# Sistemi per il controllo motori

**TALENTIS 4ª SESSIONE - 28 MAGGIO 2018**

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Central Lab

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# Prodotti ST per il controllo motori



*Applicazioni e prodotti ST*

Motor Control

**Motion Control Industrial Drives**

Robotics, HVAC, pumps, CNC.

**Home appliances**

White Goods, Refrigerators, Room air conditioning

**New applications**

Fitness, Healthcare, Pedelec and Drone

**A complete offer of ST devices**

- **(IPMs) SLLIMM™**
  - **Diodes**
  - **Power transistors**
  - **Gate Drivers**
- **Control unit**
- **AC switches**
- **Sensors**
- **Motor driver ICs**
- **Power Management**

**Motor Control libraries**


# Prodotti ST per il controllo motori



*Dal prodotto ……alla soluzione*

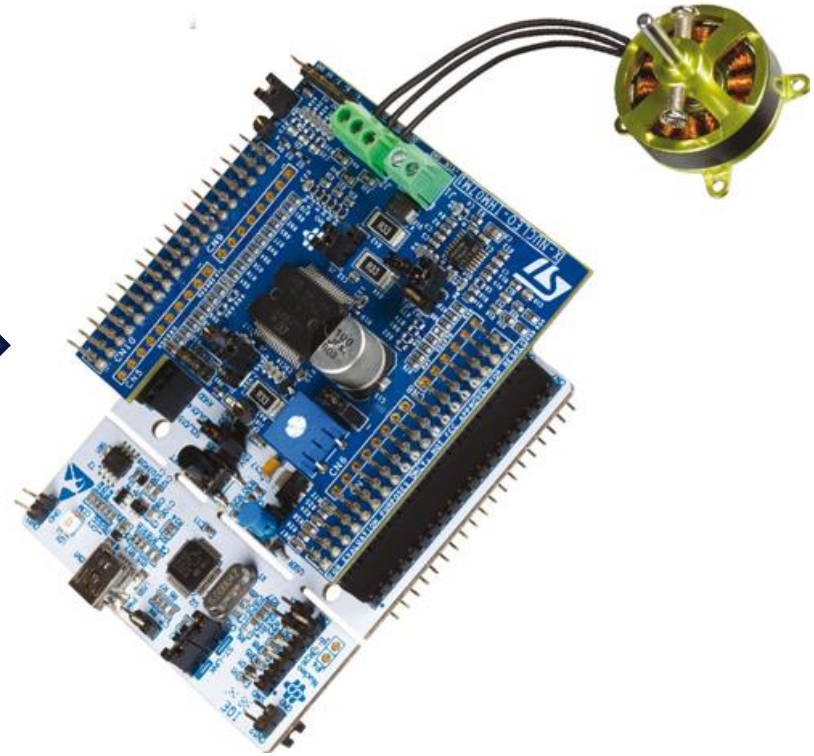
ST Product portfolio


**Microcontroller STM32**

**Gate Driver**


**Power Diode**

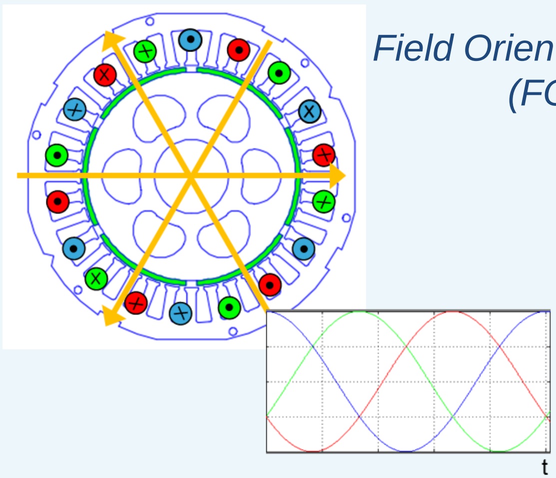
