

Stages of Motor Control

TI Precision Labs – Motor Drivers

Presented and prepared by Anthony Lodi

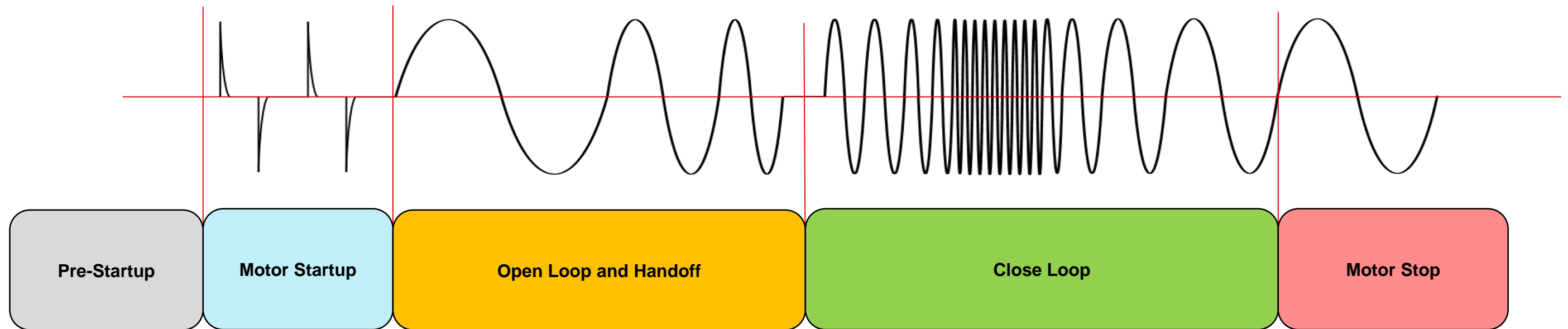
Overview

- Why discuss the stages of motor control?
- Sensored vs sensorless
- Pre-startup stage
- Motor startup methods
- Open loop acceleration
- Closed loop operation
- Motor stop operation
- Stages of sensorless motor control block diagram

Why discuss the stages of motor control?

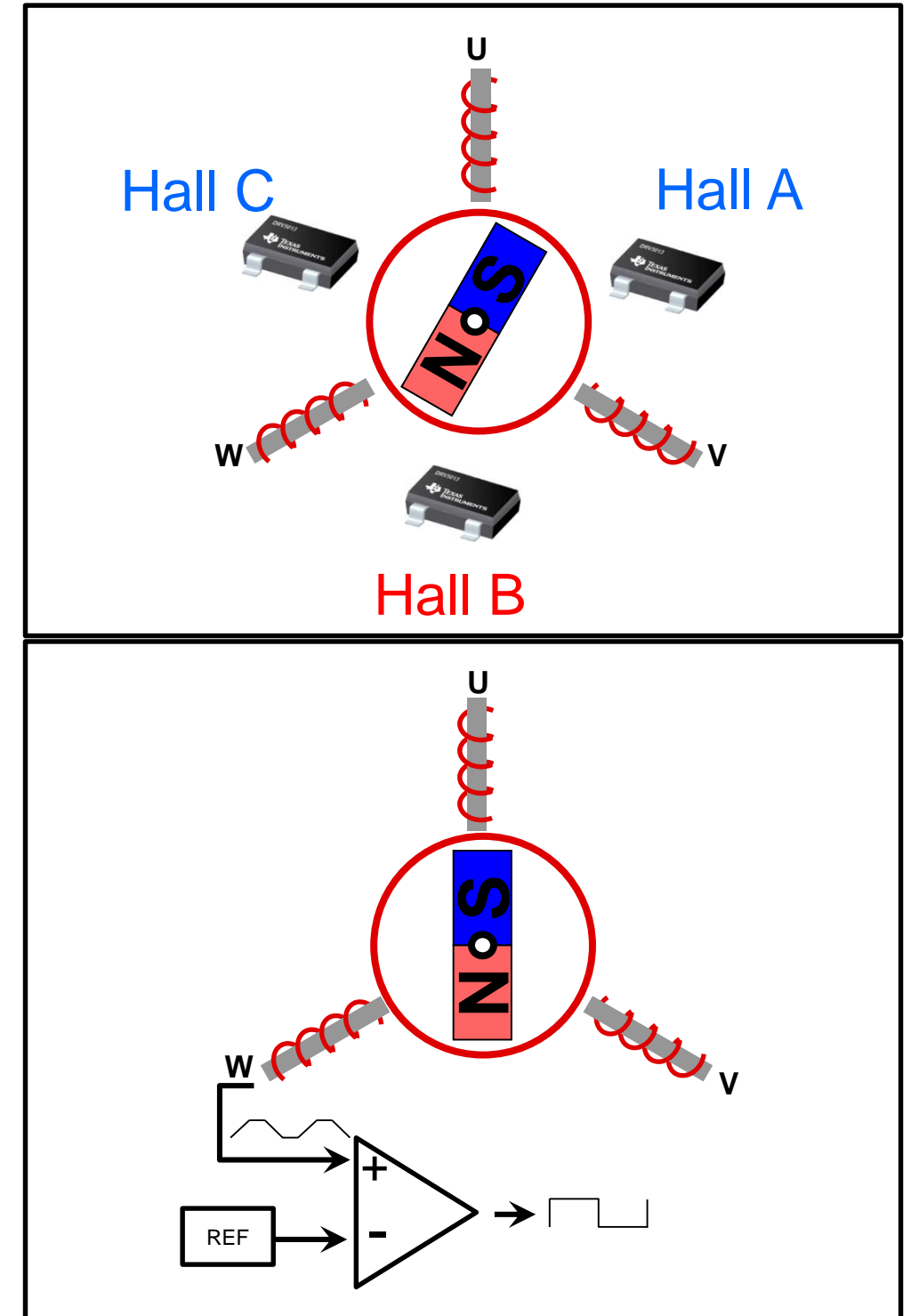
- Stages of motor control is about the sequence of events necessary to start spinning a motor, to increase the speed of the motor, and to stop the motor

