Series ETS25 – singleturn, digital output, not redundant

Key features ETS25:
- Efficient, fast signal transmission (length of signal lines limited by clock rate)
- Synchronous Serial Interface (SSI, 10 to 18 bit) or
- Serial Peripheral Interface (SPI, 14 bit)

Electrical data ETS25 – singleturn, digital output, not redundant

Output signal	SPI	SSI (binary code)
Effective electrical angle of rotation 1.)	360°	
Independent linearity (best straight line) 1.)	±0,3% @ 360°	
Resolution	14 bit	10 to 18 bit
Supply voltage	5 VDC ±10%	5 to 30 V
Power consumption (no load)	≤ 12 mA	
Insulation voltage 1.)	1000 VAC @ 50 Hz, 1 min	
Insulation resistance 1.)	2 MOhm @ 500 VDC, 1 min	
MTTF (EN29500-2005-1)	2046a	-
Voltage level at output	5 V	±5 V (differential voltage 10 V)
Max. data- / clock rate	siehe details of SPI protocoll	4 MHz

1.) According IEC 60393

Cable/colour assignment – option 05SPI, not redundant

Function:	Option R (round signal cable)	Option F (flatribbon cable)
VSUP	red	Lead 1 (red)
GND	black	Lead 2
CS, MOSI	yellow	Lead 3
CLK	green	Lead 4
DATA	orange	Lead 5
-	brown n/c	

Cable/colour assignment – option SSI

Funktion:	Option R (Rundkabel)	Option F (Flachbandkabel)
VSUP	rot	Lead 1 (red)
GND	schwarz	Lead 2
CLK+	brown	Lead 3
CLK-	orange	Lead 4
DATA-	green	Lead 5
DATA+	yellow	Lead 6

For details on zero point definition and output programming see page 30.

Order Code ETS25 – singleturn, digital output, not redundant							
Description	Selection: standard=**black/bold**, possible options=*grey/italic*						
Series	**ETS25**						
Shaft diameter, shaft length: **Shaft diameter Ø 6 mm, shaft length 22 mm** *Shaft diameter Ø 6.35 mm, shaft length 22 mm* *Custom shaft dimensions [mm] Ø ≤6.35 mm*		**6x22** *6,35x22* *XxXX*					
Supply voltage / output signal: **SPI (14 Bit) / V_{SUP} = 5 VDC ± 10%** **SSI, 16 bit / V_{SUP} = 5 to 30 V** *SSI, custom resolution 10 to 18 bit / V_{SUP} = 5 to 30 V*			**05SPI** **SSI** *SSI [10-18]*				
Operational torque: **Standard torque** *Improved/medium torque*				**-** *MT*			
Shaft sealing: **None** *With shaft sealing*					**-** *D*		
Electrical connection, cable length: **Flat ribbon cable, standard length 0.15** *Flat ribbon cable with custom length [x,xx m]* *Round cable with custom length [x,xx m]* *(max. 1 m for SPI, recommended < 15 cm)*						**F0,15** *FX,XX* *RX,XX*	
Anti-rotation pin, zero point definition: **Pin A** *Pin B* *None (pins removed)* *(no zero point definition possible)*							**A** *B* -

Order example ETS25 – singleturn, digital output, not redundant
Requirement: Shaft Ø 6.00 mm, shaft length 22 mm, 14 Bit/5 VDC/SPI, no shaft sealing, flat ribbon cable 0.15 m, anti-rotation pin B
Example for order code: ETS25 6x22 05SPI F0,15B

Synchronous Serial Interface (SSI) - A simple yet robust interface

The synchronous serial interface (SSI) is a serial interface, i.e. the individual bits are transmitted in chronological order. The basis of data transmission is a shift register in which the encoder provides its current measured value. The rotary encoders function as so-called SSI slaves, because they only supply the values from the shift register at the DO (data out) output on receipt of a clock sequence sent out by the SSI master, the so-called "clock" signal (CLK). This clock signal is applied to the CLK input of the encoder. Both the clock signal and the data signal are transmitted differentially, which makes this type of data interface particularly robust against interference. In short, SSI enables the memory of a sensor to be read out reliably from an external source.

Data transmission
The SSI electronics of the encoder reacts to the first falling edge that arrives via the CLK line of the master, loads the current data into the register and transmits it bit by bit to the receiver with each rising edge of the clock. The composition of the transmitted information is not standardised and varies from manufacturer to manufacturer, sometimes even from product to product.

In MEGATRON's encoders, the position information is transmitted first (starting with the Most Significant Bit MSB, ending with the Least Significant Bit LSB). The maximum value of this information is limited by the number of bits transmitted. This is also the resolution of the measurement data. For example, a resolution of 10 bits corresponds to a number of 210 = 1024 steps, which are divided over the angular range of 360°. Thus, after receiving the position information, it is easy to calculate back to the absolute angle, because each single step would correspond to 360/1024 = 0.35°.
The position information is followed by a bit sequence of status data that can be of great interest for the application. This includes whether the magnetic field acting on the Hall sensor is within the permissible limits (i.e. the distance of the magnet from the sensor). The last bit is the parity bit. This takes the values HIGH or LOW as required, so that the encoder always sends an even number of bits (even parity). The receiver, i.e. the SSI master, must be set to the total length of the transmitted information including the parity bit.

