Torque motor manual

version 2.2

TECNOTION®

direct drive in motion

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APPENDIX - TABLE OF CONTENTS

1. BEFORE YOU START

This is the manual for your Tecnotion motor. Please read this manual very carefully. The information provided is important for a safe and warranted installation and operation of the motor. Be sure to have this manual at hand when installing or working with the motor.

1.1 About this manual

This manual describes the use of a Tecnotion torque motor system. These motors can be applied in numerous application devices. This manual is intended for technicians who construct a machine that includes a torque motor system. It will give insight what aspects to consider for the design and installation for a torque motor.

1.2 Intended use

A torque motor system is a permanent-magnet direct drive motor that rotates along an axis. It is intended to be used wherever a rotary movement is required. Only use this torque motor system as intended, every other use is not-intended use and therefore not warranted.

1.3 Use of symbols

!	This symbol describes a tip to inform the user.
(!)	This symbol is a non-safety related important notice that the user should be aware of.
⚠ 🛇	These symbols warn about safety information that should be respected.

1.4 Important notice

⚠	Tecnotion declines all responsibility in case of accident or damage due to negligence or lack of observance of the instructions described in this manual. Tecnotion also declines all responsibility in case of accident or damage in conditions that differ from those indicated in the manual; Tecnotion also declines all responsibility for damage caused by improper use of the motor.
⚠	Handle the components of the motor with care, packed as well as unpacked.
⚠	Do not expose the magnets to temperatures higher than 70° C. The magnets may be demagnetized at higher temperatures.
⚠	Do not expose the stator to temperatures above 100 no curing° C. The filler material or wiring may be damaged.
⚠	Unpack the motor and check its integrity. If there is any irregularity, contact the dealer or Tecnotion, signaling the nature of the defects. Make a note of the serial number. This facilitates the correspondence with the supplier.

1.5 Safety warnings

Use of magnets

⚠	The used magnets show large attraction forces on all ferromagnetic objects such as iron. These forces cannot be controlled by hand. They may cause serious jamming danger. Do not bring any soft magnetic objects (iron) nearer than 25 cm of the magnetic side of the magnets of the rotor.

Provide sufficient radial and axial centering and guidance to prevent collision during installation.

Be sure that the stator and rotor are fixed into your machine before removing the magnetic field protection plates. The stator and rotor will attract each other during installation. These forces cannot be controlled by hand. Put the magnetic field protection plates on again before dismounting them.

Magnetic sensitive objects like banking cards, pacemakers or other magnetic information carriers may be damaged if they are brought within 1 m of the magnets (plates or rotor).

If at any time and in any situation there is any doubt about the safety of the motor, do not use it and contact your supplier.

Mechanical safety

The motor is used as a part of a machine. The user has to take care that the machine as a whole fulfils all CE requirements.

The motor is powered by a servo amplifier. In case of a power disruption or fatal error this may automatically result in a free run out of the motor. Make mechanical precautions to prevent damage on the motor or your machine in the case of such an event.

The magnets can detach from the rotor when the motor is operated above its allowed maximum rotational speed. This can cause personal injury or damage to the motor and the entire application. This speed varies per motor type. Please set the correct maximum speed for the installed torque motor. Refer to appendix G for maximum mechanical speed.

Earthing

Before installing the motor, make sure that the supply mains are grounded and operate in conformity with the regulations in force.

Make sure that there is an effective protective earth. Make sure that there is no voltage at the wire terminals before connecting.

An earth connection does not work on non-conducting mounting surfaces like granite. In these cases the protective earth must be established by an earthing wire.

Maintenance

Before carrying out checks or doing any maintenance, clear the system by disconnecting the voltage. Be sure that there is no possibility of accidental connections.

The components can be damaged when cleaned with a non-prescribed cleaning agent. Use only isopropanol as a cleaning agent.

Adhesives and activators can damage the stator and rotor.

UV blacklight can cause irreversible damage to the eyes and other tissue when exposed. When using a UV blacklight installation wear appropriate protective clothing and glasses.

The motor contains permanent magnets that produce a magnetic stray field. For transport safety please check chapter 6 for information on transport.

1.6 Certification

All information about certifications can be found in this chapter. The declaration of conformity or compliance can be found in appendix F.

1.6.1 CE Certification

Tecnotion B.V. declares that all torque motors mentioned in this installation manual are manufactured in accordance with European directive 2006/95/EC and in conformity with the following standards, see Table 1.

Table 1: Applicable standards

Standard	Name of standard
EN 60034-1: 2010	Rotating Electrical Machines, Part 1: Rating and performance.
EN 60204-1: 2010	Safety of machinery - Electrical equipment of machines, Part 1: General requirements

1.6.2 Restriction of Hazardous Substances (RoHS)

Tecnotion B.V. declares to be compliant with the RoHS-guideline. Therefore Tecnotion ensures that all products are free from lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls or polybrominated diphenyl ethers.

1.7 Overview applicable standards

The table below gives an overview of applicable standards per motor type.

Table 2: Applicable standards per motortype

Series	CE	RoHS
QTR 65	Yes	Yes
QTR 78	Yes	Yes
QTR 105	Yes	Yes
QTR 133	Yes	Yes
QTR 160	Yes	Yes
QTR digital Hall module	Yes	Yes
QTL 210	Yes	Yes
QTL 230	Yes	Yes
QTL 290	Yes	Yes
QTL 310	Yes	Yes

2. OVERVIEW & SPECIFICATIONS

This chapter gives an overview of the motor and its components and specifications.

2.1 Introduction of the motor

Tecnotion torque motors are so called frameless torque motors. They can be applied in numerous application devices. For a fully functional torque motor system the user needs to provide additional components like an:

- axis,
- bearing system,
- encoder and controller system.

In paragraph 2.4 & 2.5 more information can be found on the basic and additional components.

2.2 Motor family and series

The torque motor family currently consist of nine diameter types and seven heights. This covers a continuous torque range of 0.29Nm up to 329Nm. The figure on the right gives an overview of the torque range.

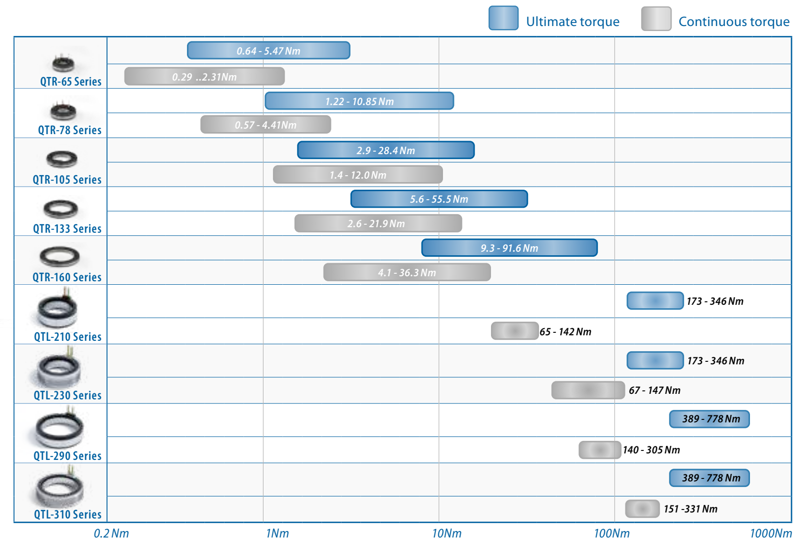


Figure 1: Torque range

Naming of the motors is done through the convention below:

QTR/QTL-X-XXX-XX-X

- Winding type: N, S, Y or Z
  For optimization of speed or low busvoltage
- Axial height of the stator: 17, 25, 34, 60, 65, 85 or 105 mm
  For exact height please review appendix A
- Outside diameter of rotor: 65, 78, 105, 133, 160, 210/230 or 290/310mm
  For exact height please review appendix A
- Magnet type: A or X
  X type for improved torque specs
- Family designation : QTR / QTL

2.3 Specifications

All torque motors have their own extensive drawings that can be found in appendix A.

2.4 Basic components

A Tecnotion QTR torque motor kit consists of a rotor containing the magnets and a stator containing the coils. The bigger torque motors are provided with a temperature sensor. A QTL torque motor has optionally a ring with cooling channels wrapped around the stator and four brackets and spacers to fix the rotor and stator in place. In case of the water-cooled motor there are a total of four brackets. Additionally it has integrated temperature sensors. See Figure 2.

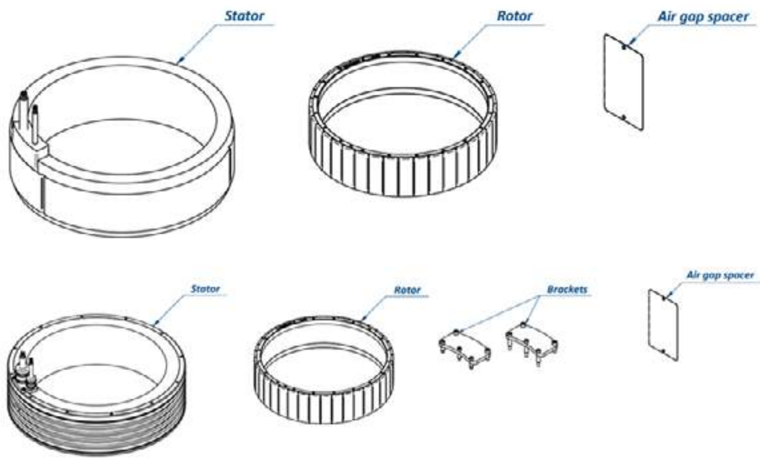


Figure 2: Basic components QTL motor kit

The voltage rating of 300, 600 or 680 Vdc varies per torque motor. Should another cable exit type or voltage rating be required please contact your local Tecnotion representative to explore the possibilities. Common methods of construction of the stator into an application are clamping or bonding. The torque motor lamination stack surface is made of bare steel and is prone to corrosion. When the lamination stack surface is not protected it will show corrosion, this however will not affect performance.

2.4.1 Rotor

The rotor, containing the magnets, is usually the moving part of the torque motor. The rotor can be fastened into an application by means of bonding, clamping, or bolting, depending on the motor type. The rotor of QTL motor can be fastened into an application by means of bolting.

Magnetic field protection ring

The rotor an be supplied with a magnetic field neutralizing protection ring (QTR-65, QTR-78 and QTL series don't have a protection ring), see Figure 3. It functions as a shield for the magnetic forces. With the ring installed the rotor can be handled safely.

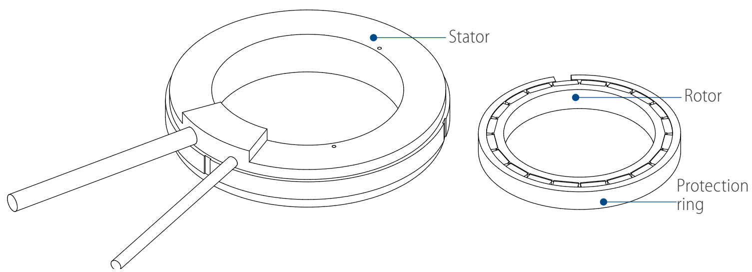


Figure 3: Protection ring

2.4.2 Stator

The stator comes in different diameters and heights. It has a separate power and temperature sensor cable both with a length of 0.5 m. The cable exit can, depending on the motor type, be in axial or radial direction (see Figure 4). The QTL torque motor has a separate power and temperature sensor cable both with a length of 2 m. The stator can be fastened into an application by means of bolting, bonding, crimping and/or clamping depending on the motor type.

2.4.3 QTL torque motor kit fixation brackets

The stator and rotor are locked together using fixation brackets, see Figure 2. The function of the fixation brackets is to keep the stator and rotor locked in place to ensure safety during transport and installation.

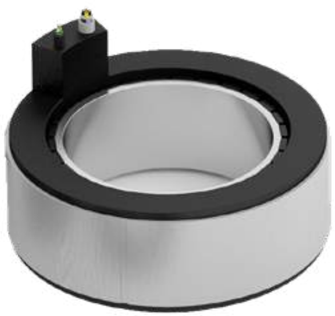


Figure 4: QTR motor with axial exit

2.5 Additional components

To construct a complete motion system, additional components are required. These components are not included when buying a Tecnotion torque motor. Please review the following minimum required components for setting up a complete motion system:

- Power supply with sufficient power and voltage rating.
- Cables and connectors for connecting the torque motor to the drive system.
- Amplifier and servo drive system.
- Bearing system, with sufficient stiffness and appropriate friction force.
- Mechanical infrastructure for containing the rotor and stator and to accommodate heat transfer.

Optional:

- Ruler disc and/or encoder system and/or Tecnotion digital Hall module.
- Braking mechanism.

Digital Hall module

The digital Hall module (see below) can be used to determine the electrical position of the rotor. The module is a replacement for a 'wake-and-shake' of the motor. It means that the module only functions when the QTR stator is not powered. This module cannot commutate over the entire speed- and load bandwidth.

3. MOTOR CONFIGURATION

This chapter gives information for designing an application driven by a Tecnotion torque motor. Please take notice of the advice, tips and warnings in this chapter to make sure the torque motor performs in the best possible way.

3.1 Safety

Use of magnets

The used magnets show large attraction forces on all ferromagnetic objects such as iron. These forces cannot be controlled by hand. They may cause serious jamming danger. Do not bring any soft magnetic objects (iron) nearer than 25 cm of the magnetic side of the magnets of the rotor.

Provide sufficient radial and axial centering and guidance to prevent collision during installation.

Be sure that the stator and rotor are fixed into your machine before removing the magnetic field protection plates. The stator and rotor will attract each other during installation. These forces cannot be controlled by hand. Put the magnetic field protection plates or fixation brackets on again before dismounting them.

Magnetic sensitive objects like banking cards, pacemakers or other magnetic information carriers may be damaged if they are brought within 1 m of the magnets (plates or rotor).

If at any time and in any situation there is any doubt about the safety of the motor, do not use it and contact your supplier.

Mechanical safety

The motor is used as a part of a machine. The user has to take care that the machine as a whole fulfils all CE requirements.

Be sure your machine as a whole meets the requirements of all applicable electrical standards, such as the EN 60204 standard.

The motor is powered by a servo amplifier. In case of a power disruption or fatal error this may automatically result in a free run out of the motor. Make mechanical precautions to prevent damage on the motor or your machine in the case of such an event.

The magnets can detach from the rotor when the motor is operated above its allowed maximum rotational speed. This can cause personal injury or damage to the motor and the entire application. This speed varies per motor type. Please set the correct maximum speed for the installed torque motor. Refer to appendix G for maximum mechanical speed.

3.2 Properties

The relevant properties concerning configuration of a torque motor are described below.

Corrosion

The Tecnotion torque motor lamination stack surface is made of bare steel and is prone to corrosion. When the lamination stack surface is not protected it will show corrosion, this however will not affect performance.

Cooling

In order to achieve rated performance, the stator needs to be mounted in a cooled housing. The full lamination stack needs to be in contact with a 20°C surface. Insufficient cooling will have an effect on the motor's continuous torque.

Air gap
The correct air gap will be ensured by installing the Tecnotion torque motor according the instructions in this manual.

Thermal conduction
Tecnotion torque motors dissipate heat through the lamination stack. Most heat dissipates through the larger stack surface, though the lamination stack shoulders also have an important function. Proper clamping of the shoulders helps dissipate the heat. Cooling is needed when the motor is operated at continuous or stall torque.

For smaller motors (17 mm and 25 mm height) shoulder clamping can be sufficient (see Figure 5). For larger motors it is needed for the motor to lose its heat through the lamination stack. This can be done by a cooled housing or heat sink.

For catalogue performance the lamination stack surface needs to be in full contact with a body or heat sink kept at a maximum of 20°C. When only the shoulders of the lamination stack are in contact with a cooling/clamping surface, the available continuous torque is affected. The available continuous torque can be reduced by up to 75%. This reduction is affected by the motor size, clamping force and various changes in the environment.

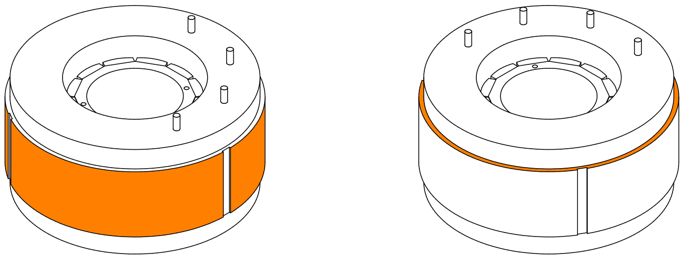


Figure 5: Cooling surface indicated in orange

3.3 Housing requirements

Pay attention to the different housing/connection requirements for the various torque series. When clamping the stator all specifications apply. When a bonding-connection is used, the angularity does not apply. Always use the correct concentricity and centering of the rotor in the stator. Centering of the stator is done on the lamination stack. Rotor centering can be done on the inside of the rotor.

3.4 Mounting

There are a number of factors to consider when mounting a torque motor. Most importantly the method of mounting of the stator can affect performance. A tradeoff has to be made between thermal conduction, cost of infrastructure (housing) and ease of (de)installation.

When designing a mounting/housing, these questions can help:

- Does the application use a high continuous load (that requires good thermal conductivity) or short peak loads (with sufficient downtime for cooling)?
- What clamping force or shear strength is to be expected to keep the stator in place?
- Is a quick (de)installation of the motor required?

3.4.1 Stator

Do not clamp the stator on the black polyurethane casting, this can damage the coils.

Do not center the stator on the black polyurethane casting.

To ensure a good connection when mounting a stator, pay attention to the proper alignment, sufficient clamping force/tightening torque and heat extraction. Thermal properties are affected by the mounting method, either by variation in the contact surface or by additional thermal resistances (adhesives).

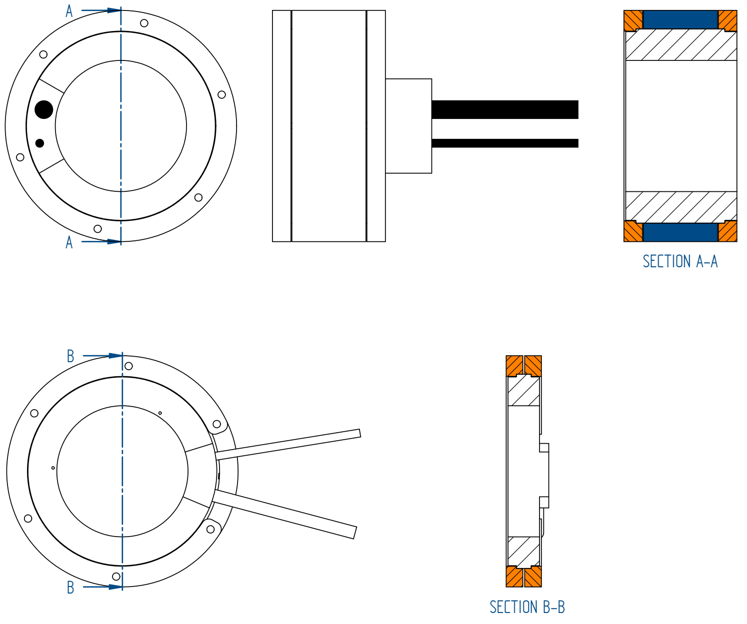


Figure 6: Heat extraction in orange

QTL 230 and QTL 310 cooling ring

It is necessary to check if the substances present in and around the intended application do not react with any part of the motor, in particular the NBR O-rings sealing the cooling ring (see Figure 7) as this could lead to a leakage of the cooling medium possibly resulting in diminished performance, short-circuiting, corrosion and/or contamination of the application. It is the responsibility of the user to design the housing in such a way that it is leak-proof and compatible with the intended application.

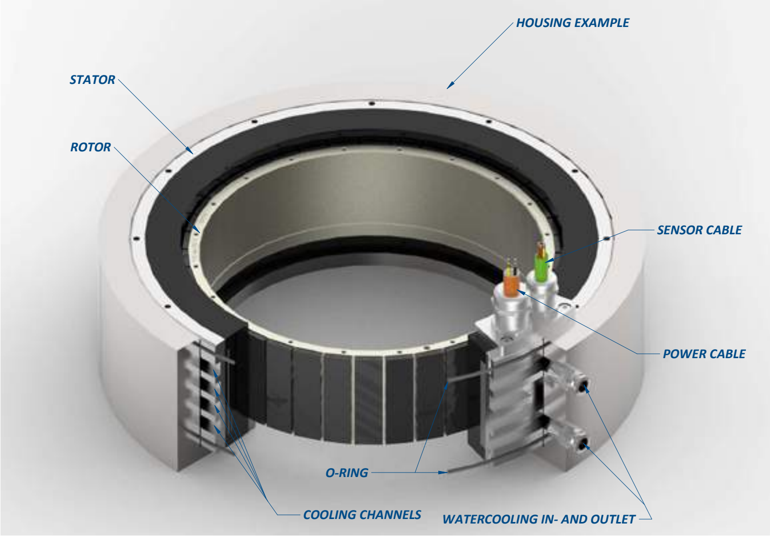


Figure 7: Material overview of QTL 230 and QTL 310 with O-rings

3.4.2 Rotor

The main objective when mounting the rotor is proper positioning – axial and radial – of the motor. Other than positioning the rotor, the proper clamping/bonding/bolting force needs to be considered. The steel of the rotor compared to the stator lamination stack allows for higher clamp forces.

Mounting a rotor requires a strong and rigid axle. Take into consideration that heat dissipation trough the axle will be minimal. Tecnotion recommends two options when mounting a QTR rotor. The rotor can either be mounted by clamping it axially or by bonding (see Figure 8), or by bolting in case of a QTL rotor.

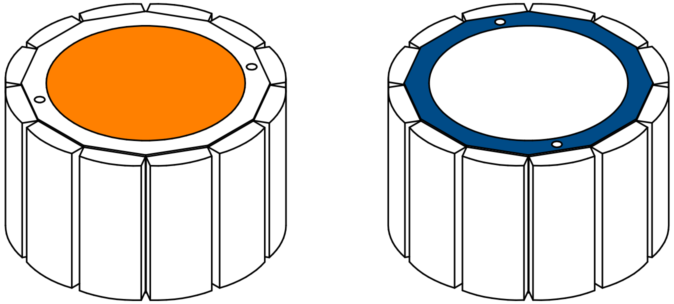


Figure 8: Bonding surface (left), clamping surface (right)

QTR 65 and QTR 78 housing specification

The following specifications apply when designing a housing for a Tecnotion QTR 65 or QTR 78 stator. The stator's main contact area is the lamination stack. The lamination stack is used both for cooling and clamping/bonding purposes. The stator requires a housing with specifications according to Figure 9 and Table 3.

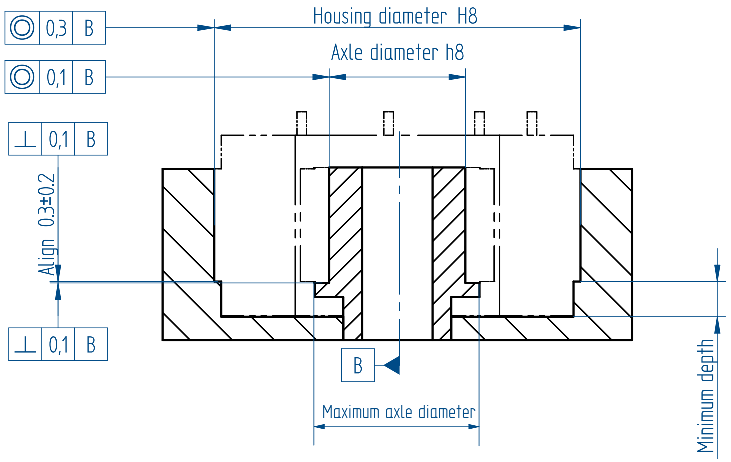


Figure 9: QTR 65 and QTR 78 housing requirement tolerances for mounting/centering purposes

! Pay attention to the angularity and parallelism when installing a Tecnotion QTR stator.

Table 3: Housing specification QTR 65 and QTR 78

Motor	QTR 65-17/25 series	QTR 65-34/60 series	QTR 78-17/25 series	QTR 78-34/60 series
Alignment	Axial alignment of the rotor in stator must be within 0,3 mm +/- 0,2 mm			
Minimum depth	5.5 mm	7.5 mm	5.5 mm	7.5 mm
Housing diameter	65 mm H8		78 mm H8	
Axle diameter	17 mm h8		29 mm h8	
Max. axle diameter	23 mm		35 mm	

QTR 1xx housing specification

When mounting a QTR 105, QTR 133 or QTR 160 stator different tolerances apply. See the specifications according to Figure 10 and Table 4. When the housing meets the tolerances described, the torque motor will perform best.

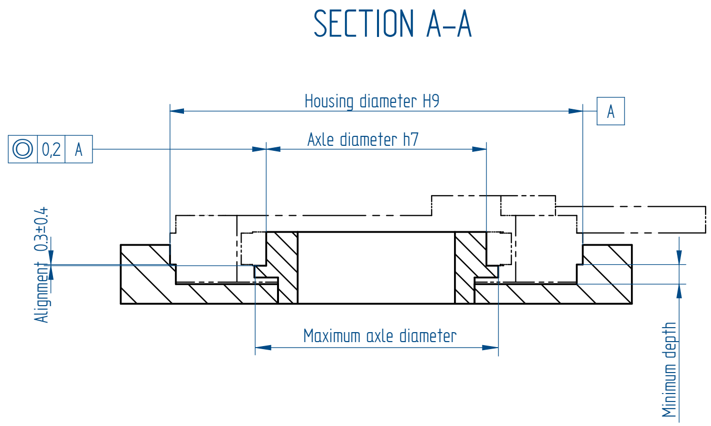


Figure 10: QTR 1xx housing requirement tolerances for mounting/centering purposes

! When using a digital Hall module: Tecnotion advices to bond rather than clamp the stator.

Table 4: Housing specification QTR 105, QTR 133 and QTR 160

Motor	QTR 105-17/25	QTR 105-34	QTR 105-60	QTR 133-17/25	QTR 133-34	QTR 133-60	QTR 160 17/25	QTR 160-34	QTR 160-60
Alignment	Axial alignment of the rotor in stator must be within 0.3 mm +/- 0.4 mm								
Minimum depth	4.5 mm	5.0 mm	5.5 mm	4.5 mm	5.0 mm	5.5 mm	4.5 mm	5.0 mm	5.5 mm
Housing diameter	105 mm H9			133 mm H9			160 mm H9		
Axle diameter	56 mm h7			84 mm h7			111 mm h7		
Max. axle diameter	62 mm			91 mm			118 mm		

⚠ Beware of the maximum temperature when curing the bonding material.
For the stator, no curing above 100°C. Risk of damaging the stator.
For the rotor, no curing above 70°C. Above 70°C, risk of demagnatizing the magnets.

QTL series housing specification

In order to design the most suitable housing for a particular application the dimensions of the stator and rotor are given below. The stator of the water cooled motors and rotor have bolting holes for fastening it to the application. This method is advised. The stator of the non-water cooled motors do not have bolting holes, therefore fixing the motor to the housing should be done by bonding, crimping or tangential clamping. Axial clamping is not advised because the lamination stack can be damaged due to compression. The requirements to fixate the motor within the housing are dependent on the application and the intended movement profile. The non-water cooled QTL motors are very similar to the QTR series and the same methods of fixation, with the exception of axial clamping, can be applied. When designing the housing of a water cooled motor it is important to take into consideration that the O-ring needs to maintain a seal at all times. Always use the correct concentricity and centering of the rotor in the stator. Centering of the stator is done on the rotor ring, not the filler material. Rotor centering can be done on the inside of the rotor ring. See the specifications according to Figure 11 and Table 5.

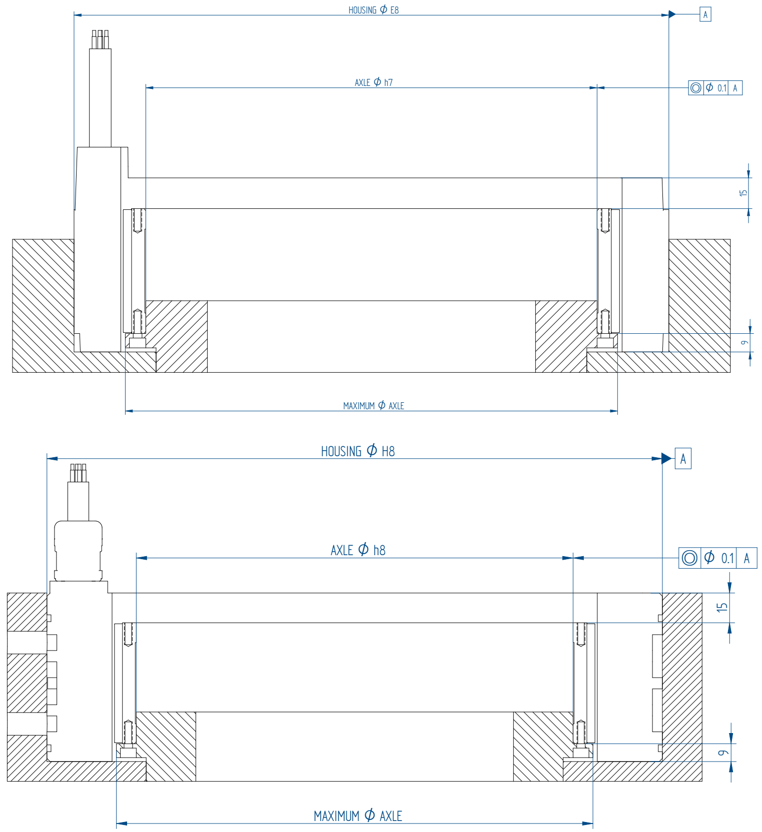


Figure 11: QTL 210 and 290 (above) QTL 230, 310, 385 and 485 (below) housing requirement tolerances for mounting/centering purposes

Table 5: Housing specification QTL 210, QTL 230, QTL 290 ,QTL 310, QTL 385 and QTL 485

	QTL 210	QTL 230	QTL 290	QTL 310	QTL-385	QTL-485
ID Housing	210 E8	230 H8	290 E8	310 H8	385 H8	485 H8
OD Rotor axle	140 h7	140 h8	220 h7	220 h8	280 h8	366 h8
Max. axle diameter	154 mm		234 mm		304 mm	394 mm

3.5 Electrical interface

Tecnotion torque motors come with various cable configurations. The main difference can be seen by:

- QTR 65 and QTR 78 motors use 4 'flying leads' for powering the motor.
- QTR 105, QTR 133 and QTR 160 motors have two cables, the larger one being the power cable, the smaller being the temperature sensor cable. Both cables being shielded with braided metal.

! The temperature sensor cable can be cut off if the sensor is not used.

⚠ QTR 65 and QTR 78 have no strain relief, provide proper strain relief in construction.

The cable exit differs for various Tecnotion torque motors (see Figure 12).

- The 65 mm and 78 mm Tecnotion torque motors use flying lead power cables. These motors do not have a temperature sensor (cable).
- Tecnotion torque motors of 105, 133 and 160 diameters with a 17, 25 or 34 mm height use a radial cable exit.
- Tecnotion torque motors of 105, 133 and 160 diameters with a 60 mm height and all QTL motors use an axial cable exit.

