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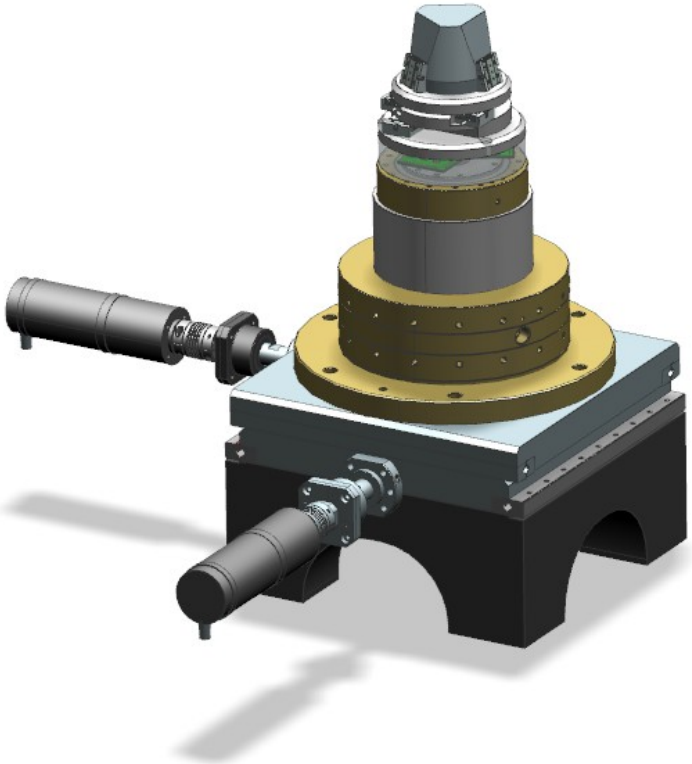
Motor types state of the art: case study using of servomotor and piezo motors on a high performance goniometer