At the end of the process, the master usually does not send any further edges to the encoder via the CLK line. The encoder then waits for a time t_m, (retriggerable monoflop) since the last CLK edge and then updates the data in the shift register. This is therefore the minimum pause time between two consecutive clock sequences when the master requires new, updated measurement data. The exact protocol description of the HTS encoders follows on the next page

Ring shift
However, if clock edges continue to be sent, then the encoder will start transmitting the same data set repeatedly after a zero bit. This procedure is also called ringshift. This makes sense, for example, if the parity bit would be incorrect from the master's point of view, if the data is otherwise corrupt and a new transmission is therefore requested, or if a higher transmission reliability is generally desired by comparing multiple transmissions of the same data. With ring shift, the transmission is also terminated and the latest measurement data is only loaded into the register again when no more clock signals arrive at the encoder for a minimum time t_m.

Early stop
The transmission of the data can be interrupted by the master at any time, e.g. also after the 10th bit. Even then, the internal timer (monoflop) expires, causing the data in the register to be reloaded after the time t_m. In this way, for example, only a part of the encoder data can be read out (e.g. 10 of the available 16 bits, no status data at all) and a higher update rate can be achieved, as the remaining information is simply omitted.

Notes on cable length
The higher the transmission rate (clock rate), the smaller the realisable cable length with SSI. These are physical limits that are not limited by the sensor product itself. A simple blanket statement about the actual realisable length is not easily possible.

The cable length that can actually be realised in the application is influenced by the following factors:
- Quality and design of the cable (shielding, conductor cross-section, conductor resistance, twisted cores, etc.).
- Ambient conditions (sources of interference such as motors, etc.)

We explicitly refer to the RS-422 standard regarding cable lengths.

Protocol description – Synchronous Serial Interface (SSI)

The HTS25K SSI encoder provides a 10-bit to 18-bit absolute position output, while 16 bit is the standard (ex works) configuration. This means that the full rotation angle (360°) is divided into steps of the respective resolution (16 bits yields 65.536 steps of approx. 0.005 degrees).
Standard configuration (16 bit output) yields the following pulse train, consisting both of position and status data:

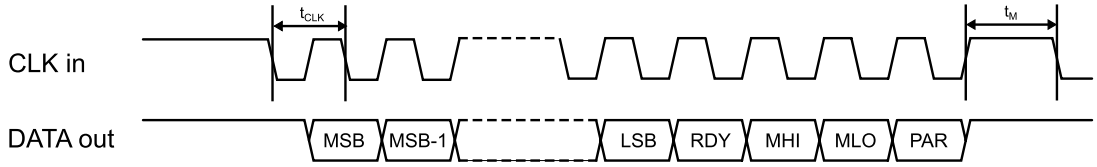
20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
16 bits position data																	3 bits status data			

The data structure for any resolution is as follows:

Position data (10 to 18 bits)				Status (3-bit)			Parity 1 bit
MSB	MSB-1	...	LSB	RDY	MHI	MLO	PAR

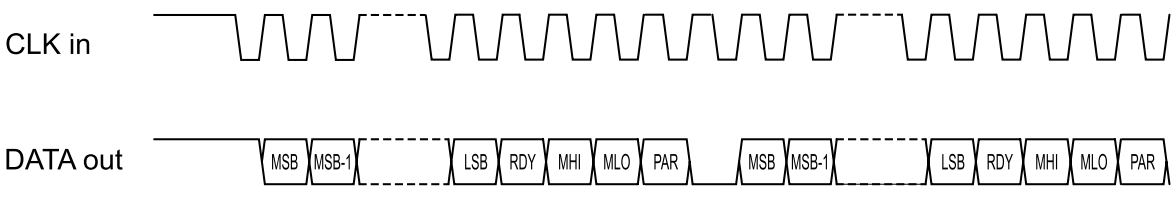
Abbreviation	Description
MSB to LSB	n-bits position data, selectable from 10 to 18 bits ex works, standard is 16 bit
RDY	The encoder is ready (if value is HIGH).
MHI	This indicates that the magnet strength detected by the Hall chip is too strong. If this is consistently HIGH, change to a weaker magnet or increase the distance between the encoder and the magnet. The value for this alarm is displayed as 1.
MLO	This indicates that the magnet strength detected by the Hall chip is too weak. If this is consistently HIGH, change to a stronger magnet or decrease the distance between the encoder and the magnet. The value for this alarm is displayed as 1.
PAR	Parity is even

