

Stepper Motors and Back EMF

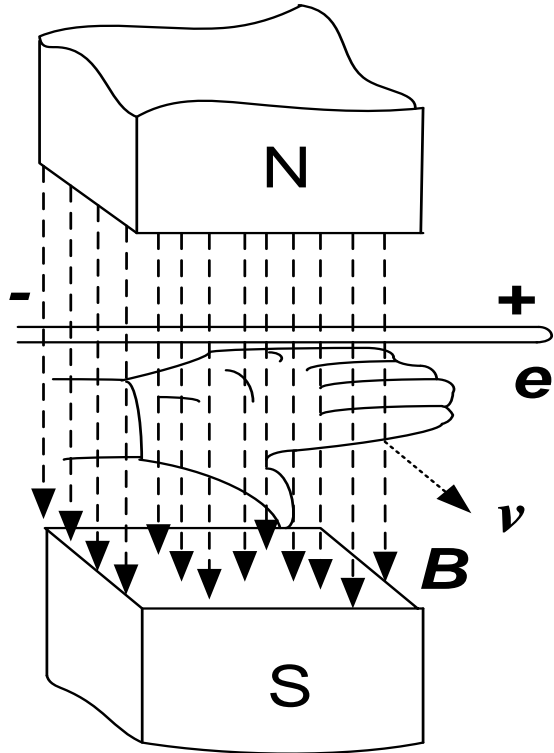
Jian Zhao

Dec. 2022



- What is back EMF?
- Back EMF in a stepper motor
- Using back EMF for diagnostics
- Summary / Q&A

What is Back EMF?

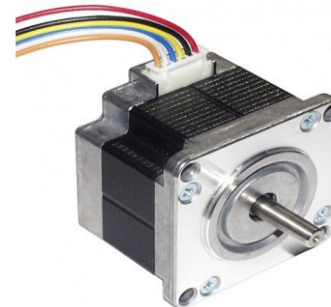


Right-hand rule



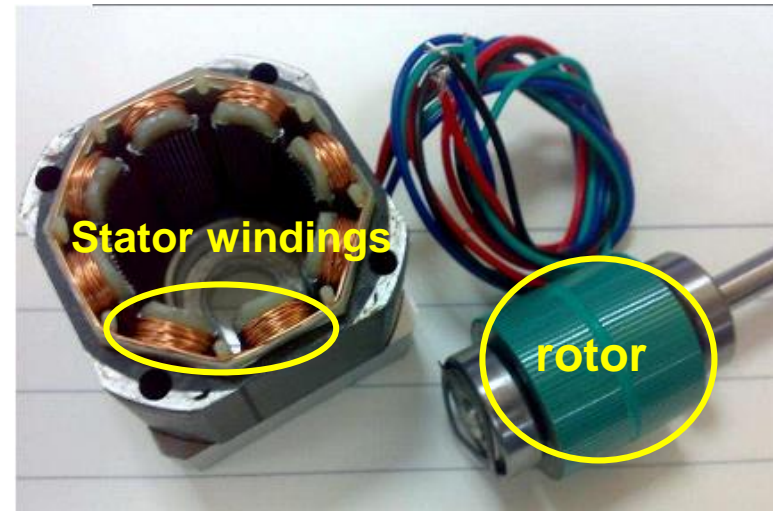
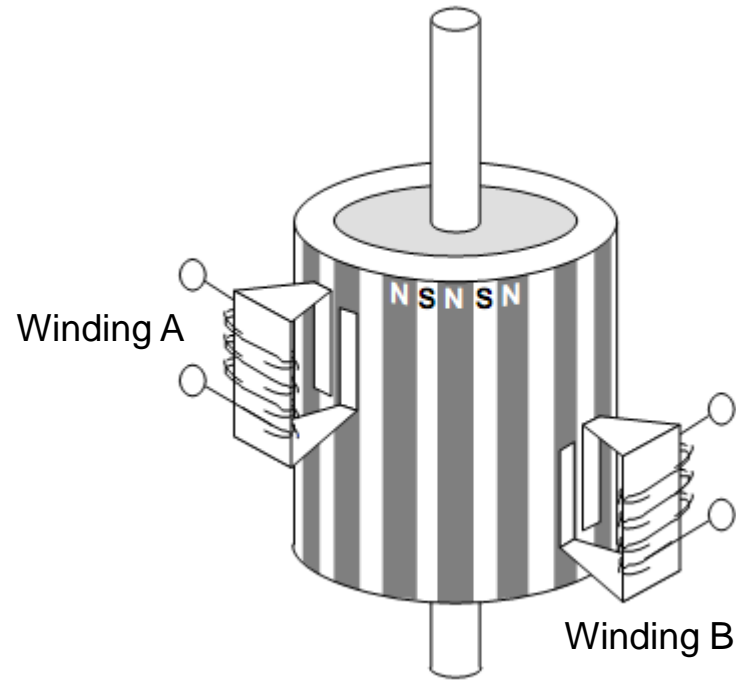
**Brushed
DC Motor**

**Brushless
DC Motor**

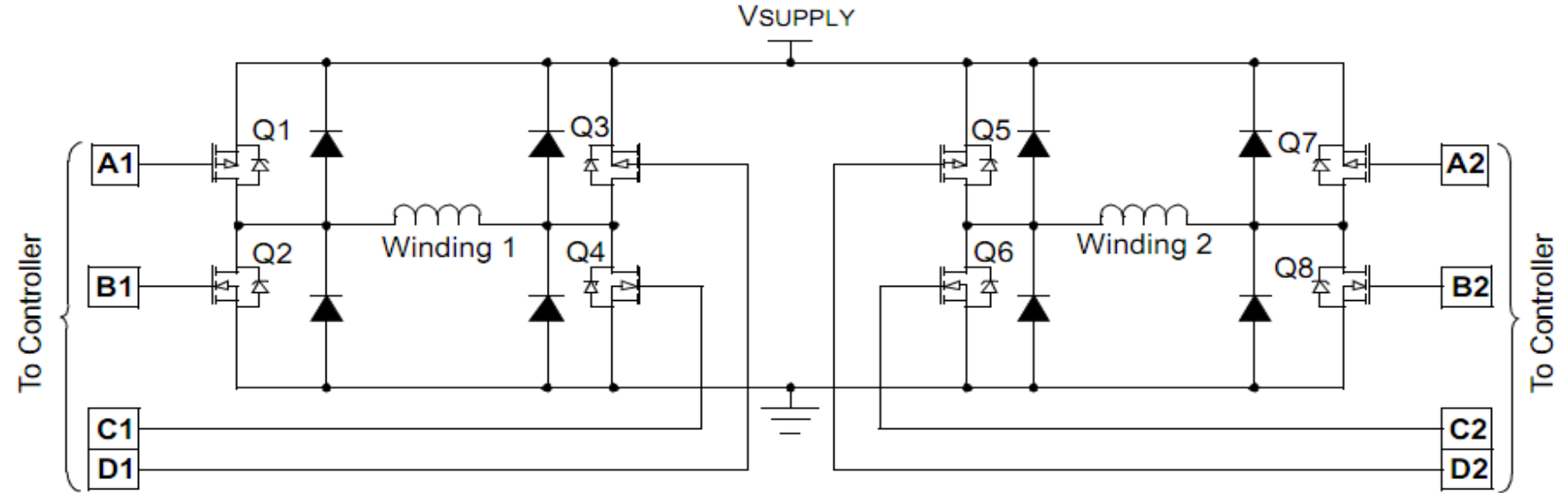
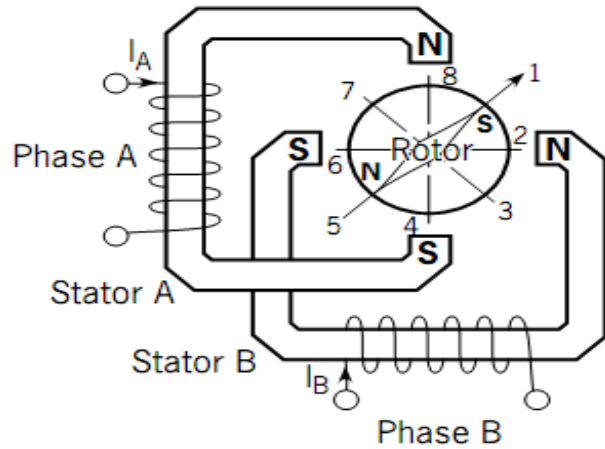


