How to Run an HDD Spindle Motor Quietly and Efficiently

Bert White

Corporate Fellow

Silicon Systems

Storage Products Group
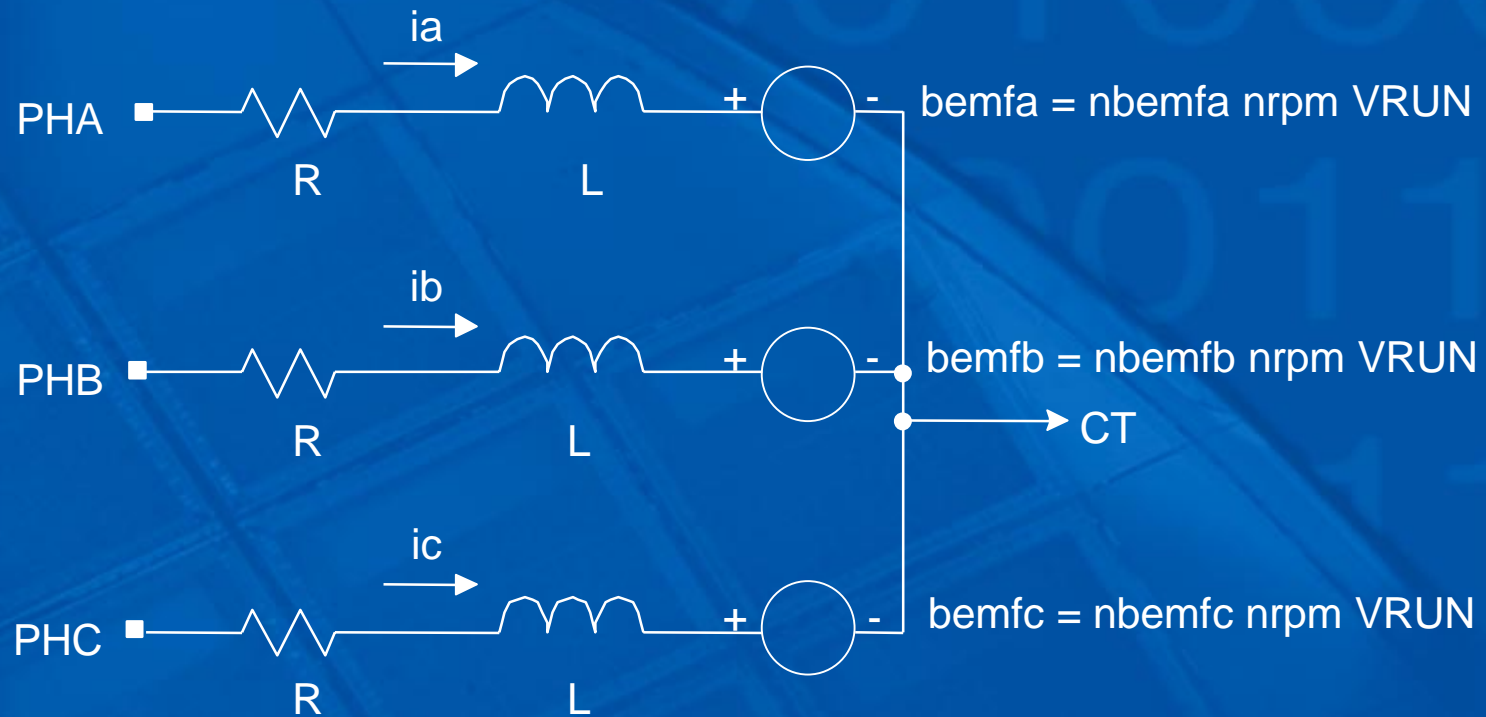
TEXAS INSTRUMENTS

Outline

- Spindle Motor Basics
    - Electrical equivalent of a spindle motor
    - PWM
    - Transconductance loop
- Acoustic Noise
    - How does a motor driver create it?
    - How can a motor driver minimize it?
- 32H6910 SPM Driver Section
- 32H6910 Measured Data
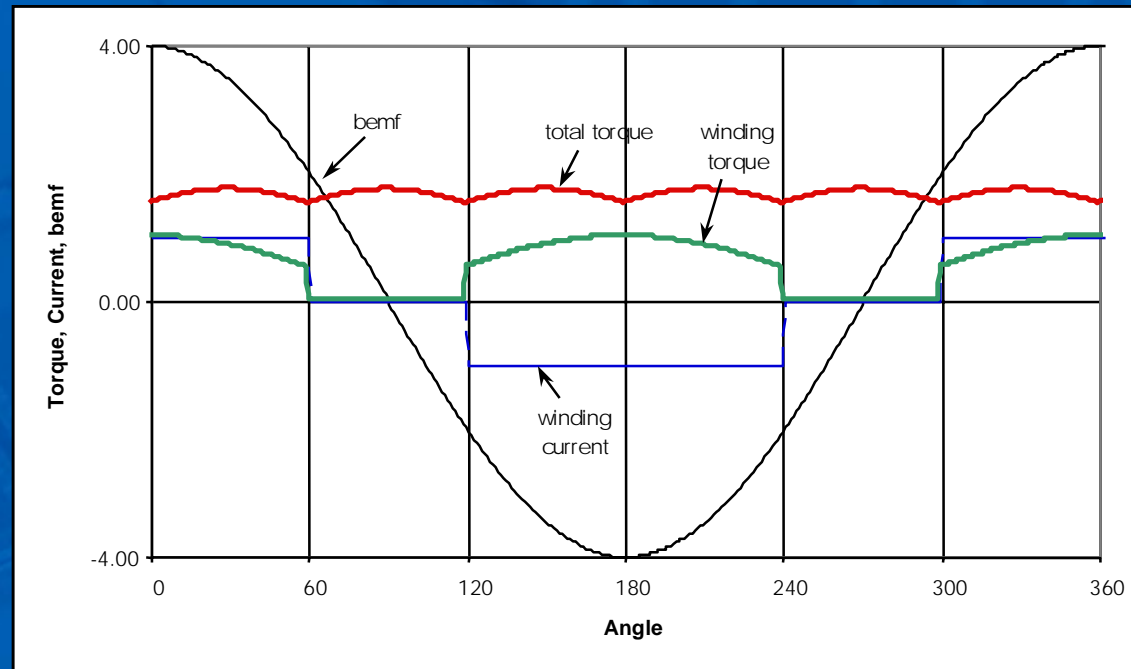- Summary