Data is transmitted according to the following timing diagram:



Symbol	Description	Min.	Typ.	Max.
t_{CLK}	Serial clock period	4 µs		$t_{M/2}$
t_M	monoflop, time between two successive SSI reads		16.5 µs	18 µs

Data is latched on the first CLK falling edge and is transmitted on the next falling edge. Both signals are transmitted differentially and therefore have 2 connections (+/-) each. Data will be refreshed when the next monoflop (t_M) expires. If another clock train is sent before this time expires, the same position data is output, and the data is separated by a single low bit:



Protocol description ETS25 – Serial Peripheral Interface (SPI)

Introduction
The encoder is configured as a Slave node. The serial protocol of the is a three wires protocol (/SS, SCLK, MOSI-MISO):

- /SS output is a 5 V tolerant digital input
- SCLK output is a 5 V tolerant digital input
- MOSI-MISO output is a 5 V tolerant open drain digital input/output

Basic knowledge of the standard SPI specification is required for the good understanding of the present section.

Even clock changes are used to sample the data. The positive going edge shifts a bit to the Slave's output stage and the negative going edge samples the bit at the Master's input stage.

MOSI (Master Out Slave In)
The Master sends a command to the Slave to get the angle information.

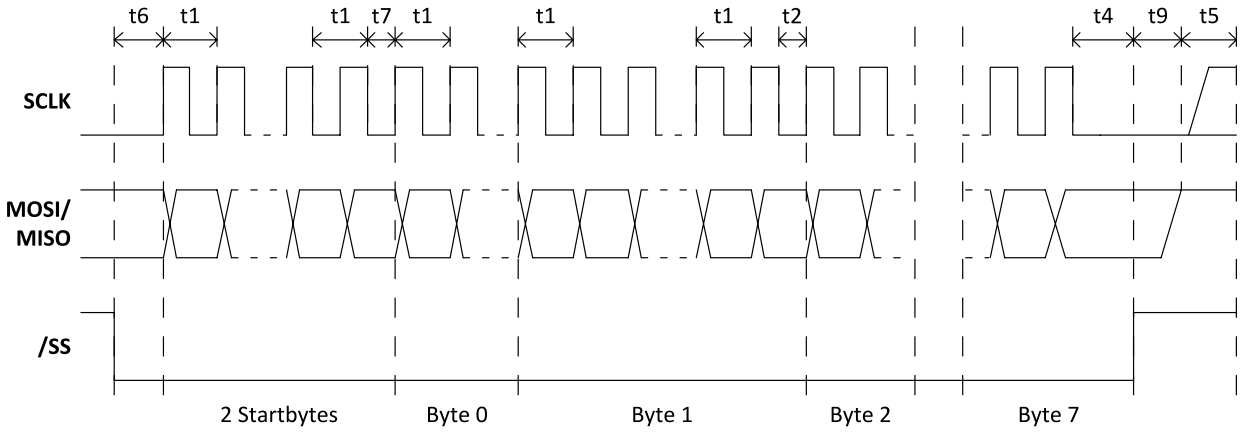
MISO (Master In Slave Out)
The MISO of the slave is an open-collector stage. Due to the capacitive load, a >1 kΩ pull-up is used for the recessive high level (in fast mode). Note that MOSI and MISO use the same physical wire of the ETS25.

/SS (Slave Select)
The /SS output enables a frame transfer. It allows a re-synchronization between Slave and Master in case of a communication error.

Master Start-Up
/SS, SCLK, MISO can be undefined during the Master start-up as long as the Slave is re-synchronized before the first frame transfer.

Slave Start-Up
The slave start-up (after power-up or an internal failure) takes 16 ms. Within this time /SS and SCLK is ignored by the Slave. The first frame can therefore be sent after 16 ms. MISO is Hi-Z (i.e. Hi-Impedance) until the Slave is selected by its /SS input. The encoder will cope with any signal from the Master while starting up.

Timing
To synchronize communication, the Master deactivates /SS high for at least t5 (1.5 ms). In this case, the Slave will be ready to receive a new frame. The Master can re-synchronize at any time, even in the middle of a byte transfer. Note: Any time shorter than t5 leads to an undefined frame state, because the Slave may or may not have seen /SS inactive.