**Power MOSFETs**

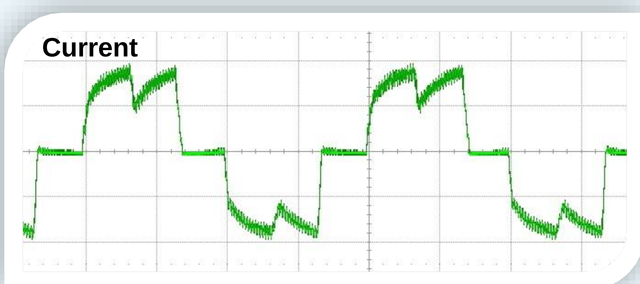
# Tecniche per il controllo motori

*3-phase Brushless motor*

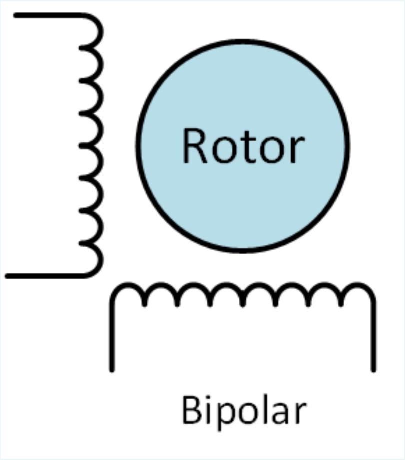
*Field Oriented Control (FOC)*




*Six-Step control*



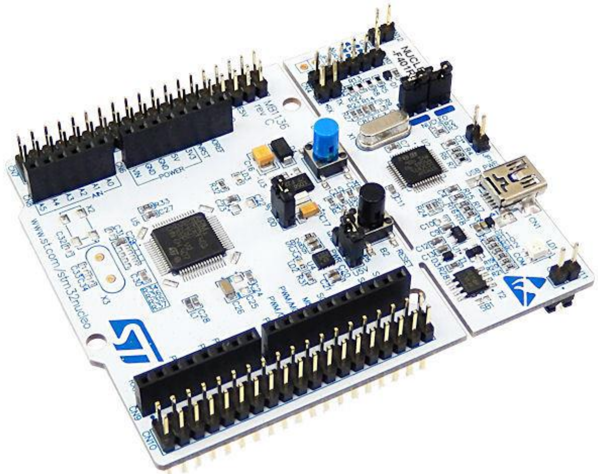

*2-phase (4 wires) Stepper motor*



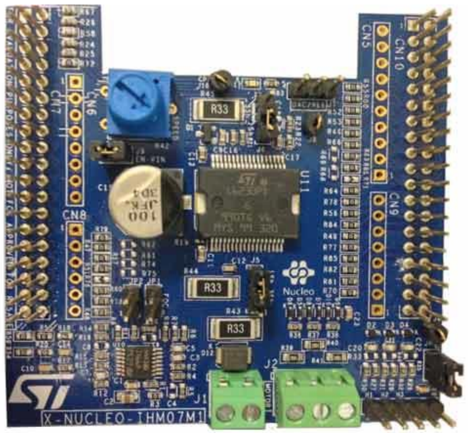
# Schede di sviluppo ST per il controllo motori



*Schede NUCLEO e X-NUCLEO per il controllo motori*



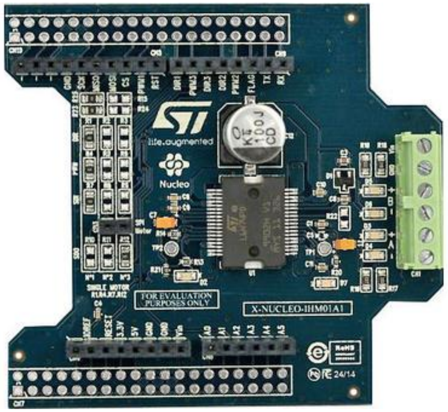
NUCLEO-F303RE/ NUCLEO-F334R8
**STM32 Microcontroller**



X-NUCLEO-IHM07M1
**Three-phase brushless DC motor drive**

Three-phase
brushless motor
(3 wires)

Two-phase
Stepper motor
(4 wires)



X-NUCLEO-IHM01A1
Stepper motor driver board

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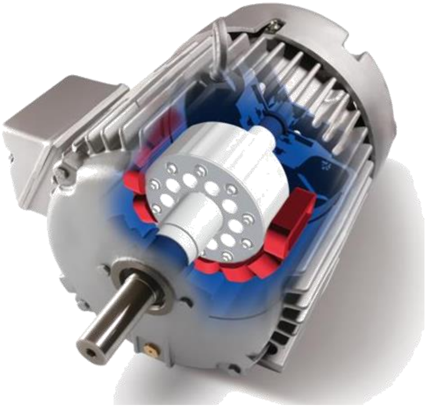
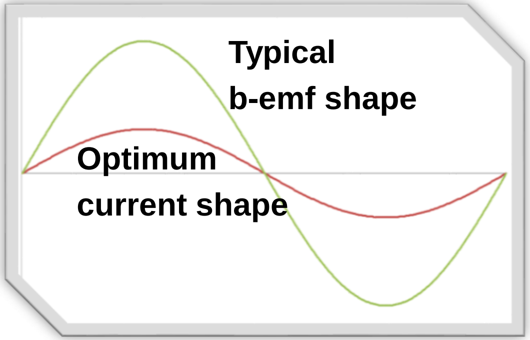
# PMSM motors

