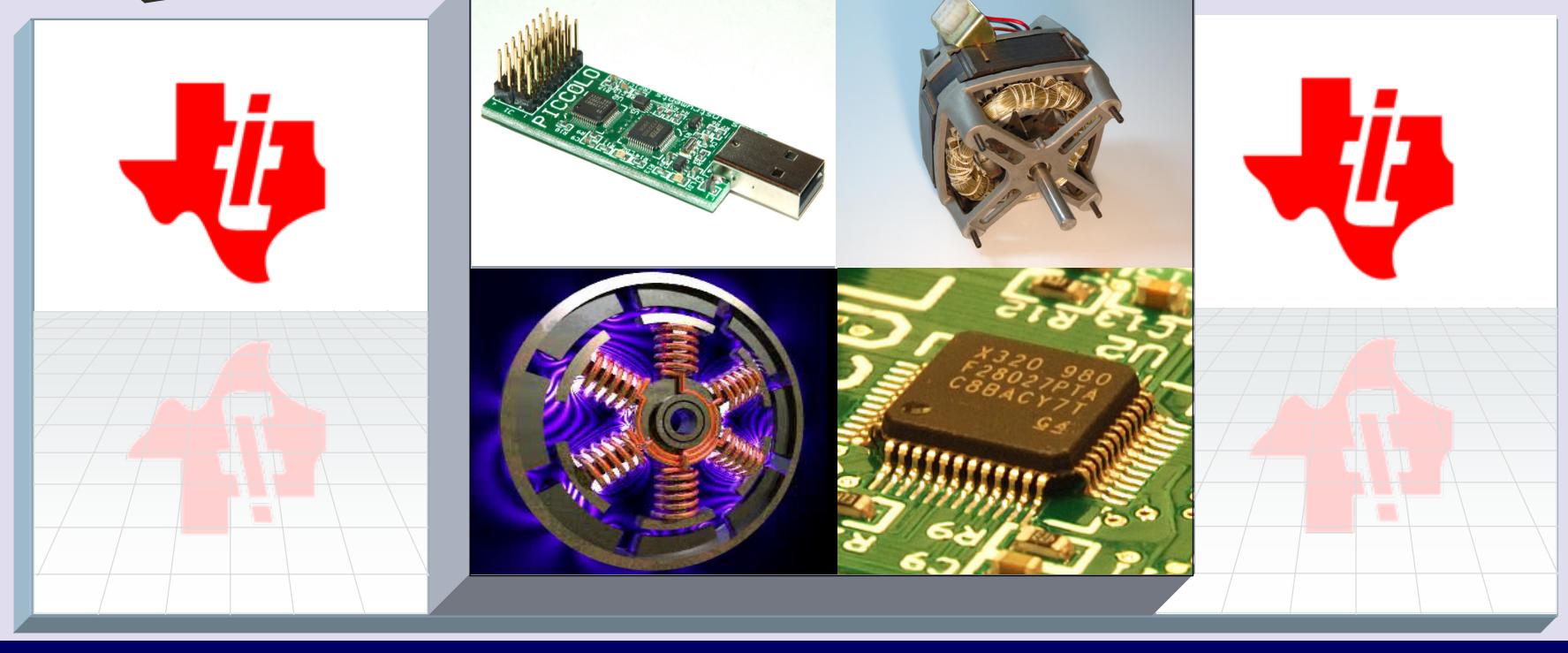


# Spinning Metal with TI



Dave Wilson  
Team Lead, Motor Solutions Group

 **TEXAS  
INSTRUMENTS**

# In Today's Exciting Episode...

- Motor Topologies and Operation
- Digital Control Techniques
- Power Modulation and Regeneration
- TI Motor Control Solutions

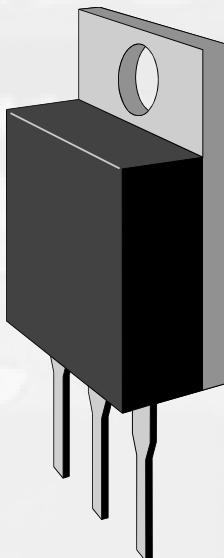


# Control Partitioning

*Intelligence*



*Power Conversion*



*Motor*



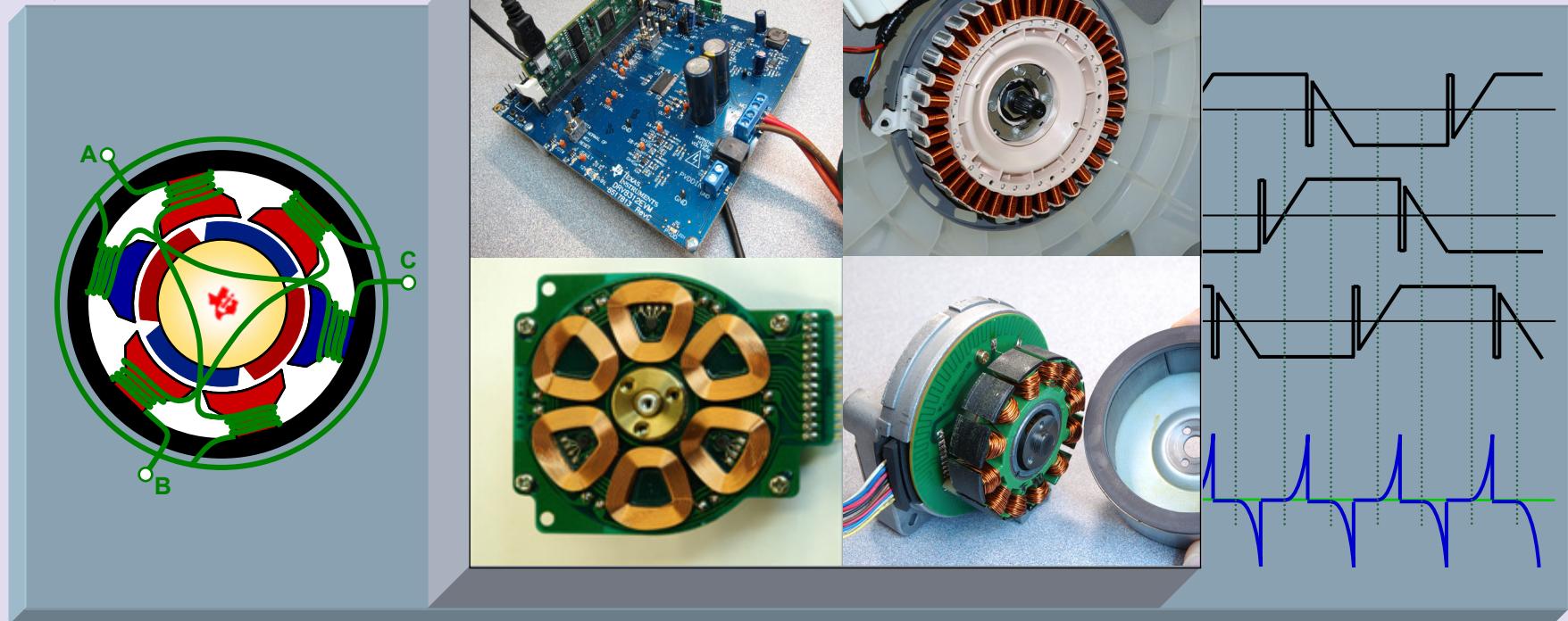
**Feedback vs. Feedforward**

- Digital Control
- PI(D) controllers
- Observers
- Field Oriented Control
- Sensorless FOC

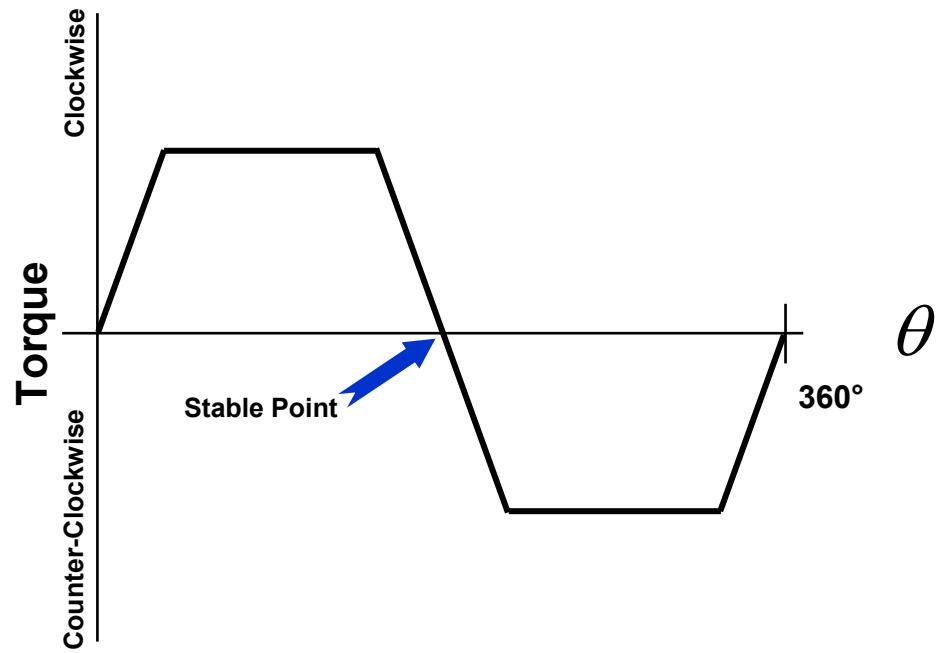
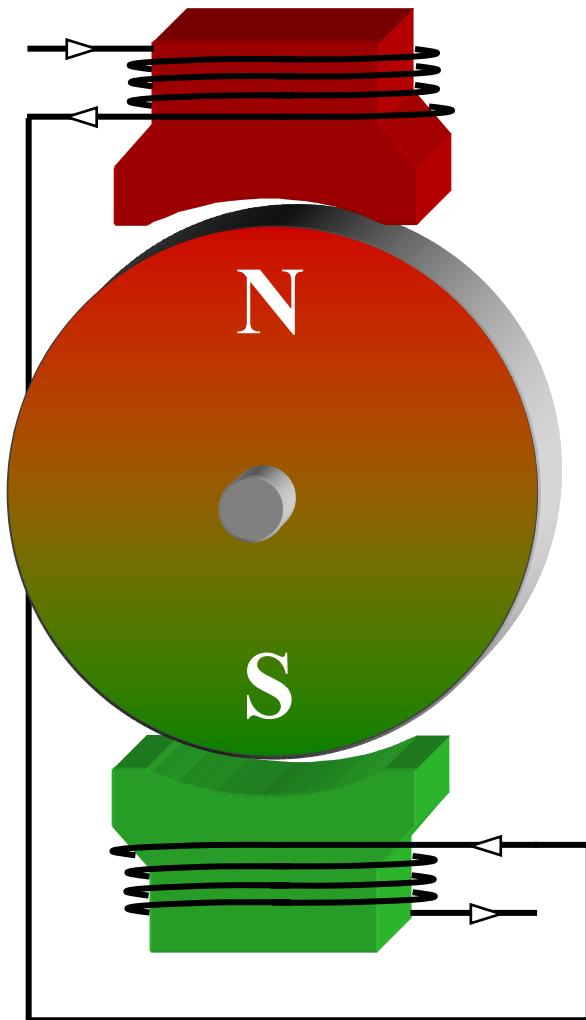
**Space Vector Modulation  
Power Regeneration**