Motor Operation



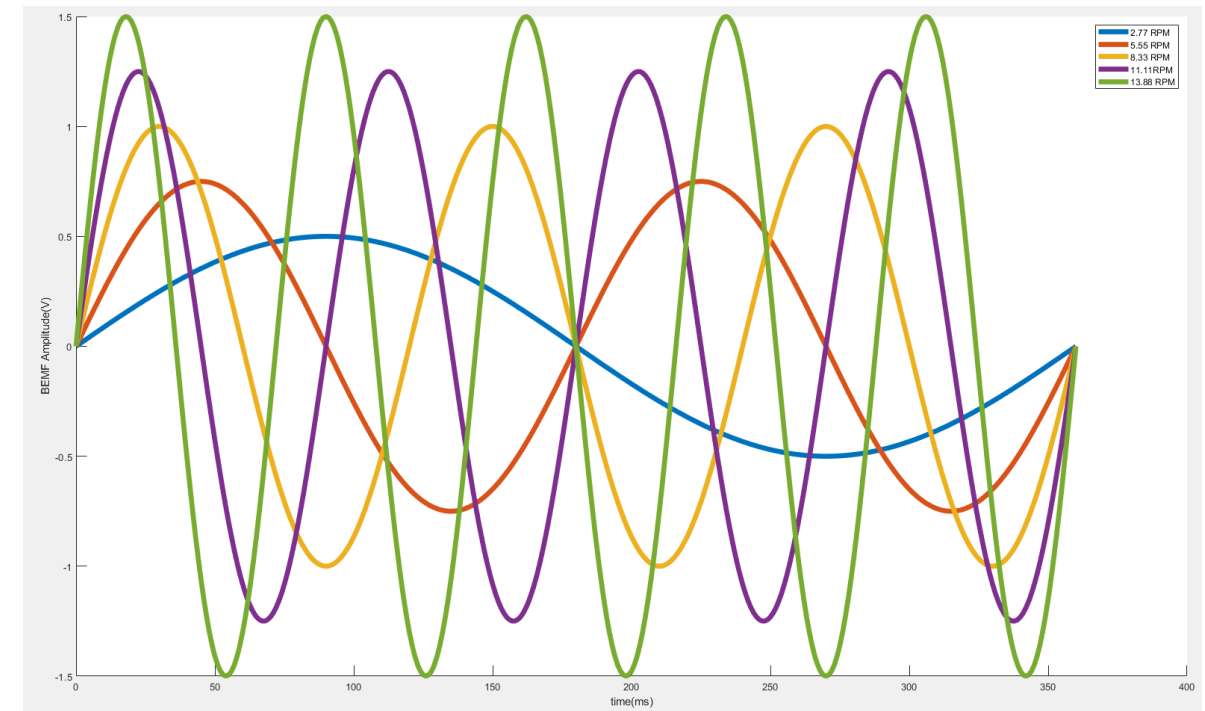
Sensored vs sensorless

- Sensored motor control
 - Relies on sensors to determine rotor position
- Sensorless motor control
 - Relies on back-EMF to determine rotor position
- To find out more information on sensored vs sensorless control, visit the *Motor Drivers: Sensored vs. Sensorless Control* section of this training series.



Pre-startup stage

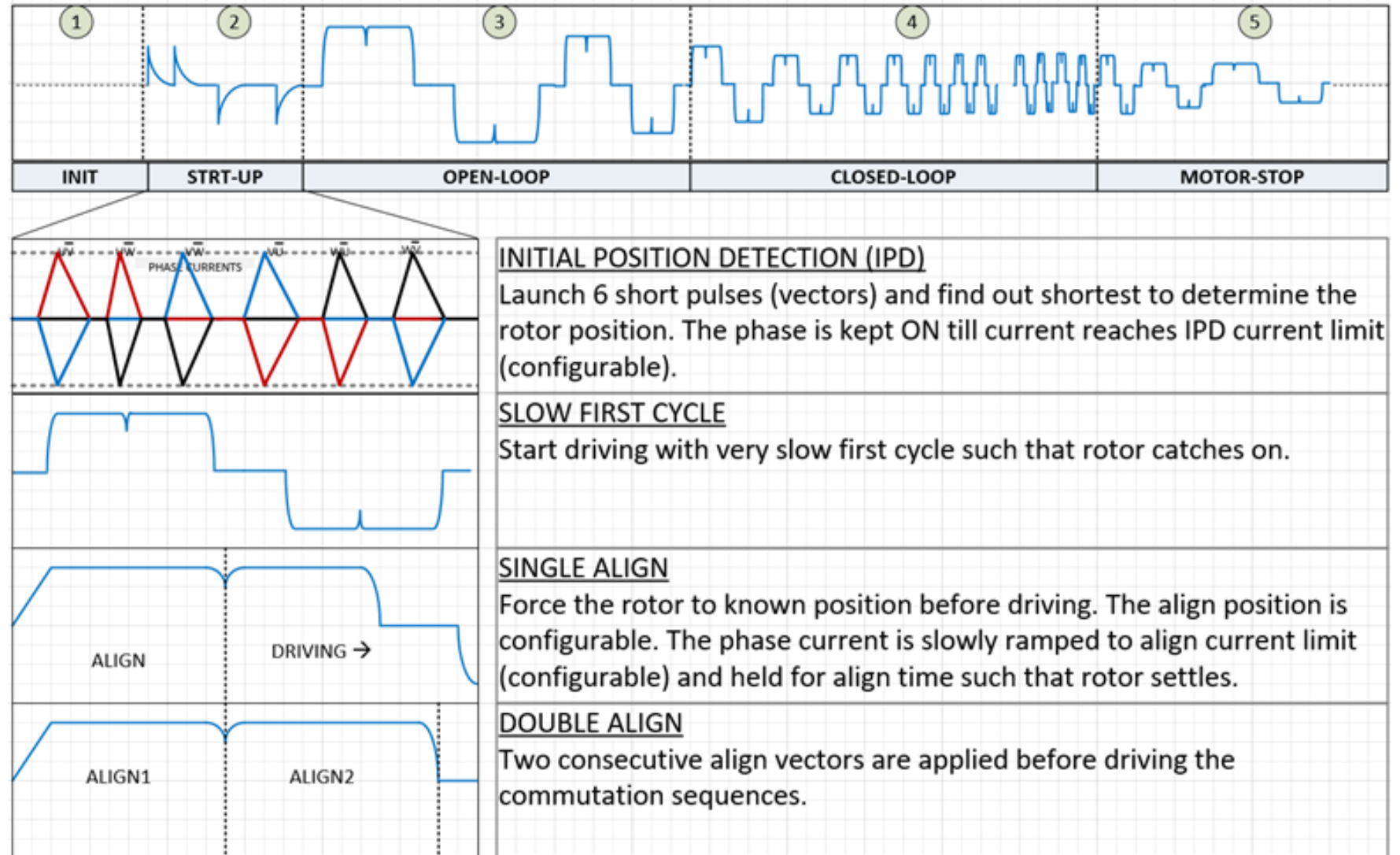
- Motor driver system monitors back-EMF to detect if the motor is spinning
- No back-EMF – motor driver system enters startup stage
- Back-EMF present and motor spinning in wrong direction – motor driver system enters stop stage
- Back-EMF present and motor spinning in correct direction – motor driver system enters closed loop commutation



Back-EMF amplitude at different motor speeds

Startup stage

- Need to know the position of the rotor to begin commutation
- 4 methods for sensorless startup
 - Single Align
 - Double Align
 - Slow First Cycle (SFC)
 - Initial Position Detection (IPD)



