EPOS4:
Sensors and start procdure of sinusoidal commutation

Topic:

- What kind of sensors are mandatory for a sinusoidal commutation?
- When does sinusoidal commutation become active during the inital movement?

Solution:

There are two different kinds of winding commutation in case of brushless motors (= EC motors):

- **Block commutation:**
  Block commutation is the most simple way of commutation. Block commutation just switches the windings stepwise on / off based on the signal pattern of the three hall sensors. Finally the commutation results in a torque ripple of 14% within each commutation cycle (see attached document "Block-Commutation_TorqueRipple.pdf") as a matter of principle due to the stepwise "hard" switching of the windings.
- **Sinusoidal commutation:**
  Sinusoidal commutation (or so-called FOC "Field Oriented Control) applies a "sinusoidal" winding current based on the accurate information about the position of the motor's rotor. The rotor position is derived from the encoder information. Finally this type of commutation results in zero torque ripple and lowest motor noise.

Modern controllers like the EPOS4 use block or sinusoidal commutation depending on the configuration and feedback sensors in use.

Solution:

Sinusoidal commutation demands for a high-resolution sensor like an analog or digital incremental or absolute encoder plus partly hall sensors for the start procedure during the first electrical turn of the motor shaft after power-up.

In case of an 1-pole pair motor (= 2 poles) one electrical turn of the motor shaft corresponds to one 360° mechanical turn of the motor shaft. If a multiple pole pair motor is in use, one electrical turn just corresponds to a mechanical movement of the motor shaft of 360° divided by the pole pair number. If there is a 2-pole pair motor (= 4 poles) in use (like maxon's "EC-4pole") for example, one electrical 360° turn corresponds to 180° mechanical turn of the motor shaft. maxon's EC-flat or EC-i motors have a high pole pair number, i.e. one electrical turn just corresponds to a fraction (= 360°/pole pair number) of a mechanical turn of the motor shaft.

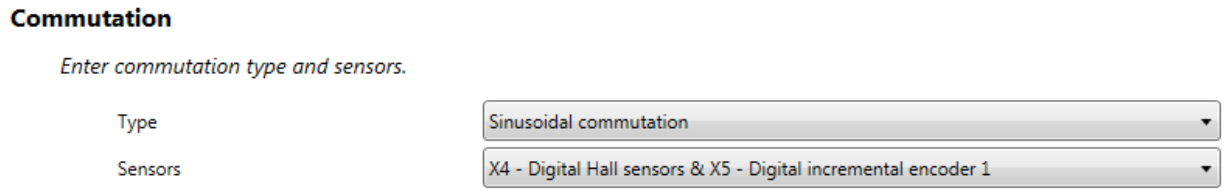
The concrete start procedure of the sinusoidal commutation depends on the type of encoder and configuration. There might be block commutation in use during the first electrical turn of the motor shaft until the position of the encoder in relation to the motor's rotor is detected and the sinusoidal commutation can be processed.

If an application demands for a smooth motion without torque ripple right after power-on or an application might just turn the motor shaft within less than 360°, it is recommended to choose an encoder type and configuration which enables the controller to start sinusoidal commutation immediately.

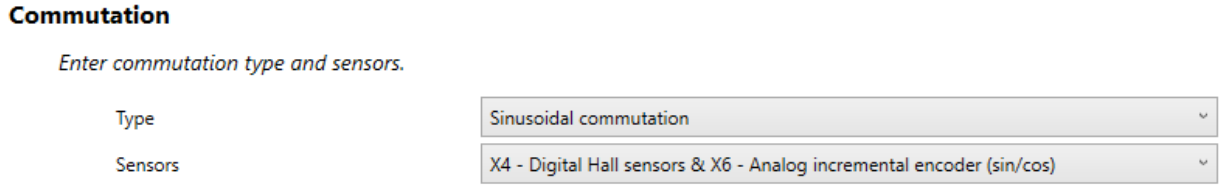
The EPOS4 offers different configuration features (by EPOS Studio's "Startup Wizard") for the sinusoidal commutation in case of encoders in use. Please find below an overview of possible sensor configurations for sinusoidal configuration plus some hints about preconditions and the resulting behaviour during the first initial movement within one electrical turn of the motor shaft (after power-on or reset).

1. **Sinusoidal commutation based on**
   "Hall sensors + Digital / analog incremental encoder“

EPOS Studio’s „Startup” Wizard -> Commutation: Hall sensors + Digital incremental:



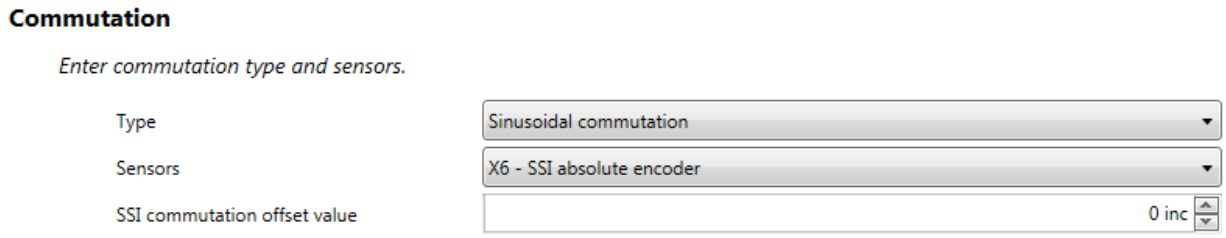
Or:
EPOS Studio’s „Startup” Wizard -> Commutation: Hall sensors + Analog incremental (SinCos):



