MR TML0360 to TML0530####-###-####-###-MR	TMB & TMM####-###-####-###-ML TML0360 to TML0530####-###-####-###-ML
	
TML0210 & TML0291####-###-####-###-MC	**TML0210 & TML0291####-###-####-###-MO**
	

TML0210 & TML0291####-###-####-###-KC	TML0210 & TML0291####-###-####-###-KO
	

TMK####-050-####-###-MR & TMK####-070-####-###-MR	TMK####-050-####-###-ML & TMK####-070-####-###-ML
	
TMK####-050-####-###-KR & TMK####-070-####-###-KR	**TMK####-050-####-###-KL & TMK####-070-####-###-KL**
	

7.3 Spike suppressor

The **I**nterface **M**otor **SP**ike **S**uppressor, called IMSPS allows the user to protect the motor against possible overvoltage on the neutral point and prevent damage to the motor (refer to §5.3 for more information). The purpose of the IMSPS is to limit the voltage.

7.3.1 General safety instructions

Please read all safety precautions listed below before handling an IMSPS:

General precautions	
⚠	**1.** The IMSPS is designed to be used in an industrial environment, and should be handled and operated by skilled technicians only, under the condition they have read and understood this chapter **2.** The IMSPS must be handled in an ESD protected environment. **3.** Never use the IMSPS for purposes other than those described in this chapter **4.** IMSPS operation is not allowed without ground connection, with a bad ground quality (high impedance), or with a bad connection to the ground (wire or connection not conform) **5.** Handling is not permitted if the electrical appliances are switched on. **6.** By the functioning of the IMSPS, a current > 3.5 mA can exist between the neutral point wire and the ground. It is necessary to connect a second ground cable to the screw provided on the IMSPS.

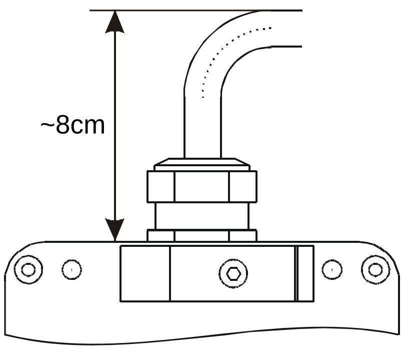
7.3.2 Characteristics

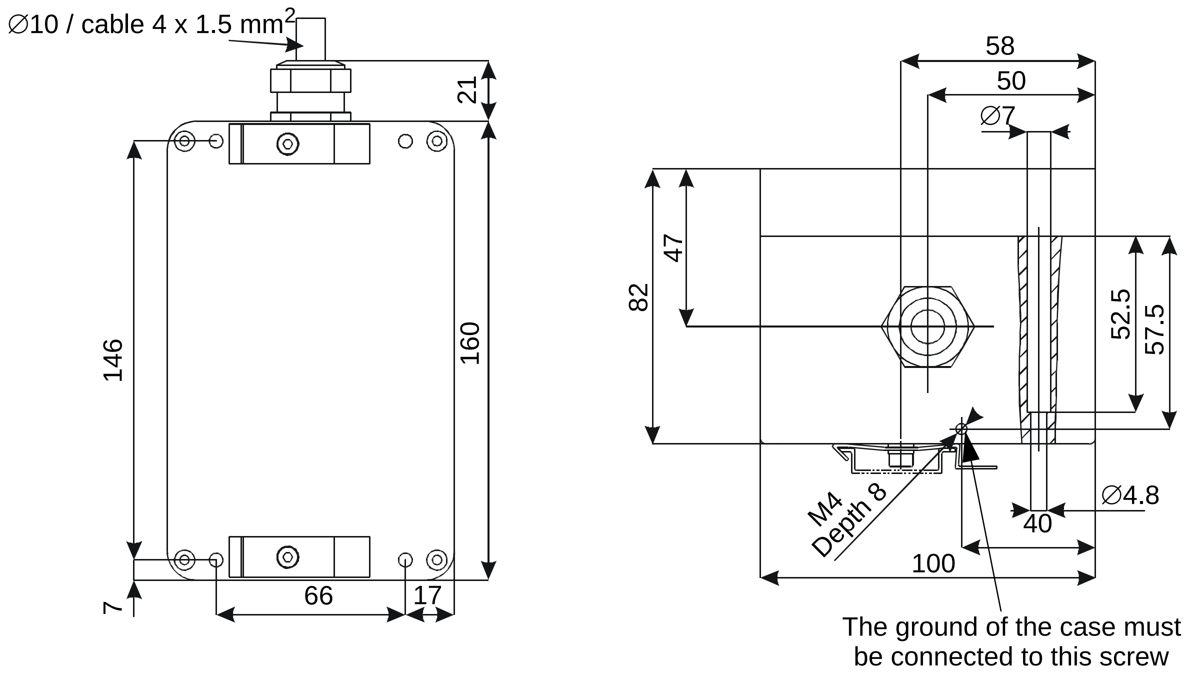
Generals characteristics of the IMSPS are:

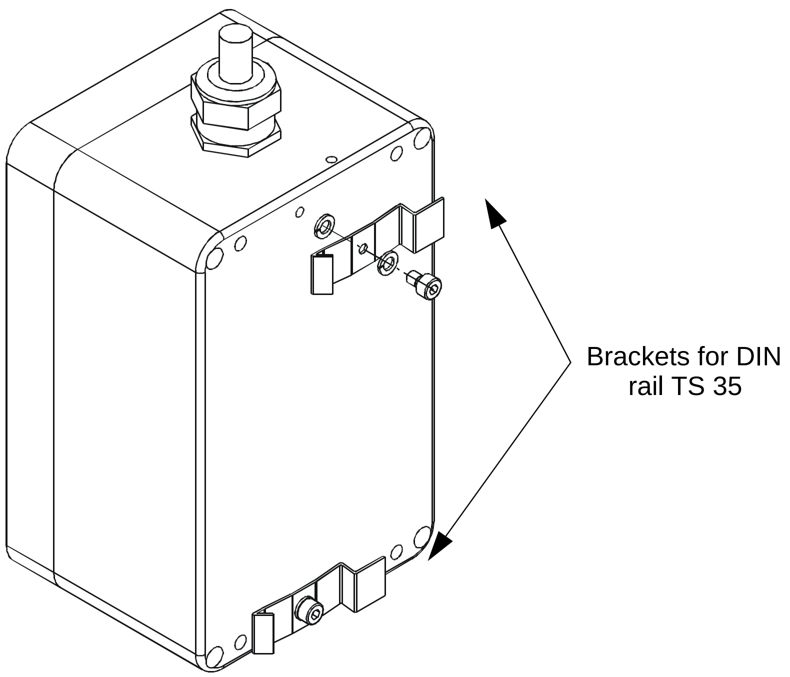
- Saturation voltage: 1000V ±10%
- Maximum current: $15mA_{RMS}$
- Degree of protection: IP 65
- Temperature range: +5°C to +40°C
- Gross weight: ≈2Kg

7.3.3 Installation

The IMSPS is delivered with a one meter cable (∅ 10mm). The external dimensions of the case are: 160mm(L) x 100mm(W) x 81mm(H). Be aware that the space available to interface the IMSPS must accommodate the strain relief and bend radius of the cable (~8cm). The mounting holes provide clearance for 4 M4 screws.







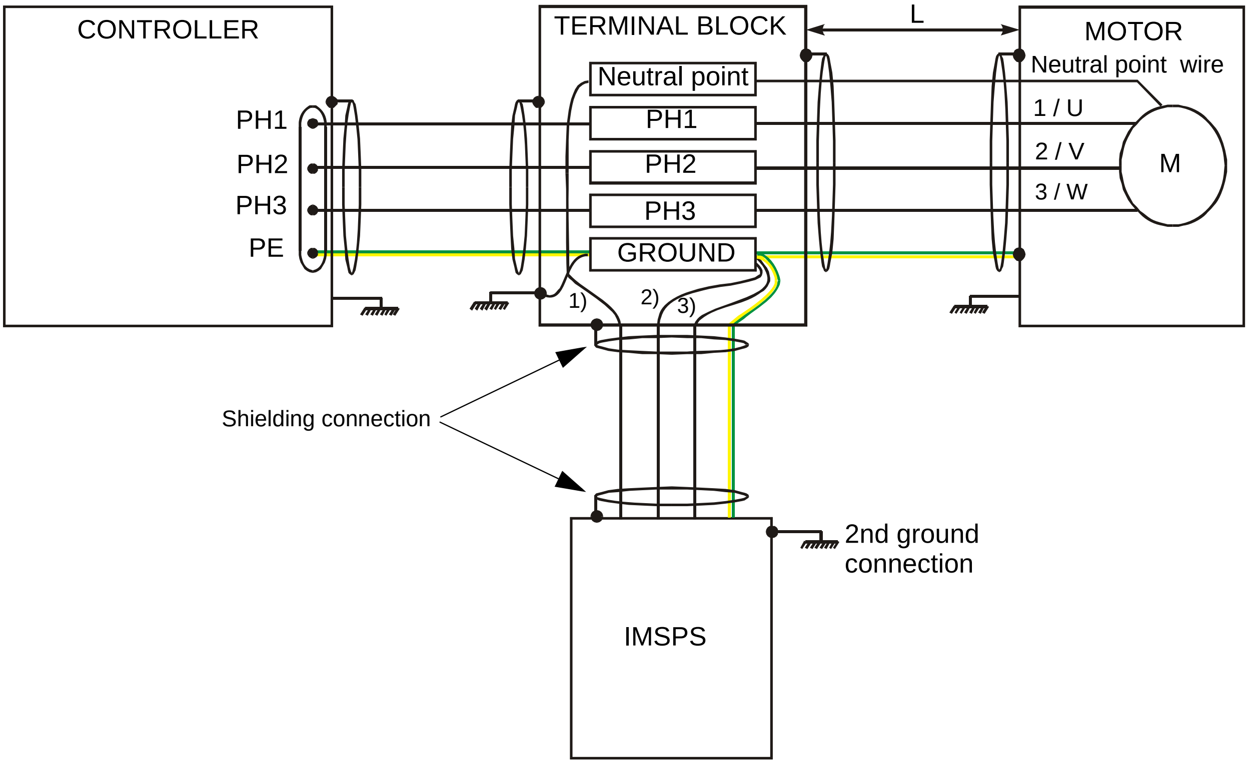
7.3.4 Connection procedure

The IMSPS can be connected in two ways:

7.3.4.1 IMSPS, controller and motor connected to the same terminal block

- Switch off the controller (and the electrical panel if the terminal block is inside).
- Fasten the case with the brackets or open it and use the M4 screws (4x).
- Connect the ground of the case of the IMSPS (using the screw under the strain relief) as well as the ground wire (yellow/green) to the ground of the terminal block. We also recommend to connect the black wires number 2 and 3 (not used in the IMSPS) to the ground of the terminal block.
- Connect the shield of the IMSPS cable to the terminal block.
- Connect the neutral point wire (black cable number 1) protected by an insulation (ESD protection).

- Close the cover if the 4 screws have been used to fasten the case.
- Switch on the controller



1) Neutral point wire (black wire number 1)
2) This wire must be connected to the ground (as this wire is not connected inside the IMSPS)
3) This wire must be connected to the ground (as this wire is not connected inside the IMSPS)

Remark: **An IMSPS is needed for each power bridge which means:**

- If two motors are connected to a single axis controller, only one IMSPS is required (which means that both neutral point wires are connected together).
- If two motors are connectedto a dual axes controller, two different IMSPS are required.
- Large torque motors may have more than one cable output, each sector being supplied by a single controller. In this case, each cable output need an IMSPS and neutral wires must not be connected together.

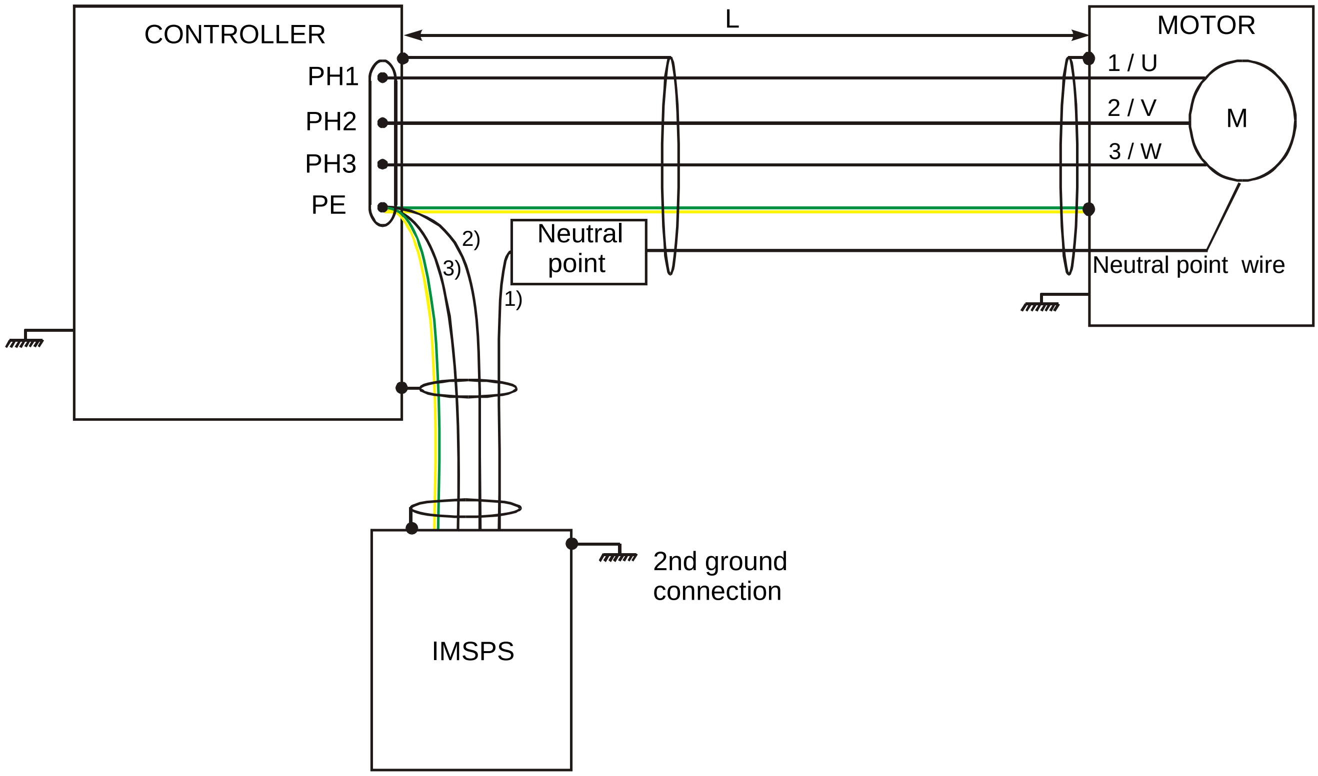
To guarantee a proper motor protection, the cable length between the motor and the terminal block must be: L < 10m.
Refer to §9.8.2 for more information about the electrical connection if the neutral point wire is present and the IMSPS is not used.
The neutral point wire of the motor is a black wire with number Br1 or a black wire with number 5 or a white cable. A second wire (a black wire with number Br2 or a black wire with number 6 or a black wire without label) must be connected to the ground as it is not connected inside the motor.
If the phases 1, 2 and 3 (also mentioned U, V and W) of the motor are connected respectively to PH1, PH2 and PH3 of the electronics, the motor will turn in the clockwise direction when watching the motor from the cable output side.

7.3.4.2 IMSPS directly connected to the controller

- Switch off the controller (and the electrical panel if the terminal block is inside).
- Fasten the case with the brackets or open it and use the M4 screws (4x).
- Connect the ground of the case of the IMSPS (using the screw under the strain relief) as well as the

ground wire (yellow/green) directly to the motor connector of the controller. We also recommend to connect the black wires number 2 and 3 (not used in the IMSPS) to the ground of the controller.

- Connect the shield of the cable of the IMSPS to the shield of the motor.
- Connect the neutral point wire (black cable number 1) protected by an insulation (ESD protection) before cabling.
- Close the cover if the 4 screws have been used to fasten the case.
- Switch on the controller



1) Neutral point wire (black wire number 1).
2) This wire must be connected to the ground (as this wire is not connected inside the IMSPS).
3) This wire must be connected to the ground (as this wire is not connected inside the IMSPS).

Remark: **An IMSPS is needed for each power bridge which means:**

- If two motors are connected to a single axis controller, only one IMSPS is required (which means that both neutral point wires are connected together).
- If two motors are connectedto a dual axes controller, two different IMSPS are required.
- Large torque motors may have more than one cable output, each sector being supplied by a single controller. In this case, each cable output need an IMSPS and neutral wires must not be connected together.

To guarantee a proper motor protection, the cable length between the motor and the controller must be: L < 10m
Refer to §9.8.2 for more information about the electrical connection if the neutral point wire is present and the IMSPS is not used.
The neutral point wire of the motor is a black wire with number Br1 or a black wire with number 5 or a white cable. The second wire (associated to the neutral point wire) which is a black wire with number Br2 or a black wire with number 6 or a black wire without label must be connected to the ground.
If the phases 1, 2 and 3 (also mentioned U, V and W) of the motor are connected respectively to PH1, PH2 and PH3 of the electronics, the motor will turn in the clockwise direction when watching the motor from the cable output side.

7.3.4.3 Disconnection procedure

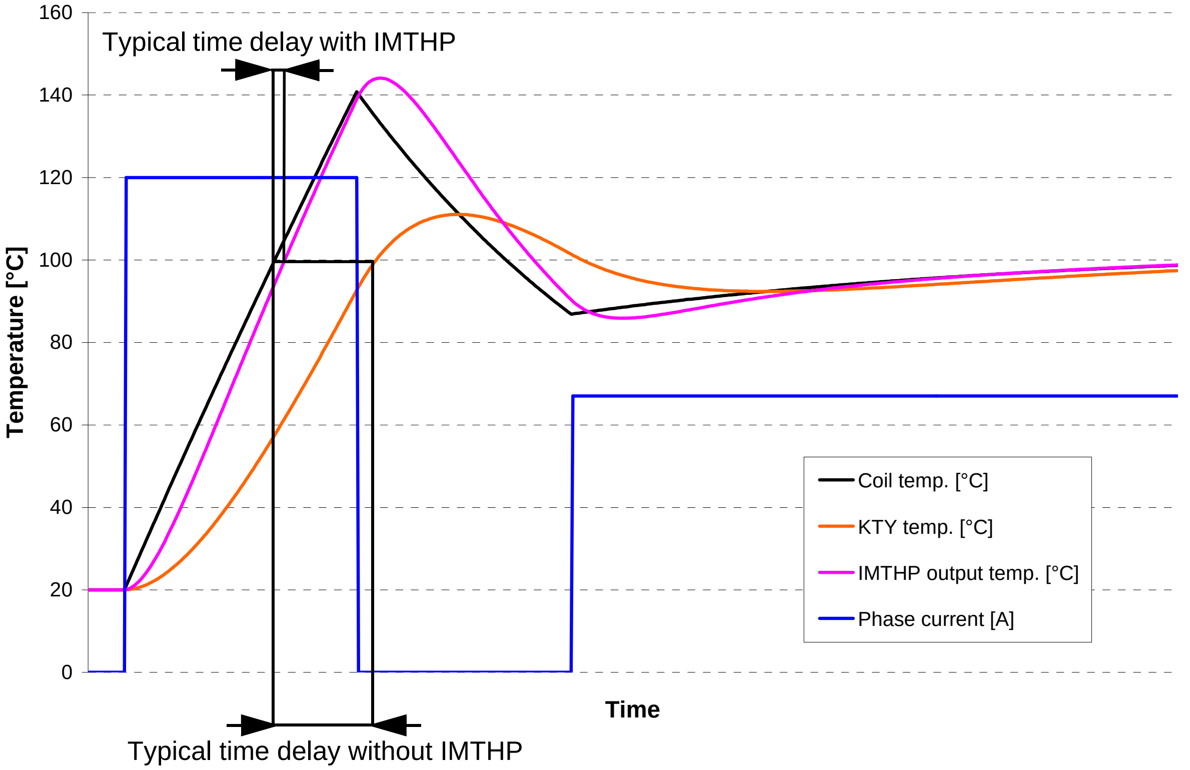
- Switch off the controller (and the electrical panel if the terminal block is inside).
- Disconnect the neutral point wire of the IMSPS either on the terminal block or on the motor connection of the controller.
- Disconnect the ground wire of the IMSPS either on the terminal block or on the motor connection of the controller as well as the one of the case.
- Open the cover of the case if the 4 screws have been used to fasten it.
- Remove the IMSPS and close the cover if opened.