Protocol description ETS25 – Serial Peripheral Interface (SPI) (continuation)

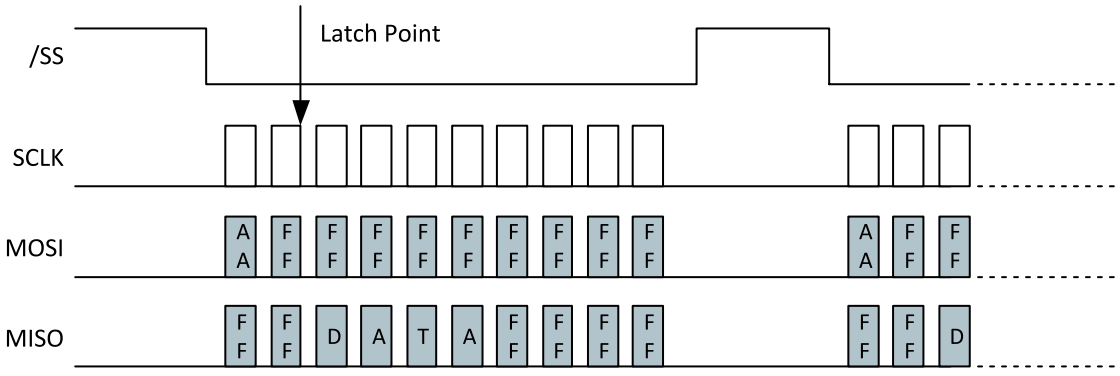
Description Timings

Timings	Min	Max	Remarks
t1	2.3 µs	-	No capacitive load on MISO. t1 is the minimum clock period for any bits within a byte.
t2	12.5 µs	-	t2 the minimum time between any other byte
t4	2.3 µs	-	Time between last clock and /SS=high=chip de-selection
t5	300 µs	-	Minimum /SS = Hi time where it's guaranteed that a frame re-synchronizations will be started
t5	0 µs	-	Maximum /SS = Hi time where it's guaranteed that NO frame re-synchronizations will be started.
t6	2.3 µs	-	The time t6 defines the minimum time between /SS = Lo and the first clock edge
t7	15 µs	-	t7 is the minimum time between the StartByte and the Byte0
t9	-	< 1 µs	Maximum time between /SS = Hi and MISO Bus HighImpedance
$T_{Startup}$	-	< 10 ms	Minimum time between reset-inactive and any master signal change

Slave Reset
On internal soft failures the Slave resets after 1 second or after an (error) frame is sent. On internal hard failures the Slave resets itself. In that case, the Serial Protocol will not come up. The serial protocol link is enabled only after the completion of the first synchronization (the Master deactivates /SS for at least t5).

Frame Layer

Command Device Mechanism
Before each transmission of a data frame, the Master should send a byte AAh to enable a frame transfer. The latch point for the angle measurement is at the last clock before the first data frame byte.



Data Frame Structure

A data frame consists of 10 bytes:

- 2 start bytes (AAh followed by FFh)
- 2 data bytes (DATA16 – most significant byte first)
- 2 inverted data bytes (/DATA16 - most significant byte first)
- 4 all-Hi bytes

The Master should send AAh (55h in case of inverting transistor) followed by 9 bytes FFh. The Slave will answer with two bytes FFh followed by 4 data bytes and 4 bytes FFh.

Protocol description ETS25 – Serial Peripheral Interface (SPI) (Fortsetzung)

Timing
There are no timing limits for frames: a frame transmission could be initiated at any time. There is no interframe time defined.

Data Structure
The DATA16 could be a valid angle or an error condition. The two meanings are distinguished by the LSB.

DATA16: Angle A[13:0] with (Angle Span)/2^{14}

Most Significant Byte								Least Significant Byte							
MSB							LSB	MSB							LSB
A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0	0	1

DATA16: Error

Most Significant Byte								Least Significant Byte							
MSB							LSB	MSB							LSB
E15	E14	E13	E12	E11	E10	E9	E8	E7	E6	E5	E4	E3	E2	E1	E0

DATA16: Error

BIT	Name	Description
E0	0	
E1	1	
E2	F_ADCMONITOR	ADC Failure
E3	F_ADCSATURA	ADC Saturation (Electrical failure or field too strong)
E4	F_RGTOOLOW	Analog Gain Below Trimmed Threshold (Likely reason: field too weak)
E5	F_MAGTOOLOW	Magnetic Field Too Weak
E6	F_MAGTOOHIGH	Magnetic Field Too Strong
E7	F_RGTOOHIGH	Analog Gain Above Trimmed Threshold (Likely reason: field too strong)
E8	F_FGCLAMP	Never occurring in serial protocol
E9	F_ROCLAMP	Analog Chain Rough Offset Compensation: Clipping
E10	F_MT7V	Device Supply VDD Greater than 7V
E11	-	
E12	-	
E13	-	
E14	F_DACMONITOR	Never occurring in serial protocol
E15	-	

Angle Calculation
All communication timing is independent (asynchronous) of the angle data processing. The angle is calculated continuously by the Slave every 350 µs at most. The last angle calculated is hold to be read by the Master at any time. Only valid angles are transferred by the Slave, because any internal failure of the Slave will lead to a soft reset.

Error Handling
In case of any errors listed above, the Serial protocol will be initialized and the error condition can be read by the master. The slave will perform a soft reset once the error frame is sent. In case of any other errors (ROM CRC error, EEPROM CRC error, RAM check error, intelligent watchdog error…) the Slave's serial protocol is not initialized. The MOSI/MISO output will stay Hi-impedant (no error frames are sent).

