# STM32 PMSM SDK 5.2 training

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# High Frequency Injection

Introduction to the ST algorithm

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# Sensorless @ low speed

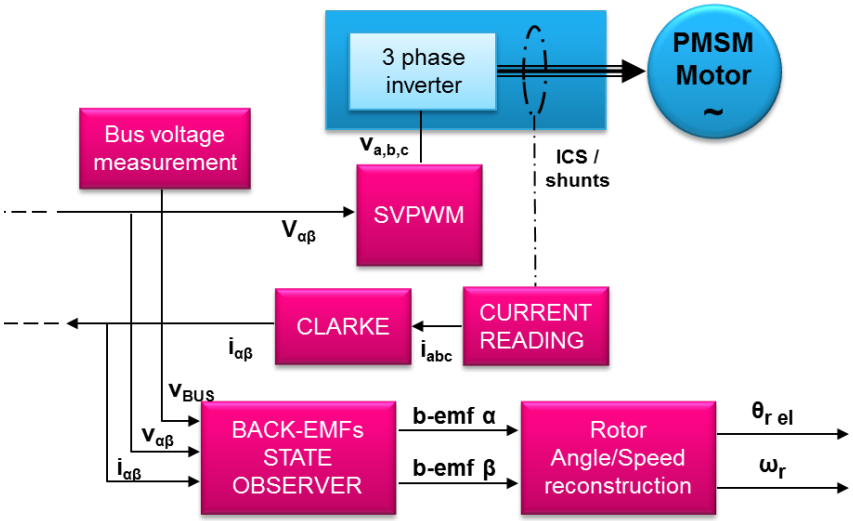


- Sensorless algorithms, used for sensing rotor angle and speed, such as Flux estimators / State observers / EKFs, are based or linked to motor's back-emfs, generated when the rotor moves:

$$e_\alpha = \Phi_m p \omega_r \cos(\theta_r)$$

$$e_\beta = -\Phi_m p \omega_r \sin(\theta_r)$$

- At very low speed back-emfs become very small




- Downhill, a PLL or CORDIC has to extract rotor angle from b-emfs…

**Efficient FOC / SPEED regulation becomes rough at speed < 4% (typical)**

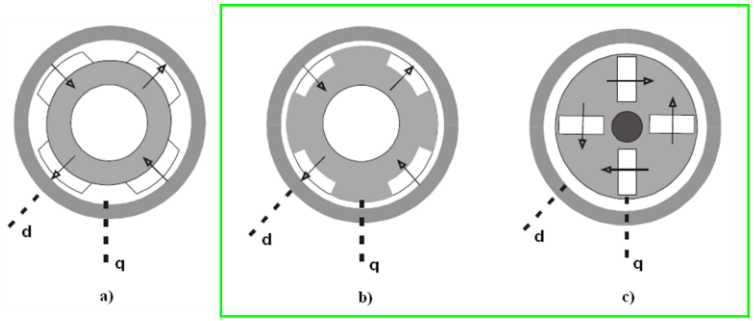
Patented

# HFI sensorless algorithm



- HFI sensor-less algorithm for I-PMSM is able to detect rotor angular position at ***zero speed*** exploiting the peculiar anisotropy of their magnetic structure.

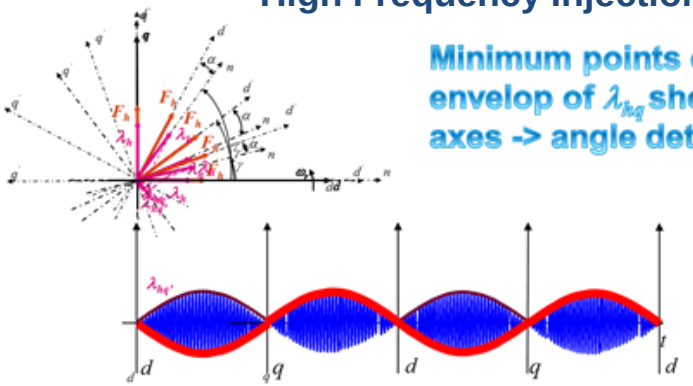
- Will be fully presented in another session.




a)SM-PMSM: Surface mounted permanent magnets -> $L_d=L_q$
b) & c)I-PMSM: Internal permanent magnets -> $L_d<L_q$
In particular: b) inset magnets; c) radial buried magnets.