Electrical Equivalent of Spindle Motor

torque = K $_T$ (ianbemfa + ionbemfb + icnbemfc)

Efficient Motor Driver

- Motor current must be in phase with bemf

- Peak motor current should occur when bemf is peakŁ

- Pulse Width Modulation (PWM) should be used to minimize driver power dissipation
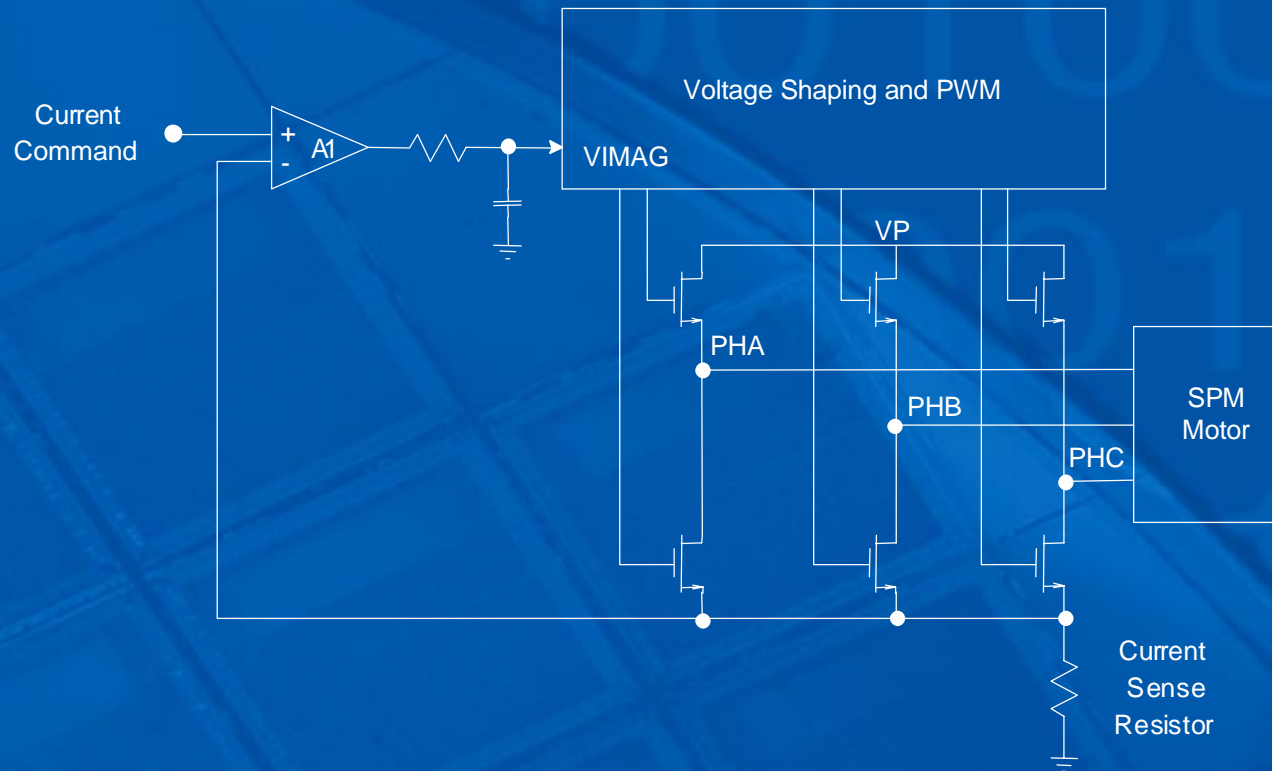
6-State Winding Current and Torque

Note: These ideal curves neglect the effect of winding inductance – a significant omission!