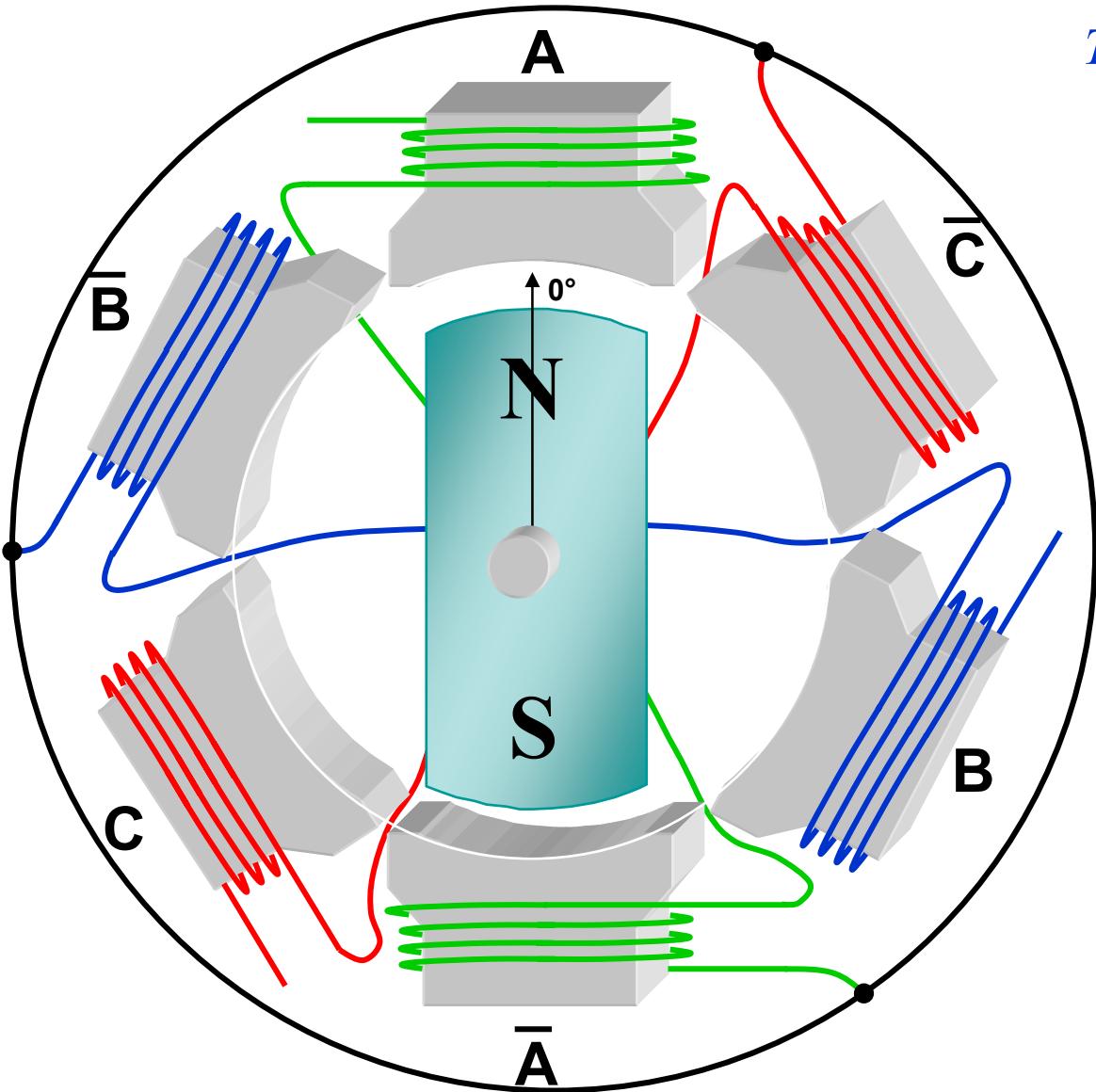
**Brushless DC  
ACIM  
PMSM  
Stepper**

# Brushless DC Motors

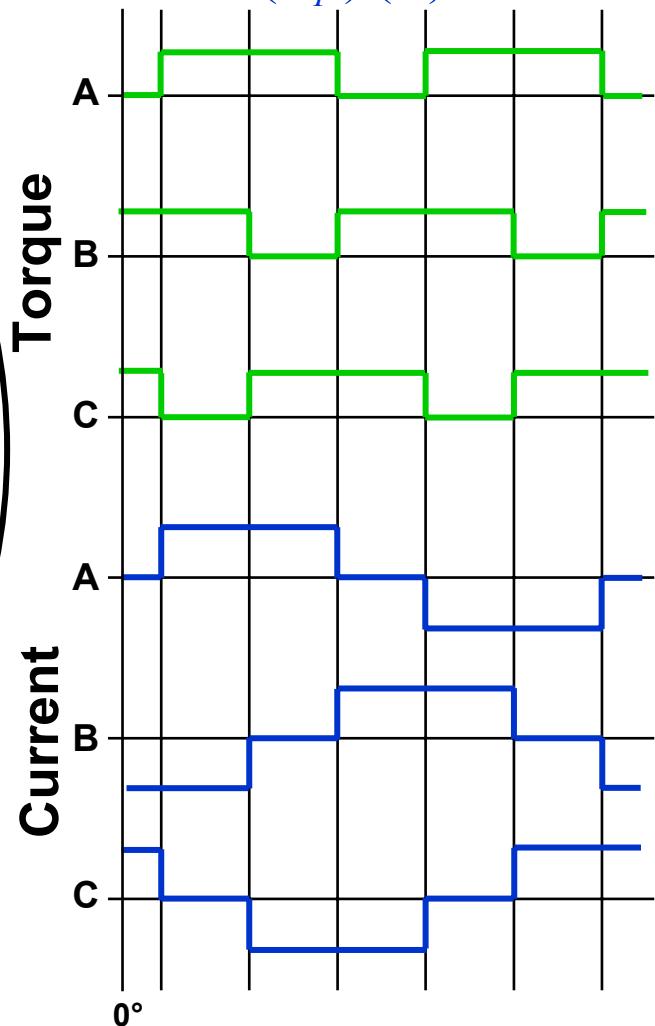


# Torque in a BLDC Motor



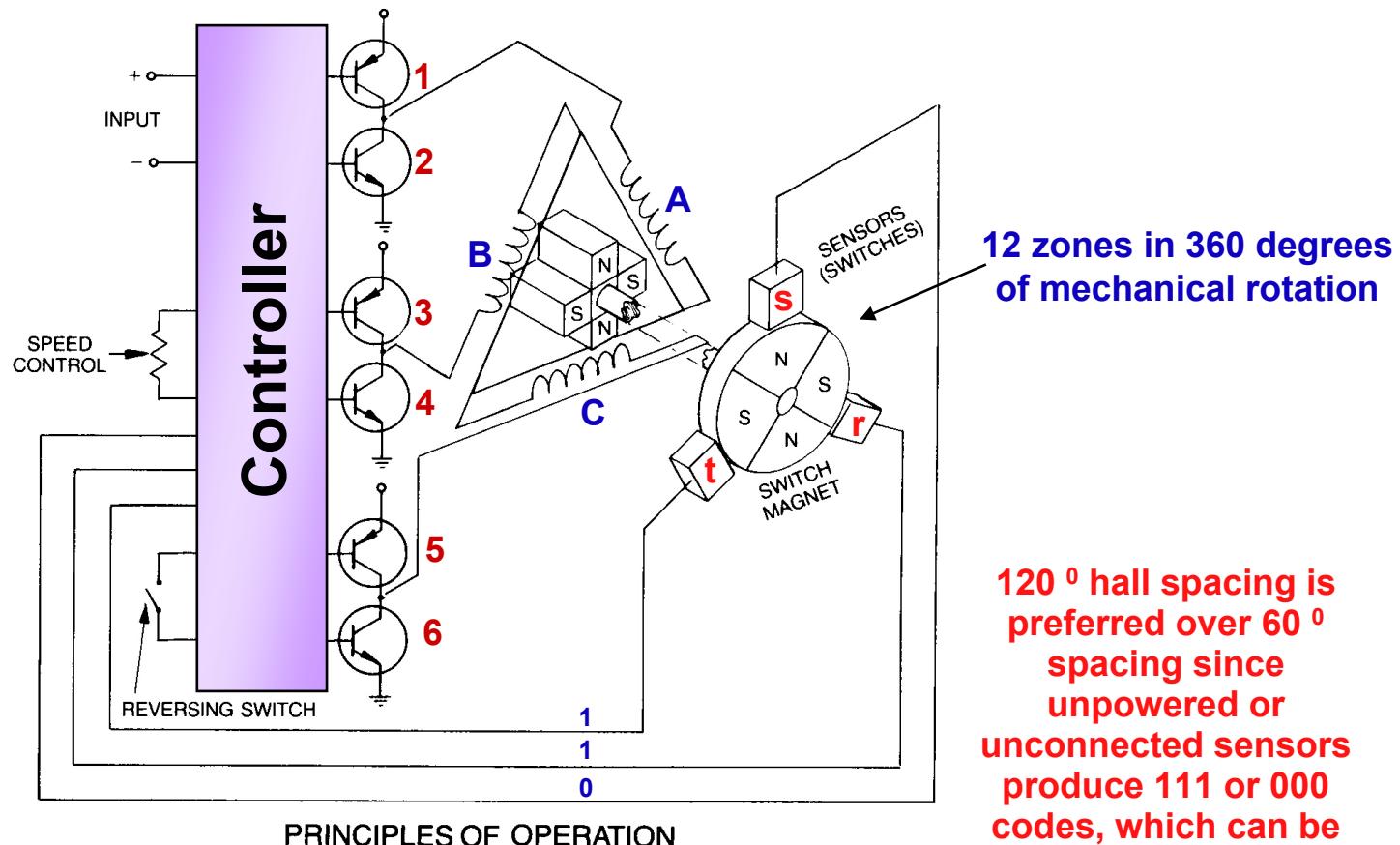


$$\begin{aligned} \text{Torque} &= (4NBlr)(I) \\ &= (k_T)(I) \end{aligned}$$



TI Spins Motors...Smarter, Safer, Greener.

