Motor Controller Basics

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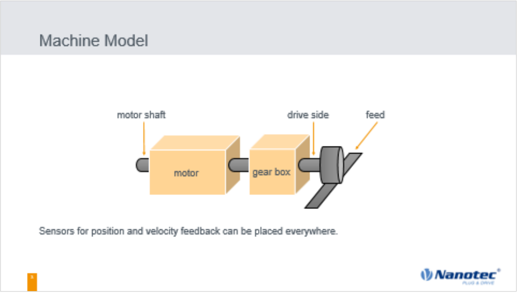
Machine Model
motor shaft
drive side
feed
motor
gear box
Sensors for position and velocity feedback can be placed everywhere.
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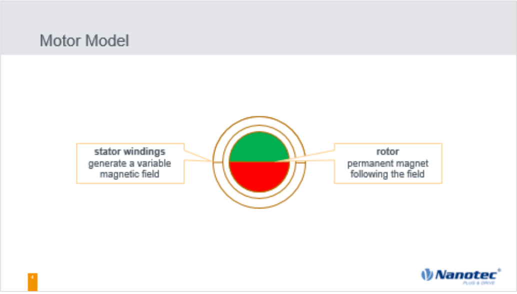
Motor Model
stator windings
generate a variable magnetic field
rotor
permanent magnet following the field
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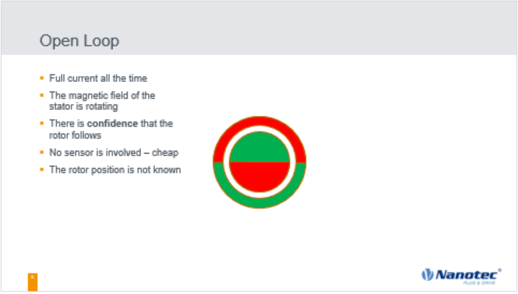
Open Loop
Full current all the time
The magnetic field of the stator is rotating
There is confidence that the rotor follows
No sensor is involved – cheap
The rotor position is not known
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Closed Loop
no torque at 0°
no rotor movement
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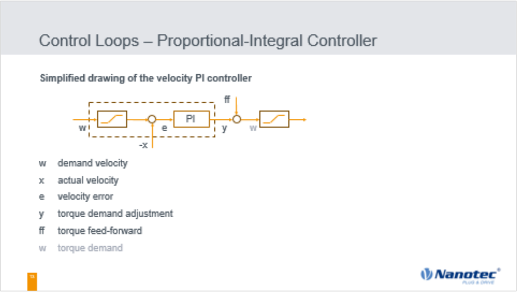
Control Loops – Proportional-Integral Controller
Simplified drawing of the velocity PI controller
ff
w
PI
e
y
-x
w demand velocity
x actual velocity
e velocity error
y torque demand adjustment
ff torque feed-forward
w torque demand
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Trajectory – Jerk Limited
Torque
Jerk
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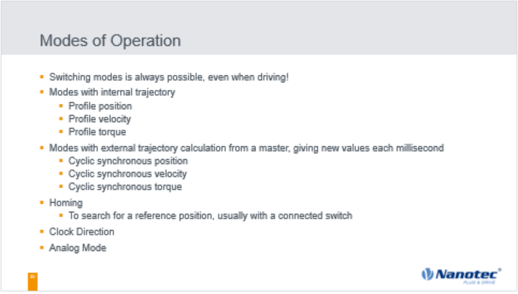
Modes of Operation
Switching modes is always possible, even when driving!
Modes with internal trajectory
Profile position
Profile velocity
Profile torque
Modes with external trajectory calculation from a master, giving new values each millisecond
Cyclic synchronous position
Cyclic synchronous velocity
Cyclic synchronous torque
Homing
To search for a reference position, usually with a connected switch
Clock Direction
Analog Mode
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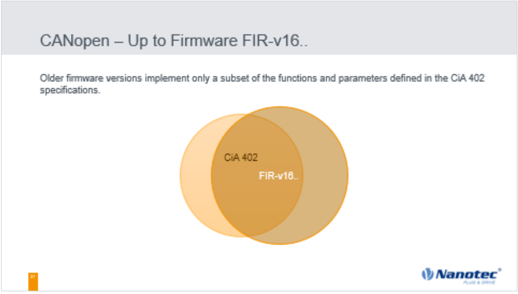
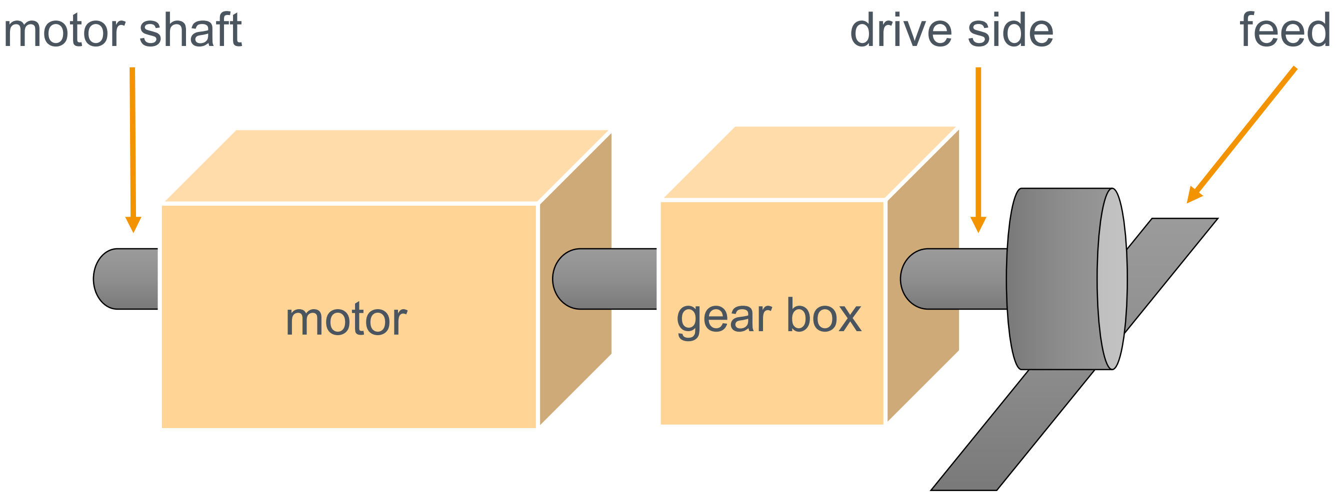