PWM Drivers are Required for Maximum Power Efficiency

VP

Ton = B T

OUT

Vout = B VP

Toff = (1 - B)T

GND
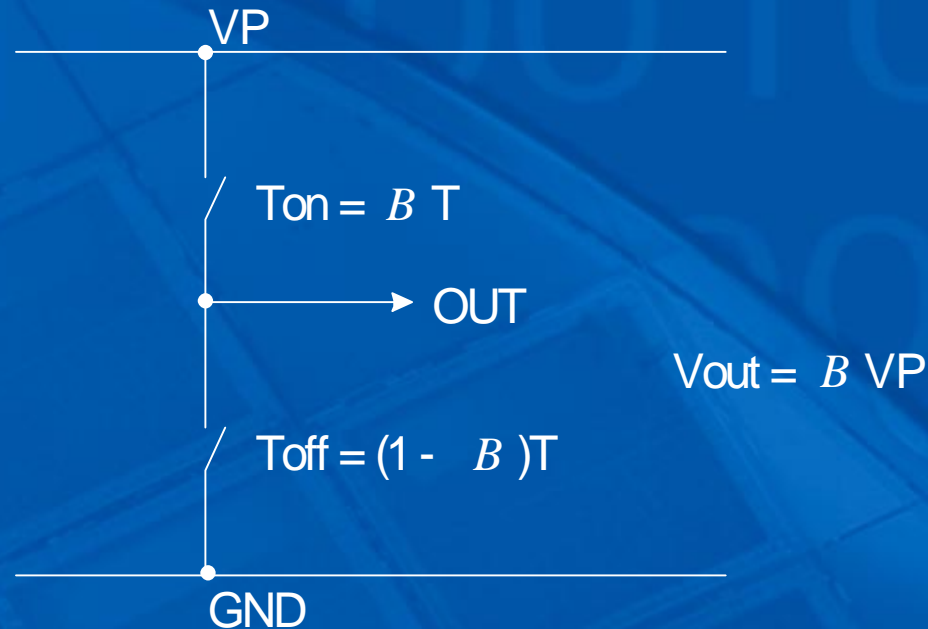
- Typical PWM frequency (1/T) is 20-30 kHz
- PWM Drivers are LOW IMPEDANCE!

Transconductance Loop

The transconductance loop permits current control with voltage mode drivers

Transconductance Loop Advantages

- Permits supply current control during motor start
- Simplifies the speed control equations
- Reduces torque ripple caused by phase to phase resistance variations

