maxon EC motor ironless winding
Technology – short and to the point

Characteristics of the **maxon EC motors** with ironless winding:
- Brushless DC motor (BLDC)
- Long service life
- Highly efficient
- Linear motor characteristics, excellent control properties
- Ironless winding system maxon with three phases in the stator
- Lowest electrical time constant and low inductance
- No detent
- Good heat dissipation, high overload capacity
- Rotating NdFeB permanent magnet with 1 or 2 pole pairs

Characteristics of the **maxon ECX SPEED** range:
- Power optimized, with high speeds up to 120 000 rpm
- Robust design
- Various types: e.g. short/long, sterilizable
- Lowest residual imbalance
- Easily configured online
- Fast delivery

Characteristics of the **maxon EC** range:
- Power-optimized, with high speeds of up to 25,000 rpm
- Robust design
- Lowest residual imbalance

Characteristics of the **maxon EC-max** range:
- attractive price-performance ratio
- robust steel casing
- speeds of up to 20 000 rpm
- rotor with 1 pole pair

Characteristics of the **maxon ECX PRIME and EC-4pole** range:
- Highest power density thanks to rotor with 2 pole pairs
- Knitted winding system maxon with optimised interconnection of the partial windings
- Speeds of up to 50 000 rpm
- High-quality magnetic return material to reduce eddy current losses
- Mechanical time constants below 3 ms
- Special version

Legend
The commutation angle is based on the length of a full commutation sequence (360°e). The length of a commutation interval is therefore 60°e.
The commutation rotor position is identical to the motor shaft position for motors with 1 pole pair. The values of the shaft position are halved for motors with 2 pole pairs.

Program

- **ECX SPEED**
- **ECX PRIME**
- **EC**
- **EC-max**
- **EC-4pole**

- **with Hall sensors**
- **sensorless**
- **with integrated electronics**
- **sterilizable**
- **heavy duty**

1 Flange, front
2 Housing
3 Laminated steel stack
4 Winding
5 Permanent magnet
6 Shaft
7 Print with Hall sensors
8 Control magnet
9 Ball bearing
10 Flange, rear

Electronical commutation

Block commutation
Rotor position is reported by three in-built Hall sensors. The Hall sensors arranged offset by 120° provide six different signal combinations per revolution. The three partial windings are now supplied in six different conducting phases in accordance with the sensor information. The current and voltage curves are block-shaped. The switching position of each electronic commutation is offset by 30° from the respective torque maximum.

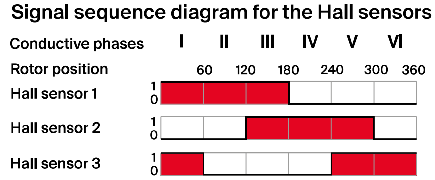
Properties of block commutation
- Relatively simple and favorably priced electronics
- Torque ripple of 14%
- Controlled motor start-up
- High starting torques and accelerations possible
- Servo drives, Start/stop operation
- Positioning tasks
- The data of the maxon EC motors are determined with block commutation.

Sensorless block commutation
The rotor position is determined using the progression of the induced voltage. The electronics evaluate the zero crossing of the induced voltage (EMF) and commute the motor current after a speed dependent pause (30°e after EMF zero crossing).
When stalled or at low speed, the voltage signal is too small and the zero crossing cannot be detected precisely. This is why special algorithms are required for starting (similar to stepper motor control).
To allow EC motors to be commuted without sensors in a Δ arrangement, a virtual star point is usually created in the electronics.

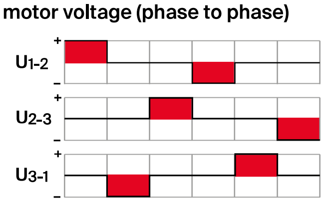
Properties of sensorless commutation
- Torque ripple of 14% (block commutation)
- No defined start-up
- Not suitable for low speeds and for dynamic applications
- Continuous operation at higher speeds (Fans, mills, drills)

Block commutation

Signal sequence diagram for the Hall sensors



Supplied motor voltage (phase to phase)