**High Frequency Injection**

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

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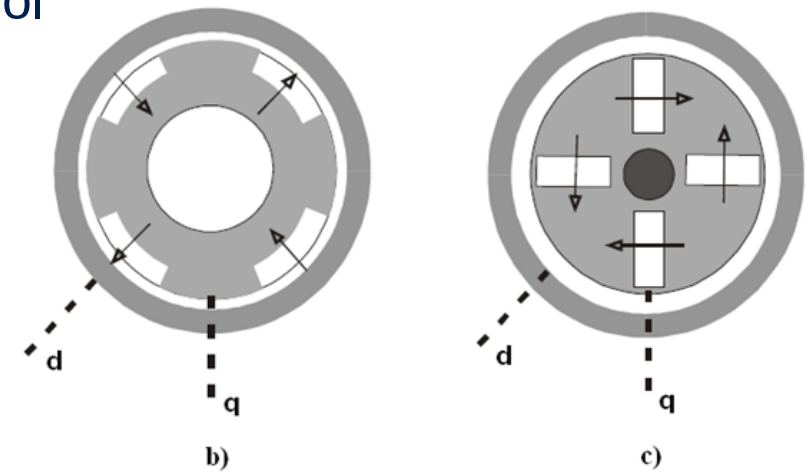
# Sensorless @ very low and zero speed



- The IPMSM magnetic anisotropy is exploited to achieve zero speed sensorless control




**Ld<Lq**

- Accordingly with literature, different kind of test signals can be superimposed to the Field Oriented Control classical scheme to evaluate rotor position
  - Zero sequence voltage exploitation
  - High frequency injection
  - Low frequency injection

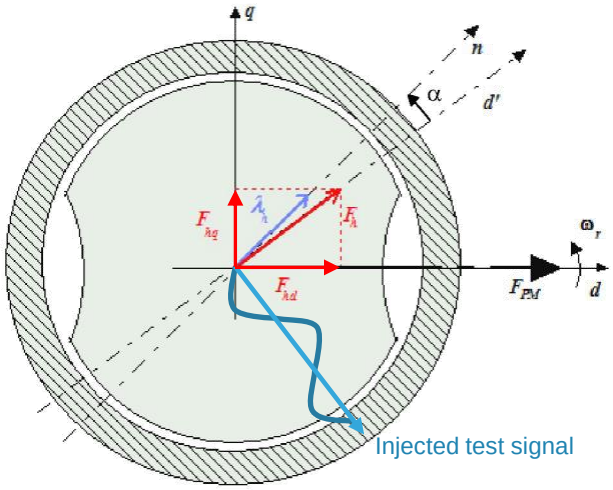
- Torque ripple minimized
- No additional hardware
- Easily adaptable to the SDK

# STM32 High Frequency Injection



## The Flux Deviation method

- Being the rotor located at a given angle, supplying the machine with an high frequency (200Hz-1kHz) sinusoidal test signal (it can be a voltage or a current), directed along a generic d' axis




- An $\mathcal{F}.m.m$ $F_h$ is obtained; due to the saliency of the rotor, $F_{hd}$ (its component on the true d axis) sees an $\mathcal{R}_d$ larger than the $\mathcal{R}_q$ seen by $F_{hq}$
- As a consequence, the flux generated $\lambda_h$ shows a phase displacement α from $F_h$ , and a small portion of $\lambda_h$ appears on q' → **flux deviation**