7.4 Thermal protection interface

7.4.1 Working principle

The IMTHP is intended to be used with TMB, TML, TMM and TMK torque motors. From the temperature sensors of these motors consisting of 3 KTY (one for each phase), the IMTHP emulates a single KTY output based on the maximum temperature measured on the inputs. The IMTHP can thus be used with a controller having a single temperature sensor input. If the controller does not have any, an 'Alarm' and an 'Error' output (digital) are also provided allowing the user to interface any type of industrial controller to protect the motor. Moreover, the IMTHP acts as a galvanic insulation between high voltage (motor side) and safety low voltage (24V, controller side).

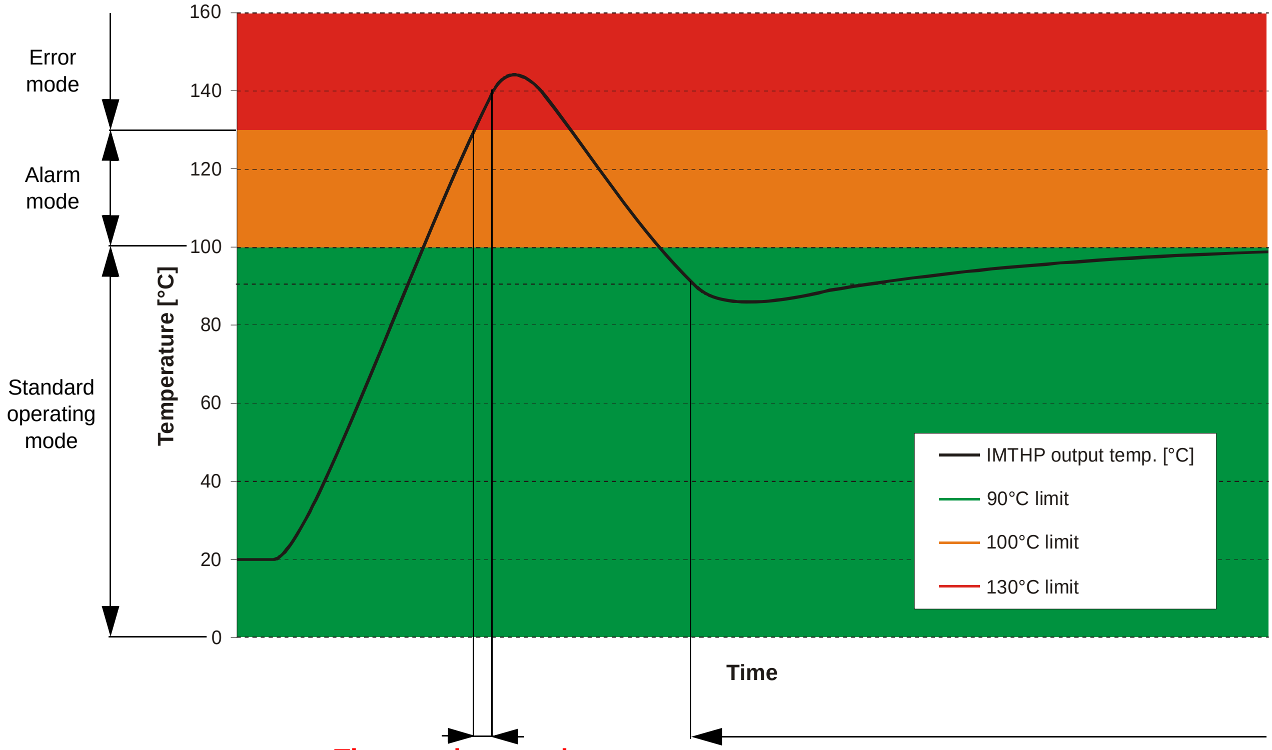
The following graph shows that the IMTHP also compensates the measurement delay of the KTY sensors improving then their thermal inertia.



The LED present on the front panel indicates the four different status of the IMTHP:

- Green LED: The IMTHP is working properly which means that the temperature inside the motor is lower than 100°C.
- Orange LED: The IMTHP is in alarm mode (alarm relay is opened) which means that the temperature inside the motor is between 100°C and 130°C. The IMTHP returns to the normal state (green LED) as soon as the temperature drops below 90°C.
- Red LED: The IMTHP is in error mode (alarm and error relay as well as the KTY output are opened) which means that either the temperature inside the motor is greater than 130°C or the KTY input(s) is short-circuited or broken. The IMTHP returns to the normal state (green LED) as soon as the temperature drops below 90°C.
- LED switched off: The IMTHP is not working which means that either the IMTHP is not powered or a fatal error has been detected inside the IMTHP. If such a case occurs and if the IMTHP is actually powered, the IMTHP **must** be sent back to ETEL for repairing.

The first three status mentioned above are represented on the following graph:



The user has maximum 1sec (reaction time) to switch off the power of the motor.

After an alarm and an error, the IMTHP returns to the standard operating mode as soon as the temperature drops below 90°C.

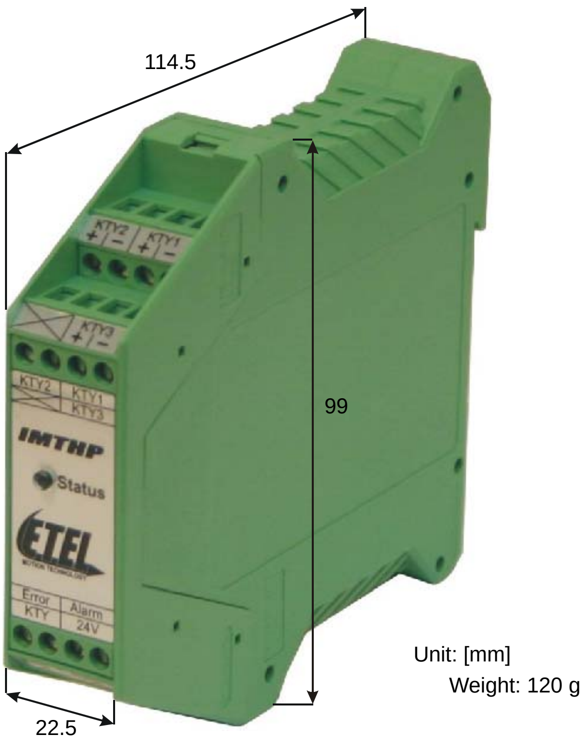
Remark: If the configuration H of the temperature sensor (refer to §6.3.1) is redundant which means there are two sensors per phase. If one does not work any more, simply disconnect the faulty one at the IMTHP level and replace it by the spare one.

7.4.2 Ratings and specifications

IMTHP SPECIFICATIONS			
	Min.	Typ.	Max.
Power supply voltage	+18VDC	+24VDC	+30VDC
Power supply current at +24VDC	-	-	100mA
KTY output measurement current	0.5mA	1mA	5mA
KTY output resistance precision at 1mA (0°C to +150°C)	-	-	±2%
Relay outputs resistance	-	-	25Ω
KTY inputs measurement current	-	1mA	-
Alarm level	97°C	100°C	103°C
Error level	126°C	130°C	134°C
Error reset	87°C	90°C	93°C
Standard compliance	EN50178 (overvoltage category 3, pollution degree 2)		

IMTHP ABSOLUTE MAXIMUM RATINGS	
Power supply input voltage	+31VDC
Relay outputs current	100mA
Relay outputs voltage	100VDC
Output voltage (KTY and relays) with respect to 0V	-5DVC to +48VDC
KTY output current	10mA

7.4.3 Outline dimensions

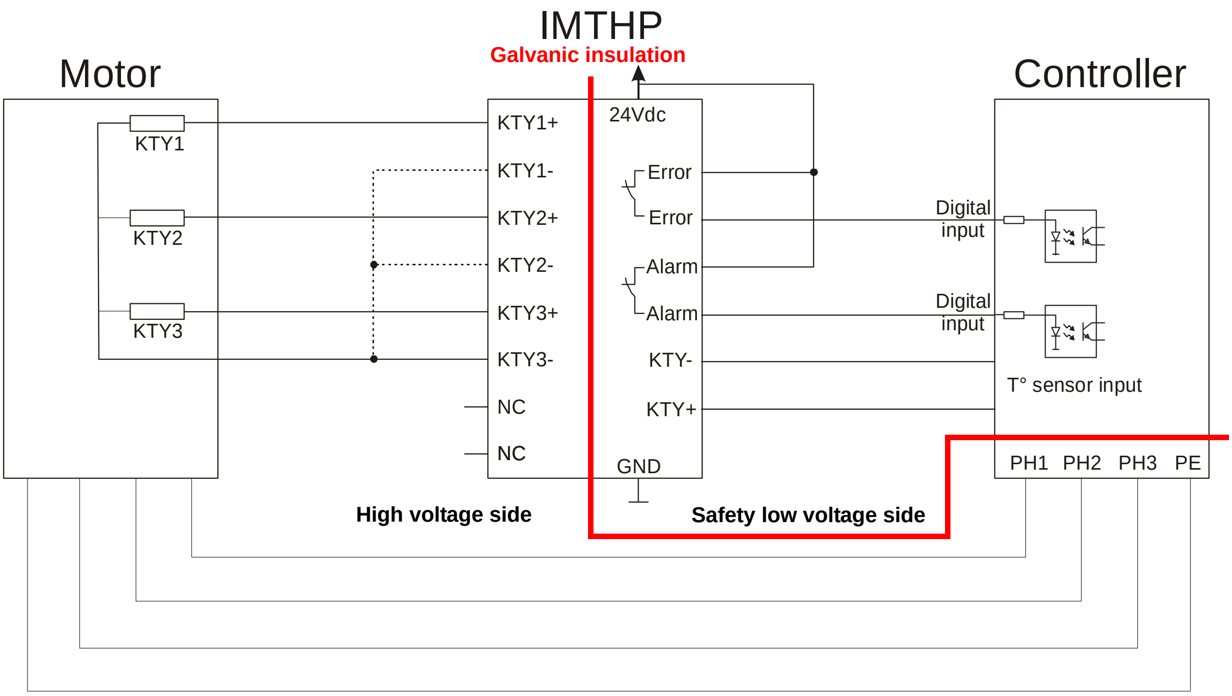


Remark: The green IMTHP must be used with the torque motors.

The housing can be mounted on a DIN rail TS 35.

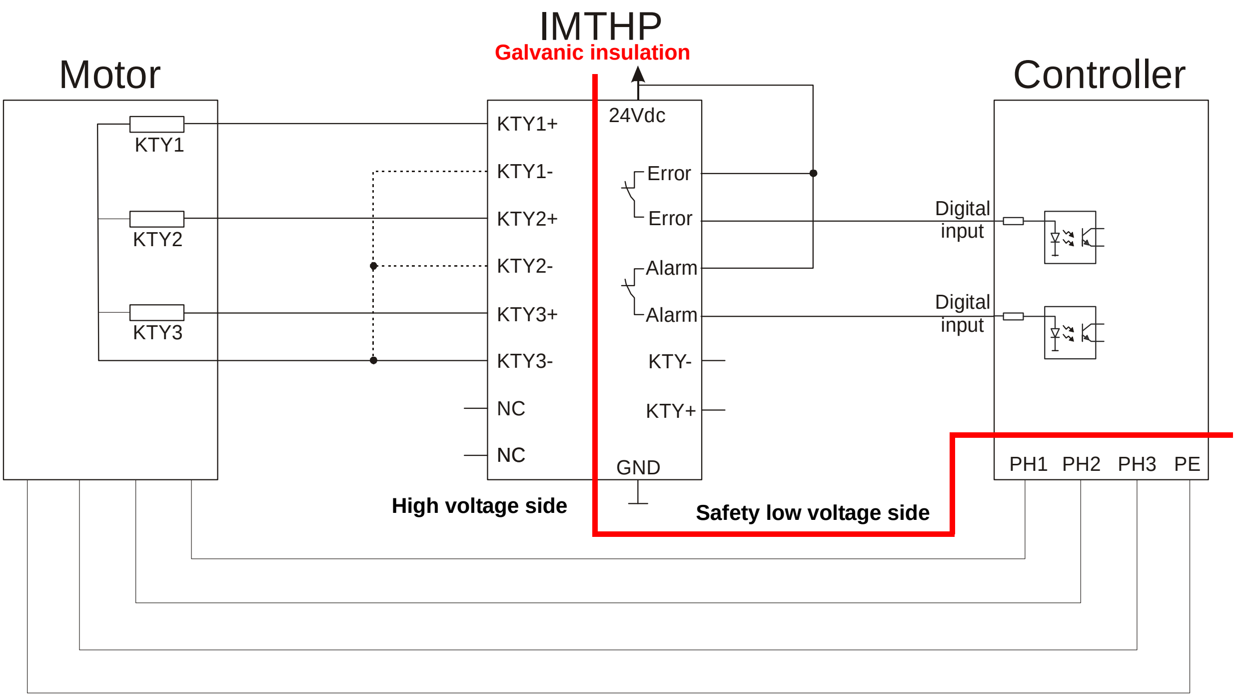
7.4.4 Connection diagram

- **Use of a controller with a temperature sensor input:**



Remark: The 'Error', 'Alarm' and 'KTY' outputs can be connected individually.

- **Use of a controller without temperature sensor input:**



As soon as the 'Error' relay is opened (red LED is ON), the digital input is not powered any more. From then on, the customer has **one second** to stop the working process and switch off the power of the motor to avoid burning the motor.

Remark: KTY1-, KTY2- and KTY3- are hard-wired inside the IMTHP, thus it is sufficient to connect only one of them. Only one motor can be connected per IMTHP. The diameter of the wire which can be connected to the IMTHP goes from 0.14 to 2.5 mm^2 (26 to 14 AWG).

7.4.5 General operating conditions

The IMTHP is designed to operate in a non-aggressive and clean environment, with a humidity rate ranging between 10% and 85%, an altitude < 2000m (6562 ft), and a temperature ranging between 0°C (32°F) and +50°C (122°F). The IMTHP must be connected to an electrical network of overvoltage category 3 (refer to EN 50178 and UL 804 standards for more information) and be in an enclosure respecting a pollution degree of 2 (refer to UL 508C and EN 50178 standards for more information).

The IMTHP is not designed or intended for use in the on-line control of air traffic, aircraft navigation and communications as well as critical components in life support systems or in the design, construction, operation and maintenance of any nuclear facility.

7.4.6 Commissioning

Follow step by step this procedure to make sure that the IMTHP is correctly connected:

1) Switch on the IMTHP while keeping switched off the motor (motor’s coil at ambient temperature):

- The LED is green => the IMTHP is correctly connected
- The LED is red => at least one KTY sensor is faulty or not connected
- The LED is switched off => the IMTHP is not powered or faulty

2) Check the status of the digital inputs connected to the ’error’ and ’alarm’ relays (they must show that both relays are closed (refer to the corresponding **’Hardware Manual’** for more information about the digital inputs)) or/and monitor the KTY output to be sure that this output works correctly.

3) Switch on the motor (low power) and disconnect one of the three KTY sensors to check if the LED of the IMTHP turns red and if the controller switches off the power in the motor.

From now on, if everything works correctly, the maximum continuous power can be used.

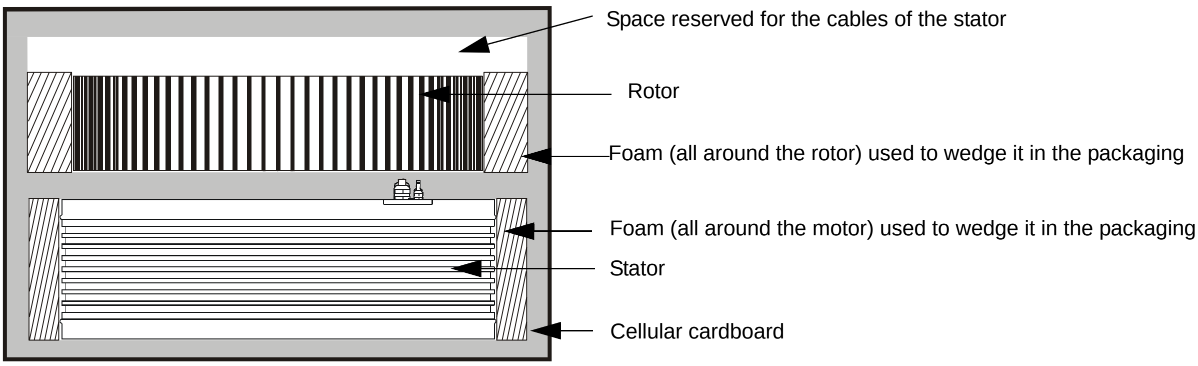
8. Logistics

8.1 Contents of the shipment

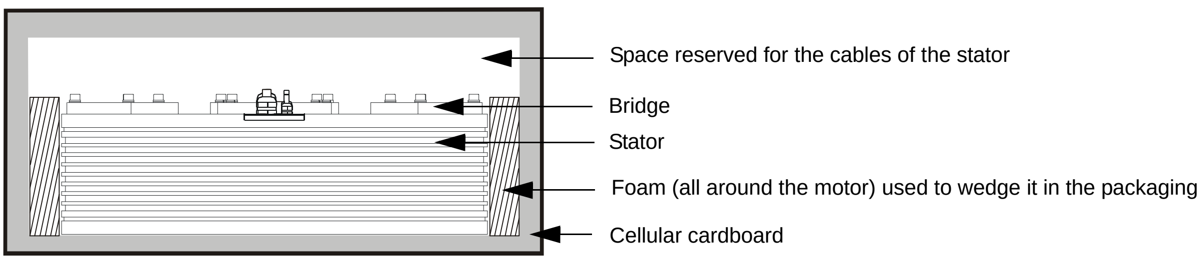
The torque motor stator and rotor are delivered in the same packaging. If the motor is ordered without a bridge, the rotor will be packaged above the stator (refer to §7.2.1 for more information about the bridge)

	Caution	**If a mounting bridge is present, it must NOT be removed at any time during transport, storage or handling of the motor. Bridge removal should occur only after the motor is installed in the customer's interface and the rotor is fixed to the shaft.**

Torque motor delivered without bridge



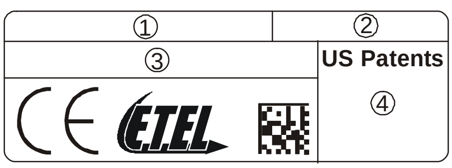
Torque motor delivered with bridge



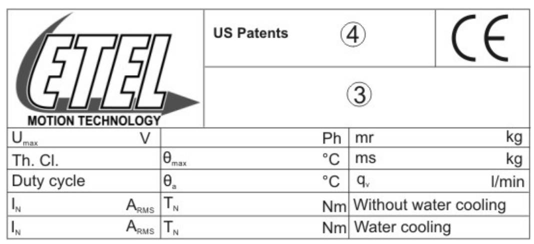
Remark: Torque motors up to TM#0360, are delivered in cardboard boxes.
Torque motors above TM#0360 are delivered in wooden crates.

A temperature sensor configuration, 3 name plates (one of each) and four O-rings (for TMB and TMK motors) are delivered separately with each torque motor. Here is an example of the name plates:

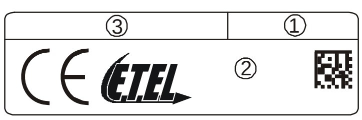
Stator



Complete motor



Rotor



① Identification number
② Serial number
③ Ordering information
④ US Patents number

Remark: The bottom line of the complete motor name plate is not present on the TMM and TML motors.

8.2 Transport

The following instructions must be respected during the transport of ETEL's torque motors.

Transport	
	1. ETEL's torque motors must be transported flat. It is important to respect the top/bottom label present on the packaging. **2.** If a torque motor has to be sent back to ETEL, it must be shipped in its original packaging.

After receiving the goods:

- Check if the packaging is damaged. **If so, this procedure must be followed:**

  - Do not refuse the shipment

  - Indicate on the delivery slip that the packaging is damaged

  - Inspect for possible damage

  - If damage is discovered, leave the system in its original container and notify the carrier by registered mail that the package has been accepted under condition (refer to the INCOTERMS 2000 for more information about the responsibilities).

  - Contact your ETEL representative immediately

- Compare the order form with the supplied goods. If a difference is noticed, contact your ETEL representative immediately.