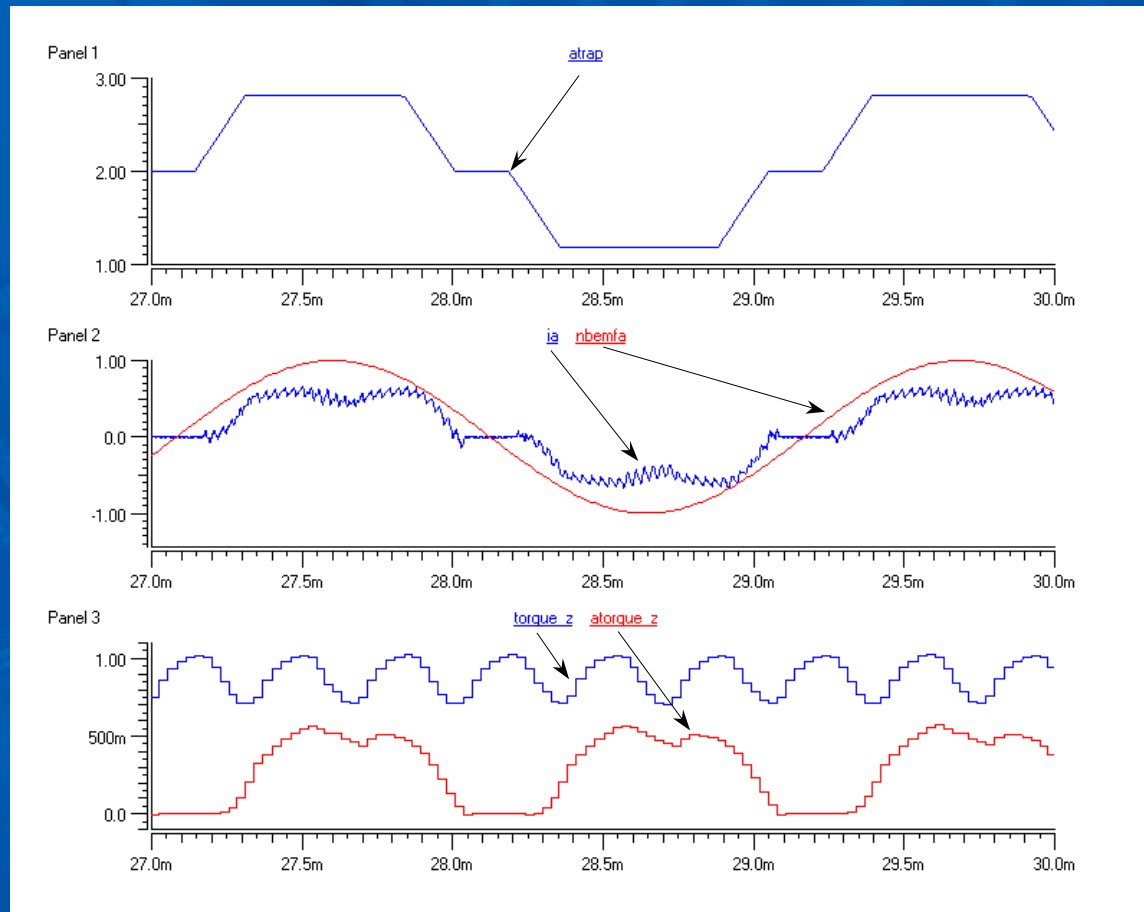# Jerk Causes Acoustic Noise

- Jerk is defined as d/dt of acceleration
- Jerk excites noise-generating mechanical resonances
- Jerk is minimized by minimizing torque ripple
- Per-phase torque ripple is essential — but its slope should be minimized
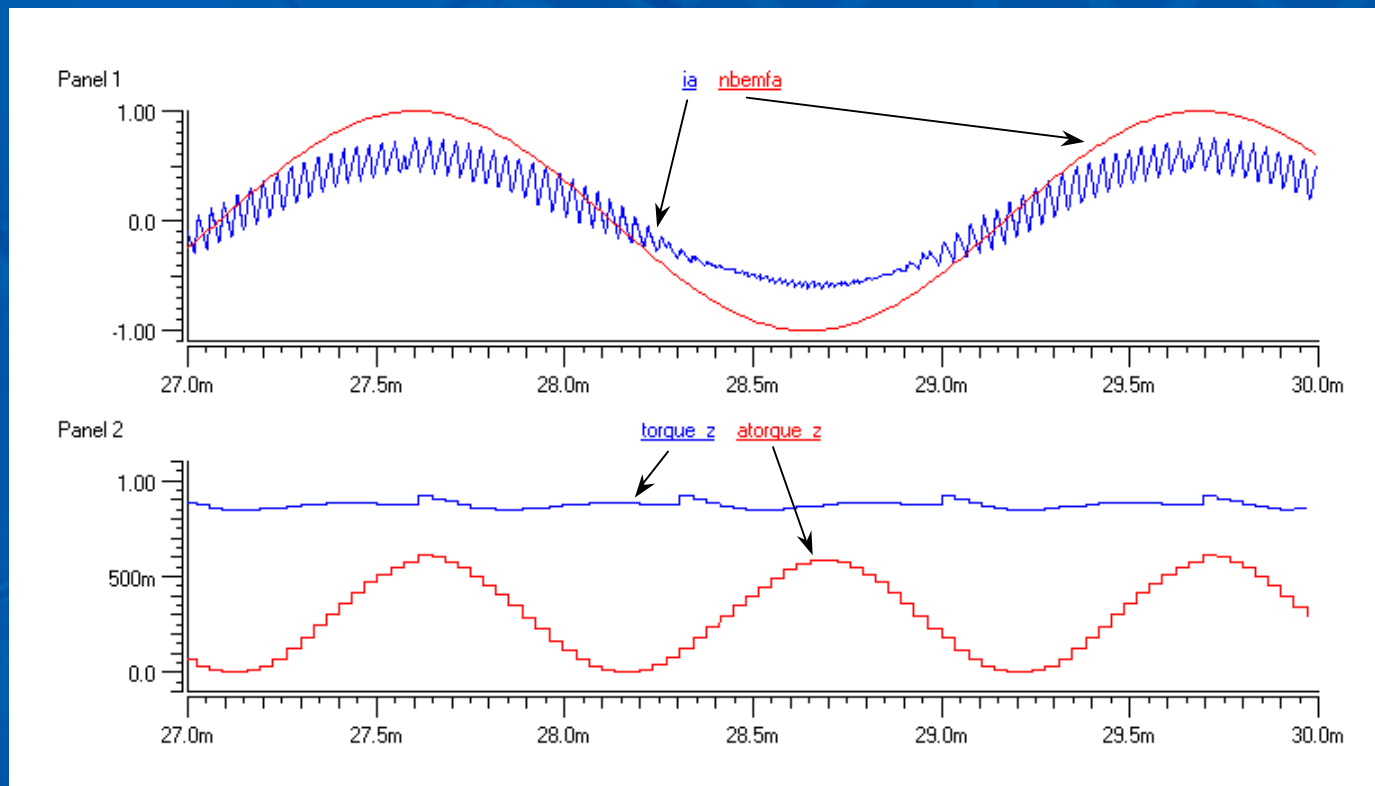
6-State Torque Ripple
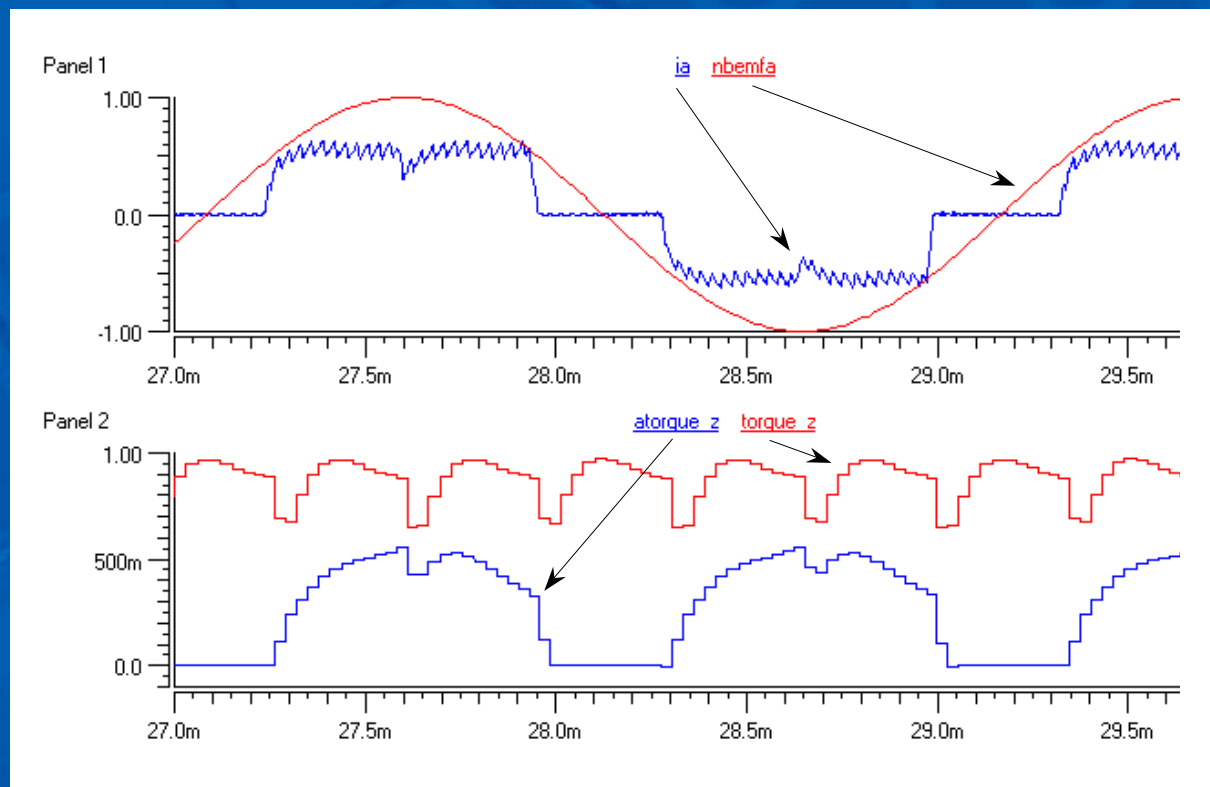
Not a Pretty Sight!