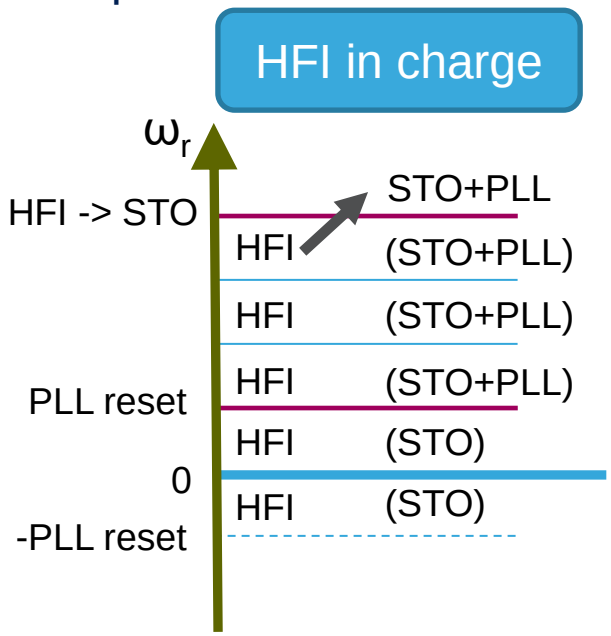
# High Frequency Injection

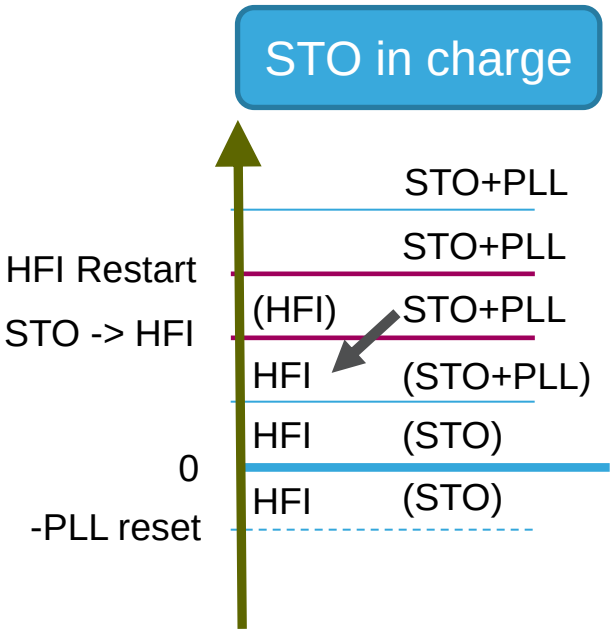


## Run Mode

- In run mode, the 2 sensorless algorithms, HFI and State Observer are conveniently merged, to cover the whole speed range of the motor, from negative max to positive max, zero included.