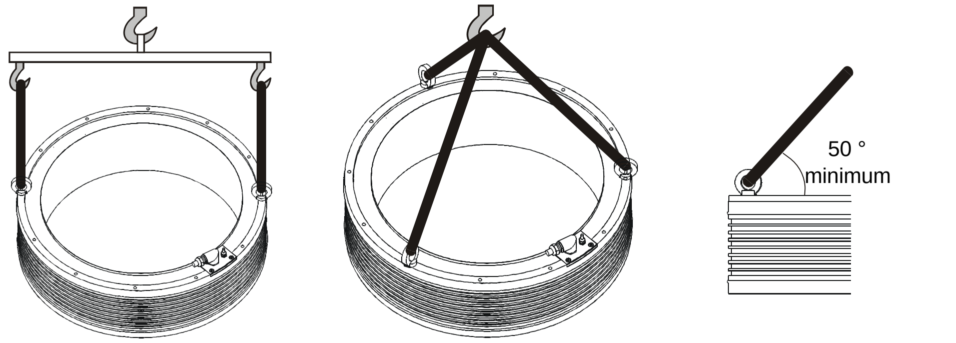
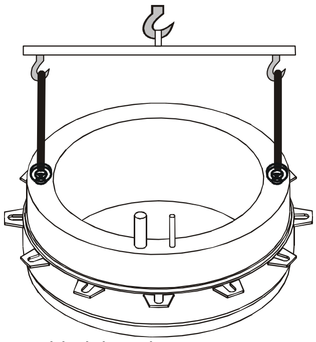
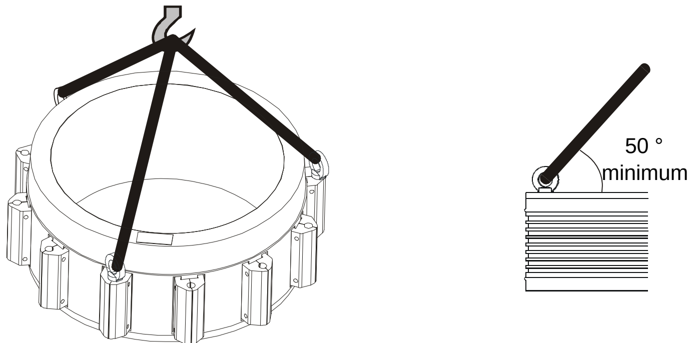
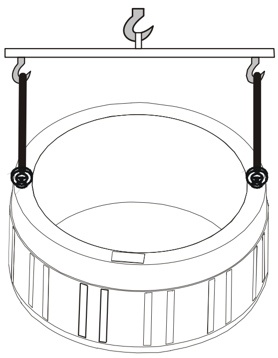
8.3 Handling

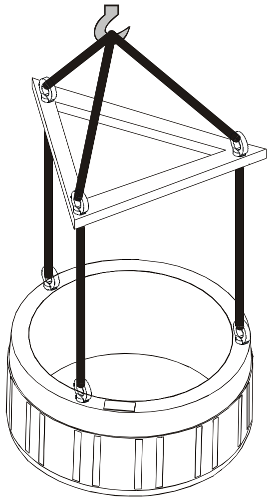
The following instructions must be respected when handling ETEL's torque motors.

Unpacking	
	1. Inform all people with active implants and prosthesis to keep at a safe distance from the working area (refer to §9.4 for more information). **2.** Place warning labels indicating "**Strong Magnetic induction**" and "**No Pacemaker**" on the unwrapped pieces which include permanent magnets.
	3. Clean the unpacking area of all ferromagnetic objects (steel particles, screws, tools, metal tables,...) and move to a safe place all types of recording or measuring devices.
	4. Indicate the working area as magnetically dangerous environment. **5.** In the event of an accident while unpacking/packing a torque motor, **always have to hand at least two wedges** (approx. 10°-15°) of solid, non-magnetic material (f.e. aluminum) as well as a non-magnetic hammer (approx. 2-3 kg). In emergency cases, these tools are for separating parts magnetically attached to the rotor in order to free caught limbs (finger, hand, foot). Never place a stator directly on a rotor.
	6. ETEL's motors must be handled by experienced staff wearing protection clothes (gloves, protective footwear...). **7.** Open the packaging and remove the top protection. **8. Never pull or hold the motor by its cable(s) or strain relief.** **9.** Check whether the delivery was damaged during the transport. If damage is noticed, contact the carrier immediately (ETEL is not responsible for damages occurred during the transport). **10.** Remove the torque motor from its packaging according to the procedure described in §8.3.1. **11.** If the stator and the rotor are delivered separately, be careful not to put them in close proximity to each other. If them become attached, separate them with a non-magnetic material (wood,...) at least 40 mm thick. **12.** During the handling, the motor must not suffer any kind of shock (fall,...) or stress. **13.** The motor's packagings are the customer's property.Sort and recycle all possible scraps coming from the packaging.

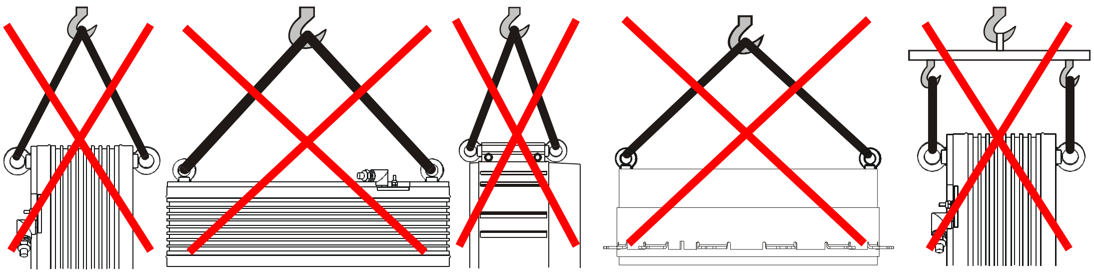
8.3.1 Handling procedure

8.3.1.1 Handling without bridge

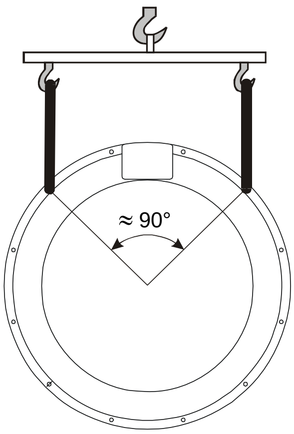
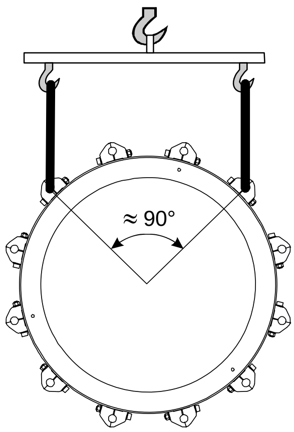
Motor series	Handling procedure without bridge
TMB & TMK	 - If only two lifting rings are used, they must be diametrically opposed and a spreader bar must be used. - If three or more lifting rings are used, they must be equally spread (120° between each lifting ring for a set of 3, 90° between each lifting ring for a set of 4, ...). Independent of the number of lifting rings used, all slings must have the same length and a minimum angle of 50° between the sling and the motor.
From TML0210-070 to TML0291	 **No radial force can be applied on the lifting holes!** - Two diametrically opposed holes are provided then these motors must be handled with a spreader bar.
From TML0360 to TML0530	 - If three or more lifting rings are used, they must be equally spread (120° between each lifting ring for a set of 3, 90° between each lifting ring for a set of 4, ...). Independent of the number of lifting rings used, all slings must have the same length and a minimum angle of 50° between the sling and the motor.
From TMM0140-100 to TMM0291	 **No radial force can be applied on the lifting holes!** - Two diametrically opposed holes are provided then these motors must be handled with a spreader bar.

Motor series	Handling procedure without bridge
From TMM0360 to TMM0530	 **No radial force can be applied on the lifting holes!** - Three holes are provided with these motors. A lifting equipment is necessary to handle it as mentioned above.

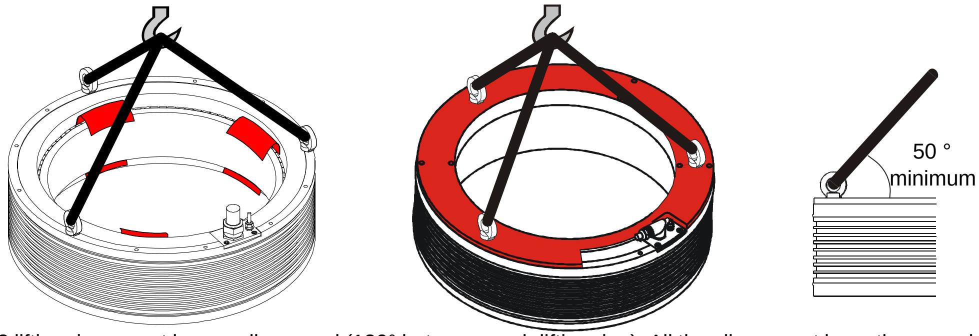
- It is **strictly forbidden** to handle the stator and/or the rotor with the following solutions (too much stress would be applied to the motor) for all motors bigger than TM#0450.

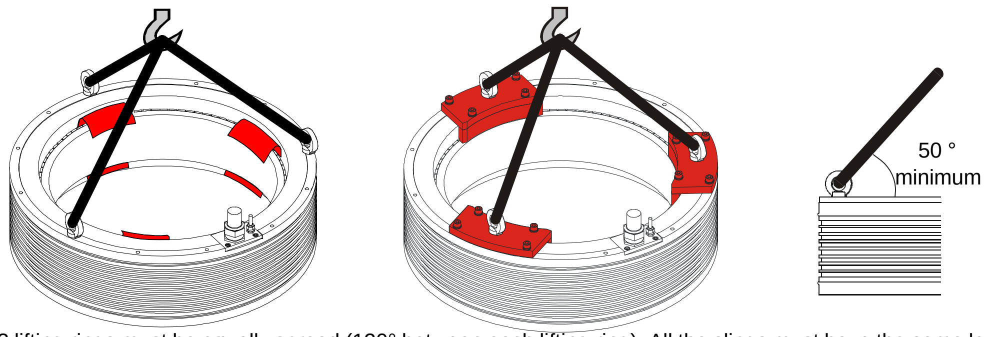
Motor series	Handling procedure without bridge
All motors > TM#0450	

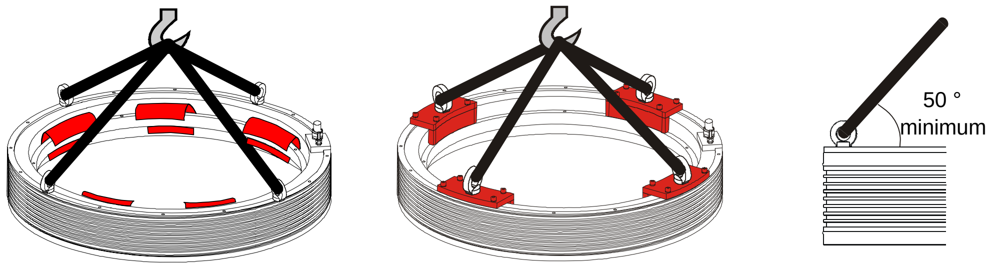
- To handle a TMB, TMK or TML motor **vertically** or to turn it over, proceed as follows.

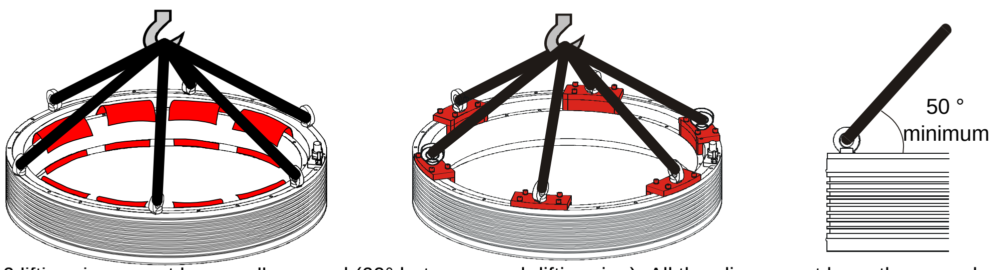
Motor series	Handling procedure
All TMB, TMK and TML0360 to TML0530	TMB & TMK   TML0360 to TML0530 **It is strictly forbidden to use the three lifting holes as no radial force can be applied on these holes!**

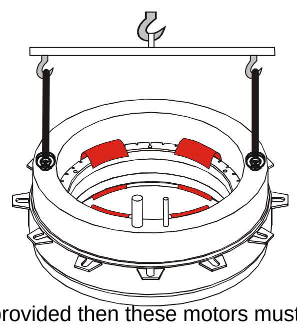
8.3.1.2 Handling with bridge

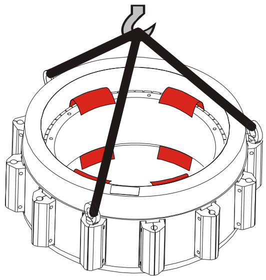
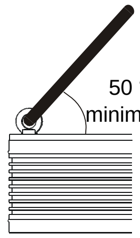
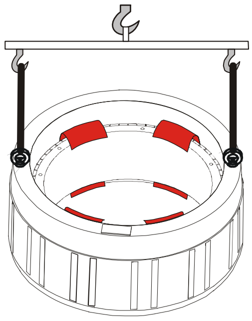
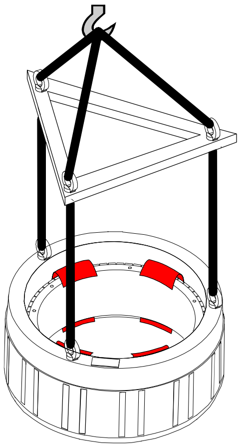
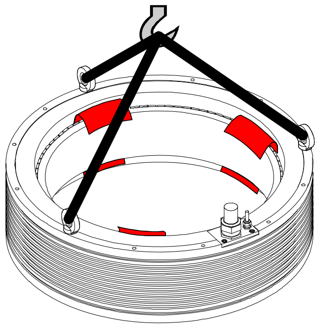
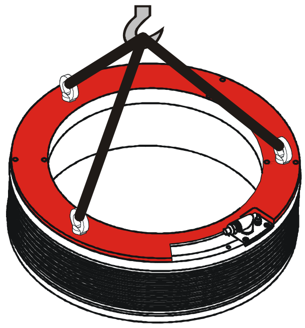
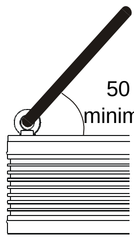
<table>
<tr><th>Motor series</th><th>Handling procedure with bridge</th></tr>
<tr><td>From TMB0140 to TMB0291</td><td>

- The 3 lifting rings must be equally spread (120° between each lifting ring). All the slings must have the same length and a minimum angle of 50° is needed between the sling and the motor.</td></tr>
<tr><td>From TMB0360 to TMB0530</td><td>

- The 3 lifting rings must be equally spread (120° between each lifting ring). All the slings must have the same length and a minimum angle of 50° is needed between the sling and the motor.</td></tr>
<tr><td>For TMB0760</td><td>

- The 4 lifting rings must be equally spread (90° between each lifting ring). All the slings must have the same length and a minimum angle of 50° is needed between the sling and the motor.</td></tr>
<tr><td>For TMB0990 and TMB1221</td><td>

- The 6 lifting rings must be equally spread (60° between each lifting ring). All the slings must have the same length and a minimum angle of 50° is needed between the sling and the motor.</td></tr>
<tr><td>From TML0210-070 to TML0291</td><td>
- Two diametrically opposed holes are provided then these motors must be handled with a spreader bar.</td></tr>
</table>

Motor series	Handling procedure with bridge
From TML0360 to TML0530	  - If three or more lifting rings are used, they must be equally spread (120° between each lifting ring for a set of 3, 90° between each lifting ring for a set of 4, ...). Independent of the number of lifting rings used, all slings must have the same length and a minimum angle of 50° between the sling and the motor.
From TMM0140-100 to TMM0291	 - Two diametrically opposed holes are provided then these motors must be handled with a spreader bar.
From TMM0360 to TMM0530	 **No radial force can be applied on the lifting holes!** - Three holes are provided with these motors. A lifting equipment is necessary to handle it as mentioned above.
TMK	 Only for TMK####-050 & TMK####-070  Only for TMK####-100 & TMK####-150  - The 3 lifting rings must be equally spread (120° between each lifting ring). All the slings must have the same length and a minimum angle of 50° is needed between the sling and the motor.

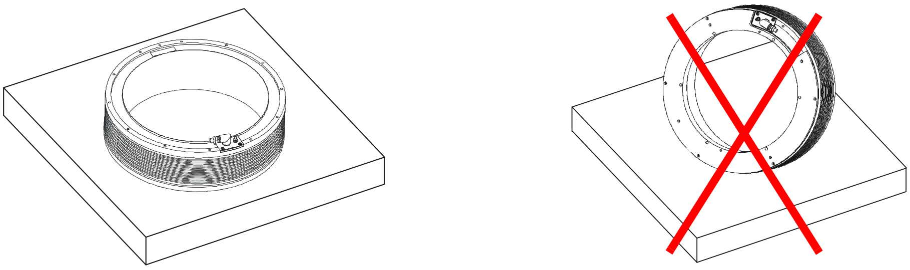
Remark: Refer to §7.2.1 for more information about the bridges.

8.4 Storage

The following instructions must be respected during the storage of ETEL's torque motors:

<table>
<tr><th colspan="2">Storage</th></tr>
<tr><td></td><td>

1. Area used to store motor parts equipped with permanent magnets must be clearly delimited and indicated with “**Caution! Powerful magnets!**“ labels.
2. Clean the storage area of all ferromagnetic objects (steel particles, screws, tools, metal tables,...) and move all types of recording or measuring devices to a safe place.
3. Magnetic parts must be separated and wrapped in non-magnetic protections. These protections should be at least 40 mm thick (f.e. wood).
4. Motors and rotors should be stored in their original packaging and put down flat. For a short period the motor can be stored out of its packaging provided that it is fully supported and with the output cables turned towards the top as mentioned below.
The storage room air humidity should be between 5% and 85% and the temperature between -10°C and +60°C(*).



5. Be careful not to jam the output cables under the motor.
6. Do not store motors on top of each other.
7. During a long storage period or in tropical countries, it is recommended to wrap the motor with rust preventive packaging.

</td></tr>
</table>

(*): if the motor is stored at an ambient temperature different from the operating range (refer to §9.1.1), the motor must be slowly brought back to the operating ambient temperature before starting operation. It is necessary to respect this recommendation to avoid thermal shocks.

9. Integration guide

9.1 General warnings

Assembly	
	**1. Inform all people with active implants and prosthesis to keep at a safe distance from the working area** (refer to §9.4 for more information). **2.** Place warning labels indicating **"Strong Magnetic induction"** and **"No pacemaker"** around the working area, warning of the danger due to permanent magnets.
	**3.** Clean the working area of all ferromagnetic objects (steel particles, screws, tools, metal tables,...) and move to a safe place all types of recording or measuring devices.
	**4.** Indicate the working area as magnetically dangerous environment. **5.** Anyone wearing watches, **pacemakers**, magnetic data carriers should keep at a safe distance from the delimited area. **6.** In the event of an accident while handling a torque motor, **always have to hand at least two wedges** (approx. 10°-15°) of solid, non-magnetic material (f.e. aluminum) as well as a non-magnetic hammer (approx. 2-3 kg). In emergency cases, these tools are for separating parts magnetically attached to the rotor in order to free caught limbs (finger, hand, foot). Never place a stator directly on a rotor.
	**7.** The motor must be mounted according to the instructions given in this manual. **8.** Only trained staff can have access to the delimited working area. **9.** Only a qualified and trained technician is allowed to handle, install and operate the system, respecting all specific regulations of the respective country concerning both safety and EMC (ElectroMagnetic Compatibility) aspects. They must wear protection clothes (gloves, protective footwear...). **10.** Never pull or hold the motor by its cable(s) or strain relief. **11.** The compatibility between external components and the motor has to be verified, in order to avoid galvanic corrosion. **12.** During the handling, the motor must not suffer any kind of shock (fall,...) or stress. The handling precautions listed in §8.3 must have been read and understood. **13.** The system in which the motor must be mounted, must not be electrically connected. **14.** Before mounting the motor, clean the entire surface of the stator and the one in contact with it, grease the O-ring with an ordinary lubricant grease and mount the O-ring (avoid twisting the O-ring). **15.** Once mounted, test whether the motor moves without contact between rotor and stator over one entire revolution. It is normal to observe variations in the forces, depending on the position (detent torque). **16.** Do not touch the power cable if an external element causes a movement on a non-connected motor, as an induced current may be generated.

9.1.1 Environment

The acceptable operating conditions for an ETEL Torque motor are as follows:

- Ambient temperature +5°C to +40° C.
- Humidity (non condensing) from 5% to 85%.
- Torque motors can be used in most industrial environments, however:
    - contact with ferromagnetic components, oils (can be very aggressive), acid and base must be avoided.
    - contact with corrosives gaz and vapors, special radiation (UV, X, Gamma …) must be qualified (please contact your ETEL representative)
- Standard torque motors are not vacuum compatible.