- **Permanent Magnet Synchronous Motor (PMSM)**
  - Stator can be the same as AC IM
  - Rotor houses permanent magnets
    - on the surface → Surface Mounted (SM) PMSM
    - Buried within the rotor →Internal (I) PMSM
  - Stator excitation frequency must be synchronous with rotor electrical speed
  - Rotation induces sinusoidal Back Electro-Motive Force (BEMF) in motor phases
  - Gives best performances (torque steadiness) when driven by sinusoidal phase current



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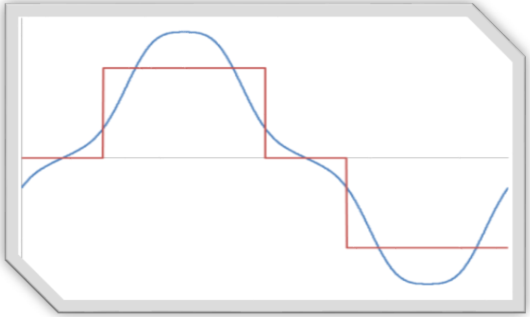
# BLDC motors

- **Permanent Magnet BrushLess DC motors (BLDC)**
  - Like PMSM - and despite of their name - require alternating stator current
  - Like in PMSM, rotor houses permanent magnets, usually glued on the surface
  - Like PMSM, stator excitation frequency matches rotor electrical speed
  - Unlike PMSM, rotor spinning induced trapezoidal shaped Back Electro-Motive Force (Bemf)
  - Gives best performances (torque steadiness) when driven by rectangular-shaped currents

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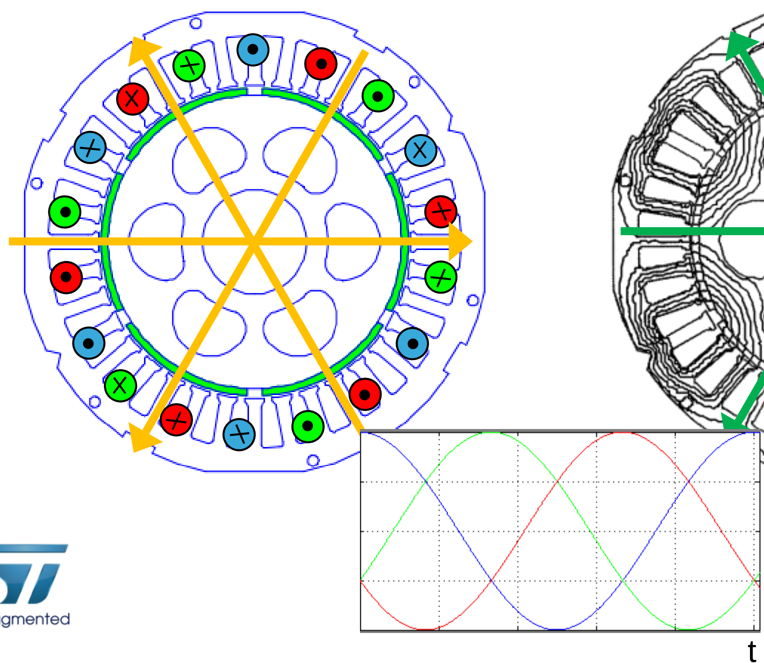
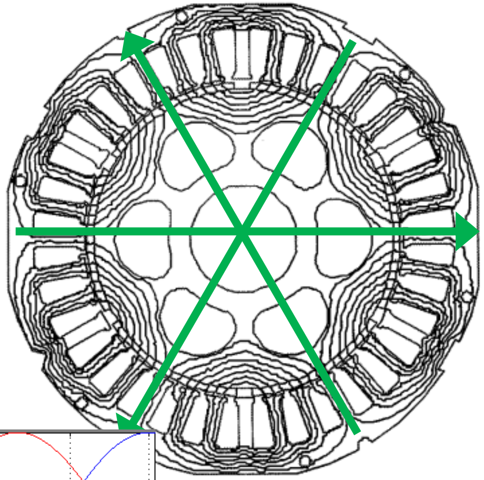
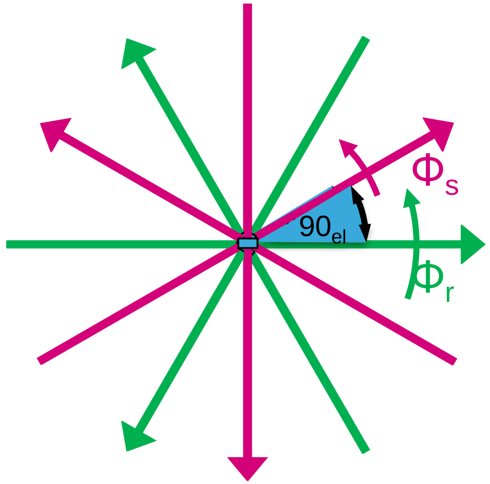
# PMSM FOC Overview