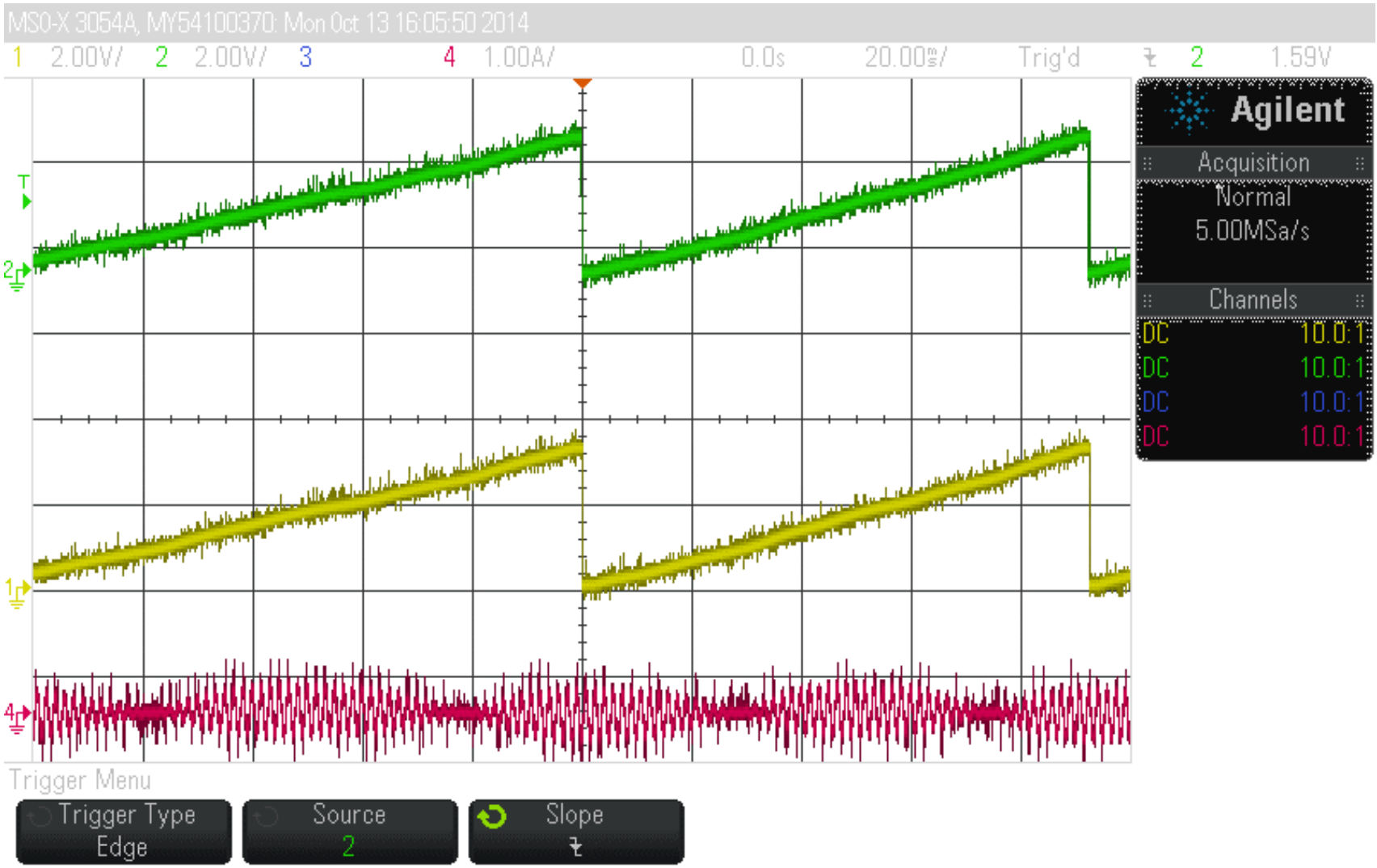
- This is accomplished by executing - in certain speed areas - both the algorithms, giving prevalence to the most suitable one, but being ready to switch to the other as needed.
  This is represented in the two diagram below:



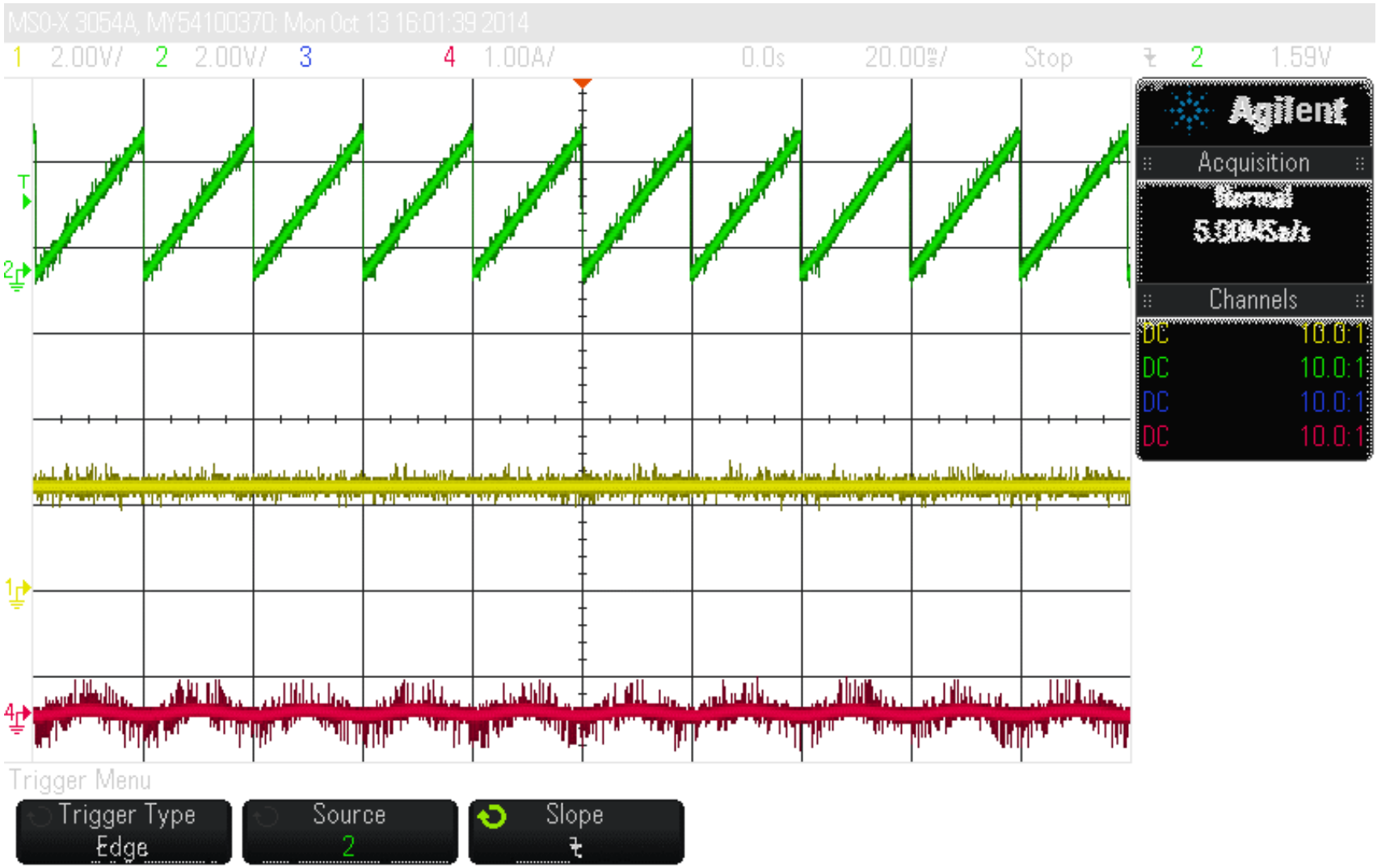
# Both HFI and STO working and calculate angle separately