Contact your ETEL representative for more information concerning applications that require operation outside of these conditions.

9.1.2 Housing

The housing structure which the torque motor will interface must be strong enough to hold the stator and to avoid distortions when the stator is in place, and the rotor is in operation. Use the motor peak torque (refer to §3.2.2 or to the data sheet of the corresponding motor for more information) as the minimum value for calculating stiffness, and consider the impact of any vibrations on the fastening parts and on the encoder functionality.

Pay close attention to the mechanical tolerances. Here is given the outside diameter of the stator frame of ETEL's torque motors (according to EN 20286-2 standard) and the recommended inside diameter of the customer's housing (according to EN 20286-2 standard). **Always refer to the data sheet of the corresponding torque motor for dimensions and tolerances!**

Motor families	Outside diameter of the stator	Inside diameter of the customer's housing
TMB and TMK	f9	H8
TMM0140	k10	0.263 0.2
TMM0175	k10	0.293 0.23
TML and TMM0210	k10	0.3 0.235
TML and TMM0291	k10	0.33 0.26
TML and TMM0360	0.2 0.08	0.38 0.25
TML and TMM0450	k10	0.37 0.3
TML and TMM0530	0.2 0.08	0.38 0.25

9.1.3 Shaft

The inside diameter of the rotor of ETEL's torque motors meets the H8 tolerance range (according to EN 20286-2 standard). The shaft outside diameter should be designed to take the inside diameter of the rotor into account.
Always refer to the data sheet of the corresponding torque motor for dimensions and tolerances!

Secure the shaft to the rotor with a clamp ring, as used to secure the stator into the housing. The rotor yoke ring includes tapped holes, like the stator frame.

9.1.4 Electromagnetic Compatibility (EMC)

A torque motor acts as an antenna and emits interferences produced by the power supply. The parameters which affect the level of perturbation are mainly:

- The power supply characteristics (dV/dt, current value,...).
- The length of the motor power cable.

To reduce interference, it is necessary to:

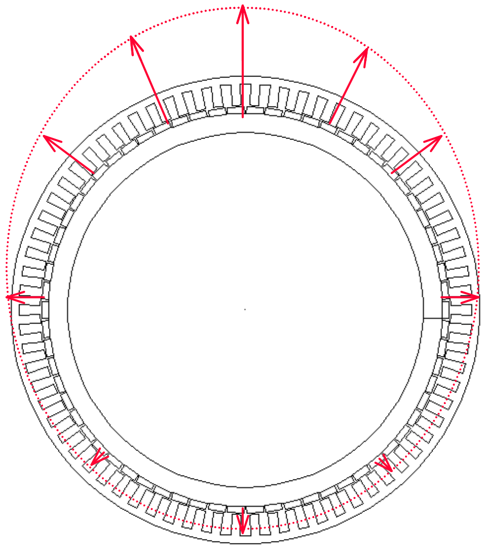
- Ground power and temperature sensor cables on both ends.
- Never use ceramic bearings! The stator is connected to ground and acts as a Faraday cage. The rotor is grounded by means of the steel bearings.
- Ground by means of surfaces and not with wires connections.

9.2 Forces between stator and rotor

ETEL's torque motors require a maximum concentricity between 0.2 mm for the TM#0140 motor series and 0.8 mm for the TM#1221 motor series.

9.2.1 Radial forces between the stator and the rotor

If the rotor is off-centered compared with the stator, there are radial forces between the stator and the rotor. These force can be as large as 33335 N/mm for the TM#1221-150.



The following table gives the radial forces for the torque motor with an active length of 100mm.

Motor series (*)	Radial forces (**)
TM#0140-100	750 N/mm
TM#0175-100	915 N/mm
TM#0210-100	2775 N/mm
TM#0291-100	2608 N/mm
TM#0360-100	4777 N/mm
TM#0450-100	5129 N/mm
TM#0530-100	4846 N/mm
TMB0760-100	7790 N/mm
TMB0990-100	10397 N/mm
TMB1221-100	12253 N/mm

Motor series	Radial forces (**)
TMK0175-100	3308
TMK0291-100	8941
TMK0360-100	13538

(*): TM# means TMB, TML and/or TMM.
(**): given in Newton [N] per mm of radial eccentricity.

Calculation of the radial forces [N/mm] can be performed using:

$$Force = Table\ value \cdot \frac{L}{100}$$

where L [mm] represents the active length of the lamination stack and can be equal to 30, 50, 70, 100 or 150 mm.

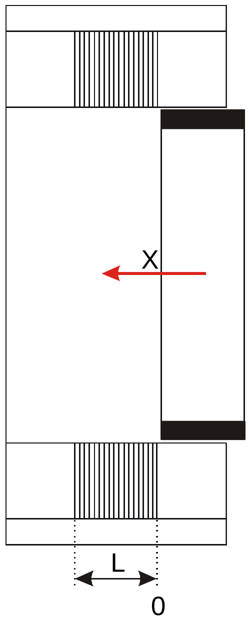
Example:

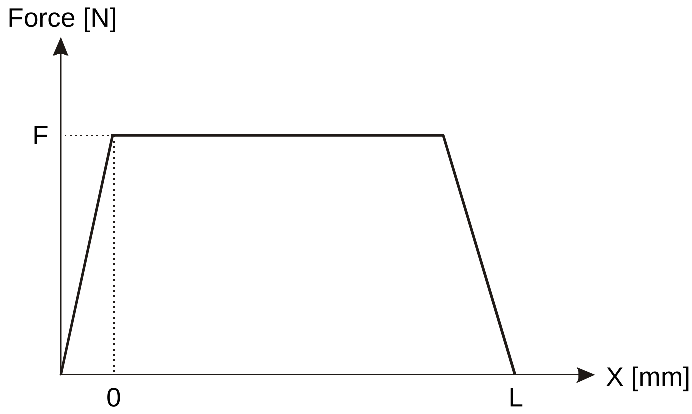
For a TMB0360-150, the radial forces value will be equal to:

$$(TMB0360 - 100) \cdot \frac{L}{100} = 7651 \cdot \frac{150}{100} = 11476N/mm$$

9.2.2 Axial forces between the stator and the rotor

When the rotor is inserted inside the stator, there is an axial force between the two components (10 N per magnet). This force does not depend on the axial position of the rotor in the stator.





The following table provides the axial forces for each torque motor series.

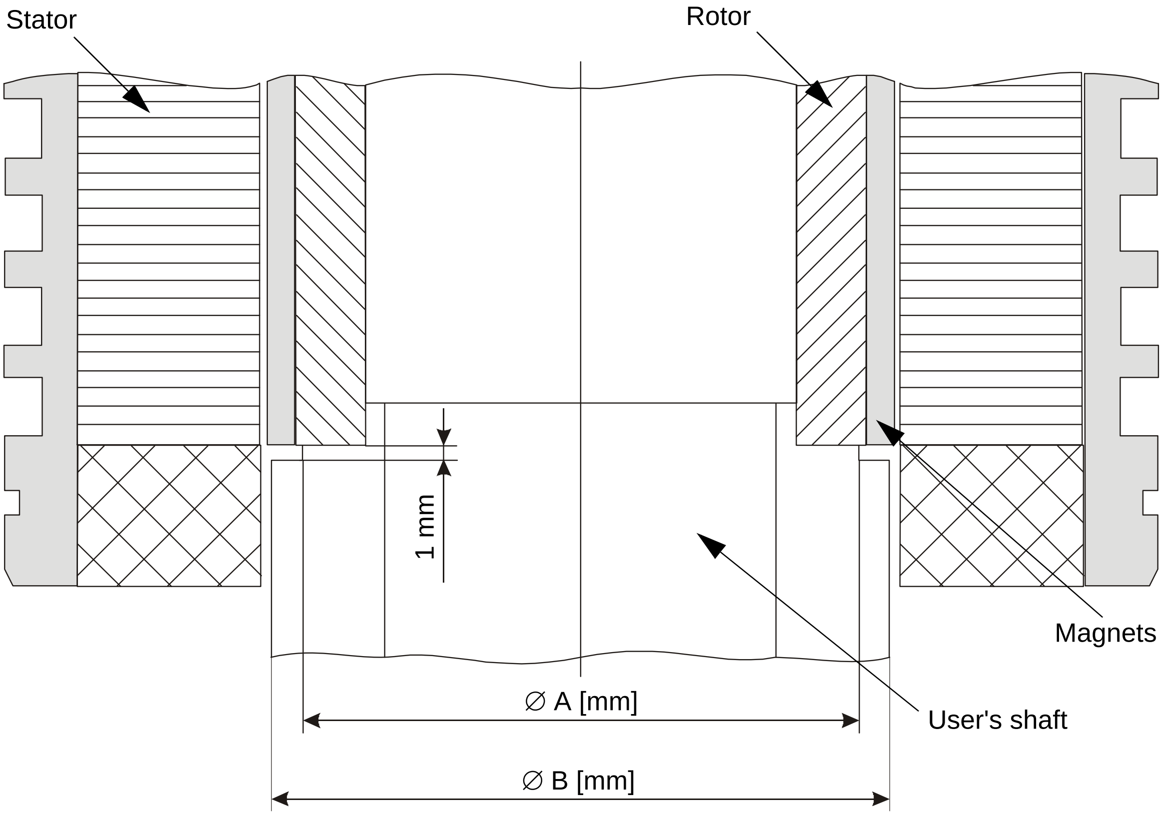
Motor series (*)	Force to insert the rotor into the stator
TM#0140	200 N
TM#0175	291 N
TM#0210	371 N
TM#0291	565 N
TM#0360	784 N
TM#0450	819 N
TM#0530	1025 N
TMB0760	1605 N
TMB0990	2134 N
TMB1221	2560 N

Motor series	Force to insert the rotor into the stator
TMK0175-100	281 N
TMK0291-100	484 N
TMK0360-100	714 N

(*): TM# means TMB, TML and/or TMM.

9.3 Magnet clearance and interface diameters

Due to the tolerance on the magnet length, the user's shaft design must include a 1mm space between the rotor magnets and the shaft for the TMB, TML and TMM torque motors:



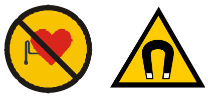
The following table provides the maximum allowable diameter (A and B) for the customer's shaft:

Motor series	∅ A [mm]	∅ B [mm]
TM#0140	78.5	88
TM#0175	108.5	118
TM#0210	159	168
TM#0291	219	228
TM#0360	288.5	298
TM#0450	373.5	383
TM#0530	448	458
TMB0760	678	688
TMB0990	908	918
TMB1221	1138	1148

9.4 Magnetic induction

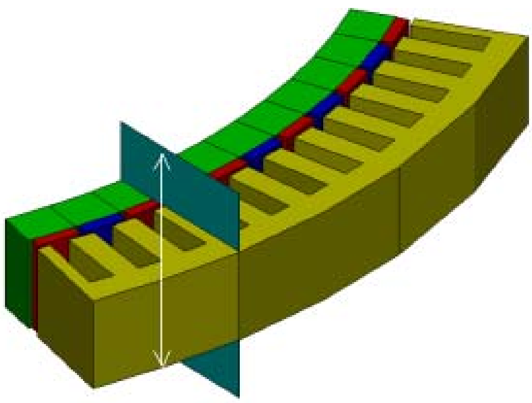
9.4.1 Warnings

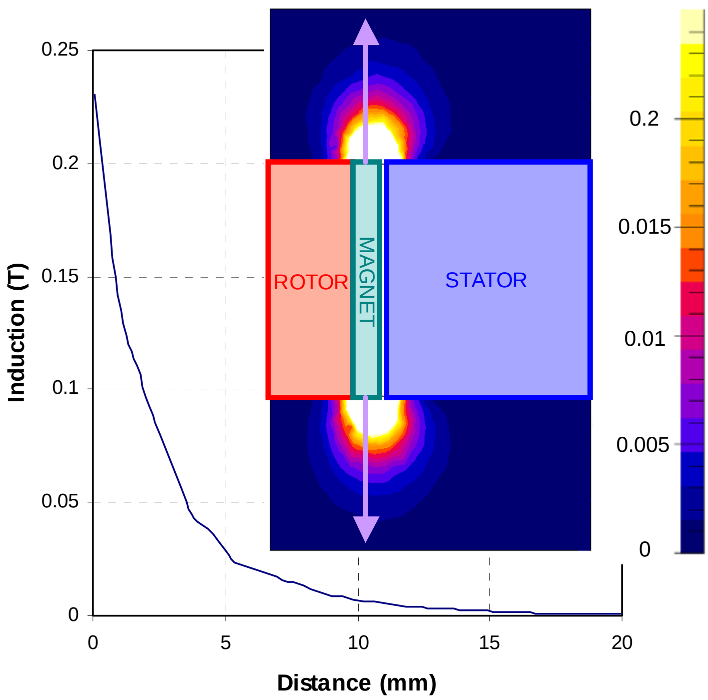
For all torque motors, depending on the distance with respect to the stator and rotor mounted together, the following precautions must be taken into account:

Induction level	Distance	Precautions	
B ≤ 0.000125T	≥ 50 mm	- No precautions required	
B ≤ 0.00125T	≥ 30 mm		- Persons wearing pacemakers should not approach.
B ≤ 0.2T	≥ 10 mm		- For persons with no health issue: only persons trained to work under this magnetic induction are tolerated. - The following persons are not authorized to approach: (1) Pregnant women during the first trimester (2) Persons wearing pacemaker; (3) Persons wearing hearing device. - Destruction of material such as magnetic card, floppies, monitor, watches, keys, ... (1) Do not approach ferromagnetic material to the rotor.
B ≥ 0.2T	≤ 10 mm		- Approach under medical warrant.

9.4.2 Induction level

Sensitive devices (measuring system, watch, credit card, etc) and components can be disrupted by the magnetic induction generated by the permanent magnets of the rotor. It is therefore necessary to maintain a certain distance between the device and the magnets to avoid damage. The following graph represents the magnetic induction leakage level (along the arrow) according to the distance.





9.5 Thermal consideration

To prevent the magnets from overheating, the following power (given in Watt [W]) must be dissipated by the rotor at the maximum speed given on the data sheet:

TMB, TML & TMM	0140	0175	0210	0291	0360	0450	0530	0760	0990	1221
030	12.1	17.7	26	38.3	54.2	73.3	87.1	134	196	246
050	17.4	25.5	38.1	55.5	77.3	103	123	190	271	341
070	22.6	33.2	50.3	72.8	100	133	159	246	346	435
100	30.4	44.8	68.3	98.6	135	178	213	330	458	576
150	43.4	67.2	98.6	142	193	253	303	469	644	811

TMK	0175	0291	0360
050	48	114	102
070	48	114	150
100	93	114	150
150	93	231	300

9.6 Mounting procedure

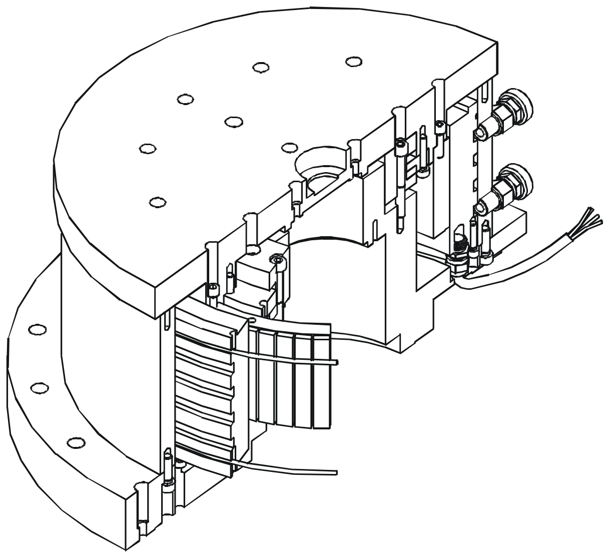
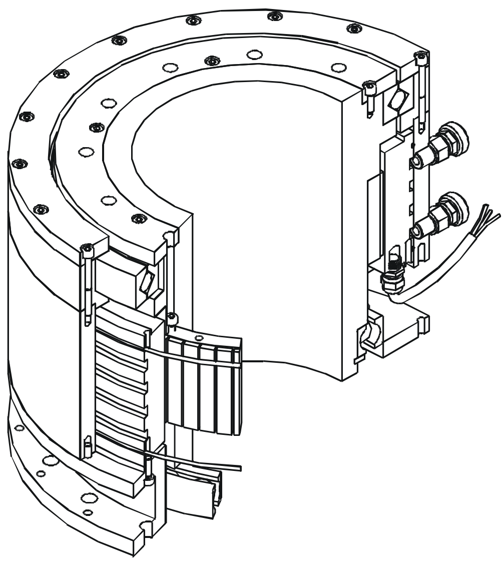
⚠	Caution	**If the procedures below are not strictly applied, the assembly tolerances (eccentricity, eg.) may not be acceptable for correct operation of the torque motor! ETEL will assume no responsibility if these mounting recommendations are not followed. If none of the mounting procedures described below is suitable for your application, contact ETEL for a technical assistance.**

9.6.1 Interface design

To meet the values given in the data sheets of the torque motors:

- The stator must be attached to a structure having a black or dark metallic dissipating surface for thermal exchange (if no water cooling present), which is at least three times the surface of the lamination stack when fixed along the complete outer diameter.
- The rotor must be attached to a structure having a black or dark metallic dissipating surface for thermal exchange (even if water cooling present at the stator) which is at least twice the rotor surface.

In the mounting procedures, the two following types of motor assembly will be considered:

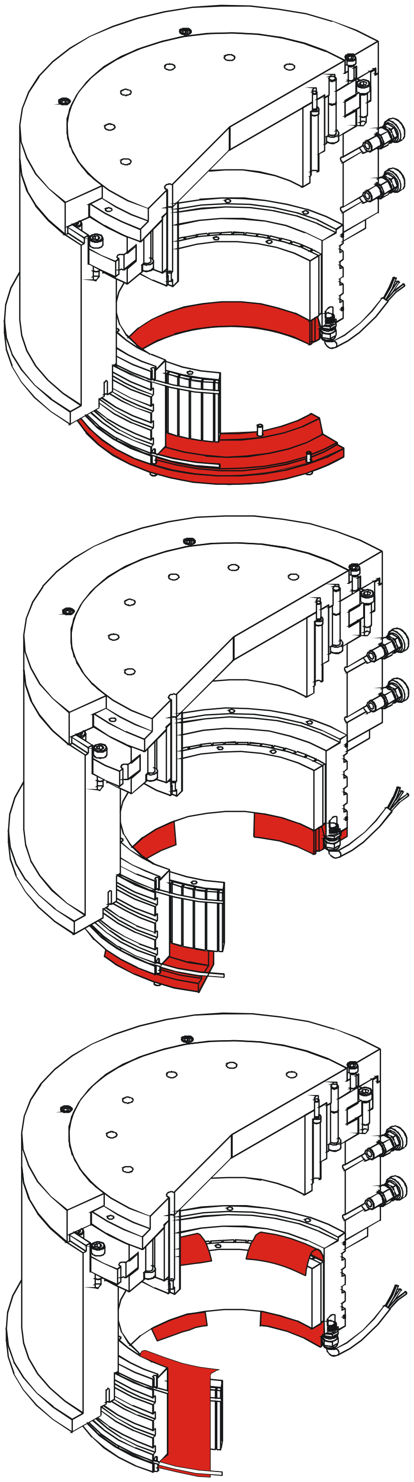
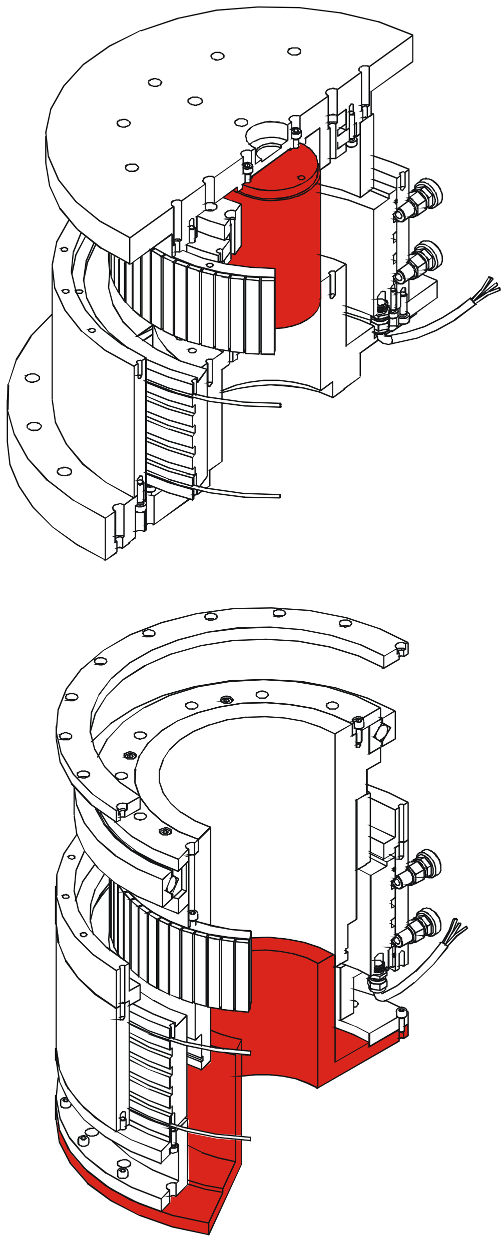
<table>
<tr><th colspan="2">Type of motor assembly</th></tr>
<tr><th>High rigidity table</th><th>Dynamic table</th></tr>
<tr><td>
This assembly is generally used in the machine tool industry where the goal is to reach very high angular accuracy and good repeatability. This design is made for high stiffness and high precision applications. A high accuracy bearing, such as axial-radial or cross-roller bearing, is needed for this design.</td><td>
This assembly is used in general industry application such as, machine tool, pick & place or assembly. The important parameters are the speed and the precision. The diameters are generally smaller than indexing tables. The most commonly used bearing for this design is an angular contact or groove ball bearing.</td></tr>
</table>

Remark: Refer to §6.4.2 for more information about the flatness of the user structure.