CANopen – Up to Firmware FIR-v16..
Older firmware versions implement only a subset of the functions and parameters defined in the CiA 402 specifications.
CiA 402
FIR-v16..
Nanotec

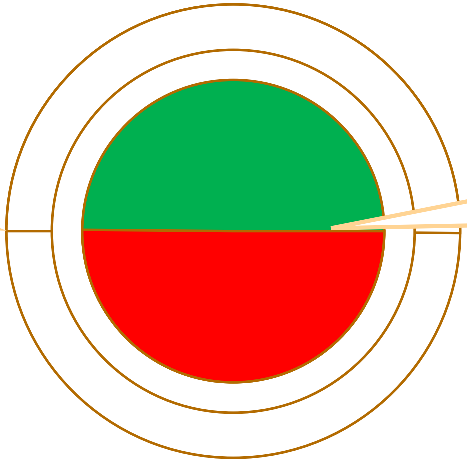
Machine Model



Sensors for position and velocity feedback can be placed everywhere.

Motor Model

stator windings
generate a variable
magnetic field



rotor
permanent magnet
following the field

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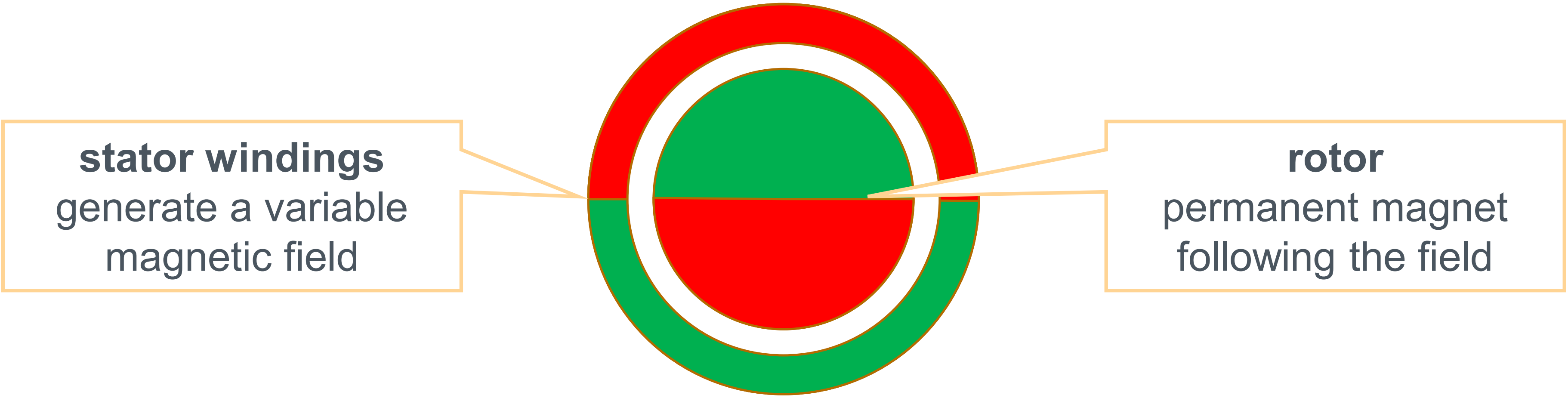
Motor Model


stator windings
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magnetic field
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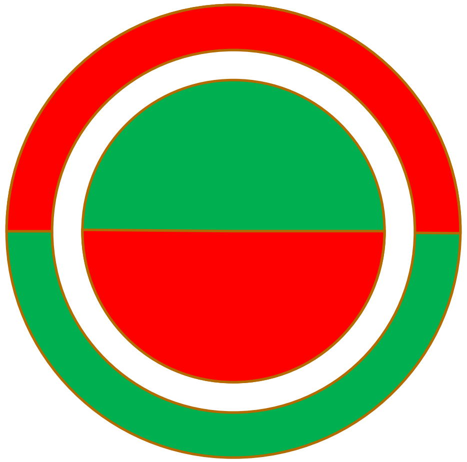
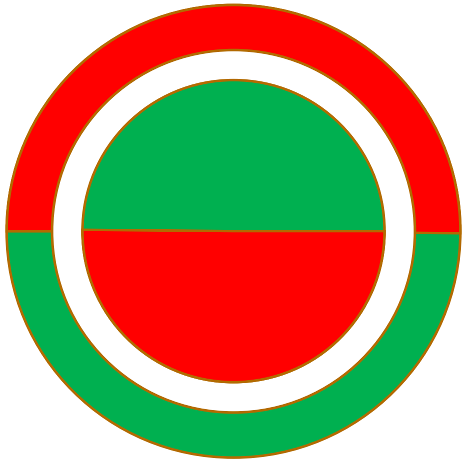
Open Loop

- Full current all the time
- The magnetic field of the stator is rotating
- There is **confidence** that the rotor follows
- No sensor is involved – cheap
- The rotor position is not known