- Field Oriented Control: stator currents (Field) are controlled in amplitude and phase (Orientation) with respect to rotor flux
  - ➢current sensing is mandatory (3shunt/1shunt/ICS)
  - ➢speed / position sensing is mandatory (encoder/Hall/sensorless alg)
  - ➢current controllers needed (PI/D,FF)
    - ❖not easy… high frequency sinusoidal references + stiff amplitude modulation..
    - ❖reference frame transformation (Clarke / Park) allows to simplify the problem:



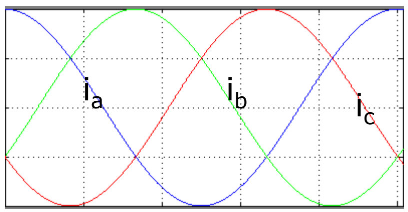






$T_e$ maximized if…

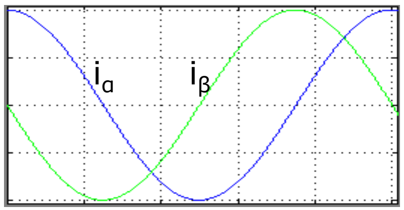
# PMSM FOC overview: reference frame transformations

- Clarke: transforms $i_a, i_b, i_c$ (120°) to $i_\alpha, i_\beta$ (90°); (consider that ia+ib+ic=0);

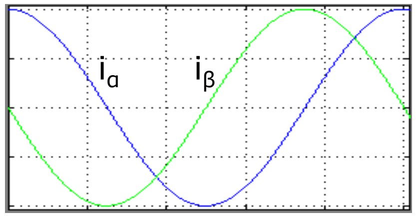



$$i_\alpha = i_{as}$$

$$i_\beta = -\frac{i_{as} + 2 i_{bs}}{\sqrt{3}}$$

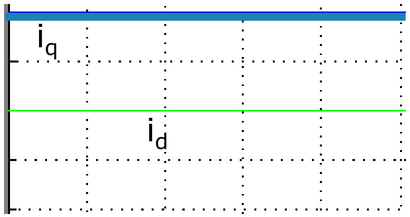



- Park: currents $i_\alpha, i_\beta$ , transformed on a reference frame rotating with their frequency, become DC currents $i_q, i_d$ (90°)!

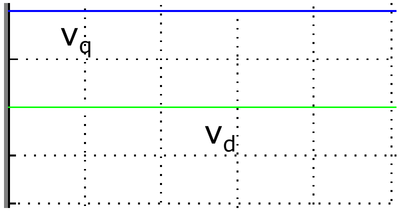



$$i_{qs} = i_\alpha \cos\theta_r - i_\beta \sin\theta_r$$

$$i_{ds} = i_a \sin\theta_r + i_\beta \cos\theta_r$$

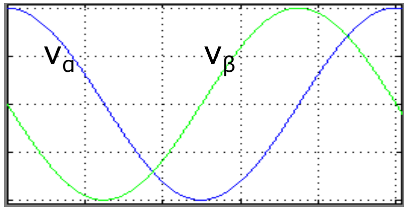



- PI regulators now work efficiently in a 'DC' domain; their DC outputs, voltage reference $v_q, v_d$ are handled by the Reverse Park -> $v_\alpha, v_\beta$ AC domain