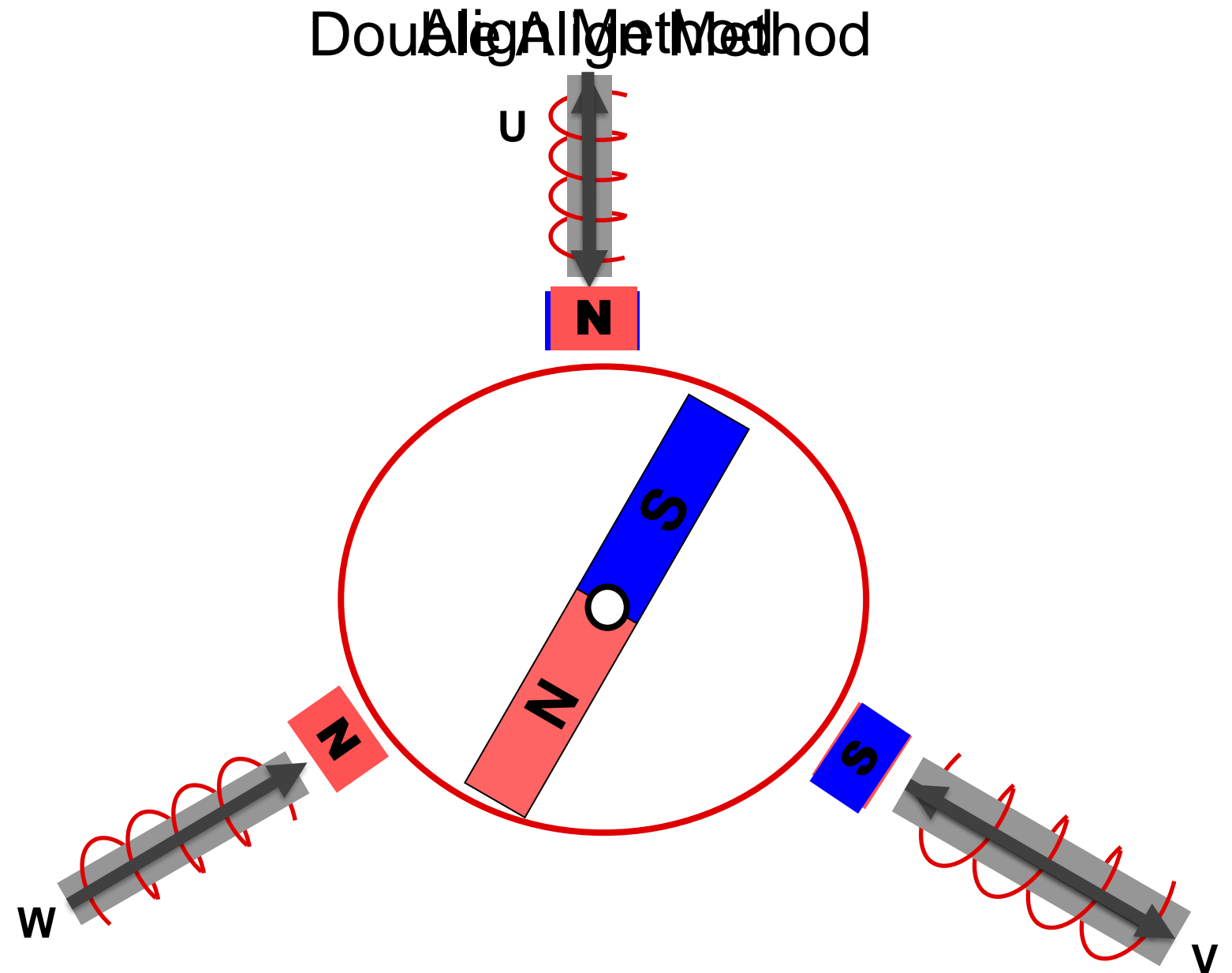
Align and Double Align

Align

- A magnetic field is applied between 2 of the phases
- The rotor aligns with the magnetic field

Double Align

- A magnetic field is applied between 2 of the phases
- A second magnetic field is then applied between 2 phases
- The rotor aligns with the magnetic field



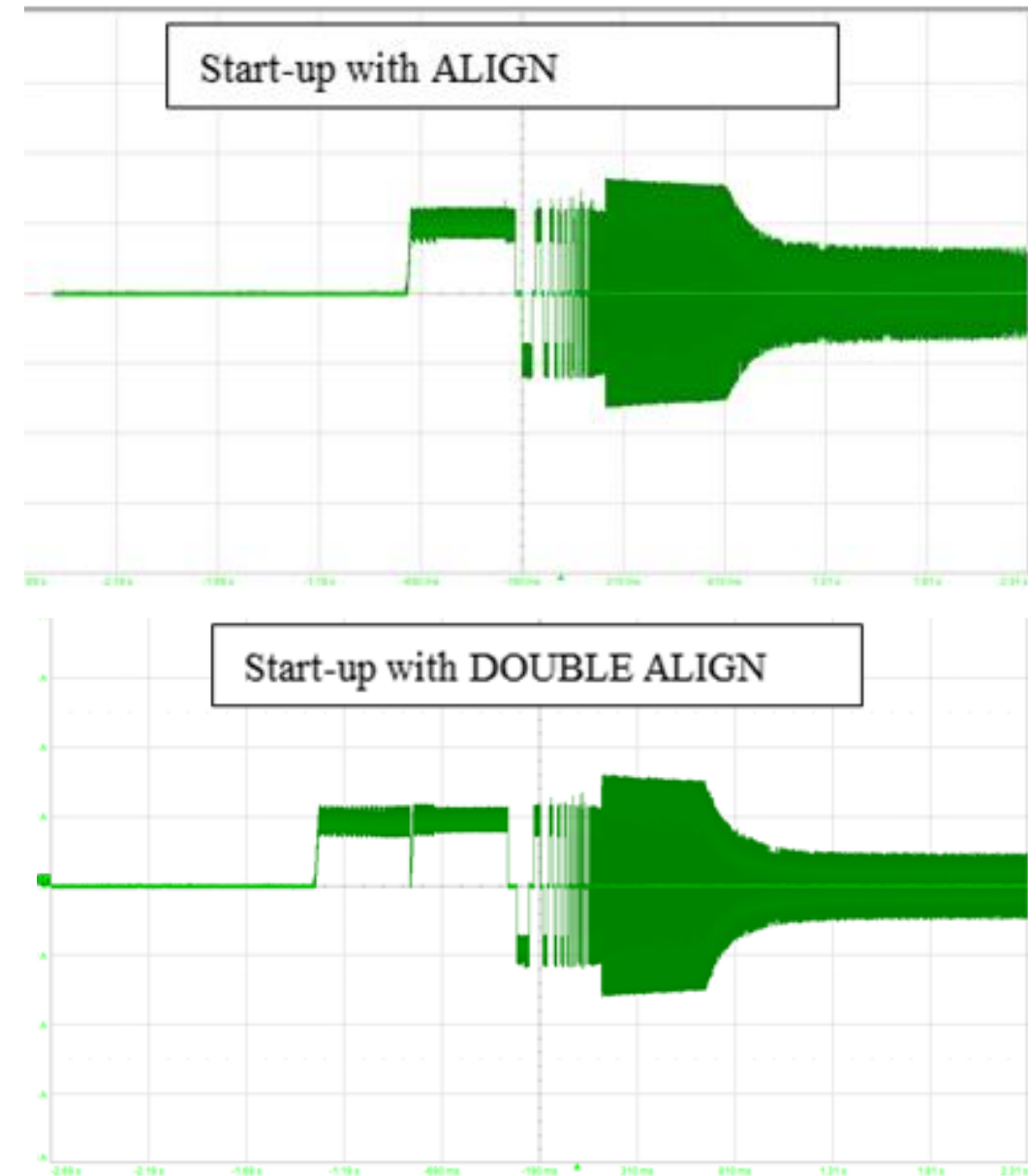
Align and Double Align

Align

- A magnetic field is applied between 2 of the phases
- The rotor aligns with the magnetic field