15 October 2021

Requeriments on a motion system

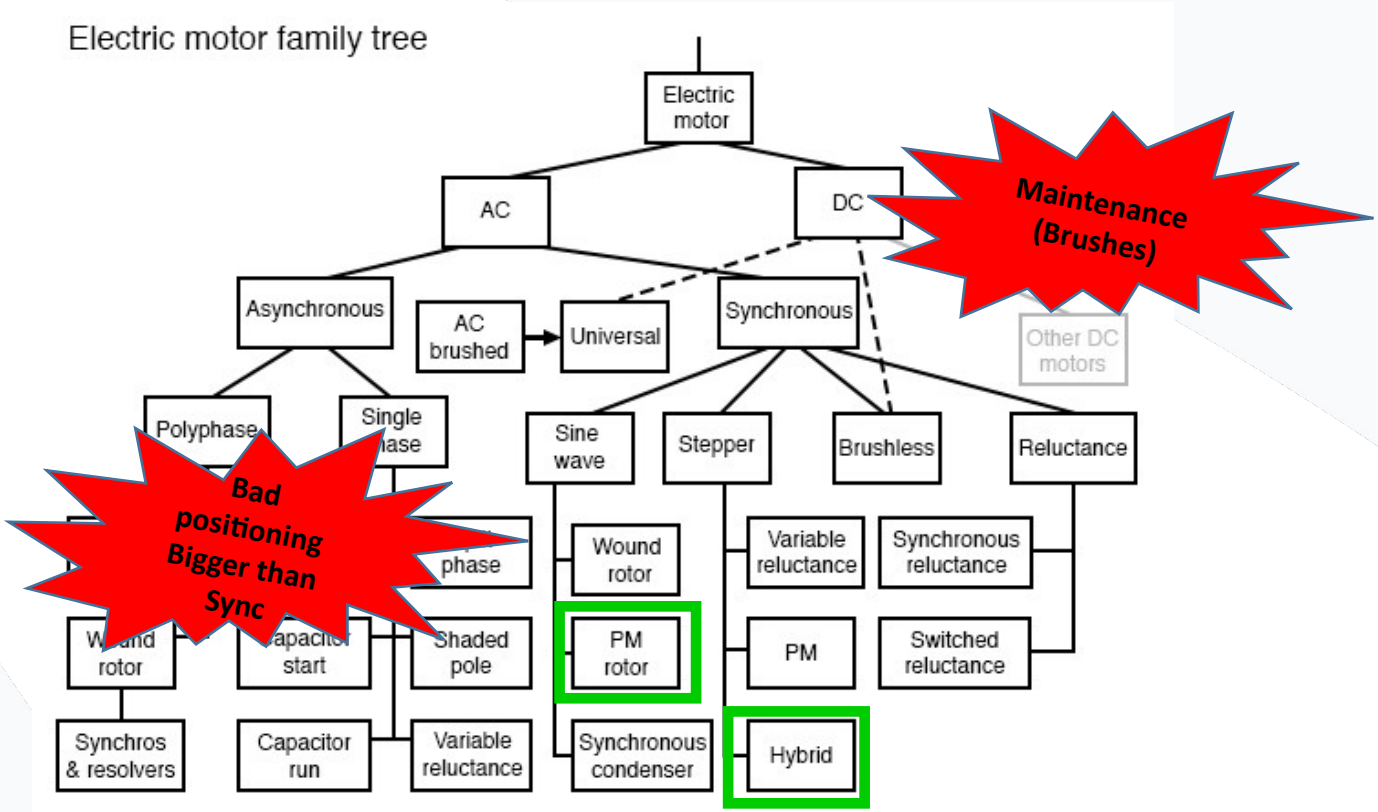


- Ω rotation must be moved
  - Speed range from 360deg/s
  - Target Resolution 20µdeg
  - Speed stability
  - Position error in movements <500µdeg@360deg/s
- XYZ axis must be moved simultaneously
  - Stroke: 5 mm
  - Speed: 0,5 to 5mm/s
  - Resolution: 1nm
- Additionally synchronization between Ω rotation and XYZ piezo stages is required:
  - in helical scan experiments (Ω rotation and XYZ axis)
  - to correct the sphere of confusion of the goniometer (required to be ≤ 100nm) (Ω rotation and X/Y axes)

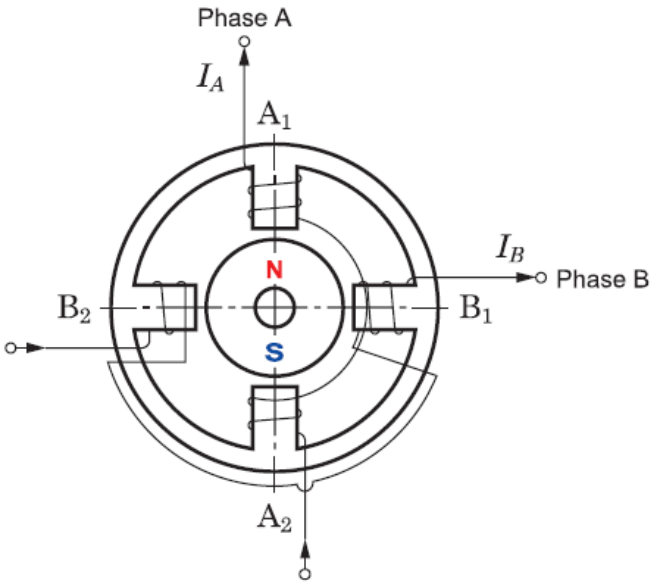
What are we looking on a motion system?

- Fit with the mechanical requirements
- Be able to synchronize with other motors
- Easy to integrate with control system
- Simple design
- Standard motors to minimize the spares
- Low maintenance
- *Good position accuracy and detent torque
- Special features: Vacuum, non-magnetic, temperature,…

Electric motors

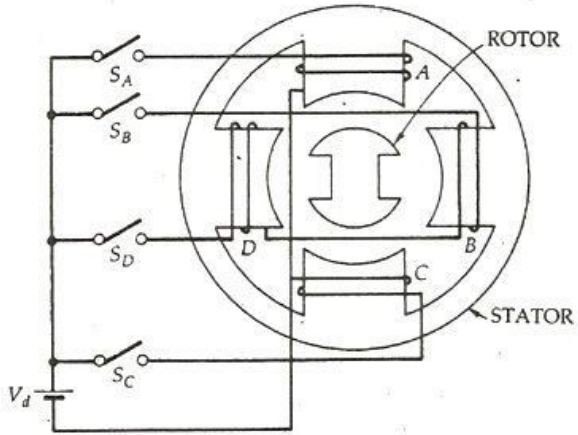


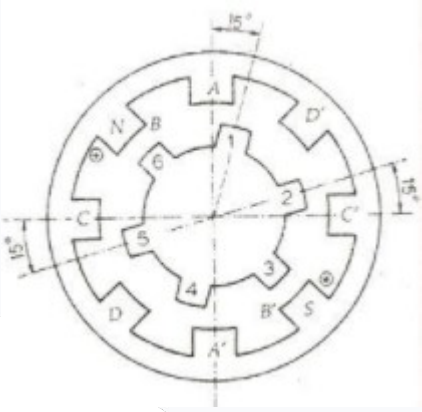
Permanent Magnet
- Simple motor
- High Torque
- Holding torque