Series ETS25X – singleturn, SPI output, redundant

Key features ETS25X:

- Independent signal processing. The ETS25X rotary encoder electronics are based on one Hall IC in which two semiconductor elements independently capture, evaluate and output measured values
- Supply voltage, signal output and ground are galvanically insulated => separate electrical connections
- Supply voltage: 2 x 5 VDC ±10%
- Signal output: 2 x SPI
- Maximum allowed signal cable length (each) 0.6 m

Electrical data ETS25X – singleturn, SPI output, redundant

Effective electrical angle of rotation 1.)	360°
Sense of rotation (when looking at the shaft, from the front)	Clockwise/clockwise (ganging)
Independent linearity (best straight line) 1.)	±0.4% @ 360°
Absolute linearity 1.)	±0.8% @ 360°
Output signal	SPI
Resolution	14 Bit
Update rate	200 µs
Supply voltage	5 VDC ±10%
Power consumption (no load)	≤ 24 mA
Insulation voltage 1.)	1000 VAC @ 50 Hz, 1 min
Insulation resistance 1.)	2 MOhm @ 500 VDC, 1 min
MTTF (EN29500-2005-1)	2046a

1.) According IEC 60393

Cable and pin assignment ETS25X

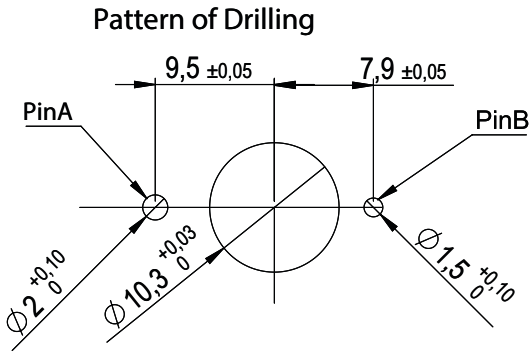
Function:	Option F:	Explanation:
VSUP 1	Lead 1 (red)	5 pol. flat ribbon cable no. 1
GND 1	Lead 2	5 pol. flat ribbon cable no. 1
Data 1	Lead 3	5 pol. flat ribbon cable no. 1
Clock 1	Lead 4	5 pol. flat ribbon cable no. 1
Chipselect 1	Lead 5	5 pol. flat ribbon cable no. 1
VSUP 2	Lead 1 (red)	5 pol. flat ribbon cable no. 2
GND 2	Lead 2	5 pol. flat ribbon cable no. 2
Data 2	Lead 3	5 pol. flat ribbon cable no. 2
Clock 2	Lead 4	5 pol. flat ribbon cable no. 2
Chipselect 2	Lead 5	5 pol. flat ribbon cable no. 2

For details on zero point definition and output programming see page 30.

Order Code ETS25X – redundant, singleturn, digital output							
Description	Selection: standard=**black/bold**, possible options=*grey/italic*						
Series	**ETS25X**						
Shaft diameter, shaft length: **Shaft diameter Ø 6 mm, shaft length 22 mm** *Shaft diameter Ø 6.35 mm, shaft length 22 mm* *Custom shaft dimensions [mm] Ø ≤ 6.35 mm*		**6x22** *6,35x22* *XxXX*					
Supply voltage / output signal: **5 VDC ± 10% / SPI (14 Bit), redundant**			**05SPI**				
Operational Torque: **Standard torque** *Improved/medium torque*				**-** *MT*			
Shaft sealing: **None** *With shaft sealing*					**-** *D*		
Electrical connection, cable length: **Flat ribbon cable, standard length 0.15 m, two arranged above each other** *Flat ribbon cable with custom length [x,xx m], two arranged above each other* *Round cable with custom length [x,xx m]* *(max. 0.6 m)*						**F0,15** *FX,XX* *RX,XX*	
Anti-rotation pin, zero point definition: *Pin A* **Pin B** *None (pins removed)* *(no zero point definition possible)*							*A* **B** -

Order example ETS25X
Specifications: Shaft Ø 6.00 mm, shaft length 22 mm, 14 Bit/5 VDC/SPI, no shaft sealing, two 5 pol. flat ribbon cables arranged one above the other with cable length 0.15 m for each flat ribbon cable, anti-rotation pin B
Example for order code: ETS25X 6x22 05SPI F0,15B