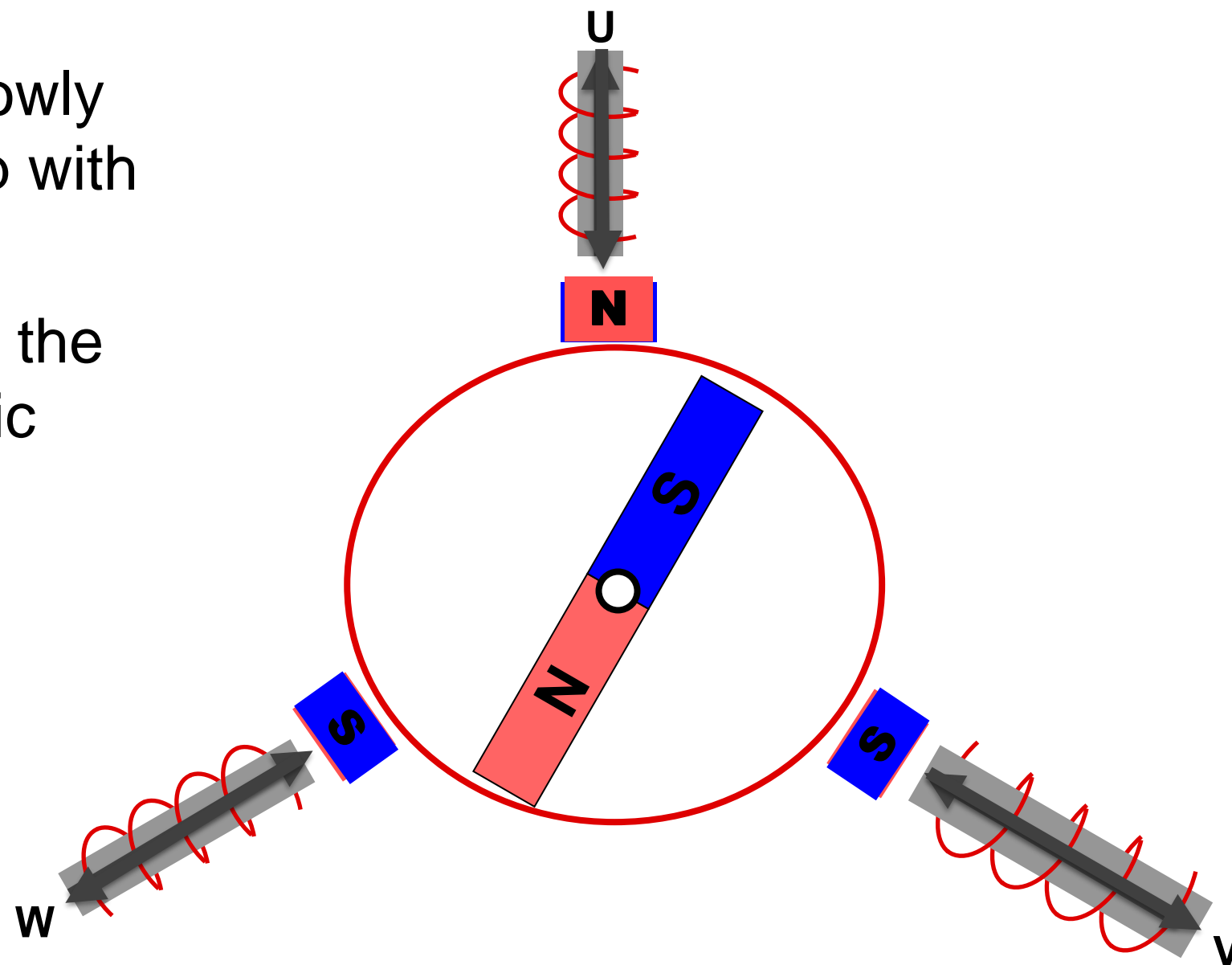
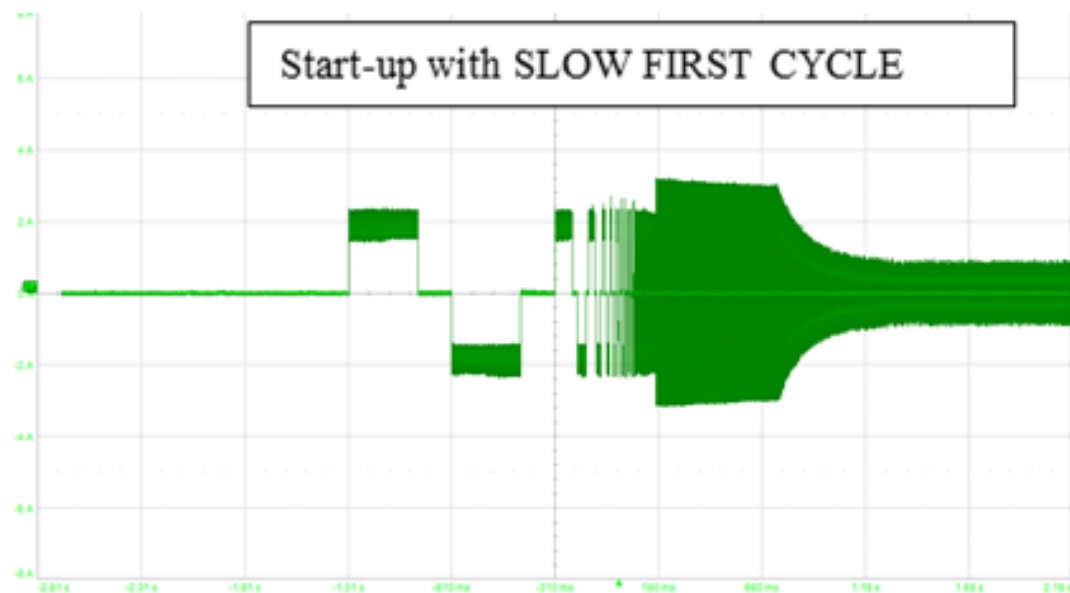
Double Align

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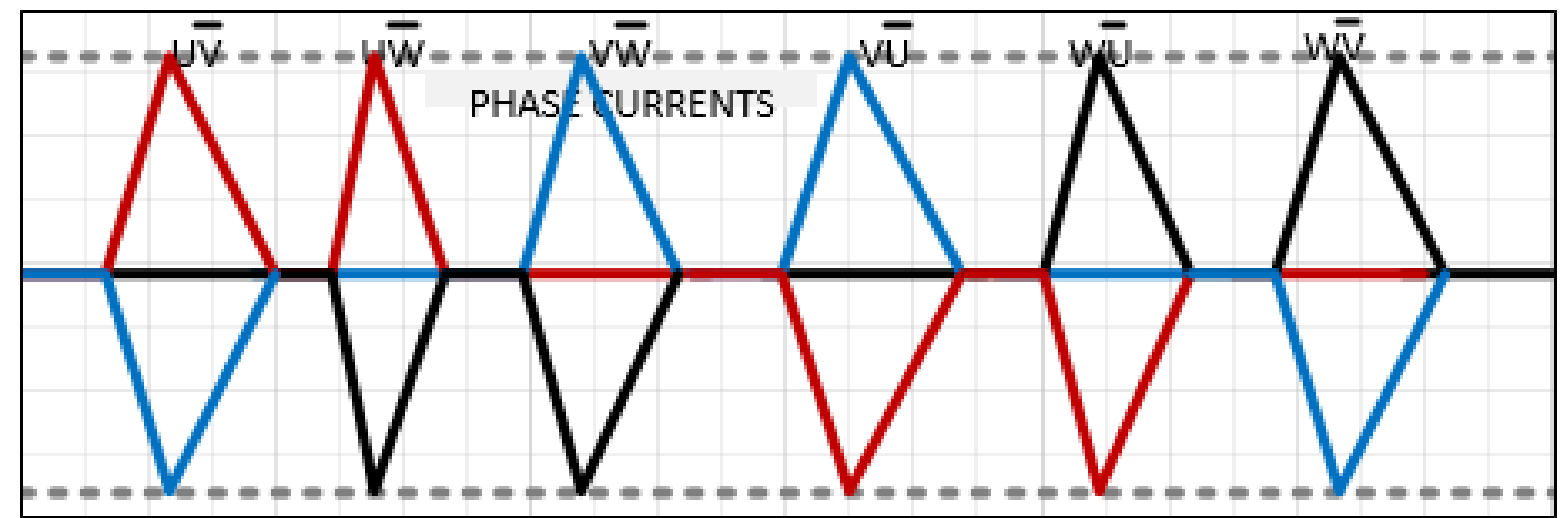
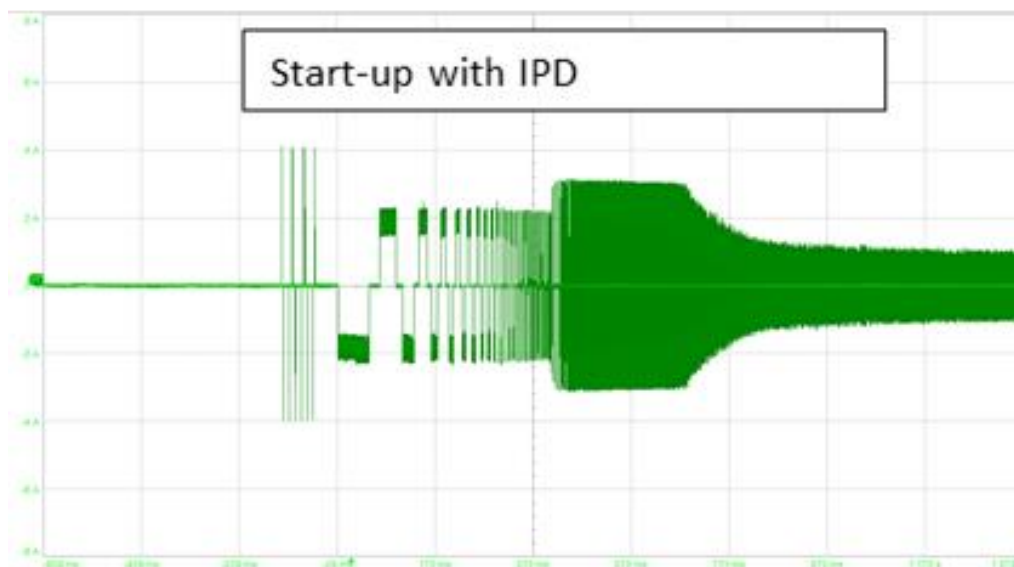
Slow First Cycle (SFC)

