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

Characteristics of **maxon EC motors**
- Brushless DC motor
- Long service life
- Speeds of up to 50 000 rpm and higher are possible
- 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 Neodymium permanent magnet with 1 or 2 pole pairs.
- Lowest residual unbalance

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 *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 25 000 rpm
- High-quality magnetic return material to reduce eddy current losses
- Mechanical time constants below 3 ms

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 unbalance and bearing load.

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

- **EC-Program**
- ***EC*-max-Program**
- ***EC*-4pole**

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

1. Flange
2. Housing
3. Laminated steel stack
4. Winding
5. Permanent magnet
6. Shaft
7. Balancing disks
8. Print with Hall sensors
9. Control magnet
10. Ball bearing
11. Spring (bearing preload)

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
- The data of the maxon EC motors are determined with block commutation.

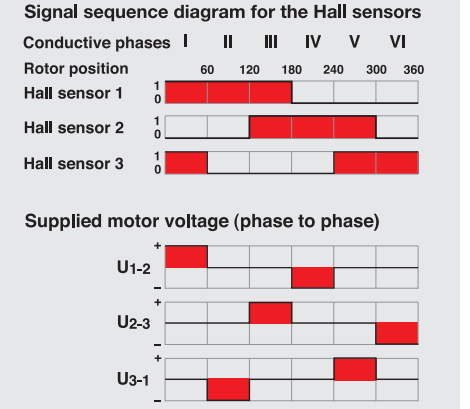
Possible applications
- Highly dynamic servo drives
- Start/stop operation
- Positioning tasks

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° after EMF zero crossing).
The amplitude of the induced voltage is dependent on the speed. 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.

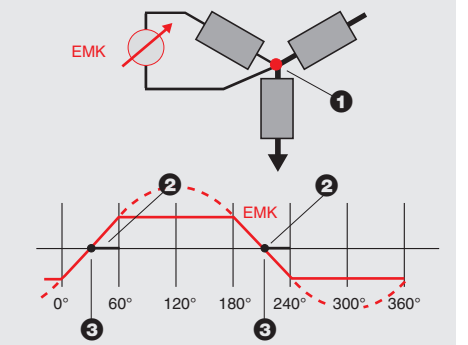
Properties of sensorless commutation
- Torque ripple of 14 % (block commutation)
- No defined start-up
- Not suitable for low speeds
- Not suitable for dynamic applications

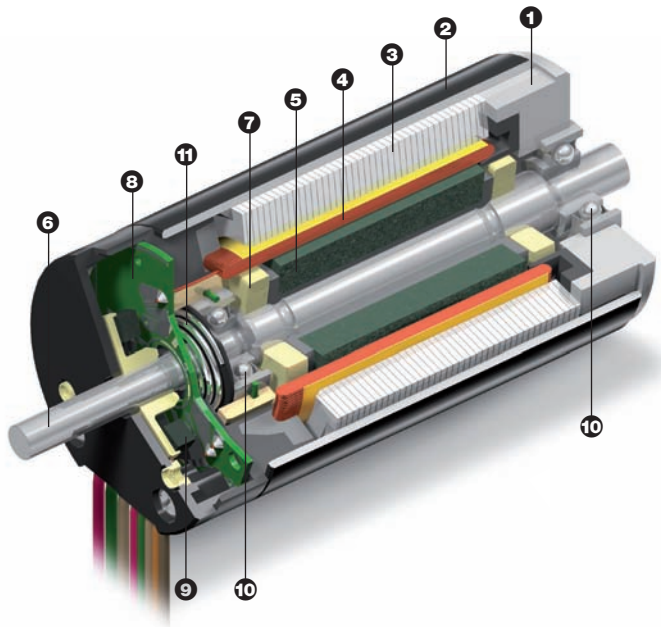
Possible applications
- Continuous operation at higher speeds
- Fans