Sensorless commutation

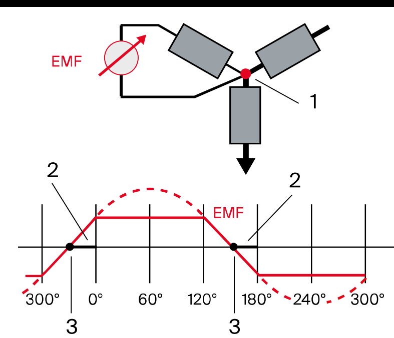
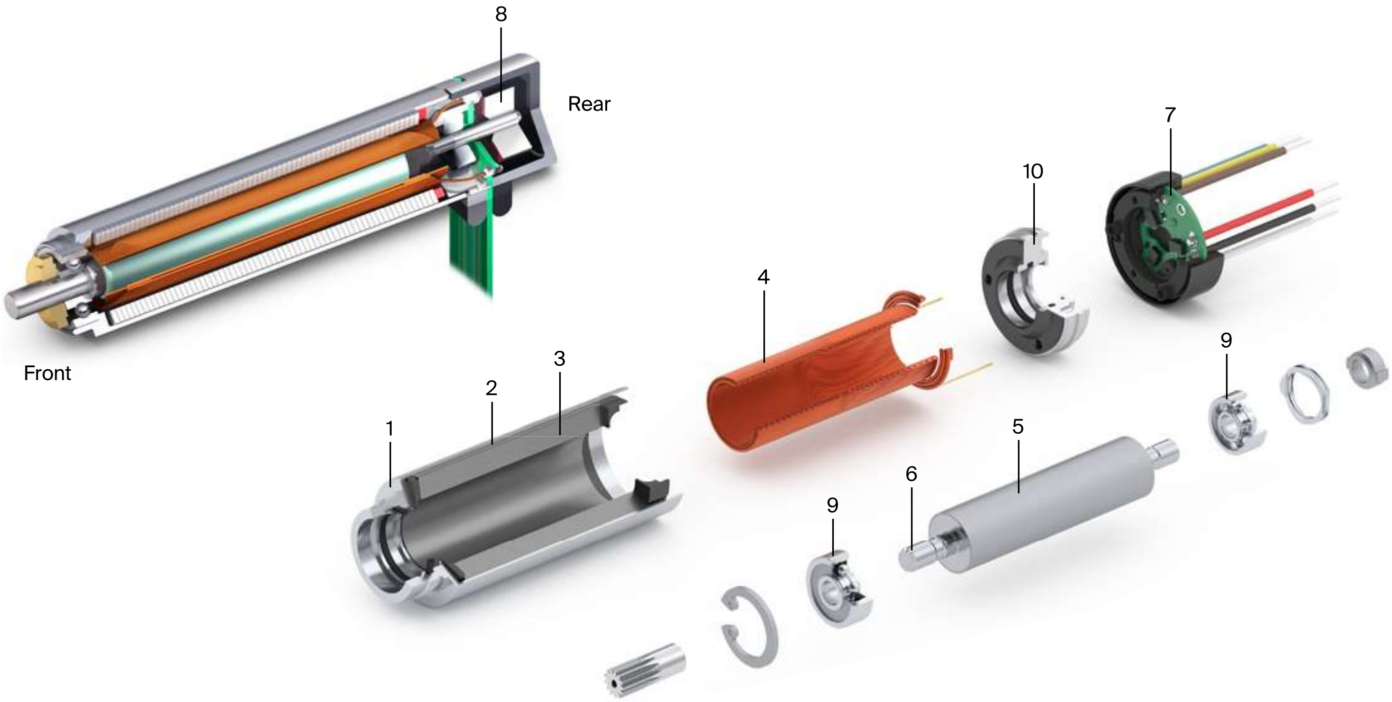


Diagram applies to phase 1



Sinusoidal commutation
The high resolution signals from the encoder or resolver are used for generating sine-shape motor currents in the electronics. The currents through the three motor windings are related to the rotor position and are shifted at each phase by 120° (sinusoidal commutation). This results in the very smooth, precise running of the motor and, in a very precise, high quality control.

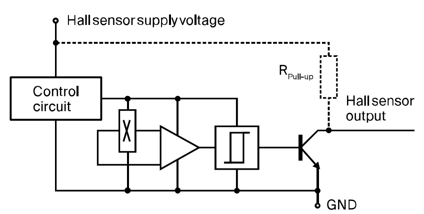
Properties of sinusoidal commutation
- More expensive electronics
- Field-oriented control (FOC)
- No torque ripple
- Very smooth running, even at very low speeds
- Approx. 5% more continuous torque compared to block commutation
- Highly dynamic servo drives
- Positioning tasks