9.6.2 Mounting tools

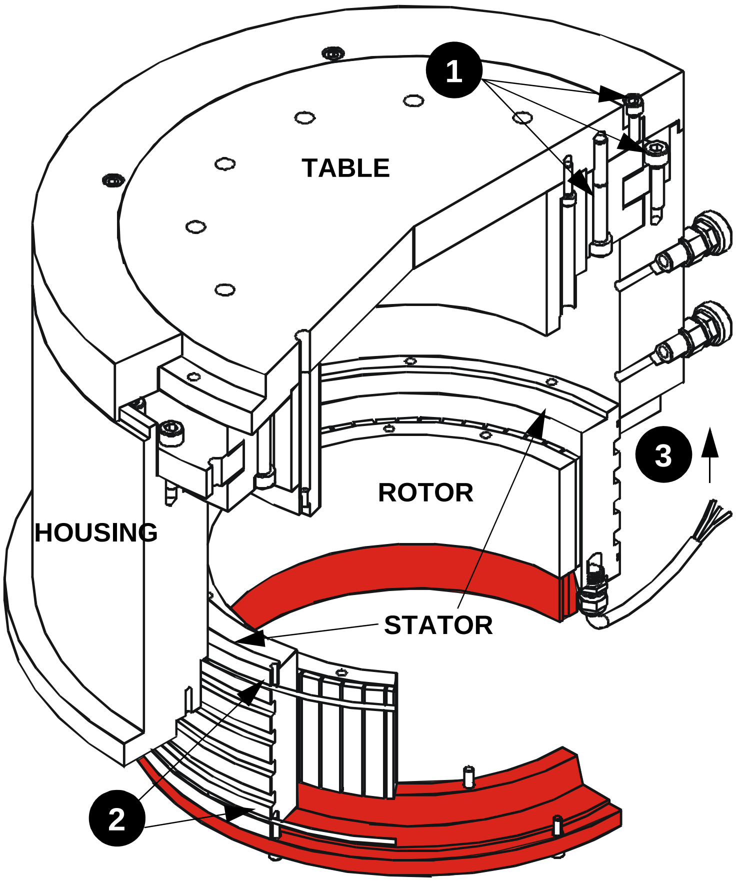
For both above-mentioned types of motor assembly, there are two mounting methods:

- Use of an ETEL bridge (ring, segmented or magnetic). Refer to §7.2.1 for more information.
- Use of a guide tool (provided by the customer).

Mounting tools	
ETEL's bridge	**Guide tool**
	

Remark: The following mounting procedures are identical with any kind of bridge.

9.6.3 'High rigidity table' assembly, using an ETEL bridge



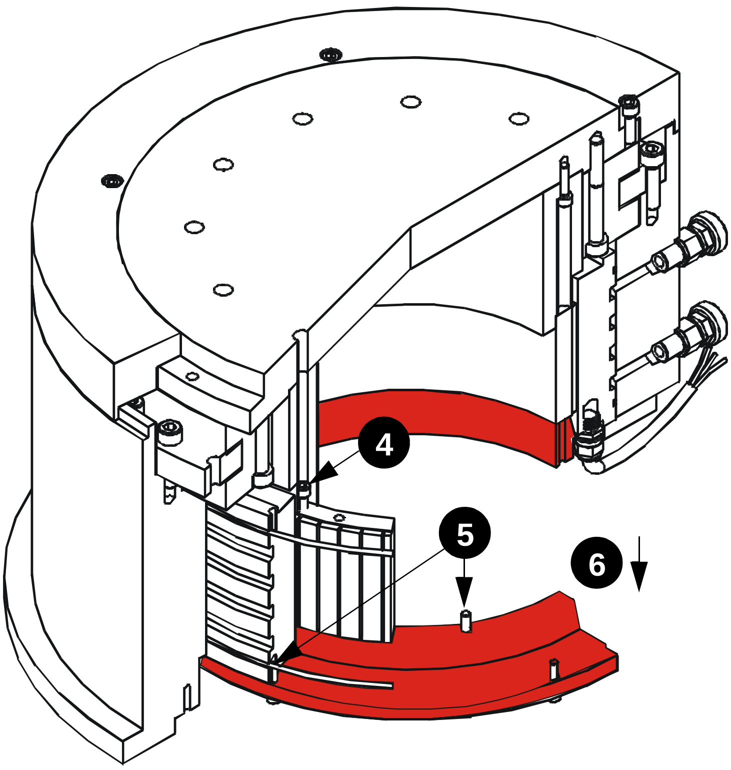
1: Mount and secure the bearing, between the rotating and the static part (table and housing).

2: Mount the O-rings on the stator if cooling is used **(be careful not to twist the O-rings to avoid leakage)**.

3: Insert the assembly 'stator + rotor + bridge'. The output cables (strain relief) must be aligned with the water cooling inlet and outlet (refer to §6.1 for more information).

Beware of the O-rings during the insertion.

Take care of the powerful magnetic induction around the rotor. Do not approach a metallic part at less than 5 cm from the magnets of the rotor.

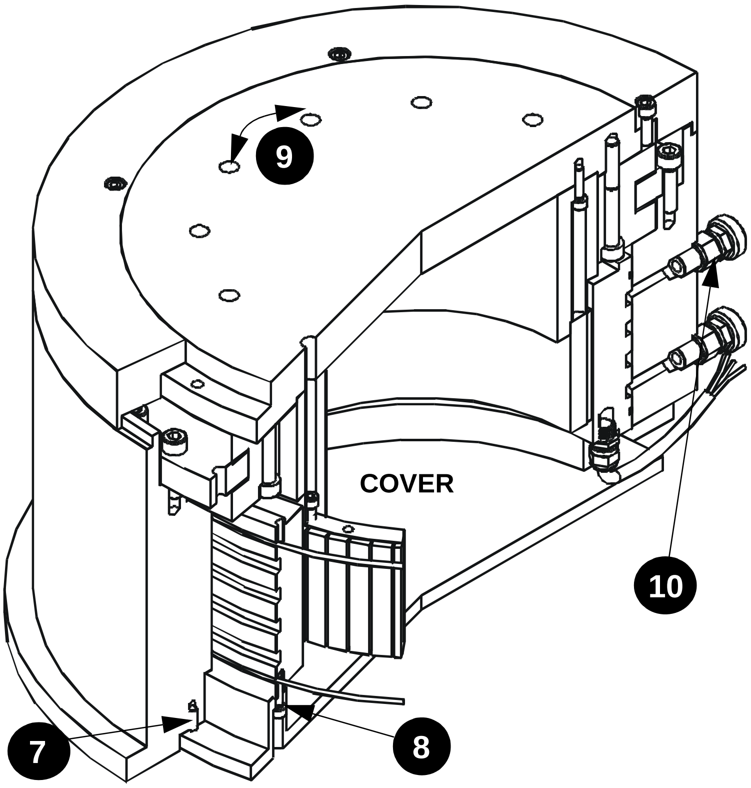


4: Secure the rotor to the shaft. Refer to §6.4 to know the tightening torque.

5: Unscrew the bridge.

6: Remove the bridge from the rotor and the stator.

Note: The stator is maintained in position by the attraction forces.



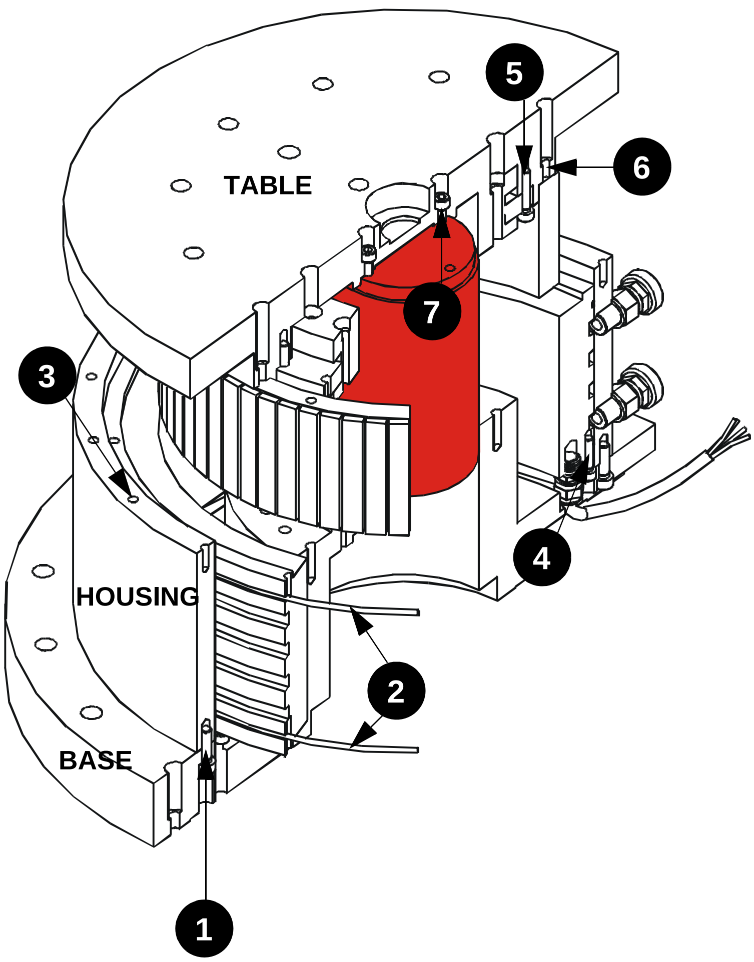
7: Secure the bottom cover.

8: Secure the stator to the bottom cover. Refer to §6.4 to know the tightening torque.

9: Check whether the motor moves without contact between rotor and stator over one entire revolution. It is normal to observe variations in the forces, depending on the position (detent torque).

10: Mount the accessories (water cooling inlet and outlet, power connector, encoder, etc...). Please refer to the encoder manufacturer's documentation for installation instructions.

9.6.4 'High rigidity table' assembly, using a guide tool



Static assembly:

1: Mount and secure the housing on the base.

2: Mount the O-rings on the stator if cooling is used **(be careful not to twist the O-rings to avoid leakage)**.

3: Insert the stator into the housing.

Beware of the O-ring during the insertion.

4: Secure the stator on the base. Refer to §6.4 to know the tightening torque.

Rotary assembly:

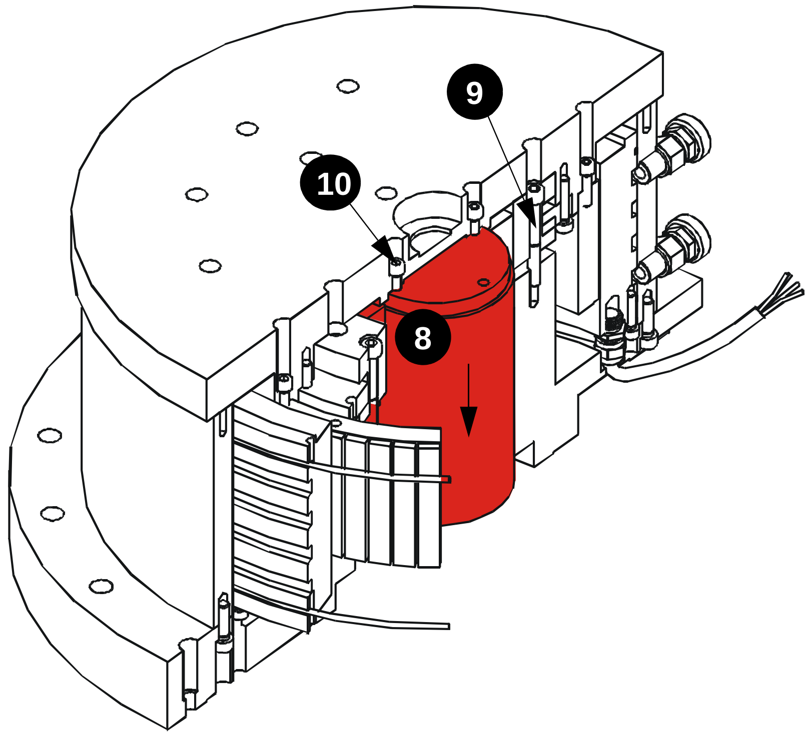
5: Mount and secure the bearing.

6: Insert and secure the rotor into the rotary assembly. Refer to §6.4 to know the tightening torque.

Beware of the powerful magnetic induction near the rotor. Do not approach a metallic part at less than 5 cm from the magnets of the rotor.

7: Mount the guide tool.

Warning: the rotary part must be guided by the guide tool before rotor and stator face each other.

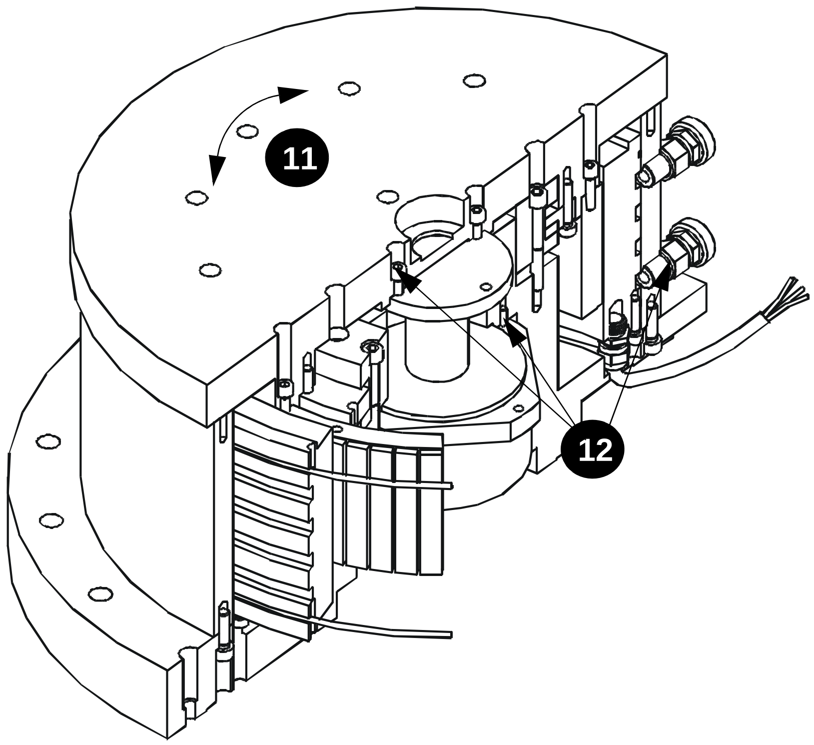


8: Insert the rotary assembly into the housing.

Beware of the attraction forces due to the magnets of the rotor.

9: Secure the bearing on the static assembly.

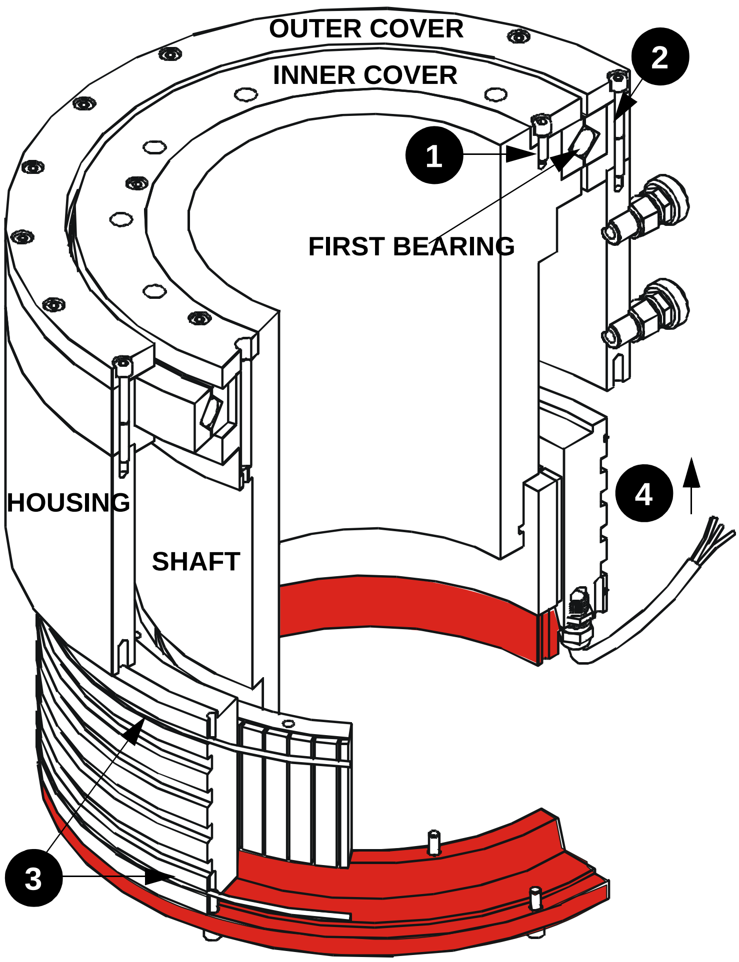
10: Unlock and remove the guide tool.



11: Check whether the motor moves without contact between rotor and stator over one entire revolution. It is normal to observe variations in the forces, depending on the position (detent torque).

12: Mount the accessories (water cooling inlet and outlet, power connector, encoder, etc...). Please refer to the encoder manufacturer's documentation for installation instruction.

9.6.5 'Rotary table or motor' assembly, using an ETEL bridge



1: Mount and secure the first bearing on the shaft with an inner cover.

2: Mount and secure the first bearing on the housing with an outer cover.

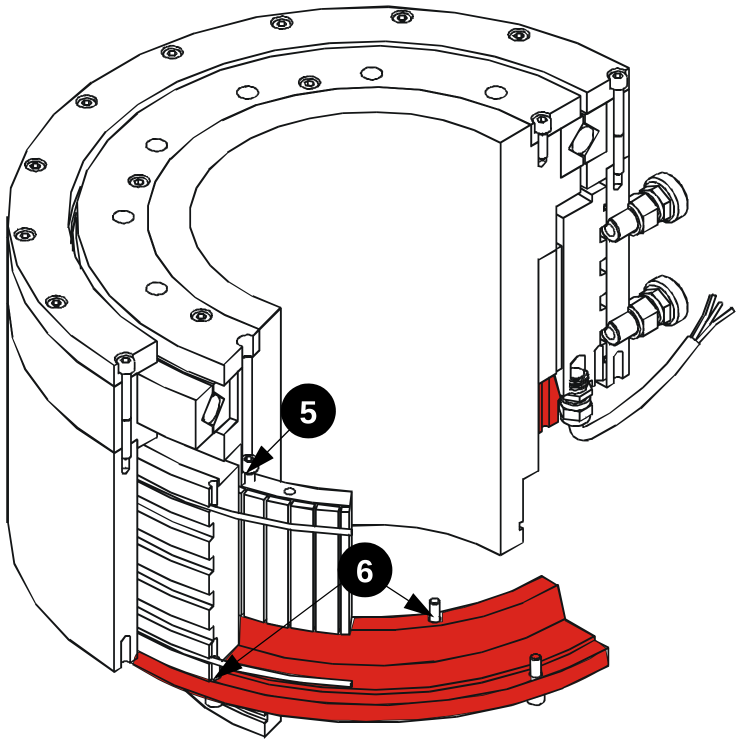
To ensure smooth operation, the assembly must be stiff.