**Stepper
Motor**

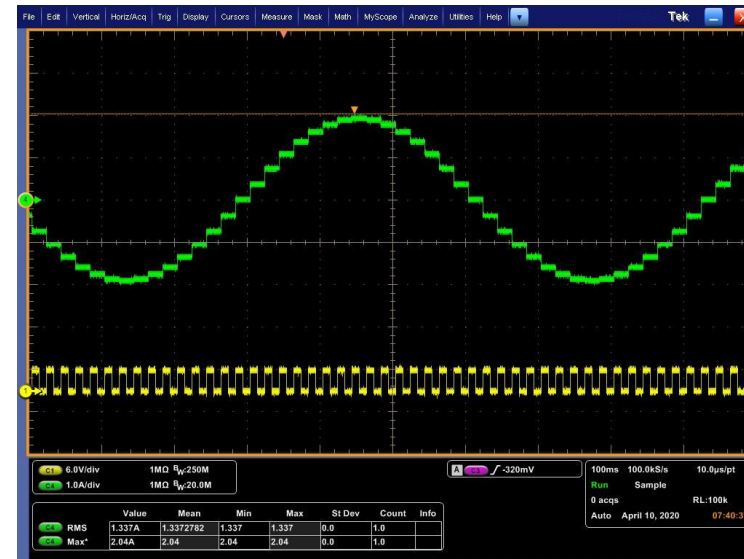
Stepper Motor Construction



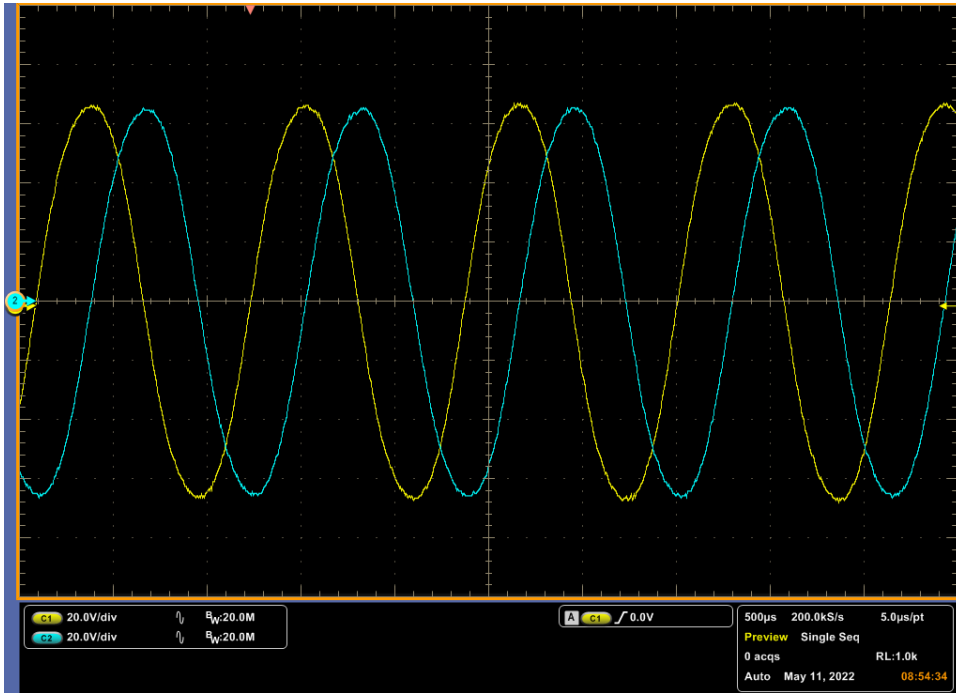
Driving a Stepper Motor



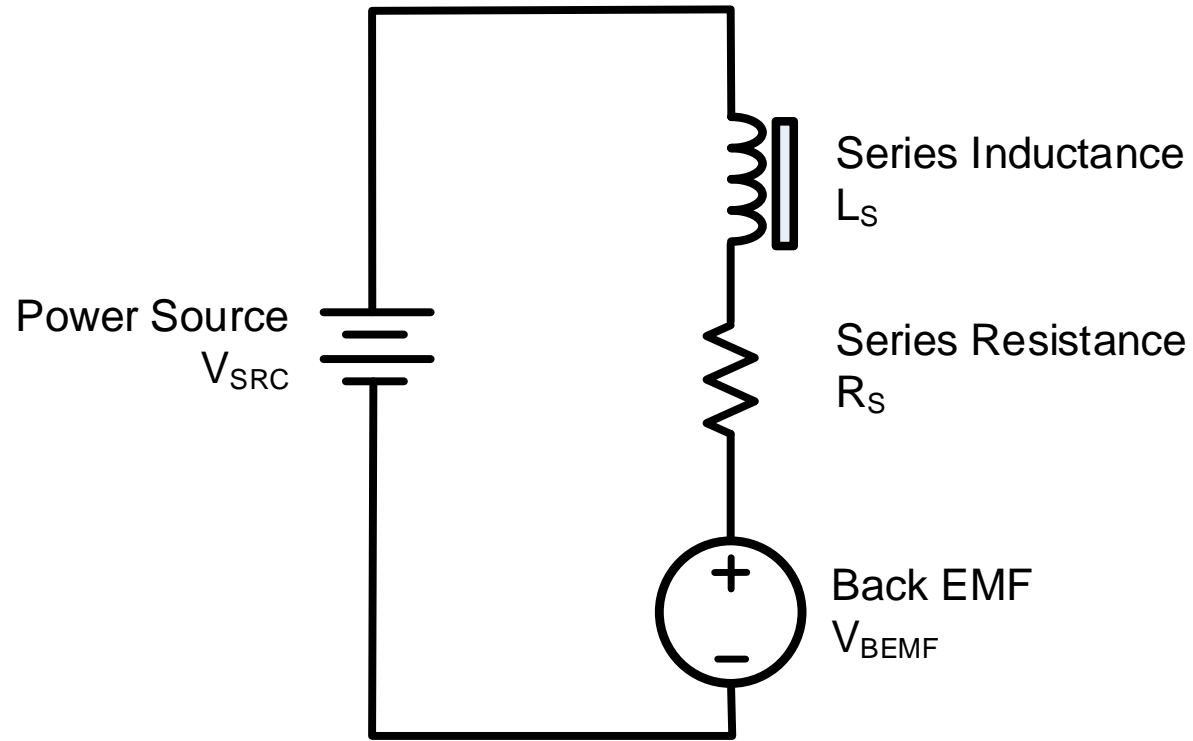
Winding current can be modulated so it approaches sine and cosine waveforms.