# Control of a Brushless D.C. Motor

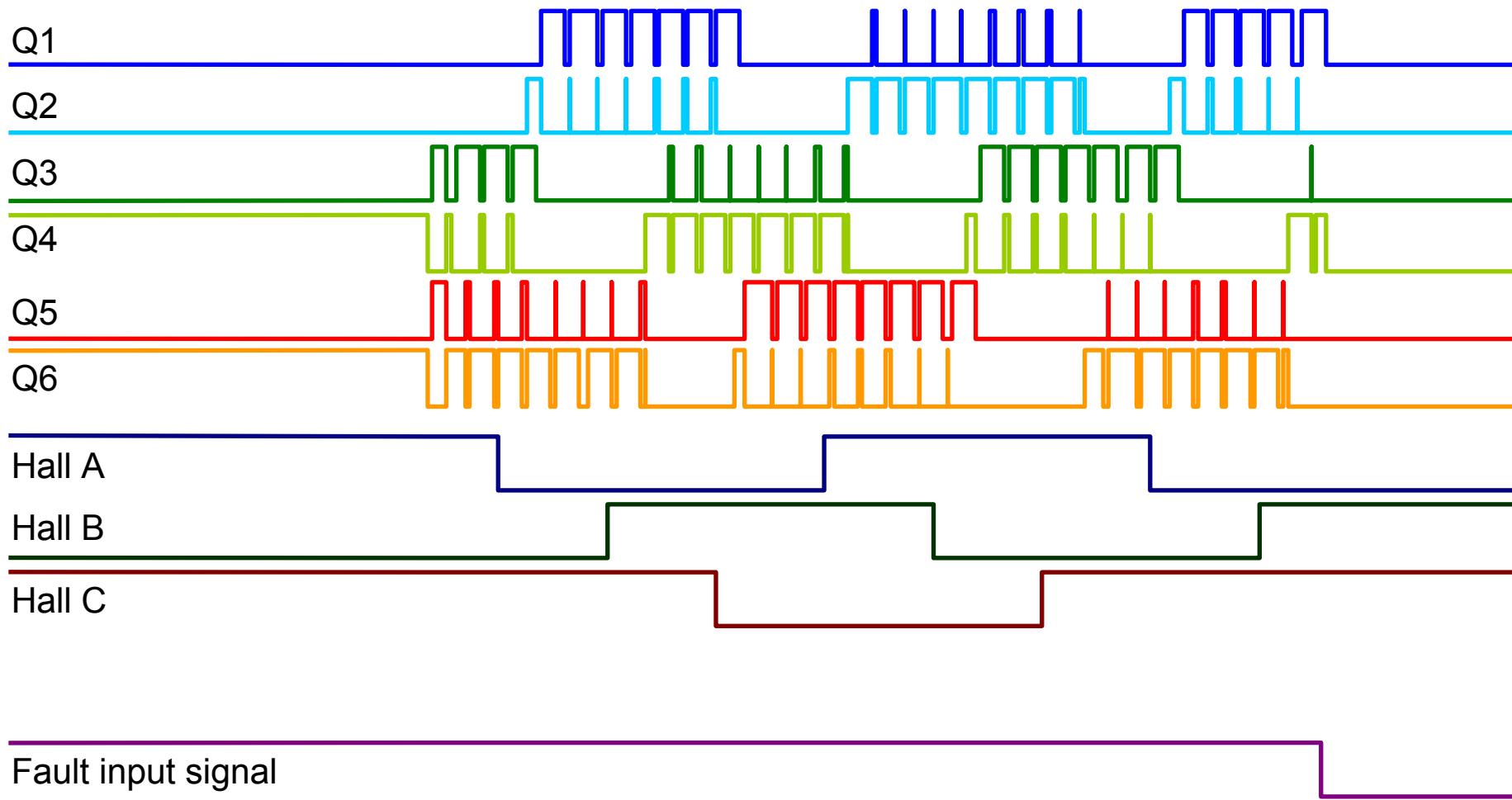


Source: Eastern Air Devices, Inc. Brushless DC Motor Brochure

TI Spins Motors...Smarter, Safer, Greener.

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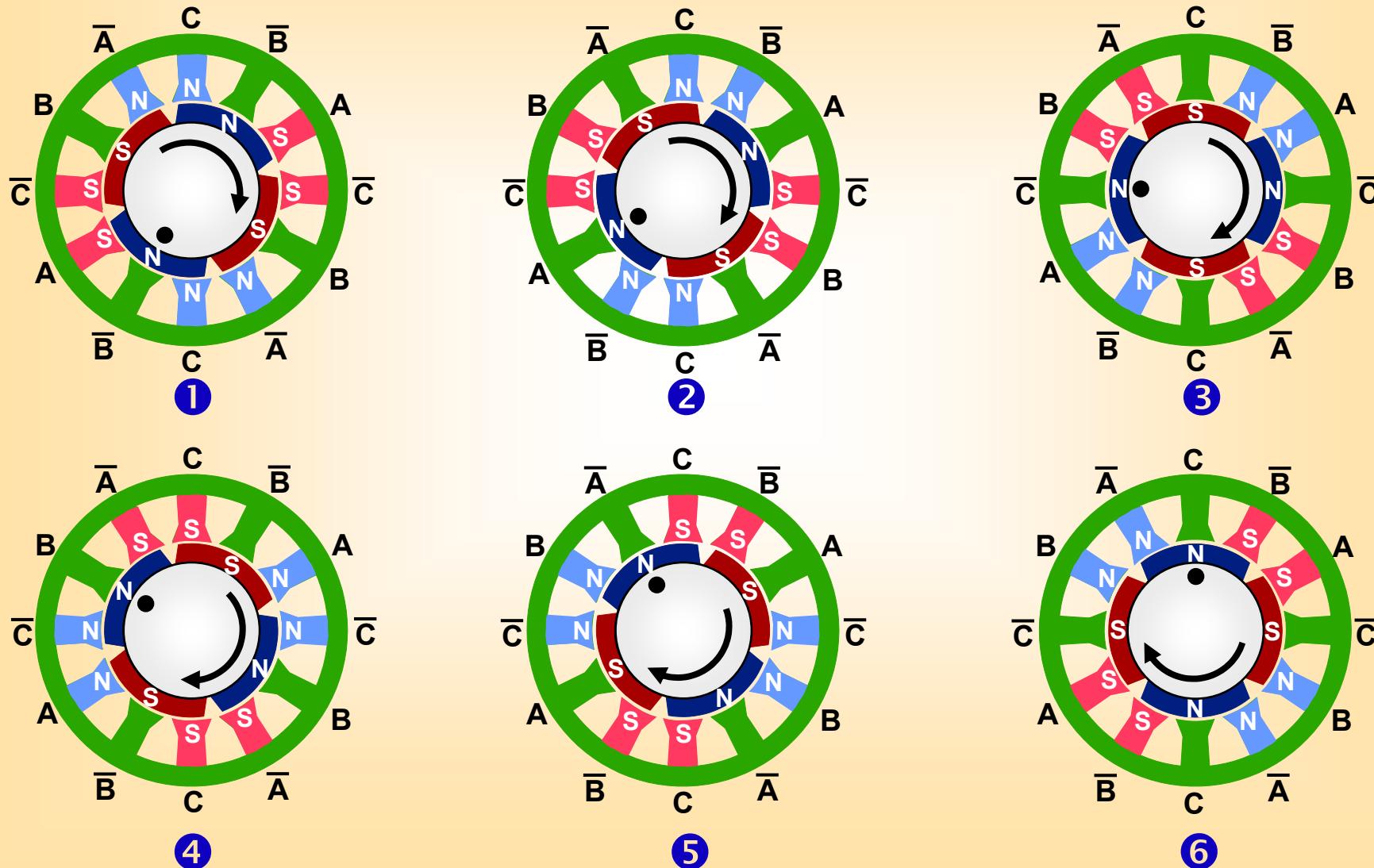
# BLDC Commutation



TI Spins Motors...Smarter, Safer, Greener.