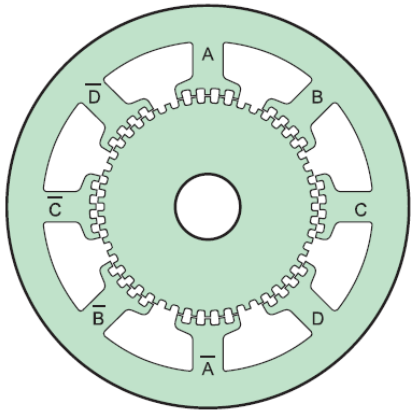


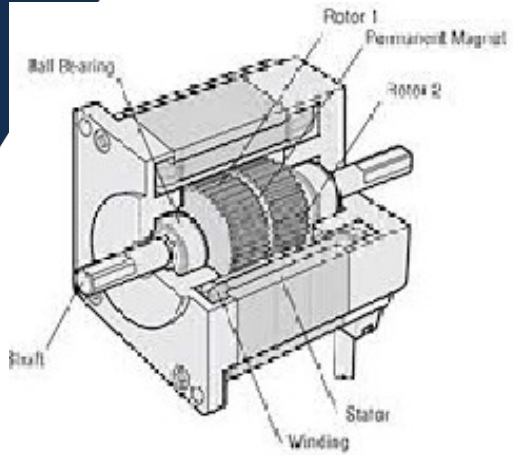
Variable Reluctance

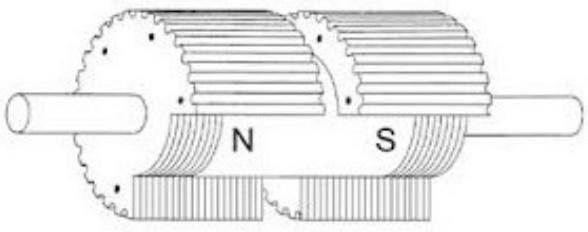
- Rotor is a ferromagnetic material
- It needs more than 2phases



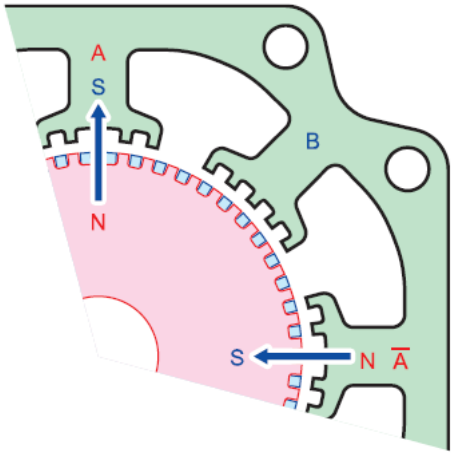








Hybrid Stepper Motor Rotor



Hybrid synchronous

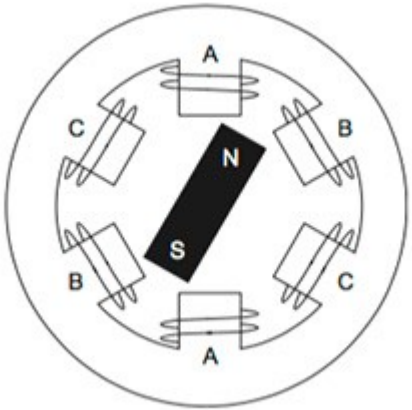
- Permanent magnet on axial direction
- Up to 400steps/rev

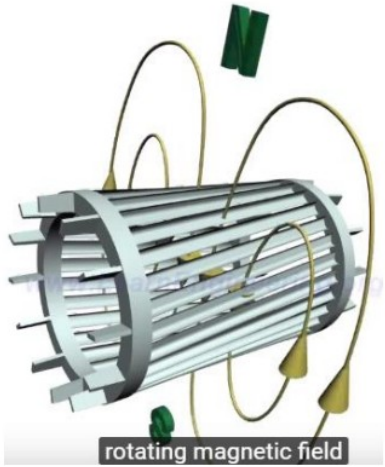
Electric Motors. Steppers

Advantages / Types of Stepper Motor	Permanent Magnet	Variable Reluctance	Hybrid
Step Angle	7.5° or larger	1.8° or smaller	1.8° or smaller
Output Torque	Moderate	Low	High
Detent Torque	Yes	No	Yes
Pulse Rate / Speed	Low	High	High
Acceleration / Response	Slow	Fast	Fast
Noise	Quiet	Loud	Quiet
Microstep	Yes	No	Yes
Design	Simple	Moderate	Complex