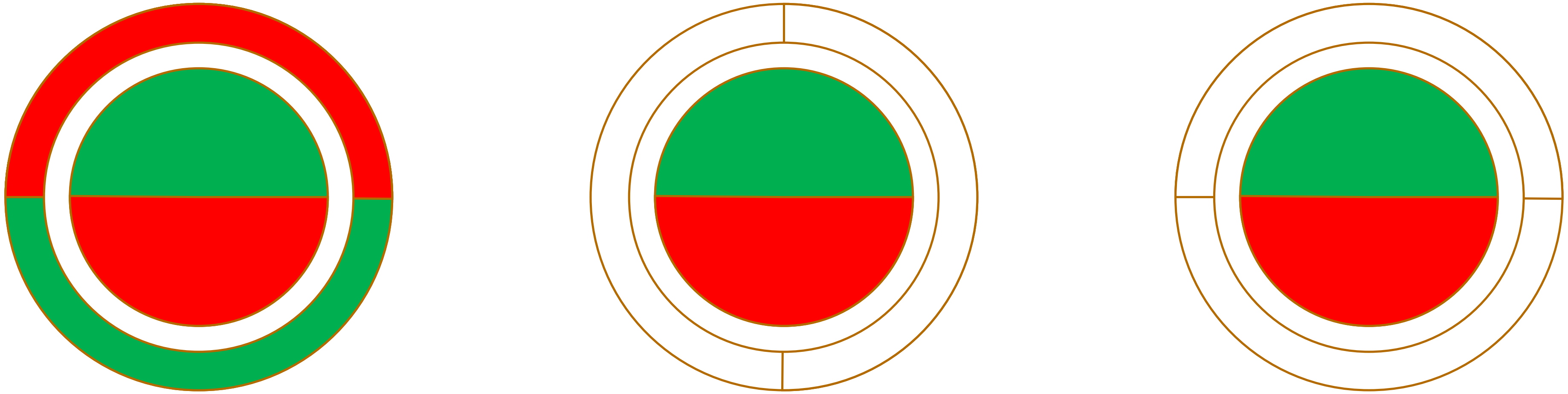
Open Loop

- Full current all the time
- The magnetic field of the stator is rotating
- It is **assumed** that the rotor follows
- No sensor is involved – cheap
- The rotor position is not known



If the magnetic field rotation is too quick, the rotor will not follow.

Closed Loop



no torque at 0°
no rotor movement

Closed Loop

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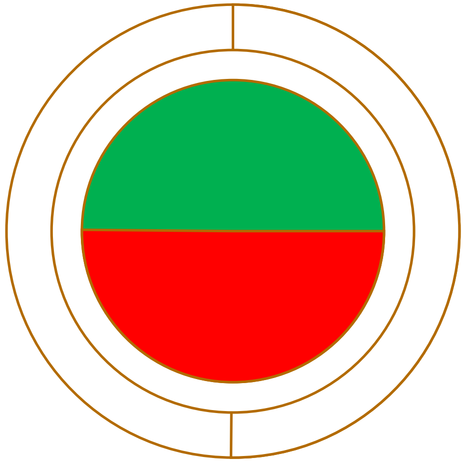
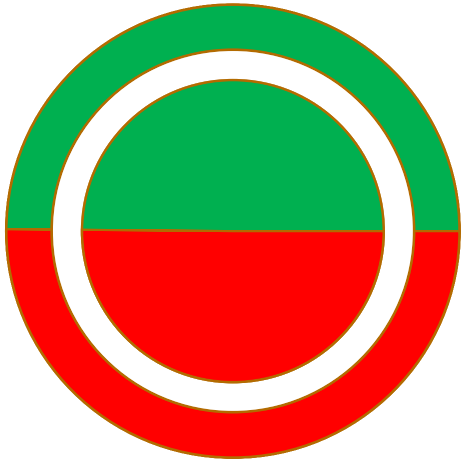
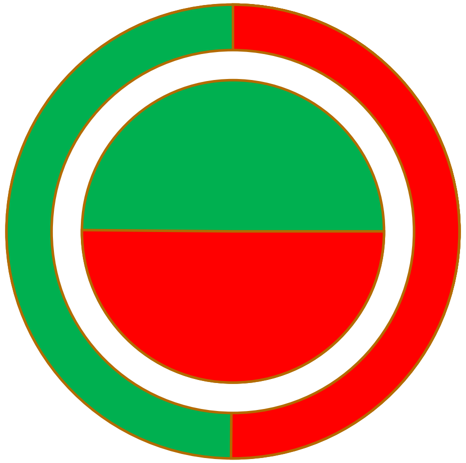




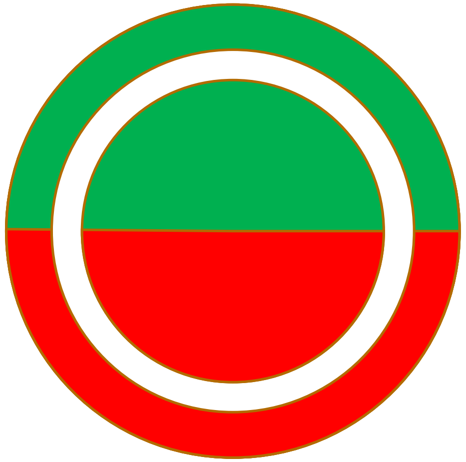
no torque at 180° –
but instable rotor will flip eventually

Closed Loop

no torque at 0°
no rotor movement



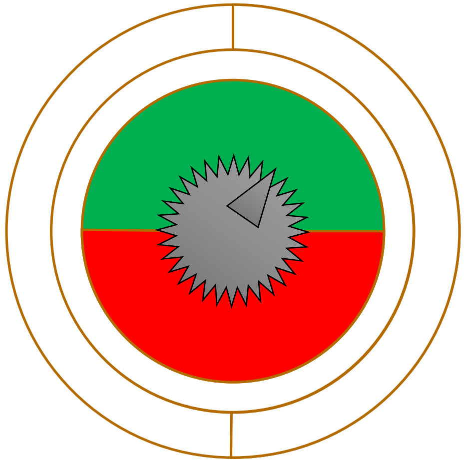
max torque at 90°



no torque at 180° –
but instable rotor will flip eventually

Closed Loop – Energy-Efficient Movement

- Current creates acceleration
- No current, no acceleration
- When the rotor has stopped the current is 0
- The magnetic field of the stator is always at an angle of 90° to the rotor
- Rotor position must be known
- Sensor is needed for positioning, otherwise sensorless control can be used