- A commutation sequence is done slowly to allow the rotor position to catch up with the magnetic fields
- By the end of the commutation cycle the rotor will be aligned with the magnetic fields

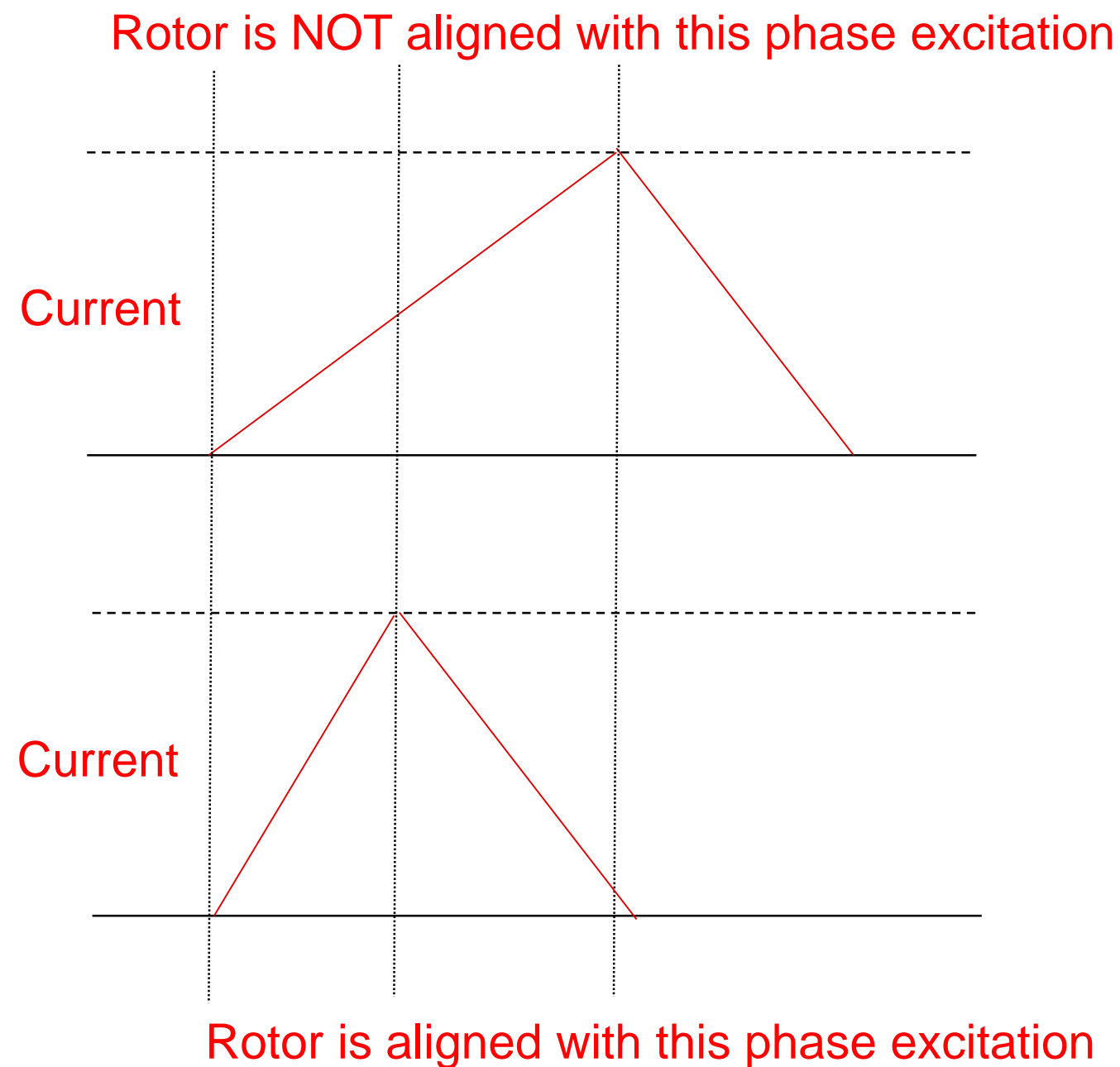
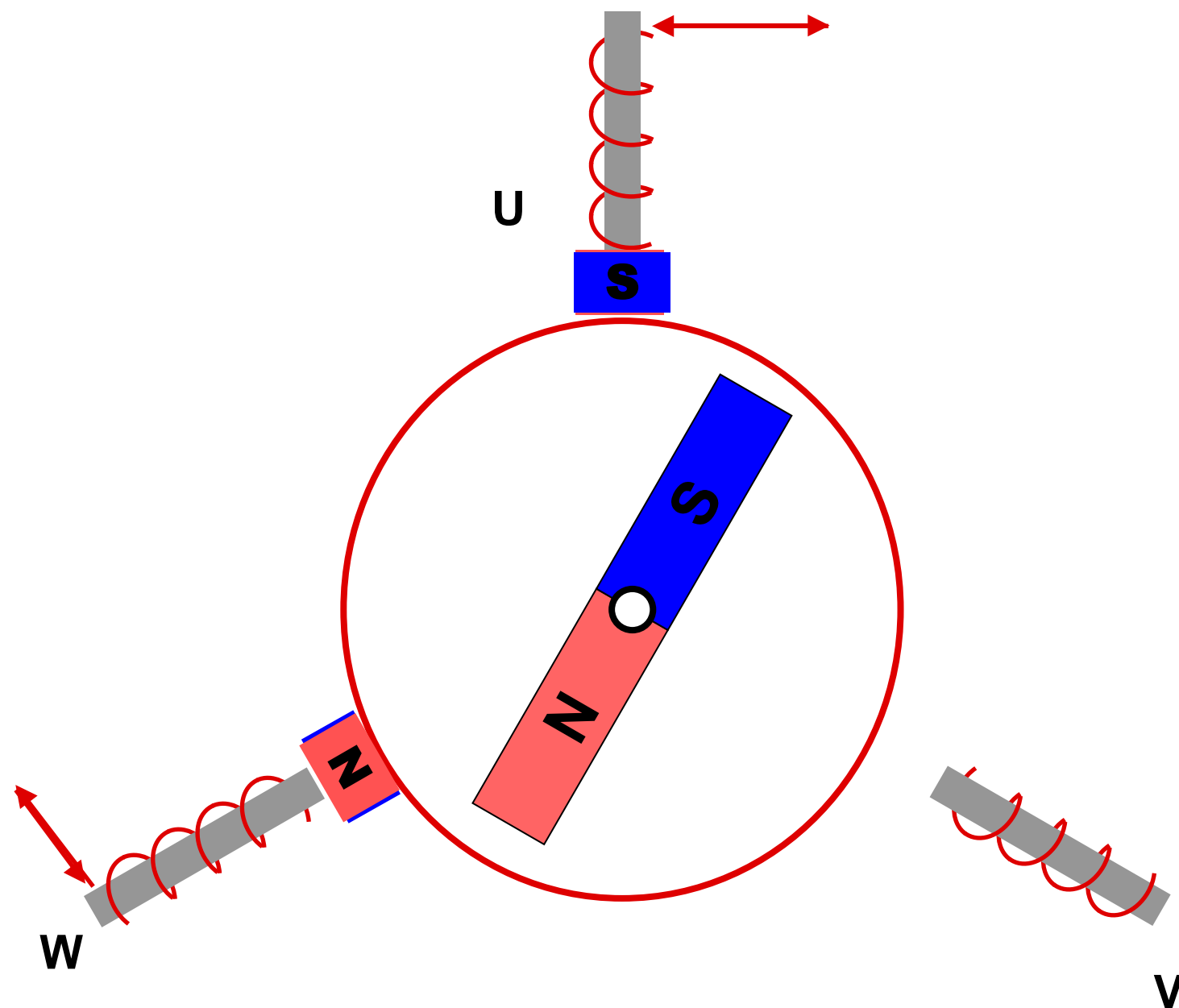