Synchronous

- Rotor is a magnet
- Speed of rotor proportional to frequency(slip=0)
-



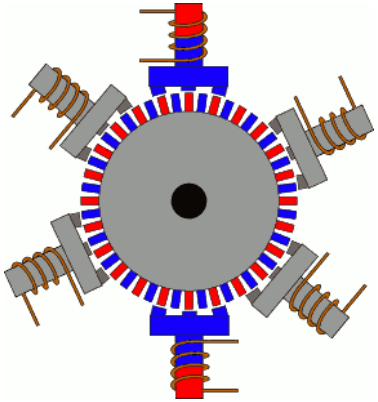


Asynchronous

- Rotor is a coil
- Rotor speed lower than current frequency
- Less efficient
- Bigger that Synchronous motor
- No holding force
- Cheap

Hybrid Stepper

- Position accuracy
- More steps per revolution
- Close loop correct the lost steps
- Detent torque also without power
- Torque decreases with speed

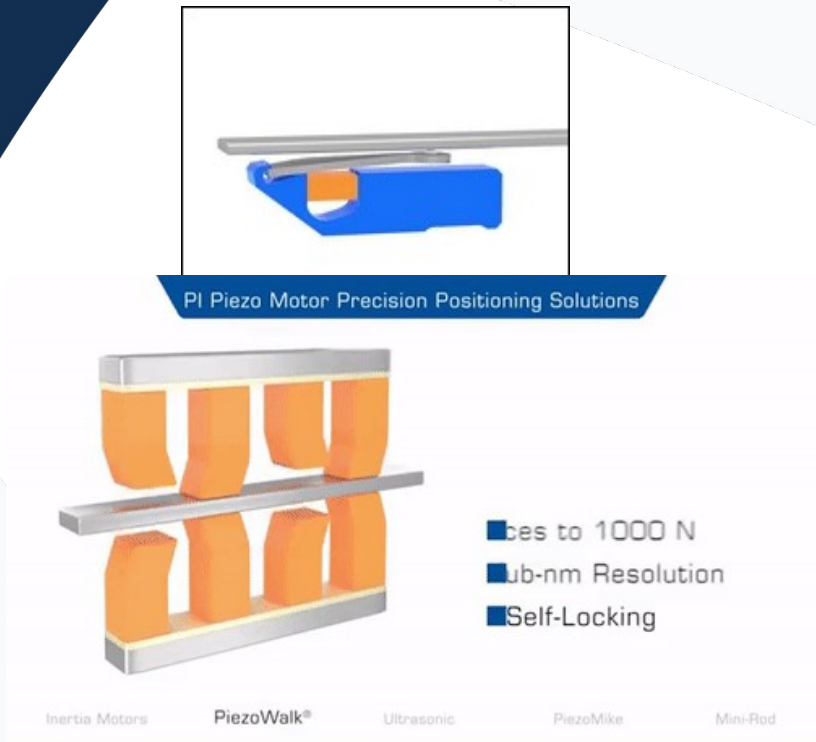


Synchronous AC

- More speed
- Close loop maximize the torque keeping the permanent magnet and magnetic field at 90º ($T=B \cdot M \cdot \sin\Theta$)
- High torque at high speed
- Holding torque by close loop

Piezo actuators

- Produces a linear motion
- Big pushing forces
- Small stroke(microns)
- DC voltage drive
- No detent force
- Easy control electronics
- High resolution
- Low accuracy



Piezo motor

- High variety of devices.
- Small force
- Integrates the stage and the encoder
- Difficult control and motor dependent

What are we looking on a motion system?