# Angle calculation using the HFI is for high speed stopped

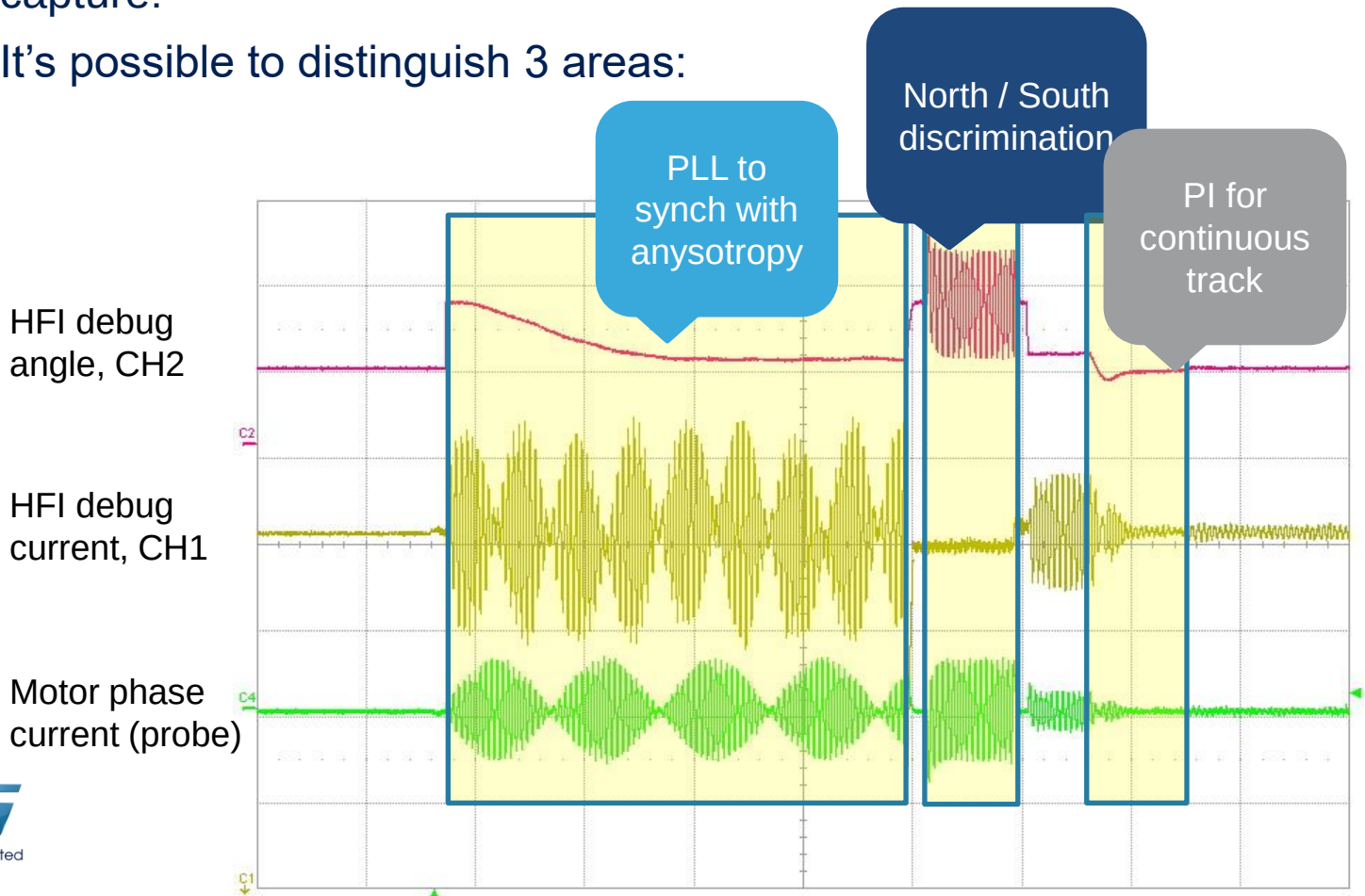




# HFI incremental system build



- STEP7: if the motor is suitable for HFI, like motor1, it's possible to continue and finalize the procedure. Set as debug variables «HFI debug current» and «HFI debug angle» as predefined CH1 and CH2, compile, download, start, capture:
- It's possible to distinguish 3 areas:



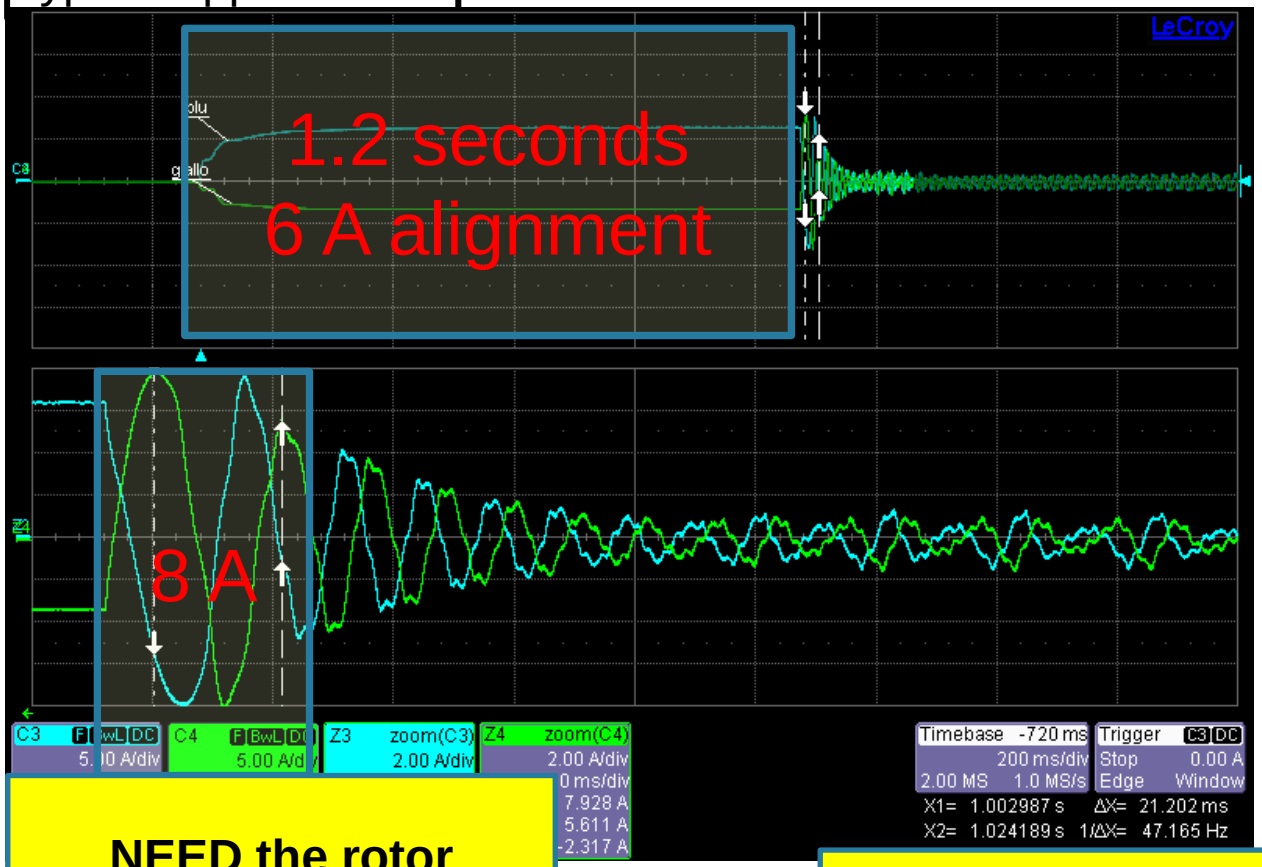
# Compressor startup: typical approach



**A long stressful alignment phase is carried out to make the rotor starts from a known angle**

**Stressful (≈ IPM rated) open loop stator current, at each motor startup**

typical approach




**NEED the rotor follows the open loop generated stator field**

**NEED to quickly reach high speed to lubricate and before load