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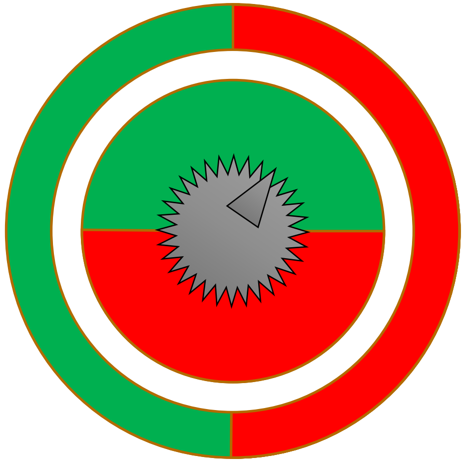

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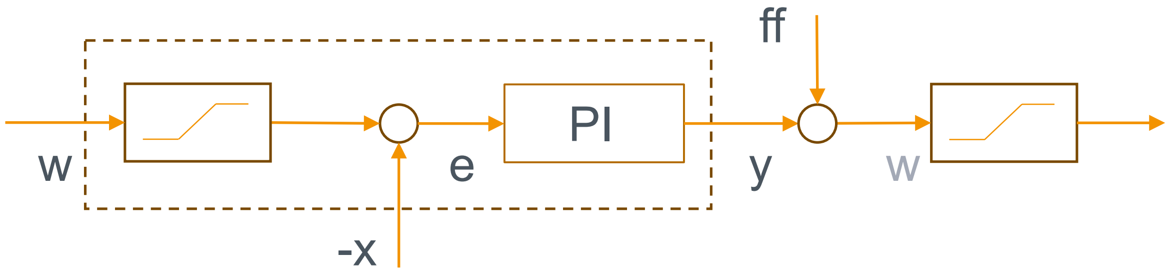
Control Loops – Proportional-Integral Controller