Legend
1 Star point
2 Time delay 30°e
3 Zero crossing of EMF

Hall sensor circuit

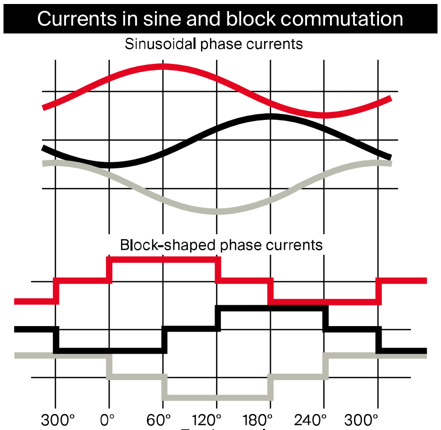
The open collector output of Hall sensors does not normally have its own pull-up resistance, as this is integral in maxon controllers. Any exceptions are specifically mentioned in the relevant motor data sheets.

Wiring diagram for Hall sensors



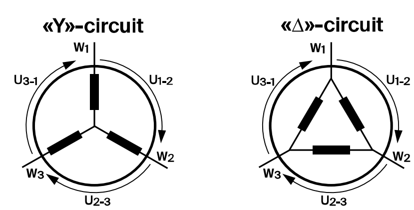
The power consumption of a Hall sensor is typically 4 mA (for output of Hall sensor = “HI”).

Currents in sine and block commutation



Winding arrangement

The maxon rhombic winding is divided into three partial windings, each shifted by 120°. The partial windings can be connected in two different manners - “Y” or “Δ”. This changes the speed and torque inversely proportional by the factor $\sqrt{3}$.
However, the winding arrangement does not play a decisive role in the selection of the motor. It is important that the motor-specific parameters (speed and torque constants) are in line with requirements.



Bearings and service life

The long service life of the brushless design can only be properly exploited by using pre-loaded ball bearings.
- Bearings designed for tens of thousands of hours
- Service life is affected by maximum speed, residual unbalance and bearing load

For further explanations, please see page 190 or “The selection of high-precision microdrives” by Dr. Urs Kafader.

maxon EC motor iron-cored winding
Technology – short and to the point

Characteristics of the **maxon EC motors** with iron winding:
– Brushless DC motor (BLDC)
– Long service life
– Comparatively high inertia
– Motor characteristics may vary from the strongly linear behaviour
– Hall sensor signals utilizable for simple speed and position control
– Multipole NdFeB permanent magnet
– Smaller commutation steps
– Winding with iron core and several teeth per phase in the stator
– Low detent torque
– Good heat dissipation, high overload capacity

Properties of the **maxon ECX TORQUE-**Programs:
– Highly dynamic due to internal, multipole rotor
– Mechanical time constants below one millisecond
– High torque density
– Easily configured online
– Fast delivery

Properties of the **maxon IDX** program:
– High continuous torque
– High power density
– IP65-protected design
– Easily configured online

Characteristics of the **maxon EC-i** program:
– Highly dynamic due to internal, multipole rotor
– Mechanical time constants below 3 ms
– High torque density
– Speeds of up to 15,000 rpm

Properties of the **maxon ECX-FLAT** and **EC-flat** programs:
– Attractive price-performance ratio
– High torques due to external, multipole rotor
– Excellent heat dissipation at higher speeds thanks to open design
– Variants with open rotor or fan for even higher torques
– Flat design for when space is limited

Program

– **ECX TORQUE**
– **IDX**
– **ECX FLAT**
– **EC-i**
– **EC flat**

– **with Hall sensors**
– **sensorless**
– **with integrated electronics**

1 Flange, front
2 Housing
3 Laminated steel stack
4 Winding
5 Permanent magnet
6 Shaft
7 Print with Hall sensors
8 Ball bearing
9 Spring (bearing preload)
10 Flange, rear

Electronical commutation

Block commutation
Rotor position is reported by three built-in Hall sensors which deliver six different signal combinations per commutation sequence. The three phases are powered in six different conducting phases in line with this sensor information. The current and voltage curves are block-shaped. The switching position of every electronic commutation lies symmetrically around the respective torque maximum.

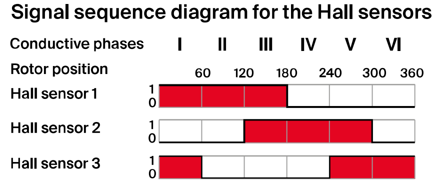
Properties of block commutation
– Relatively simple and favorably priced electronics
– Controlled motor start-up
– High starting torques and accelerations possible
– Servo drives, start/stop operation
– Positioning tasks
– The data of the maxon EC motors are determined with block commutation.