! QTR 1xx Y and Z have different cable exit dimensions.

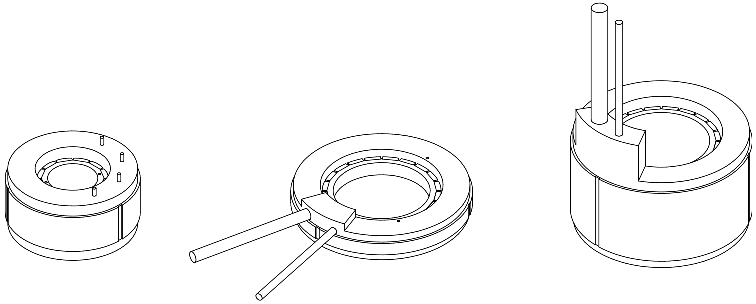


Figure 12: Axial flying lead (left), radial shielded cables (middle), axial shielded cables (right)

QTL torque motor

The QTL torque motor has two cables exiting the stator axially. The larger orange one being the power cable, the smaller green one being the temperature sensor cable. Both cables being shielded with braided metal.

3.5.1 Cable specifications & protective earth

See Table 6 for cable specifications and identification. If desired you can shorten these cables and provide them with appropriate connectors.

Table 6: Cable specification and identification

Motor	QTR 65 QTR 78	QTR 105 N QTR 133 N QTR 160 N			QTR 105 Y/Z QTR 133 Y/Z QTR 160 Y/Z		QTL 210 N QTL230 N QTL 290 N QTL 310 N	
Motor height	All	17-25-34	60	All	17-25-34	All	65-85-105	
Type of cable	4 flying leads (3 phases, 1 ground)	Shielded power		Shielded sensor	Shielded power	Shielded sensor	Shielded power	Shielded sensor
Length	500 mm							
Cable diameter in mm	2.06	6.5	9.5	4.5	6.6	4.5	10.6	6.4
Bending radius in mm	10.3	42.3	38.4	27	99	27	79.5	48
Rated voltage Vdc	600	320	600	n/s	320	n/s	680	30

Internally the motor's protective earth wire is galvanically connected to the lamination stack. This wire must be connected to the protective earth connector of the servo amplifier.

⚠ Provide the motor system with protective earth lines to the amplifier that are as short as possible..

The details about the QTR 1xx sensor cable wire identification are shown in Table 7.

Table 7: Sensor cable wire identification QTR 1xx

Sensor cable (color)	Connection to servo controller
PTC (white)	PTC
PTC (brown)	PTC
KTY21 (green)	KTY83-122
KTY21 (yellow)	KTY83-122
Shield	Protective earth

3.5.2 Wiring schemes

Below are the wiring schemes for the different torque motors.

QTR 65 & QTR 78

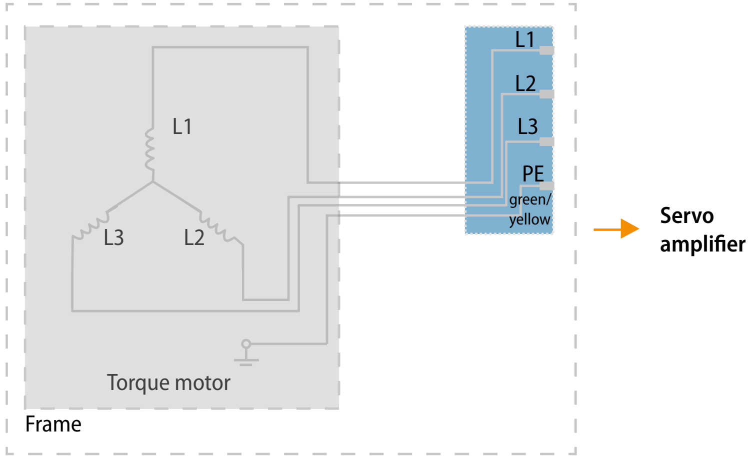


Figure 13: Wiring scheme for QTR 65 and QTR 78

Table 8: Power cables wire identification QTR 65 and QTR 78

Power cable		17/25/34/60	Connection to servo controller
3-phases	L1	black	3-phases
	L2	red	
	L3	white	
Protective earth		green/yellow	Protective earth

QTR 1xx N+Y

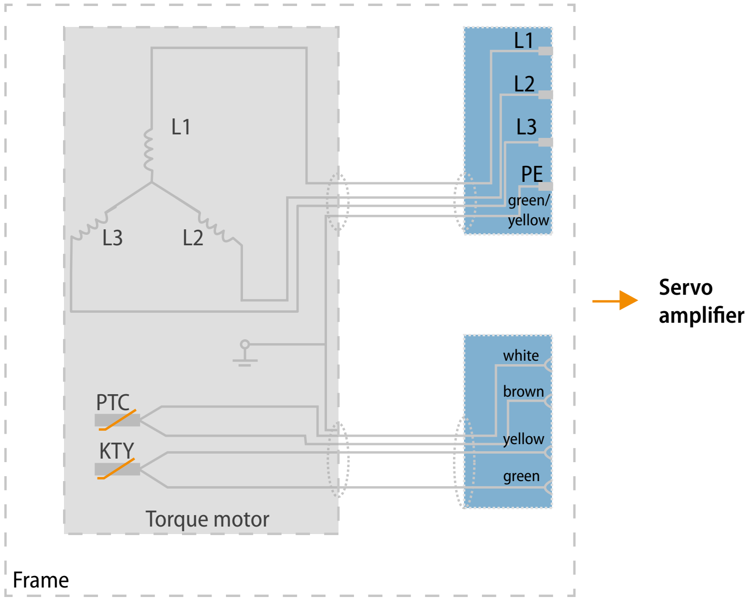


Figure 14: Wiring scheme for QTR 105, QTR 133 and QTR 160

Table 9: Power cables wire identification QTR 1xx N+Y

Powercable		17/25/34	60	Connection to servo controller
3-phases	L1	black	black '1'	3-phases
	L2	red	black '2'	
	L3	white	black '3'	
Protective earth		green/yellow		Protective earth
Shield		Protective earth		

QTR 1xx Z

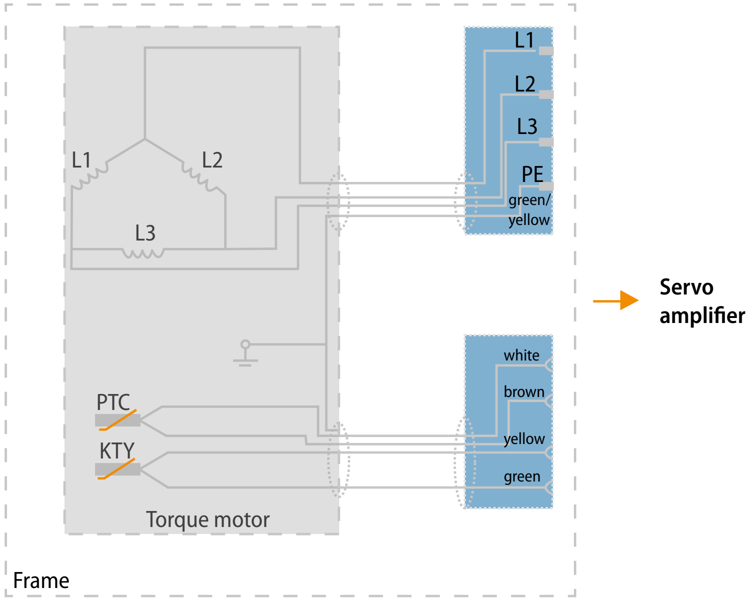


Figure 15: Wiring scheme for torque Z windings

Table 10: Power cables wire identification QTR 1xx Z

Powercable		17/25/34	60	Connection to servo controller
3-phases	L1	black	black '1'	3-phases
	L2	red	black '2'	
	L3	white	black '3'	
Protective earth		green/yellow		Protective earth
Shield		Protective earth		

QTL series

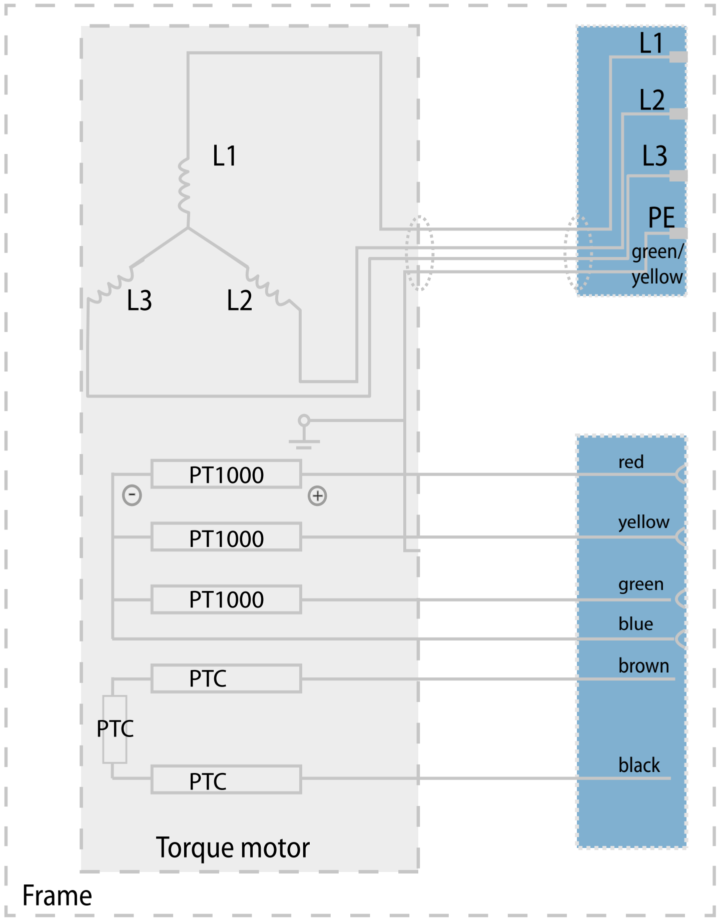


Figure 16: Wiring scheme for QTL series

Table 11: Power cables designation QTL series

Phase	Cable designation
L1	U/L1/C/L+
L2	V/L2
L3	W/L3/D/L-
PE	GN/YE

Table 12: Sensor cable wire identification QTL series

Component	Colour
PTC	Brown
PTC	Black
PT1000 (1) +	Red
Not used	Orange
PT1000 (2) +	Green
PT1000 (3) +	**Yellow**
PT1000 common -	**Blue**
Not used	**Violet**

3.6 Temperature sensors

Tecnotion can supply three types of temperature sensors with its torque motors:

- PTC-sensors
- KTY-sensors
- PT1000

The PTC-sensor can be used as a cut-off sensor when the maximum temperature is exceeded. The KTY-sensor can be used for monitoring purposes as well.

! Tecnotion QTR 65 and QTR 78 torque motors do not use any temperature sensors.

! Tecnotion QTR 105, QTR 133 and QTR 160 stators are equipped with two temperature sensors, one PTC-1k-type and one KTY83-122 type.

! Tecnotion QTL 210, QTL 230, QTL 290 and QTL 310 stators are equipped with 3 x PTC 1kΩ in series and 3 x PT1000 in parallel.

In cases where long peak currents are demanded, the thermal response time of the stator is too long to ensure a proper overheating protection by the sensors. The temperature sensors can ensure a proper protection up to an I_{rms} of 45% of the ultimate current of the motor. This corresponds with a temperature increase of 4.5°C/s. These long peak current conditions can occur for example during an accidental run or by taking a new axis in control. In this case I^2t protection is essential to prevent the stator from overheating. In almost all controllers an I^2t protection can be set in the software.

3.6.1 PTC characteristic

The PTC-1k type is a sensor which has a very sudden resistance rise near the critical temperature of the stator of 110°C. The PTC-1k type is almost a digital indicator: temperature below vs. above critical temperature. Therefore it is very useful for signaling over temperature without requiring sensitive electronics.

It is not possible to obtain a direct temperature signal from this sensor. At room temperature the PTC has an electrical resistance <100 Ω. When the temperature rises to the critical temperature the resistance will increase rather uniformly up to 1000 Ω. Above this temperature the resistance increases exponentially. 1000 Ω is the switching resistance. The amplifier should immediately stop the power supply when this resistance is exceeded. In this way overheating and motor damage can be prevented.

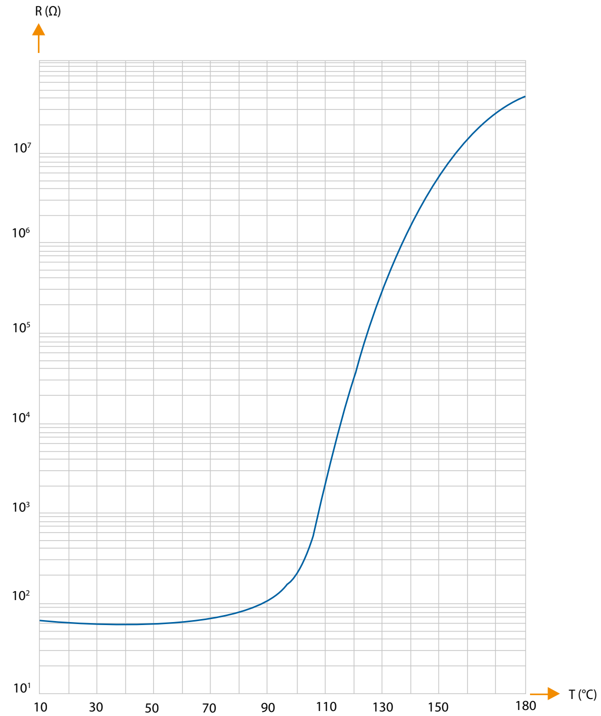


Figure 17: Temperature dependence of the PTC-1k sensor

3.6.2 KTY characteristic

The KTY83-122 sensor has a rather stable and slow temperature coefficient as shown in Figure 18. The sensor can supply a temperature reading in the whole range. Therefore it is useful to monitor the coil temperature during tests and to decide whether the thermal margins are enough to guarantee error-free running of the machine under certain conditions.

Disadvantage of the sensor is that it requires sensitive and accurate electronics to obtain a reliable reading. Please configure the sensor according to the wiring scheme in Figure 19 to attain a correct read out.

Table 13: KTY83-122 characteristic values

T (°C)	20	25	30	40	50	60	70	80	90	100	110	120	130
R_{NOM} (Ω)	972	1010	1049	1130	1214	1301	1392	1487	1585	1687	1792	1900	2012

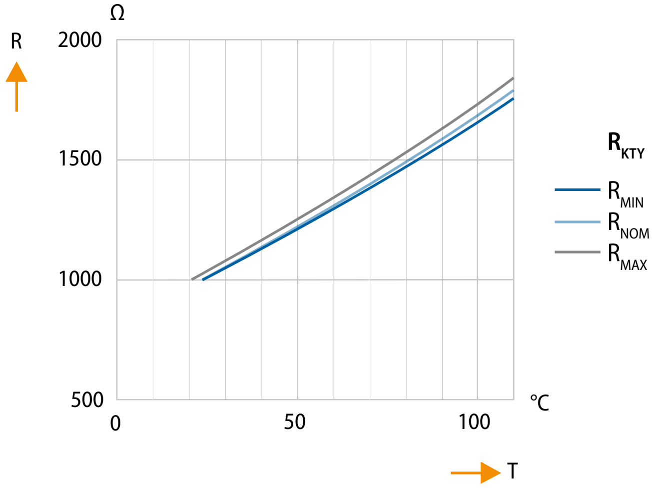


Figure 18: Temperature dependence of the KTY83-122 sensor

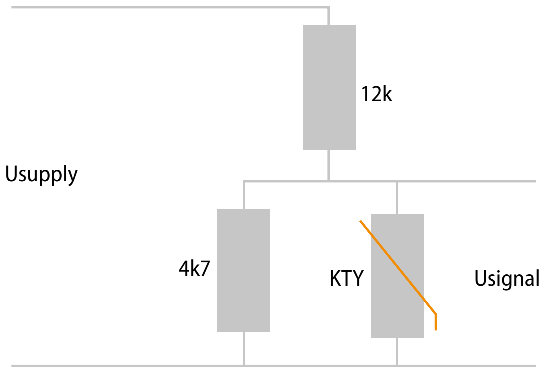


Figure 19: Wiring scheme for KTY83-122 sensor

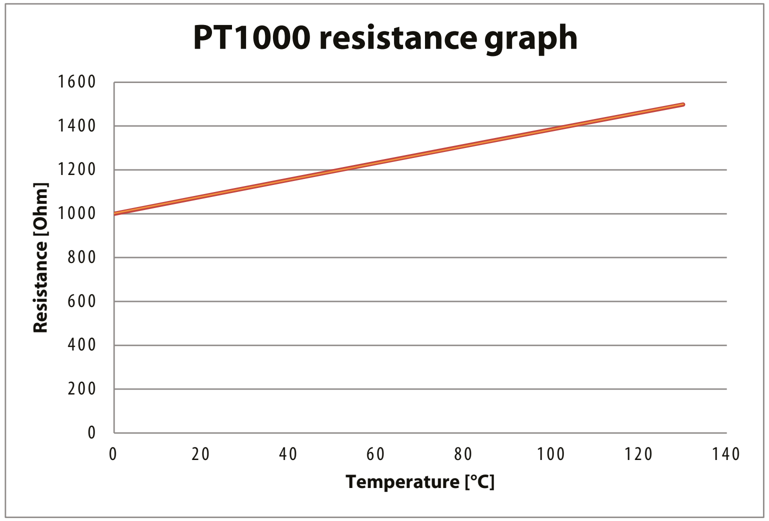


Figure 20: PT 1000 sensor characteristics

3.7 Accessories

3.7.1 Digital Hall module

Tecnotion QTR motors can be equipped with a digital Hall module for 'wake and-shake' functionality. (digital Hall module is not available for QTL series). Before the motor is switched on this digital Hall module can determine the position and direction of rotation of the rotor. For drawings of the digital Hall module see appendix B.

The QTR digital Hall modules can only be used as a wake-and-shake replacement. This means that the module only functions when the torque stator is not powered.

3.7.2 Configuration

A filter needs to be placed on the output following scheme in Figure 15. Values for R and C may deviate as long as R*C (time constant) equals 47 ms.

When considering EMC it is best to use connectors with a metal (conducting) housing. The cable shield has to be connected to the connector housing.

Connecting the Hall module to the connector has to be done with ESD protection.

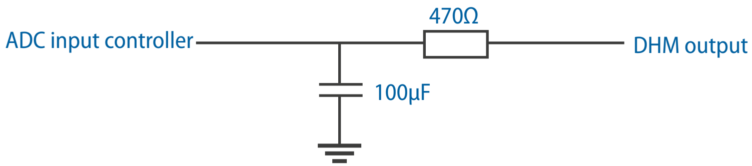


Figure 21: Output filter

Tecnotion digital Hall modules are shipped with the screws used to install them. A Philips ph0 screwdriver is used to mount the module on the QTR stator. The digital Hall module requires a QTR stator with prepared mounting holes for the digital Hall module.

When the sensor is mounted it is not possible to insert or extract the rotor from the sensor side.

Table 14: General specifications

Type	Value
Input voltage	+5 ... 15 Vdc
Output signal	Source type TTL, max 2.5mA, 5±0.5Vdc (3 signals) AquadB, max 2.5mA, 5±0.5Vdc (2 signals). (Not applicable for QTR0xx)
Cable	Shielded 0.5m length
Cable diameter	4.7
EMC	Conform EN61000-6-2 (Immunity)
RoHS	Conform
Reach	Conform

Table 15: Electrical interface

Color	Function
White	0V
Brown	+5 ... 15V
Grey	Hall A1
Green	Hall A2
Red	Hall B
Yellow	Hall C

QTR digital Hall timing and alignment

The timing diagrams are applicable when the rotor moves clockwise	Legend for TTL diagrams	Legend for AquadB diagrams (not applicable for QTR 65 /78)

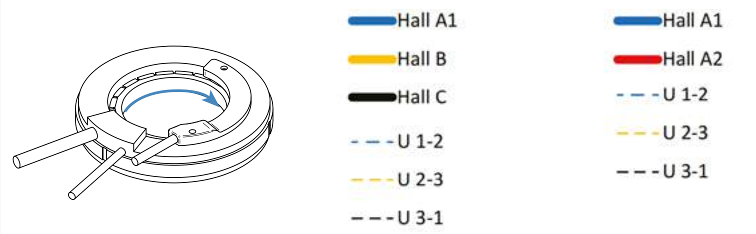


Figure 22: Legend for the timing diagrams

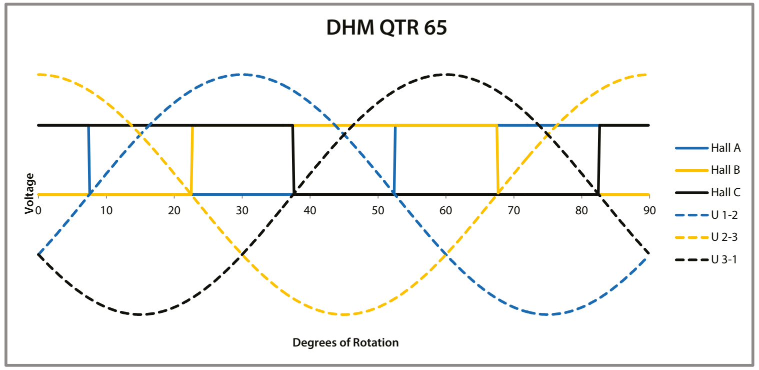


Figure 23: Timing diagram of QTR 65 series

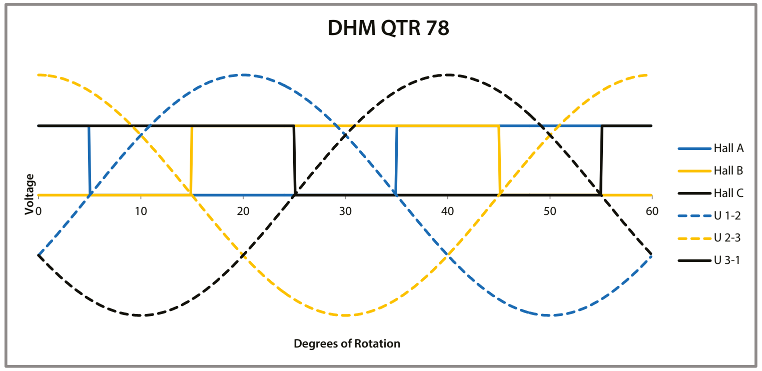


Figure 24: Timing diagram of QTR 78 series

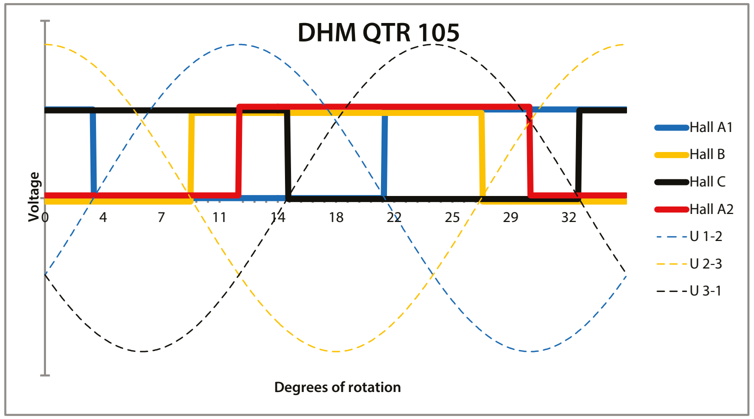


Figure 25: Timing diagram of QTR 105 series

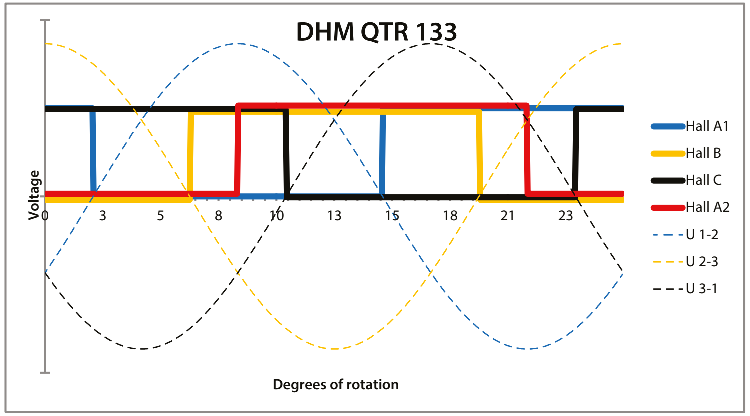


Figure 26: Timing diagram of QTR 133 series

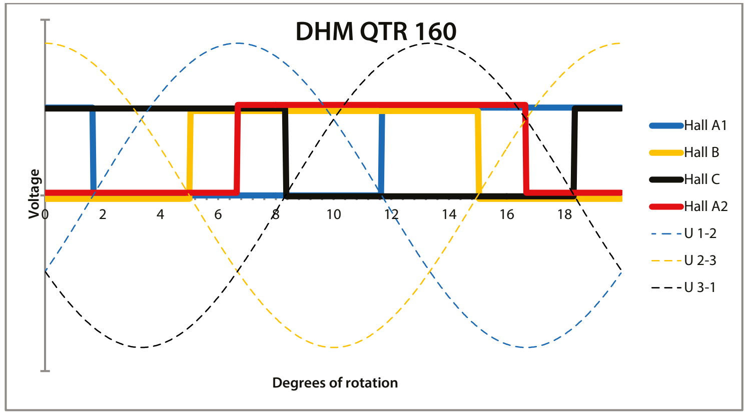


Figure 27: Timing diagram of QTR 160 series

Fore more information on mounting the digital Hall module on the QTR series, please check the build in dimension drawings in Appendix B from page 58.

4. INSTALLATION

Please follow the installation order in this manual. A different order may cause dangerous situations and damage due to uncontrolled magnetic attracion forces.

4.1 Safety

The rotor with the installed magnets show large attraction forces on all ferromagnetic objects such as iron. These forces cannot be controlled by hand. They may cause serious jamming danger. Do not bring any soft magnetic objects (iron) nearer than 25 cm of the magnetic side of the rotor. Do not remove the fixation brackets before the stator and rotor are installed (applies only for QTL motor kits).

Put the magnetic field neutralizing protection cover on the rotor again when dismounting them. This does not apply to QTR 65, QTR 78 motors and all QTL motors (are supplied without protection rings).

The stator and rotor will attract each other during installation. These forces cannot be controlled by hand. Provide sufficient radial and axial centering and guidance to prevent collision during installation.

Magnetic sensitive objects like banking cards, pacemakers or other magnetic information carriers may be damaged if they are brought within 1 m of the rotor.

A torque motor is powered by a servo amplifier. In case of a power disruption or fatal error this may automatically result in a free run out of the motor. Make mechanical precautions on the motor or your machine to prevent damage or personal injury in case of such an event.

When handling the motor it may be necessary to use a lifting aid. When lifting lugs are used, no radial forces may be applied when using the bolting holes of the motor.

Before starting any activity on the wiring, make sure that the mains are disconnected. Work carefully according the instructions belonging to the applied servo controller. Be sure your machine as a whole meets the requirements of all applicable electrical standards, such as the EN 60204 standard.

QTR 65 and QTR 78 have no strain relief, provide proper strain relief in construction.

Applies for QTL motors:
- Only remove the fixation brackets when indicated
- Remove the fixation brackets before operation
- Installation on ferro-magnetic material can cause acceleration of the rotor plus stator

Please contact us if you are planning on separating the stator and rotor. Always use non-ferromagnetic tooling when installing and/or working on or near the QTL motor.

Beware of the maximum temperature when curing the bonding material.
- For the stator, no curing above 100˚C. Risk of damaging the stator.
- For the rotor, no curing above 70˚C. Above 70˚C, risk of demagnatizing the magnets.

4.2 Introduction

QTR 65, QTR 78 motors and all QTL motors come pre-assembled. The rotor is shipped inside the stator in the motor's packaging. The rotor and stator of the QTL are separated by a 1 mm thick non-ferromagnetic shim. This package can be installed in the application directly or it can be disassembled before final installation.

Do not switch on the motor before proper installation and removal of the shim! And if applicable, the fixation brackets.

For QTR 105, QTR 133 and QTR 160 motors the rotor and stator are separated in the packaging. Installation requires the removal of the magnetic protection ring and insertion of the rotor in the stator. Because there is a considerable amount of attraction force between rotor and stator special tooling and/or non-ferromagnetic shims are required.

4.3 Before you start

The magnets on the rotor are attracted by the ferromagnetic material in the lamination stack of the stator. This attraction is present in two directions, axial and radial. During installation specific tooling or system design is required to enable controlled and safe insertion of the rotor into the stator. Perform the installation checks below before installing the components.

- Check axial attraction force and radial attraction force and size tooling accordingly.
- Always use non-ferromagnetic tooling for the rotor assembly.
- Specific tooling is required for mounting the connectors to the power and sensor cables. Please verify with your connector supplier what tooling is required.

> **!** Check the installation video on www.tecnotion.com

4.3.1 Cleaning

> **⚠** The stator and rotor can be damaged when cleaned with a non-prescribed cleaning agent. Use only isopropanol as a cleaning agent.

> **!** Oxidation on the lamination stack surface can be removed with Scotch-Brite.

For general, non-cleanroom applications, the rotor and stator do not need to be cleaned before installation or commissioning. For cleaning purposes Tecnotion prescribes isopropanol as cleaning agent for the stator and rotor.

4.3.2 Axial attraction

The rotor is attracted by the stator in axial direction. The forces are the largest when the rotor starts to enter the stator, see Figure 28. It is in equilibrium when the rotor is symmetrical between the lamination stacks. The axial forces for QTR 65, 78, 105, 133 and 160 are shown in Figure 29 through Figure 33.