Back EMF in the Stepper Motor



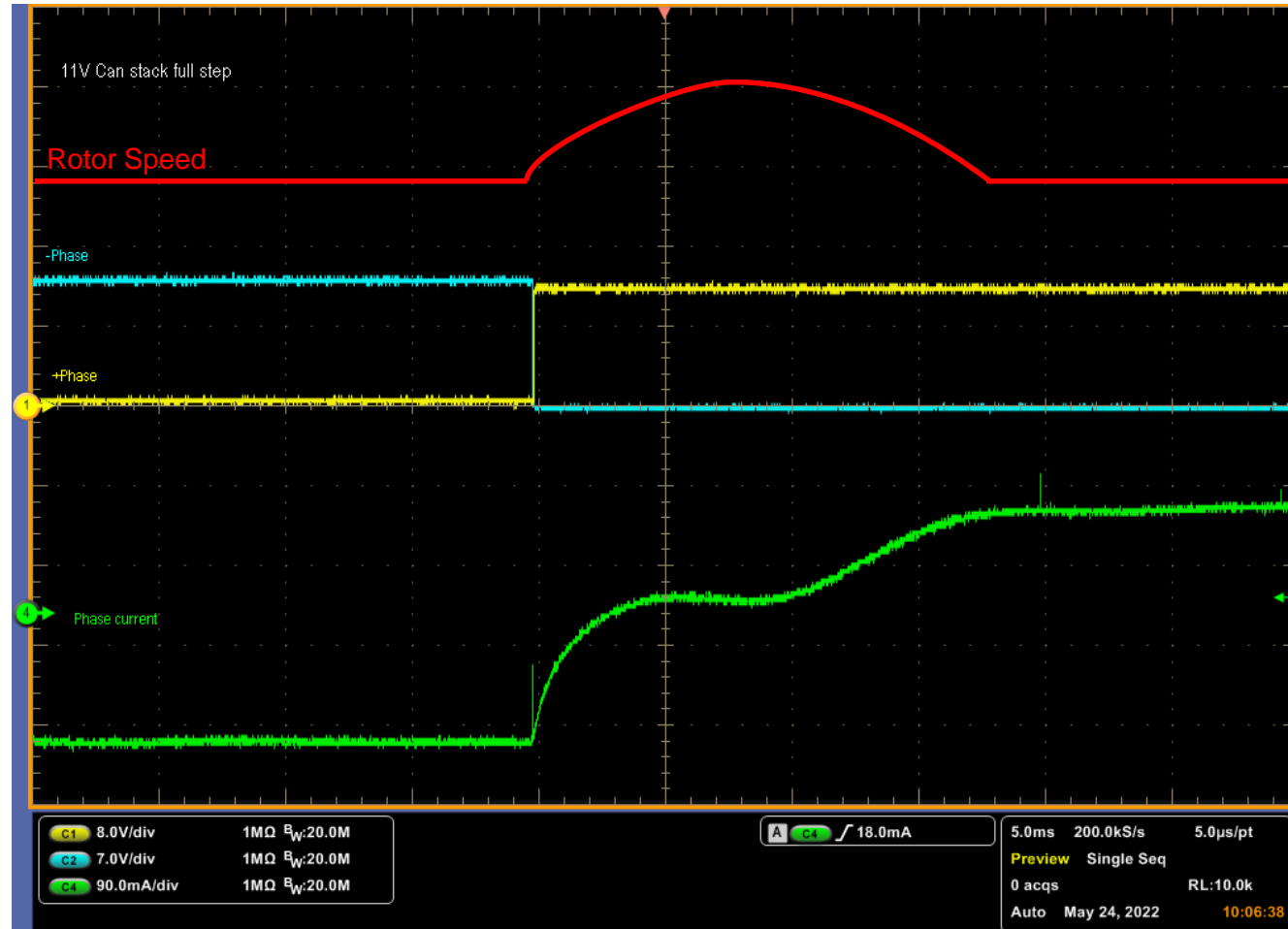
Effect of BEMF on Winding Current



$$V = L \cdot \frac{di}{dt}$$

Effect of BEMF on Winding Current

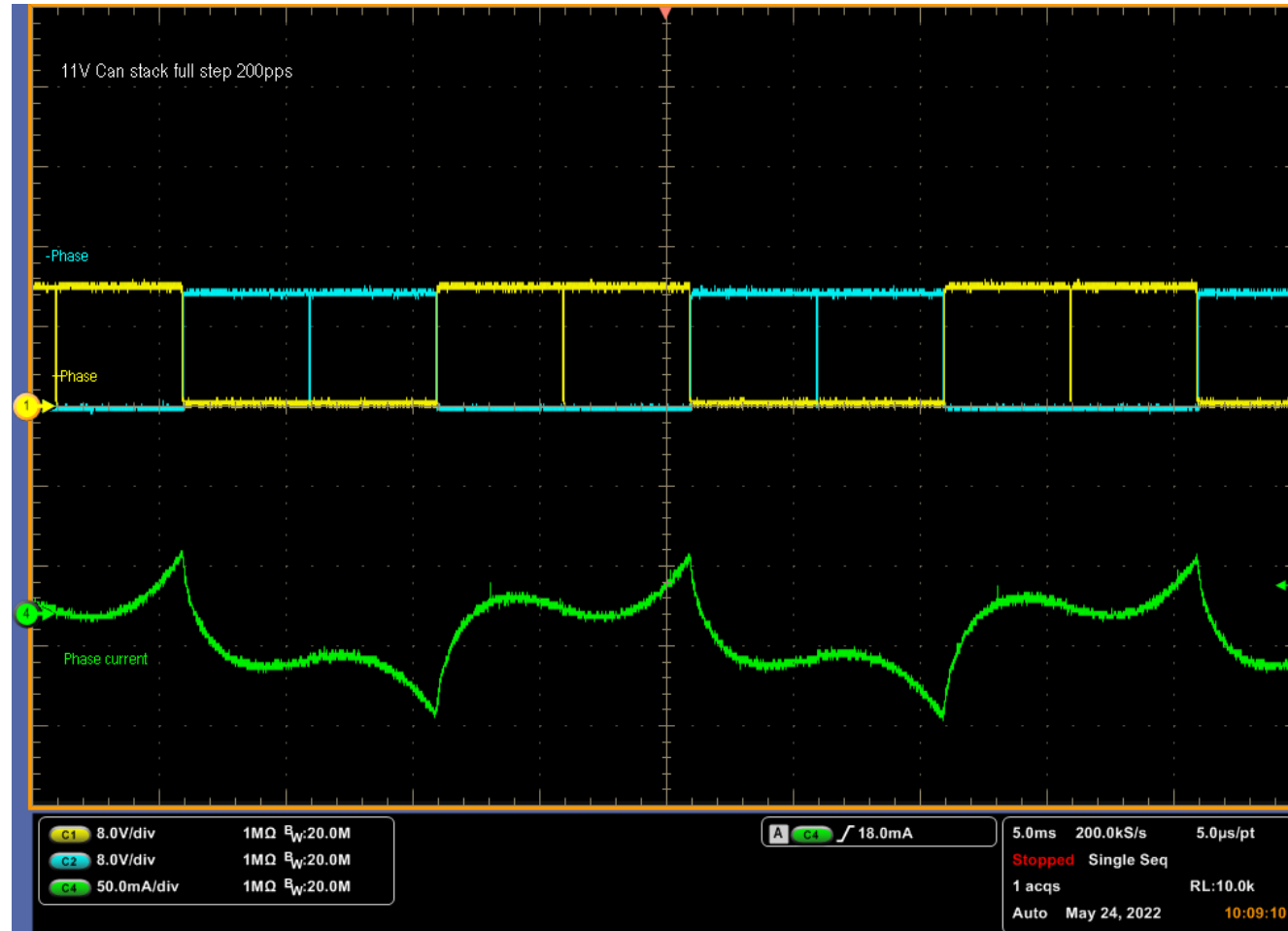
Low Voltage



Yellow: Voltage Green: Current

Effect of BEMF on Winding Current

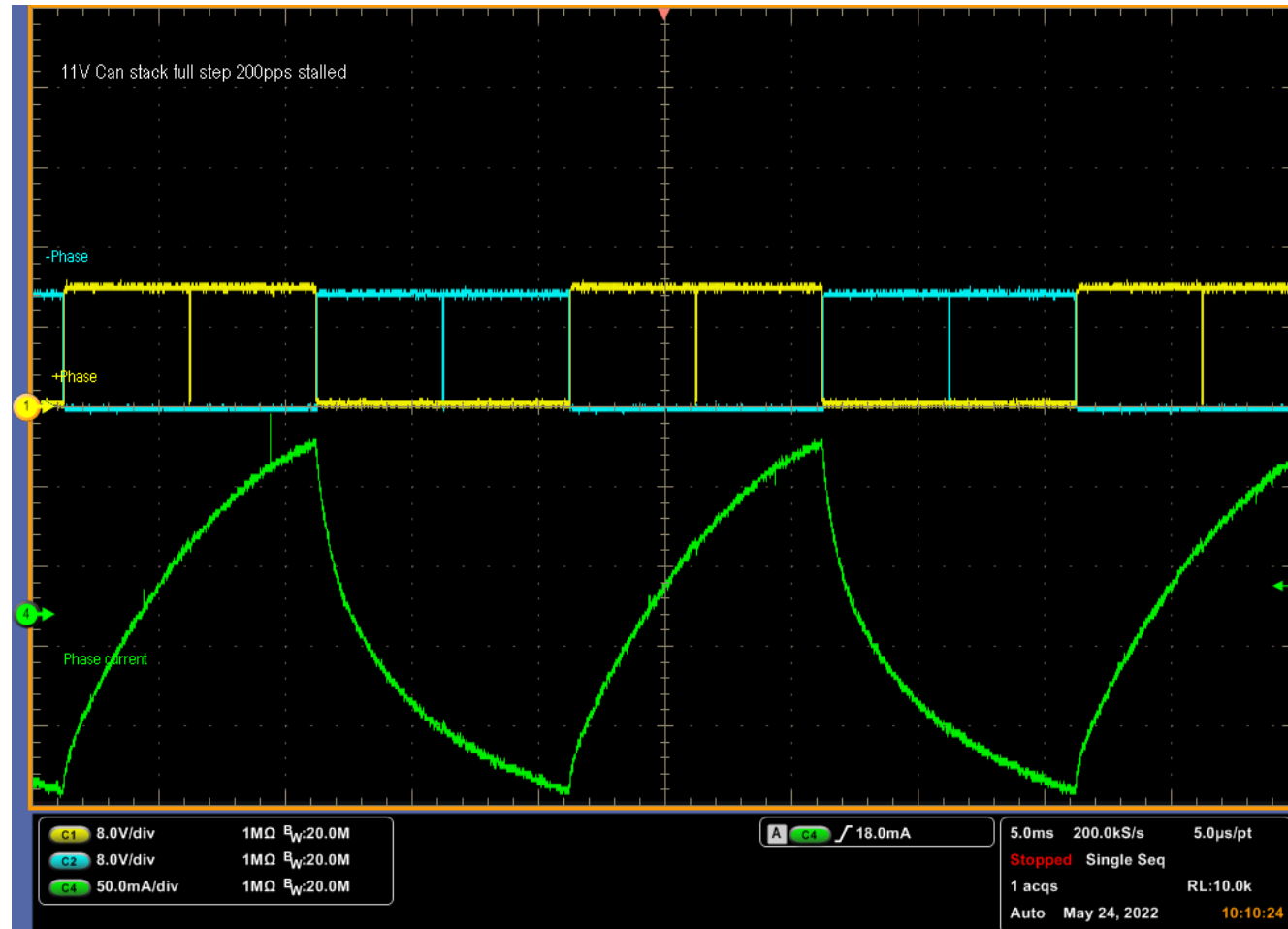
High Step Rate