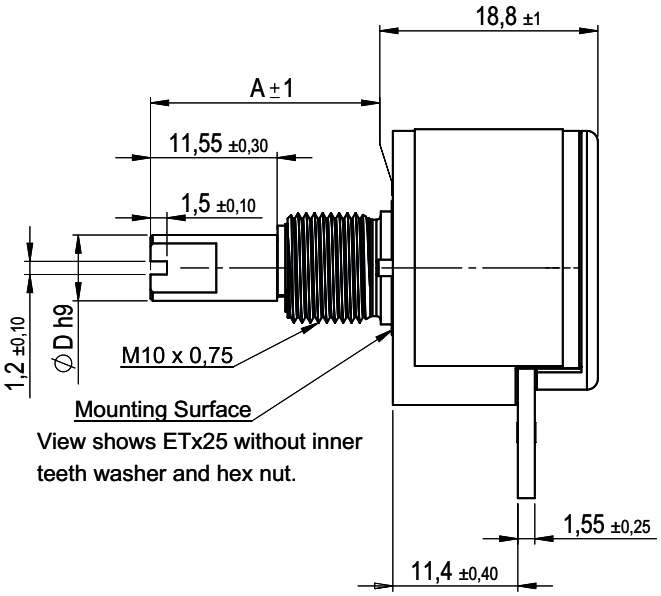
Drilling pattern

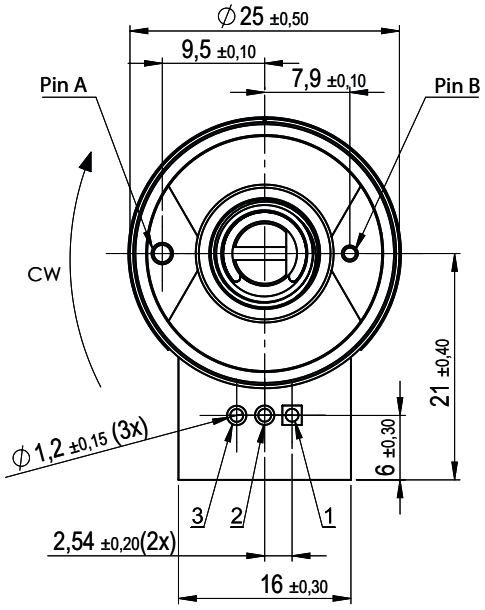


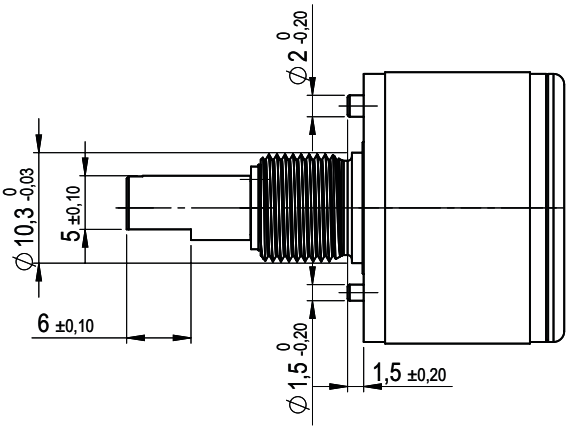
Either pin A or pin B must be chosen as anti-rotation pin. Please select by specifying the variant in the order code.The unused pin can be left out when drilling.

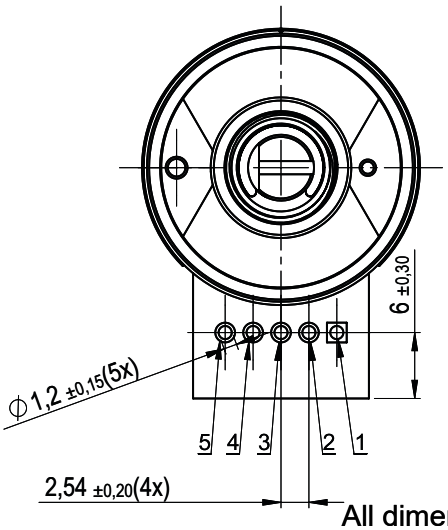
Drawings ETx25 – with solder holes (option L)

Option L







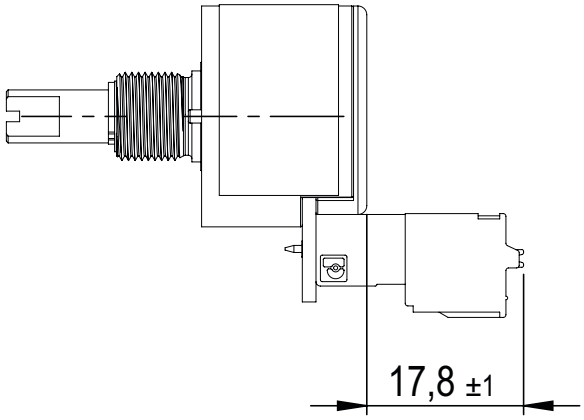


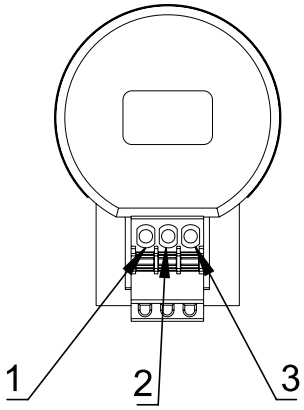
All dimensions in mm

Standard shaft dimensions / tolerances	
Shaft length A	22 +/- 1 mm
Shaft diameter D	6 h9 mm, 6.35 h9 mm
Shaft flattening (D-flat)	6 +/- 0.1 mm