builds up**

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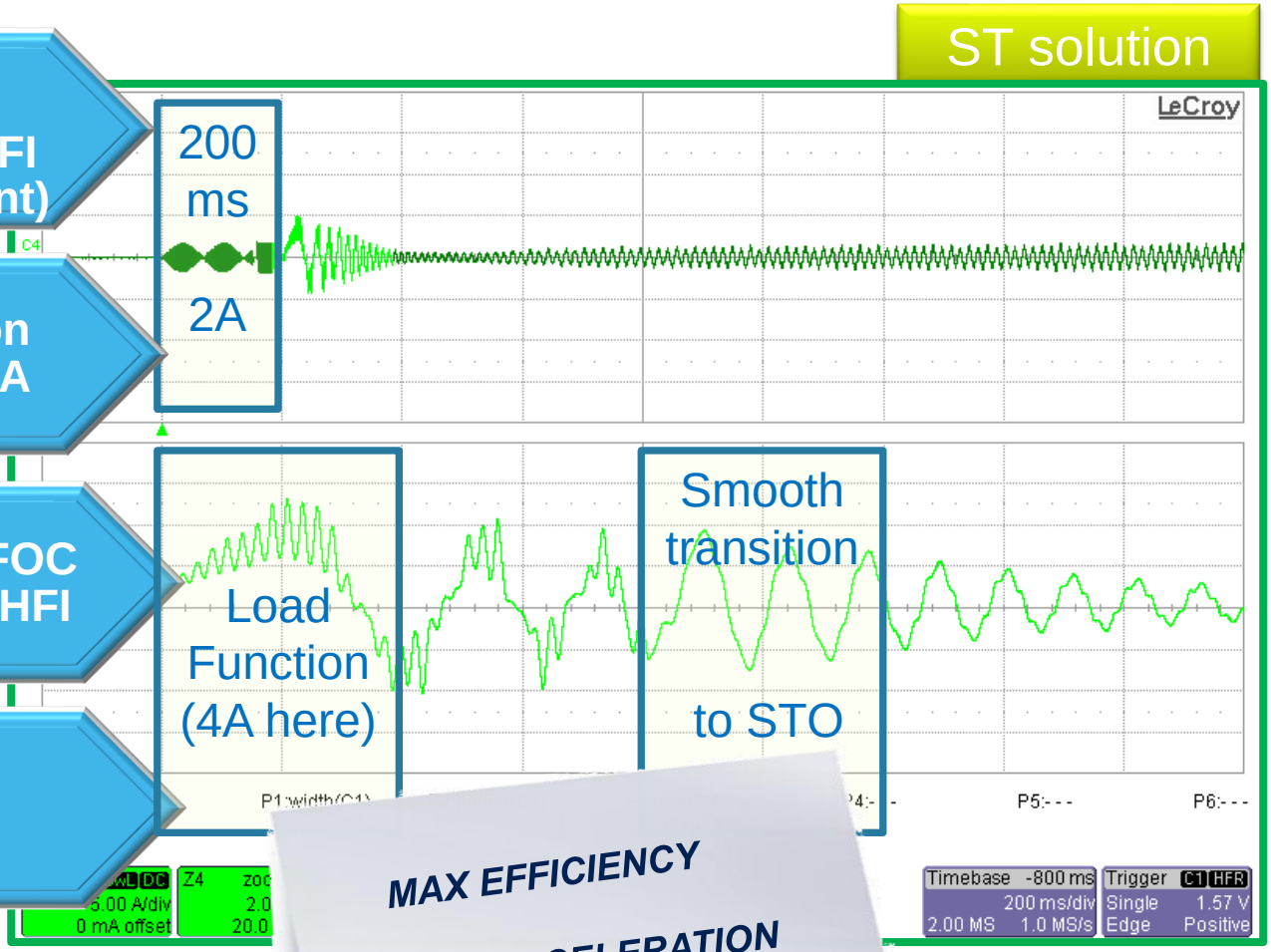
# ST HFI solution at compressor startup



- Initial natural rotor angle measured on HFI (not an alignment)
- Angle detection takes 200ms,2A
- Rotor starts in FOC closed loop on HFI
- MTPA




**MAX EFFICIENCY**

**MAX ACCELERATION**

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… more

# Thanks