- As a matter of principle there is some initial movement of the motor shaft required after power-on (or reset) to detect the motor's rotor position in relation to the encoder position. This means that the first movement of the motor starts with block commutation and the controller switches to sinusoidal commutation within the initial electrical turn of the motor shaft.
- EPOS4:
  The sinusoidal commutation is activated after the detection of the hall sensor 3 and is finally adjusted by crossing the next hall sensor signals.
- The incremental encoder has to be mounted on the motor shaft but does not have to be aligned to a specific rotor position.

2. Sinusoidal commutation based on "SSI absolute encoder" (without Hall sensors)

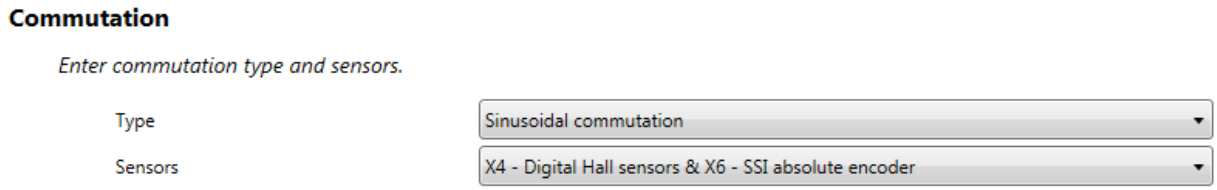
EPOS Studio's „Startup" Wizard -> Commutation: SSI absolute encoder:



- Sinusoidal commutation is activated immediately based on the information of the absolute encoder which has to be mounted and aligned in a defined way concerning the motor's rotor position.
- maxon's absolute encoders are mounted and aligned in a defined position related to the motor's rotor.
- In case of a 3rd party absolute encoder or a maxon encoder which was not mounted by maxon it is mandatory that …
  - ⇨ … the encoder is mounted on the motor sahft.
  - ⇨ … the so-called "SSI commutation offset value" (EPOS4 object: 0x3012/0x0A) is evaluated and configured properly.
- If no maxon motor / encoder combination is in use, the information about the configuration of the "SSI commutation offset value" (EPOS4 object: 0x3012/0x0A) can be found here:
  - ⇨ EPOS Studio / Start-up Wizard
    -> Controller / Commutation
  - ⇨ EPOS4 Application Notes Collection:
    -> Chapter "7 Adjustment of SSI Commutation Offset Value"

3. **Sinusoidal commutation based on "Hall sensors + SSI absolute encoder"**

EPOS Studio's „Startup" Wizard -> Commutation: Hall sensors + SSI absolute encoder:



- The commutation's principle and start-up is the same like in case of a system and configuration using "Hall sensors & Digital inkremental encoder".
- There is some initial movement of the motor shaft required after power-on (or reset) to detect the motor's rotor position in relation to the encoder position. This means that the first movement of the motor starts with block commutation and the controller switches to sinusoidal commutation within the initial electrical turn of the motor shaft.
- EPOS4:
  The sinusoidal commutation is activated after the detection of the hall sensor 3 and is finally adjusted by crossing the next hall sensor signals.
- The absolute encoder has to be mounted on the motor shaft but must not aligned to a defined position of the motor's rotor.

Conclusion and best practice hints:

- It is mandatory to have an encoder in use for sinusoidal commutation!
- The encoder has to be mounted on the motor shaft!
- If there is an incremental encoder in use, it is not possible to detect the encoder's position in relation to the motor's rotor. The initial movement after power-on (or reset) will start with block commutation and switch to sinusoidal commutation after the detection of the mandatory hall sensor signals within the first electrical turn of the motor shaft.
- If an **immediate activation of sinusoidal commutation** is required by an application (e.g. because the complete movement does not exceed 360° at all), it is mandatory that an absolute encoder is mounted on the motor shaft. It is also mandatory then to configure **"SSI Absolute Encoder"** for commutation and not(!!) "Digital Hall sensors & SSI Absolute Encoder".
    - If a maxon motor / encoder combinationen is in use, the encoder and the motor's rotor are mounted and aligned in a defined position and there is no need to adjust the "SSI commutation offset value" (EPOS4 object: 0x3012/0x0A).
    - If a 3rd party encoder is in use or the encoder was not mounted by maxon, it is mandatory to …
        - ⇨ … evaluate and configure the "SSI commutation offset value" (EPOS4 object: 0x3012/0x0A) in case of using the commutation type "SSI absolute encoder" (without hall sensors).

    or

        - ⇨ … the commutation type "Digital Hall sensors & SSI Absolute Encoder" has to be selected. In case of this configuration the first electrical turn of the motor shaft after power-on (or reset) starts with a block commutation before the controller automatically changes to sinusoidal commutation.