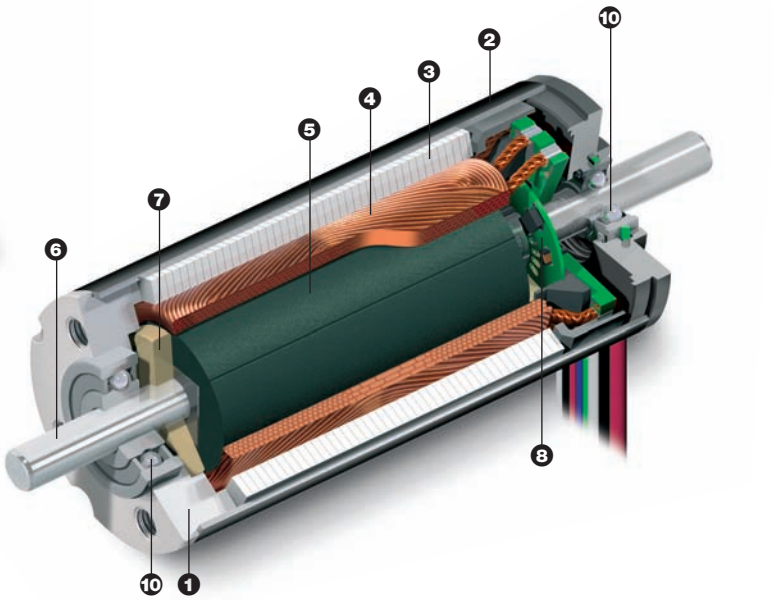
Block commutation



Sensorless commutation







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 degrees (sinusoidal commutation). This results in the very smooth, precise running of the motor and, in a very precise, high quality control.

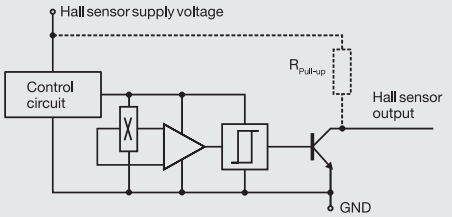
Properties of sinusoidal commutation
- More expensive electronics
- No torque ripple
- Very smooth running, even at very low speeds
- Approx. 5% more continuous torque compared to block commutation

Possible applications
- Highly dynamic servo drives
- Positioning tasks

Hall sensor circuit

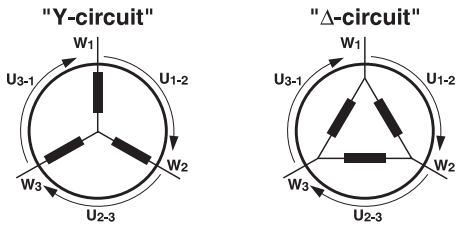
The open collector output of Hall sensors does not normally have its own pull-up resistance, as this is integral in maxon controllers. Any exceptions are specifically mentioned in the relevant motor data sheets.

Wiring diagram for Hall sensors



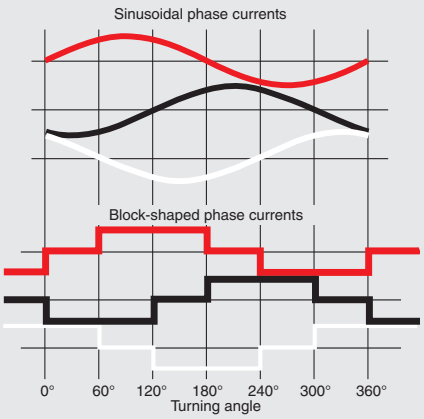
Winding arrangement

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 line with requirements.



The maximum permissible winding temperature is 125°C or 155°C depending on motor type.

Currents in sine and block commutation



Legend
❶ Star point
❷ Time delay 30°
❸ Zero crossing of EMF

For further explanations, please see page 137 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 **maxon EC flat motors** and **EC-i motors**
- Brushless DC motor
- Long service life
- Flat design for when space is limited
- Comparatively high inertia
- Motor characteristics may vary from the strongly linear behaviour
- Hall sensor signals utilizable for simple speed and position control
- Winding with iron core and several teeth per phase in the stator
- Low detent torque
- Good heat dissipation, high overload capacity
- Multipole Neodymium permanent magnet
- Smaller commutation steps

Characteristics of **maxon EC flat motors**
- Attractive price/performance ratio
- High torques due to external, multipole rotor
- Excellent heat dissipation at higher speeds thanks to open design
- Speeds of up to 20 000 rpm rotor with 1 pole pair

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

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

Program

- **EC flat motor**

- **with Hall sensors**
- **sensorless**
- **with integrated electronics**

1. Flange
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)

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
- The data of the maxon EC motors are determined with block commutation.

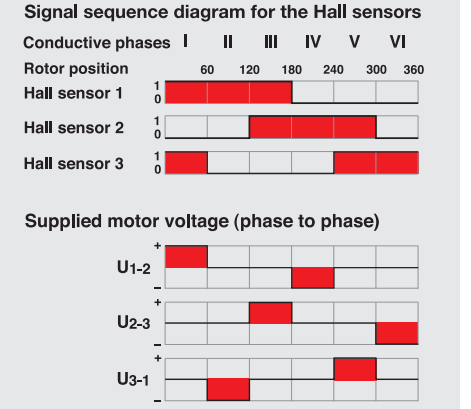
Possible applications
- Highly dynamic servo drives
- Start/stop operation
- Positioning tasks

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° after EMF zero crossing).
The amplitude of the induced voltage is dependent on the speed. 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.