Yellow: Voltage Green: Current

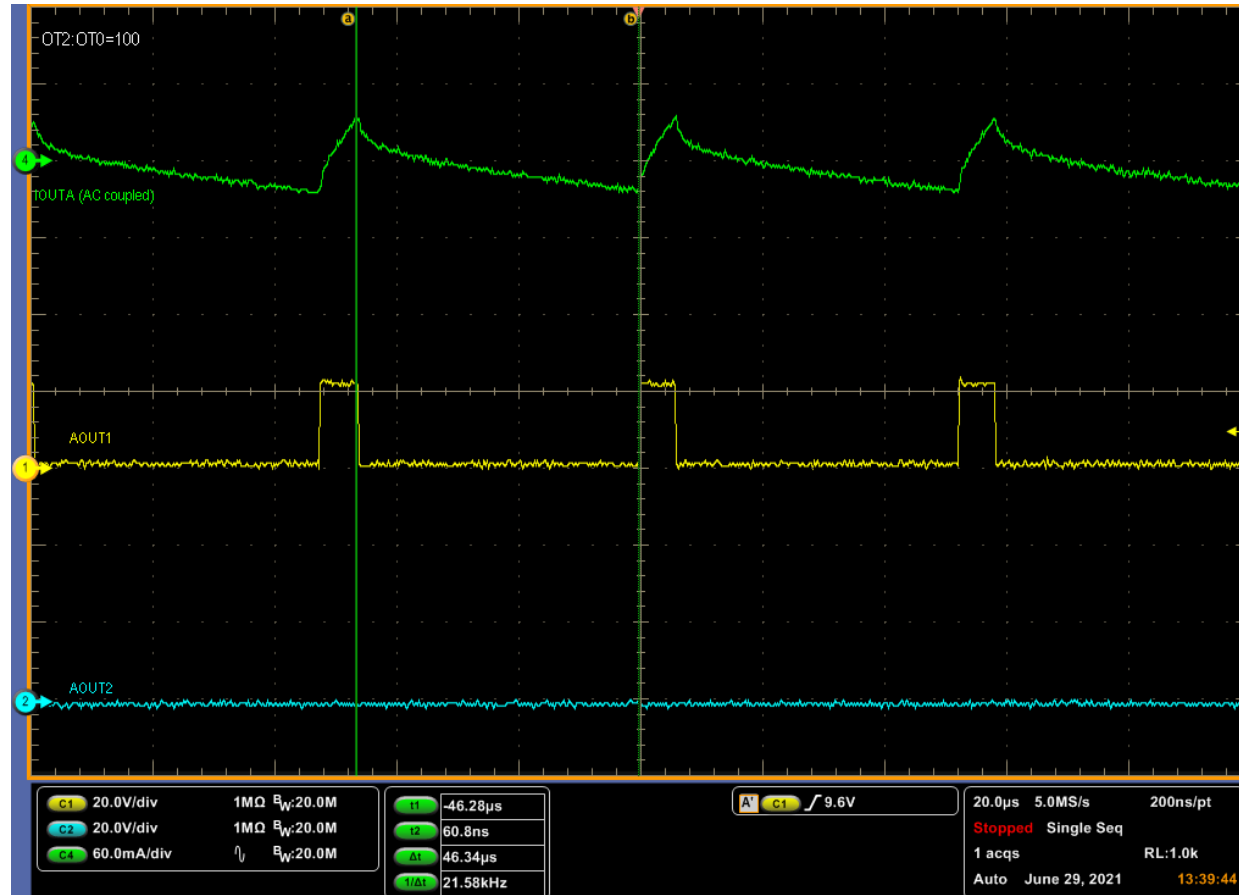
Effect of BEMF on Winding Current

Rotor Stalled



Yellow: Voltage Green: Current

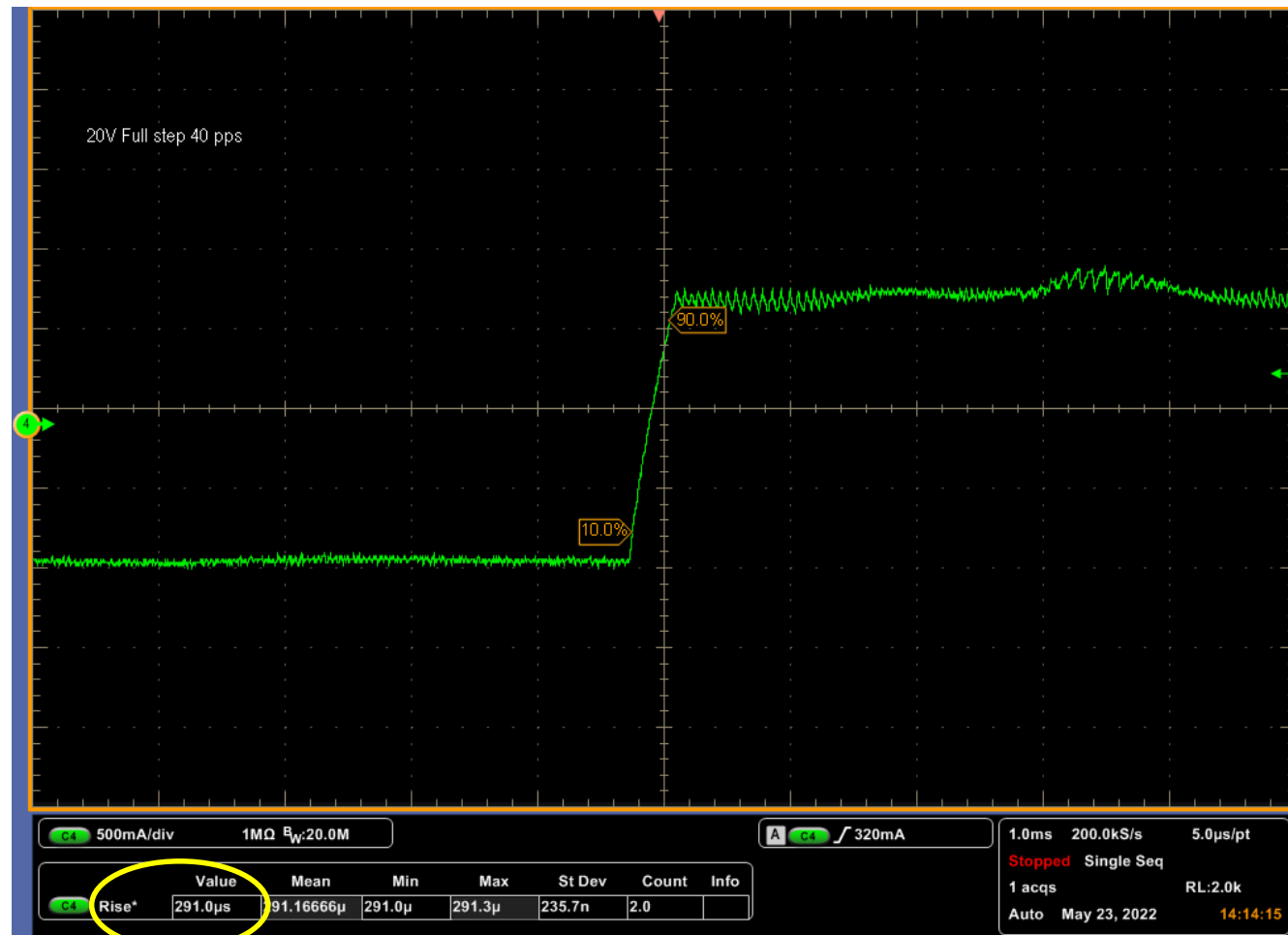
Constant Current Drive



Yellow: Voltage Green: Current

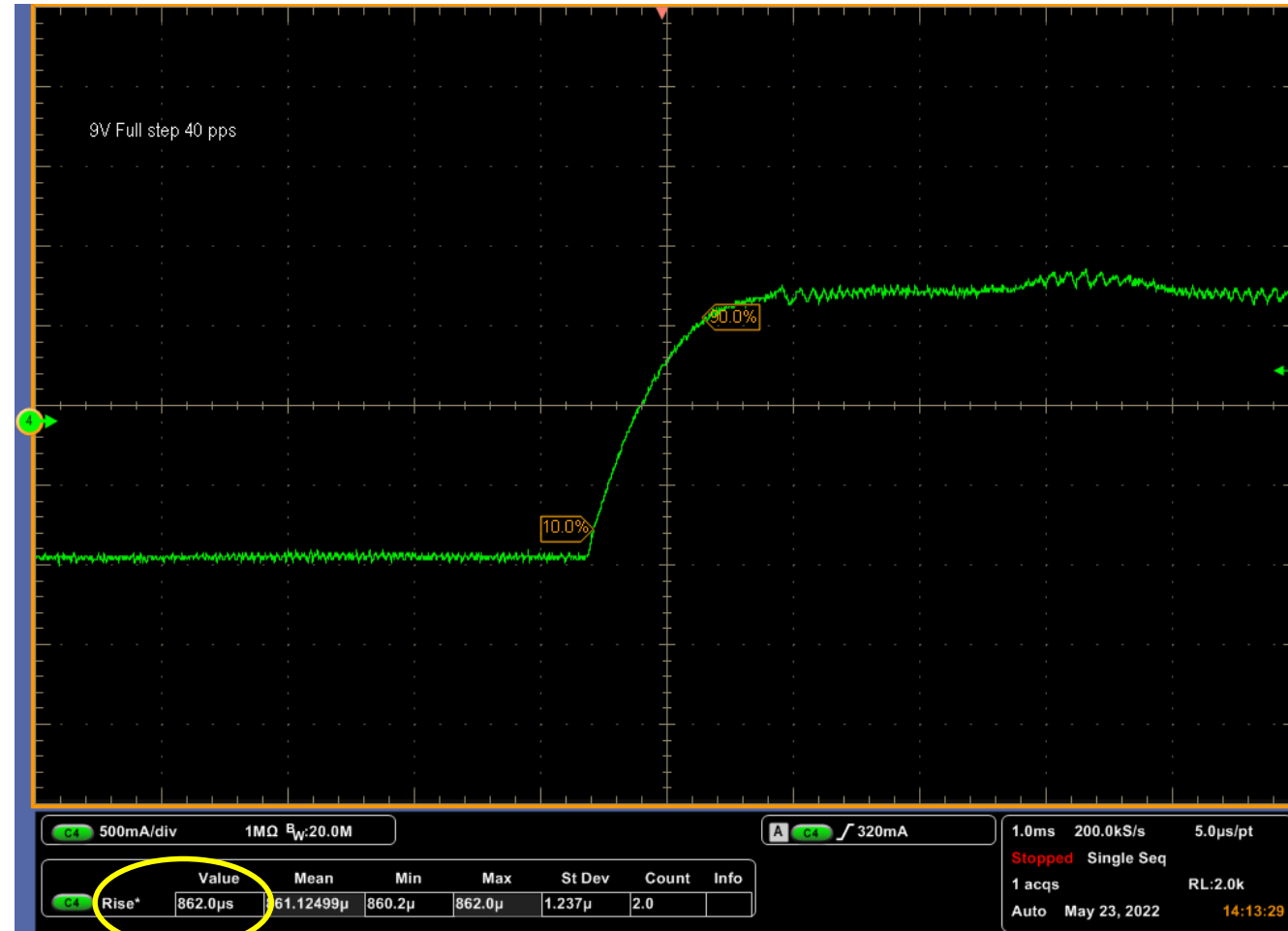
Effect of Supply Voltage on Constant Current