 **Texas  
Instruments**

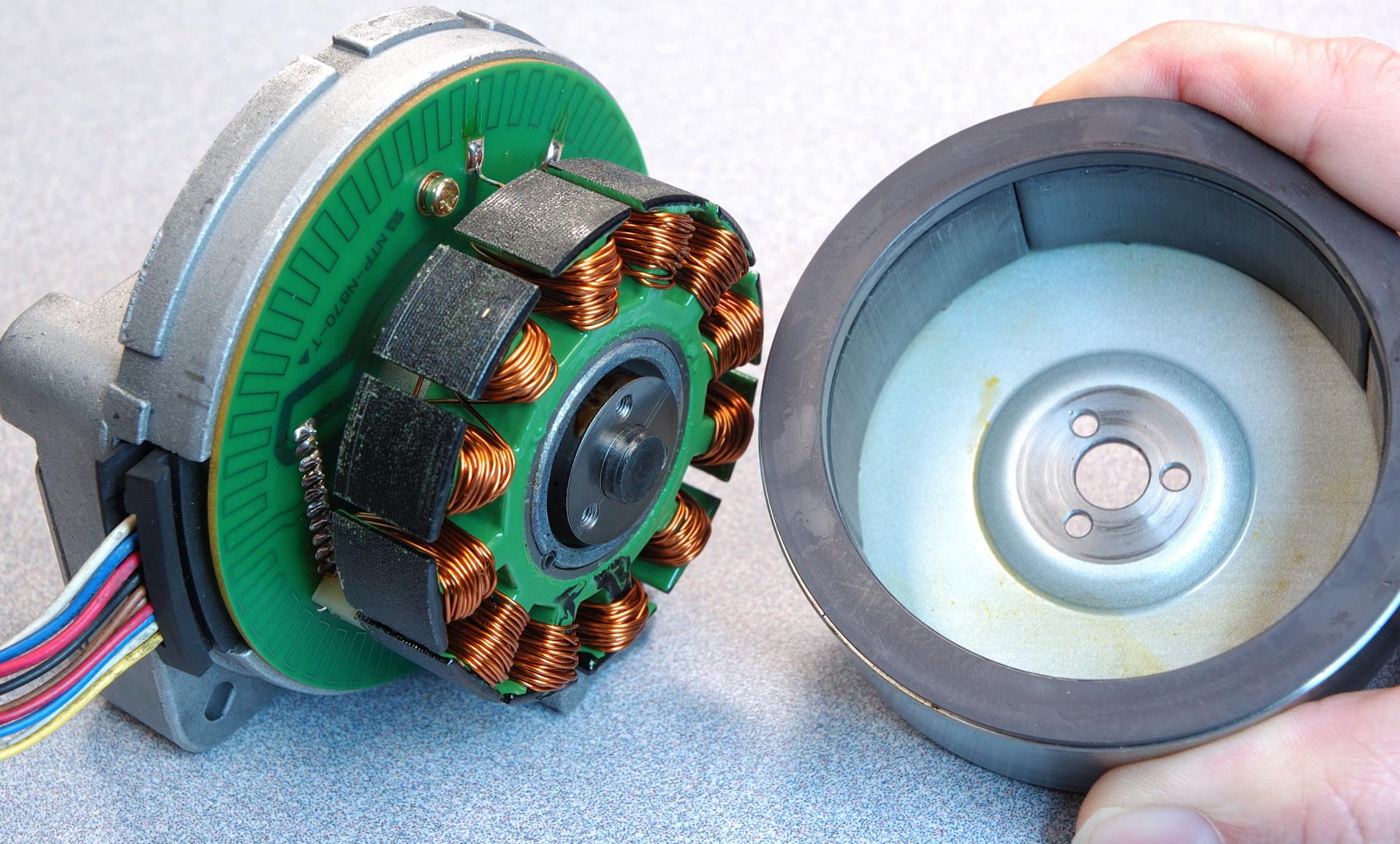
# Commutation of a Brushless DC Motor



TI Spins Motors...Smarter, Safer, Greener.

 **Texas  
Instruments**

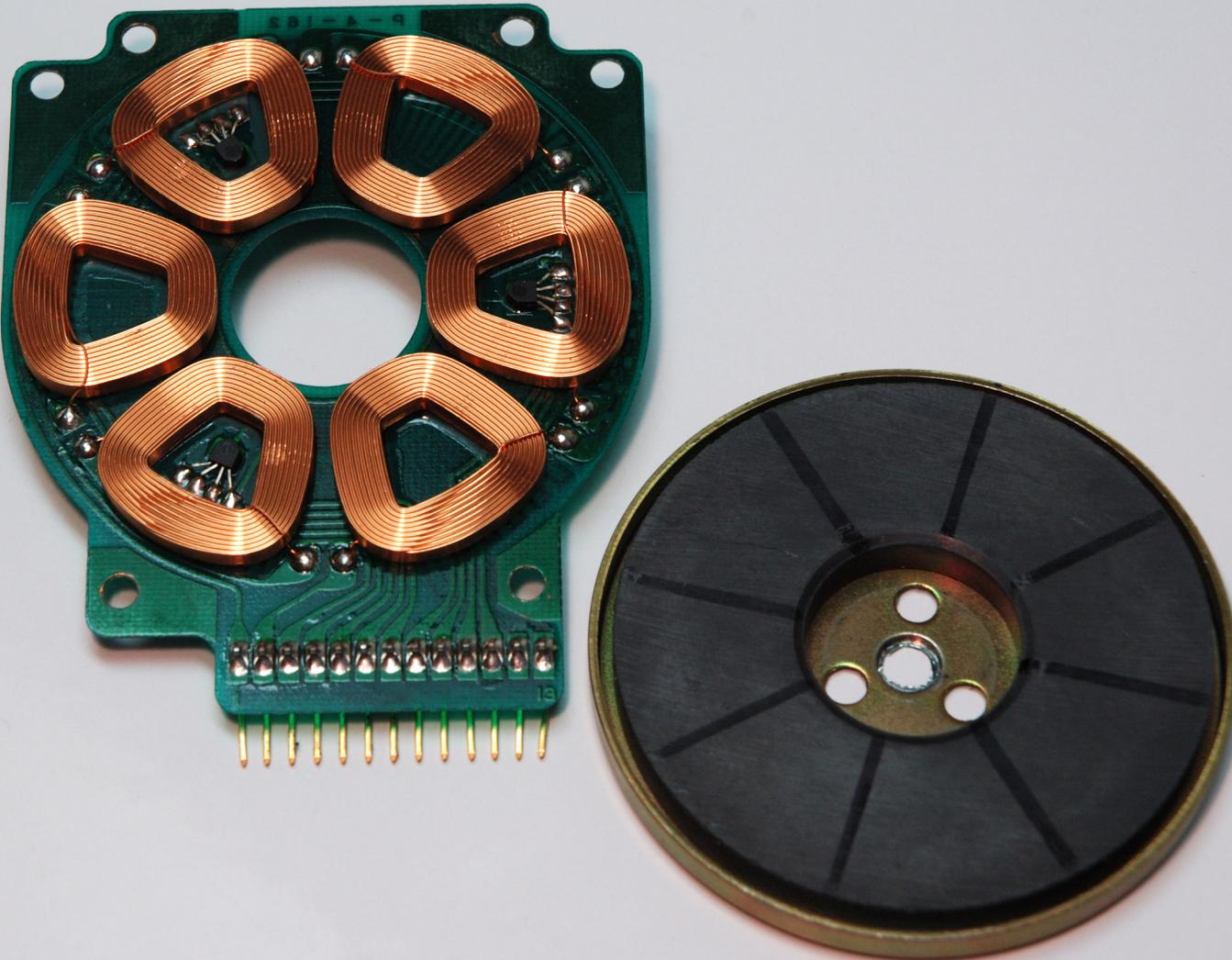
# Spoke Design BLDC Motor



TI Spins Motors...Smarter, Safer, Greener.

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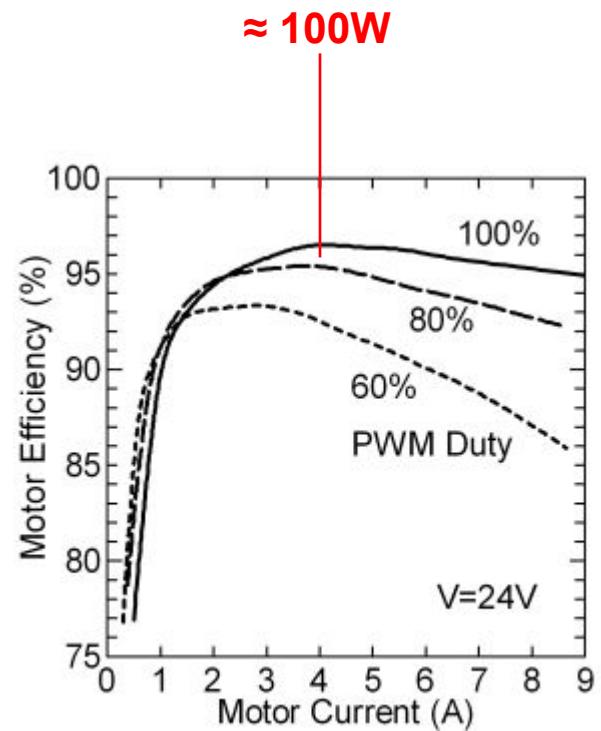
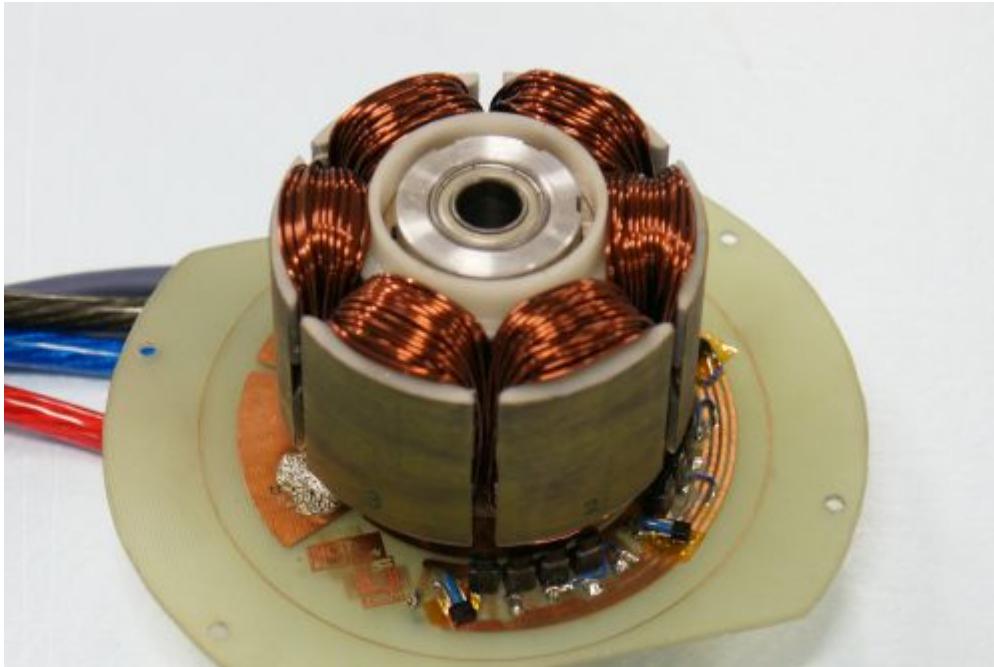
# Disk Drive BLDC Motor



TI Spins Motors...Smarter, Safer, Greener.