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- Be able to synchronize with other motors
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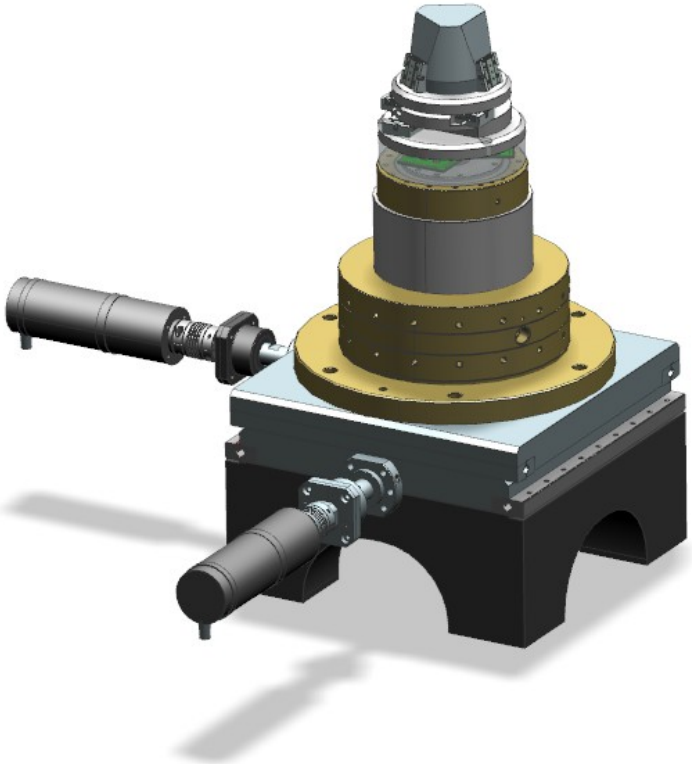
Summary table

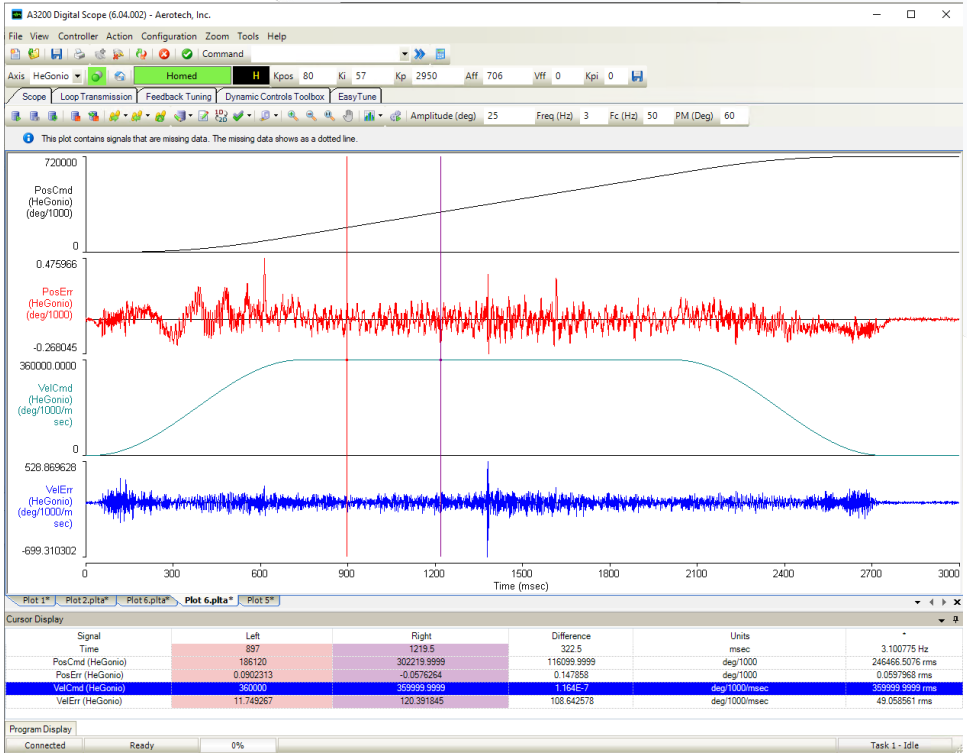
	Stepper	AC Synchronous	Piezo Actuat.	Piezo motor
Resolution	High	medium	Very high	High
Speed	medium	High	medium	medium
Speed stability	medium	High	High	Low
Design Flexib.	Yes	Yes	Yes	No
Stroke	>10cm	>10cm	<100µm	Few mm
Compactness	Low	Low	Low	High
Control system	Standard	standard	Not complex	Not standard
Detent torque	Yes	No	No	Yes
Force/Torque	High	high	medium	Low
Feedback	Not needed	needed	needed	Needed
Cabling	4(no encoder)	3	2	2

Piezo motors technologies



- Ω
  - AC synchronous motor 18 phases
  - Relative encoders. Resolution 5µdeg
  - Aerothech motor and controller
- XY
  - Piezo stage from smaract
  - Controlled by Aerotech controller (step/direction)
  - Compactness reduces ununiform inertia and space
- Z
  - 3 piezo stages in paralel to increase the force
- Table of the Goniometer XY
  - Steeper motors

Preliminary results



Aknowlegements

- https://www.orientalmotor.com /
- https://www.smaract.com/
- https://www.physikinstrumente.com /
- https://www.sinerges.com /

THANK YOU
Questions?