High Voltage

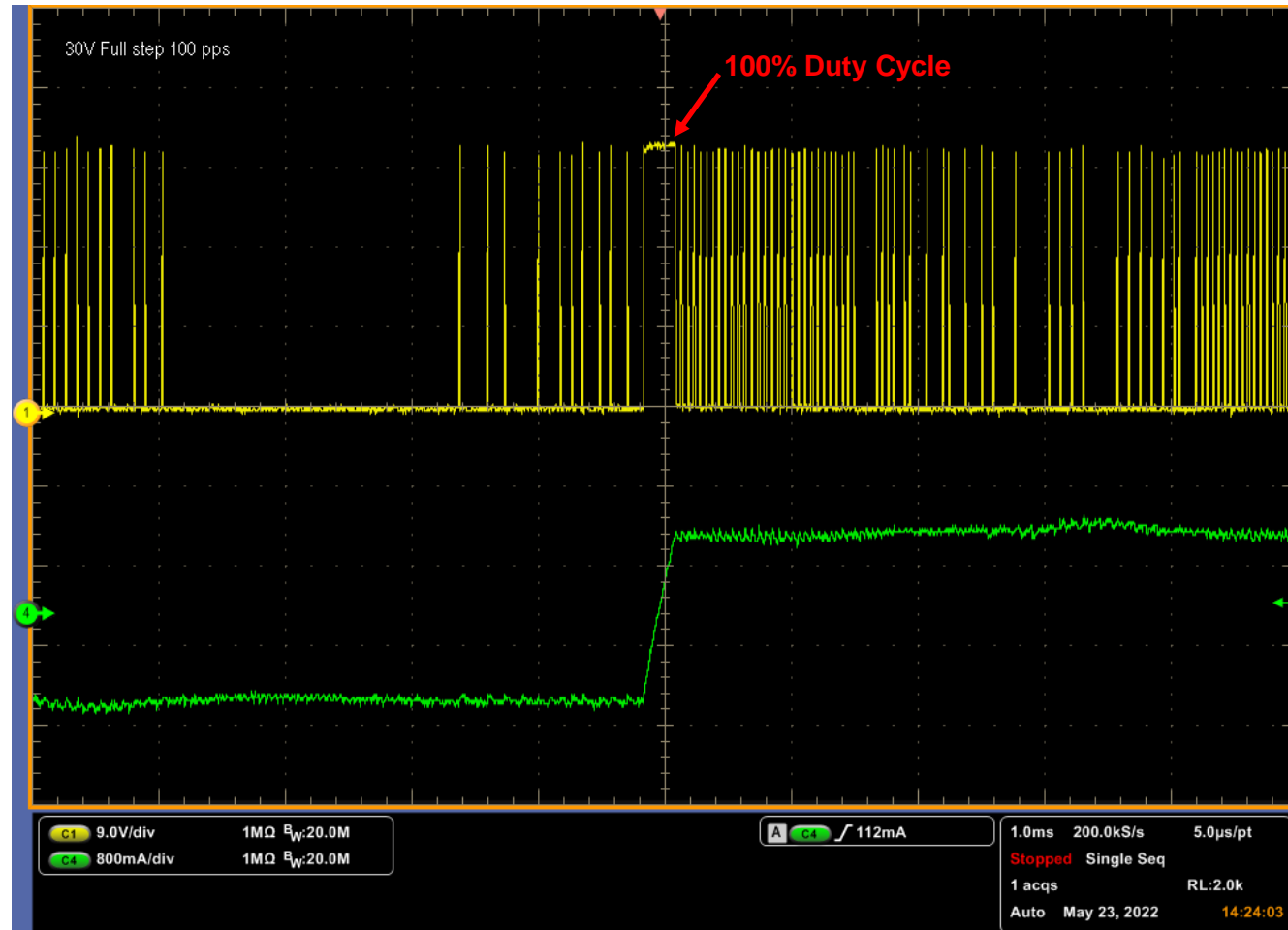


Effect of Supply Voltage on Constant Current

Low Voltage

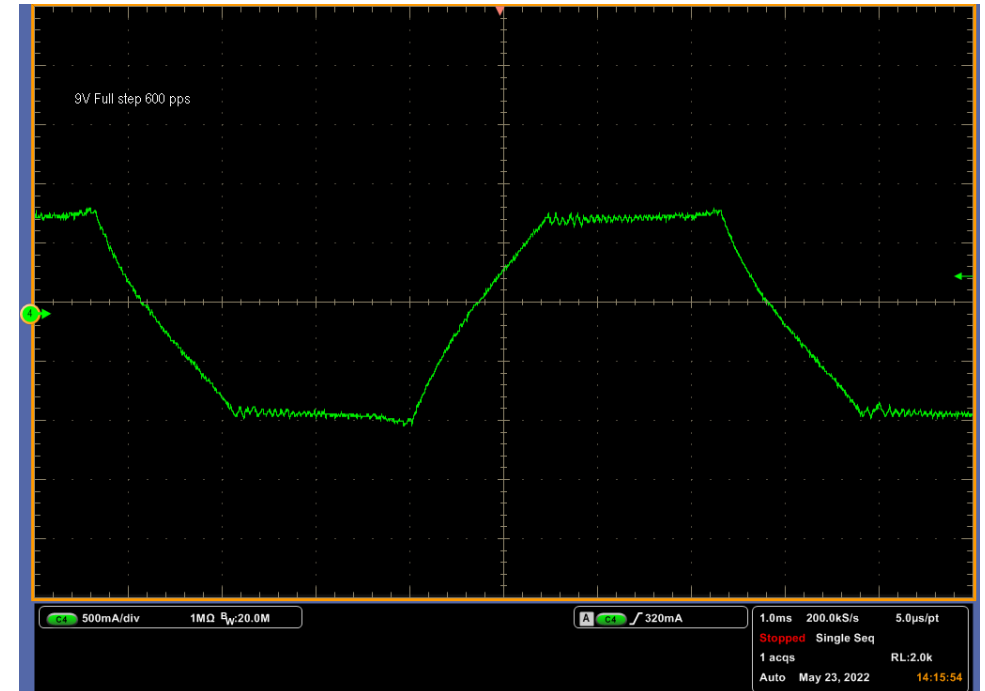
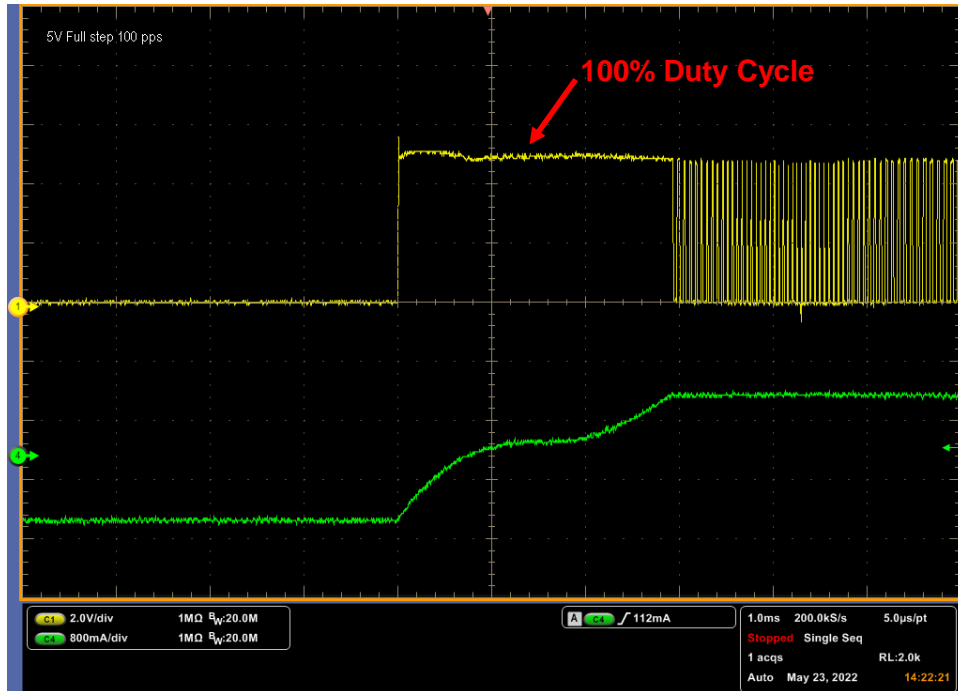