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# 96% BLDC Motor Efficiency

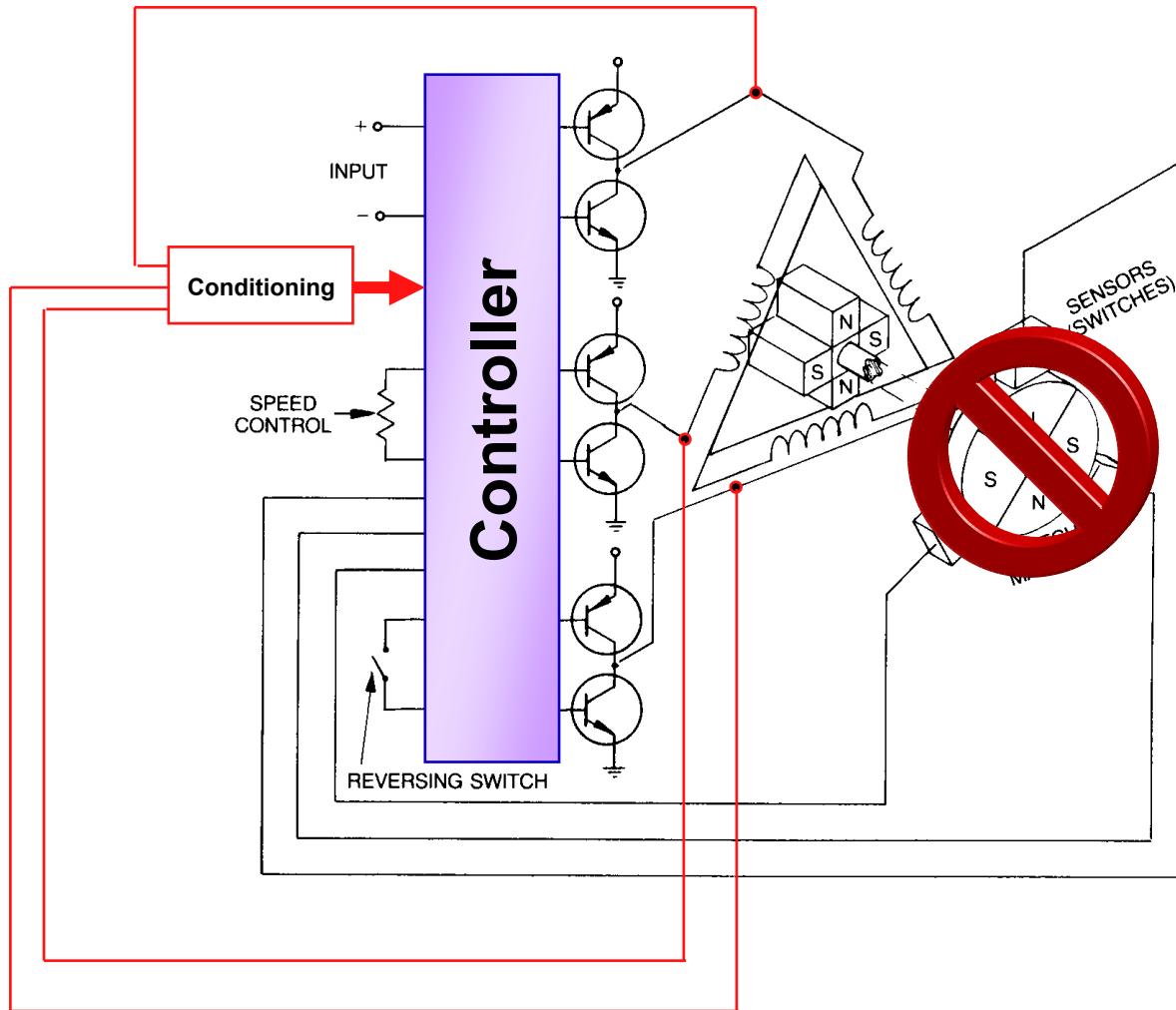


Using iron based amorphous core material, Japanese researchers at Tokai University break 96% efficiency barrier!

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Instruments**

# BLDC Control

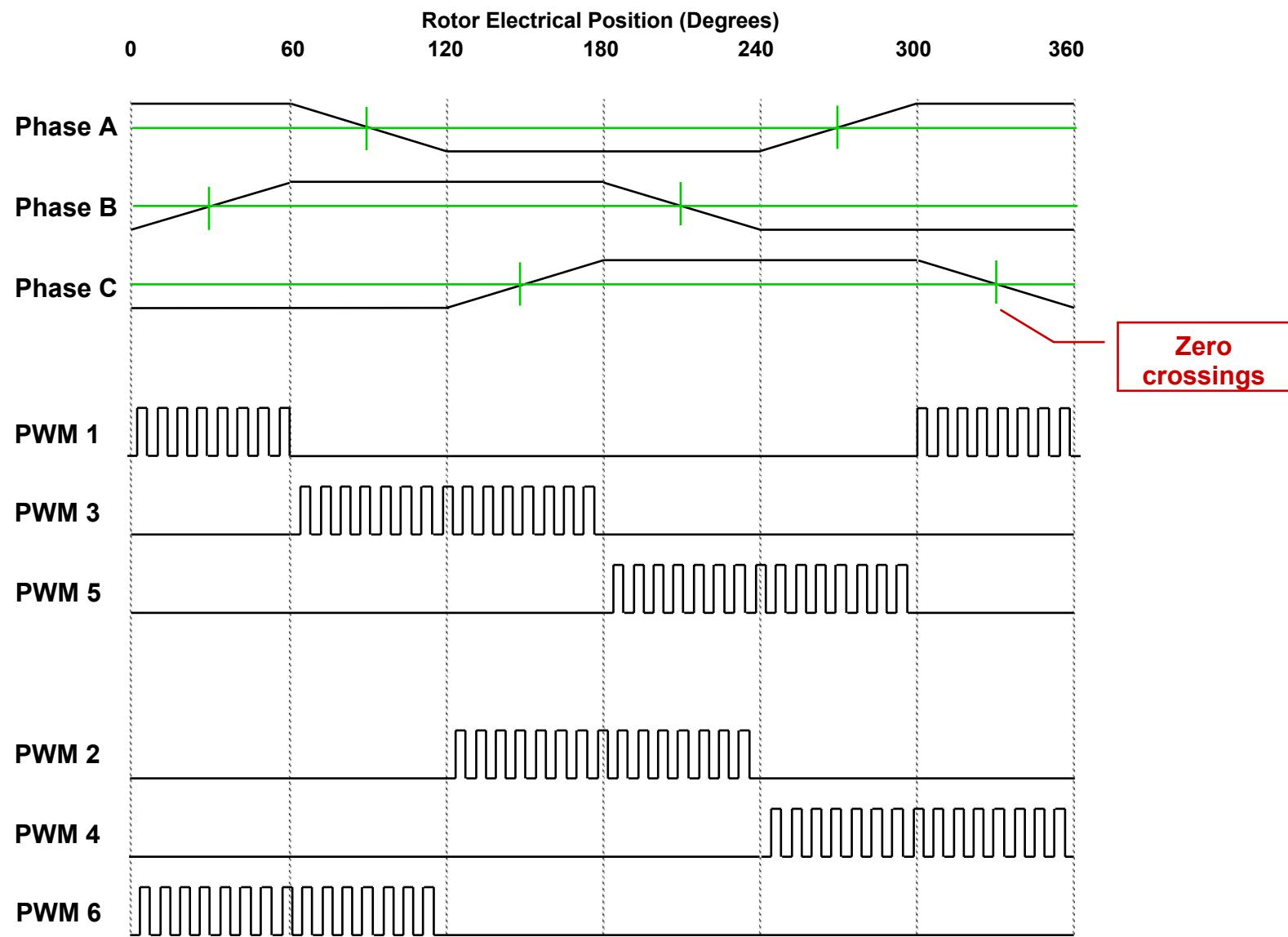


Source: *Eastern Air Devices, Inc. Brushless DC Motor Brochure*

TI Spins Motors...Smarter, Safer, Greener.