Initial Position Detection (IPD)

- Used to detect the position of the rotor
- Applies high frequency pulse of voltage to the coils
- Monitors time it takes for current in coils to reach a predefined level

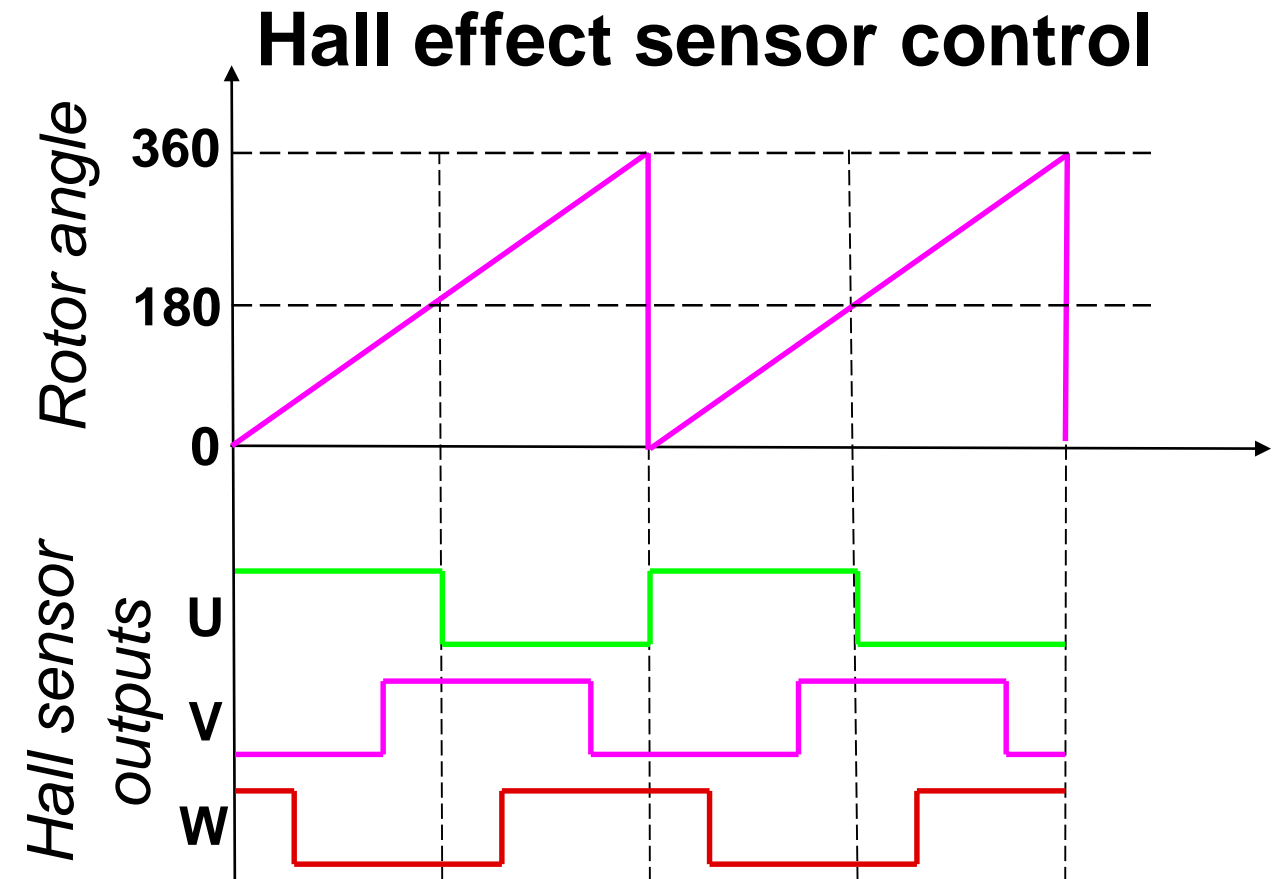


Initial Position Detection (continued)



Closed loop startup

- Possible for sensed applications
- Position of rotor determined from sensors
- Allows for immediate commutation of motor