Constant Current & BEMF



Yellow: Voltage Green: Current

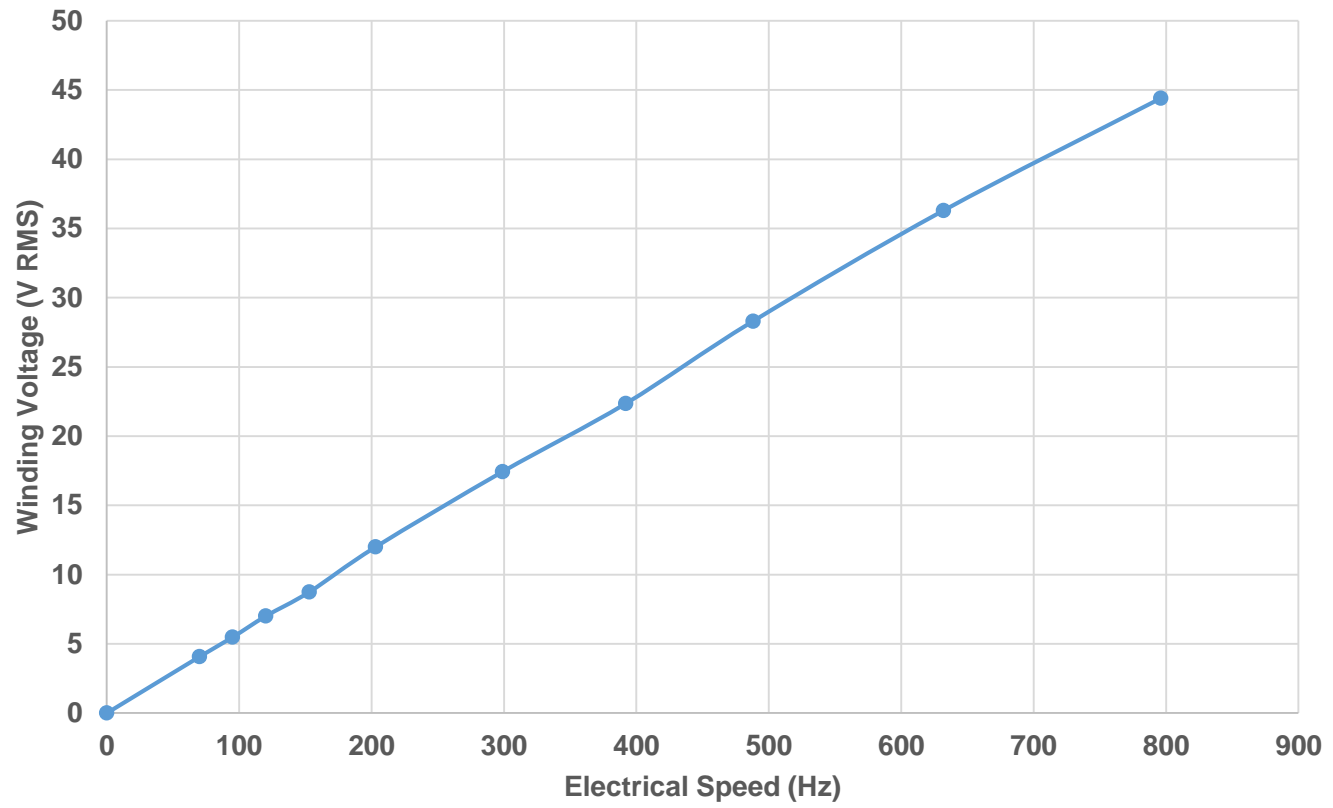
Constant Current & BEMF



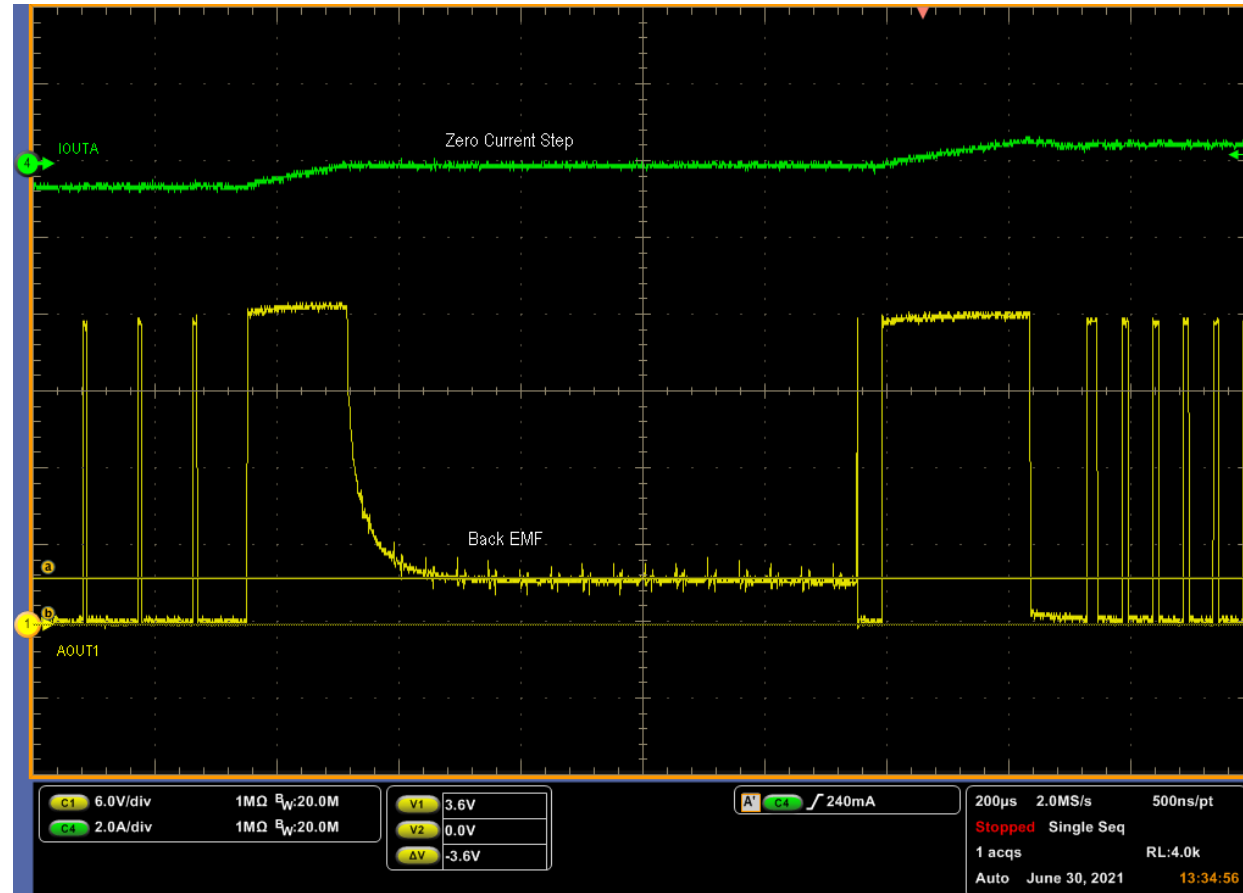
Yellow: Voltage Green: Current

Using Back EMF Information

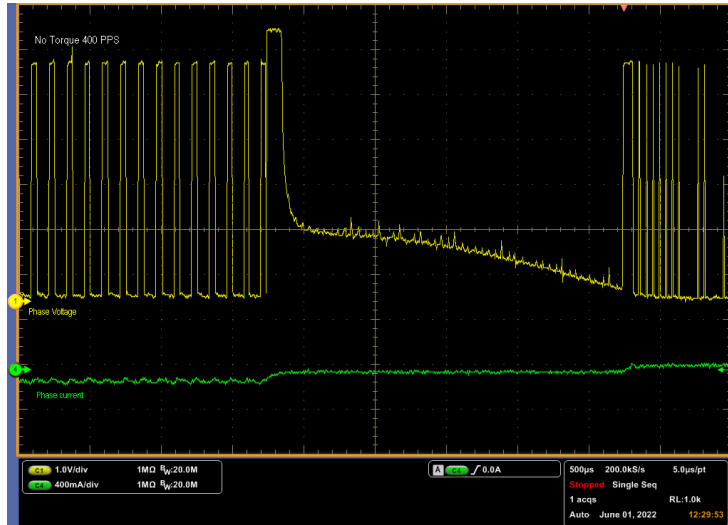
Back EMF vs. Speed



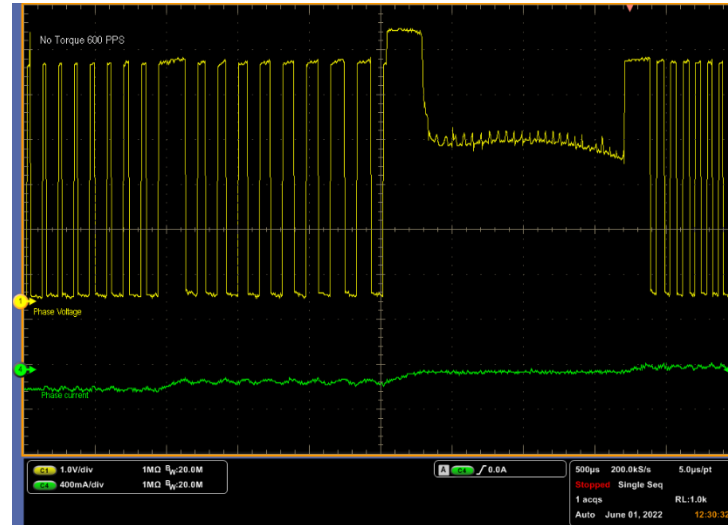
Measuring the Back EMF



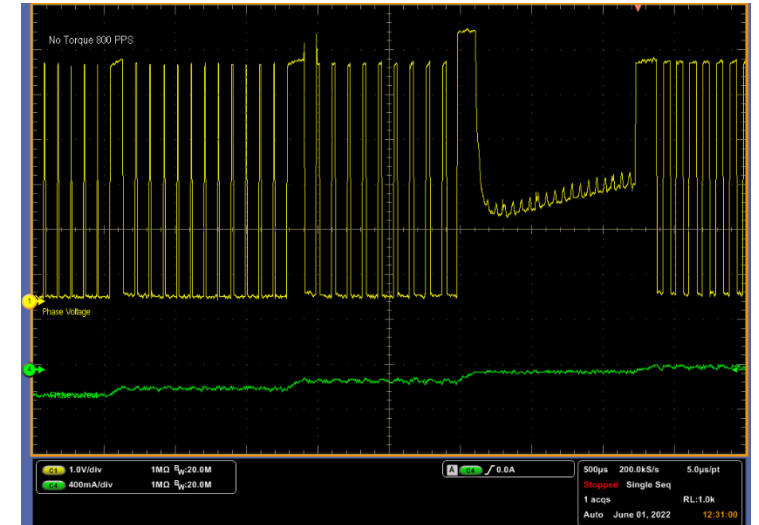
Back EMF Measurements vs. Rotor Speed



400 PPS

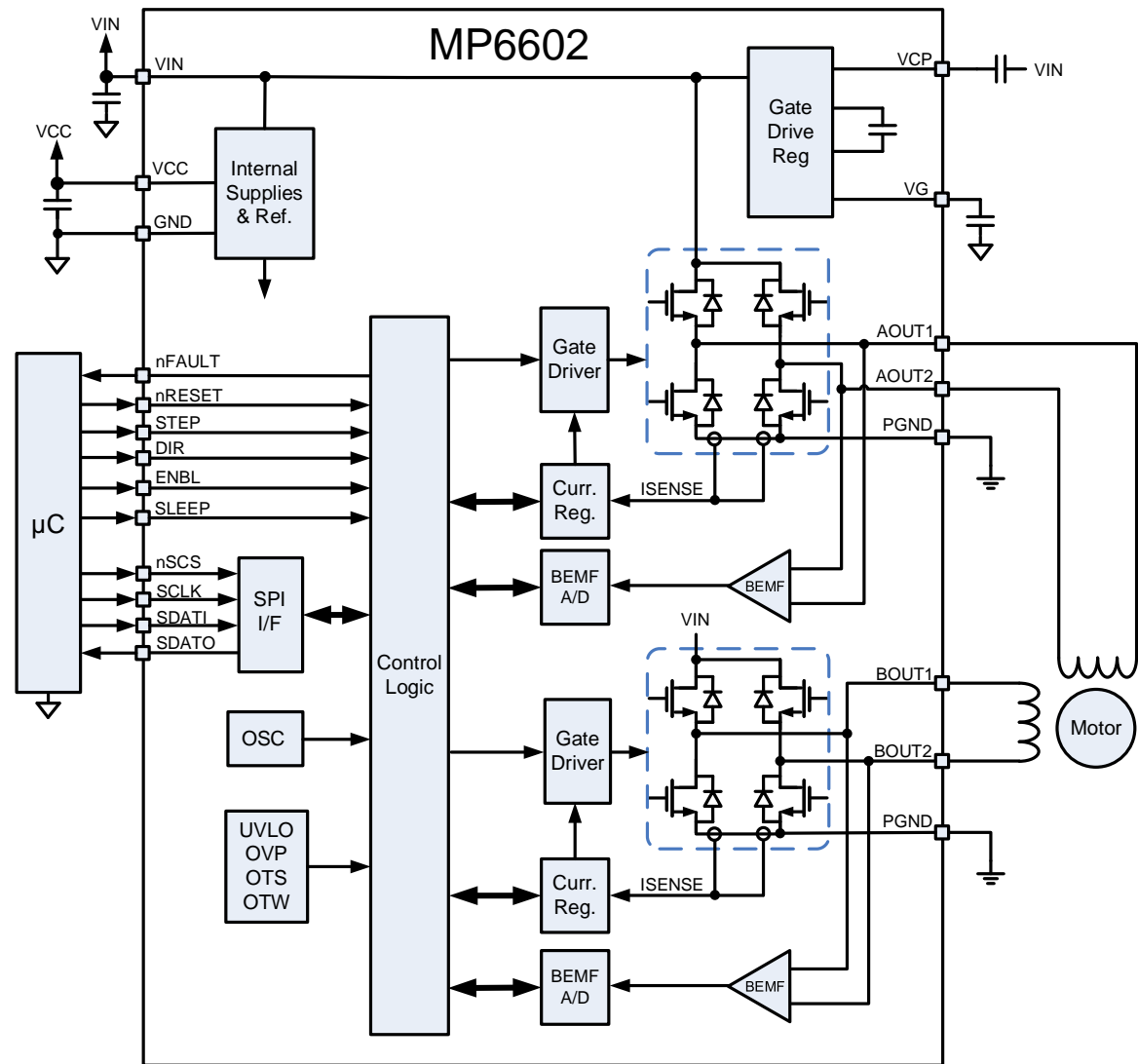


600 PPS

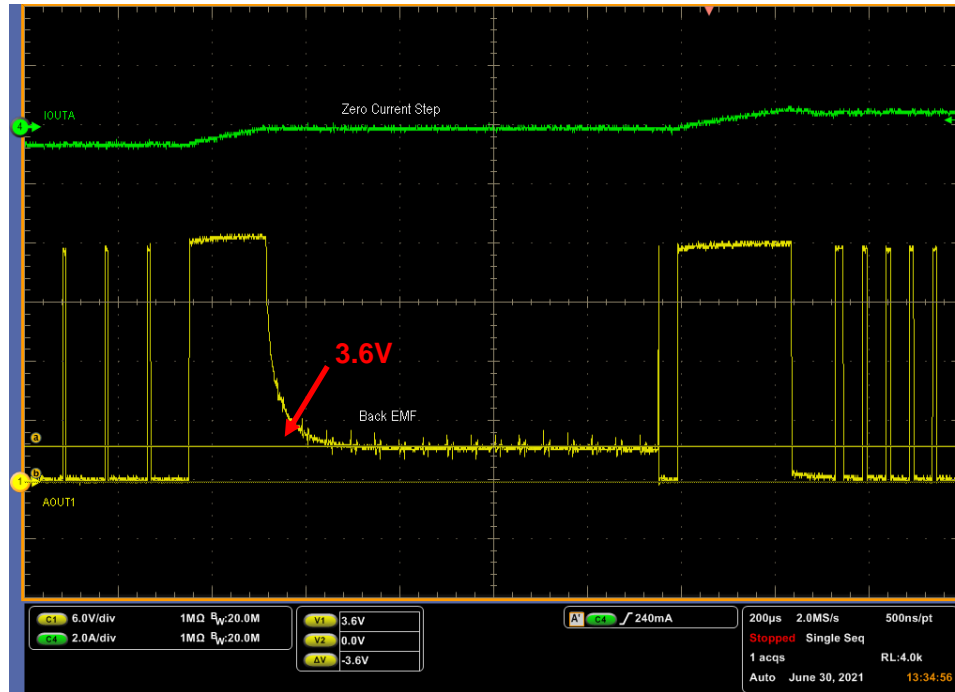


800 PPS

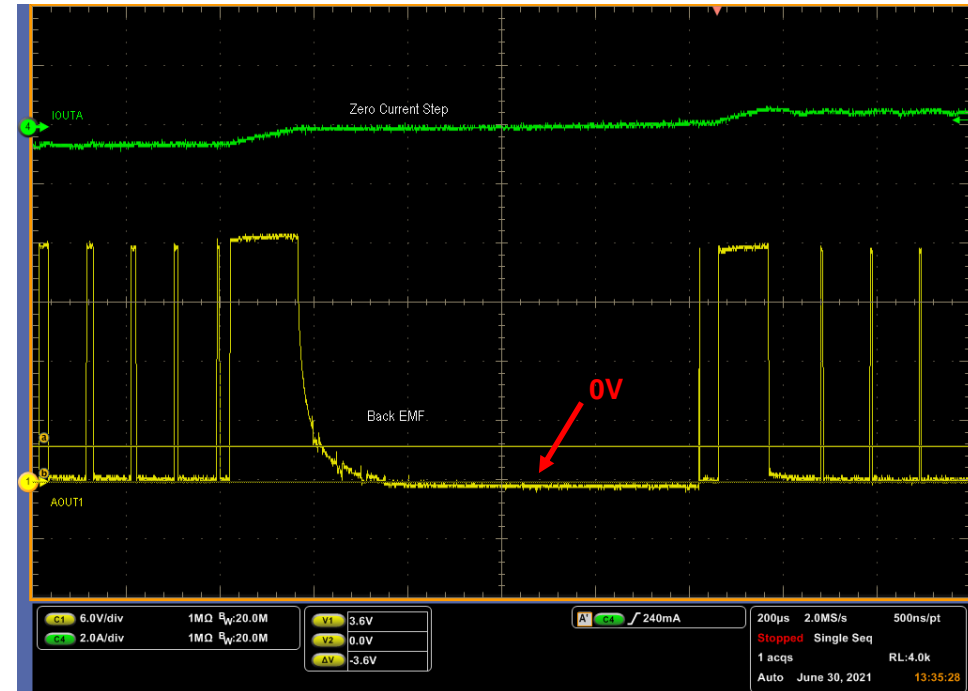
How to Measure BEMF?