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Instruments**

# Traditional Sensorless Commutation

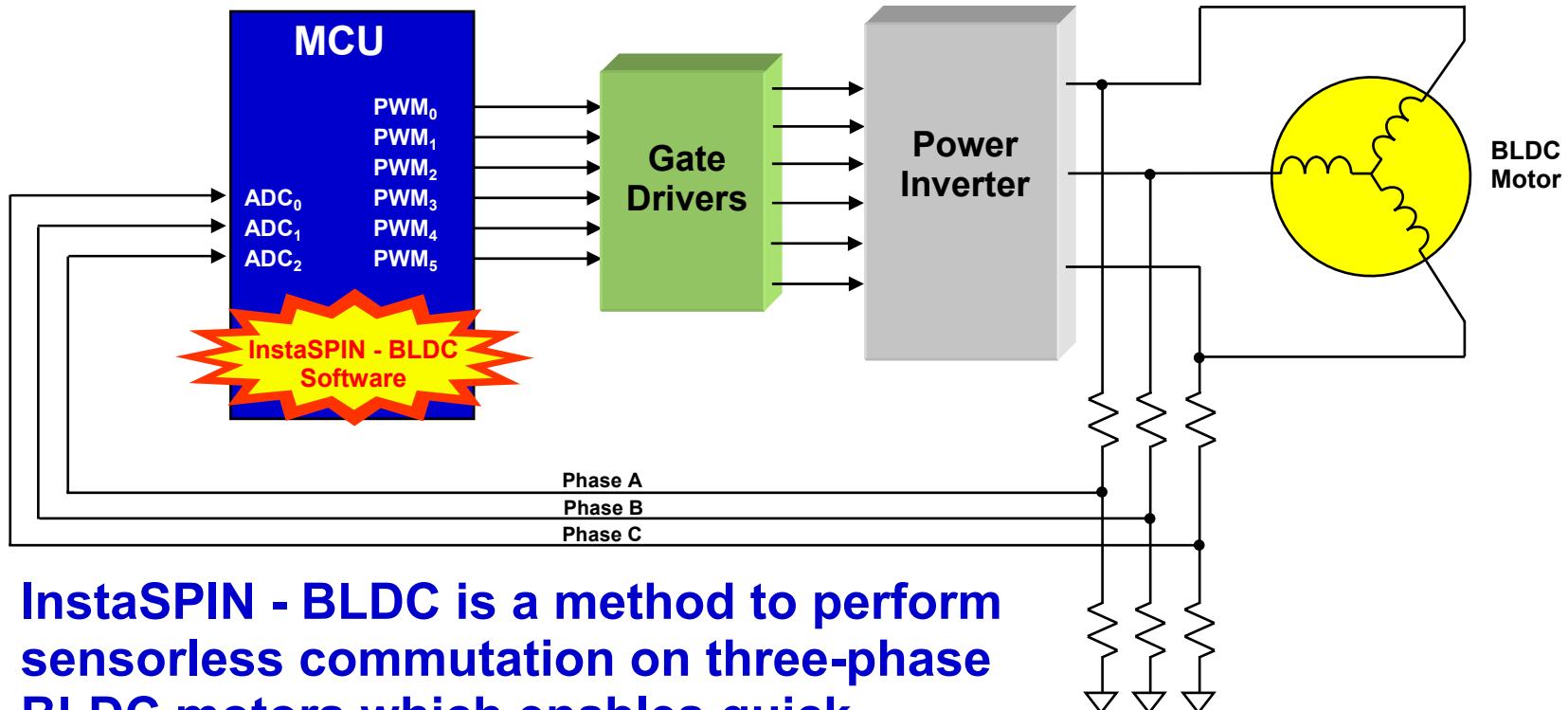


TI Spins Motors...Smarter, Safer, Greener.

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Instruments**

# Introducing InstaSPIN – BLDC!

## What is InstaSPIN - BLDC?



**InstaSPIN - BLDC is a method to perform sensorless commutation on three-phase BLDC motors which enables quick commissioning, robust control (even at low speeds), and exceptional adaptation to velocity perturbations.**

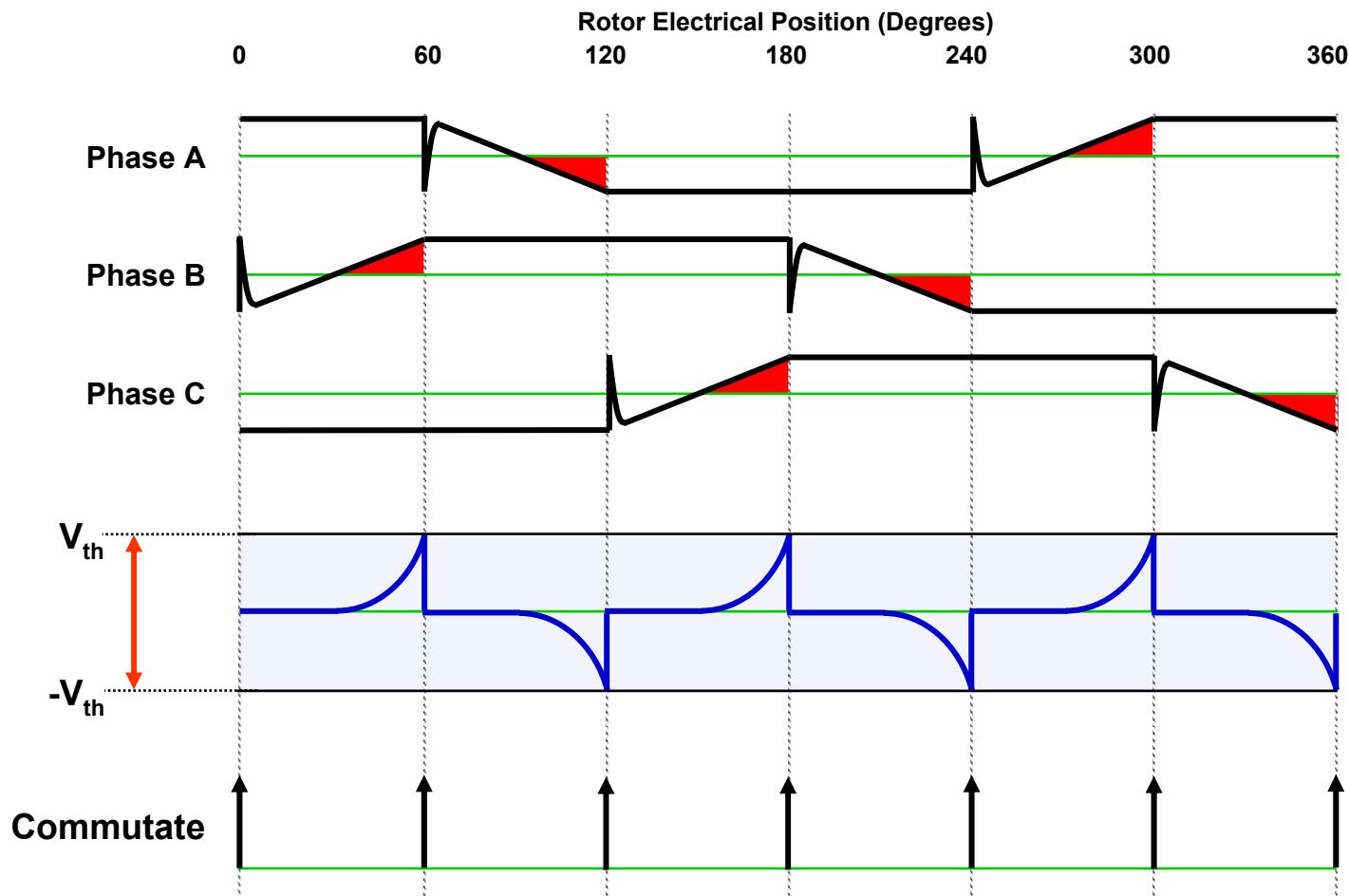
TI Spins Motors...Smarter, Safer, Greener.

 **Texas  
Instruments**

# The InstaSPIN Advantage

-  Extremely robust! (InstaSPIN has currently been tested on about 80 different motors. In each case, the motor was running in under 30 seconds, and suitably tuned in under two minutes.)
-  Extremely simple! Only one parameter needs to be adjusted to tune the commutation process.
-  Commutation advance easily accomplished at high speed by dynamically lowering the threshold level.
-  Back-EMF integration creates a less noisy signal for commutation control. This results in more reliable low speed operation.
-  InstaSPIN immediately adapts to acceleration changes (unlike the zero-cross timing technique).

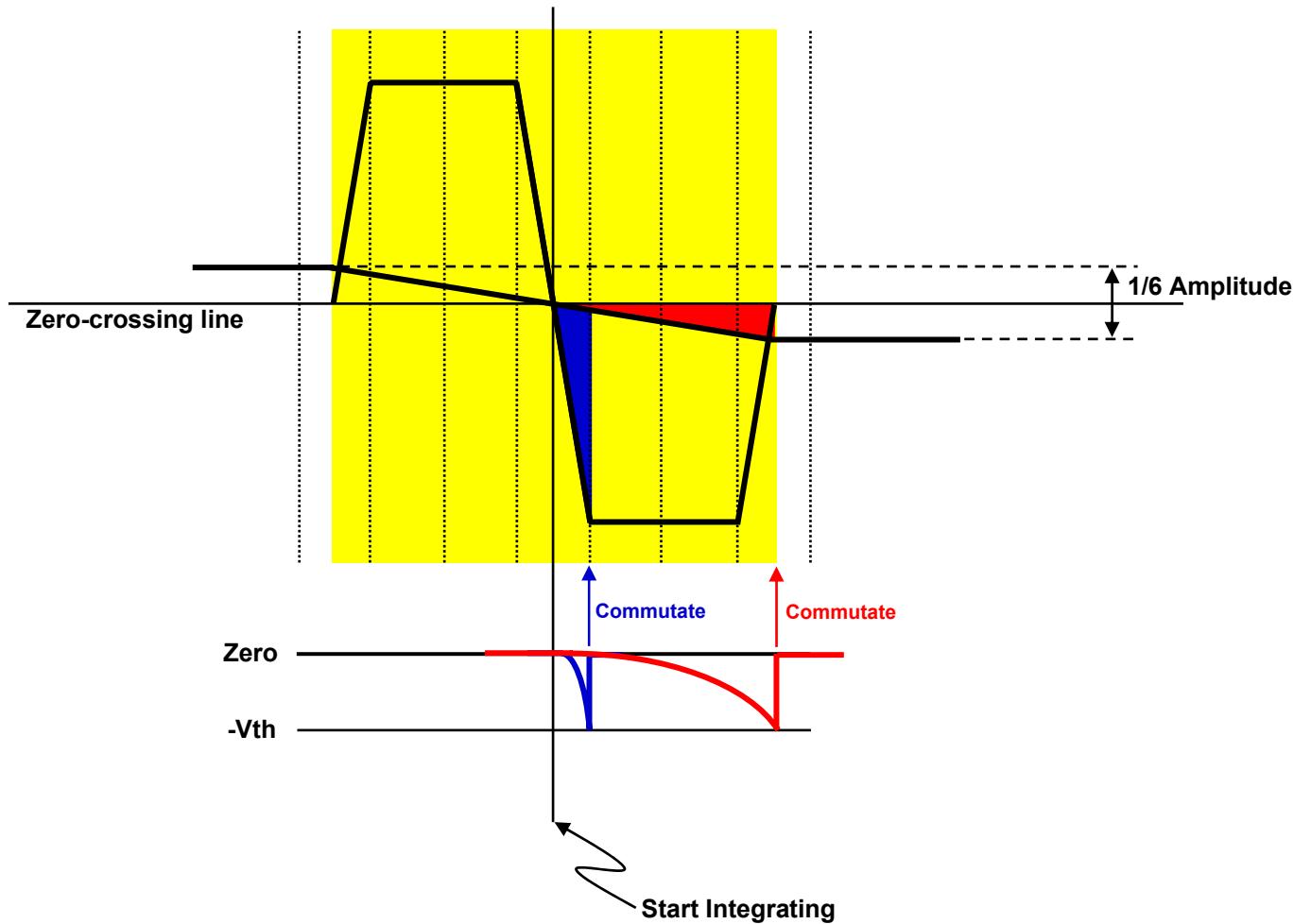
# InstaSPIN - BLDC...A Peek Under the Hood



TI Spins Motors...Smarter, Safer, Greener.