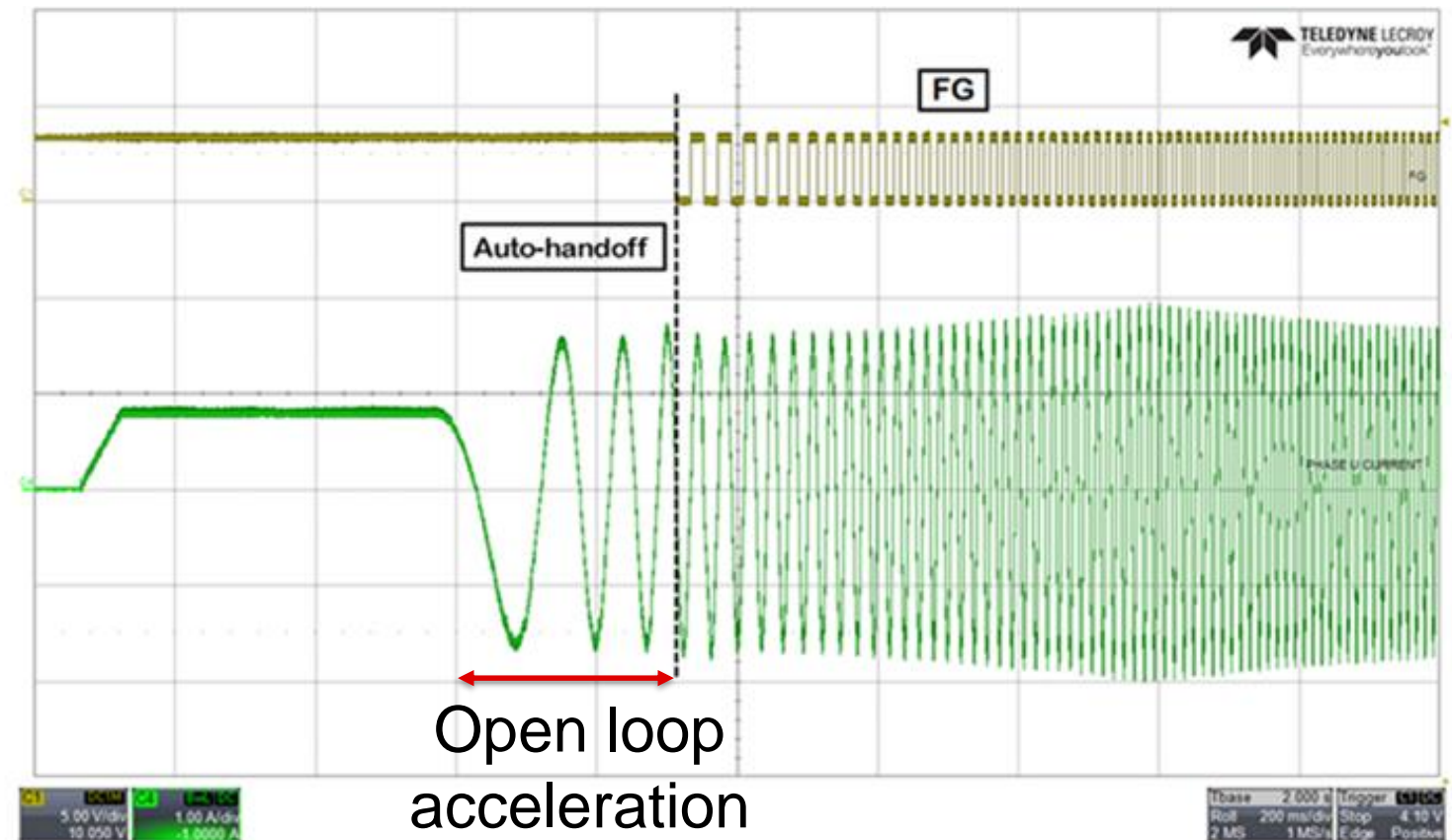
Advantages and disadvantages

Sensorless startup methods	Rotation	Startup time	Noise
Align/Double Align	Can spin backwards (-)	Slowest startup (-)	Quiet (+)
Slow First Cycle (SFC)	Can spin backwards (-)	Fastest startup (+)	Quiet (+)
Initial Position Detection (IPD)	Does not spin backwards (+)	Slower startup than SFC (-)	Noisiest (-)

- For more information on sensorless startup methods, visit the *Sensorless Startup Methods* video of this training series.

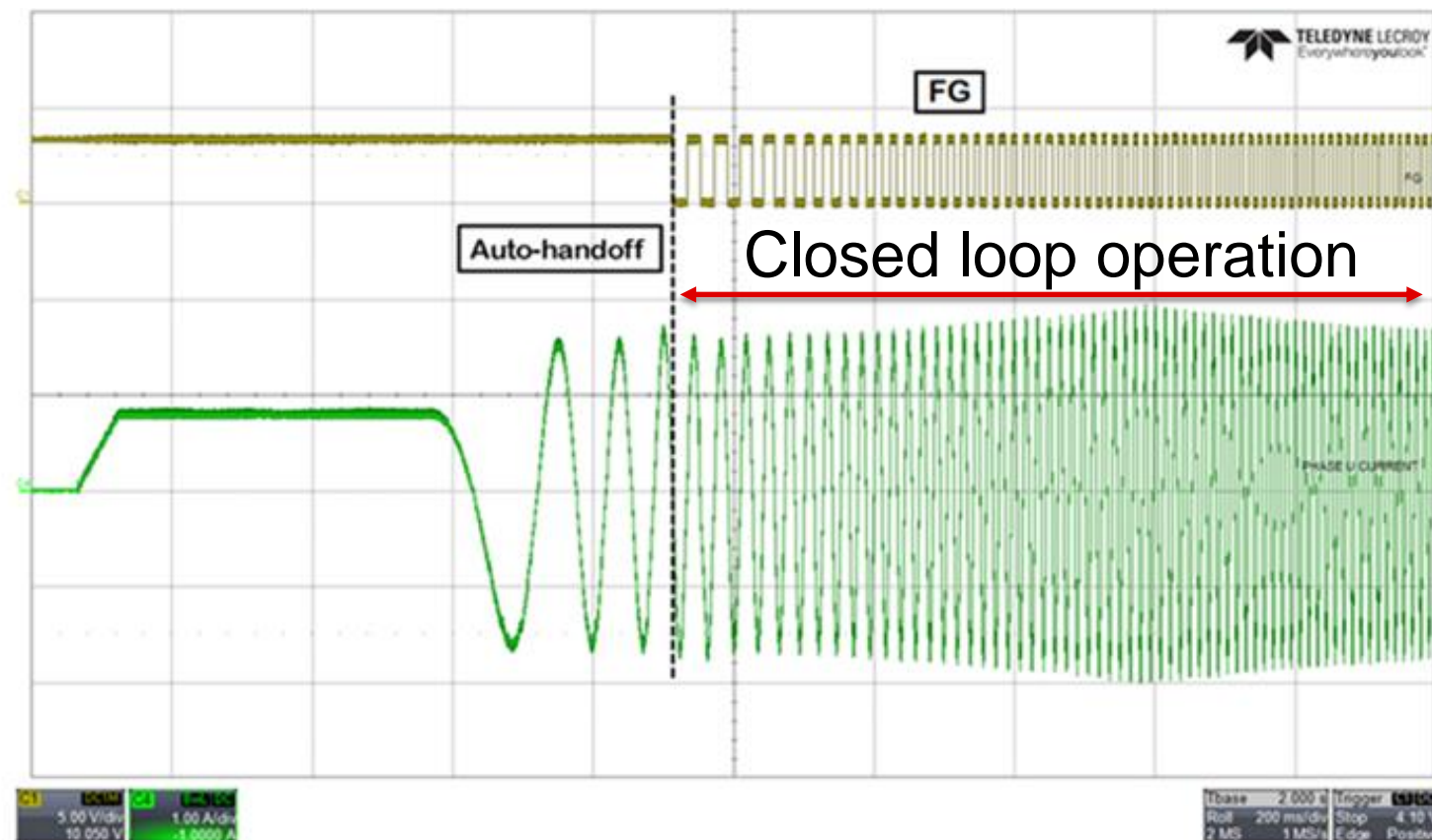
Open loop acceleration stage

- Acceleration performed slowly
- Current limiting can be accomplished through phase current monitoring
- Open loop stage lasts until sufficient back-EMF is generated
- Fault can occur if control is misaligned or if motor speed is insufficient.



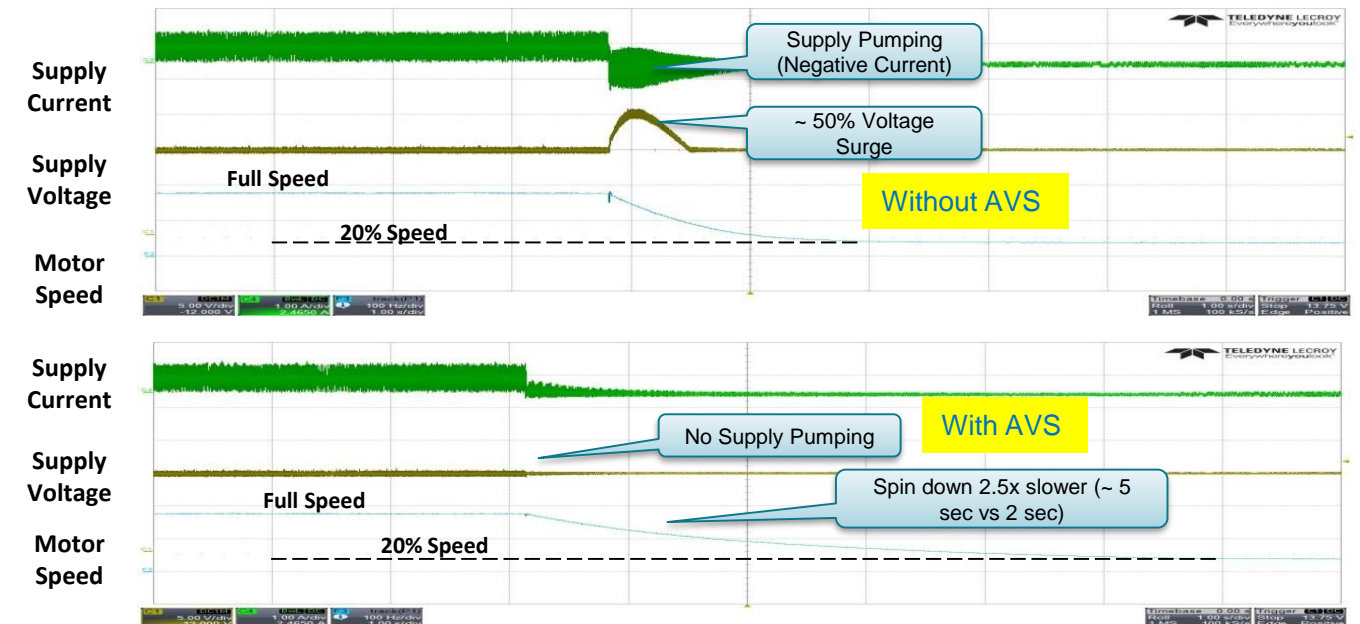
Closed loop operation stage

- Position and speed of the rotor can be determined from back EMF
- Acceleration can be performed quicker
- Allows for efficient commutation