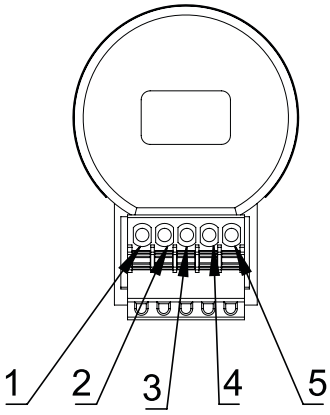
Drawings ETx25 – clamping terminals (option K) and cable versions (options R and F)

Option K (clamping terminals)



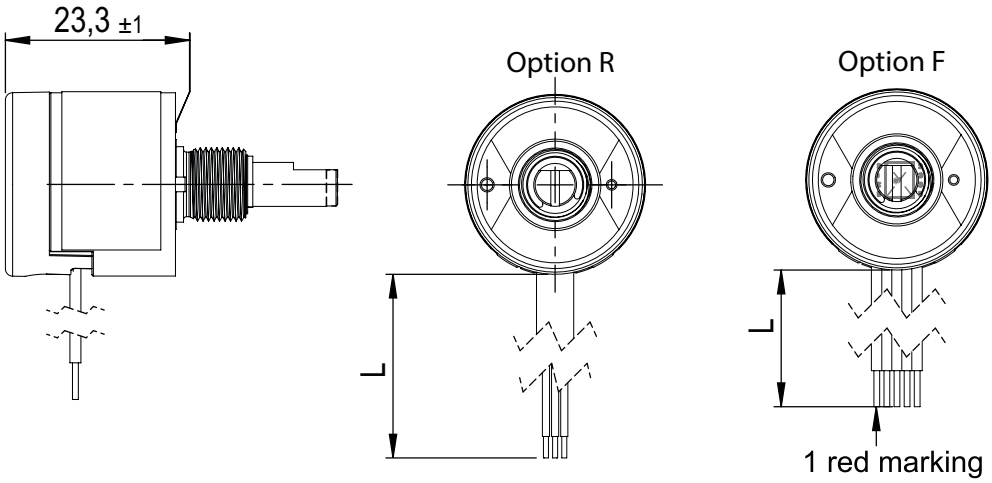


Connector Phönix:
MCV0,5-3-G2,5
FK-MC0,5-3-St2,5



Connector Phönix:
MCV0,5-5-G2,5
FK-MC0,5-5-St2,5

Options F (flat ribbon cable) and R (round control cable)



Cable specs for option F (flat ribbon cable) and R (round control cable)						
Option	**Standard cable length L**	**Number of single strands (depends on electronics)**	**Cable sheath Ø or width**	**Single strands cross section**	**Allowed tolerance (L)**	**Minimum bending radius**
R	Standard 1000 mm	3	4.3 mm	AWG26	-20 mm to +50 mm	3 x D Ø (D = cable sheath diameter Ø)
		6	5.2 mm			
		8	5.6 mm			
		12	6 mm	AWG28		
F	150 mm	3 to 12	ca. 1.25 per strand	AWG26	-20 mm to +25 mm	-
Cables without cable shield						

(*) Tolerances according IPC Association

Cable length tolerances – custom lengths	
Length L	**Tolerance**
≤ 0.3 m	+25 mm / -20 mm
> 0.3 m - 1.5 m	+50 mm / -20 mm
> 1.5 m - 3 m	+100 mm / -40 mm
> 3 m - 7.5 m	+150 mm / -60 mm
Cable harness length measured from sensor surface or soldering pad including connector. Minimum cable length: 0.08 m (for round cable), 0.05 m for ribbon cable	