Simplified drawing of the velocity PI controller



w demand velocity

x actual velocity

e velocity error

y torque demand adjustment

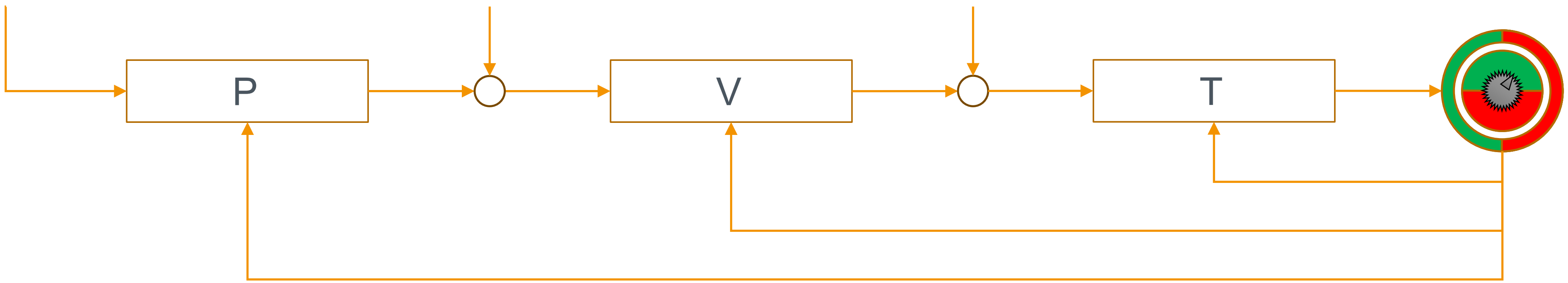
ff torque feed-forward

w torque demand

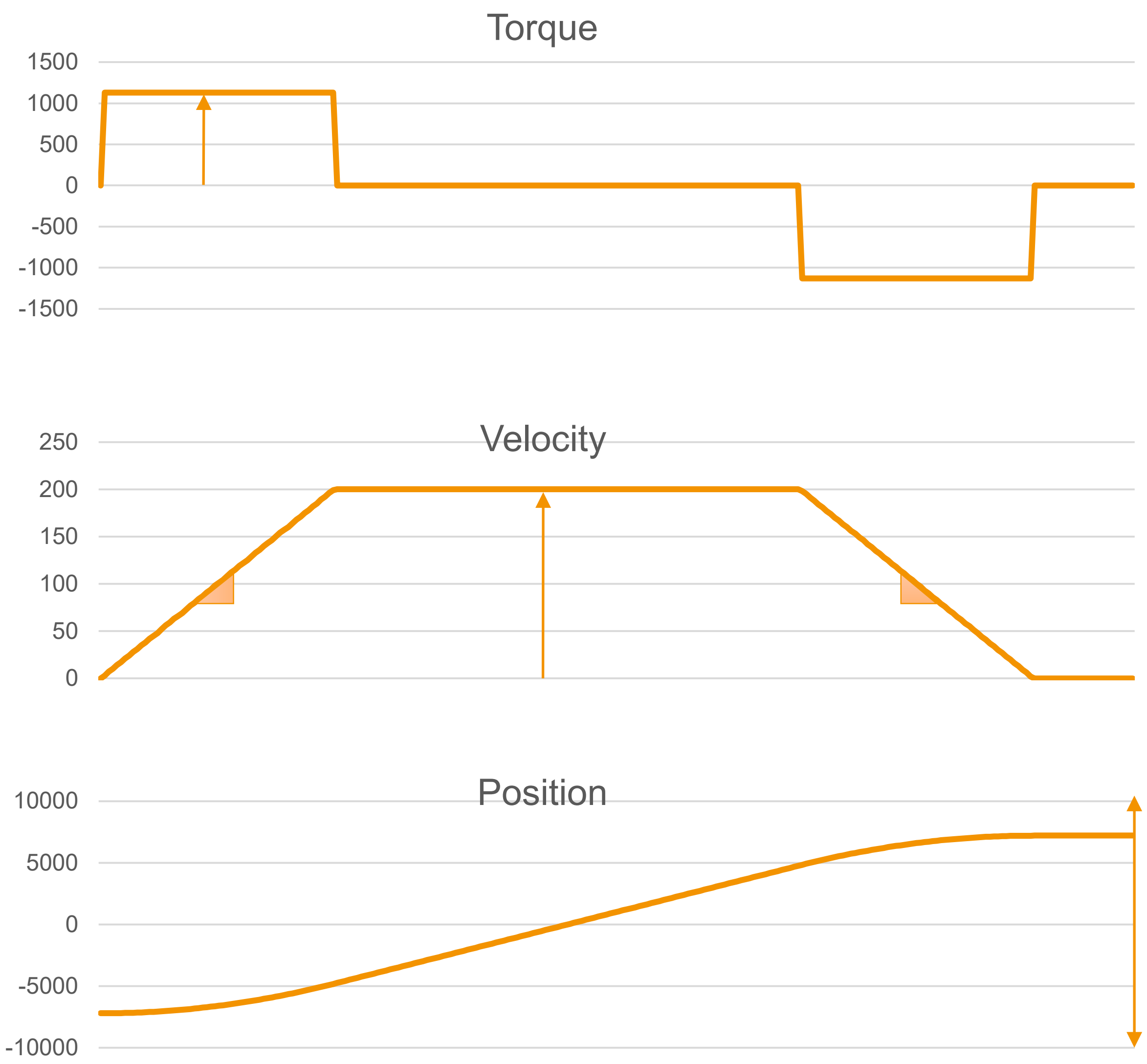
Control Loops – The Controller Cascade

There are PI controllers for

- position
- velocity