Trapezoidal Torque Ripple

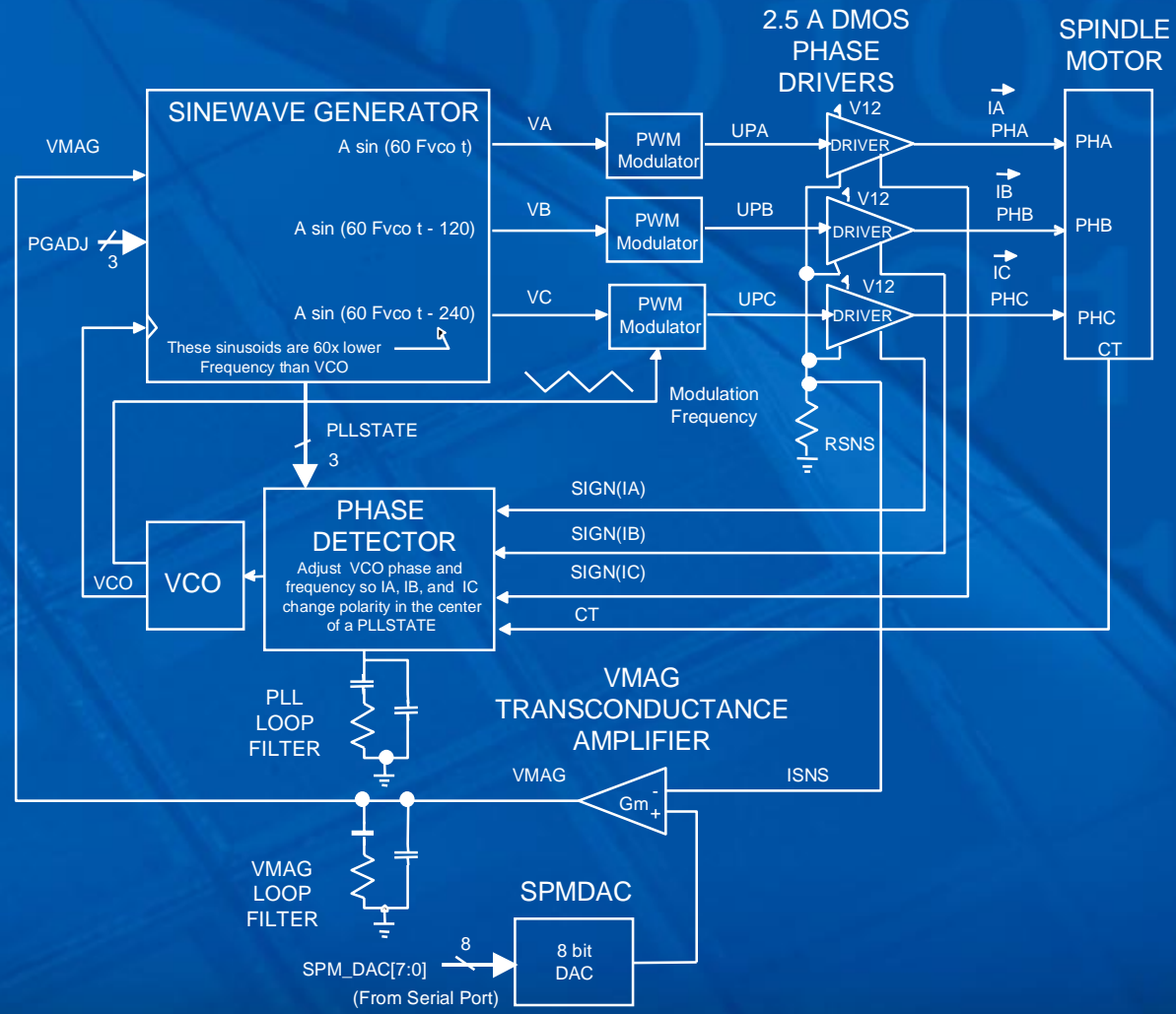Only a Little Bit Better!

Sinusoidal Torque Ripple

A h h h!