Mechanical and environmental data, miscellaneous	
Mechanical angle of rotation 1.)	Endless or 320° (270°/180°/90°), ±5° with mechanical stop option
Lifetime 2.)	≤ 100 Mio. shaft rotation movements Option D: Sealing of the shaft is working up to 200 000 shaft rotation movements
Bearing	Sleeve bearing
Max. operational speed	100 rpm (< 1 min. 800 rpm)
Operational torque	0.1 ≤ M ≤ 0.6 Ncm (without shaft sealing) 0.3 ≤ M ≤ 1.3 Ncm (@RT, 10 rpm) (with increased torque)
Operating temperature range	Standard: -40 to +85 °C (cable fixed installed) Option TS: -25 to +70 °C
Storage temperature range	Standard: -40 to +105 °C Option TS: -40 to +90 °C (teach-In multiturn)
Protection grade (IEC 60529) front side	From shaft side: ▪ IP40 standard ▪ IP55M (IP66S) with shaft sealing (option D)
Protection grade (IEC 60529) rear side	▪ IP50 Solder holes / clamping terminals (solder holes / connector excluded) ▪ IP66 flat ribbon and round signal cable (cable ends excluded) ▪ IP00 option TS (teach-in multiturn)
Vibration (DIN EN 60068-2-6)	±1.5 mm / 30 g / 10 to 2000 Hz / 16 frequency cycles (3x4 h)
Shock (DIN EN 60068-2-27)	100 g / 6 ms / half sine (3x6 shocks)
Housing diameter	Ø 25 mm
Housing depth	see drawings
Shaft diameter	Standards: Ø 6 mm, Ø 6.35 mm Option: User defined shaft diameter [mm]
Max. radial load	1 N
Max. axial load	1 N
Mass (circa)	▪ ca. 26 g (option L: solder lugs) ▪ ca. 60 g (option R: cable, valid for 1 m only) ▪ ca. 32 g (option F: flat ribbon cable, valid for 15 cm only) ▪ ca. 27 g (option K: clamping terminals) ▪ ca. 31 g (option TS: teach-In multiturn)
Connection type	▪ Solder lugs (option L) ▪ Ribbon cable (option F) ▪ Cable (option R) ▪ Connector (option K)
Connection position	Radial
Sensor mounting	Bushing via M10 x 0,75
Fastening parts included in delivery	Hex nut and tooth washer, if option D is ordered then an additional O-Ring is part of delivery as sealing between mounting panel and rotary encoder.
Fastening torque mounting nut	≤ 3 Nm
Material shaft	Stainless steel

1.) According IEC 60393
2.) Determined by climatic conditions according to IEC 68-1, para. 5.3.1 without load collectives

Immunity / Electrostatic Discharge	
EN 61000-4-3 RF sine wave	Class A
EN 61000-4-6 Conducted sine wave	Class A
EN 61000-4-8 Power frequency magnetic fields	Class A
EN 61000-4-2 ESD 3.)	Class B

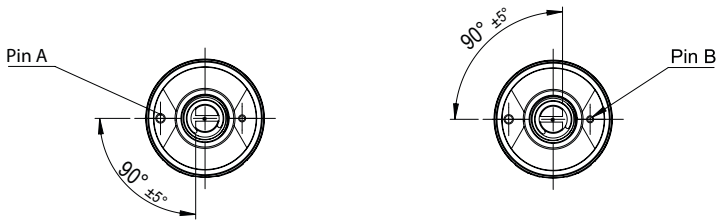
3.) Not tested for Option TS

Definition of the zero position / anti-rotation pin

Output at the zero point:
ETA25 (analogue outputs): Output signal 0% full scale (F. S.)
ETP25 (PWM output): duty cycle 10% (10% duty cycle)
ETS25 (serial output): Output signal 0% full scale (F. S.)
ETI25 (incremental output): The index signal is output (Z)

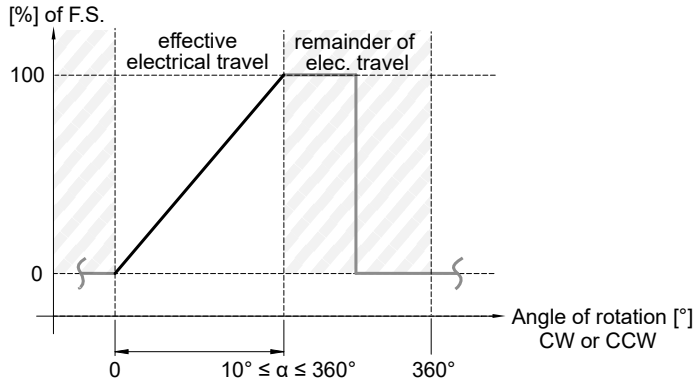
Position of the zero position:

Option anti-rotation pin A	Zero position when shaft flattening faces anti-rotation pin A
Option anti-rotation pin B	Zero position when shaft flattening faces anti-rotation pin B



Signal definition for custom rotation angles (without mechanical stop)

Custom angles <360°	When programming the electrical angle of rotation of <360°, the remaining non-effective range of rotation is divided equally into high and low. Valid only for encoders without mechanical stop!



Mechanical stop and centre detent for manual encoder applications

- A mechanical stop limits the rotation to either 320°, 270°, 180° or 90° (±5°). Other angles are not available. Due to the mechanical tolerances (±5°), the effective electrical angle is reduced by 10°.
- Optionally a centre detent can be selected in addition to the mechanical stop. It enables the operator to e. g. feel the centre position when operating the encoder by hand
- The zero point definition for mechanical stop option differs from the standard zero point definition. Only drilling pattern B (pin B) is available. See the details below.

Mechanical stop only: relationship between mechanical and effective electrical angle of rotation

Mechanical angle of rotation (±5°)	Effective electrical angle of rotation (±0.5°)
320°	310°
270°	260°
180°	170°
90°	80°