- torque



Trajectory – Trapezoid



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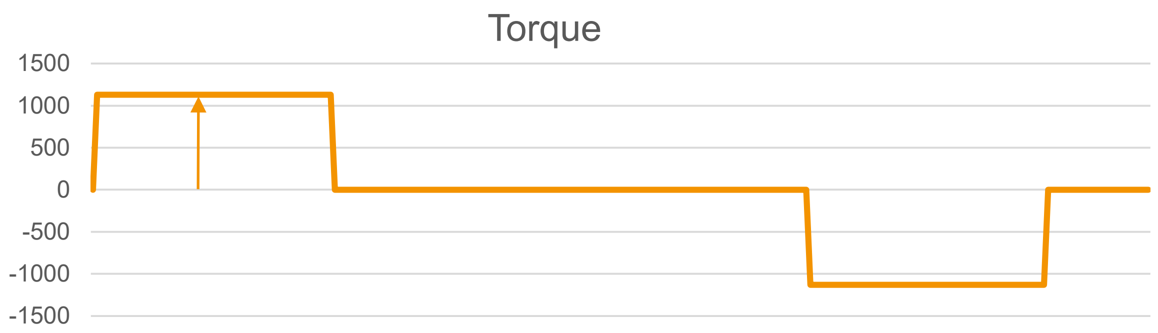
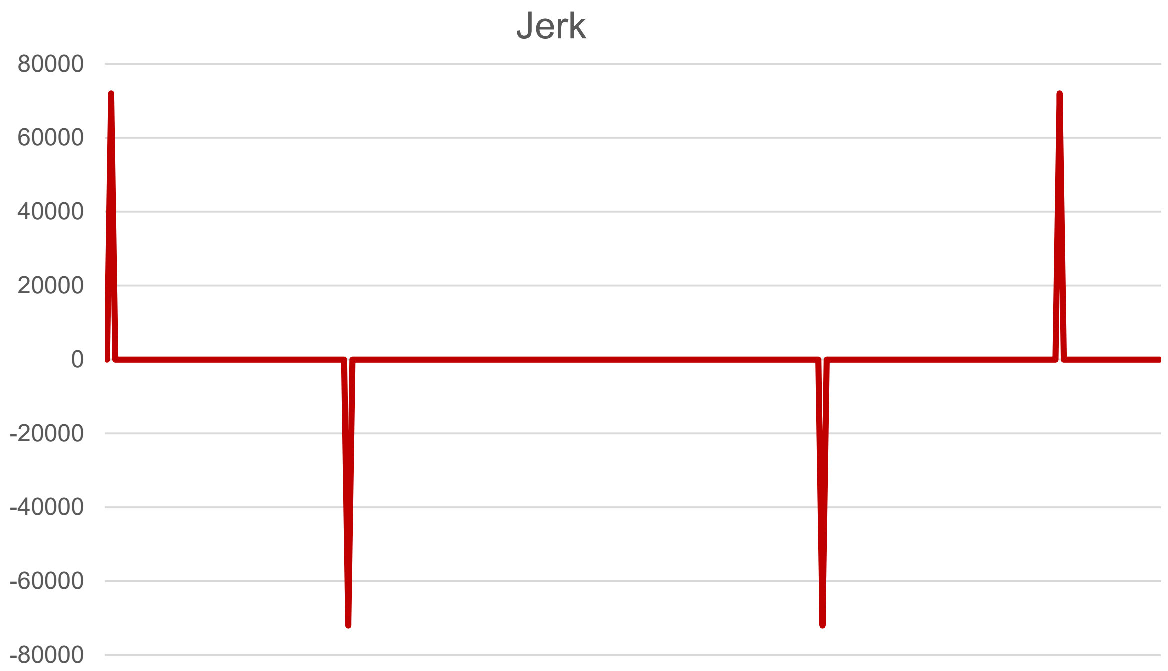
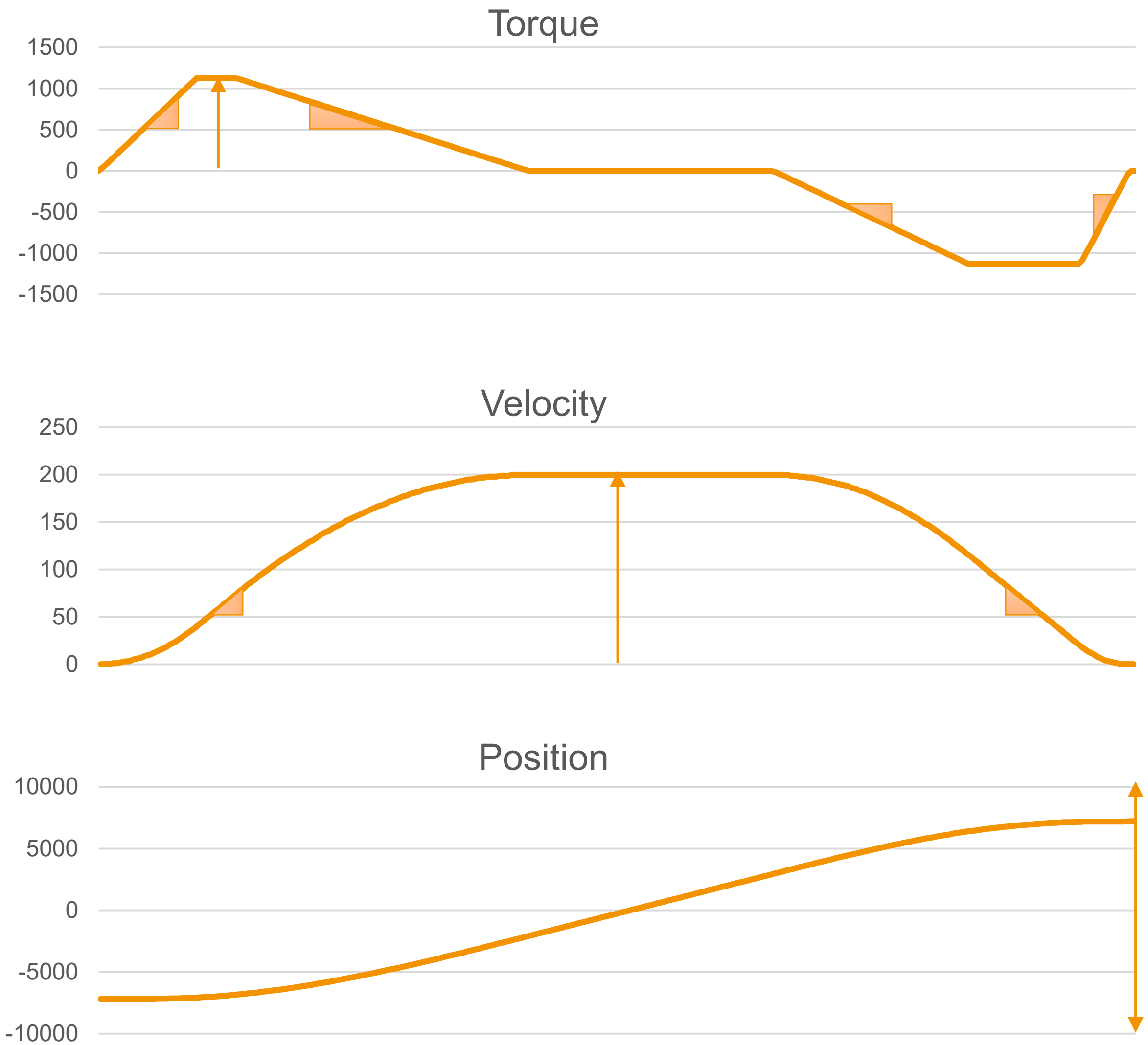




Trajectory – Jerk Limited



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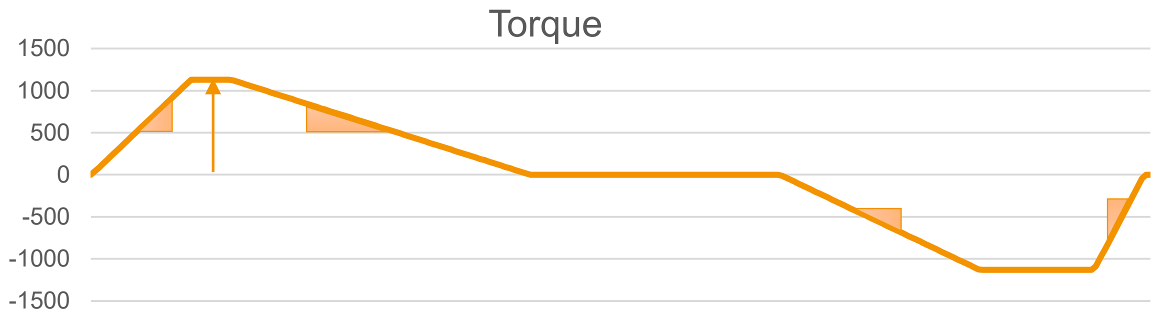