$$v_\alpha = v_{qs} \cos\theta_r + v_{ds} \sin\theta_r$$

$$v_\beta = -v_{qs} \sin\theta_r + v_{ds} \cos\theta_r$$

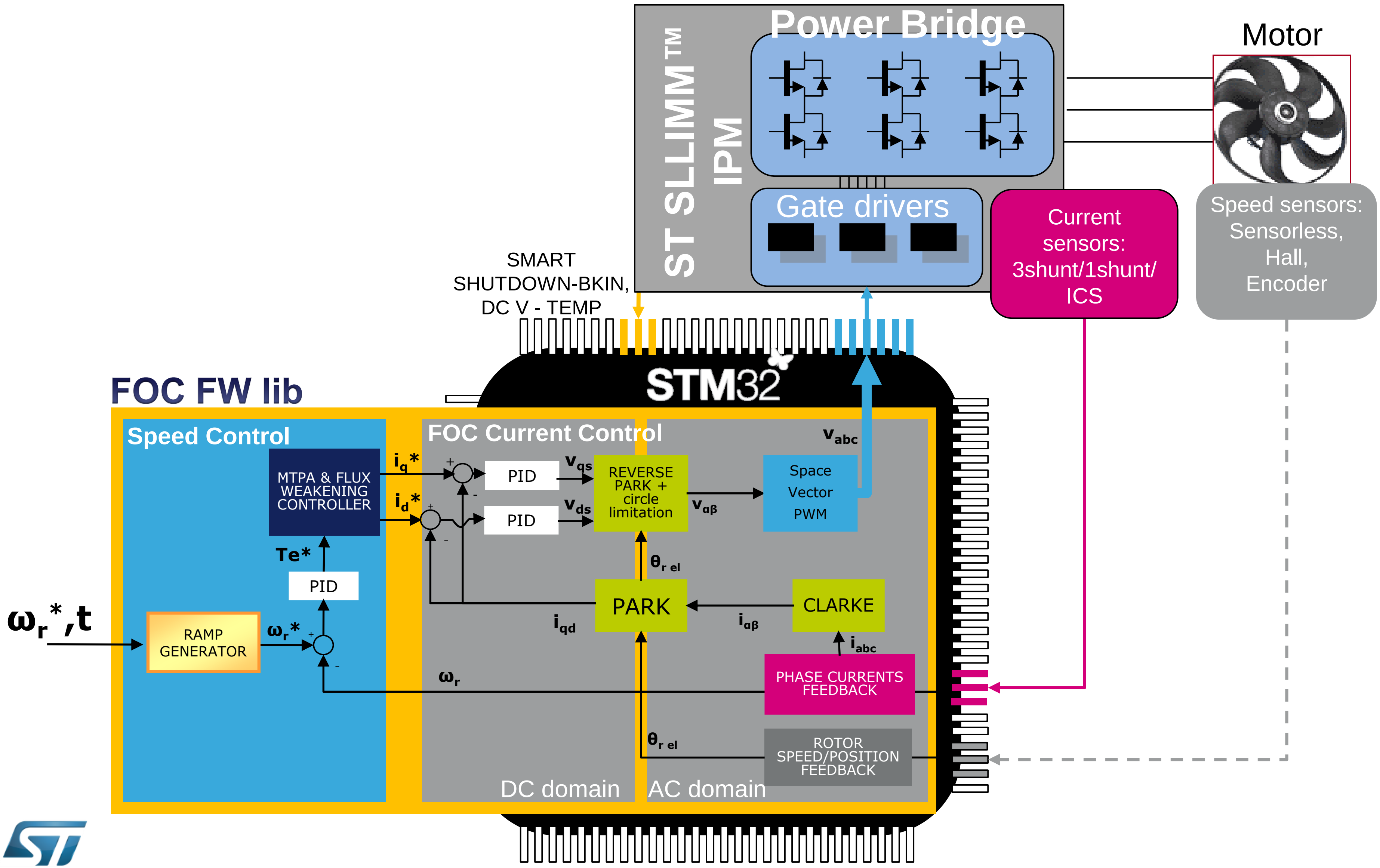


# Benefits of FOC



- Best energy efficiency even during transient operation, due to optimal current angle
- Responsive speed control to load variations, due to direct and decoupled control of electromagnetic torque and flux;
- Precise position control, due to direct and decoupled control of electromagnetic torque and flux;
- Acoustical noise reduction due to sinusoidal waveforms / optimized control