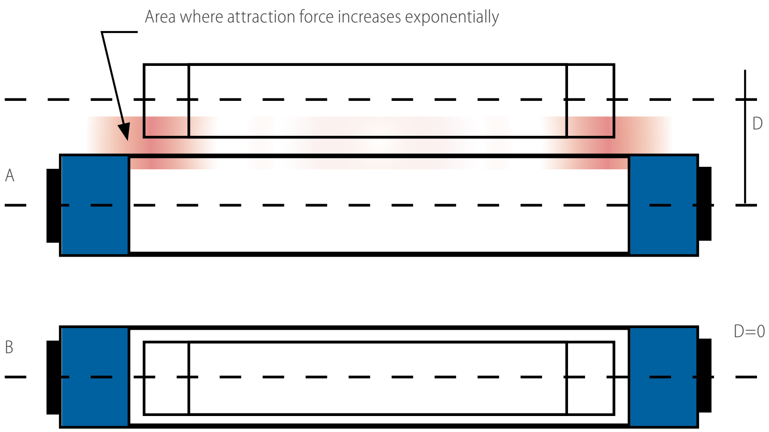


Figure 28: Behaviour of axial attraction forces
A- Attraction force increases exponentially
B - Attraction forces are in equilibrium

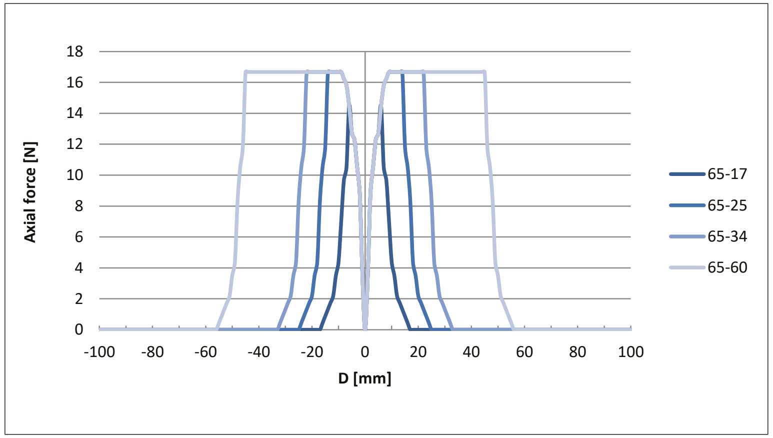


Figure 29: Axial forces QTR 65 series

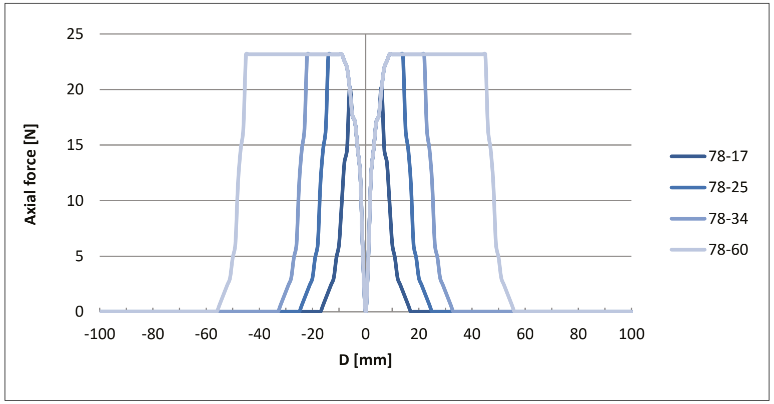


Figure 30: Axial forces QTR 78 series

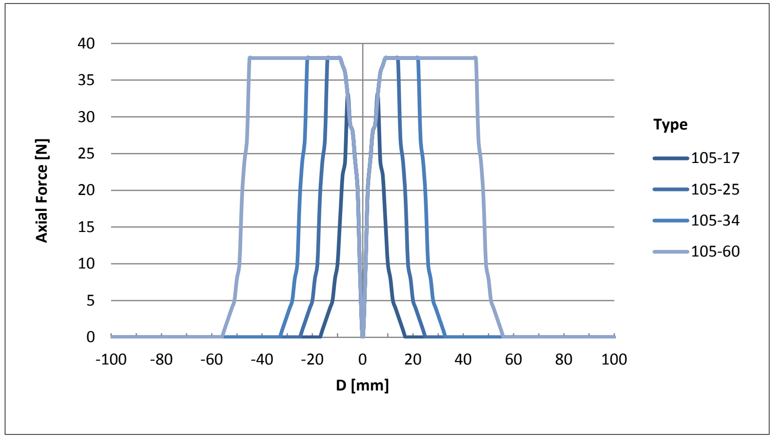


Figure 31: Axial forces QTR 105 series

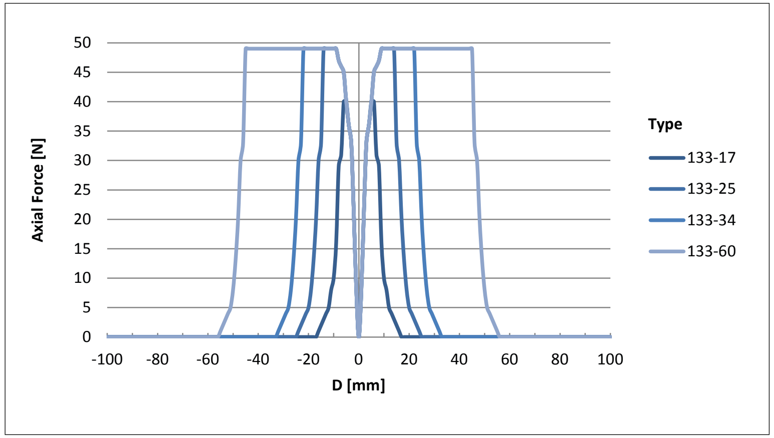


Figure 32: Axial forces QTR 133 series

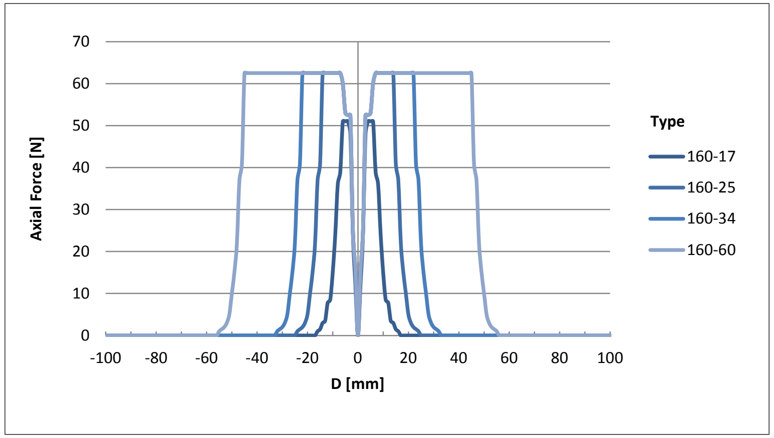


Figure 33: Axial forces QTR 160 series

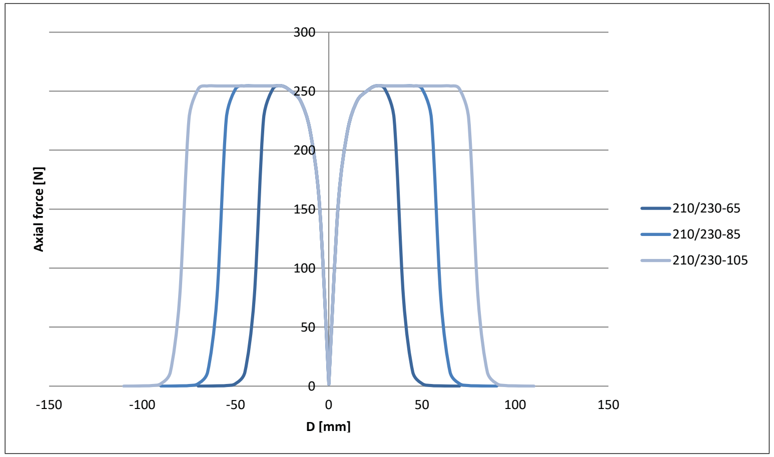


Figure 34: Axial forces QTL 210 and QTL 230 series

QTL motors axial attraction

The worst case axial attraction force is approximately 300 Newton for the QTL 210 and QTL 230 motors and 450 N for the QTL 290 and QTL 310 motors. See Figures 34 through 37 for the axial forces within the QTL series. This force is reached shortly after the rotor enters the region of attraction. The QTL motors are delivered as a kit where the rotor is already placed within the stator. It is advised keep the rotor situated inside the stator due to the high axial attraction forces without taking special care to mitigate these forces.

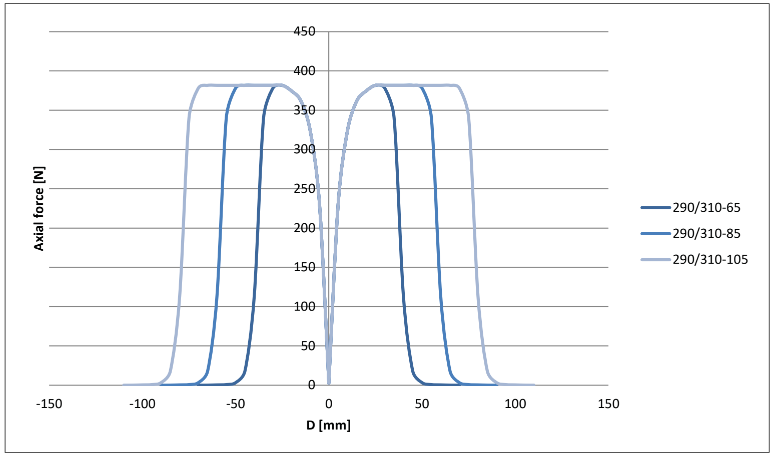


Figure 35: Axial forces QTL 290 and QTL 310 series

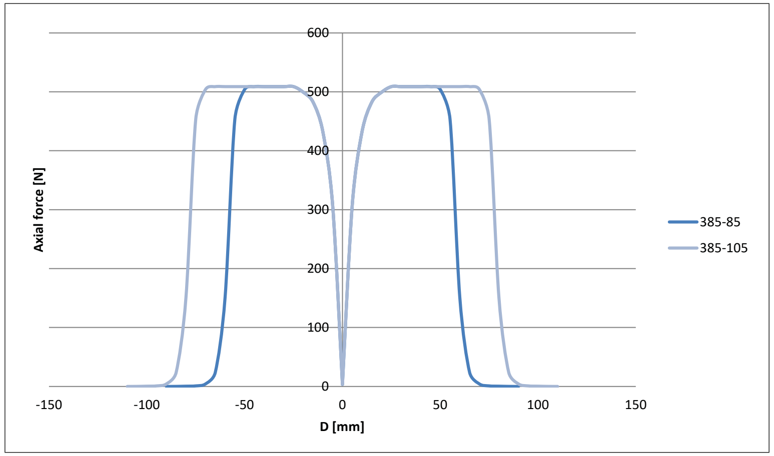


Figure 36: Axial forces QTL385 series

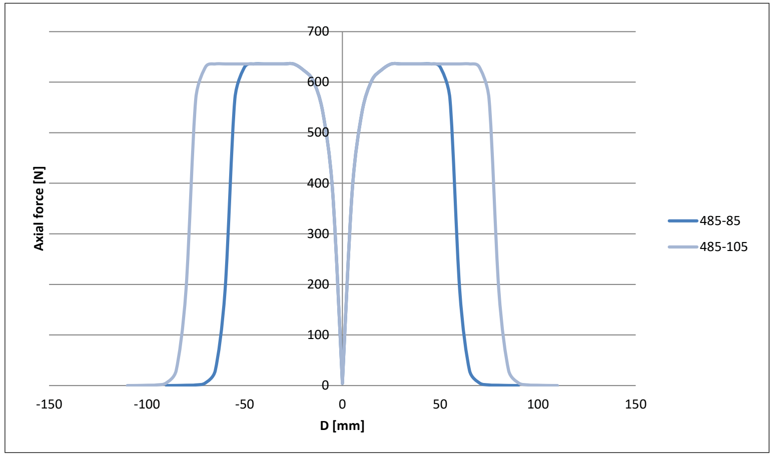
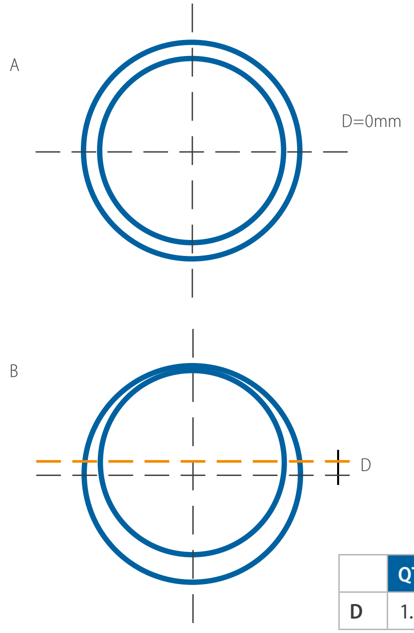


Figure 37: Axial forces QTL485 series

4.3.3 Radial attraction

The rotor is attracted by the stator in radial direction. The attraction force is zero when the rotor is exactly concentrically mounted with respect to the stator. It is at its maximum when the rotor and stator are in contact with each other. Please review Figure 37 to Figure 44 for the radial attraction forces when axially positioned like Figure 36.



	QTR	QTL 210/230	QTL 290/310
D	1.1 mm	1.4 mm	1.2 mm

Figure 38: Behaviour of radial attraction forces
A - Radial forces in equilibrium
B - Radial forces are maximal

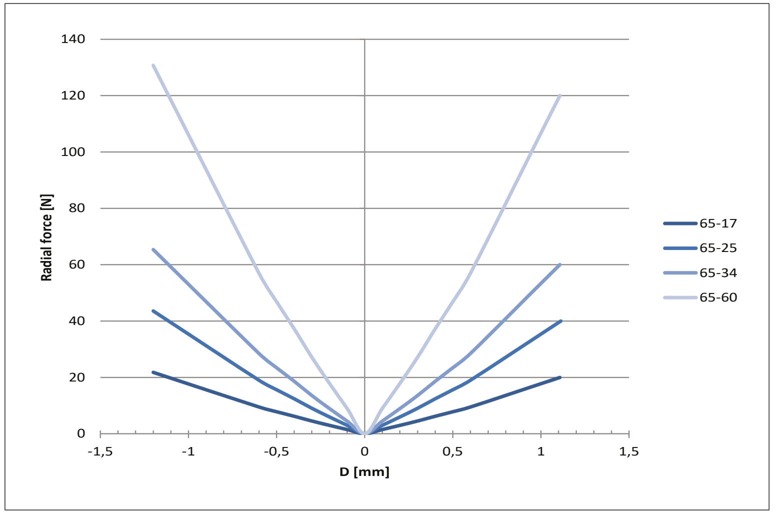


Figure 39: Radial forces QTR 65 series

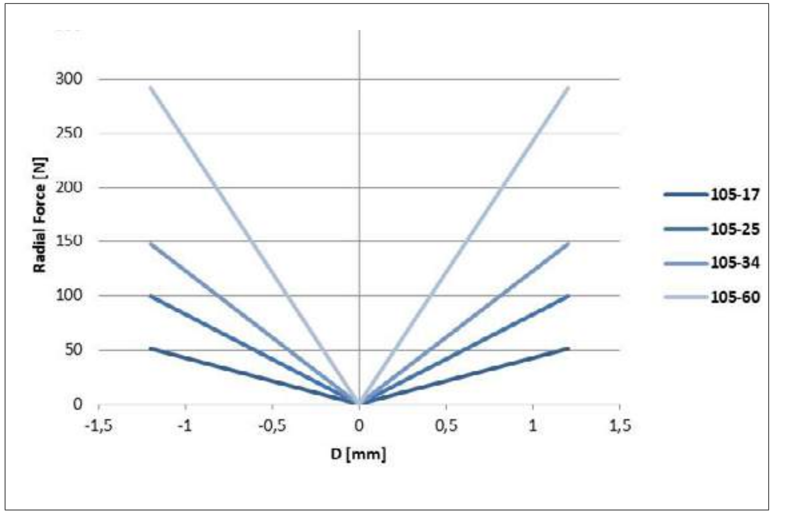


Figure 41: Radial forces QTR105 series

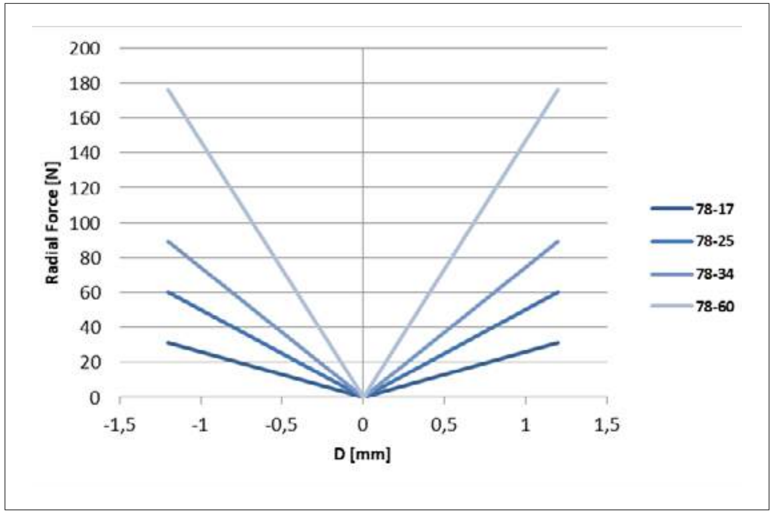


Figure 40: Radial forces QTR 78 series

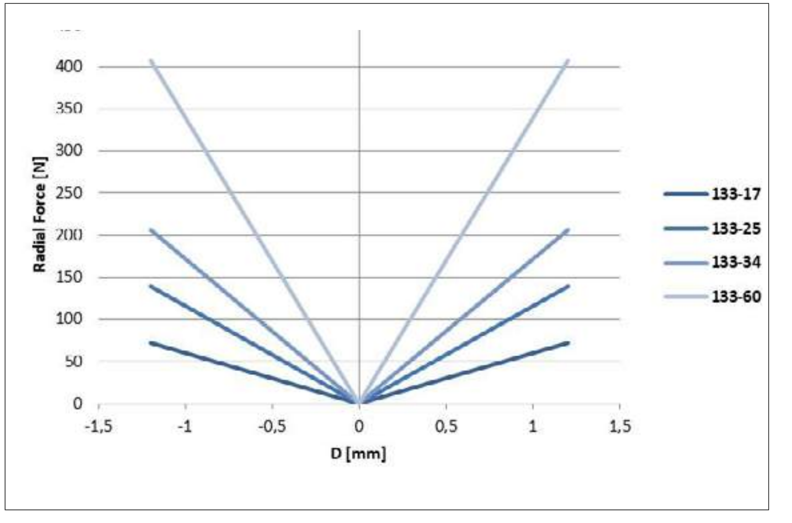


Figure 42: Radial forces QTR133 series

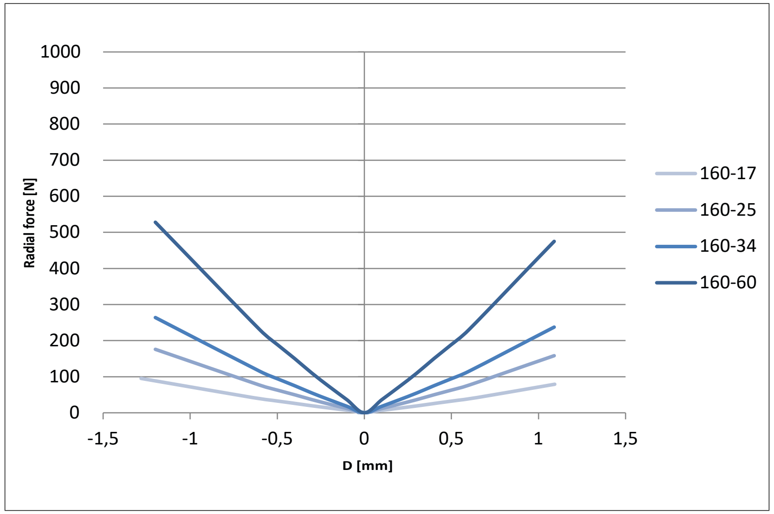


Figure 43: Radial forces QTR160 series

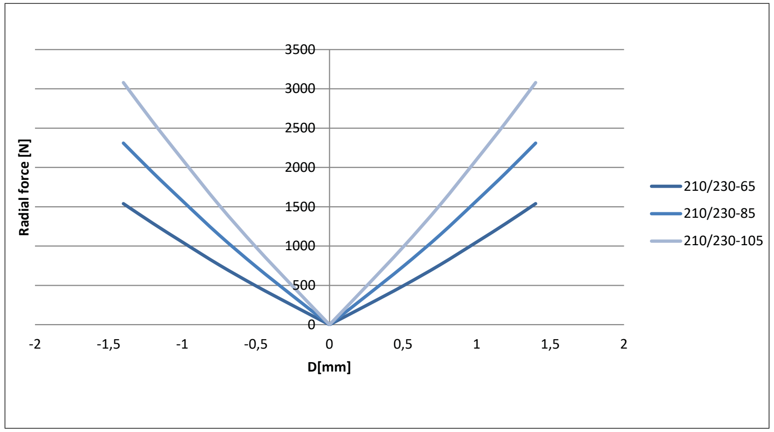


Figure 44: Radial forces QTL 210 and QTL 230 series

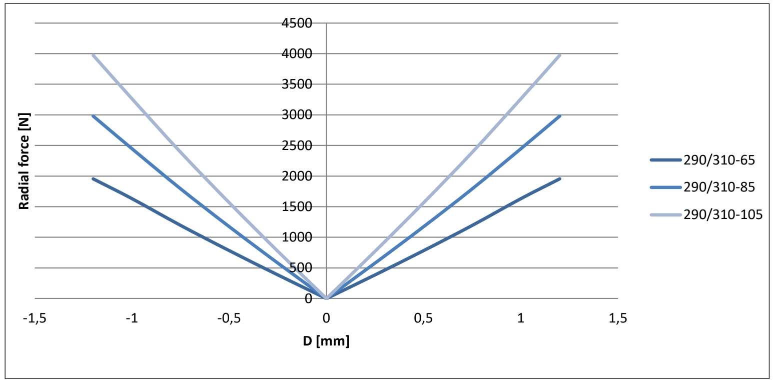


Figure 45: Radial forces QTL 290 and QTL 310 series

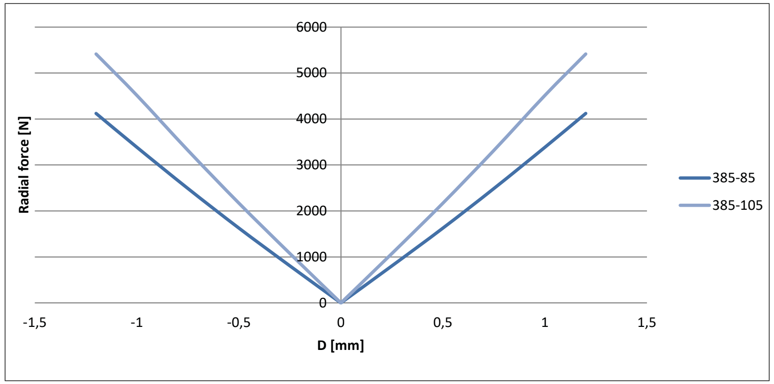


Figure 46: Radial forces QTL 385 series

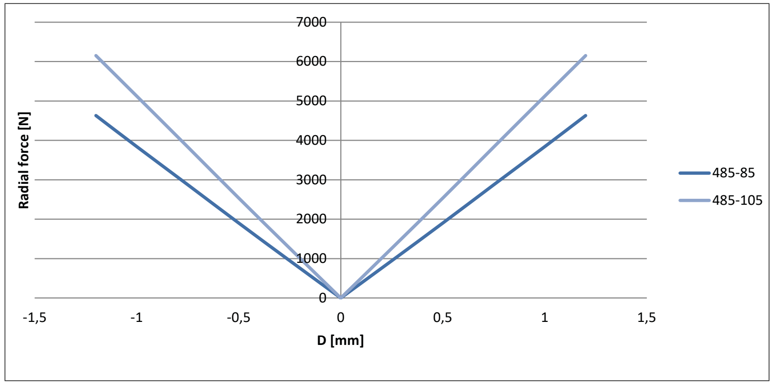


Figure 47: Radial forces QTL 485 series

4.4 Mounting options

Successfully mounting a torque motor requires the proper tooling. When mounted, the motor needs to be cooled and fixed in position properly. Cooling is needed especially in applications with high (continuous) workload.

Stators are centered and aligned via the lamination stack. Tecnotion rotors are centered and aligned on the inner diameter.

Rotors and stators can be clamped, bonded or bolted depending on the motor series, to the application following the procedures described in this chapter.

4.4.1 Stator clamping

The required clamping force is determined by the stator's outer diameter. The stators are calculated so that they keep the motor in place and optimize cooling. Some compressing effect can be expected for larger stack heights. This clamping force maximizes the contact area between motor and housing, see Figure 44 and Table 16.

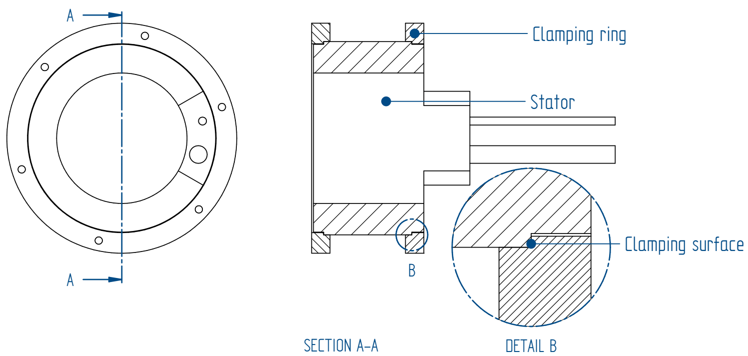


Figure 48: Example clamping ring

Clamping surface area and force are shown in Table 16.

Table 16: Stator clamping force requirement

Motor	QTR 65	QTR 78	QTR 105	QTR 133	QTR 160
Clamping OD	65	78	105	133	160
Clamping ID	62	75	102	130	157
Clamping surface (mm^2)	250	301	407	517	623
Clamping force (N)	7000	7000	14000	14000	21000

These clamping forces are a recommendation when the motor is used to its ultimate torque. At low loads, the clamping force can be reduced. It is however not recommended to install the motor with less than the required clamping force. The clamping force ensures good contact of the lamination stack and housing.

4.4.2 Stator bonding

⚠ Adhesives and activators can damage the stator and rotor. Only use adhesives that do not react with the motor materials. See appendix D (material properties).

When using a digital Hall module it's better to bond a stator to the housing.

Please consider that the adhesive used will have an effect on heat dissipation. Any adhesive will add an extra temperature resistance. This will influence cooling during operation, especially continuous performance is affected.

When using an adhesive to connect a Tecnotion stator to a housing, keep in mind the following variables:

- Heat dissipation of the stator.
- Thermal conductivity of bonding material.
- Thickness of the bonding material.
- Shear strength of the bonding material.
- Centering of the rotor in the stator.
- No reactivity with polyutherane casting.

Ideally a bonding material with a minimal thickness and high thermal conductivity is used. Table 17 below shows the influence of typical bonding material thickness and thermal conductivity on the performance of the Tecnotion QTR motor.

Table 17: Adhesive conductivity

Motor	QTR 65	QTR 78	QTR 105	QTR 133	QTR 160
Adhesive thickness (mm)	0.2				
Low resistance adhesive (Tc % @ 0,6 W/(m*K))	95%	90%	85%	80%	80%
High resistance (Tc % @ 0,1 W/(m*K))	75%	70%	70%	70%	70%

4.4.3 Rotor clamping QTR series

⚠ Do not clamp the rotor radially on its inner diameter or on the rotor magnets

If the rotor is to be clamped, the side surfaces of the rotor can be used. An example of a clamped rotor can be seen in Figure 45. The rotor is only designed to withstand axial clamping forces, not radial clamping forces.

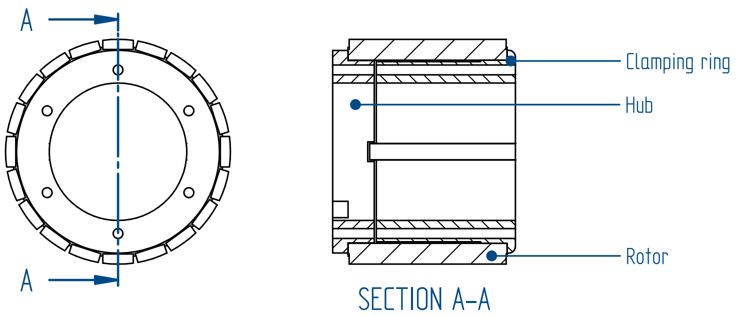


Figure 49: Example clamping ring

The sides of the rotor are described by the maximum clamping diameter and inner diameter of the steel rotor. Table 18 below describes the size and surface per motor diameter.

Table 18: Rotor clamping requirement

Motor	QTR 65	QTR 78	QTR 105	QTR 133	QTR 160
Rotor ID (mm)	17	29	56	84	111
Rotor OD (mm)	23	35	62	89	117
Surface area (mm^2)	213	327	634	784	1060
Rotor clamp force (N)	5000	5000	10000	10000	20000

4.4.4 Rotor bonding QTR series

When bonding the rotor using an adhesive, this is best done using the inside surface of the rotor. The bonding surface for a Tecnotion QTR rotor is defined by the height and inner diameter of the rotor. Find the height and diameter in following Table 19.

Table 19: Rotor bonding specifications

Motor		QTR 65	QTR 78	QTR 105	QTR 133	QTR 160
Rotor ID (mm)		17	35	62	84	111
Stack height (mm)	Rotor height (mm)	Surface area (mm^2)				
17	8,6	459.3	783.5	1513.0	2269.5	2999.0
25	16,6	886.6	1512.4	2920.4	4380.6	5788.7
34	24,6	1313.8	2241.2	4327.9	6491.8	8578.4
60	48,6	2595.6	4427.8	8550.2	12825.2	16947.6
		Minimum shear force @ Tu (N/mm^2)				
17	8,6	0.164	0.115	0.068	0.059	0.056
25	16,6	0.169	0.119	0.075	0.065	0.061
34	24,6	0.198	0.139	0.087	0.076	0.072
60	48,6	0.271	0.19	0.119	0.103	0.097

4.4.5 Mounting QTL series

Stator

The stationary part of the assembly can be fastened to the stator by use of the bolting holes in the case of the water cooled motors or clamping and/or bonding in case of the non-water cooled motors.The QTL-230 and QTL-310 stators have 12 bolting holes on each side of stator which are M5. The tightening torque of the bolts is 6 Nm. The bolt holes are a maximum of 10 mm deep, a minimum depth of 7 mm is advised. The QTL-385 has 12 M6 bolting holes on each side which are 12 mm deep. The advised tightening torque is 10 Nm and the advised minimum depth is 9 mm. The QTL-485 has 12 M8 bolting holes on each side which are 15mm deep. The advised tightening torque is 24.5 Nm and the advised minimum depth is 12 mm.

Please note that stainless steel bolts are not strong enough with regards to the mentioned tightening torque. The tightening torque is determined according to bolts of steel 8.8.

Rotor

The moving part of the assembly can be fastened to the rotor by use of the bolting holes. In case of the QTL 210 and QTL 230 these holes are M4 and are situated every 22.5° around the rotor. The QTL 290 and QTL 310 have holes that are M4 and are situated every 18° around the rotor. The tightening torque of the bolts is 3 Nm. The bolt holes are a maximum of 11 mm deep, a minimum depth of 7 mm is advised. The QTL-385 has 12 M6 bolting holes which are 12 mm deep. The advised tightening torque is 10 Nm and the advised minimum depth is 9 mm. The QTL-485 has 12 M8 bolting holes which are 15mm deep. The advised tightening torque is 24.5 Nm and the advised minimum depth is 12 mm.

Please note that stainless steel bolts are not strong enough with regards to the mentioned tightening torque. The tightening torque is determined according to bolts of steel 8.8.