Torque Ripple Summary

Waveform Type	Torque Ripple	Peak d/dt of phase A torque
6-State	37%	6 va/ms
Trapezoidal	32%	3.9 va/ms
Sinusoidal	9%	1.4 va/ms

- Sinusoidal drive reduces torque ripple 4x
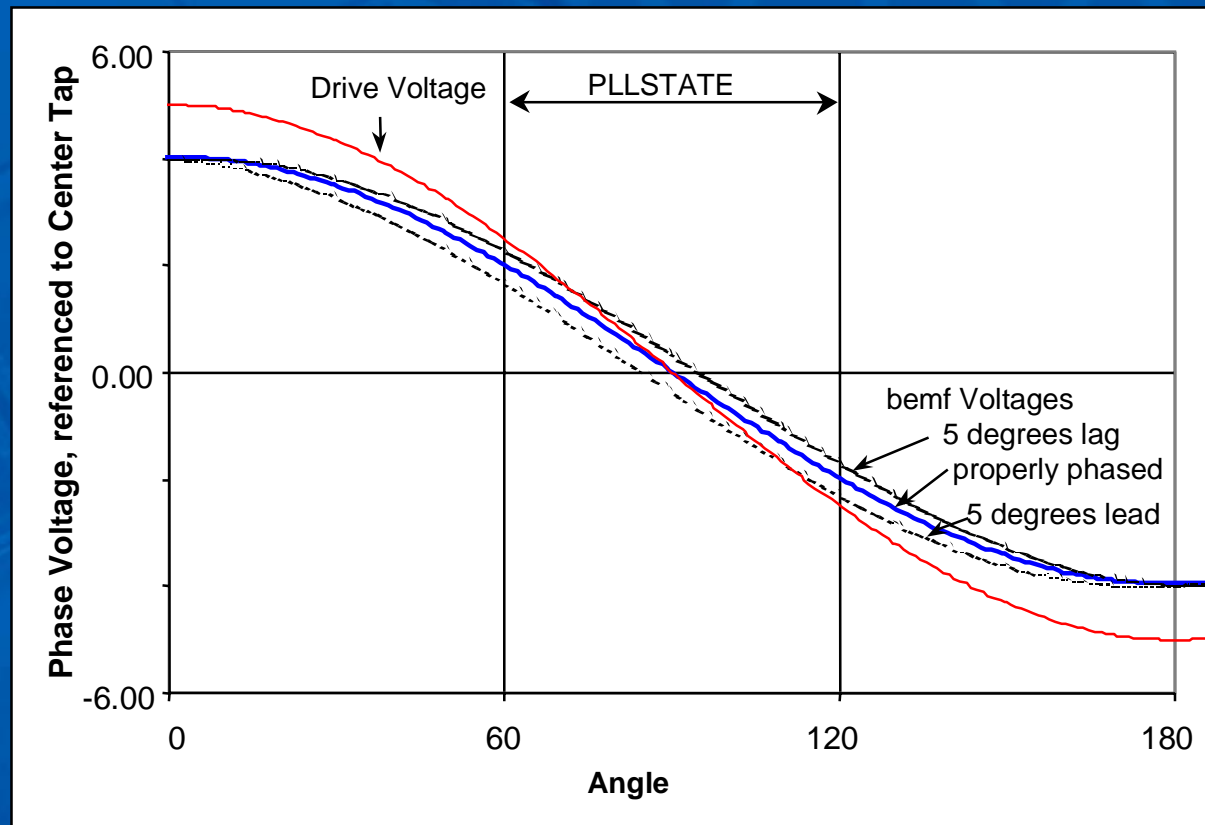- Per-Phase Torque has 4x less d/dt slope