Stall Detection

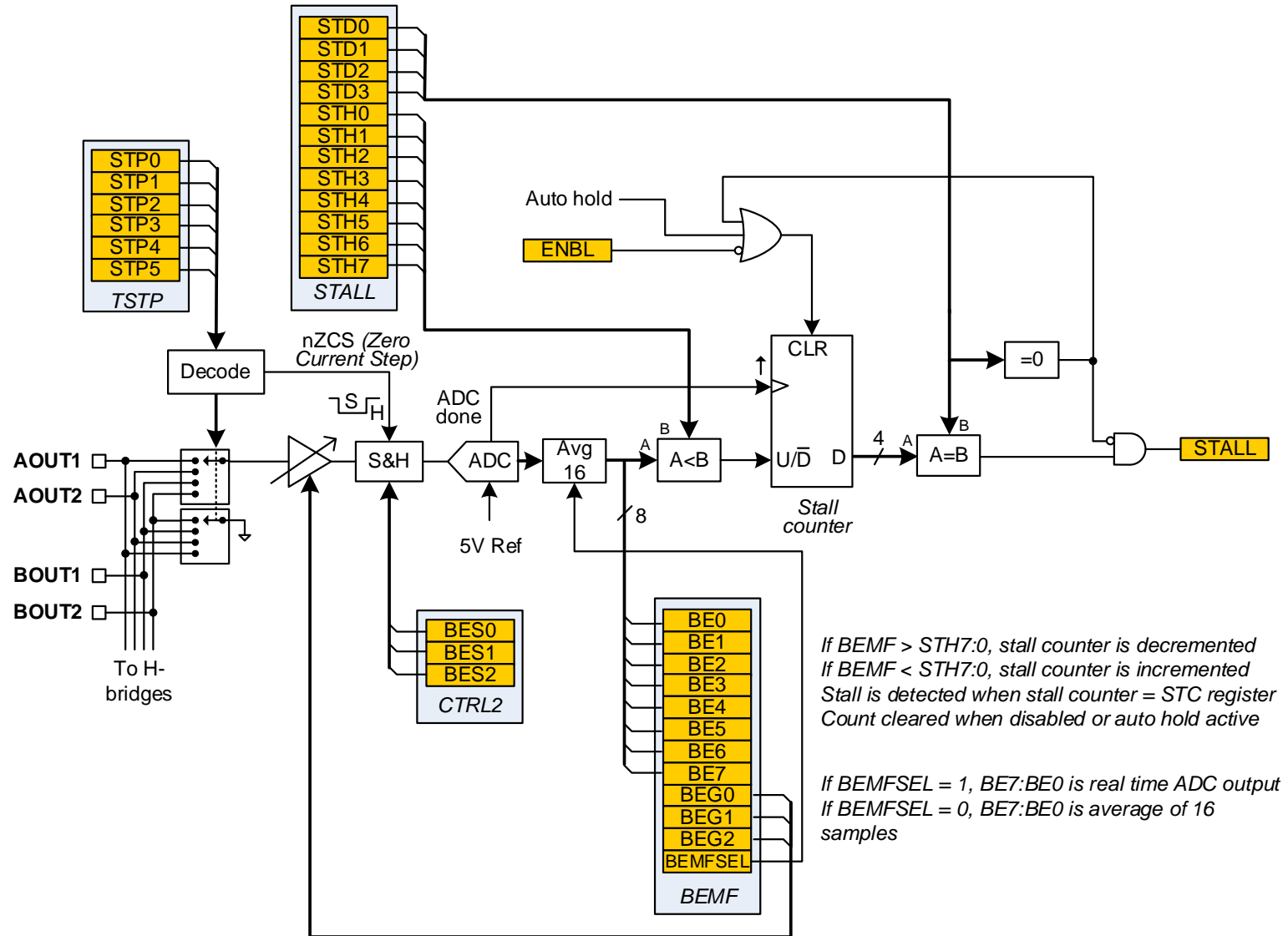


Rotating
Back EMF = 3.6V

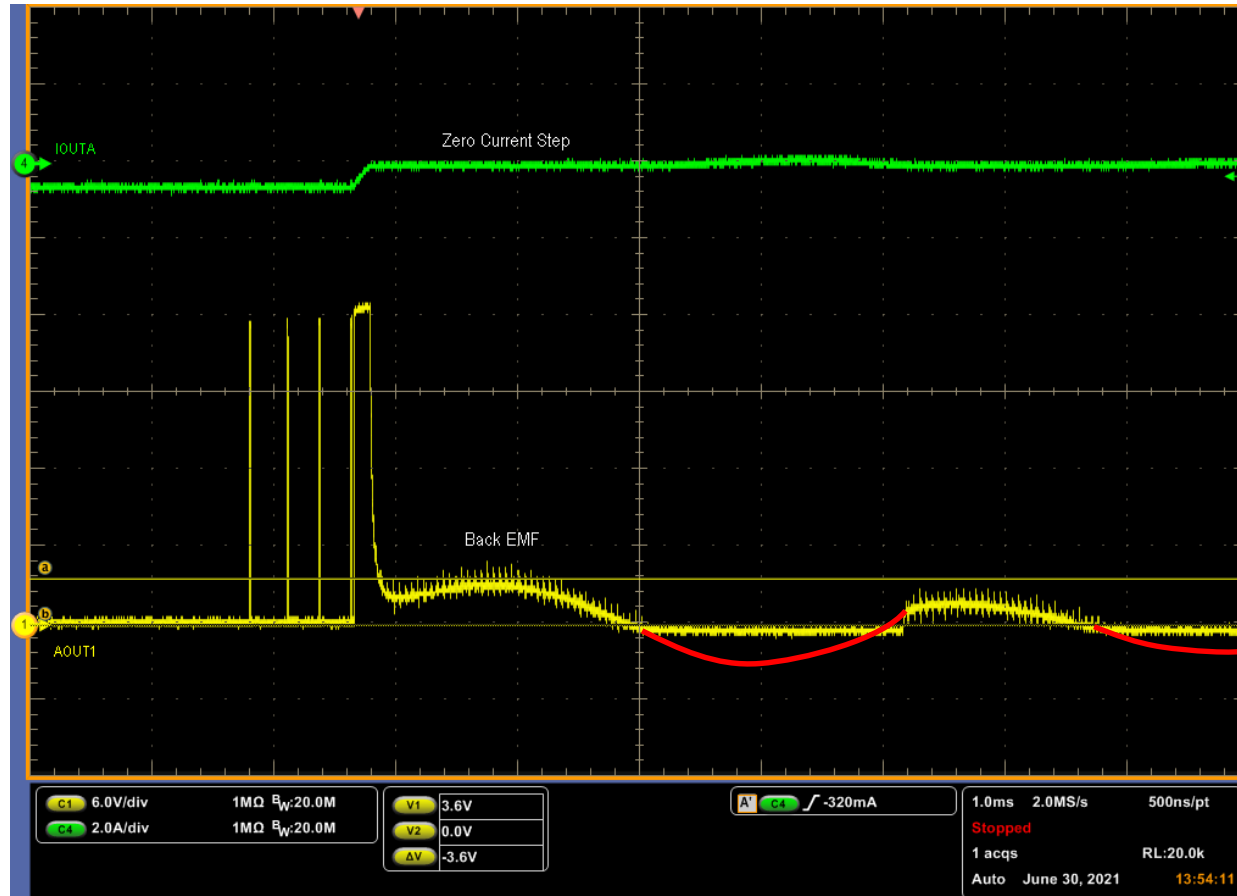


Stalled
Back EMF = 0

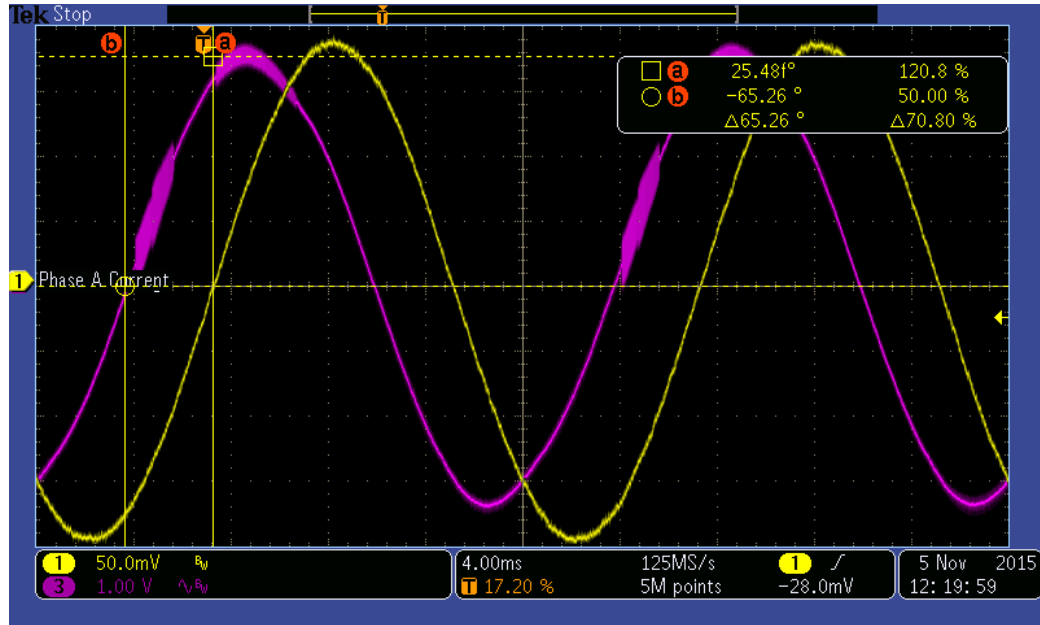
MP6602 Stall Detection



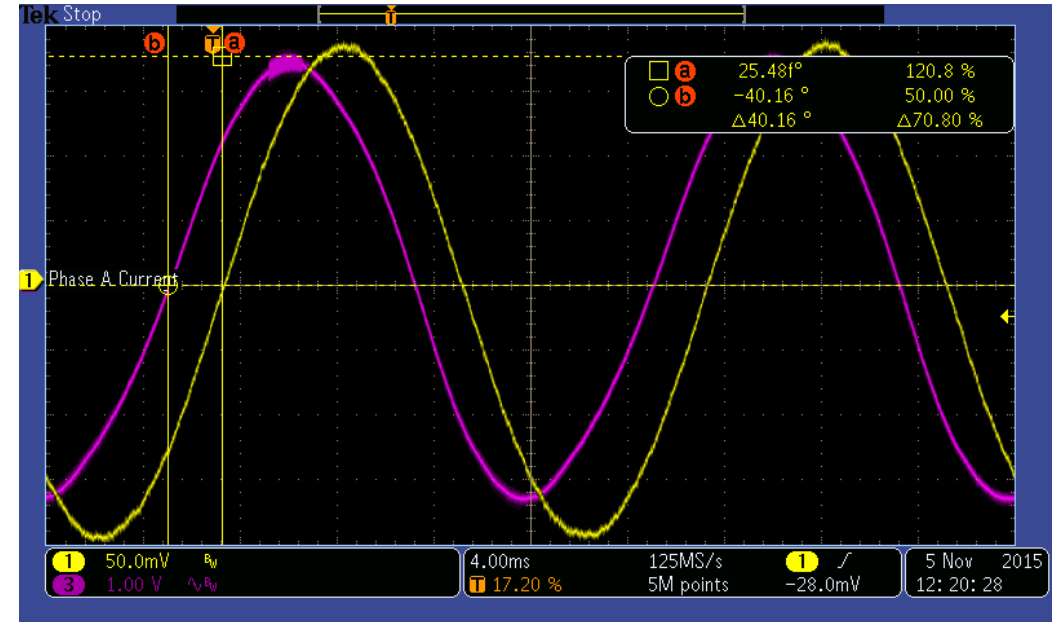
Low Step Rates



Load Torque Estimation



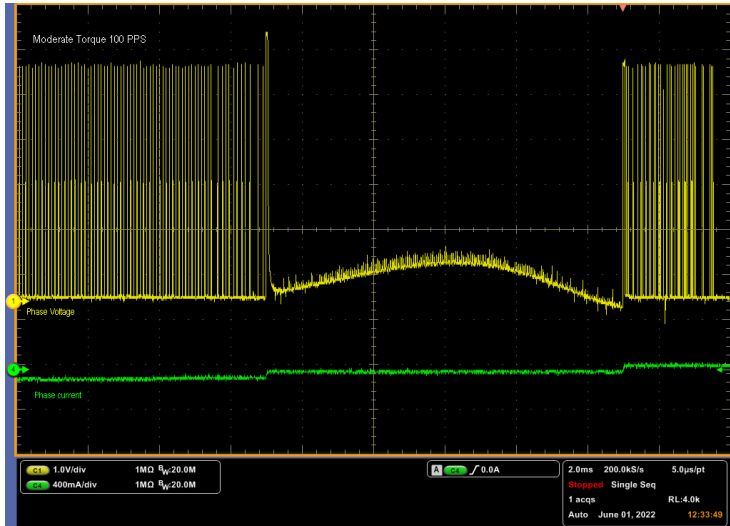
Unloaded



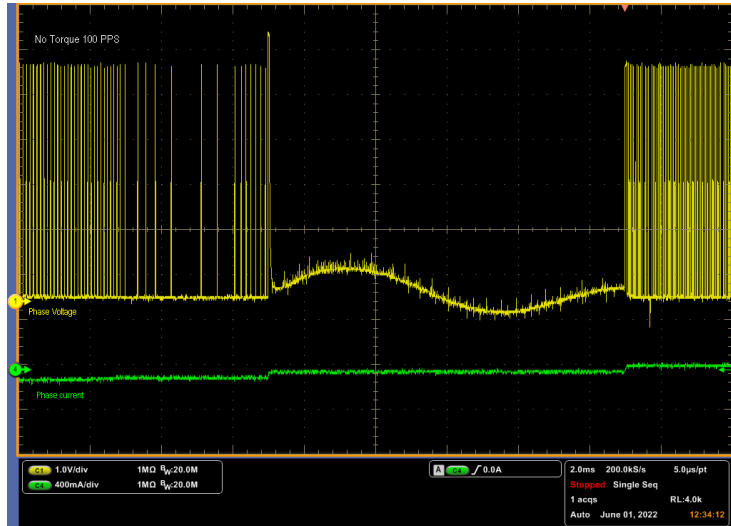
Loaded

Magenta: Voltage Yellow: Current

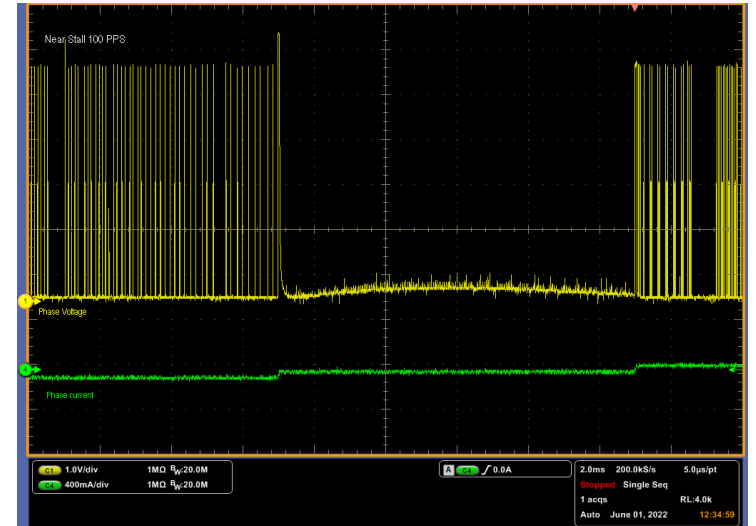