4.5 Installation of stator and rotor QTR series

Installation of stator and rotor is the process of bringing together the rotor and stator of a QTR motor. When bringing the rotor and stator together, the rotor magnets will start attracting the stator strongly. Installation should be done in compliance with the radial and axial attraction forces, see paragraphs "4.3.2 Axial attraction" & "4.3.3 Radial attraction"

All QTR 105, QTR 133 and QTR 160 motors require installation (or assembly) of the rotor and stator. These motors are shipped separately in one package/box, see Figure 36. The rotor is covered by a protection ring.

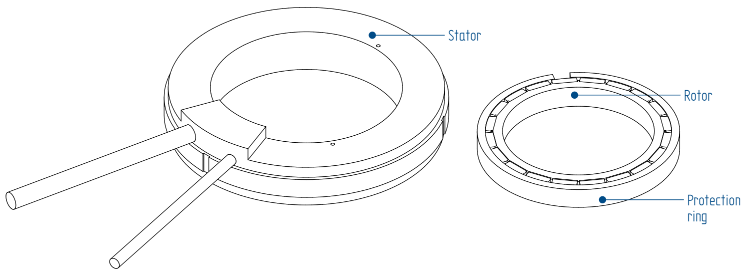


Figure 50: Rotor and stator packaging of QTR 1xx

QTR 65 and QTR 78 motors are shipped with the rotor inside the stator, the two being separated by a plastic shim, see Figure 47.

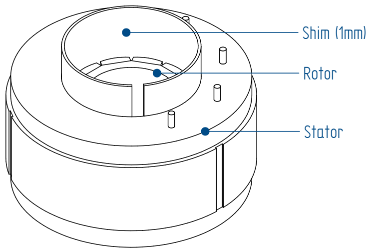


Figure 51: Rotor and stator packaging of QTR 65 and QTR 78

These motors can be built in the application as they are. If required, the rotors can be pushed out of the stator. The required force can be found in paragraph "4.3.2 Axial attraction". After disassembly the rotor and stator can be put together using the descriptions in this chapter.

4.5.1 Rotor in stator installation

Installing a rotor inside a stator can be done using a custom installation tool and optionally a 1 mm thick shim. It is advised to properly fix the stator in its housing and fix the rotor to a hub. The hub should connect to a custom alignment tool stiff enough to withstand the axial and radial alignment forces. Follow the steps below for installation:

1. Mount the stator.
2. Mount the rotor, by bonding or clamping it to a hub.
3. Install an installation tool to the rotor hub and/or line the stator inner suface with a shim.
4. Carefully insert the rotor in the stator.
5. Fixate the rotor to the axle/application.
6. Remove any shim or tooling used during installation.

4.5.2 Stator over rotor installation

Installing a stator over a rotor can be done using a centering cone or an 1 mm thick shim. Follow the steps below for installation:

1. Mount the rotor.
2. Mount the centering cone or the shim
3. Carefully pull the stator over the rotor.
4. Fixate the stator to the application.
5. Remove any cone or shim used during installation.

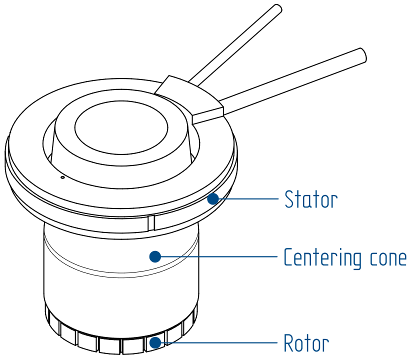


Figure 52: Cone

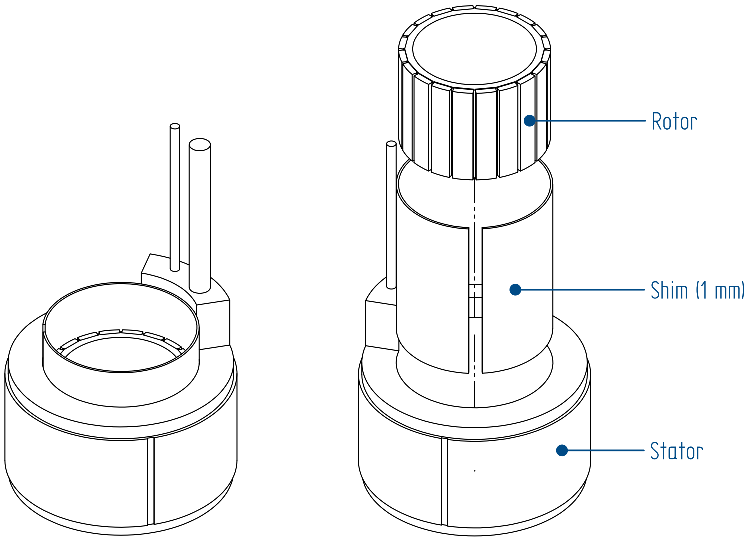


Figure 53: Shim

4.5.3 Installation of the QTL 210 & 290 motor assembly

The non-water cooled QTL motors are very similar to the QTR series and the same methods of fixation, with the exception of axial clamping, can be applied. Please contact your local Tecnotion representative to explore the possibilities

4.5.4 Installation of the QTL 230 & 310 motor assembly

When handling the motor it may be necessary to use a lifting aid. When lifting lugs are used, no radial forces may be applied when using the bolting holes of the motor.

> **!** Keep a copy of the manual on hand when installing the motor assembly.

> **!** A bevel in the stator housing is advised to minimize the risk of damaging the O-ring.

A bevel on the axis is advised so it is easier to place it in the rotor. Use the inner surface of the rotor ring to center the axle but only on either the top or bottom section, not both.

Due to the magnetic attraction forces the stator and rotor may not be perfectly circular. This does not have an impact on performance, but some force may need to be applied when fitting the axle in the rotor and the stator in the housing.

In the following summaries there are two methods described to install the motor assembly. These methods are intended as a guideline. Other installation methods are possible and could be better suited for a particular application. Our website contains animations that visualizes these steps. (see www.tecnotion.com/video)

Installation method 1

1. Place and fasten the bearing between the rotating and immovable part (axle/table) and housing.
2. Mount the O-rings on the stator. Be careful not to twist the O-rings, as this could lead to leaks. If needed a lubricant may be used, make sure that the lubricant does not react with any part of the motor.
3. Remove the two fixation brackets on the side of the assembly that enters the housing infrastructure first.
4. Insert the motor assembly (stator + rotor). The cable exit must be aligned with the cooling water inlet and outlet. Pay attention to the O-rings when inserting the assembly.
5. Fasten the rotor to the shaft. Tightening torque is stated in paragraph 4.4.5.
6. Remove the other two fixation brackets. The stator should be held in place by the magnetic attraction.

7. Attach the lower cover.
8. Tighten the stator on the lower cover. Tightening torque is stated in paragraph 4.4.5.
9. Check that the motor can make a full turn without interference. Changes in forces depending on the position of the motor are to be expected due to cogging torque.
10. Mount accessories (cooling water inlet and outlet, power cable plug, rotary encoder, etc.).

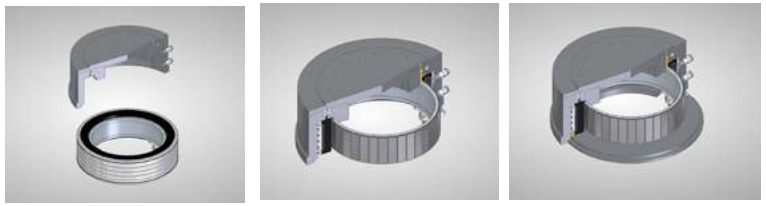


Figure 54: Installation of QTL 230 & 310 motor assembly

Installation method 2

1. Place and fasten the bearing between the rotating and immovable part (axle/table and housing).
2. Mount the O-rings on the stator. Be careful not to twist the O-rings, as this could lead to leaks. If needed a lubricant may be used, make sure that the lubricant does not react with any part of the motor.
3. Remove the two fixation brackets on the side of the assembly that enters the housing infrastructure first.
4. Fasten the rotor to the shaft. Tightening torque is stated in paragraph 4.4.5.
5. Attach the stator to the lower cover.
6. Remove the spacer foils.
7. Remove the other two fixation brackets. The stator should be held in place by the magnetic attraction.
8. Place and fasten the housing over the motor assembly (stator + rotor). The cable exit must be aligned with the cooling water inlet and outlet. Pay attention to the O-rings when inserting the assembly.
9. Check that the motor can make a full turn without interference. Changes in forces depending on the position of the motor are to be expected due to cogging torque.
10. Mount accessories (cooling water inlet and outlet, power cable plug, rotary encoder, etc.).

Check our installation videos at www.tecnotion.com/video.

4.5.5 Final check

Before starting any activity on the wiring, make sure that the mains are disconnected. Work carefully according the instructions belonging to the applied servo controller. Be sure your machine as a whole meets the requirements of all applicable electrical standards, such as the EN 60204 standard.

4.6 Electrical connections

4.6.1 General remarks

Before testing, make sure that the electrical and mechanical protection of the torque motor system is well configured.

4.6.2 Powerlines

The power cable can be confectioned by the user to fit the servo drive.

4.6.3 Protective earth

Make sure that there is an effective protective earth. Make sure that there is no voltage at the wire terminals before connecting.

4.6.4 Polarization test

Testing the polarization is very important, a wrong polarization will result in an uncontrolled run out of the axis.

4.6.5 Temperature sensor cable wiring

See paragraph "3.5.1 Cable specifications & protective earth." for all specs.

4.6.6 EMC performance

The combination of a torque motor with a servo drive needs a proper shielded connection for optimal EMC performance. Therefore it is very important to connect the shielding of the shielded (EMC) motor cable corectly to the shielding point of the servo drive.

For optimal EMC performance place the metal (conducting) rotor bearings as close as possible near the rotor, to make high frequency electrical contact with the torque stator.

If the cable is not directly connected with the drive, proper connectors must be used to pass the EMC field well.

4.7 Deinstallation

Reposition the magnetic field neutralizing protection cover on the rotor again when dismounting them.

! If deinstallation is to be expected, save the magnetic protection ring and/or shims supplied with your Tecnotion QTR motor.

! It is very important to refastened the fixation brackets (supplied with your QTL motor) on the stator and rotor before dismounting them!

In general the deinstallation order follows the reverse installation sequence as described in the installation order. This can vary however for each application design. Reposition the magnetic field neutralizing cover, if applicable, as soon as the rotor is removed from the stator.

4.8 Additional components

4.8.1 Digital Hall module

See paragraph "3.7 Accessories" for information on the digital Hall module. See appendices B and C for specifications of the digital Hall module

4.9 Coupling torque motors

Two or more torque motors can be coupled to operate together. Then the torques generated can be added together. Coupled torque motors can in principle be operated by one amplifier, provided that the maximum driver power output, is not reached. The torque motors are connected in parallel and the currents of both motors add up. It is not possible to mount motors in series with voltages adding up, because their wiring is not suitable.

Two or more motors of the same type can always be coupled. For example QTR-A-105-17N with QTR-A-105-17N. Motors of different types can only be coupled if their motor torque constants are equal.

For more information contact our application engineers at telephone number: +31 546 898 475 or support@tecnotion.com.

5. OPERATION

When you are convinced that your application's torque motor system is installed in a proper way, both mechanically and electrically, you can put your motor system into operation.

5.1 Pre-commissioning

Before powering the system, please perform a final check on the items below:

1. Does the axis rotate free over the whole turn, without touching small mechanical parts like bolts or contaminations?
2. Does your system have an emergency stop?
3. Is the temperature cable properly connected?
4. Does the motor ruler combination have the right polarization?
5. Has the power cable been connected properly?
6. Operational conditions according to IEC 60721-3. For reference check paragraph 5.4.

5.2 Configuring

Some input and output signals need to be configured by following the steps below:

1. The following motor items should be configured as parameter settings of the servo amplifier:
   - Maximum continuous current.
   - Maximum peak current.
   - Value of the coil self-inductance.
   - Maximum speed (rpm).
   - Presence/absence of an electromechanical motor brake.
   - Number of pole pairs.
   - Switching resistance of PTC.

2. The following settings for the ruler system should be configured as parameters of the servo amplifier:
   - Type of interface of the ruler system.
   - Resolution or period of the encoder.

3. These are the I/O parameters to be configured:
   - Settings of the available digital inputs and outputs. For instance, pay attention to the type of end switches if present.
   - Settings of the available analog inputs and outputs.

4. Finally the controlling parameters must be configured.
   - Current control settings. These settings depend on both motor and amplifier.
   - Speed control settings.
   - Position control settings.

5.3 Testing

After the amplifier is powered up some input and output signals need to be examined by following the steps below:

1. Check the end switches, if present, by rotating the axis manually to the switch position. Simultaneously check whether the signal is detected by the amplifier.
2. Check the presence of the PTC signal.

5.4 Operational conditions

Be aware that the motor and housing can become hot during operation. It is advised to use the temperature sensors to monitor the temperature during operation to prevent overheating.

The operational conditions of QTL motors are largely the same as the QTR motors. However, the cables of the QTL motor have an increased resistance to oils, acids and alkalis according to EN 50363-10-2.

The mentioned ambient conditions are for the primary product package contained in a secondary cardboard package. The primary package is intended for storage in warehouse and efficient packing in a secondary or tertiary package. The primary packaging itself is not suited as a transportation package. See Table 20 for the operational conditions.

Most classifications were based on the provided explanation in the norm. Not all individual parameters and the influence of different severities have been tested.

Table 20: Operational conditions

Operational (IEC 60721-3-1)				
3K22	3B1	NA	3S5	3M11

6. TRANSPORT, STORAGE & DISMANTLING

This chapter describes the requirements for transportation, storage and dismantling of the torque motors. This information needs to be taken into account together with the additional information in the main manual.

6.1 General safety rules for transport, storage & dismantling

QTR series

- Only handle the rotor with the magnetic field neutralizing protection ring in place (QTR 65 & QTR 78 don't have a protection ring).
- Only transport rotors and magnets in their original packaging. This ensures the magnetic stray field is within safe limits and that no uncontrolled attraction of ferromagnetic materials can occur.
- Do not throw away the magnetic field protection ring (QTR series) or fixation brackets (QTL series) as these are needed when de-installing the motor, they can be reused.
- Magnetic sensitive objects like banking cards, pacemakers or other magnetic information carriers may be damaged if they are brought within 1 m of the magnets (plates or rotor).
- The storage area for motor components needs to be clearly delimited with a warning sign: 'Caution powerful magnets!'.
- Only store motors in their original packaging.

QTL series

The QTL package is delivered with the rotor inside the stator locked together with fixation brackets.

- Only transport and store the QTL in its original packaging together with the fixation brackets. This ensures the magnetic stray field is within safe limits and that no uncontrolled attraction of ferromagnetic materials can occur.
- Do not lift the stator by the cables .
- The QTL stator and rotor are heavy. A lifting aid is recommended when handling the QTL, no radial forces may be applied when using the bolting holes of the motor.
- Be cautious when handling the motor inside or outside of its packaging as it could tip over and cause serious injury.
- Magnetic sensitive objects like banking cards, pacemakers or other magnetic information carriers may be damaged if they are brought within 1 m of the magnets (plates or rotor).
- The storage area for motor components needs to be clearly delimited with a warning sign: 'Caution powerful magnets!'.
- Only store motors in their original packaging.

6.2 Transport & packaging

The rotor of the torque motor contains permanent magnets that produce a magnetic strayfield. For transport safety the following needs to be taken into account when transporting magnetized materials by air.

Airfreight

When magnetic material is transported by air, the IATA airfreight packaging instruction 953 applies. Above a certain threshold value the relevant authority needs to be informed prior to shipping, see Table 21.

Table 21: Magnetic strayfield threshold value

Threshold	Field strength	Action
1	<5.25mG @2.1m of package	No action required
2	>5.25mG @2.1m of package	Notify relevant authority and label products / packages
3	>5.25mG @4.6 m of package	Relevant authority needs to authorize the shipment. Special measures need to be taken, e.g. extra packaging material / higher shipment cost.

Magnetic materials can, when transported in close proximity to each other, amplify their individual magnetic stray field strength. A single rotor can therefore have a stray field well below the safe field strength threshold, multiple rotors could surpass this threshold. No action is required for any motor in the QTR or QTL product range when packed in their original packaging.

Other means of transportation

For all other means of transportation no additional measures need to be taken regarding magnetic stray field risks other than those regarding general health and safety.

Packaging

Tecnotion products have a primary package that sits directly around the product. Tecnotion primary product package is intended only as product packaging. It's main function is to:

- Pack the product and required documentation.
- Identify the product type and serial number.
- Inform about important safety advice if required.
- Inform about important transportation and storage advice.
- Safeguard product functionality during transportation and storage.

For transportation the product and primary package will be placed into a secondary package or even a tertiary package. (Usually a 800 × 1200 mm Euro-pallet). The type and size of this package depends on the size of the order to be shipped. Typically the remaining volume in the secondary and tertiary packages will be filled with Instapak.

6.3 Storage and transportation

To ensure the product quality Tecnotion advises the storage and transportation conditions according to IEC 60721-3-1 Storage and 60721-3-2 Transportation 2018 edition.

The primary package is intended for storage in a warehouse and efficient packing in a secondary or tertiary package. The primary packaging itself is not suited as a transportation package.

The mentioned ambient transportation conditions in Table 22 below are for the primary product package contained in a secondary cardboard package.

Most classifications were based on the provided explanation in the norm. Not all individual parameters and the influence of different severities have been tested.

Table 22: Storage and transport conditions

Storage (IEC 60721-3-1)				
1K21	1B1	1C3	1S12	1M11

Transport (IEC 60721-3-1)				
2K11	2B1	2C2	2S5	2M5

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direct drive in motion

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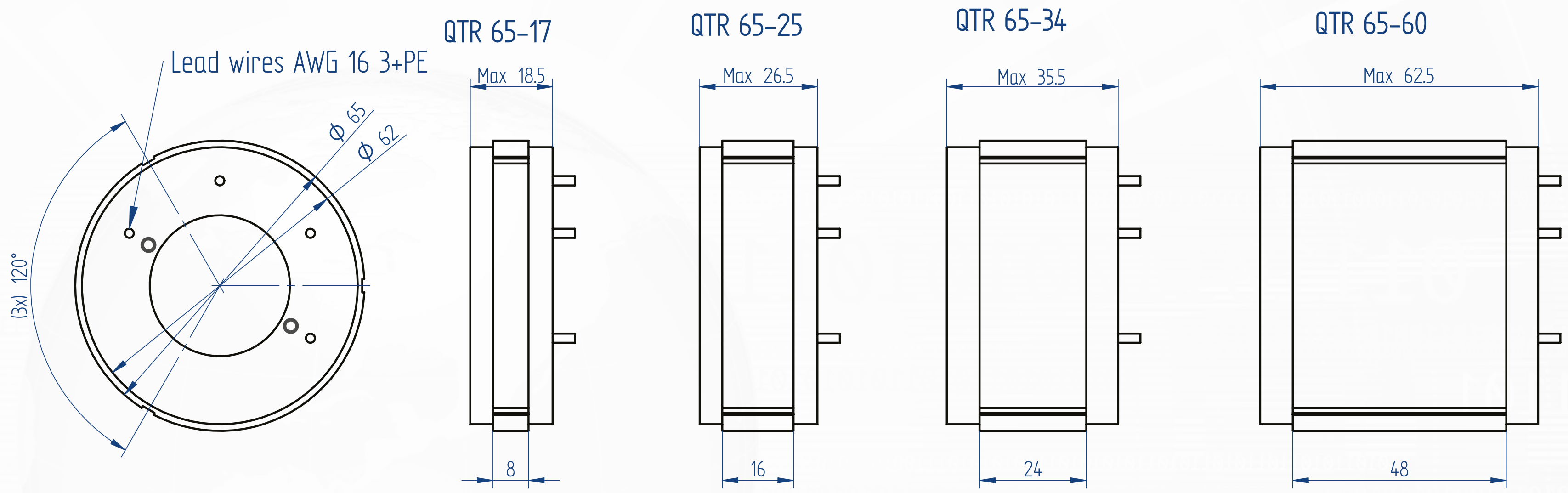
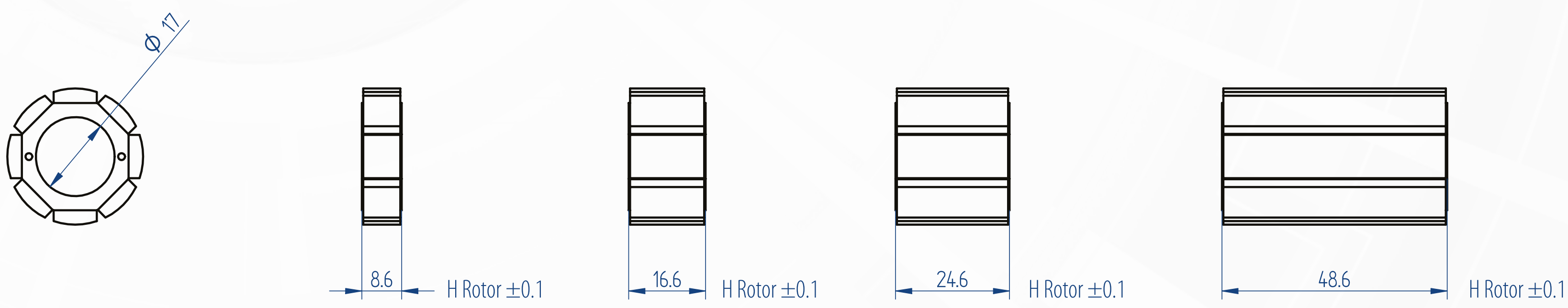
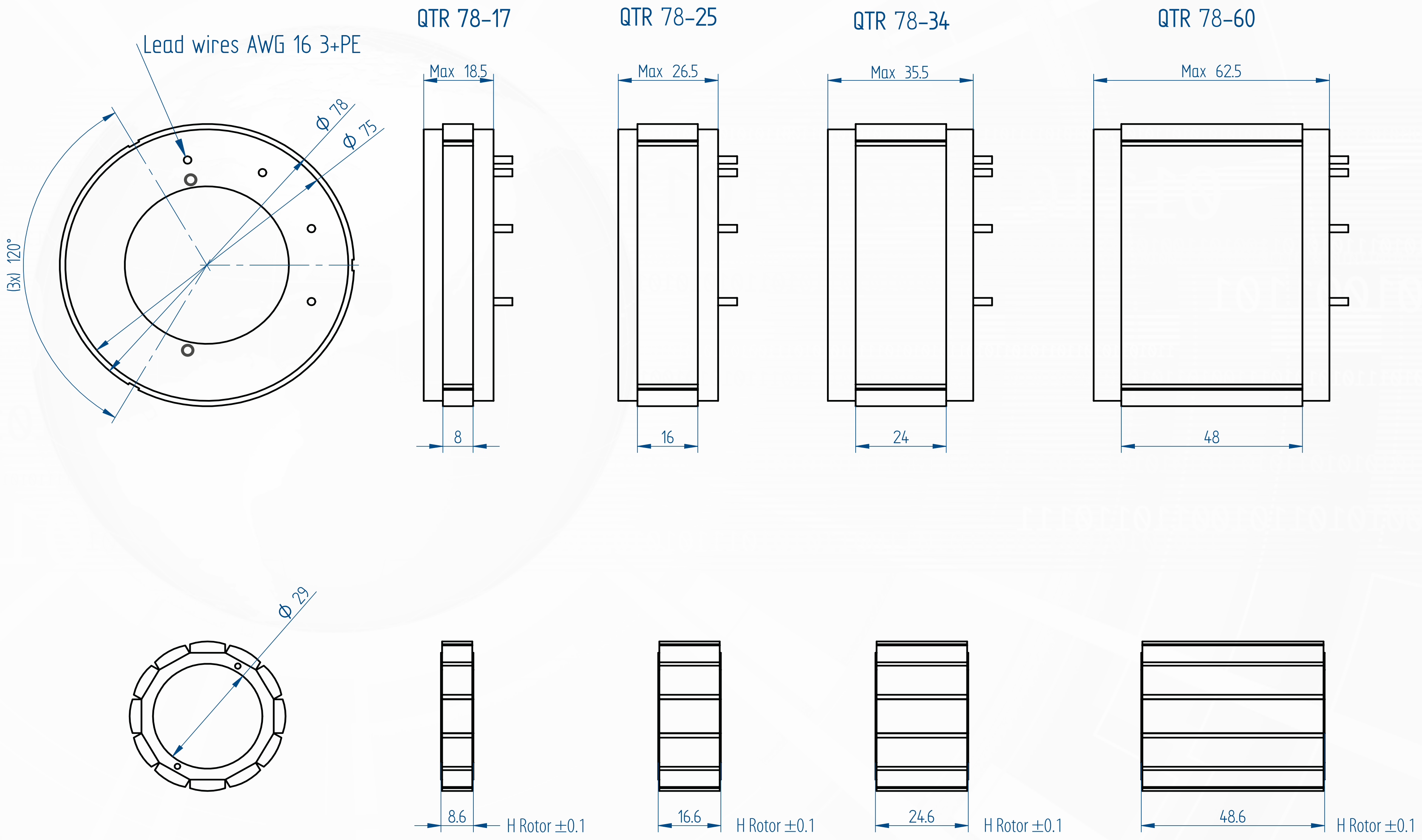


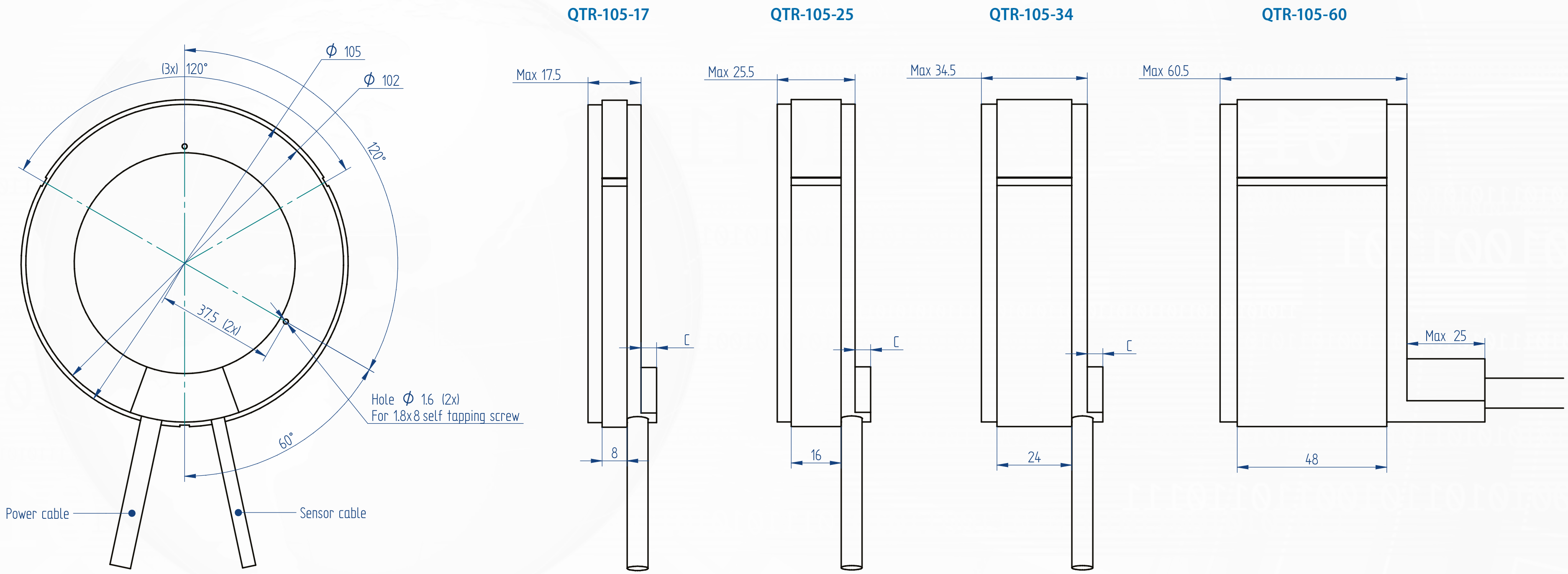


TECNOTION® direct drive in motion

APPENDIX A | Overview - QTR 78 - 17/25/34/60

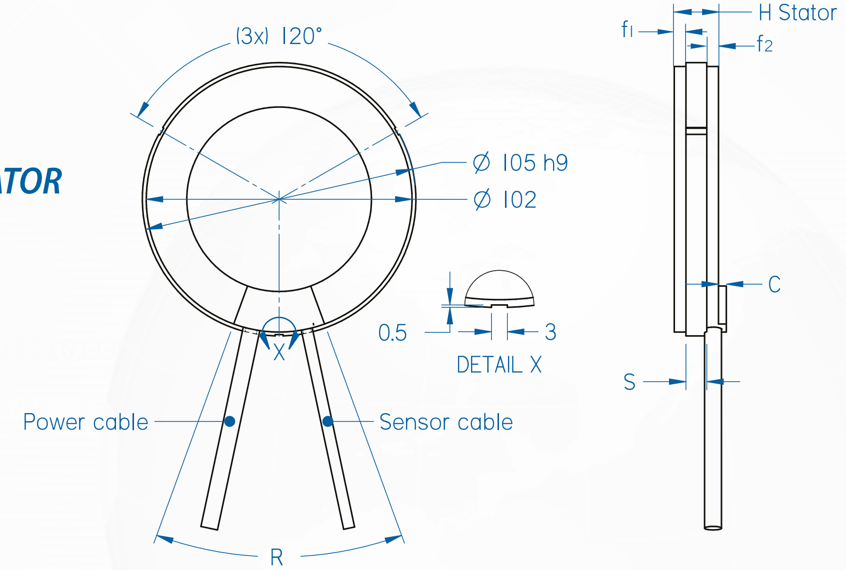


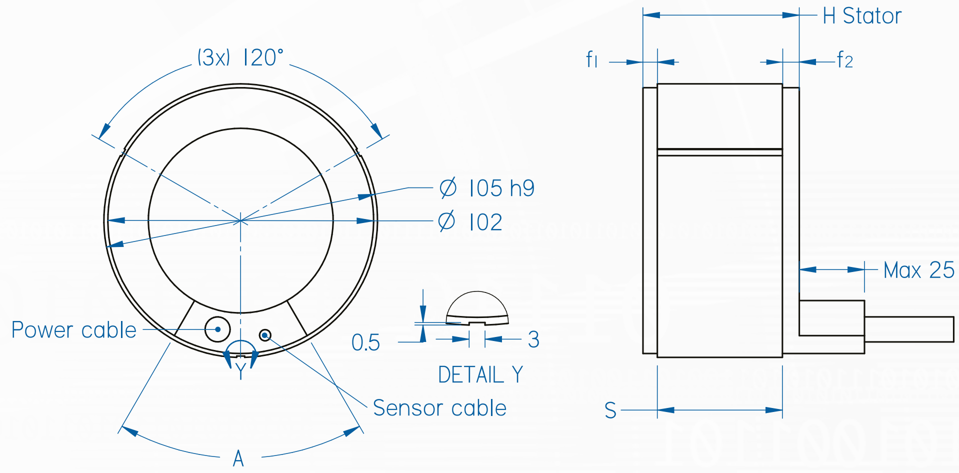
APPENDIX A | Overview - QTR 105 - 17/25/34/60