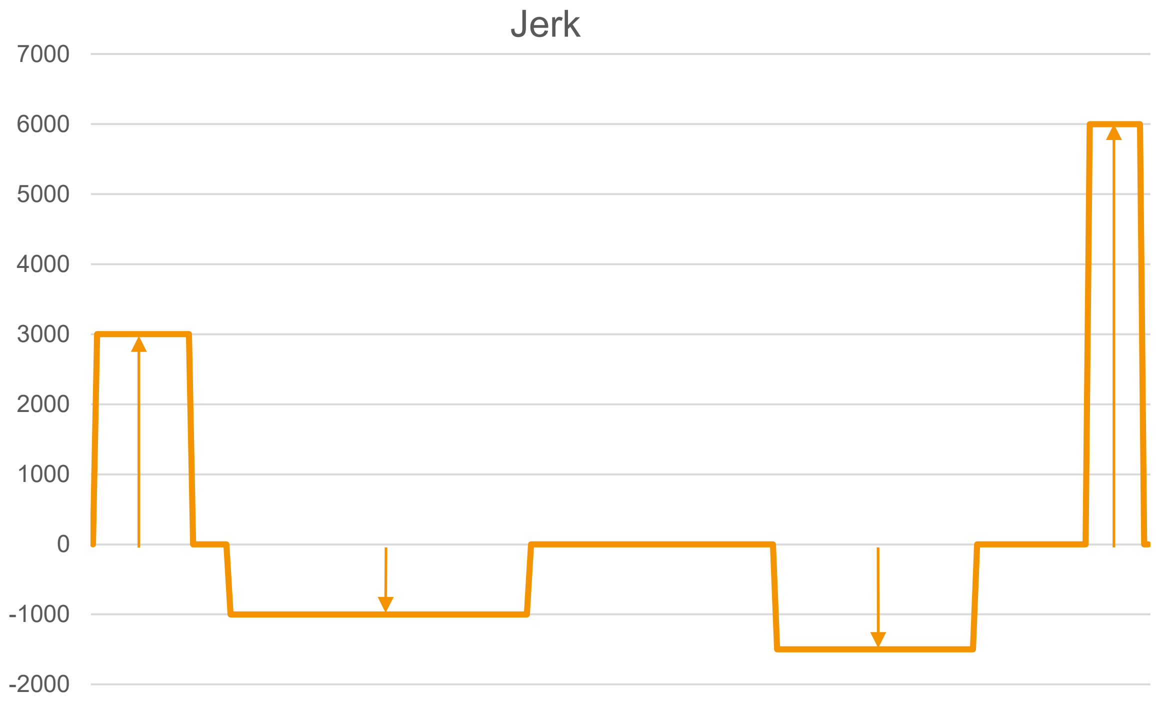

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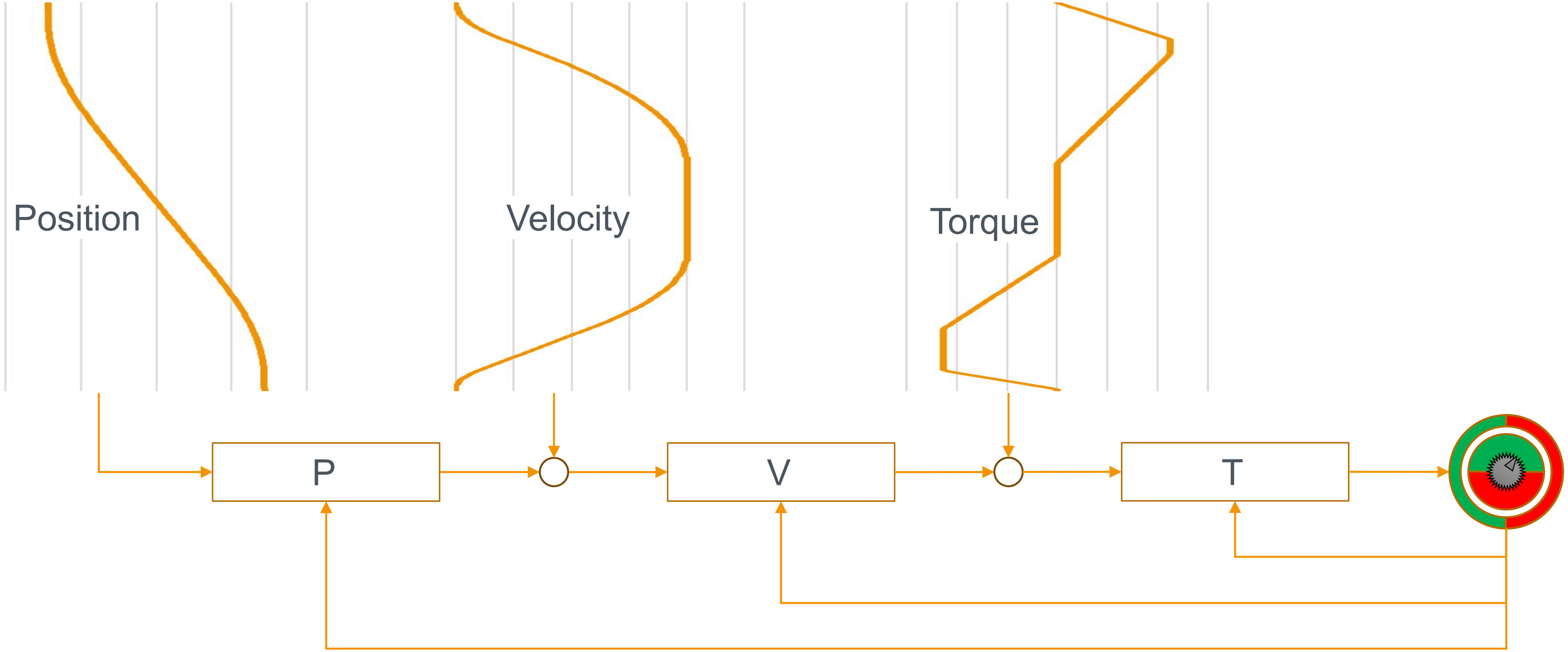
Trajectory – Feeding the Controller Cascade