3: Mount the O-rings on the stator if cooling is used **(be careful not to twist the O-rings to avoid leakage)**.

4: Insert the assembly 'stator + rotor + bridge'. The output cables (strain relief) must be aligned with the water cooling inlet and outlet (refer to §6.1 for more information).

Beware of the O-rings during the insertion.

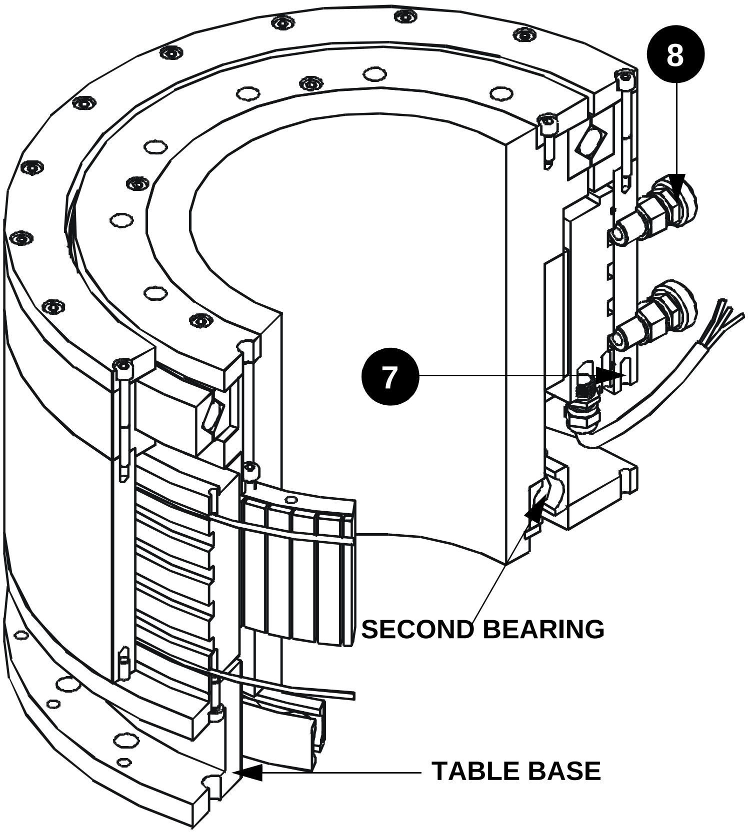
Take care of the powerful magnetic induction around the rotor. Do not approach a metallic part at less than 5 cm from the ROTOR magnets.



5: Secure the rotor to the shaft. Refer to §6.4 to know the tightening torque.

6: Remove the bridge from the rotor and the stator.

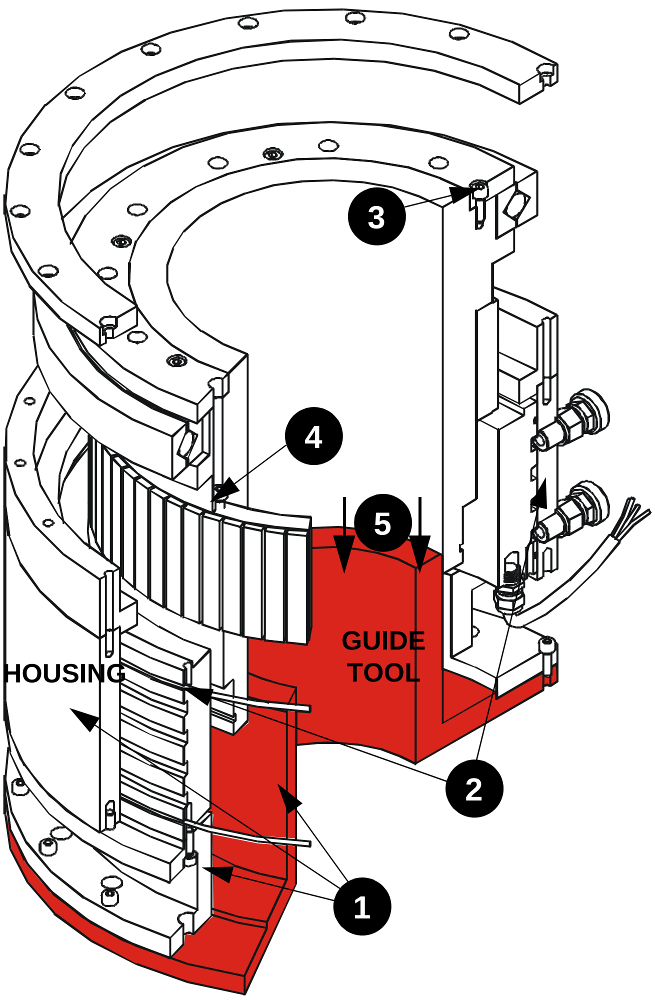
Note: The stator is maintained in position by the attraction forces.



7: Secure the stator on the housing (with a table base, e.g) and mount the second bearing (with a preload device, as required by your design). Refer to §6.4 to know the tightening torque.

8: Mount the accessories (water cooling inlet and outlet, power connector, encoder, etc... Please refer to the encoder manufacturer's documentation for installation instruction.

9.6.6 'Rotary table or motor' assembly using a guide tool



Static assembly:

1: Mount and secure the guide tool, the table base and the housing.

2: Mount the O-rings on the stator if cooling is used **(be careful not to twist the O-rings to avoid leakage)** and the stator on the table base. Refer to §6.4 to know the tightening torque.

Beware of the O-ring during the insertion.

Rotary assembly:

3: Mount and secure the bearing on the shaft with the cover.

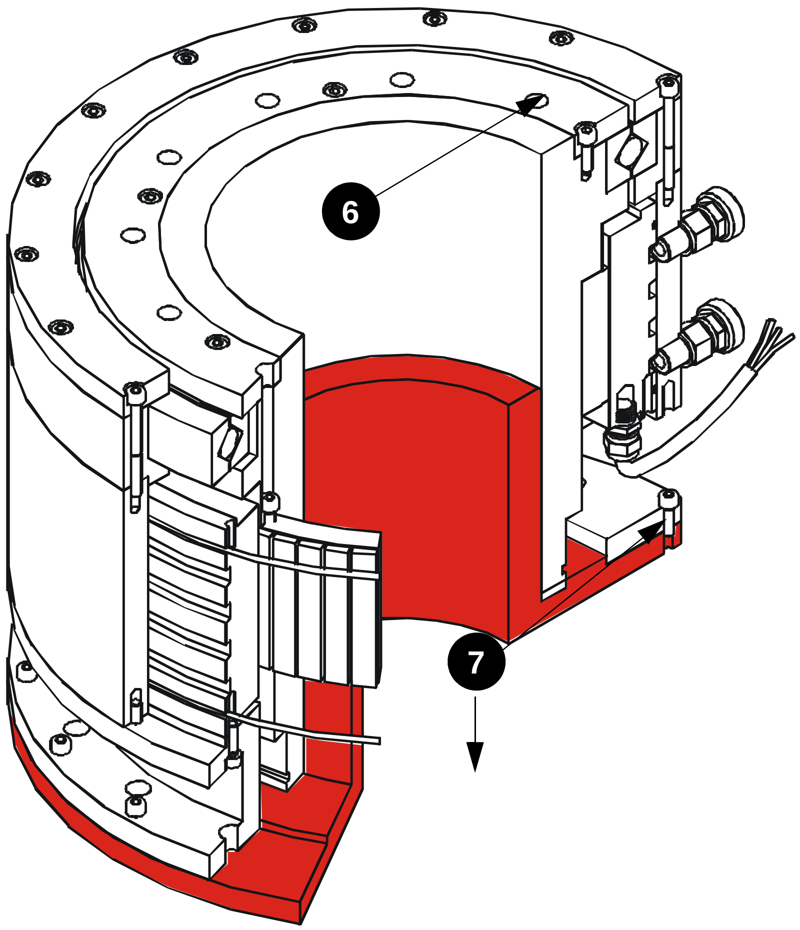
4: Mount and secure the rotor on the shaft. Refer to §6.4 to know the tightening torque.

Take care of the powerful magnetic induction around the rotor. Do not approach a metallic part at less than 5 cm from the rotor magnets.

Warning: the rotary part must be guided by the guide tool before rotor and stator face each other.

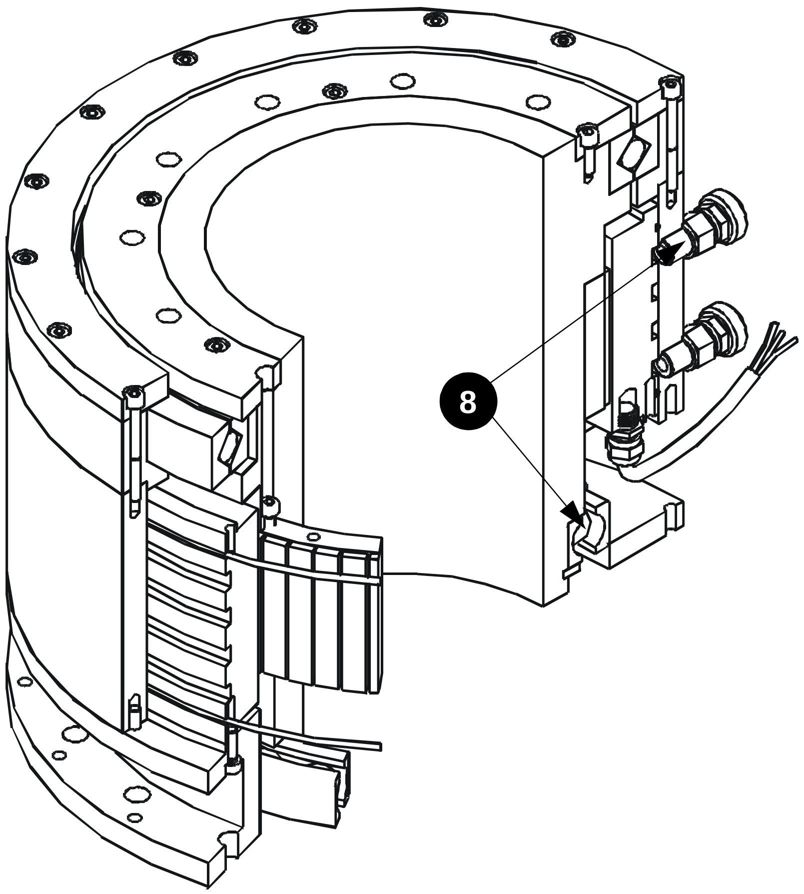
5: Insert the rotary part (shaft and rotor) into the static part (stator and external housing).

Beware of attraction forces due to the magnets of the rotor.



6: Secure the bearing to the housing with the cover and screws.

7: Unlock and remove the guide tool.



8: Mount the second bearing (with a preload device as required by your design) and add accessories like water cooling, electrical or thermal connections or encoder, etc... (please refer to the encoder manufacturer's documentation for installation instructions).

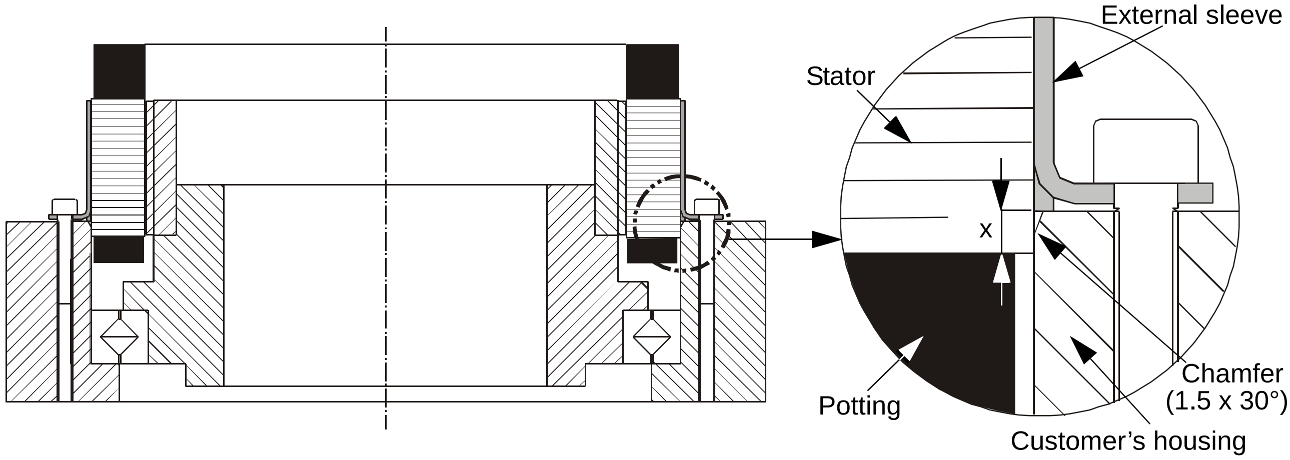
Remark: Refer to §9.6.7 for more information about the use of the magnetic bridge.

9.6.7 TML assembly

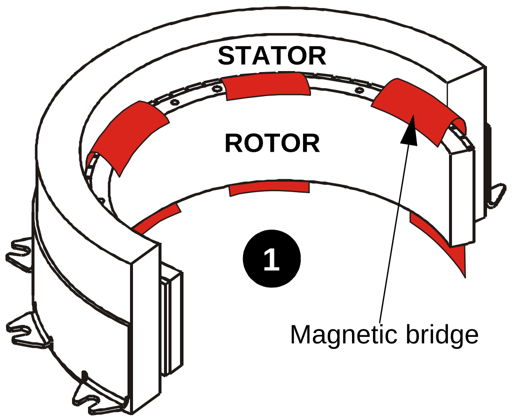
The TML0210 and TML0291 motors are delivered with an external sleeve and those from the TML0360 to the TML0530 are delivered with external lugs fixed to the lamination stack. The TML motors can be integrated into the customer's housing by using:

- An ETEL bridge: **only** the magnetic bridge can be used (refer to §7.2.1 for more information)
- A guide tool (provided by the customer): this procedure is similar to the one described in §9.6.6.

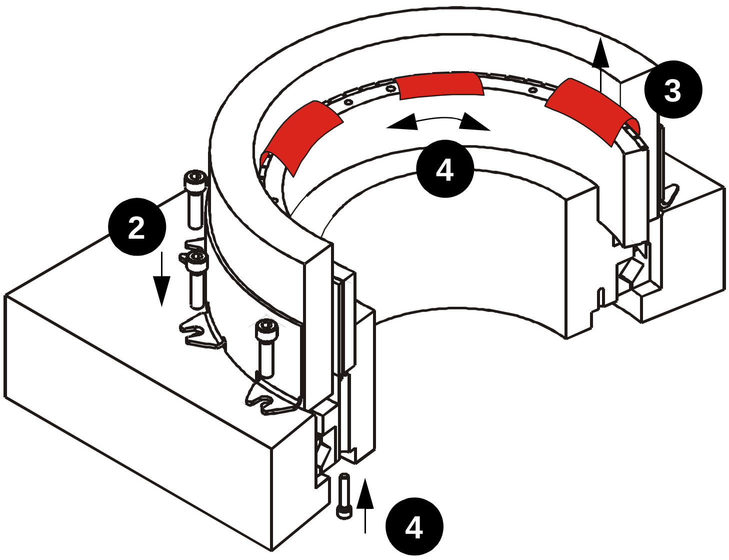
9.6.7.1 TML0210 and TML0291 assembly, using a magnetic bridge



The distance X must be used by the customer to center the motor inside its housing. It is strongly recommended to make a chamfer in the customer's housing to facilitate the integration of the motor.



1: The rotor and the stator are delivered with a magnetic bridge.

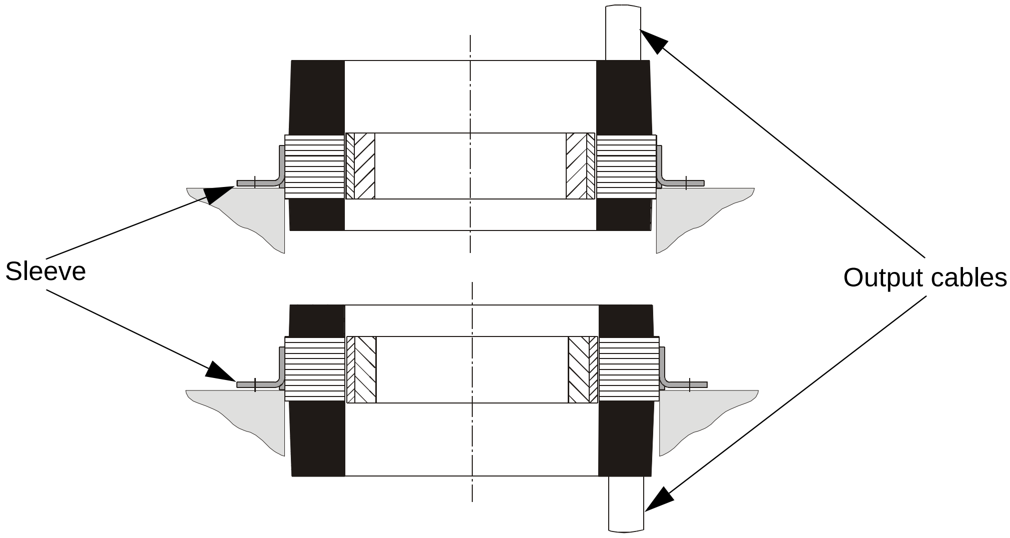


2: Fix the stator to the customer's housing.

3: Remove the bridge (the rotor is now centered by the customer's shaft).

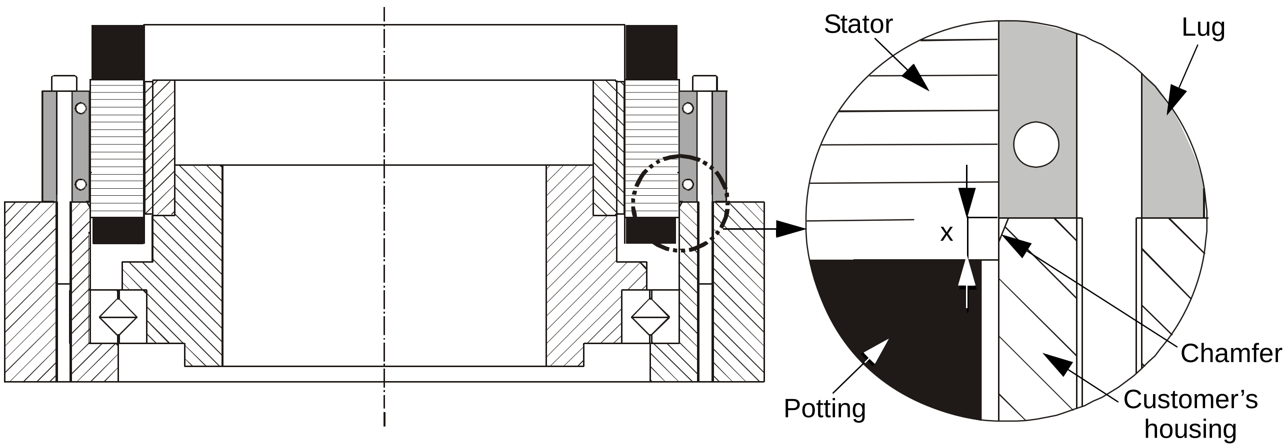
4:Turn the rotor or the shaft to align their corresponding fastening holes (as the magnetic bridge does not allow a perfect alignment) and then fix the rotor.

The sleeve can be positioned towards the output cables or on the opposite.

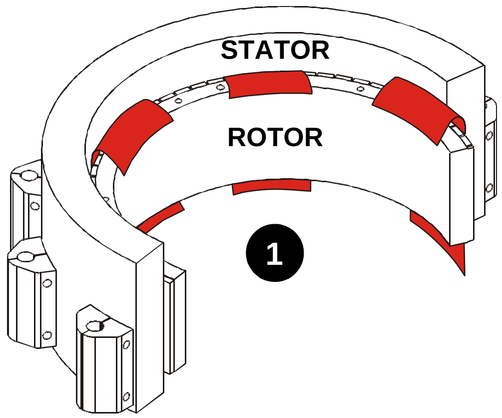


Remark: Refer to §3.3 for more information about the possible ordering information.