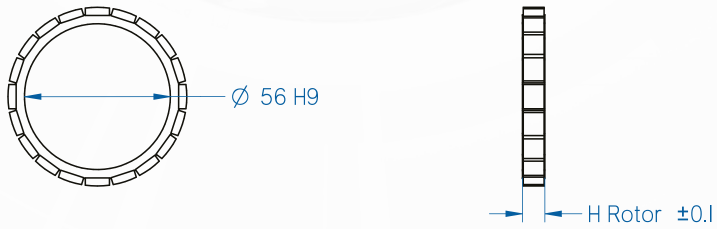
APPENDIX A | Dimensions - QTR 105 - 17/25/34/60

STATOR





ROTOR



winding	C
N	3.5
Y+Z	5.5

QTR 105	R	H stator	S	f1	f2	H rotor
17	40	17.5	8	4.5	4.5	8.6
25	40	25.5	16	4.5	4.5	16.6
34	40	34.5	24	5	5	24.6
60	60	60.5	48	5.5	6.5	48.6

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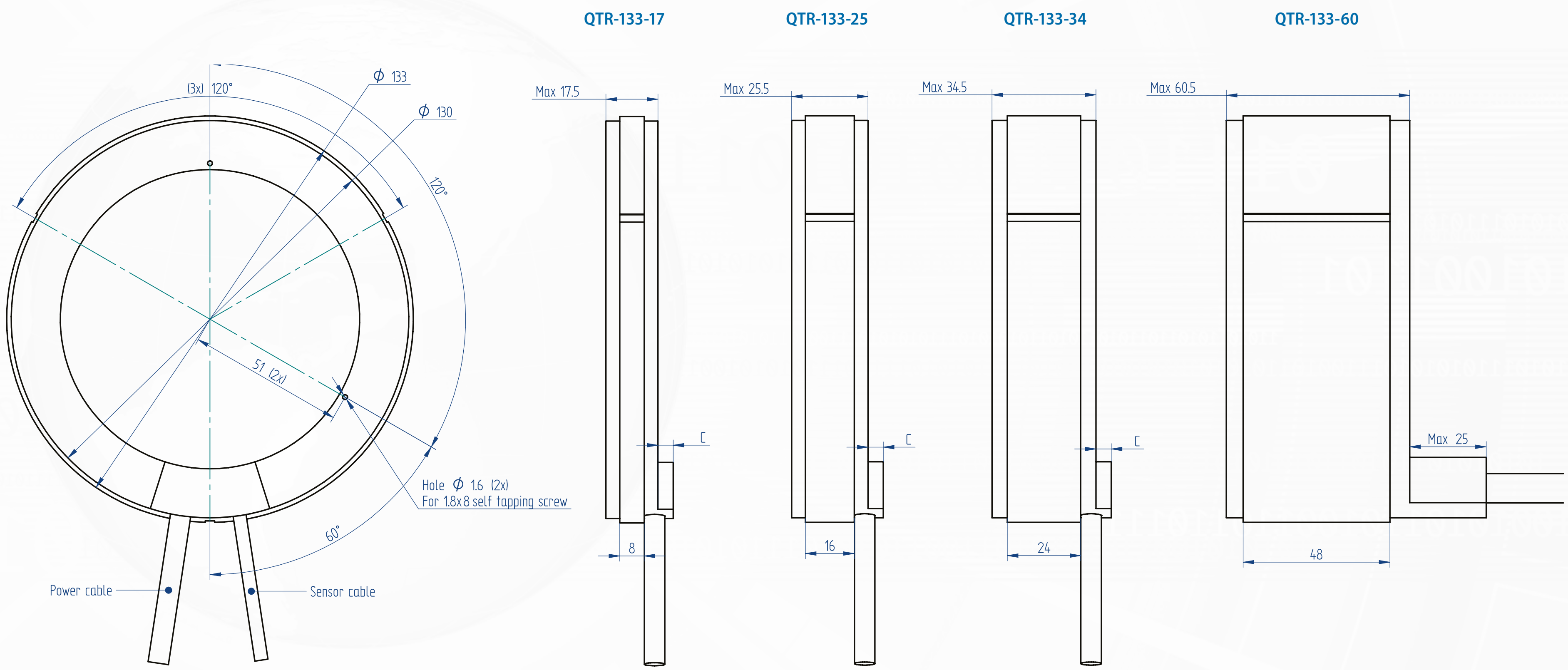
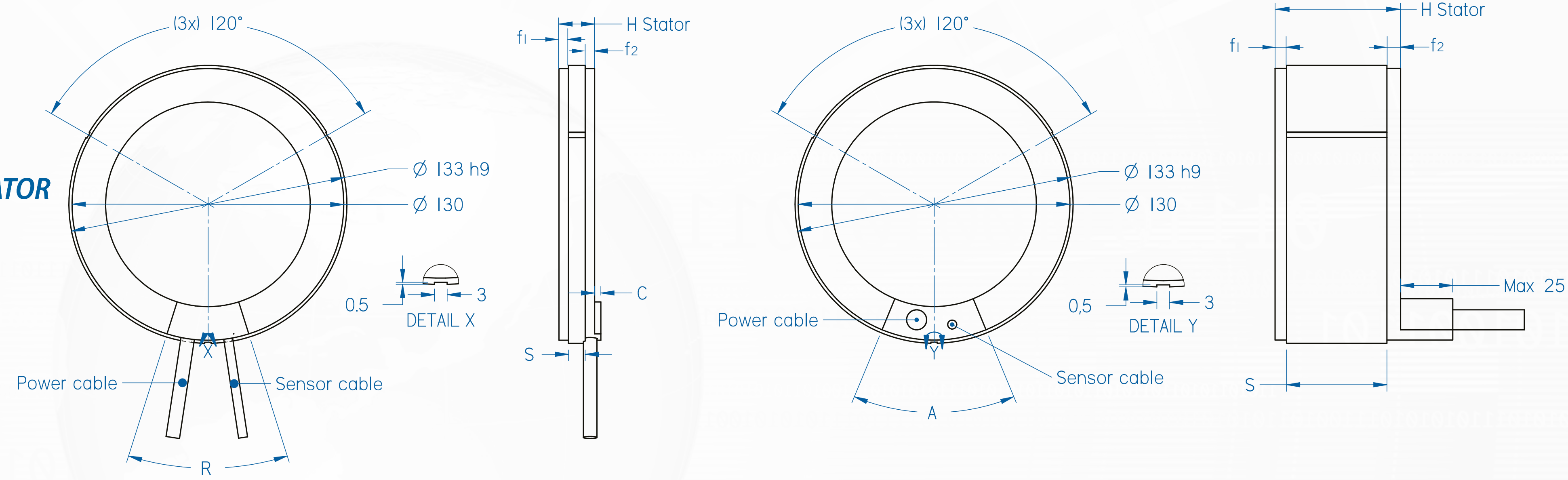
APPENDIX A | Overview - QTR 133 - 17/25/34/60



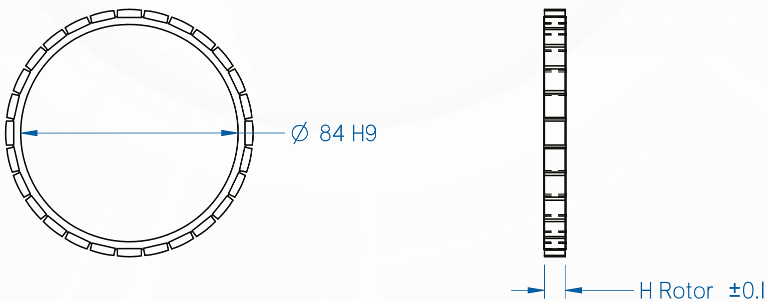
TECNOTION®
direct drive in motion

APPENDIX A | Dimensions - QTR 133 - 17/25/34/60

STATOR



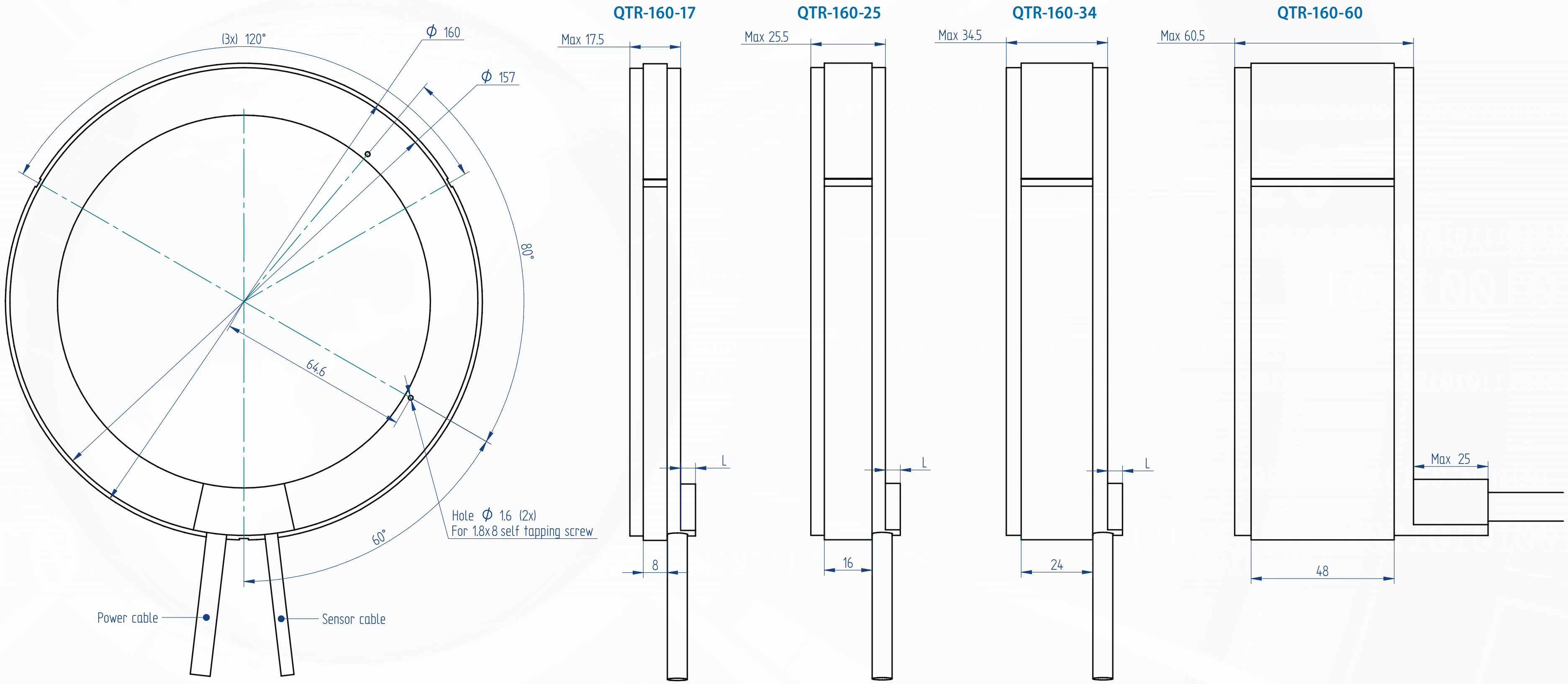
ROTOR



winding	C
N	3.5
Y+Z	5.5

QTR 133	R	H stator	S	f1	f2	H rotor
17	35	17.5	8	4.5	4.5	8.6
25	35	25.5	16	4.5	4.5	16.6
34	35	34.5	24	5	5	24.6
60	45	60.5	48	5.5	6.5	48.6

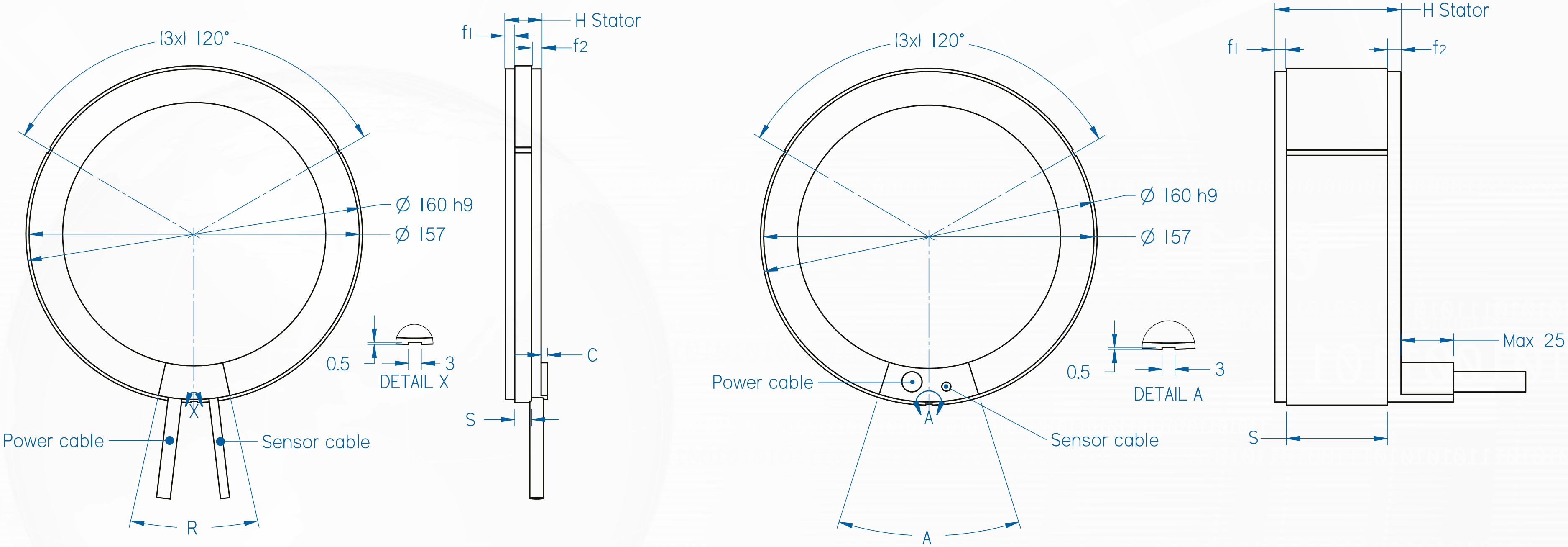
TECNOTION® direct drive in motion | APPENDIX A | Overview - QTR 160 - 17/25/34/60



TECNOTION® direct drive in motion

APPENDIX A | Dimensions - QTR 160 - 17/25/34/60

STATOR



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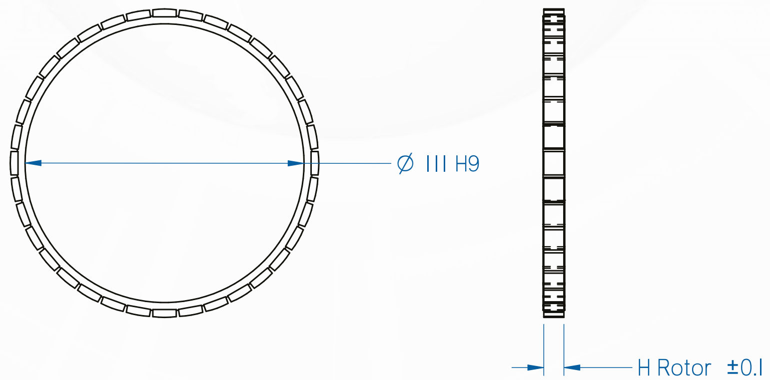


winding	C
N	3.5
Y+Z	5.5

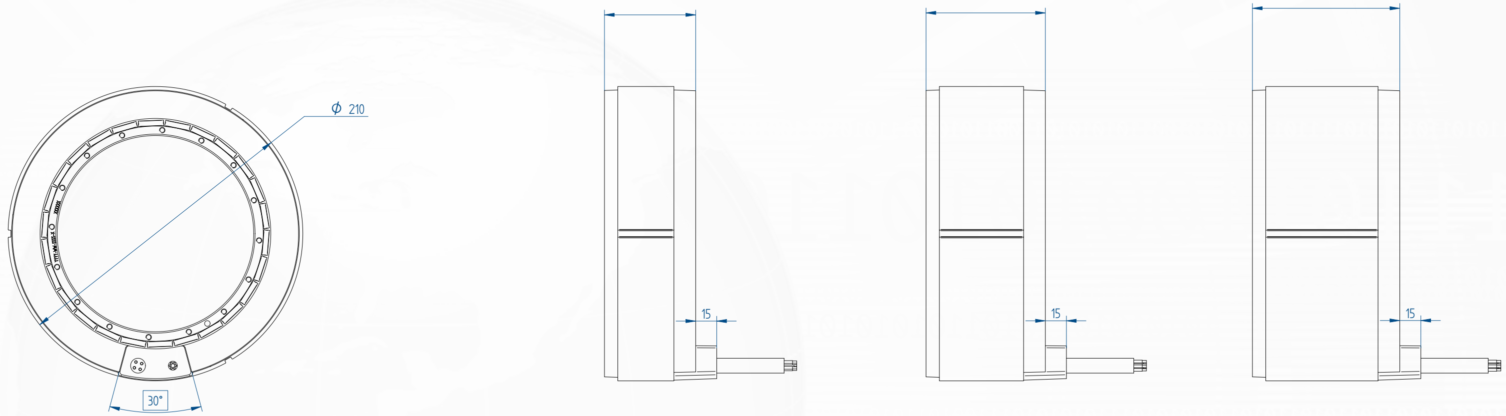
QTR 160	R	H stator	S	f1	f2	H rotor
17	25	17.5	8	4.5	4.5	8.6
25	25	25.5	16	4.5	4.5	16.6
34	25	34.5	24	5	5	24.6
60	35	60.5	48	5.5	6.5	48.6

APPENDIX A | Overview - QTL 210 - 65/85/105

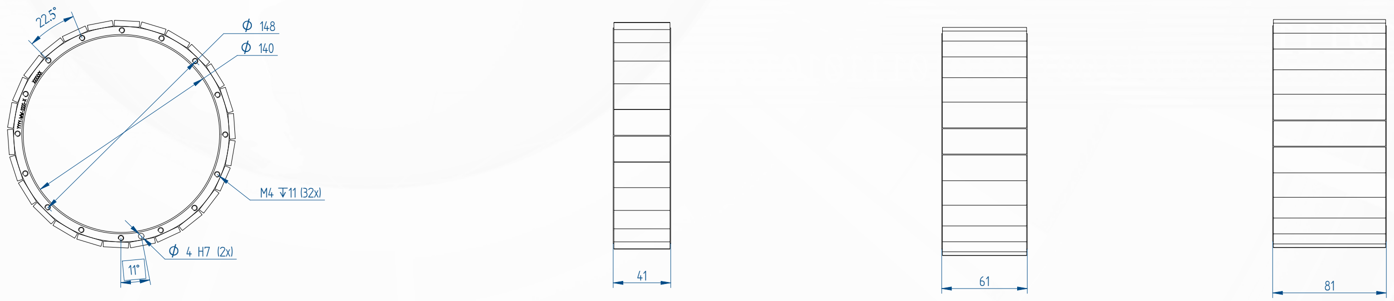
TECNOTION® direct drive in motion

QTL-A-210- 65 85 105

KIT



ROTOR

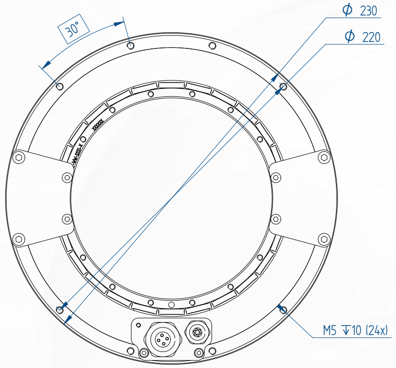


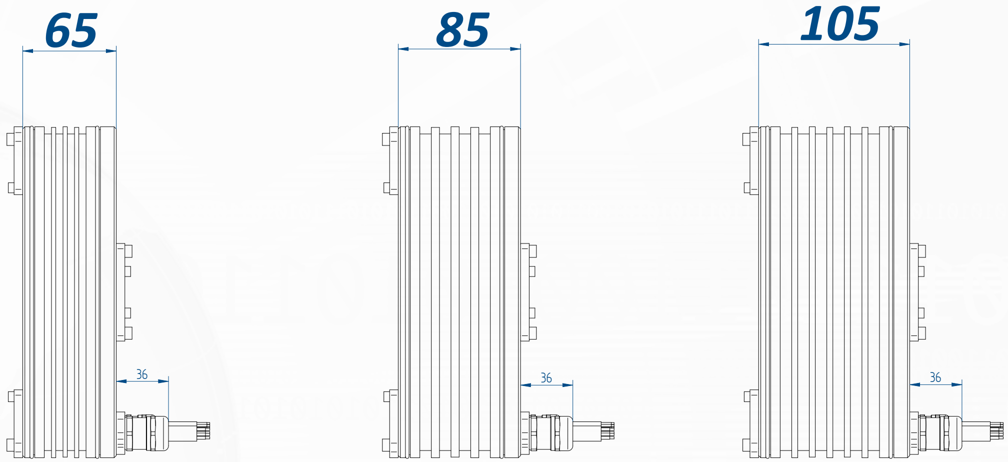
Stator OD	mm	210	h9
Rotor ID	mm	140	H8
H Rotor	mm	±0,2	

TECNOTION® direct drive in motion | APPENDIX A | Overview - QTL 230 - 65/85/105

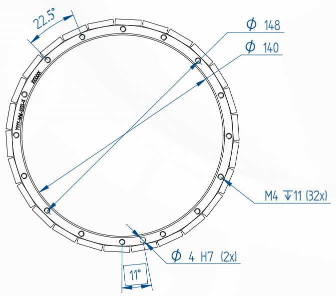
QTL-A-230-

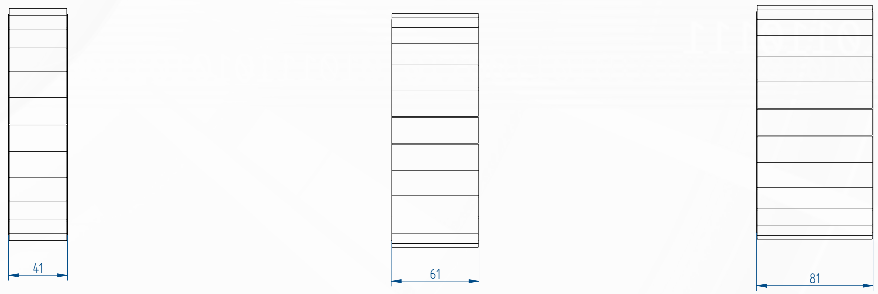
KIT





ROTOR

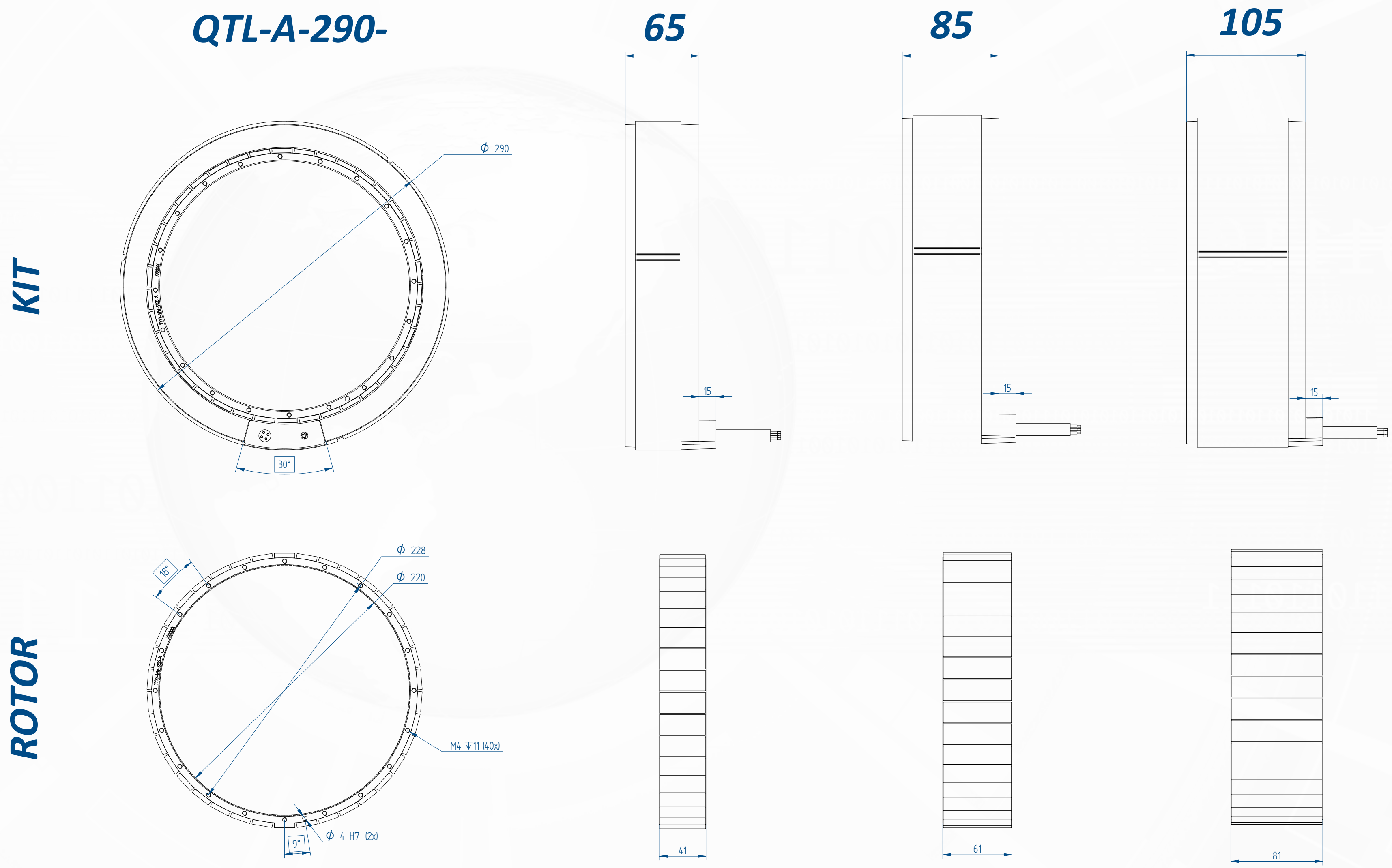




Stator OD	mm	230	f9
Rotor ID	mm	140	H8
H Rotor	mm	±0,2	

TECNOTION®
direct drive in motion

APPENDIX A | Overview - QTL 290 - 65/85/105



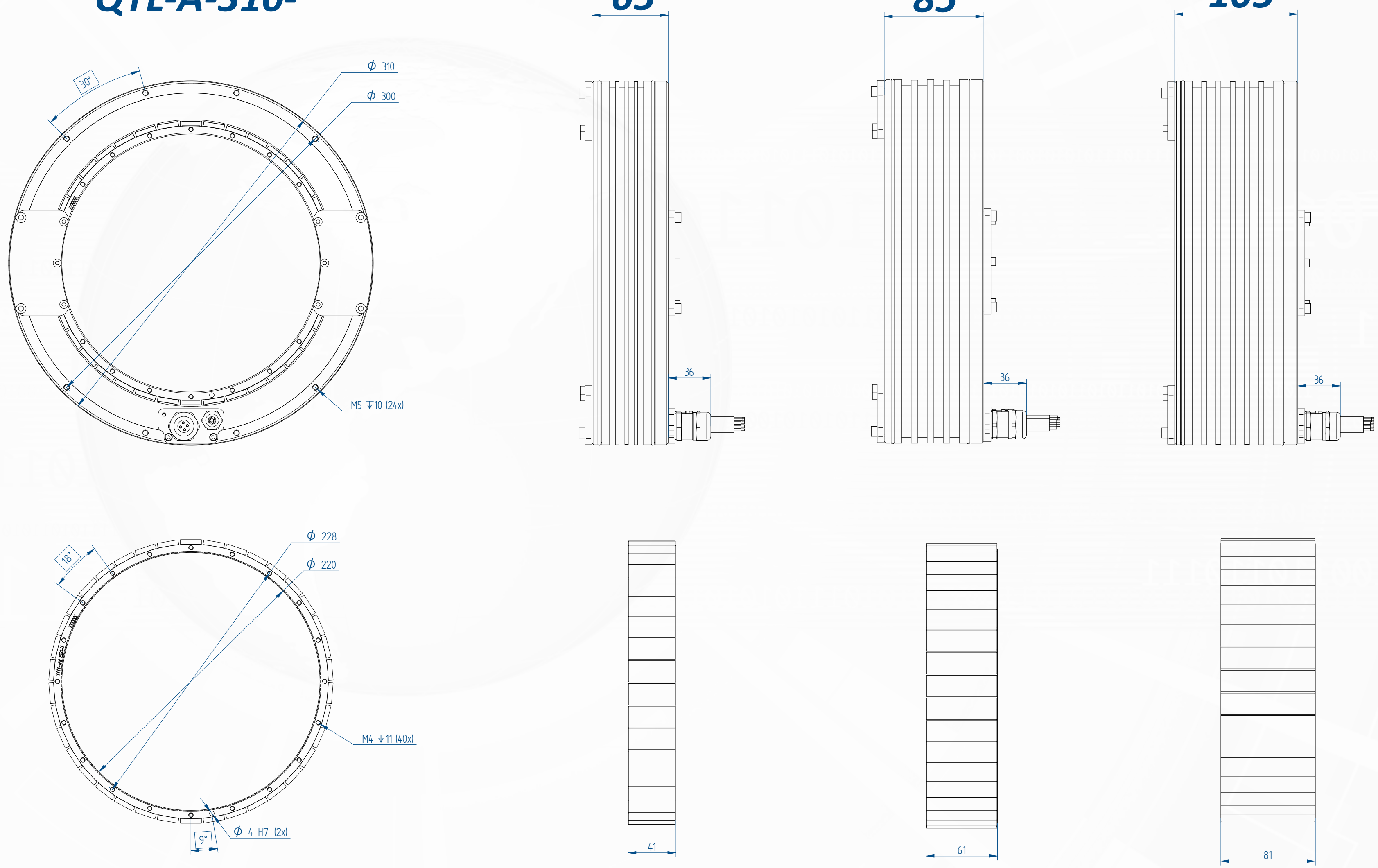
Stator OD	mm	290	h9
Rotor ID	mm	220	H8
H Rotor	mm	±0,2	