32H6910 SPM Driver Section

Phase Detector Operation

- The Phase Detector compares the phase current's zero crossing with the center of its corresponding PLLSTATE window.
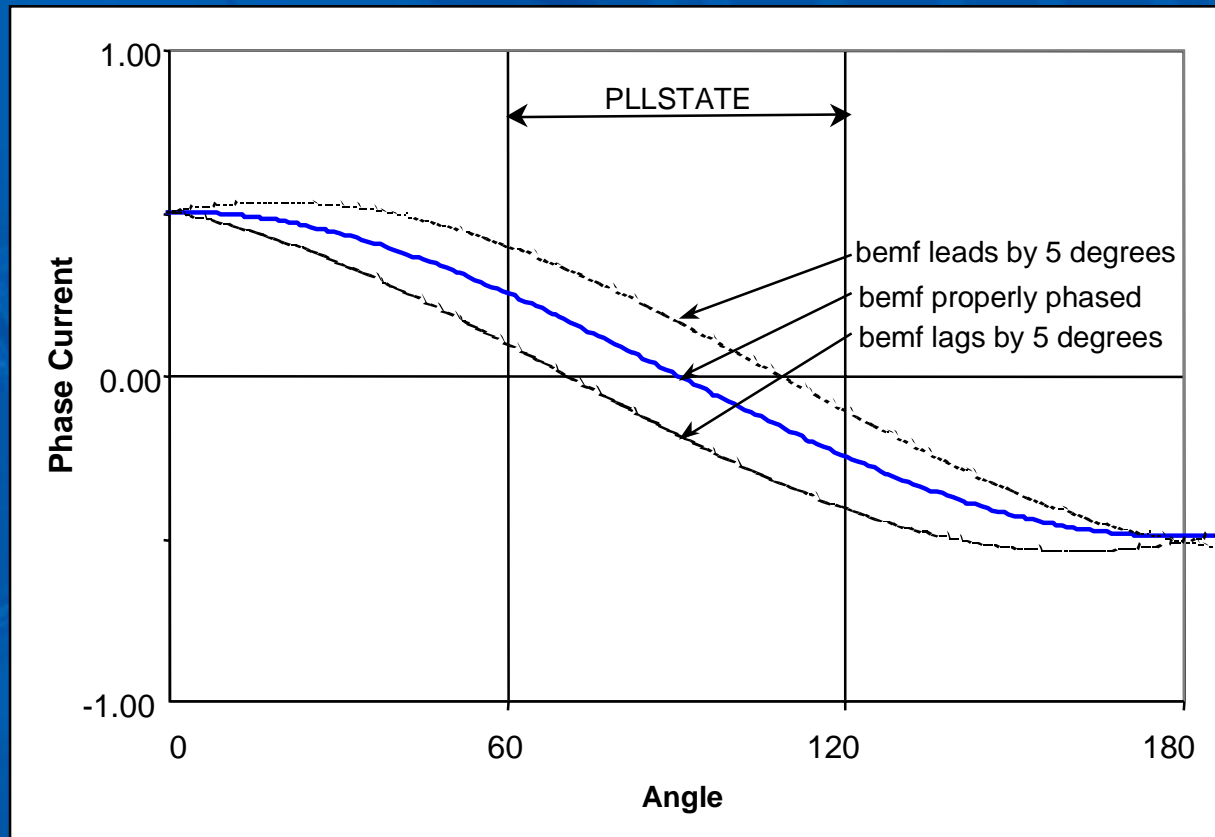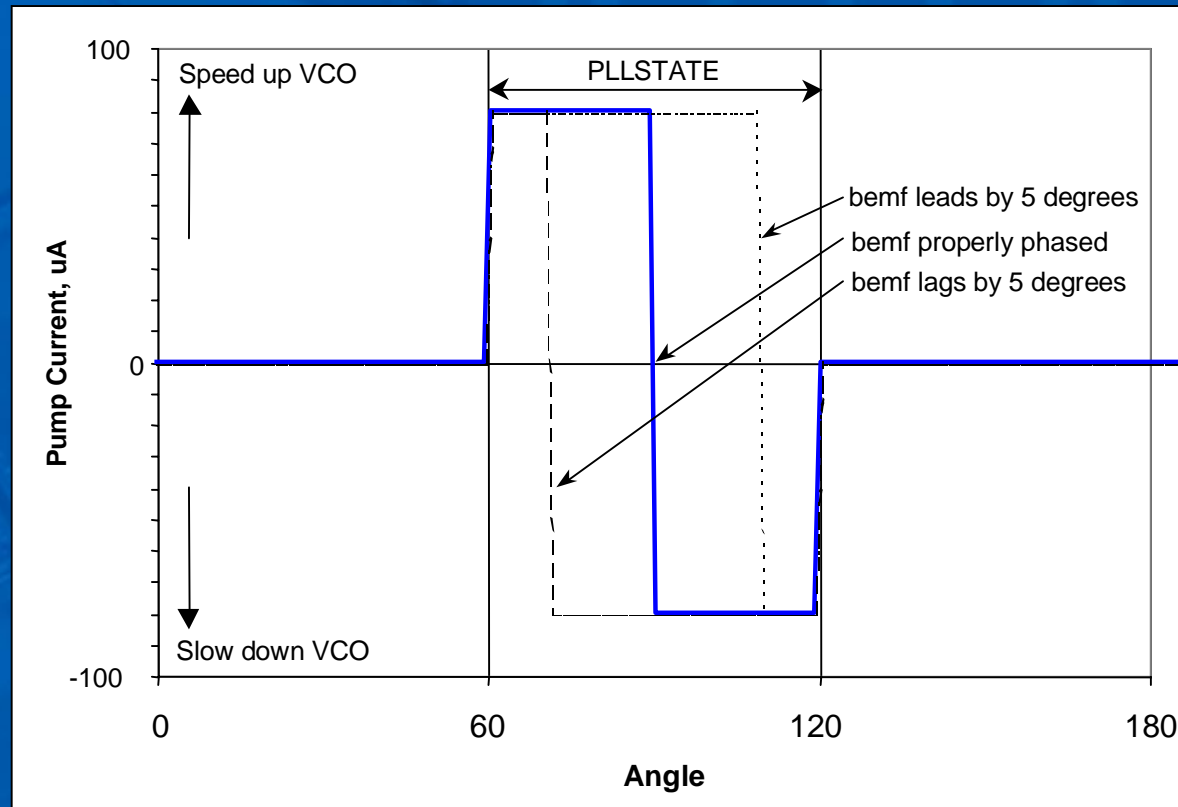
Phase Detector Waveforms

These bemf voltages . . .

Phase Detector Waveforms (cont.)