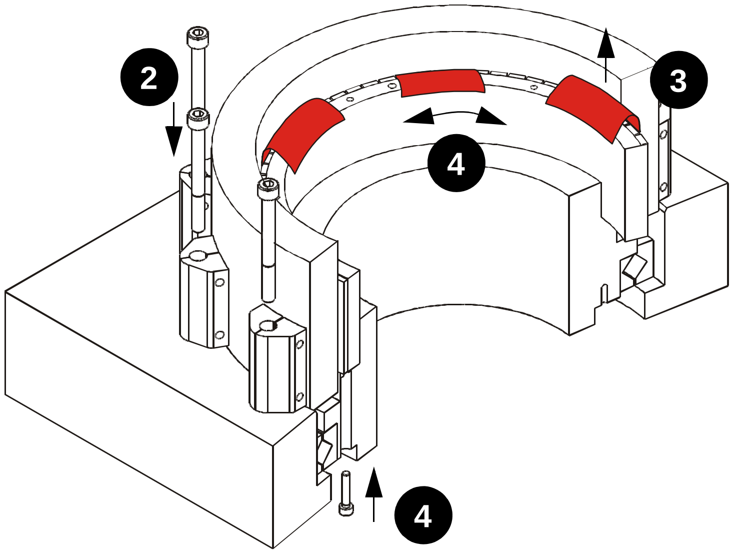
9.6.7.2 TML0360 to TML0530 assembly, using a magnetic bridge



The distance X must be used by the customer to center the motor inside its housing. It is strongly recommended to make a chamfer in the customer's housing to facilitate the integration of the motor.



1: The rotor and the stator are delivered with a magnetic bridge.

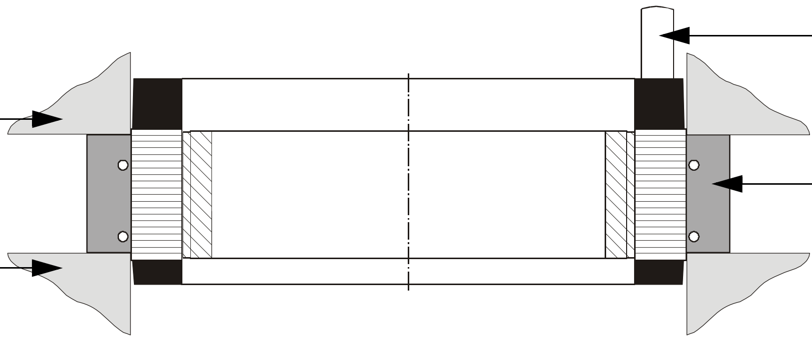


2: Fix the stator to the customer's housing.

3: Remove the bridge (the rotor is now centered by the customer's shaft).

4:Turn the rotor or the shaft to align their corresponding fastening holes (as the magnetic bridge does not allow a perfect alignment) and then fix the rotor.

The reference surface can be on either side of the lugs.



Remark: Refer to §3.3 for more information about the possible ordering information.

9.6.8 TMM assembly

The TMM motors are identical to the TML motors except that they do **NOT** have any sleeve or lugs usable for the mounting. Thus, the customer must either glue the stator inside his housing (XB5047 glue with XB5067 hardener, araldite or the equivalent) or design a clamping tool (under its own responsibility). ETEL does not recommend shrinking a TMM motors as it may damage the potting of the motor.

Remark: Refer to §9.6.7 for more information about the use of the magnetic bridge.

9.6.9 TMK assembly

The mounting of the TMK motors is identical to the one of the TMB (§9.6.3) except that:

- the rotor of the TMK is not symmetric (refer to the interface drawing for more information)
- the fastening holes on the rotor of the TMK0175 are present on one side only (refer to the interface drawing for more information)

9.7 Rotor - stator air gap checking

Once the motor has been mounted, the air gap between the rotor and the stator **must** be checked to avoid any damage while moving. To do so, insert a sheet in the air gap and make sure that you can turn around the stator without any problem. Move the motor of 90°, repeat the above-mentioned procedure and so on until the motor has been moved of one turn.

Motor series	Sheet thickness
From TM#0140 to TM#0360	0.3 mm
From TM#0450 to TM#1221	0.5 mm

9.8 Electrical connection

Please read all safety precautions listed below before handling the motor and/or the controller:

General precautions
1. Never touch the motor, the controller and/or any electrical connection points (e.g IMSPS,...) as long as the power is turned on. The power supplies must then be disconnected from the mains and be sure that it cannot be switched back on as long as a part of the system is handled. **2.** Before powering the motor, the manufacturer of the machine must establish that it complies with the national regulations and safety instructions. **3.** Before switching on the power, at least one ground wire must be permanently connected to all electrical units (controller, power supply,...). **4.** Only a competent and trained technician is allowed to install and operate the electrical equipment, in accordance with all specific regulations of the respective country concerning both safety and EMC aspects.

9.8.1 Shielding

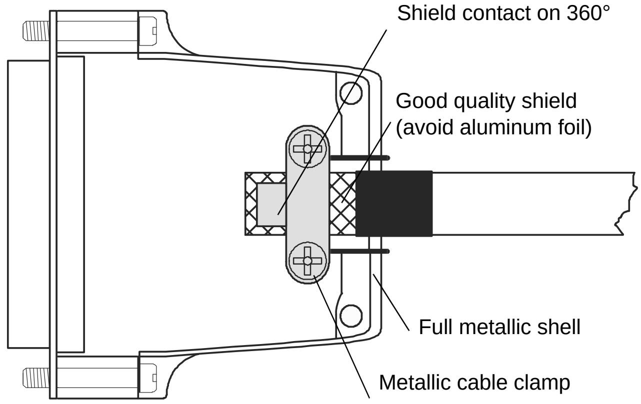
9.8.1.1 Power and temperature cables

The power and temperature sensor cables are delivered without connectors (refer to §6.2 for more information about the cables). It is necessary to use proper shielding procedures when installing a connector to avoid EMC problems. ETEL recommends the following:

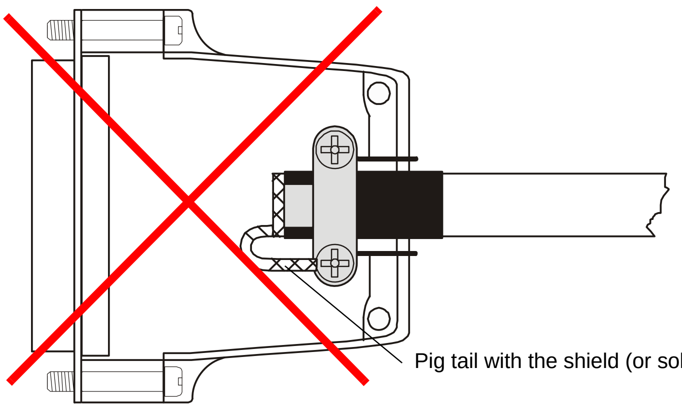
- The shield must entirely cover all wires.
- The shield contact on 360° and a metallic cable clamp is necessary.
- 'Pig tail' connections are forbidden.

Here is a shielding connection example on the position controller side:

Good shielding connection



Bad shielding connection



Remark: Only the shielding connection is considered here. The connector can be different than the one shown above.

9.8.1.2 Encoder cable

The encoder choice is application specific, therefore only general advice can be given by ETEL, however, here are some recommendations regarding proper shielding of the encoder cable:

- Simple shielded cable must be linked to the connector shells on both cable ends.
- Only full metallic conductive shell connectors must be used.
- Shielding with aluminum foil (metallized plastic film) is forbidden!
- Use only copper braid shielding (85% covering shield).
- The shield must entirely cover all wires.
- 'Pig tail' connections are forbidden!
- The shield must contact on 360° and be surrounded by a metallic cable clamp.

9.8.2 Connection to the controller

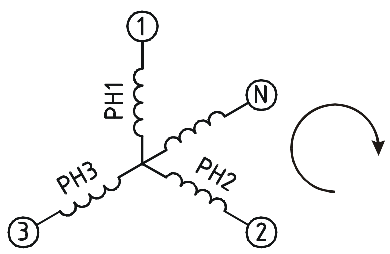
The following is a description of the connection between a motor and a controller. As mentioned in §6.2.2, there is either one or two power cables depending on the motor type.

	Caution	**ETEL SA disclaims all responsibility to possible industrial accidents and material damages if the temperature sensors are not plugged.**

Remark: **If the phases 1, 2 and 3 (also mentioned U, V and W) of the motor are connected respectively to PH1, PH2 and PH3 of the electronics, the motor will turn in the clockwise direction when watching the motor from the cable output side.**

9.8.2.1 Motor cables function

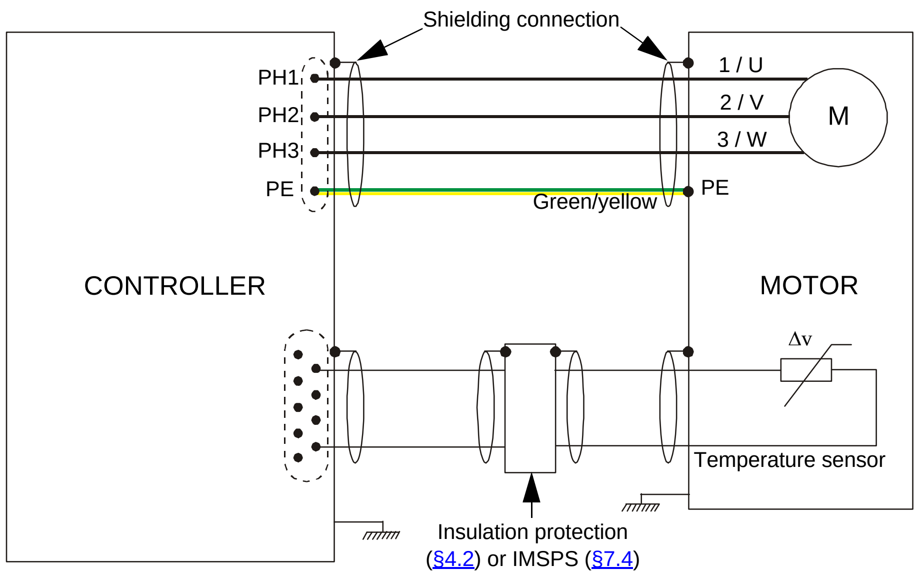
Here is the function corresponding to the colors of the motor cables:

Color and wire number	Function	Drawing
Black wire with number 1 or U	Phase 1 (PH1)	
Black wire with number 2 or V	Phase 2 (PH2)	
Black wire with number 3 or W	Phase 3 (PH3)	
Yellow and green wire	Ground (GND)	
Black wire with number Br1 or 5 or white cable	Neutral point wire	
Black wire with number Br2 or 6 or black wire without label	None(*)	

(*): This wire is automatically present when the neutral point wire is added in the motor as it is a 2 x 1 or 2 x 1.5 mm^2 cable.

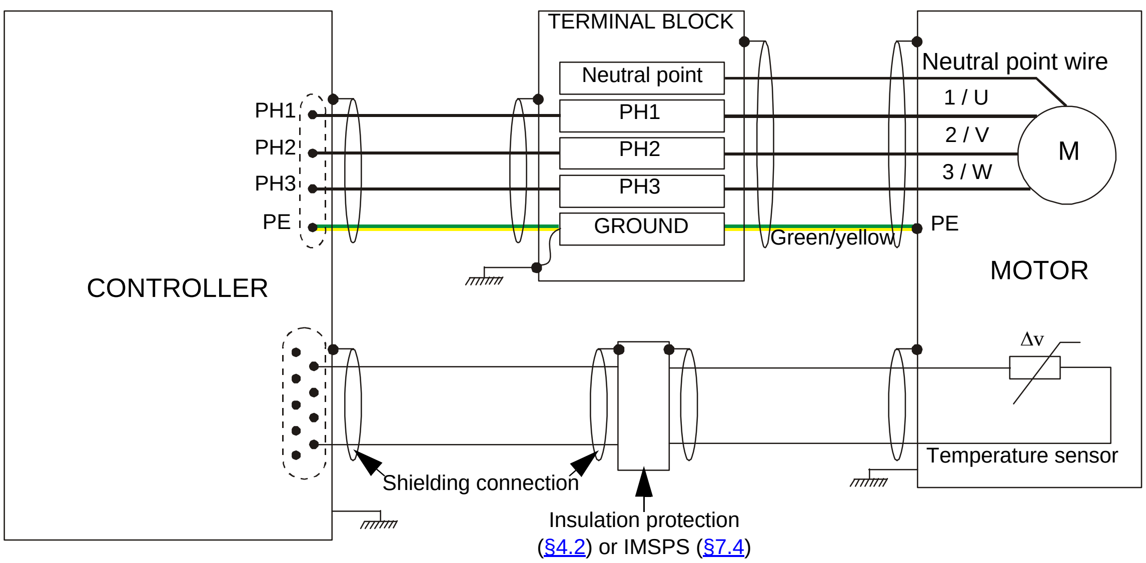
Remark: The number of wires depends on the motor type. Refer to §6.2.3 for additional information about the type of cable.
If the neutral point wire is present, this wire must be carefully insulated or connected to an IMSPS (refer to §7.3). Depending on the machine setup (controller, switching frequency, motor, cable length), voltage spikes up to 1400V may occur on the neutral point.
ETEL advises not to use the cable of the torque motors in a cable chain as it is considered as a wear component.

9.8.2.2 Connection with one power cable



Remark: If the motor is delivered with a neutral point wire, refer to §7.3.4 for more information about the electrical connection with an IMSPS.

9.8.2.3 Connection with one power cable & neutral point wire without IMSPS



Remark: If the motor's connector is shielded and complies with the industry standards in force, the neutral point wire can remain disconnected but insulated inside the connector on the strict condition that the insulation can withstand voltages of >1400V.

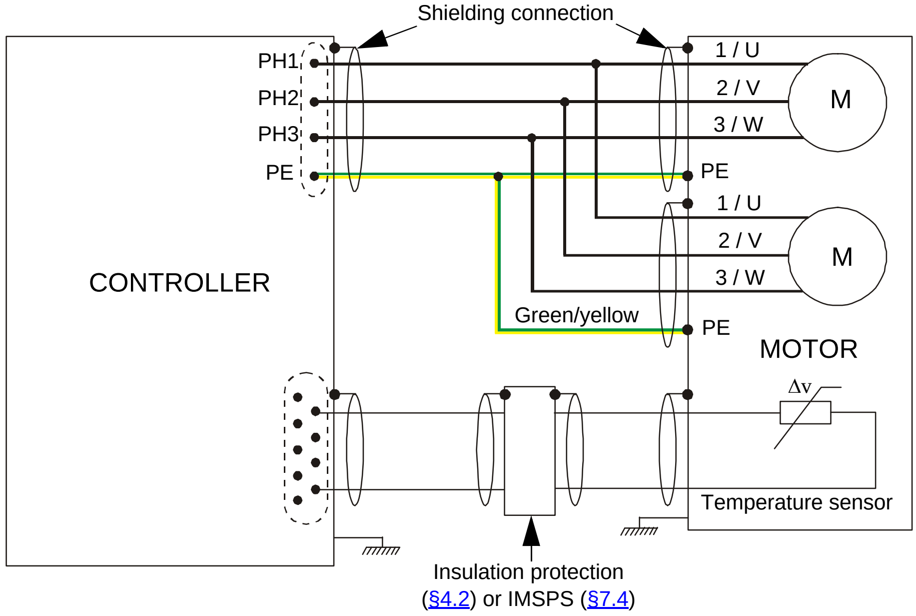
If the motor is delivered with a neutral point wire and an IMSPS is used, refer to §7.3.4 for more information about the electrical connection.

The neutral point wire of the motor is a black wire with number Br1 or a black wire with number 5 or a white cable. A second wire (a black wire with number Br2 or a black wire with number 6 or ablack wire without label) must be connected to the ground as it is not connected inside the motor.

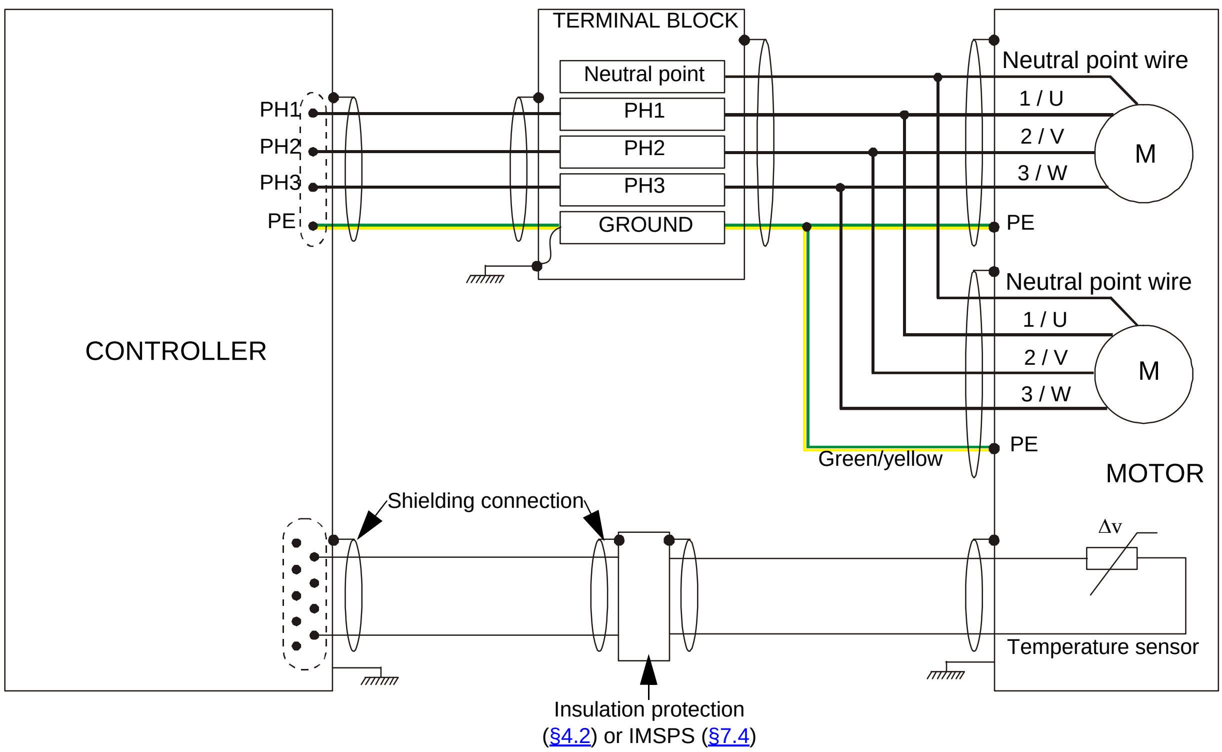
The neutral point wire of the motor must **NOT** be connected to the one of the electrical installation.

The chosen terminal block must comply with the norms in force and must be usable with high voltage (>1400V).

9.8.2.4 Connection with two power cables



9.8.2.5 Connection with two power cables & neutral point wire without IMSPS



Remark: If the motor's connector is shielded and complies with the industry standards in force, the neutral point wire can remain disconnected but insulated inside the connector on the strict condition that the insulation can withstand voltages of >1400V.

If the motor is delivered with a neutral point wire and an IMSPS is used, refer to §7.3.4 for more information about the electrical connection.

The neutral point wire of the motor is a black wire with number Br1 or a black wire with number 5 or a white cable. A second wire (a black wire with number Br2 or a black wire with number 6 or a black wire without label) must be connected to the ground as it is not connected inside the motor.

The neutral point wire of the motor must **NOT** be connected to the one of the electrical installation.

The chosen terminal block must comply with the norms in force and must be usable with high voltage (>1400V).

10. Commissioning

Please read all safety precautions listed below before commissioning the motor:

General precautions

1. Only a competent and trained technician is allowed to operate the motor, in accordance with all specific regulations of the respective country concerning both safety and EMC aspects.
2. The stator and the rotor must be connected to earth prior to any other operation. Please refer to the IEC / EN 60204-1 «Safety on the machines» directive for the earth resistance value.
3. Check that the motor rotates freely with no excessive friction. Make sure no object may block the motor movement.
4. Before starting the motor, the manufacturer of the machine must establish that it complies with the national regulations and safety instructions.
5. Before starting the motor, be sure there is no person or object in the motion range of the system. A safety fence or protective cover should be used. It is strictly forbidden to approach a powered system with the hand or an object as there is a risk of electrical hazard and risk of movement.
6. Before starting the motor, check that the cooling system works correctly.
7. Check that the master switch works correctly before starting the motor. Do not operate the machine if it does not work.
8. The power supply must include a current limitation device with the limit set to a low level. To ensure that the first movement is slow, set the speed limit to a low level.
9. Contact ETEL in case of missing or unclear information, before operating the motor.
10. Before switching on the power, at least one ground wire must be permanently connected to all electrical units.
11. Activate the possible safety and monitoring equipment of the system if present.
12. Like any other electrical device, the motor must not be located near a water tap. Take care not to spill liquid on the motor.
13. If you hear any suspicious noise, stop the motor. During the motor setting, high frequency noise can be produced. Use all necessary hearing protections.
14. The motor temperature will increase due to thermal losses. **Do not touch** motor parts while working or shortly after stop. Leave time for the motor to cool down.