TECNOTION® direct drive in motion | APPENDIX A | Overview - QTL 310 - 65/85/105

QTL-A-310- 65 85 105

KIT

ROTOR



Stator OD	mm	310	f9
Rotor ID	mm	220	H8
H Rotor	mm	±0,2	

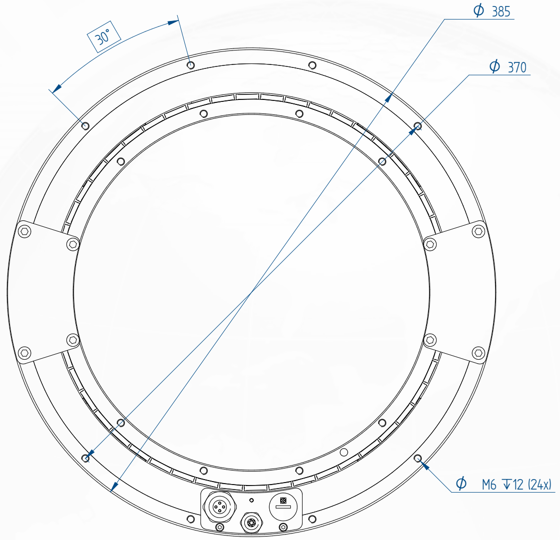
TECNOTION® direct drive in motion | APPENDIX A | Overview - QTL 385 - 85/105

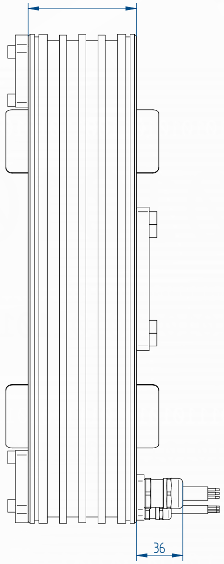
QTL-A-385-

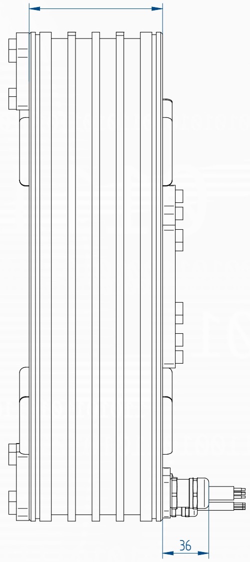
85

105

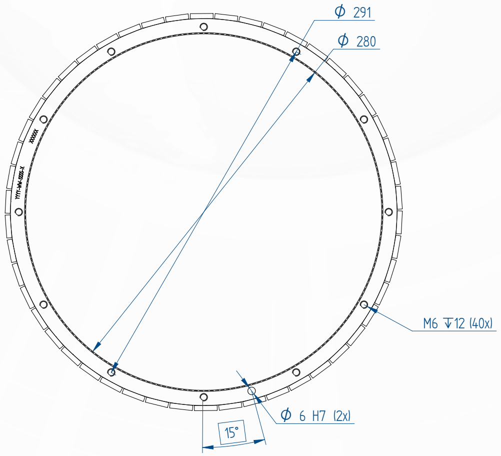
KIT

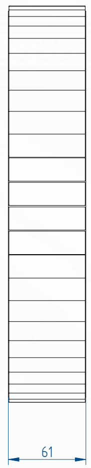


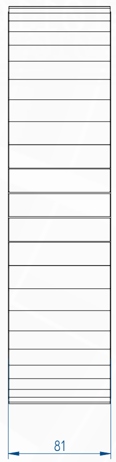




ROTOR







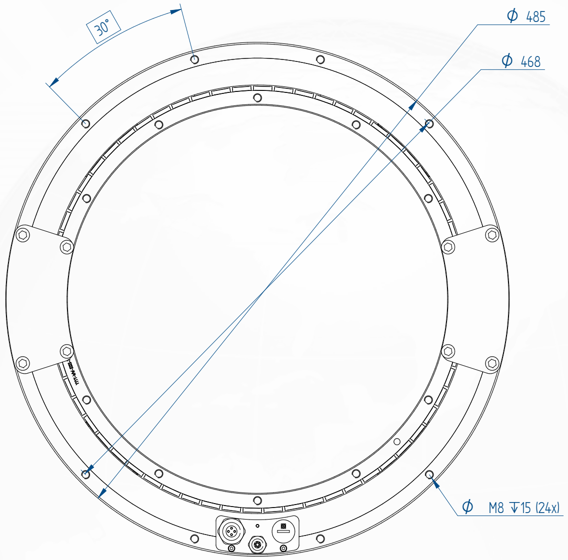
Stator OD	mm	385	f9
Rotor ID	mm	280	H8
H Rotor	mm	±0,2	

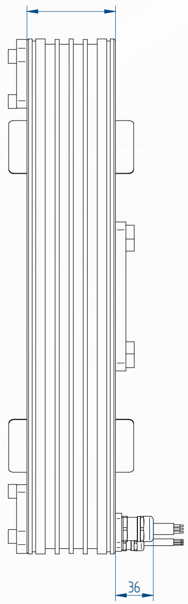
TECNOTION® direct drive in motion | APPENDIX A | Overview - QTL 485 - 85/105

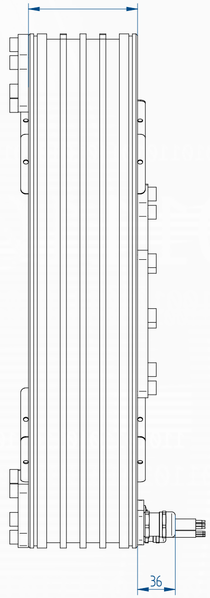
QTL-A-485-

85 **105**

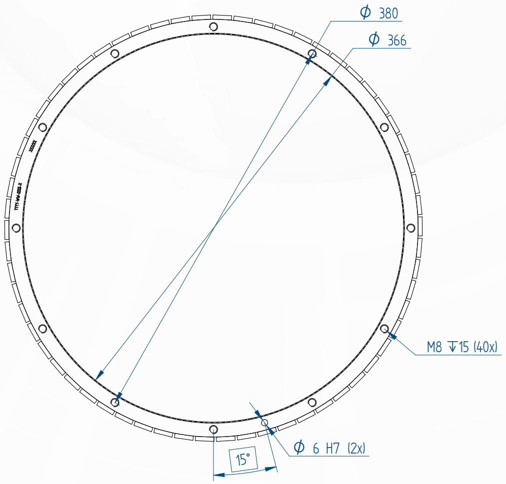
KIT

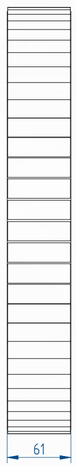


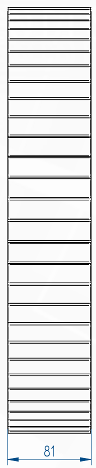




ROTOR

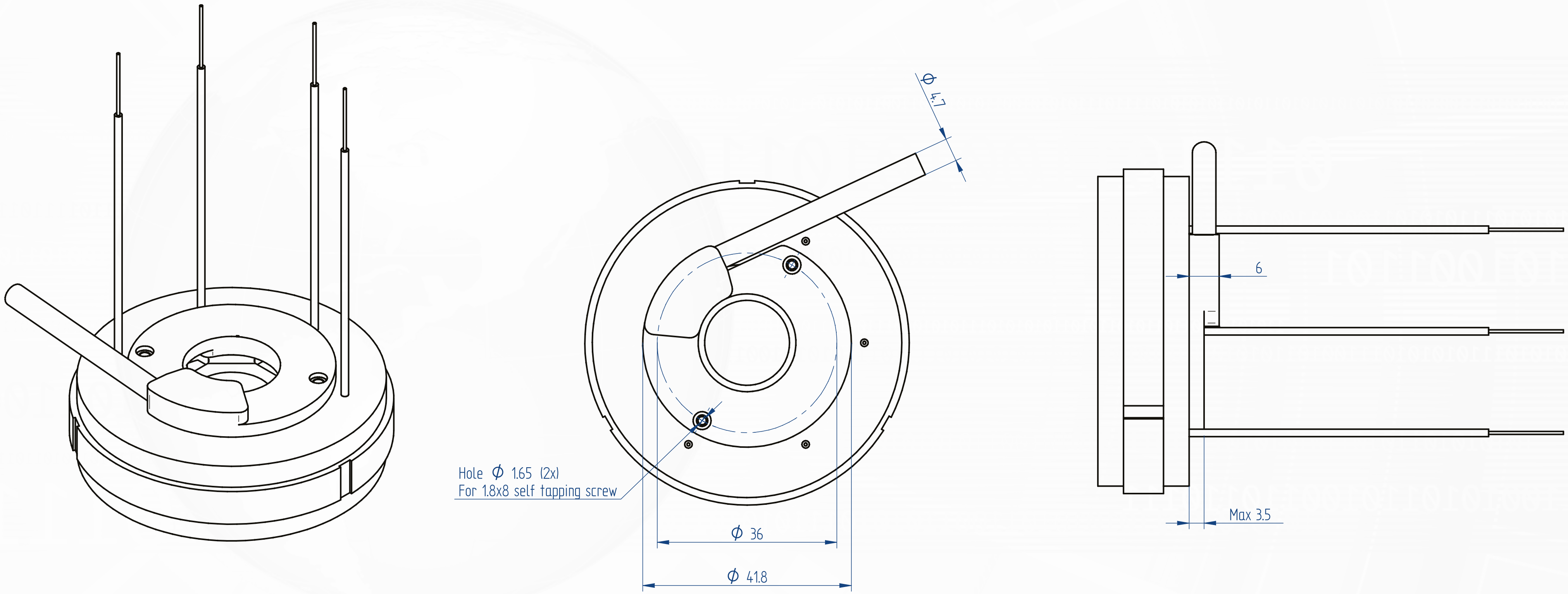






Stator OD	mm	485	f9
Rotor ID	mm	366	H8
H Rotor	mm	±0,2	

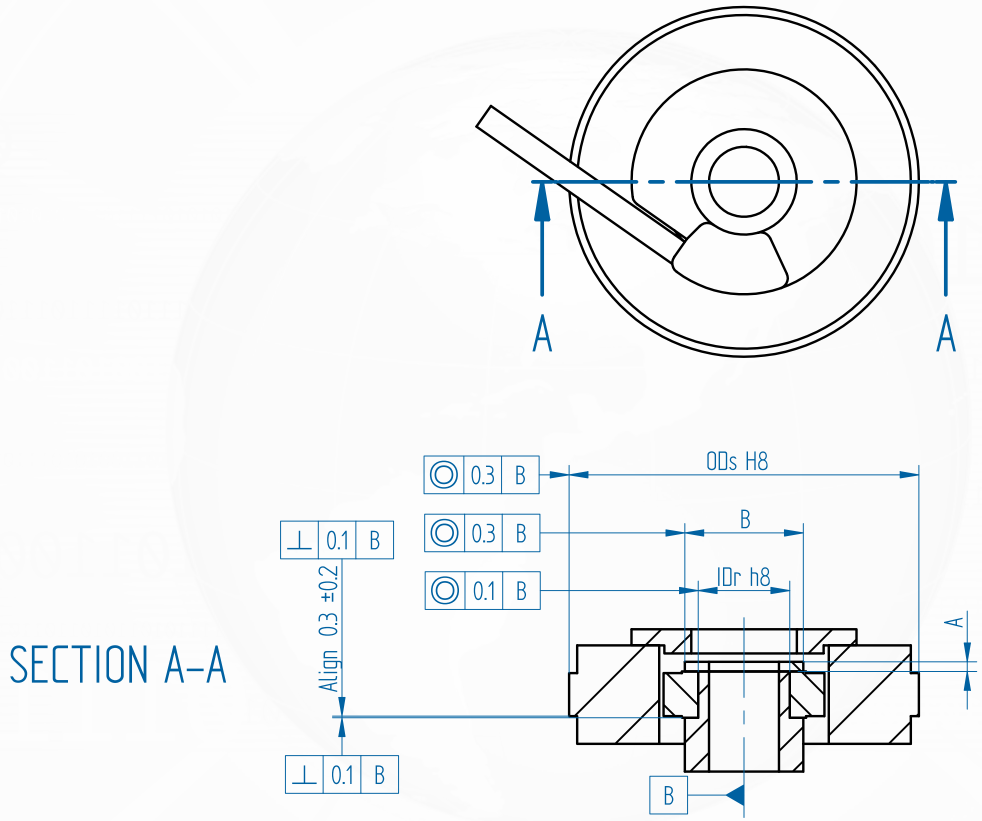
TECNOTION® direct drive in motion | APPENDIX B | QTR 65- digital Hall module



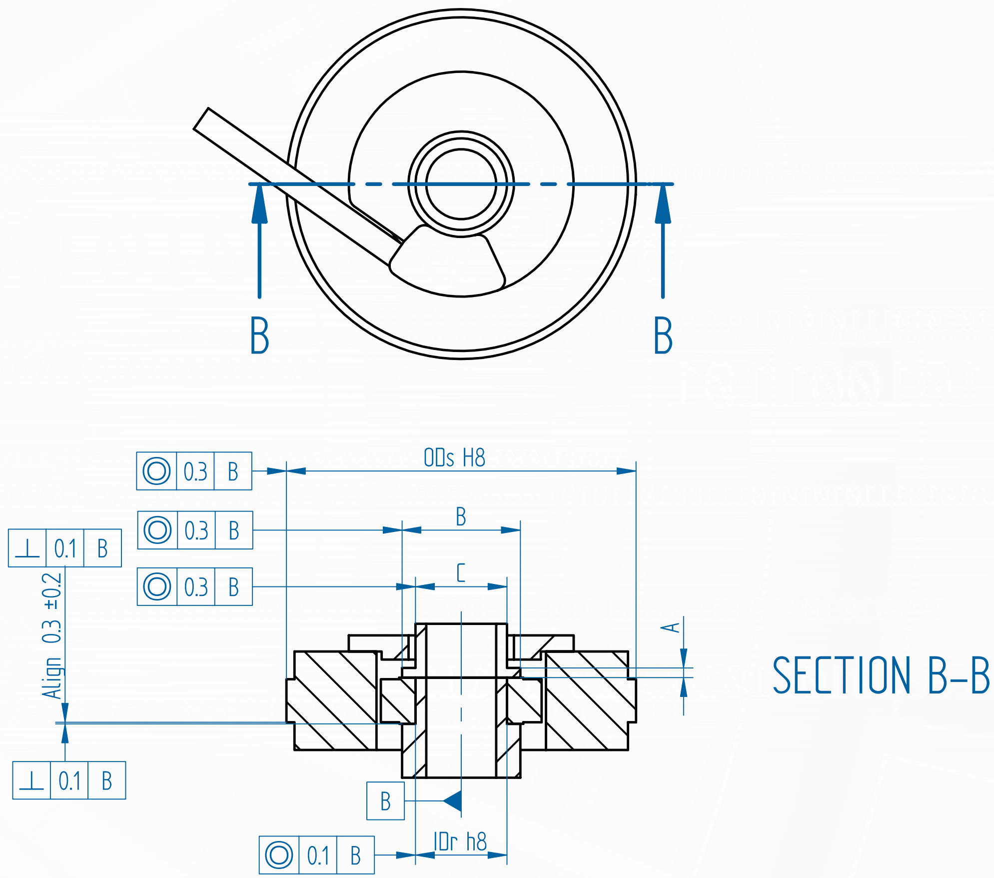
TECNOTION® direct drive in motion | APPENDIX B | QTR 65- dHm build in dimensions

APPENDIX B

QTR 65- dHm build in dimensions

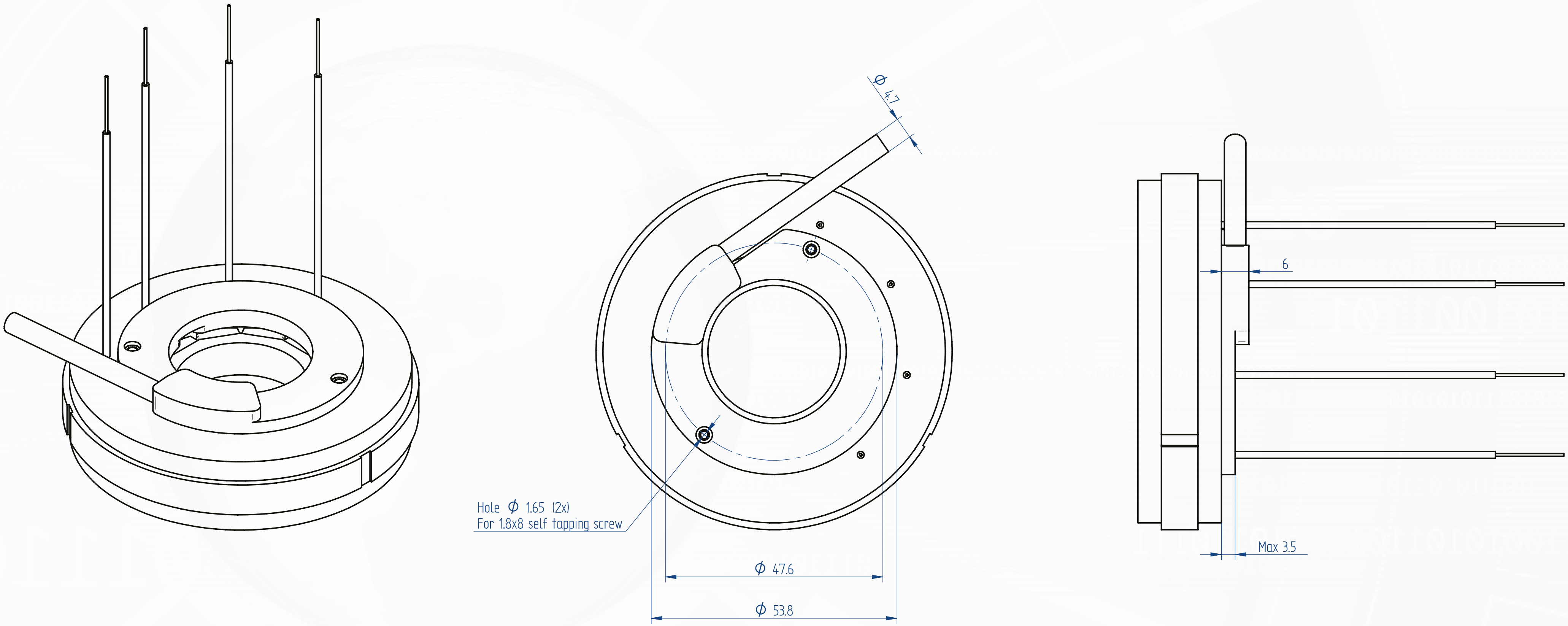


Stator height	A
17 & 25	1.8 ±0.1
34	2 ±0.1
60	3.5 ±0.1

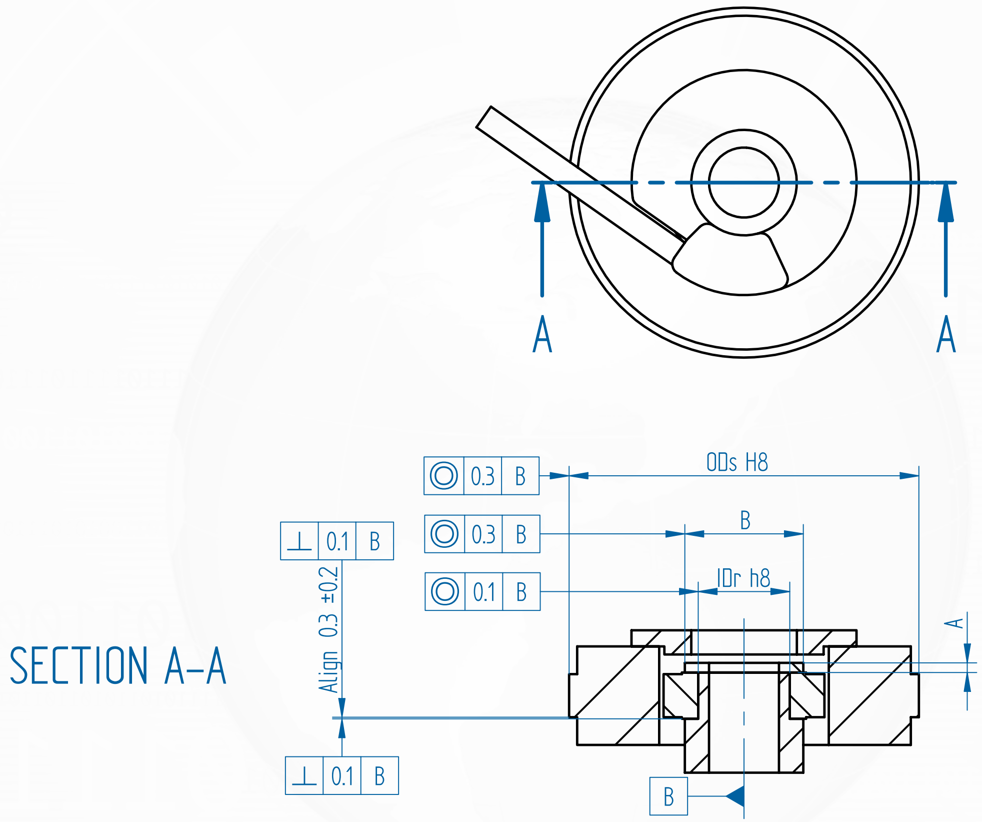


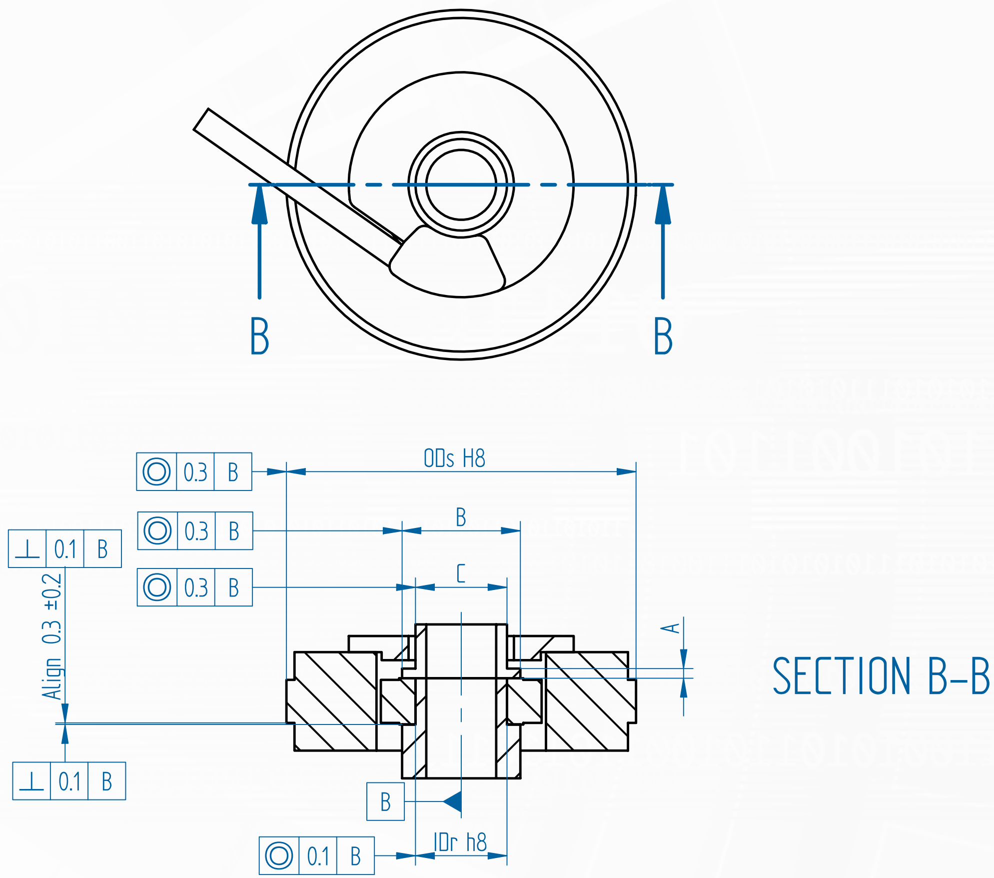
Stator diameter	B	C
65	22 ±0.2	17 ±0.1

TECNOTION® direct drive in motion | APPENDIX B | QTR 78 - digital Hall module



TECNOTION® direct drive in motion | APPENDIX B | QTR 78 - dHm build in dimensions



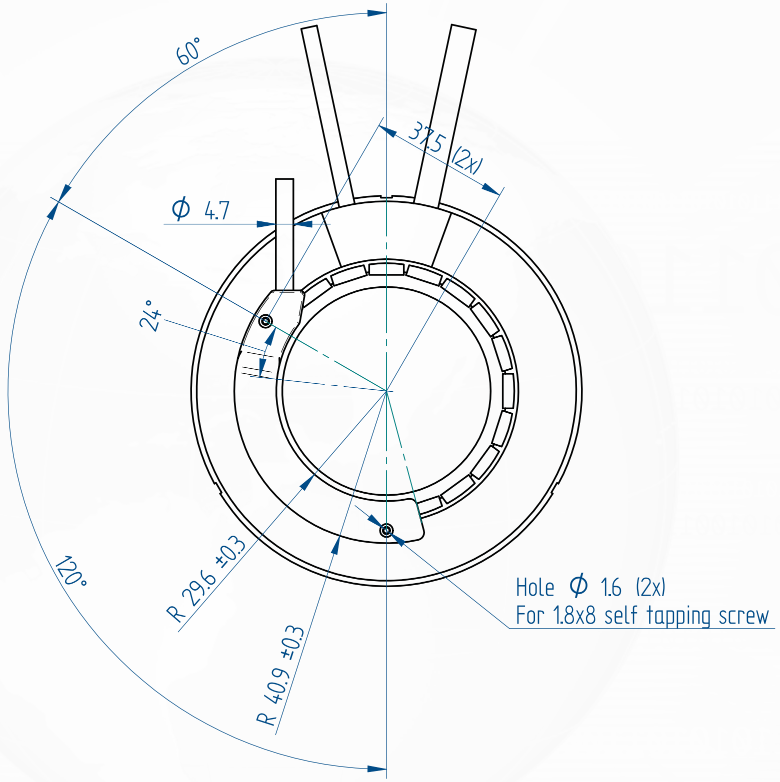


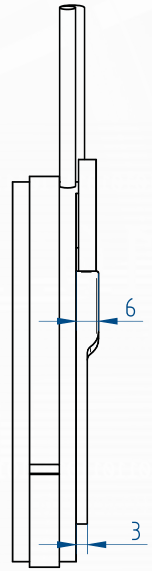
Stator height	A
17 & 25	1.8 ±0.1
34	2 ±0.1
60	3.5 ±0.1