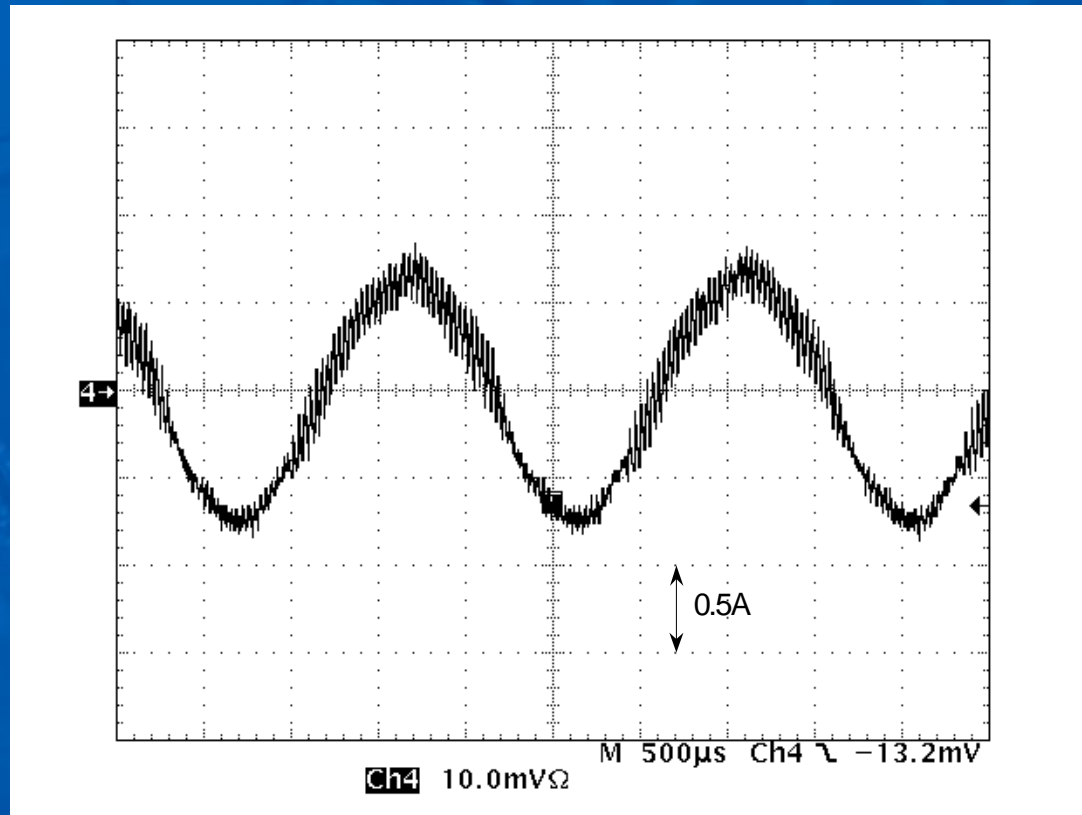. . . generate these phase currents . . .

Phase Detector Waveforms (cont.)

. . . and result in these charge pump currents.
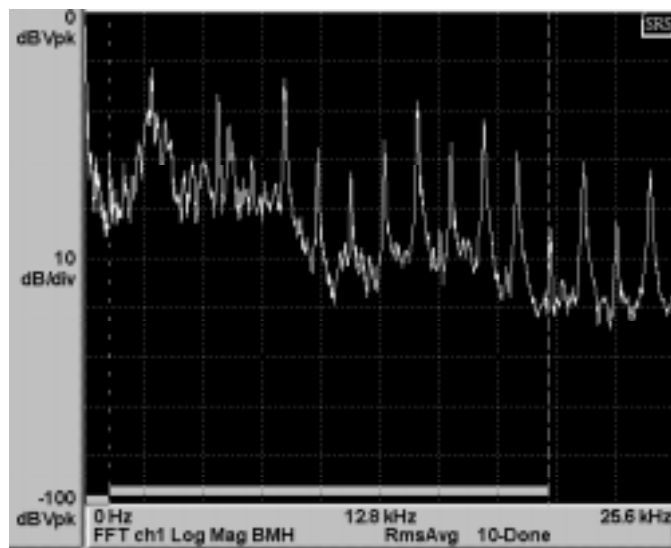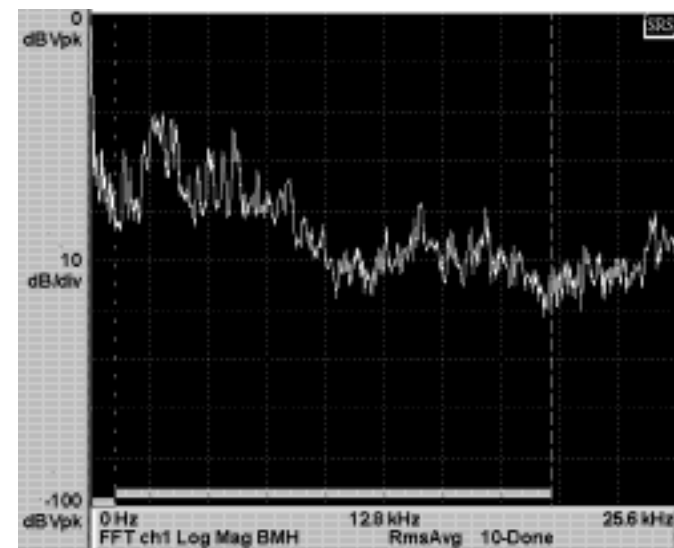
32H6910 Lab Data

Phase Current

32H6910 Lab Data (cont.)

Acoustic Noise (A-weighted)

6-State

Sinusoidal

- 3.8 dB rms reduction, 30 kHz to 20 kHz
- 10-20 dB pure-tone reduction

Conclusion

- Driving an HDD motor quietly and efficiently requires:
  - PWM drivers
  - Sinusoidal Phase Currents
- The 32H6910 implementation of PWM sinusoidal drive:
  - Reduces both measures of torque ripple by 4x
  - Reduces pure-tone acoustic noise by 10 to 20 dB
  - Reduces broad-band acoustic noise 3.8 dB