# PMSM FOC – Block Diagram

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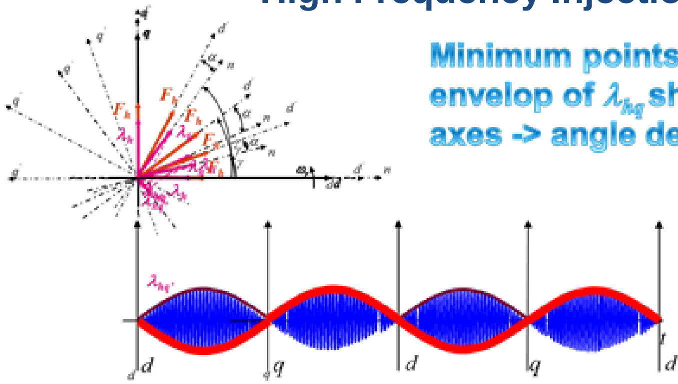
# Possible configurations 1/2

- Speed position feedback is mandatory
- Speed/position sensors supported:
  - Quadrature Encoder
    - Expensive sensor, usually only in robotics applications
  - Hall Sensors
    - Cheaper sensors, usually for application requiring full torque at zero speed
  - Sensor-less
    - High frequency injection (ST patented):
      - for anisotropic motors (IPMSM, Ld<Lq)
      - allows precise rotor angle detection; it enables advantages of FOC in torque/speed/position control mode at very low and zero speed
      - STM32F3 and STM32F4 only
    - State observer + PLL
      - Use electrical quantities (mainly current feedback) to estimate rotor position
      - Used for many applications not requiring full torque at zero speed or very low speed operations (< 3-5% of nominal speed)
    - State Observer + CORDIC

**High Frequency Injection**



**Minimum points of the envelop of $\lambda_{hq}$ show d/q axes -> angle detection !**

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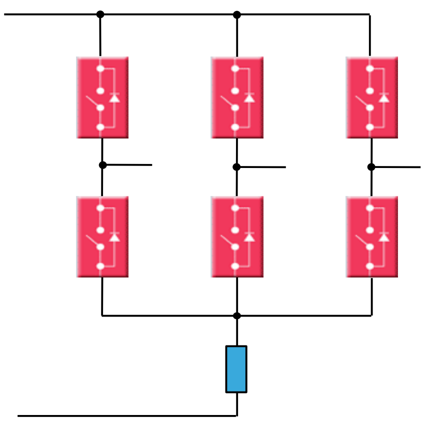
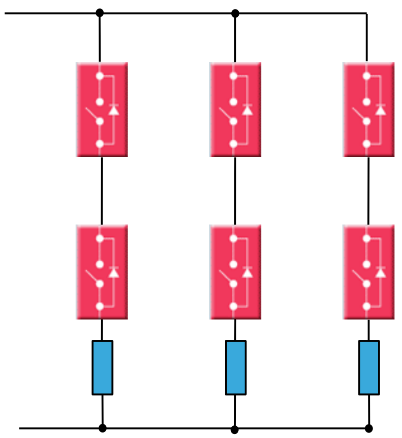
# Possible configurations 2/2

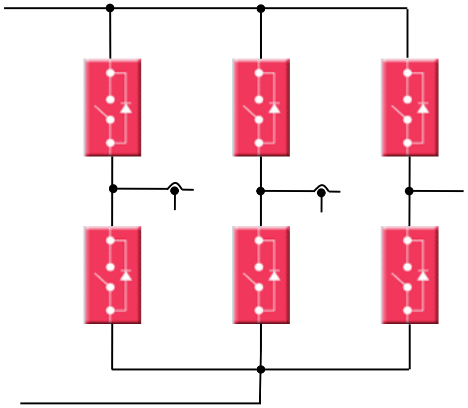


- Current feedback is mandatory

- Current sensing HW topologies:
  - 1 shunt resistor placed on the DC link
    - ST patented algorithm
    - Only one op-amp /shunt resistor is needed → lowest cost
    - Current reading algorithm may result in not accurate torque regulation
  - 3 shunt resistors placed in the three legs
    - Current reading accuracy: high
    - Best compromise cost / performances
  - 2 Isolated Current Sensors (ICS)
    - Not dissipative current sensing topology → mandatory when current exceed some tens Ampere
    - Expensive
  - Any possible configuration (2 motors x 3 current sensing x  3 speed sensors type) is supported by FW library







# Thanks