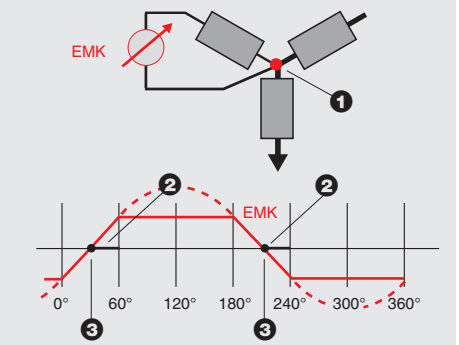
Properties of sensorless commutation
- No defined start-up
- Not suitable for low speeds
- Not suitable for dynamic applications

Possible applications
- Continuous operation at higher speeds
- Fans, pumps

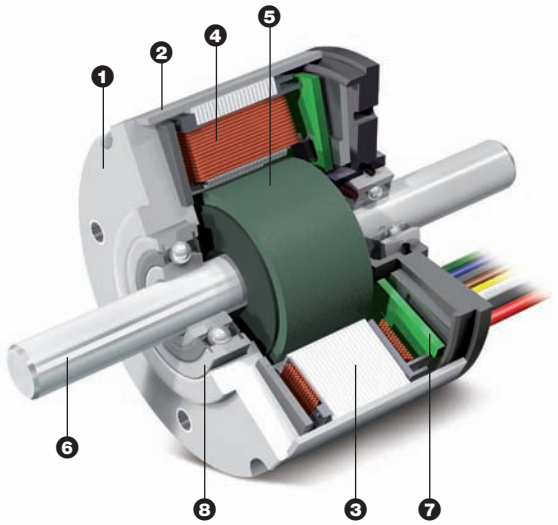
Block commutation

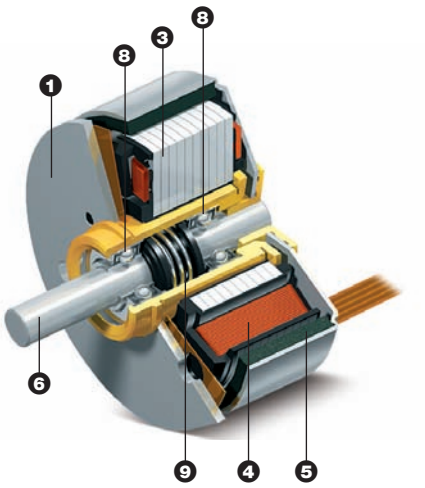


Sensorless commutation



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.





Sinusoidal commutation
Sinusoidal commutation for EC motors with slotted winding is basically possible, provided that an encoder can be mounted. The main benefit of sinusoidal commutation – the smooth operation – only comes into play to a limited degree due to the detent.

Integrated electronics

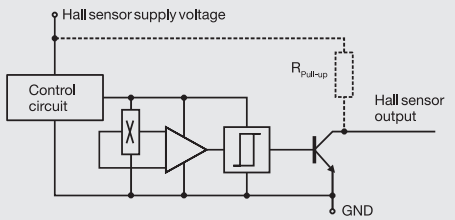
For motors with integrated electronics, the electronic commutation (mostly block commutation with Hall sensors) is built in. A speed controller and other functionalities can also be implemented.

Features
- Simple operation with DC voltage
- Fewer connections than with the EC motor
- No additional electronics required
- Output power reductions possible due to less space for power electronics

Hall sensor circuit

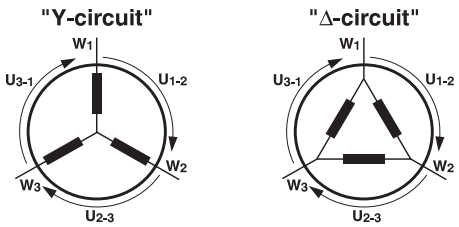
The open collector output of Hall sensors does not normally have its own pull-up resistance, as this is integral in maxon controllers. Any exceptions are specifically mentioned in the relevant motor data sheets.

Wiring diagram for Hall sensors



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 line with requirements. Flat motors and EC-i are normally “Y”-circuited.



The maximum permissible winding temperature is 125°C. (EC-i 155°C).

For further explanations, please see page 137 or “The selection of high-precision microdrives” by Dr. Urs Kafader.

Legend
❶ Star point
❷ Time delay 30°
❸ Zero crossing of EMF