Sensorless block commutation
The rotor position is determined using the progression of the induced voltage. The electronics evaluate the zero crossing of the induced voltage (EMF) and commute the motor current after a speed dependent pause (30°e after EMF zero crossing).
When stalled or at low speed, the voltage signal is too small and the zero crossing cannot be detected precisely. This is why special algorithms are required for starting (similar to stepper motor control). To allow EC motors to be commuted without sensors in a Δ arrangement, a virtual star point is usually created in the electronics.

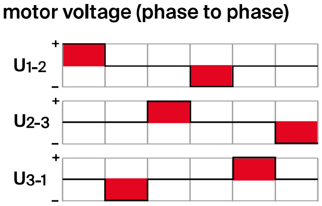
Properties of sensorless commutation
– No defined start-up
– Not suitable for low speeds and for dynamic applications
– Continuous operation at higher speeds (Fans, pumps)

Block commutation

Signal sequence diagram for the Hall sensors



Supplied motor voltage (phase to phase)



Sensorless commutation

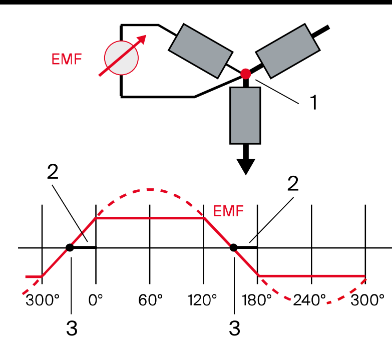
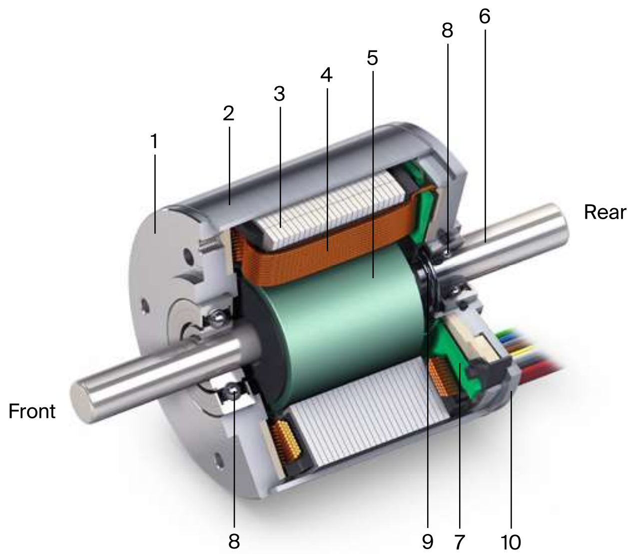
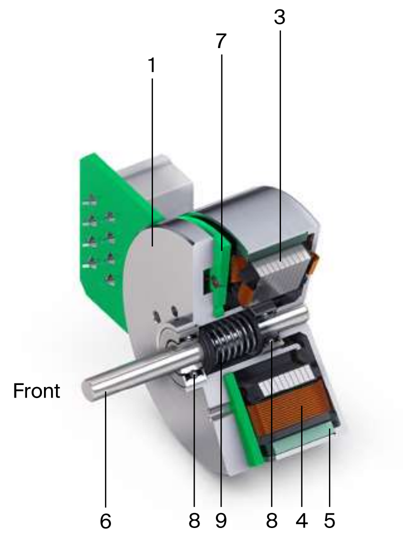


Diagram applies to phase 1

Legend
The commutation angle is based on the length of a full commutation sequence (360°e). The length of a commutation interval is therefore 60°e.
The values of the shaft position can be calculated from the commutation angle divided by the number of pole pairs.



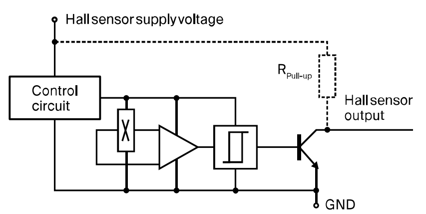


Sinusoidal commutation
Sinusoidal commutation or field-oriented control (FOC) for EC motors with grooved winding is possible. The main benefit of sinusoidal commutation – the smooth operation – only comes into play to a limited degree due to the detent.

Hall sensor circuit

The open collector output of Hall sensors does not normally have its own pull-up resistance, as this is integral in maxon controllers. Any exceptions are specifically mentioned in the relevant motor data sheets.