 **Texas  
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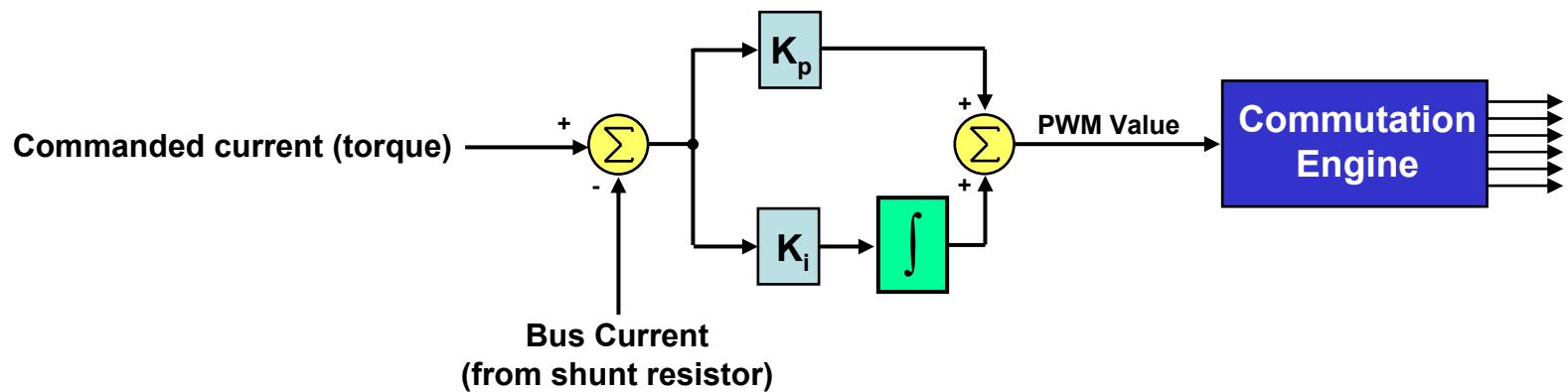
# Speed Invariant Performance



$$voltage = \frac{d\lambda}{dt} = \frac{\partial \lambda}{\partial \theta} \cdot \frac{d\theta}{dt} = \frac{\partial \lambda}{\partial \theta} \cdot \omega_m$$

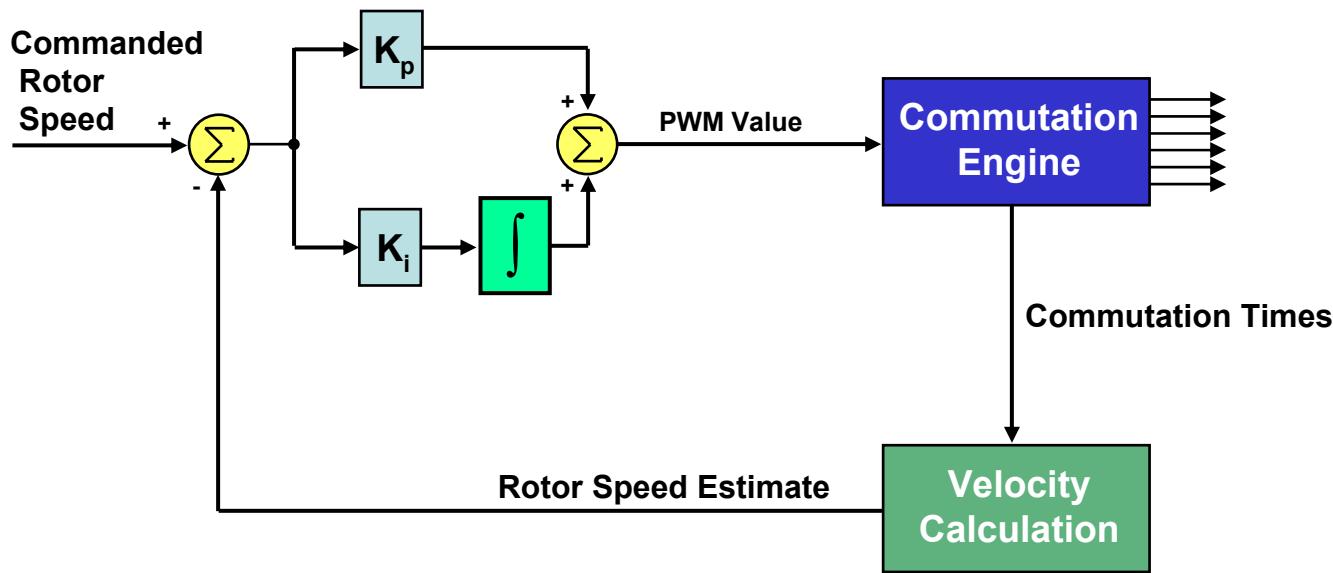
TI Spins Motors...Smarter, Safer, Greener.

# Current Mode Control Topology



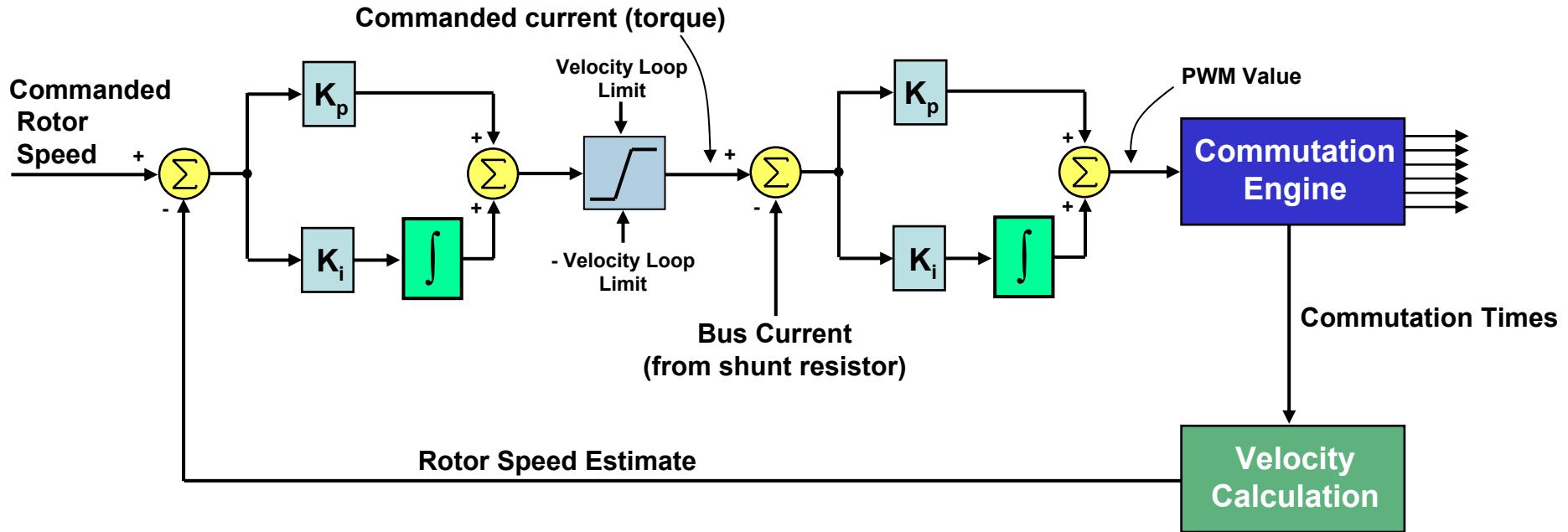
**Controls current only. Velocity is out of control.**