Modes of Operation

- Switching modes is always possible, even when driving!
- Modes with internal trajectory
  - Profile position
  - Profile velocity
  - Profile torque
- Modes with external trajectory calculation from a master, giving new values each millisecond
  - Cyclic synchronous position
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- Homing
  - To search for a reference position, usually with a connected switch
- Clock Direction
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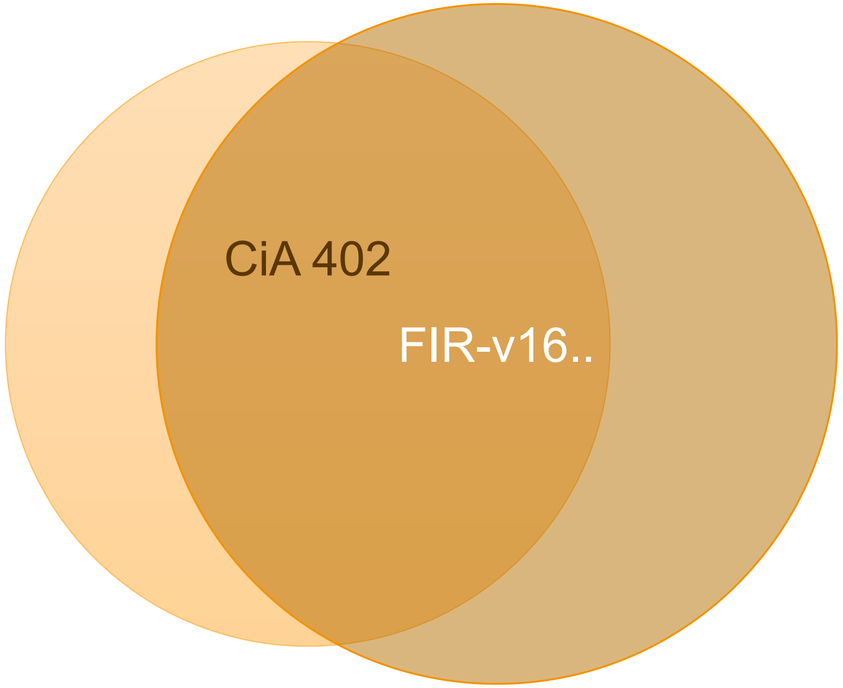
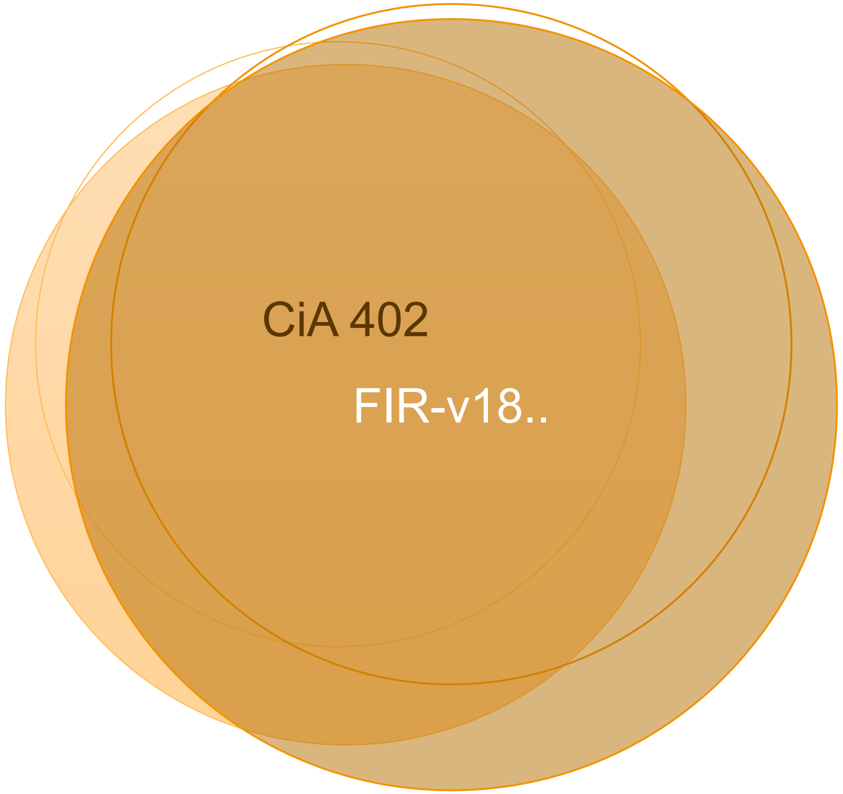


CANopen– From Firmware FIR-v18..

Newer firmware versions on the other hand implement most of them, offering better exchangeability with devices compliant to CiA 402.



CANopen – Object Dictionary

- $Index_h$:$Subindex_h$ = value
- Usual objects
  - Target velocity of 200 U/min $60FF_h:00_h = 200$
  - Mode of operation profile velocity $6060_h:00_h = 3$
- Arrays and records
  - Profile jerk

Number of subindices	$60A4_h:00_h \rightarrow 4$
Four jerk parameters in U/min/s²	$60A4_h:01_h = 3000$
	$60A4_h:02_h = 1000$
	$60A4_h:03_h = 1000$
	$60A4_h:04_h = 1000$

CANopen Protocols

SDO – Service Data Object

- Read and write access to an object via $Index_h$:$Subindex_h$
- One access per millisecond
- Transfer of Index, subindex and content

PDO – Process Data Object

- Cyclic read and write access to multiple but pre-configured objects
- Only transfer of contents
- Configuration per SDO

LSS – Layer Setting Services (CAN only)

- Node ID
- Baud rate

Motor Controllers / Drives
for BLDC and Stepper Motors

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