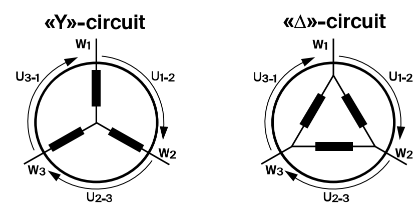
Wiring diagram for Hall sensors



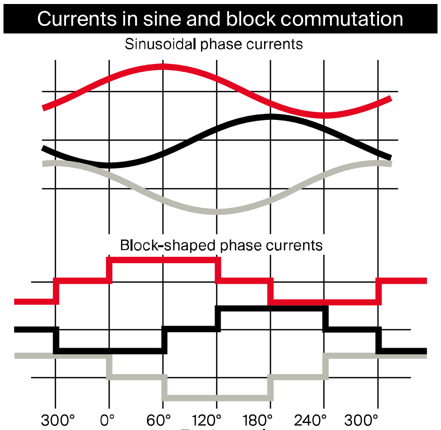
The power consumption of a Hall sensor is typically 4 mA (for output of Hall sensor = “HI”).

Winding arrangement

The winding is divided into 3 partial windings which have several stator teeth each. The partial windings can be connected in two different manners - “Y” or “Δ”. This changes the speed and torque inversely proportional by the factor $\sqrt{3}$.
However, the winding arrangement does not play a decisive role in the selection of the motor. It is important that the motor-specific parameters (speed and torque constants) are in line with requiremenats.



Currents in sine and block commutation



Bearings and service life

The long service life of the brushless design can only be properly exploited by using preloaded ball bearings.
- Bearings designed for tens of thousands of hours
- Service life is affected by maximum speed, residual imbalance and bearing load

For further explanations, please see page 190 or “The selection of high-precision microdrives” by Dr. Urs Kafader.

Legend
1 Star point
2 Time delay 30°
3 Zero crossing of EMF

In **EC frameless motor** kits, rotor and stator are delivered separately, without bearings and motor shaft. The motor is operational only when the two components are assembled

Characteristics of the **maxon EC frameless motors:**
- Brushless DC (BLDC) direct drive motor
- Long service life
- High torque grace to multi-pole motor design with NdFeB permanent magnet
- Winding with iron core and several teeth per phase in the stator
- Low detent torque
- Motor characteristics may vary from the strongly linear behavior
- Good heat dissipation, high overload capacity
- Sensor for supervising the temperature (NTC hot conductor)
- Space-saving integration into the application
- Hall sensor signals utilizable for simple speed and position control
- Flat design for space saving application integration
- Hollow shaft for transfering cables, vacuum lines, light, ...

Characteristics of the **maxon EC frameless flat** program:
- High torques due to external, multipole rotor
- Speeds of up to 10 000 rpm
- Hall sensor signals for simple speed and position control.

Properties of the maxon **EC frameless Dynamic Torque (DT)** Programs:
- Highly dynamic due to internal, multipole rotor
- Mechanical time constants below one millisecond
- High torque density
- Speeds of up to 5000 rpm
- optional TSX encoder with additional commutation signals

Program

- **EC frameless flat**
- **EC frameless DT**

- **with Hall sensors**
- **sensorless**

1 Stator packet
2 Winding
3 Rotor
4 Permanent magnet
5 Circuit board with Hall sensors

Electronical commutation

Block commutation with Hall sensors
The rotor position is reported by three built-in Hall sensors or by the optional TSX encoder. The Hall sensors are set at an angle of 120° to one another and provide six different signal combinations per turn. The three partial windings are now powered in six different conductive phases, depending on the sensor information. The current and voltage supply are block-shaped. The switching position of each electronic commutation is offset 30° from the respective torque peak.

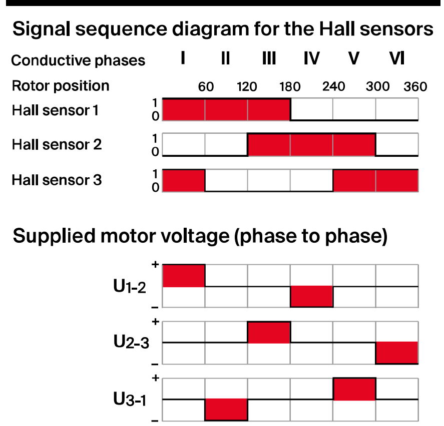
Properties of block commutation
- Relatively simple and favorably priced electronics
- Torque ripple of 14%
- Controlled motor start-up
- High starting torques and accelerations possible
- Servo drives, Start/stop operation
- Positioning tasks
- The data of the maxon EC motors are determined with block commutation.

