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

Properties of the **ECX SQUARE** program:
– Compact, one-piece housing made of a thermoset material
– Attractive price-performance ratio
– Speeds of up to 30,000 rpm
– Easily configured online

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

Program

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

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

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.

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

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).
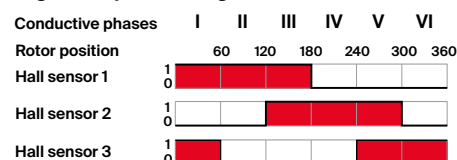To allow EC motors to be commuted without sensors in a Δ arrangement, a virtual star point is usually created in the electronics.

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)

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.

Block commutation

Signal sequence diagram for the Hall sensors

Conductive phases	I	II	III	IV	V	VI
Rotor position	60	120	180	240	300	360

Hall sensor 1
Hall sensor 2
Hall sensor 3

Supplied motor voltage (phase to phase)

U_{1-2}
U_{2-3}
U_{3-1}

Sensorless commutation

EMF

1

2   2
EMF
300° 0° 60° 120° 180° 240° 300°
3   3

Diagram applies to phase 1

8 • Rear

Front

10 • 7

4 • 3 • 2 • 1 • 6 • 9 • 5 • 9 • 9

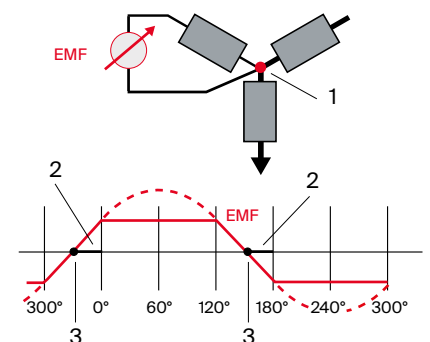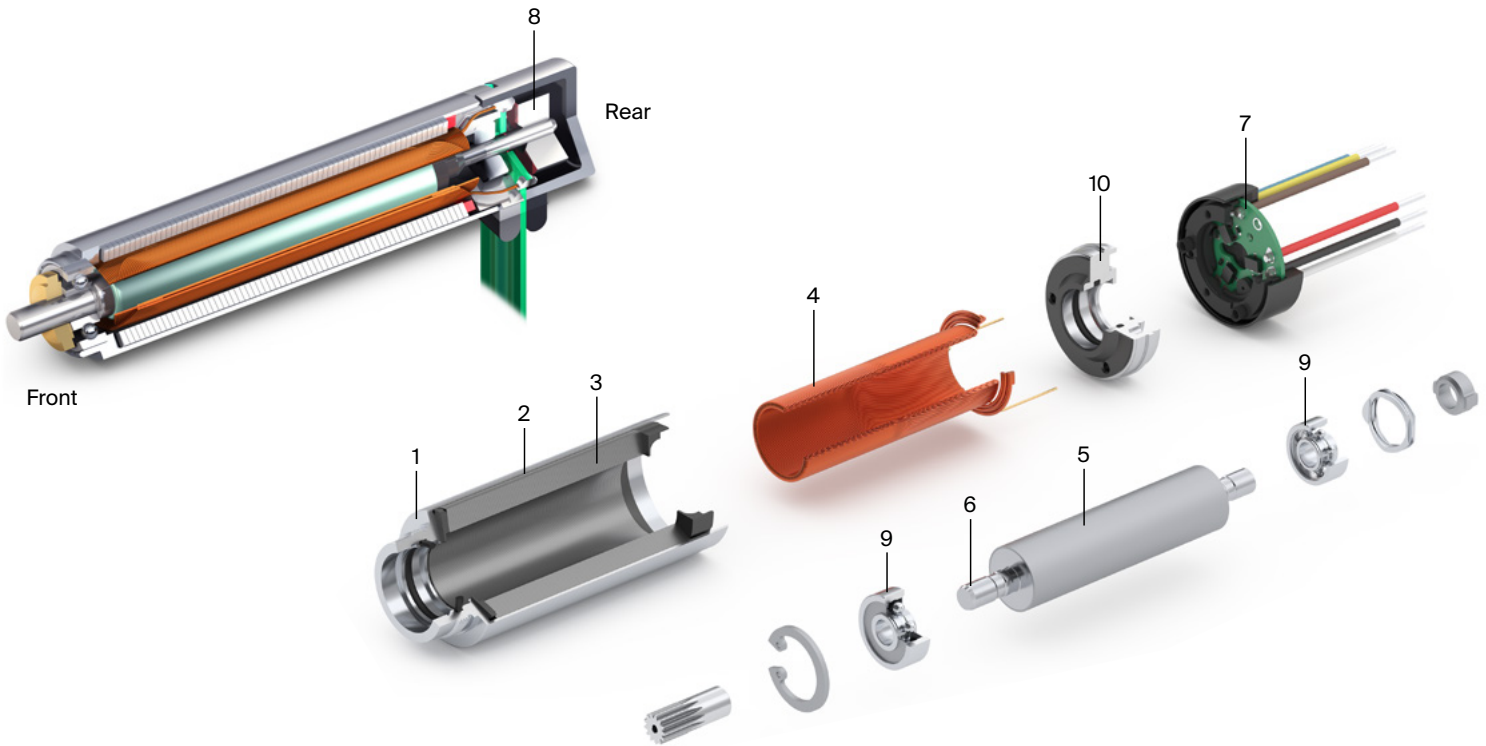## Sinusoidal commutation

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

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

Hall sensor supply voltage

$R_{Pull-up}$

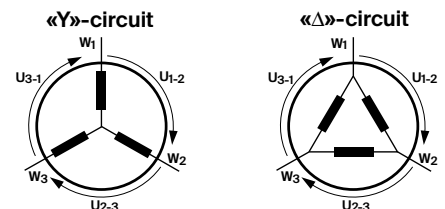Control circuit

Hall sensor output

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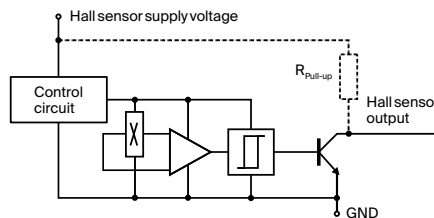
The power consumption of a Hall sensor is typically 4 mA (for output of Hall sensor = "HI").

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.
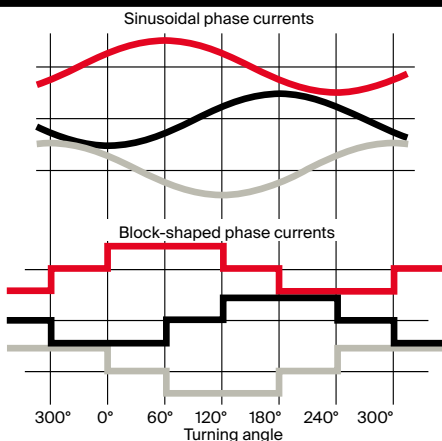
«Y»-circuit
W_1
U_{3-1} U_{1-2}
W_3 W_2
U_{2-3}

«Δ»-circuit
W_1
U_{3-1} U_{1-2}
W_3 W_2
U_{2-3}

Currents in sine and block commutation

Sinusoidal phase currents

Block-shaped phase currents

300° 0° 60° 120° 180° 240° 300°
Turning angle

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

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