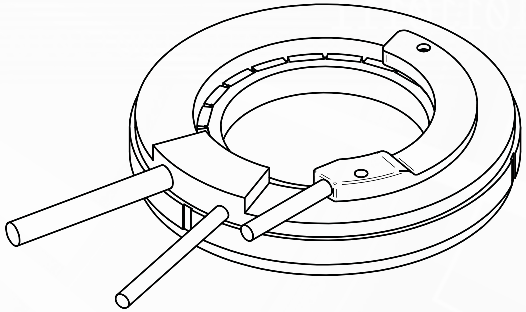
Stator diameter	B	C
78	34 ±0.2	29 ±0.1

TECNOTION®
direct drive in motion

APPENDIX B | QTR 105 - digital Hall module

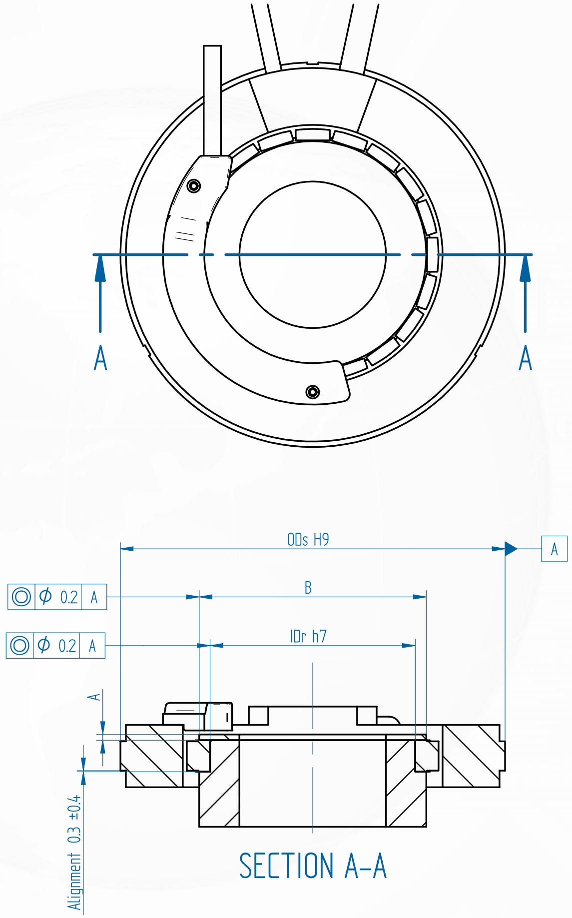


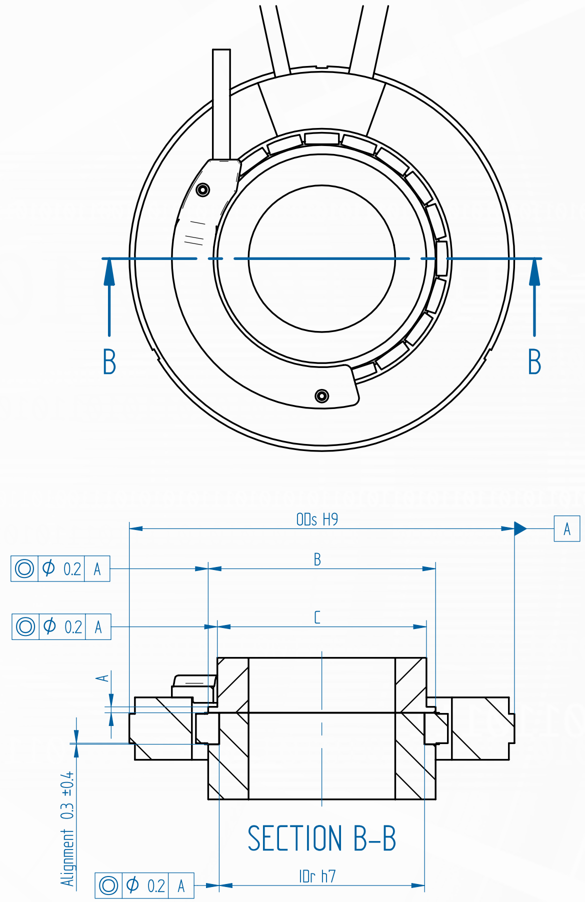




TECNOTION®
direct drive in motion

APPENDIX B | QTR 105- dHm Build in dimensions

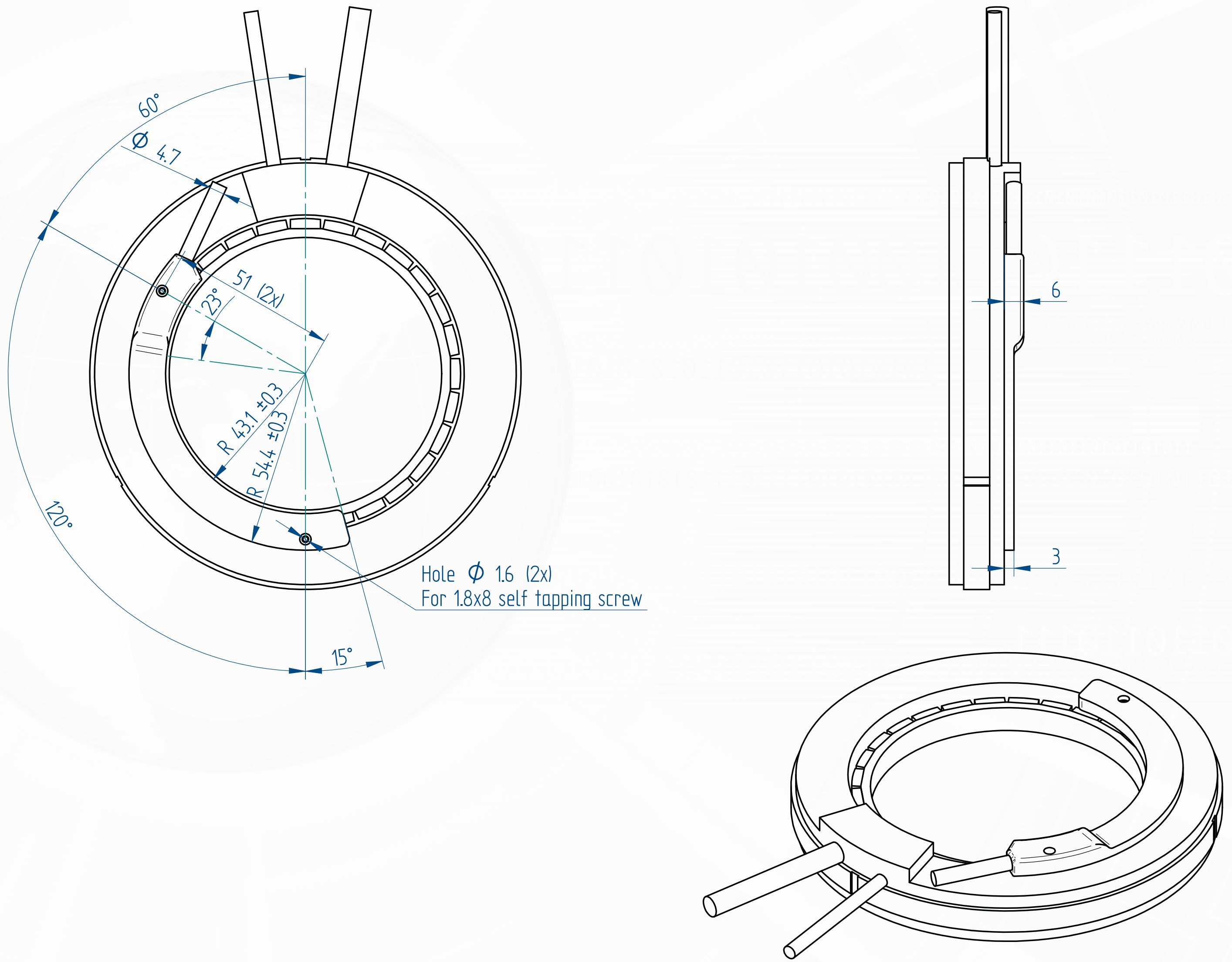




Stator height	A
17 & 25	1.4 ±0.1
34	1.9 ±0.1
60	2.4 ±0.1

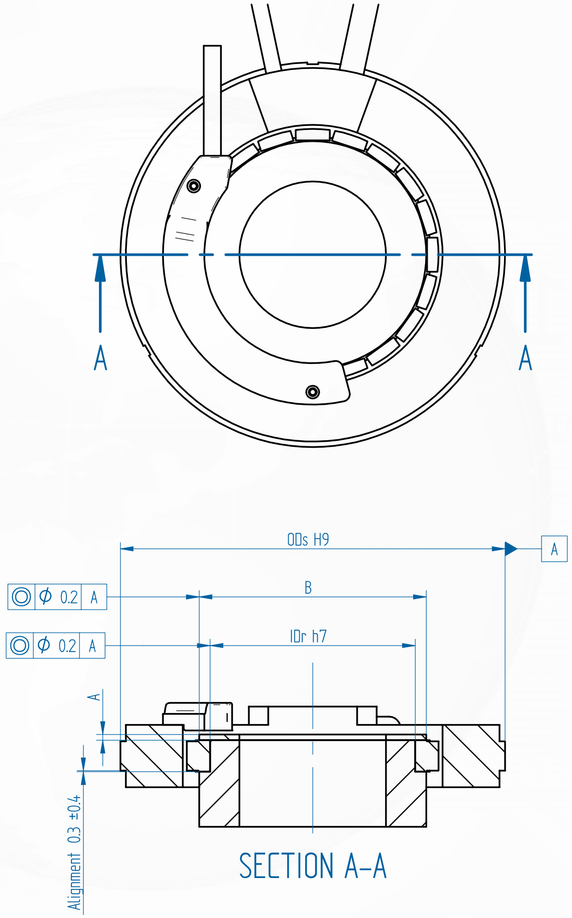
Stator diameter	B	C
105	61.3 ±0.2	56 ±0.1

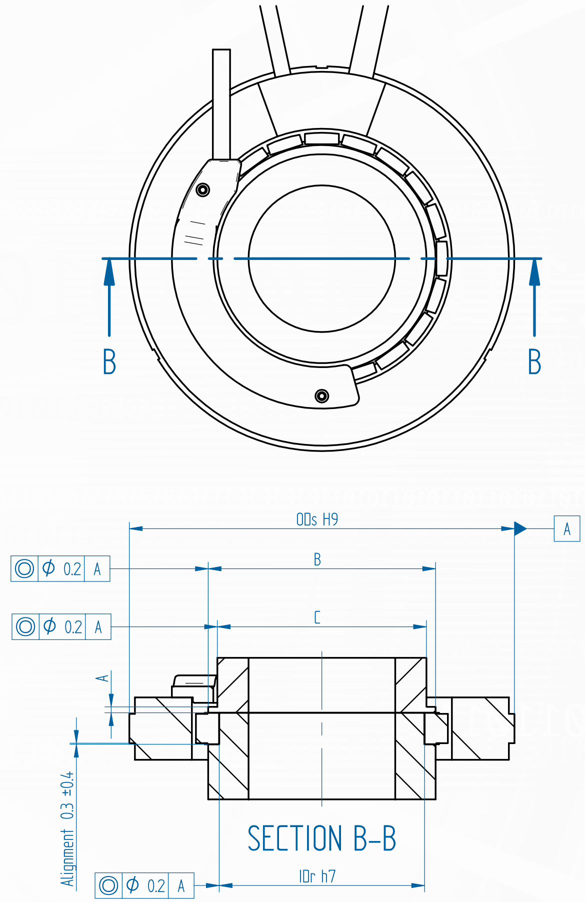
TECNOTION® direct drive in motion | APPENDIX B | QTR 133 - digital Hall module



TECNOTION®
direct drive in motion

APPENDIX B | QTR 133- dHm Build in dimensions



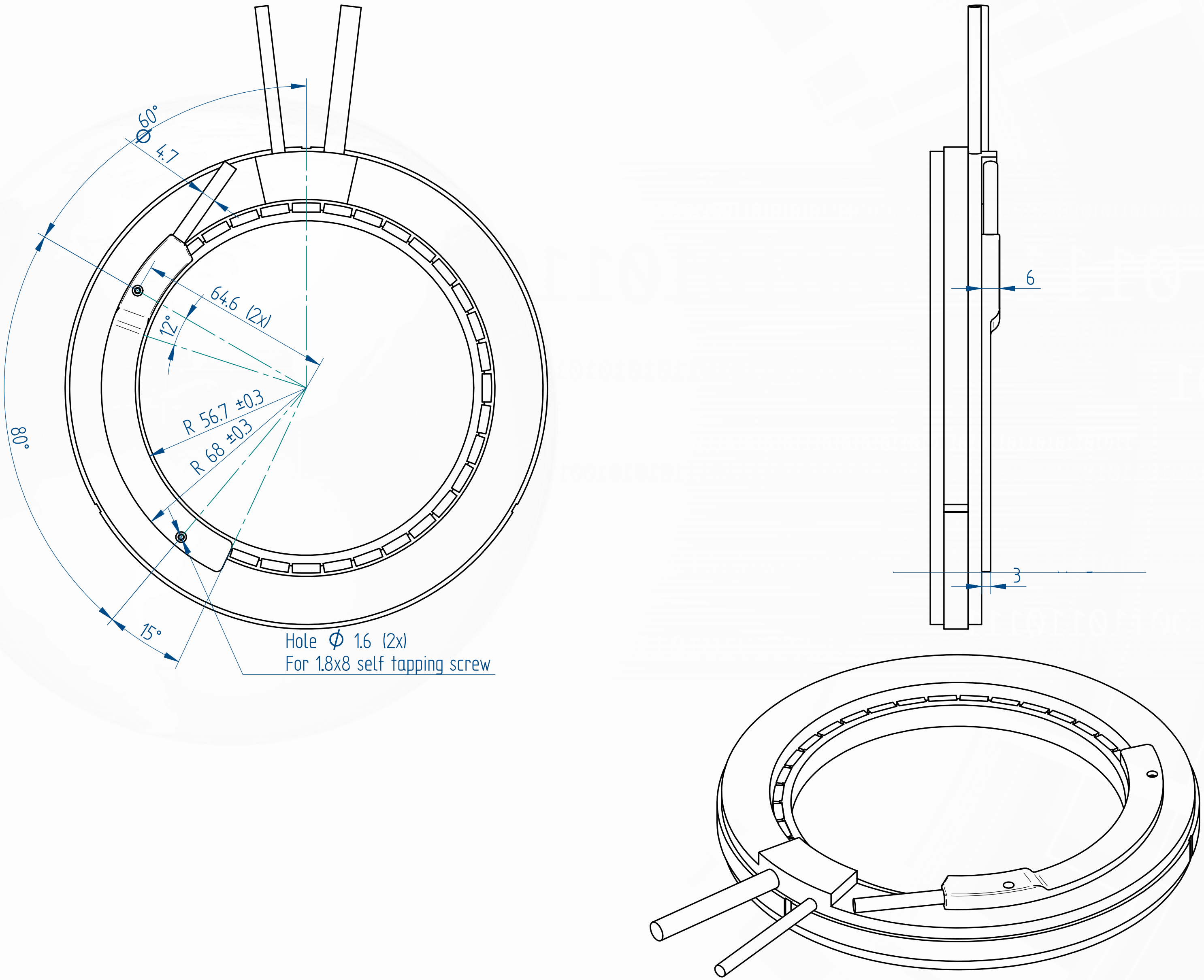


Stator height	A
17 & 25	1.4 ±0.1
34	1.9 ±0.1
60	2.4 ±0.1

Stator diameter	B	C
133	88.3 ±0.2	84 ±0.1

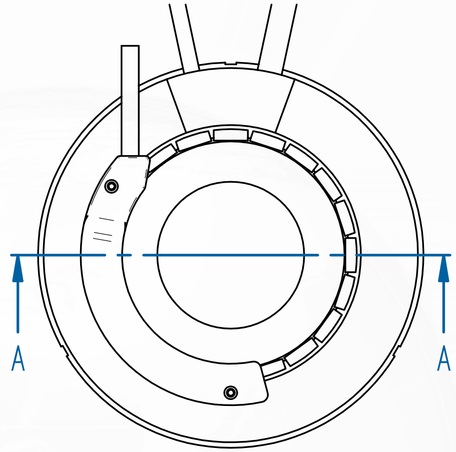
TECNOTION®
direct drive in motion

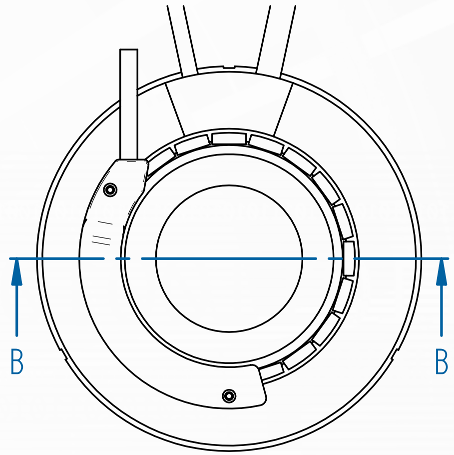
APPENDIX B | QTR 160 - digital Hall module

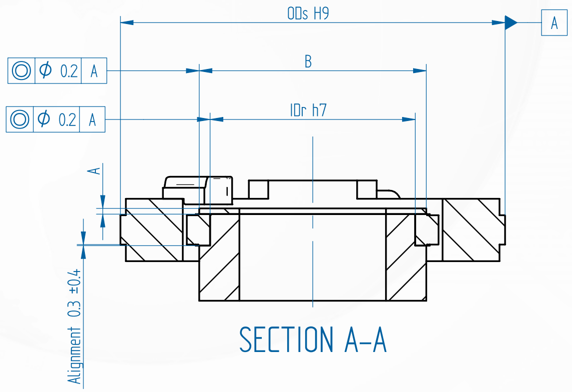


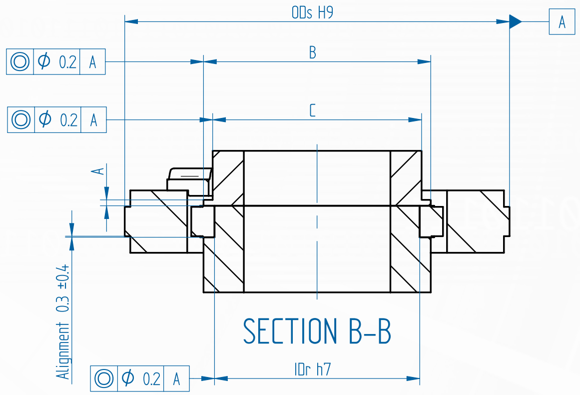
TECNOTION® direct drive in motion

APPENDIX B | QTR 160- dHm Build in dimensions







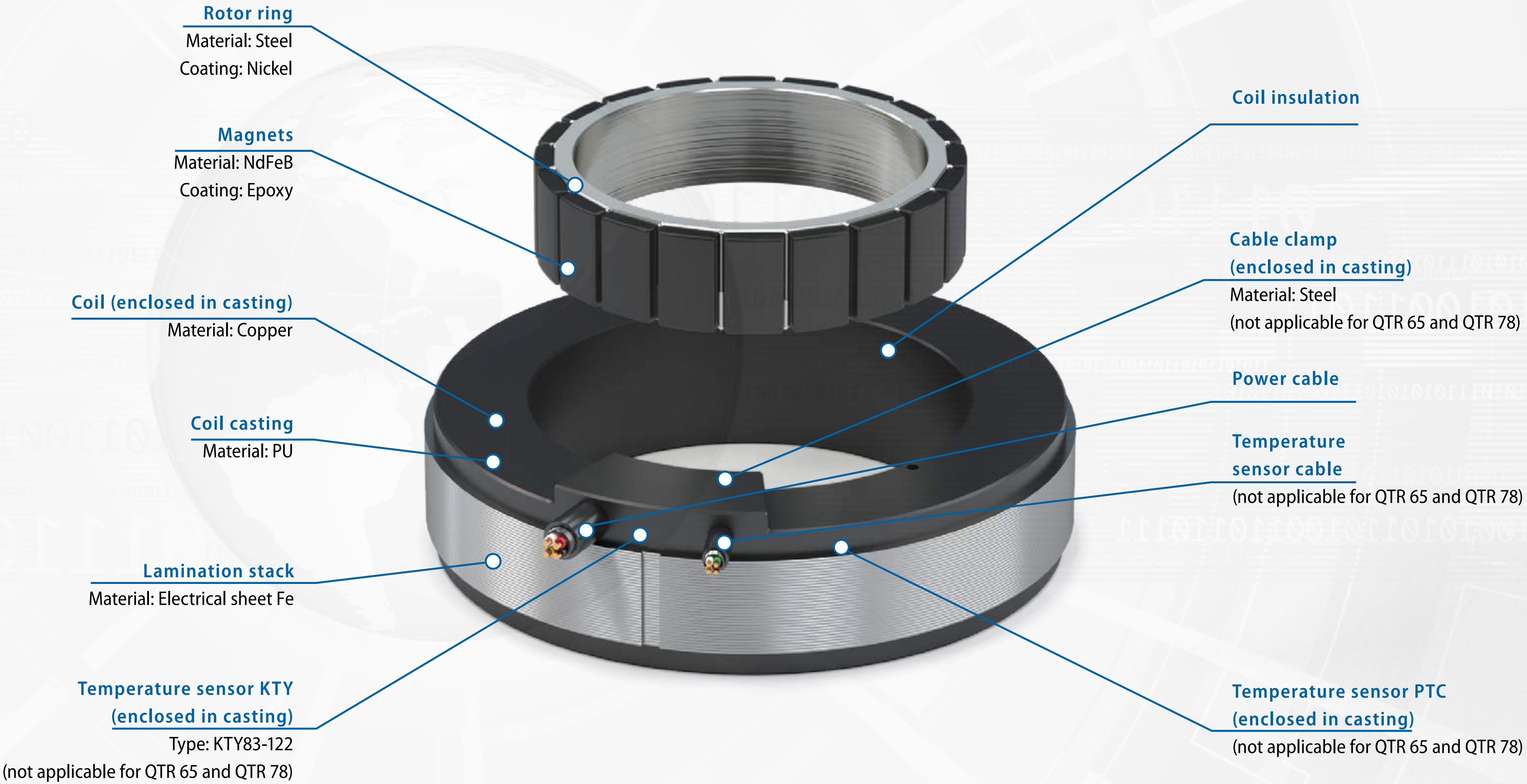


Stator height	A
17 & 25	1.4 ±0.1
34	1.9 ±0.1
60	2.4 ±0.1

Stator diameter	B	C
160	115.5 ±0.2	111 ±0.1

TECNOTION® direct drive in motion

APPENDIX C | Material overview



TECNOTION® direct drive in motion

APPENDIX D | IATA strayfield threshold

Product	Product configuration	Action		
		No action	Notify relevant authority	Authorisation by relevant authority required
QTR 65 series	Single kit in original packaging	x		
	Completely filled Euro-pallet of kits in original packaging (1200*800*1000mm)	x		
	Individual rotor	x		
QTR 78 series	Single kit in original packaging	x		
	Completely filled Euro-pallet of kit in original packaging (1200*800*1000mm)	x		
	Individual rotor	x		
QTR 105-133-160 series	Single kit in original packaging	x		
	Completely filled Euro-pallet of kit in original packaging (1200*800*1000mm)	x		
	Rotor with protection ring	x		
	Rotor without protection ring	x		
QTL series	Single kit in original packaging	x		
	Completely filled Euro-pallet of kit in original packaging (1200*800*1000mm)	x		
Products shipped in their original packaging do not need actions relevant to the IATA treshold				

TECNOTION®
direct drive in motion

APPENDIX E | CE certification

TECNOTION
THE LINEAR MOTOR COMPANY

Declaration of Conformity

We, the company

Tecnotion B.V.
Twentepoort West 15
7609 RD Almelo
Netherlands

Hereby declare that:

Our QTR Torque motors series including
QTR 65, QTR 78, QTR 105, QTR 133 and QTR 160 series

- Are in Conformity with the essential requirements of following EC Directive when installed according the installation manual

(2011/65/EU)	ROHS 2
(2015/863)	Amending Annex II to directive 2011/65/EU
(2014/35/EC)	Low voltage directive

-The following harmonized standards have been applied

EN 60034-1: 2017	Rotating electrical machines

Issued by:
B. Molkenboer

Management:
B. Jonker

Almelo, Netherlands
2019-11-14

Legally binding Signature:

TECNOTION
THE LINEAR MOTOR COMPANY

Declaration of Conformity

Directive 2014/35/EC
Directive 2011/65/EU and Directive 2015/863

We, the company

Tecnotion B.V.
Twentepoort West 15
7609 RD Almelo
Netherlands

Hereby declare that:

Our QTL Torque motors series including
QTL 210, QTL 230, QTL 290 and QTL 310 series

- Are in Conformity with the essential requirements of following EC Directive when installed according the installation manual

(2011/65/EU)	ROHS 2
(2015/863)	Amending Annex II to directive 2011/65/EU
(2014/35/EU)	Low voltage directive
(2014/30/EU)	EMC

-The following harmonized standards have been applied

EN 60034-1: 2010	Rotating electrical machines
EN 61000-6-2:2019	Immunity industrial
EN 61000-6-3:2007	Emission light industrial
EN 61000-6-4:2007	Emission industrial

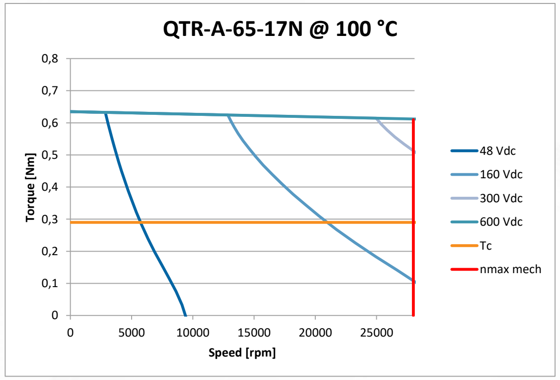
Issued by:
B. Molkenboer

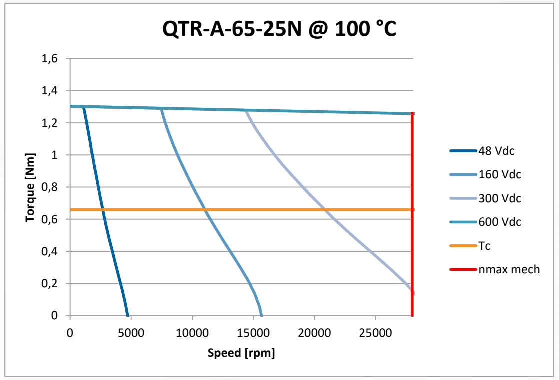
Management:
B. Jonker

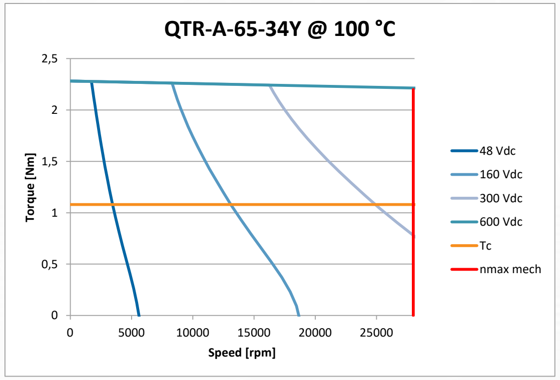
19-02-2020
Almelo, Netherlands

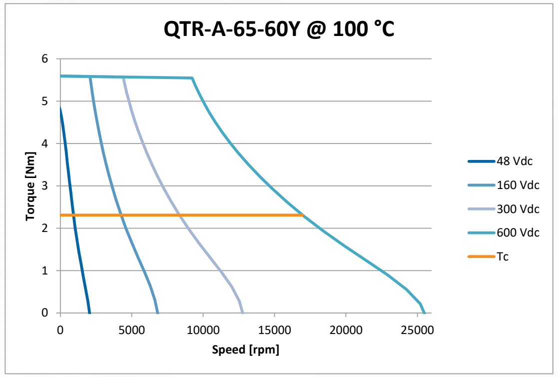
For most recent version see our website: http://www.tecnotion.com/certifications.html

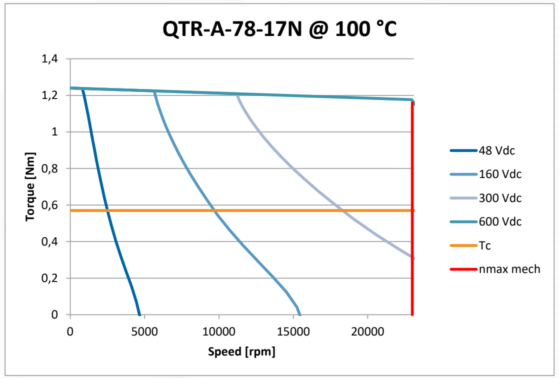
TECNOTION® direct drive in motion | APPENDIX F | T/n graphs 65/78

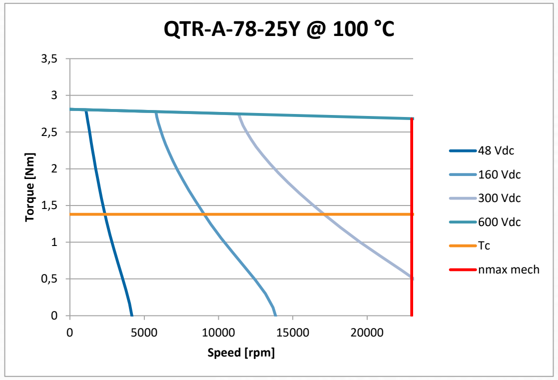


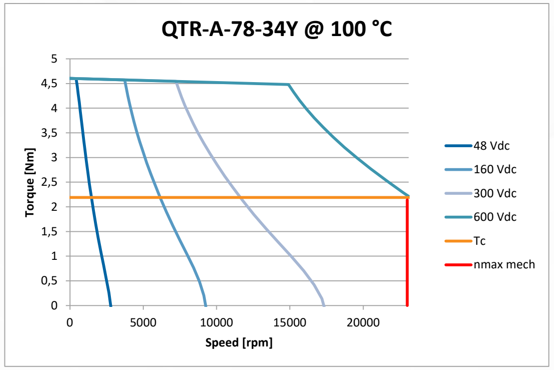


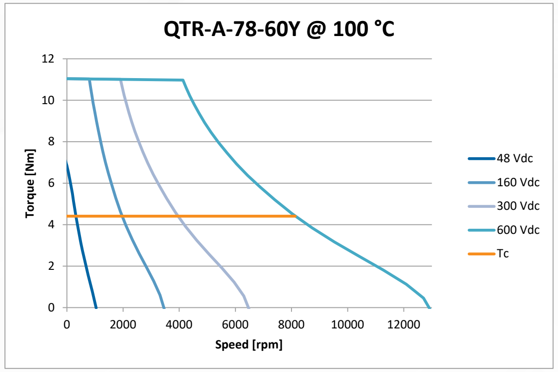








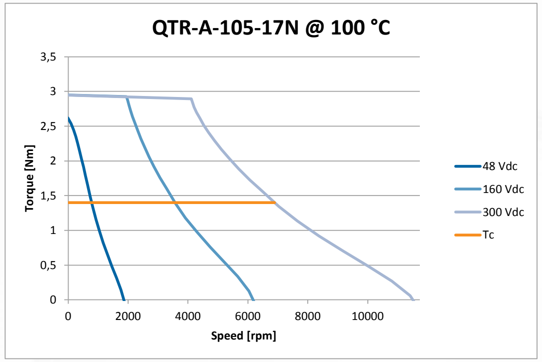


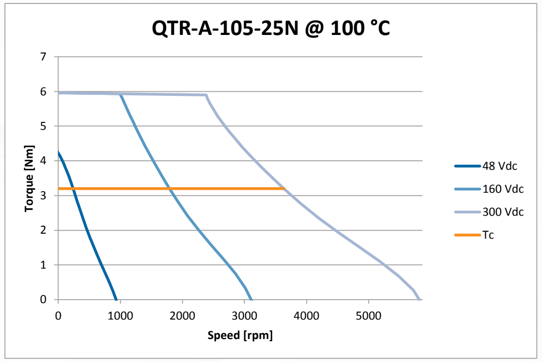


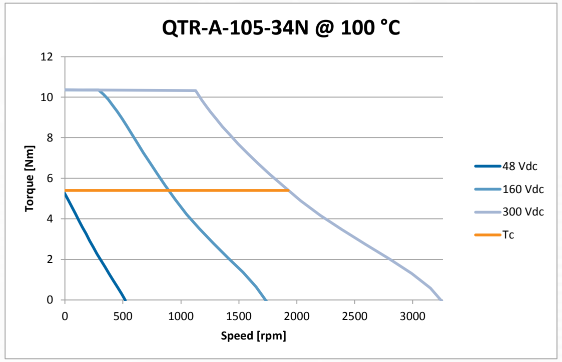
MAXIMUM allowable speed for QTR-A 65 series motors is 28.000 rpm.
MAXIMUM allowable speed for QTR-A 78 series motors is 23.000 rpm.
If you plan a high speed application, please contact Tecnotion.