Technical warnings

1. In case of emergency stop, the motor does not stop immediately.
2. **Do not plug** the motor directly to the mains (AC network).

11. Maintenance

Please read all safety precautions listed below before servicing the motor:

General precautions

1. **Troubleshooting and servicing must be performed only by ETEL's technicians or authorized distributors wearing the appropriate protective clothes.**
2. Stop the machine by using the controller commands to bring the motor to a controlled standstill. **Do not carry out any maintenance measures when the machine is running.**
3. Switch off the power supplies and the master switch of the machine (refer to the machine manufacturer for more information).
4. Wait for the discharge time of the corresponding electrical system and disconnect all the power connections.
5. Stop the pressure of the cooling system, drain off the coolant and disconnect the cooling system (refer to the cooling manufacturer for more information).
6. Disassemble the motor according to procedure.
7. Regularly clean the motor area to remove metal particles.
8. Regularly check if the stator and rotor are clean and undamaged on the air gap side.

ETEL's torque motors operate without any wear, however, operation under unusual operating conditions can reduce the lifetime. It is then recommended to make the following regular preventive inspections:

Preventive inspections	Periodicity
Inspect the coolant system to ensure proper flow rate, absence of particles in the coolant and confirm the inlet and outlet are not partially blocked.	There is no general rule but it is recommended to inspect the listed points every 3 months
Inspect the mechanical and electrical connections to avoid loose connectors.	
Inspect the cables to avoid possible wear.	
Inspect the gap and the rotor in case of possible dust, particles and leakage	

11.1 Troubleshooting

Symptoms	Causes	Actions
The motor does not move at all	- Bad electrical connections.	- Check the connections between the motor and the controller.
The motor moves in the wrong direction	- This problem can be related to the encoder.	- Check the encoder's wiring (refer to the encoder's documentation) or - Resolve the problem with the controller's software if you use an ETEL controller.
	- This problem can be related to the wiring of the motor.	- For a three-phase motor: cross 2 phases of the motor - For a two-phase motor: switch both phases. or - Resolve the problem with the controller's software if you use an ETEL controller.
Smell of burning	This problem can be related to: - a wrong controller setting - defective cooling - non conventional use compared to the data sheets	- Fill in the troubleshooting form (refer to §11.2) and contact ETEL's after-sales service
Abnormal temperature of the motor's housing	This problem can be related to: - defective cooling - wrong controller settings - defective bearings	- Check the coolant system (contact the manufacturer of the system) - Check the controller's regulation parameters

Symptoms	Causes	Actions
Unstable motor (vibrations)	- Motor insulation problem due to lightning, a wrong electric wiring...	- Check the resistance value (phases/earth and phases/sensors) > 1Mohm
	- Encoder mounting problem	- Check the mounting (rigidity)
	- Vibration of the machine	- Minimize the machine's vibrations
	- Noise on the encoder's signal	- Check the encoder's shield and connection
	- Wrong controller's settings	- Check the controller's regulation parameters
Abnormal friction noise or friction torque too high	This problem can be related to: - Centering problem of the rotor - Presence of objects in the air gap (which can deteriorate the rotor or/and the magnets)	- Check the mounting, remove particles from the air gap and contact ETEL's after-sales service in case of damage

11.2 Troubleshooting form

In case of trouble with a torque motor, send this form to ETEL representative (refer to §15.) in order to provide you with the best technical support and customer service.

Motor and machine identification

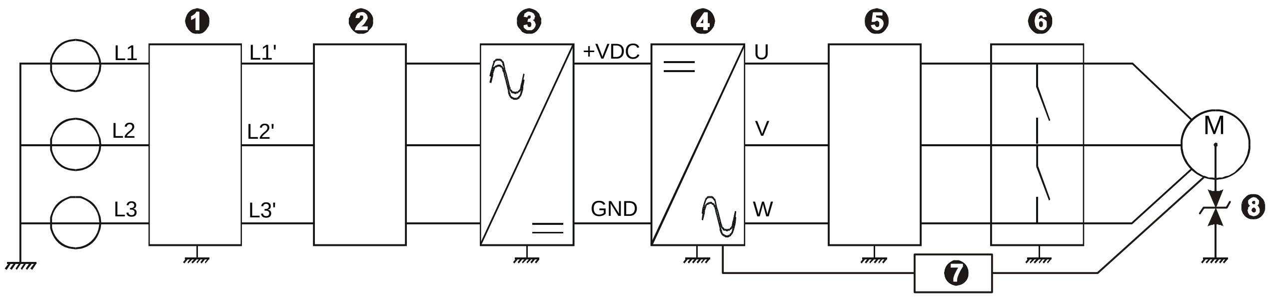
Customer machine designation: ..../ number of axes: ....

ETEL product code: TM[ ] [| | | |] - [| | |] - [| | | |] - [| | |] - [| |]

ETEL rotor serial number (see label): ....

ETEL stator serial number (see label): ....

Electronics cabinet components:



1 Mains filter type, ...	2 Choke, switching inductance/resistor type, ...	3 Power supply type, ...	4 Amplifier type, ...	5 Output filter type, ...
6 Short circuit relay type, ...	7 IMTHP used? ☐ No / ☐ Yes	8 IMSPS used? ☐ No / ☐ Yes		

☐ NC (Numerical Control), type: ....

☐ Other, comment: ....

Torque motor in service since: ....

Location (country, city): ....

Operation conditions

Motor bearing lubrication, oil/grease type: ....

Motor liquid cooling?
☐ No / ☐ Yes, coolant type: ....
Flow rate at the motor input (liter/min): ....

Is a cutting fluid (or other fluid for machine operation) used?
☐ No / ☐ Yes, fluid type: ....

Does the motor have a brake?
☐ No / ☐ Yes, brake function: ....

Failure circumstances

Failed axis designation: ....

Failure observation:
☐ Over-temperature message from the NC, comments: ....
☐ Sudden stop, comments: ....
☐ Performance degradation (vibrations, ripple), comments: ....
....
....
☐ Other, comments: ....
....
What was the machine's status when the motor failed?
☐ during machine's commissioning, comments: ....
....
☐ during normal operation (e.g. milling, turning, stalled), please specify: ....
....
☐ during other operation, comments: ....
....

Did the same failure occur before?
☐ No / ☐ Yes, when exactly: ....

Numerical Control parameters

List below all NC parameters concerning the motor, or send the corresponding file to ETEL.
....
....
....
....
....
....

Appendix

Please provide us with all documents or mechanical parts helping us to get a better understanding of the problem (photos, NC file, damaged parts). List the documents, files, photos, or parts sent to ETEL:
....
....
....
....
....
....

Customer's contact information for ETEL's technical support

Company: ....
Contact person: ....
Address: ....
Phone: .... E-mail: ....

12. Tolerances and hypothesis of the data sheets

12.1 Tolerances

The following table gives the tolerances on the values mentioned in the data sheets.

Performances		Units	Tolerances
Tp	Peak torque	Nm	Guaranteed value
Tc	Continuous torque	Nm	±10%
Ts	Stall torque	Nm	±10%
Kt	Torque constant	Nm/A_{RMS}	±5%
Ku	Back EMF constant	$V_{RMS}/(rad/s)$	±5%
Km	Motor constant	$Nm/\sqrt{W}$	±7.5%
R20	Electrical resistance at 20°C	Ohm	±5%
L1	Electrical inductance	mH	±10%
Ip	Peak current	A_{RMS}	±10%
Ic	Continuous current	A_{RMS}	±5%
Is	Stall current	A_{RMS}	±5%
Pc	Max. continuous power dissipation	W	±15%

Specifications		Units	Tolerances
Udc	Max. DC bus voltage	VDC	Controller depending
τth	Thermal time constant	s	±10% with cooling
Rth	Thermal resistance	K/W	±10% with cooling
2p	Number of poles	-	Constant
J	Rotor inertia	kgm^2	±5%
Mr	Rotor mass	kg	±5%
Ms	Stator mass	kg	±5%
Td	Max. detent torque (average to peak)	Nm	Maximum value
ns	Stall speed	rpm	±10% with cooling
$\Delta\theta$w	Water temperature difference for Pc	K	Input data
qw	Minimum water flow for $\Delta\theta$w	l/min	Minimum value
Δpw	Max. pressure drop at qw	bar	Maximum value

12.2 Thermal hypothesis

The thermal hypotheses are cooling hypotheses. Only the water cooling and the free air convection are possible.

12.2.1 Free air convection

With free air convection, the hypotheses are as follows:

- Ambient temperature at the rotor level: 20°C
- Ambient temperature at the stator level: 20°C
- Exchange surface: see corresponding data sheet

- The exchange surface at the rotor level mentioned in the data sheet must be respected
- The exchange surface at the stator level mentioned in the data sheet must be respected

Remark: If the TMM is glued to the customer's housing, the thermal resistance of the glue must be taken into account.

12.2.2 Water cooling

With water cooling, the hypotheses are as follows:

- Ambient temperature at the rotor level: 20°C
- Input temperature of the water: 20°C
- Output temperature of the water: 25°C or 30°C (refer to the data sheet of the corresponding motor type)
- Average temperature at the stator level: 22.5°C
- The exchange surface at the rotor level mentioned in the data sheet must be respected
- The exchange surface at the stator level is the one defined by the characteristics of the cooling (number of channels, width, height,...)

13. Glossary

Back EMF constant: Ku [V_{RMS}/(rad/s)]

The back EMF constant, Ku, is the back EMF (ElectroMotive Force) voltage given at 1 rad/s.
In the ETEL data sheets, the Ku is the RMS value of the voltage measured terminal to terminal given for a magnet temperature of 20°C.

Base speed: bs [rpm]

The base speed, bs, is the speed from which flux weakening must be applied to the motor if working at Ieq current.

Continuous current: Ic [A_{RMS}]

The continuous current, Ic, is the current required by the motor to reach its continuous torque Tc. The continuous current is a winding dependent term.
In the ETEL data sheets, the continuous current is given for a coil temperature of 130°C, an ambient temperature of 20°C and a magnet temperature given at stall speed. The stator and the rotor must be attached to a structure having the dissipating surface mentioned in the corresponding data sheet.

Continuous torque: Tc [Nm]

The continuous torque, Tc, is the maximum torque the motor is able to generate continuously with all phases equally sharing the load (contrary to the stall torque Ts). The continuous torque is reached when the continuous current Ic is applied to the motor. Since the continuous torque is temperature dependent, two values (with and without cooling) are presented in the ETEL data sheets.
In the ETEL data sheets, the continuous torque is given for a coil temperature of 130°C, an ambient temperature of 20°C and a magnet temperature given at stall speed. The stator and the rotor must be attached to a structure having the dissipating surface mentioned in the corresponding data sheet.

Current (depending on duty cycle): Ieq [A_{RMS}]

Refer to the definition of «Duty cycle».

Duty cycle: DC [%]

The duty cycle, Dc, is the percentage of time of the motor use:
- 100%: continuous running
- x%: during a cycle of τcy seconds, a running with Ieq current is possible during a time of x / (100*τcy) seconds and a complete stop during (100-x) / (100*τcy) seconds. Refer to the corresponding data sheet for more information

Electrical inductance: L1 [mH]

Electrical inductance of the motor from terminal to terminal (without the cables of the motor).
In the ETEL data sheets, the electrical inductance is given at the continuous current (Ic) for a motor in working conditions.

Electrical inductance: Ld/Lq [mH]

Ld = d-axis synchronous inductance. This inductance is used for setting the field weakening mode in the controller.
Lq = q-axis synchronous inductance. In normal operating mode (no field weakening), this is the inductance seen by the controller (equivalent to L1 for TMB, TMM, TML motors).
In the ETEL data sheets, the electrical inductance is given at the continuous current (Ic) for a motor in working conditions.

Electrical resistance at 20°C: R20 [Ohm]

Electrical resistance of the windings from terminal to terminal at a coil temperature of 20°C (without the cables of the motor).

Max. continuous power dissipation: Pc [W]

The max. continuous power dissipation, Pc, represents the total power to be dissipated to have a coil temperature of 130°C. If water cooling is used, the majority of the power losses is transferred to the water.
In the ETEL data sheets, the max. continuous power dissipation is given for a coil temperature of 130°C.

Max. detent torque (average to peak): Td [Nm]

The max. detent torque, Td, also referred as the cogging torque, is the alternating part of the torque required to make one revolution of a non-powered motor. The detent torque is associated with the magnetic flux created by the magnets to the lamination teeth (without current).
This variable torque depends on the relative position of the laminated teeth with regards to the magnetic poles. The detent is not dependent on the current flowing in the motor.
In the ETEL data sheets, the max. detent torque value is an average to peak value.

Max. pressure drop at qw: Δpw [bar]

The max. pressure drop at qw, Δpw, is the pressure drop needed between the input and output of the coolant in order to reach the minimum water flow qw, required for the given working conditions.
In the ETEL data sheets, this data corresponds to a maximum value.

Maximum speed: nm [rpm]

This maximum speed, nm, is the speed calculated to protect the motor, the electronics and the persons. At this speed, the voltage between the phase and the ground will be always lower than 1000Vp.

Maximum total time for one cycle: τcy [s]

Refer to the definition of «Duty cycle».

Max. winding losses (low speed): Pw [W]

The max. winding losses, Pw, are the maximum winding losses present during the x% of the duty cycle by taking into account the actual average temperature of the copper (if the x% cycle is respected).

Mechanical power (depending on Duty cycle): Pm [kW]

The mechanical power, Pm, is the maximum mechanical power the motor can develop with the current Ieq and the bus voltage Udc.

Minimum water flow for $\Delta\theta$w: qw [l/min]

$\Delta\theta$w is the minimum water (pure water) flow needed to dissipate the losses.

Motor constant: Km [Nm/$\sqrt{}$W]

The motor constant, Km, defines the torque efficiency of the motor and is typically presented in units of Nm/$\sqrt{}$W. The higher the motor constant, the lower the power losses for a specific output torque.
In the ETEL data sheets, the motor constant is given for a coil and magnet temperature of 20°C.

Number of poles: 2p

2p represents the number of poles of the rotor (p being the number of pole pairs).

Peak current: Ip [A_{RMS}]

The peak current, Ip, is the amount of current required by the motor to reach its peak torque Tp. The value for Ip is provided at a temperature that ensures the magnets of the rotor will not become demagnetized. The peak current is a winding dependent term. The maximum allowable time for application of the peak current will be dependent on the initial winding temperature. In any case, if the motor temperature is within normal operating range, the peak current can be applied for 2 seconds.

In ETEL data sheets, the peak current is given for a maximum magnet temperature of 80°C and a perfect phasing.

Peak torque: Tp [Nm]

The peak torque, Tp, is the maximum torque the motor is able to generate. This torque is reached when the peak current Ip is applied to the motor. The value for Ip is provided at a temperature that ensures the magnets of the rotor will not become demagnetized.
The maximum allowable time for application of the peak current will be dependent on the initial winding temperature. In any case, if the motor temperature is within normal operating range, the peak current can be applied for 2 seconds.
In the ETEL data sheets, the peak torque is given at the stall speed (ns) and for a maximum magnet temperature of 80°C.

Rotor inertia: J [kgm^2]

The rotor inertia, J, is the physical property of the rotor to resist changes in the magnitude or direction of its velocity by the application of a torque. The rotor inertia is dependent upon its mass and shape.

Stall current: Is [A_{RMS}]

The stall current, Is, is the current limit that should not be exceeded when the motor is operating in stall conditions. The stall current is generating the stall torque Ts and is a winding dependent term.
In the ETEL data sheets, the stall current is given for a coil temperature of 130°C and an ambient temperature of 20°C. The stator and the rotor must be attached to a structure having the dissipating surface mentioned in the corresponding data sheet.

Stall speed: ns [rpm]

The stall speed, ns, is the speed limit under which the motor cannot work in continuous duty.

Stall torque: Ts [Nm]

The stall torque, Ts, is the torque corresponding to the stall current (Is) for a magnet temperature given at stall speed.
In the ETEL data sheets, the stall torque is given for a coil temperature of 130°C and an ambient temperature of 20°C. The stator and the rotor must be attached to a structure having the dissipating surface mentioned in the corresponding data sheet.

Thermal resistance: Rth [K/W]

The thermal resistance, Rth, represents the total thermal resistance from the windings to the water (with water cooling) or to the surrounding air in free convection and radiation (without water cooling).
In the ETEL data sheets, the thermal resistance is given for a coil temperature of 130°C, an ambient temperature of 20°C and a water temperature of 20°C. The stator and the rotor must be attached to a structure having the dissipating surface mentioned in the corresponding data sheet.

Thermal time constant: τth [s]

This value is the worst case thermal time constant of a motor. It is defined as the 'cooling time constant'. It corresponds to the time required for a motor to decrease 63% of its maximum allowable temperature at no power. In the field, the 'heating time constant' is mainly used. This time constant is very similar to the 'cooling time constant' and will, in any case, be shorter (safer).

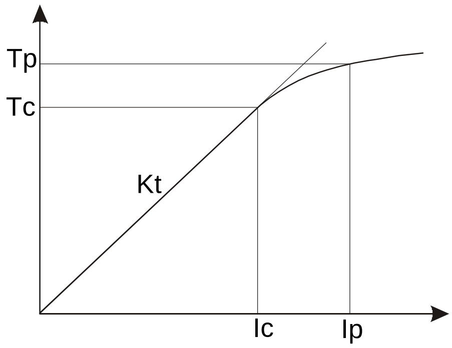
Torque at low speed: Teq [Nm]

The torque at low speed, Teq, is the torque reached at stall speed (ns) when the current Ieq is applied.

Torque constant: Kt [Nm/A_{RMS}]

The torque constant, Kt, is the ratio between the motor's output torque and the RMS current. The relationship

is essentially linear up to the continuous torque Tc. Above Tc, the non-linearity is due to saturation in the lamination stack.
In the ETEL data sheets, the torque constant is given for a magnet temperature of 20°C.



Water temperature difference for Pc: $\Delta\theta w$ [K]

$\Delta\theta w$ indicates the temperature difference between the input and output coolant.
In the ETEL data sheets, the water temperature difference is given to 5°K.

14. Unit conversion

The following tables are provided for unit conversions. To convert the unit present in column A to the unit present in the line B, multiply by the figure present in the table.

Mass unit conversion

		B			
		g	**kg**	**lb**	**oz**
A	**g**	1	0.001	0.0022	0.03527
	kg	1000	1	2.205	35.273
	lb	453.59	0.45359	1	16
	oz	28.35	0.02835	0.0625	1

Angular velocity unit conversion

		B			
		deg/s	**rad/s**	**rpm**	**rps**
A	**deg/s**	1	17.455×10^{-3}	0.167	2.777×10^{-3}
	rad/s	57.29	1	9.549	0.159
	rpm	6	0.105	1	1.667×10^{-2}
	rps	360	6.283	60	1

Rotary inertia unit conversion

		B			
		kg-m^2	**lb-in^2**	**lb-ft^2**	**oz-in^2**
A	**kg-m^2**	1	3417.63	23.73	54644.81
	lb-in^2	2.926×10^{-4}	1	69.43×10^{-4}	15.99
	lb-ft^2	4.214×10^{-2}	144.02	1	2302.73
	oz-in^2	1.83×10^{-5}	62.54×10^{-3}	4.34×10^{-4}	1

Torque unit conversion

		B			
		N-m	**lb-in**	**lb-ft**	**oz-in**
A	**N-m**	1	8.851	73.75×10^{-2}	140.84
	lb-in	0.113	1	83.33×10^{-3}	16
	lb-ft	1.355	11.99	1	191.94
	oz-in	7.1×10^{-3}	62.5×10^{-3}	5.21×10^{-3}	1

Temperature unit conversion

		B	
		°C	**°F**
A	**°C**	1	(°F) - 32 x 5 / 9
	°F	(°C) x 9 / 5 + 32	1

15. Service and support

For any inquiry regarding technical, commercial and service information relating to ETEL products, please contact your ETEL representative:

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All marketing and technical documentation as well as firmware and software can be downloaded from ETEL's web site: www.etel.ch. ETEL organizes training courses for customers on request, including theoretical presentations of our products and practical demonstrations at our facilities.