# Velocity Mode Control Topology



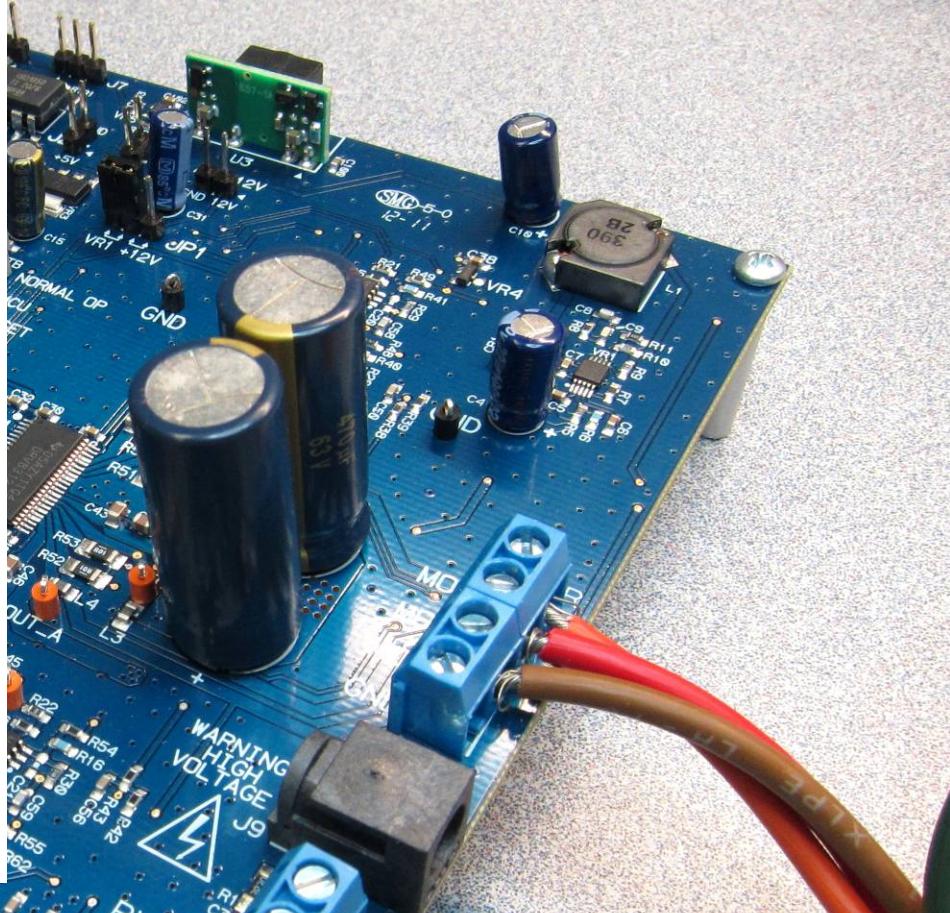
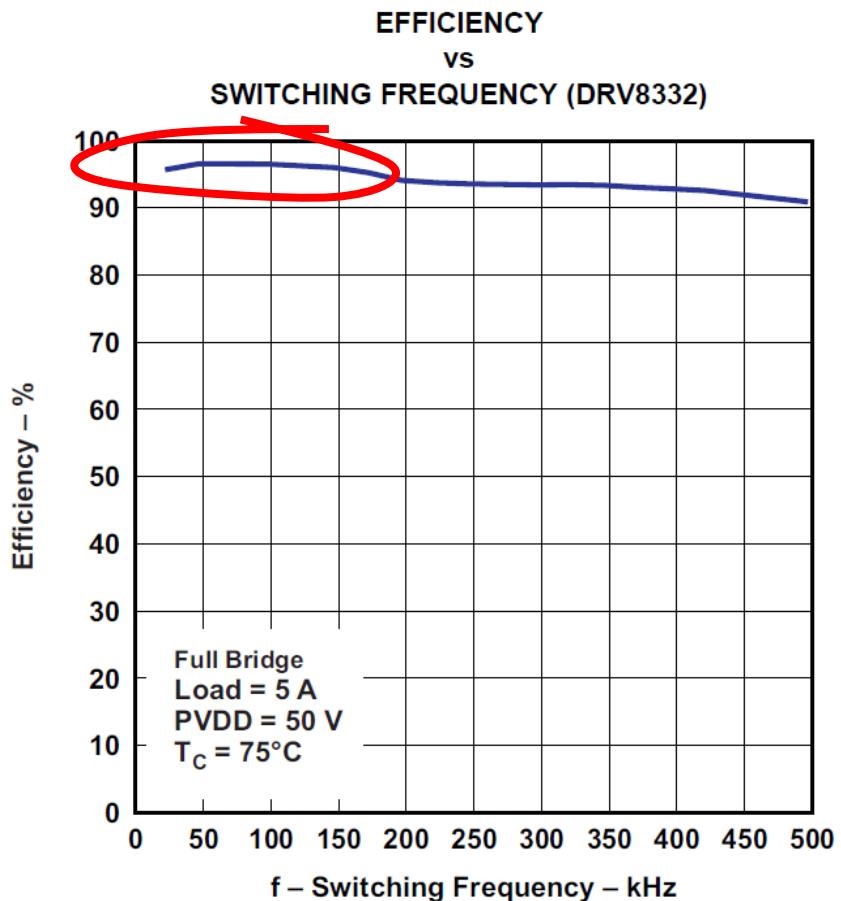
**Controls velocity only. Current is out of control.**

# Cascade Mode Control Topology



**Controls both velocity and current.**

# DRV8312 Board



# DRV8301 Board

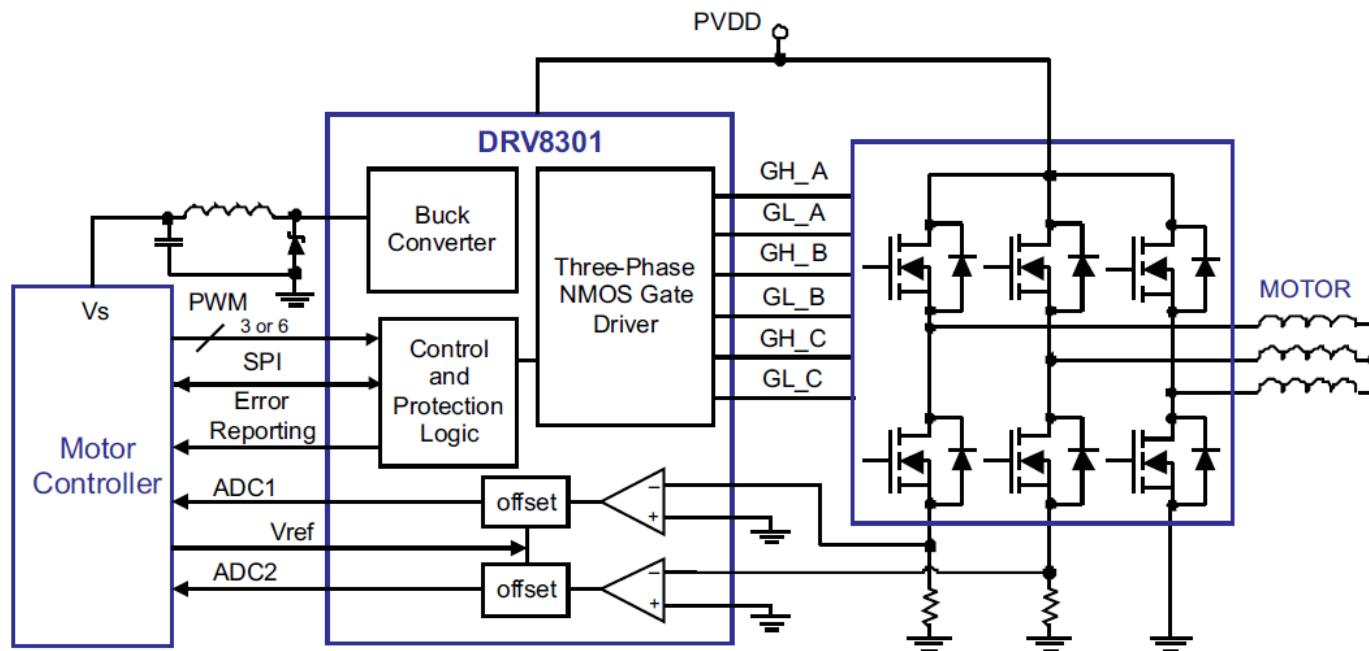
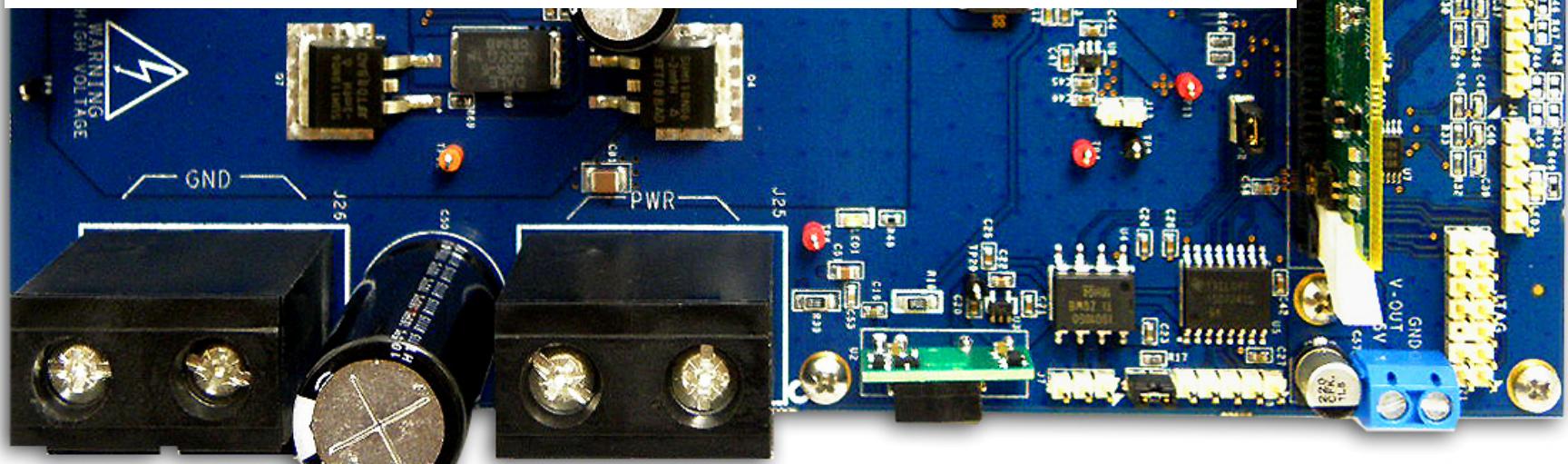


Figure 1. DRV8301 Simplified Application Schematic



# User Interface

DRV83xx InstaSPIN

File Connection Help

## InstaSPIN-BLDC

CROSSHAIRS INTERFACE DESIGNER

Main Settings D3 Engineering More...

Motor Speed (RPM)  
3529

Control Mode → Knob Function  
Duty Cycle → Duty Cycle  
Current → Motor Current (PU)  
Velocity → Motor Speed (PU)  
Cascade → Motor Speed (PU)

Duty Cycle Knob (Range -1.00 to 1.00, Value 0.46)

Motor Current (PU)  
0.00

Flux Threshold (PU)  
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0  
0.43

Graph Time Scaler 1

Flux (PU) Vag (PU) Ia (PU)

x: 2,809.1873, y: 0.8101

Graph Time Scaler 1

Flux (PU) Vag (PU) Ia (PU)

x: 2,809.1873, y: 0.8101

6057.5  
4846  
3634.5  
2423  
1211.5  
0

63590635 63592635 63594635 63596635 63598635 63600635

Motor Speed (RPM)

x: 63,178,827.0106, y: 1,412.6579

Enable Motor

Control Mode: Duty Cycle

Fault Status: Reset Fault

DC Bus: 0 9 18 27 36 45 54 63  
25.53

Driver Over-temperature Warning:

Connected Updates: ON QValue: 24

# Brushless DC Motor Summary

## Advantages

- High power output per frame size
- Easy to control with trapezoidal commutation
- High efficiency due to small rotor losses
- Low profile designs possible
- Excellent high speed performance
- Structure inherently allows heat to be easily removed

## Disadvantages

- Slightly more torque ripple than PMAC motors
- Uniform airgap flux density required for trapezoidal back-EMF is difficult to achieve
- Field weakening requires additional current
- Permanent magnetic field causes viscous drag
- Permanent magnets can be demagnetized at high temp.