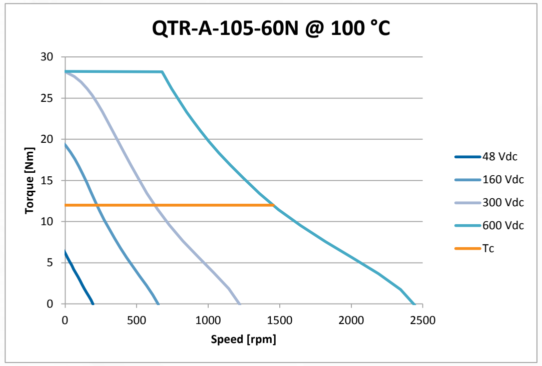
TECNOTION® direct drive in motion

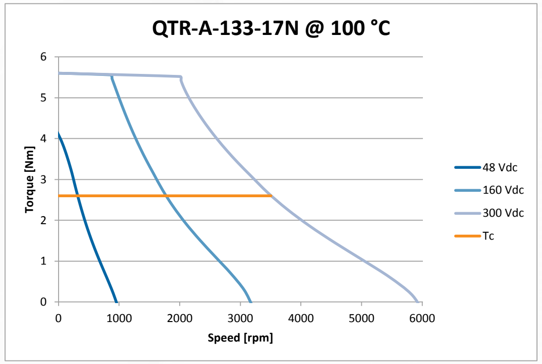
APPENDIX F | T/n graphs 105/133/160 N winding

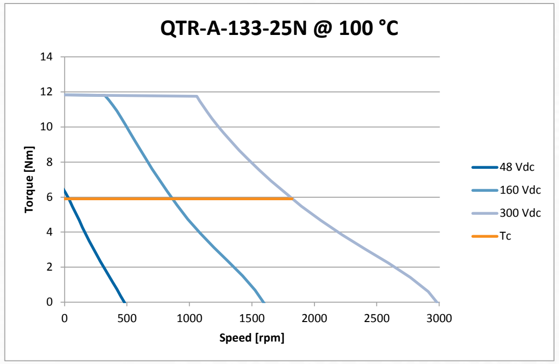


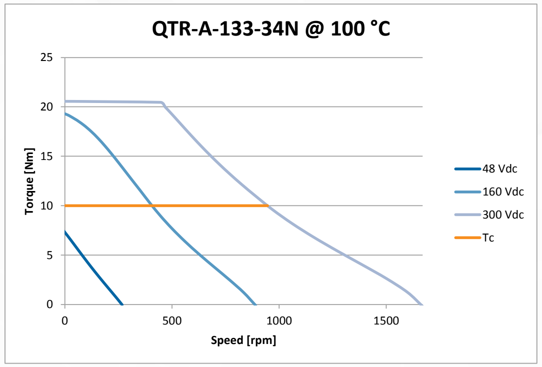


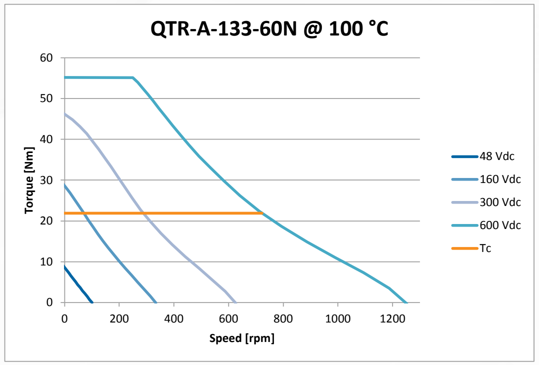


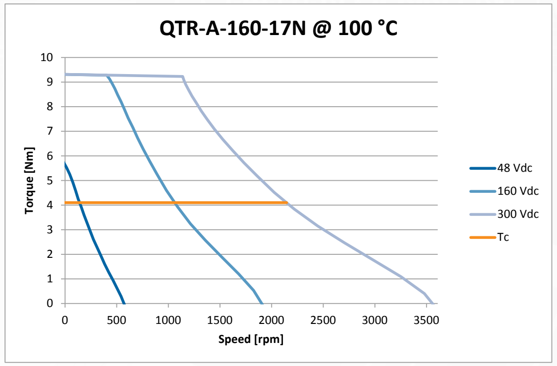




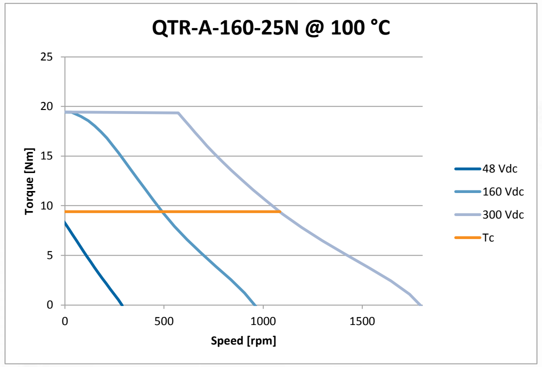


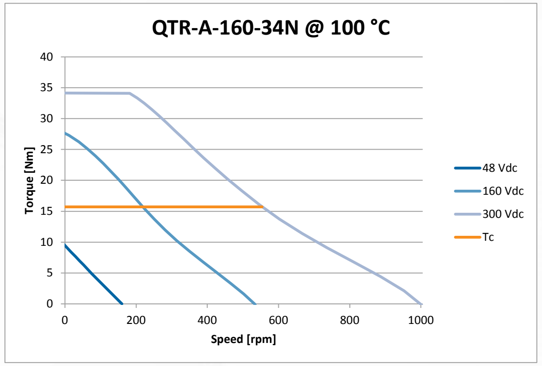


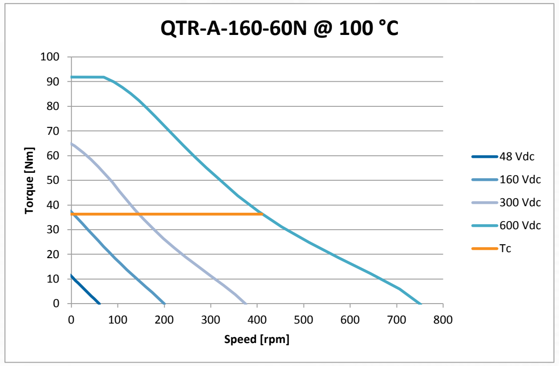




TECNOTION® direct drive in motion | APPENDIX F | T/n graphs 105/133/160 N winding







MAXIMUM allowable speed for QTR-A 105 series motors is 16.500 rpm.

MAXIMUM allowable speed for QTR-A 133 series motors is 14.000 rpm.

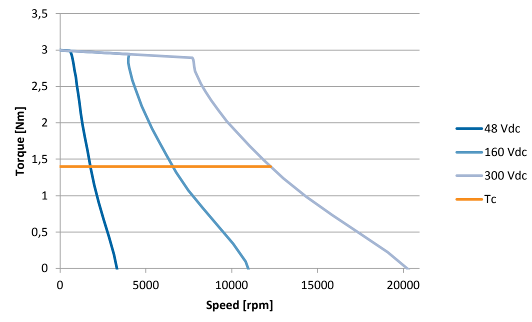
MAXIMUM allowable speed for QTR-A 160 series motors is 12.000 rpm.

If you plan a high speed application, please contact Tecnotion.

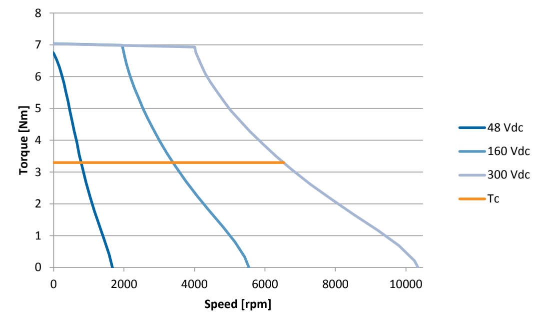
TECNOTION®
direct drive in motion

APPENDIX F | T/n graphs 105/133/160 Y&Z winding

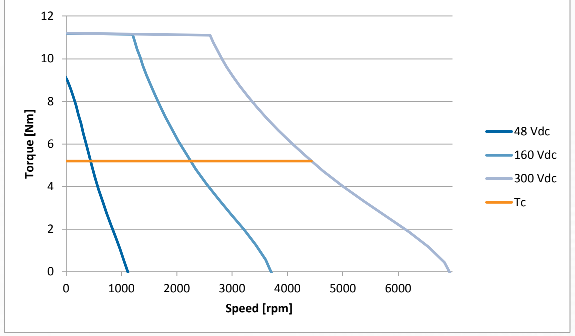
QTR-A-105-17Y @ 100 °C



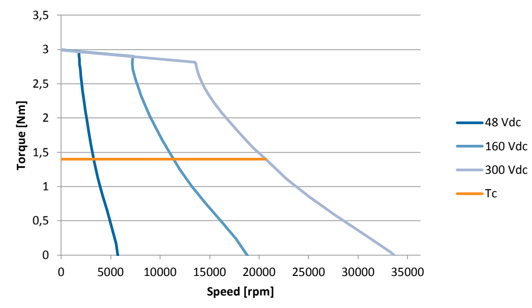
QTR-A-105-25Y @ 100 °C



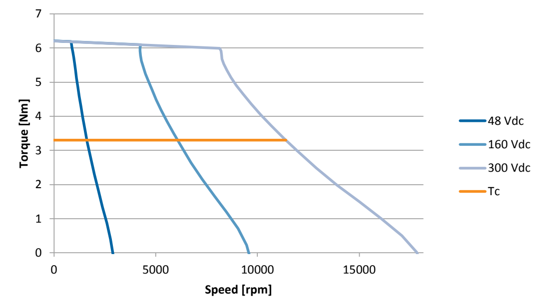
QTR-A-105-34Y @ 100 °C



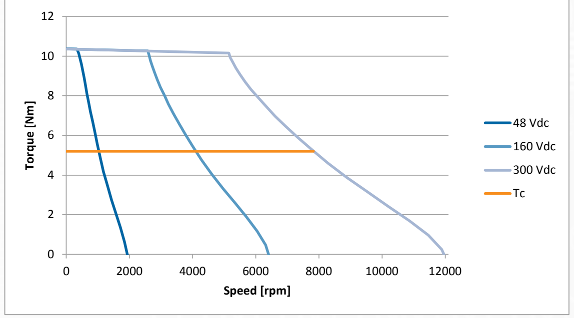
QTR-A-105-17Z @ 100 °C



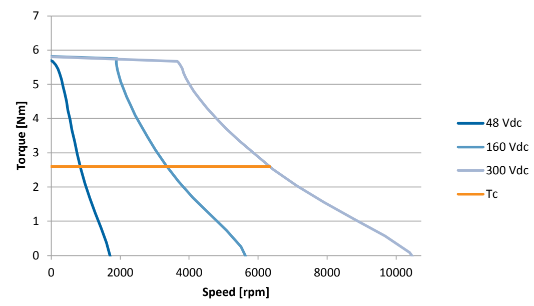
QTR-A-105-25Z @ 100 °C



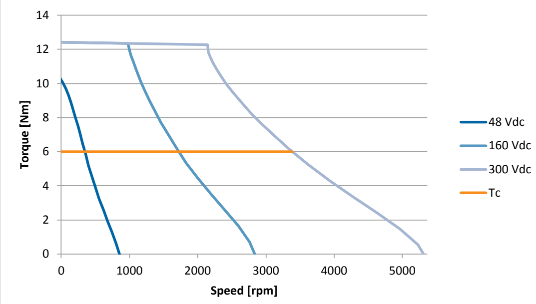
QTR-A-105-34Z @ 100 °C



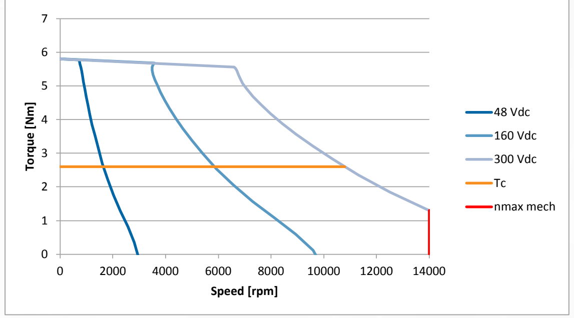
QTR-A-133-17Y @ 100 °C



QTR-A-133-25Y @ 100 °C



QTR-A-133-17Z @ 100 °C



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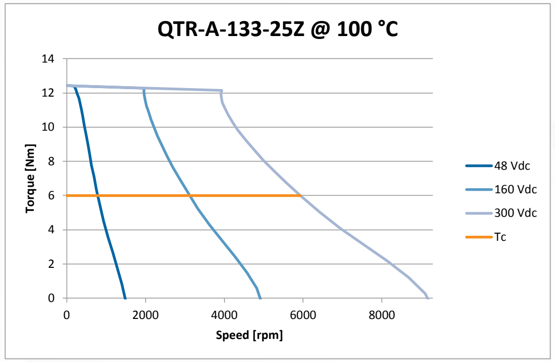
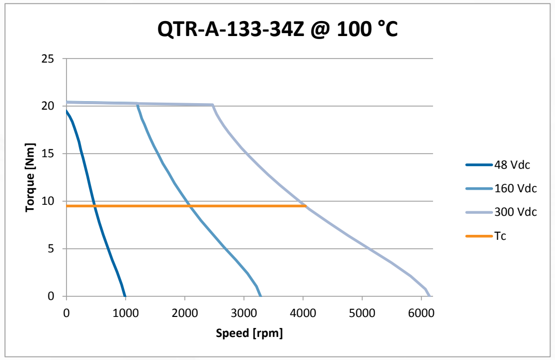
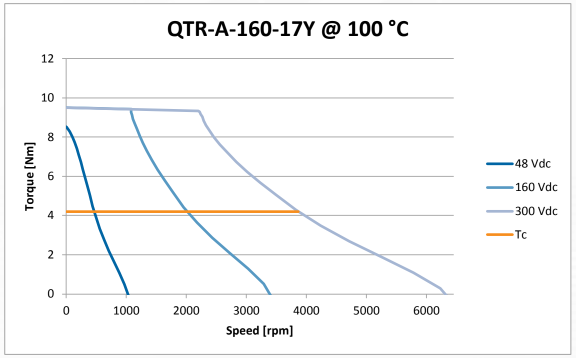
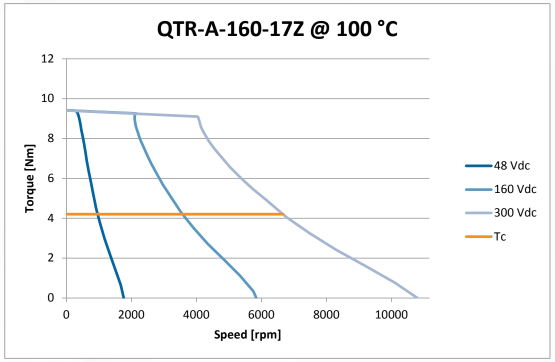
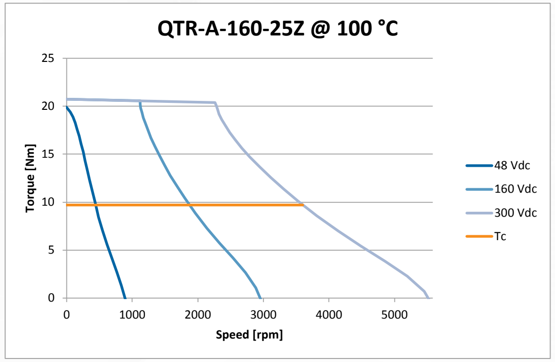
APPENDIX F | T/n graphs 105/133/160 Y&Z winding

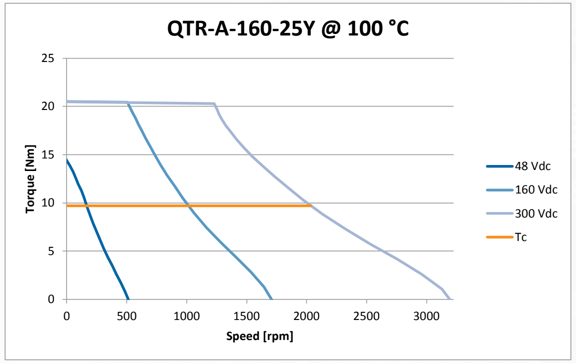


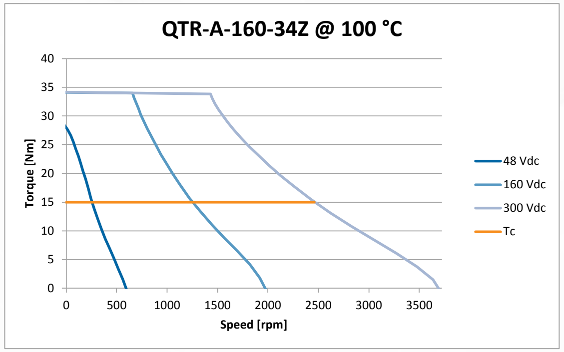












MAXIMUM allowable speed for QTR-A 105 series motors is 16.500 rpm.

MAXIMUM allowable speed for QTR-A 133 series motors is 14.000 rpm.

MAXIMUM allowable speed for QTR-A 160 series motors is 12.000 rpm.

If you plan a high speed application, please contact Tecnotion.

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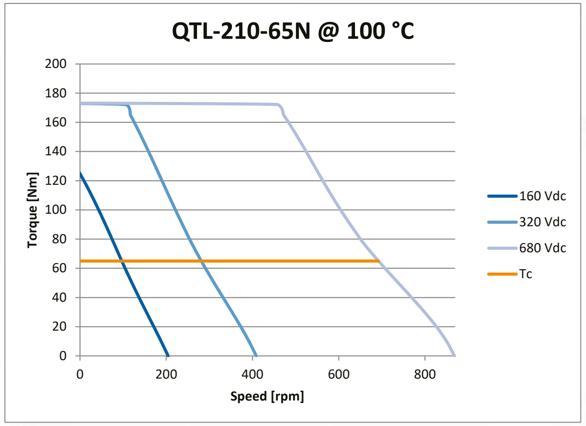
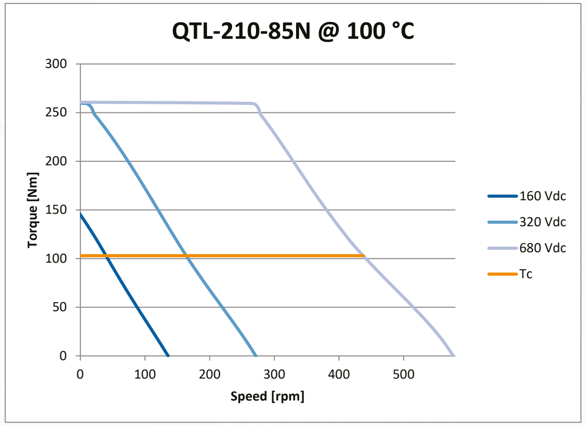
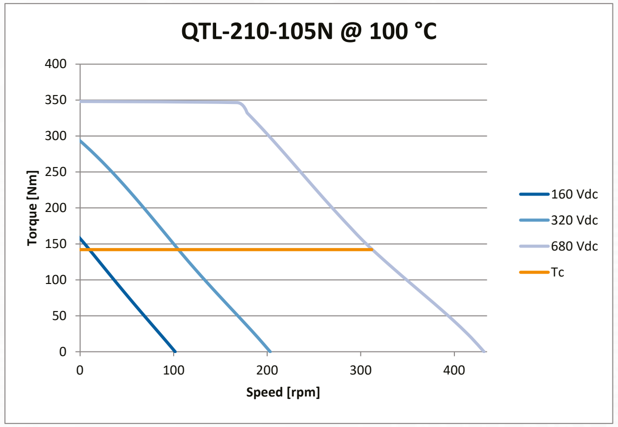
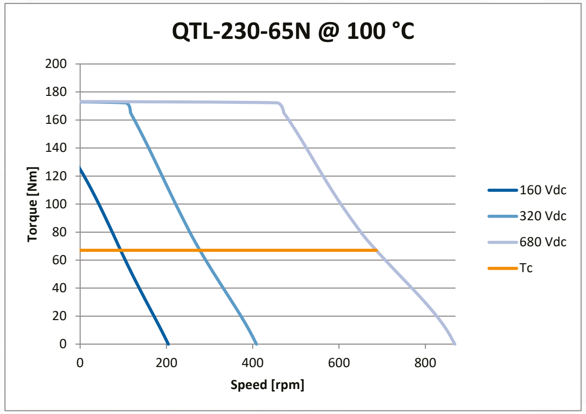
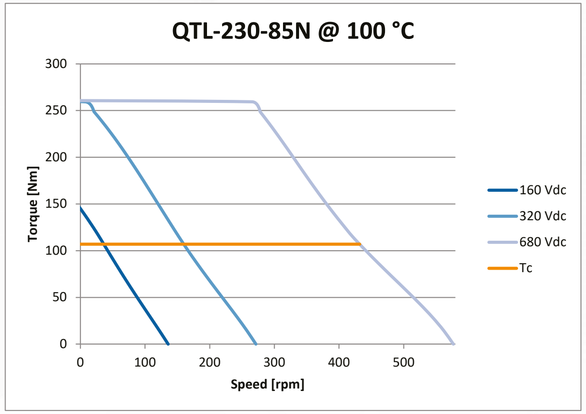
APPENDIX F | T/n graphs QTL 210/230 N winding

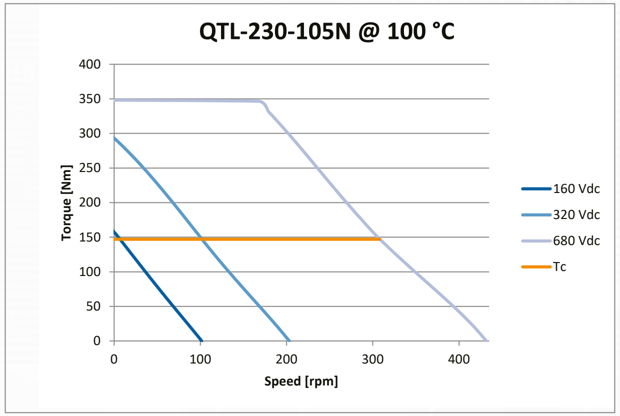












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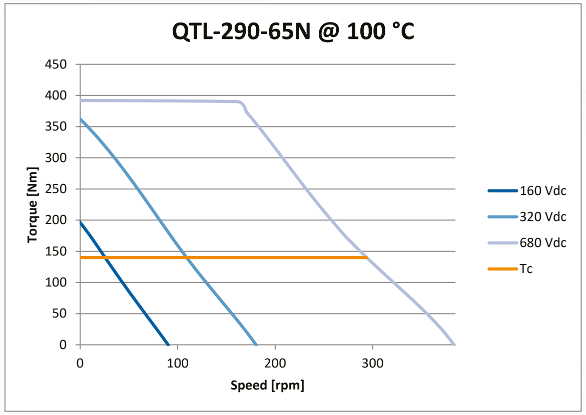
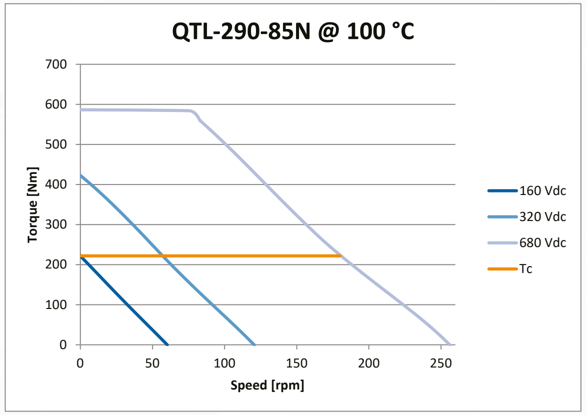
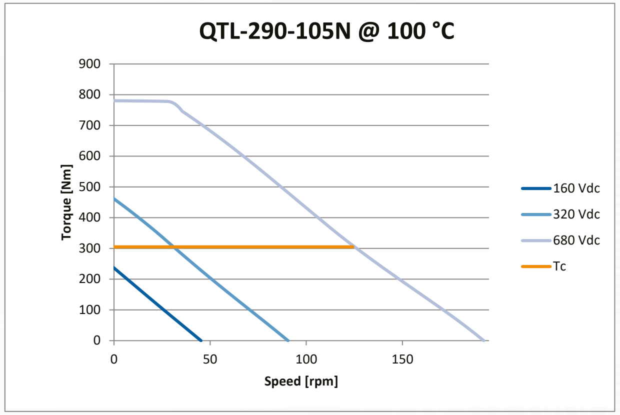
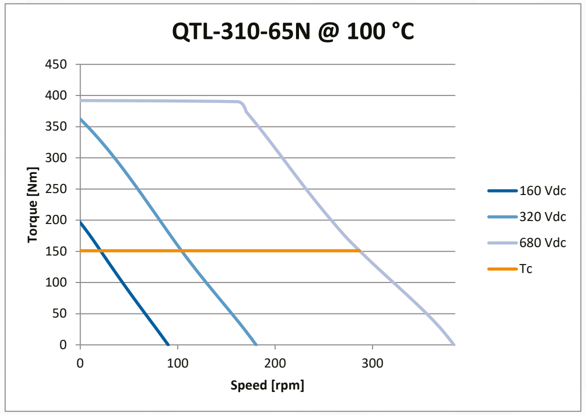
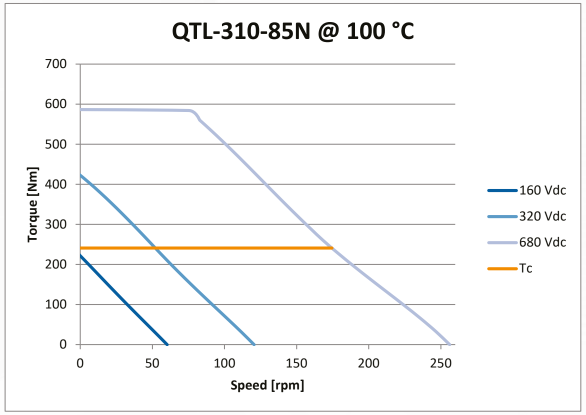
APPENDIX F | T/n graphs QTL 290/310 N winding

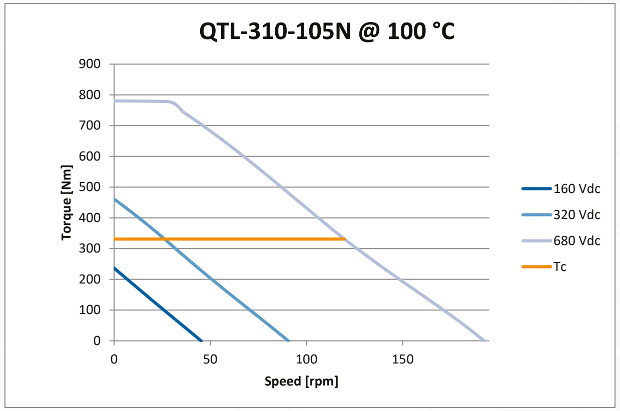












TECNOTION® direct drive in motion

Glossary

Parameter	Remark	Symbol	Unit	Definition
AWG				American Wire Gauge is a standard for wire thickness specification. The diameter "d" can be calculated with the AWG value "n". d[mm]= 0.127[mm] x 92 ^((36-n)/39).
Back EMF Phase-Phase$_{rms}$		K_e	V/krpm	Back electromotive force. A torque motor, when operated, also acts as a generator. The Back EMF describes the coefficient between the generated voltage and the speed of the motor [V/krpm]. When the generated voltage is nearly equal to the bus voltage of the system the motor cannot run any faster.
Back EMF Phase-Phase$_{peak}$		K_e	V/krpm	This value represents the maximum value of the Back EMF that is generated between the phases of the motor. It is obtained by multiplying the effective value of the Back EMF with √2.
Bending radius	minimum			Minimum bending radius for the cable when used in static configuration.
Cable mass	all cables	m	g	Mass of all cables for a length of 0.5m.
Coil induction per Phase	I < 0.6 Ip	L	mH	The induction value in [millihenry] of one phase of the motor. This value can be verified via the motor cables. But the double value will be measured because of the star point configuration of the motor, if applicable.
Coil resistance per Phase	coils @ 25°C ex. cable	R	Ohm	The resistance value in [Ohm] of one phase of the motor. This value can be verified via the motor cables. But the double value will be measured because of the star point configuration of the motor, if applicable.
Continuous power loss	coils @ 100°C	P_c	W	The maximum amount of power in [Watt] that is dissipated when the motor is operated at continuous force. The actual value can be lower as a result of variations in thermal resistance, coil temperature and winding resistance. The resistance per phase increases with the temperature according to Rph_ΔT= Rph*(1+α x ΔT). With α being the temperature coefficient for copper [1/K] and ΔT the temperature increase in [K] .
Continuous torque	coils @ 100°C	T_c	Nm	At continuous torque the heat generated and the heat flowing to the environment are equal. Dissipation occurs purely via conduction, convection and radiation. The continuous torque is specified for a aluminium mounting surface which is kept at 20°C and a thermal resistance of 0.05 K/W.
Electrical time constant	coils @ 25°C	τ_e	ms	The time after which the current reaches 63%(1-1/e) of the desired magnitude. This metric gives an indication of the reaction time of the motor.
KTY temperature sensor			Ohm/K	The temperature measurement sensor for the torque series, has a positive coefficient between temperature and resistance.
Lamination stack height		H_{arm}	mm	Height of the lamination stack.
Magnets @ 25°C				Temperature at which the specified force is rated. Permanent magnets have a negative temperature coefficient. At higher magnet temperatures the achievable force will be lower. Permanent magnets will demagnetise at a specific temperature and applied external magnetic loads. For Tecnotion torque motors this will occur around and above 70°C. At the specified 25°C this demagnetisation will not occur.
Maximum continuous current	coils @ 100°C	I_c	A_{rms}	The maximum continuous current [A] the motor can be run at to achieve the continuous torque. When cooled by means of radiation, convection and conduction through a 20°C aluminium surface and a thermal resistance of 0.05 [K/W].

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Parameter	Remark	Symbol	Unit	Definition
Maximum speed	@Tc	N_{max}	rpm	The maximum speed the torque motor can achieve at continuous torque. The actual value depends on the bus voltage and required force. Please check the T/n diagrams in the Tecnotion simulation tool.
Maximum mechanical speed	@Tc	N_{max}	rpm	The maximum mechanical speed is the speed at which the rotor will start to break down, which means that the magnets will detach from the rotor ring. This speed is much higher than the maximum speed that can be obtained by powering the motor.
Motor constant	coils @25°C	K_m	$(Nm)^2/W$	Ratio between torque in newton meter and dissipated heat in Watts [$(Nm)^2/W$]. A higher value of the constant implies that the motor dissipates less heat for the generation of a certain amount of force. The value decreases at higher coil temperatures.
Motor height		H_{motor}	mm	Height of the stator excluding the cable exit.
Motor torque constant	Up to Ic	K_t	Nm/A	Ratio between torque in newton meter and RMS current [A].
Peak current	magnet @ 25°C	I_p	Arms	The peak current [A] the motor can be run at to achieve the specified peak torque.
Peak torque	coils @100°C	T_P	Nm	The peak torque is the force generated by the motor just beyond the saturation point of the motor force constant. The coils will heat up with 6°C/s. The peak torque is determined by the tolerated material expansion due to an increased temperature of the coil. For torque motors this increase is at 6°C/s.
Poles		N_{mgn}	nr	Number of poles.
PTC temperature sensor			Ohm/K	The temperature sensor for the Torque series. This PTC-1k type sensor has a very sudden resistance rise near the critical stator temperature and can be used as a cut off sensor for protection against overheating of the stator. The PTC sensor has a positive coefficient between temperature and resistance.
Rotor ID		ID_R	mm	The inner diameter of the rotor.
Rotor iInertia		J_R	$Kg*m^2$	Moment of inertia of the rotor.
Rotor mass		M_R	g	Mass of the rotor.
Stator mass	ex. cables	M_s	g	Mass of the stator excluding cable mass.
Stator OD		OD_s	mm	The outer diameter of the stator.
Synchronous motor				An electric motor that runs at a speed directly proportional to the frequency of the current used to operate it.
Temperature cut-off sensor				A cut-off sensor is used to protect the motor from damage due to overheating. The sensor has a positive coefficient between temperature and resistance. Near 110°C the resistance increases exponentially. The sensor output can be used as input for the controller to shut off the current to prevent damage to the coils.
Temperature sensor			Ohm/K	A temperature sensor can be used for monitoring the coil temperature. Torque motors are fitted with KTY sensors.
Thermal resistance	coils to mounting surface	R_{th}	K/W	Defines how warm the coil unit will become as a result of the dissipation of power to the surface. Rtherm x dissipated power = [°C/W] x [Watt] = [C] temperature of the coil unit.

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Parameter	Remark	Symbol	Unit	Definition
Thermal time constant	to maximum coil temperature	τ_{th}	s	Time [sec] required for the coil windings to reach [1-1/e=63%] of their maximum temperature during continuous force.
Total mass	ex. cables	M_T	g	The total mass of the rotor and stator excluding cables.
Ultimate current	magnet @ 70°C	I_u	Arms	The ultimate current [A] the motor can be run at to achieve the specified ultimate force. Do not exceed this current.
Ultimate torque @ 20°C/s increase	magnet @ 25°C	T_u	Nm	The torque generated by the motor beyond the saturation point in the non linear area of the motor torque constant. The value of the motor torque constant at ultimate torque is 26% less than the linear value. efficiency of transfer of current to force is lower and causes the coils to heat up faster. For ultimate torque the temperature increase is 20°C/s.
VacRMS				The effective value of a sine shaped alternating current voltage.
Vdc				The direct current bus voltage can be calculated from the AC supply voltage by multiplication Vdc=Vac rms x (√2).
Winding type				The winding type determines balance between maximum speed, force, required current and bus voltage of the coil. N-type windings are optimised for normal currents and regular bus voltages.

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