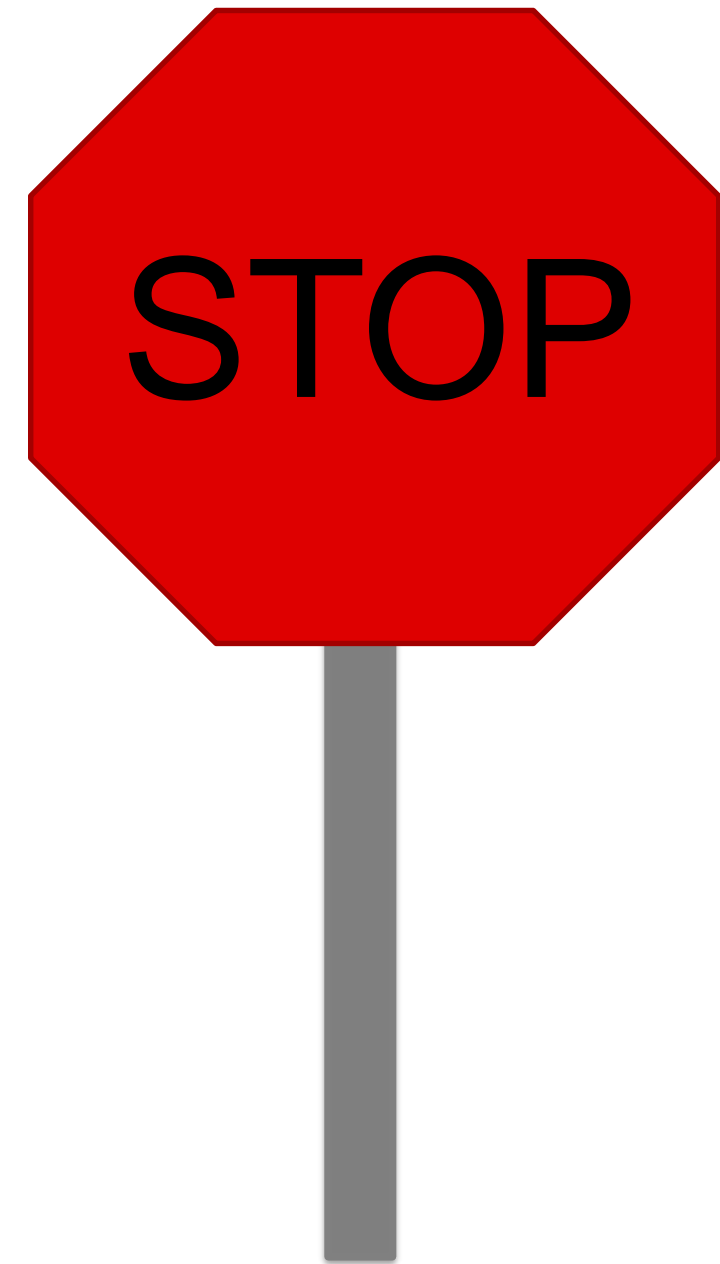
Motor stop stage

- Hi-Z braking (Coasting)
 - All MOSFETs are off, current circulates through body diodes
- Anti-Voltage Surge (AVS)
 - Slower deceleration to avoid supply voltage increase
- Regenerative Braking
 - Commutates in reverse sequence to force current into supply
 - Used to recharge battery during braking

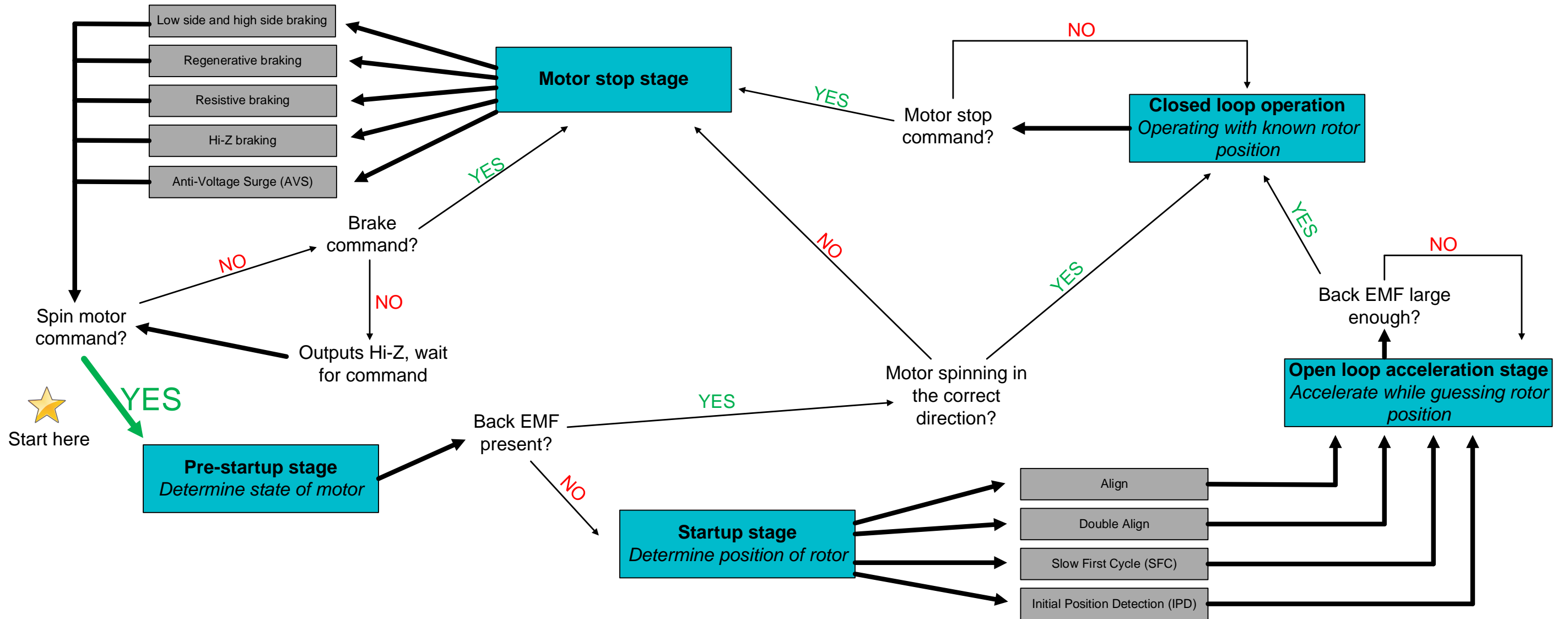


Motor stop stage

- Resistive Braking
 - Resistive path opened in parallel with power stage to dissipate energy
- Low side and high side braking
 - All of the low side or high side MOSFETs turned on, current circulates through MOSFETs
- Combination of different methods
 - A combination of methods can be used to slow the motor



Stages of sensorless motor control block diagram



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