Load Torque Estimation via BEMF Measurement



No Torque

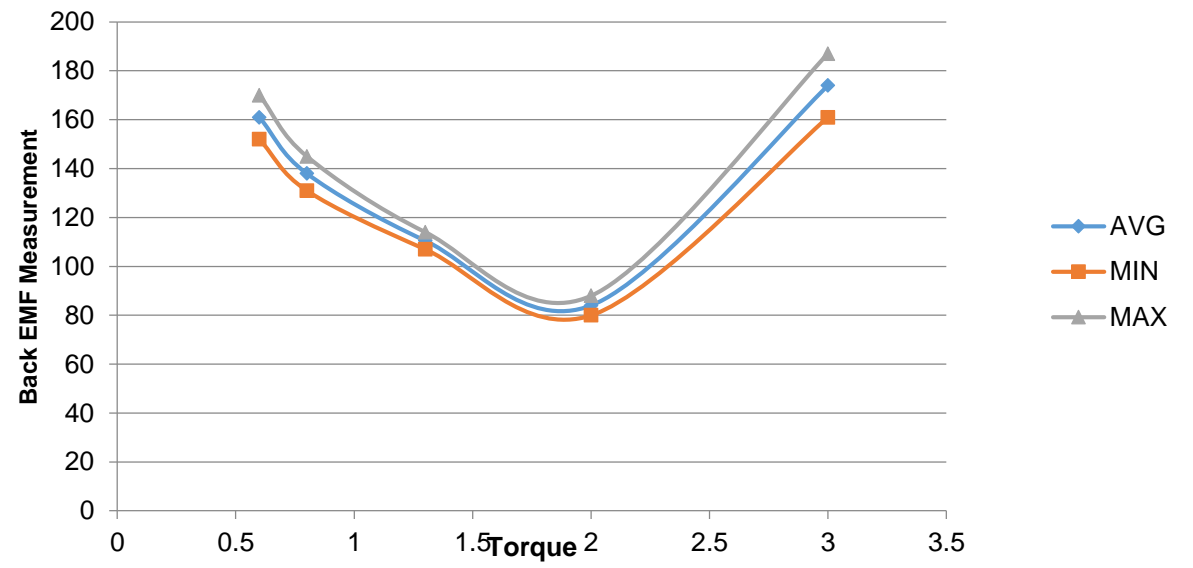
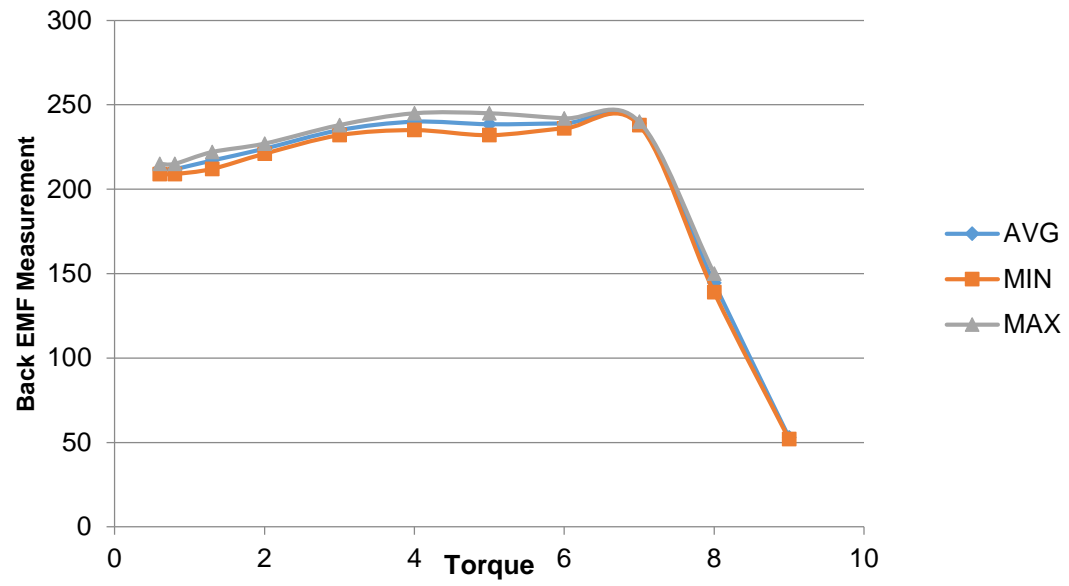


Moderate Torque



Near Stall

Load Torque vs. BEMF



Summary

- Stepper motors have back EMF, like any permanent magnet motor
- Back EMF effects the winding current, and the ability to step the motor at high speed
- Back EMF measurement can be used to provide stall detection, and in some cases provide diagnostic information