Sinusoidal commutation
Sinusoidal commutation or field-oriented control (FOC) for frameless EC motors with slotted winding is possible. However, the main benefit of sinusoidal commutation – the smooth operation – only comes into play to a limited degree due to the detent.

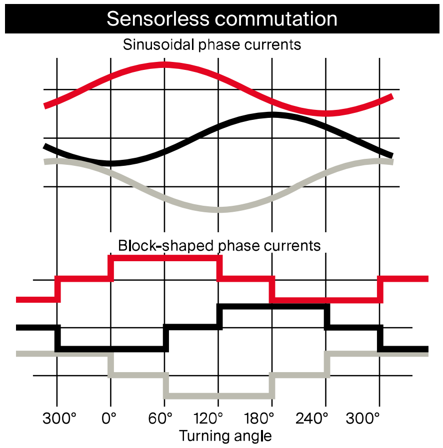
The high-resolution signals from the encoder are used for generating sine-shape motor currents in the electronics. The currents through the three motor windings are related to the rotor position and are shifted at each phase by 120° (sinusoidal commutation). This results in the theoretically very smooth, precise running of the motor and, in a very precise, high quality control.

Properties of sinusoidal commutation
- More expensive electronics
- Requires an encoder
- Precise, high quality field-oriented control (FOC)
- Approx. 5% more continuous torque compared to block commutation
- Highly dynamic servo drives
- Positioning tasks

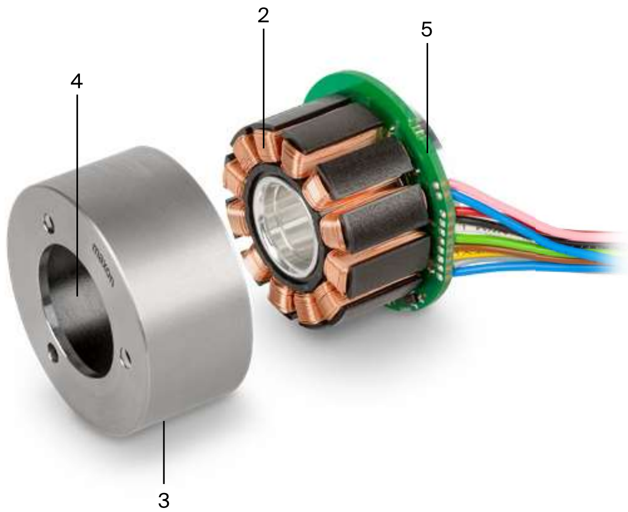
Block commutation

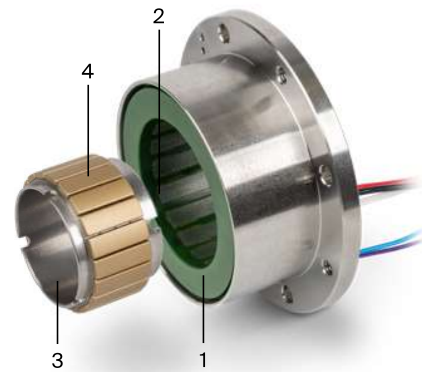


Sensorless commutation



Legend
The commutation angle is based on the length of a full commutation sequence (360°e). The length of a commutation interval is therefore 60°e.
The values of the shaft position can be calculated from the commutation angle divided by the number of pole pairs.



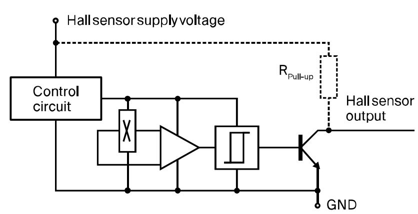


TSX MAG encoder
The optional TSX MAG encoder module can be combined with the EC frameless DT motors. The rotor of the motor needs to be equipped with an additional magnetic target ring.
The TSX MAG module will be placed on the stator leaving the hollow rotor shaft free and programmed to deliver proper commutation signals as well. Hence, rotor and stator need to be paired.

Hall sensor circuit

The open collector output of Hall sensors does not normally have its own pull-up resistance, as this is integral in maxon controllers. Any exceptions are specifically mentioned in the relevant motor data sheets.

Wiring diagram for Hall sensors



The power consumption of a Hall sensor is typically 4 mA (for output of Hall sensor = “HI”).

Integration and service life

Frameless motors are direct drives that are integrated in the application. The installation instructions available on the maxon website give detailed specification for optimum assembly.
The service life will be mainly defined by the chosen bearing assembly and the operational conditions (bearing load, speed).