

# Stepper Motors and Back EMF

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# Pete Millett – Staff Technical Marketing Engineer



## 2014–Present

- MPS Staff Technical Marketing Engineer for motor driver ICs
- Responsible for new product definitions as well as application engineering

## 2005–2013

- Systems Engineer and Systems Manager at Texas Instruments
- Product definition and systems engineering for motor driver ICs (DRV8XXX)

## 1982–2005

- Board-level hardware design engineer at various computer and consumer electronics companies

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What is back EMF?

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Back EMF in a stepper motor

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Using back EMF for diagnostics

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Summary / Q&A

# What is Back EMF?

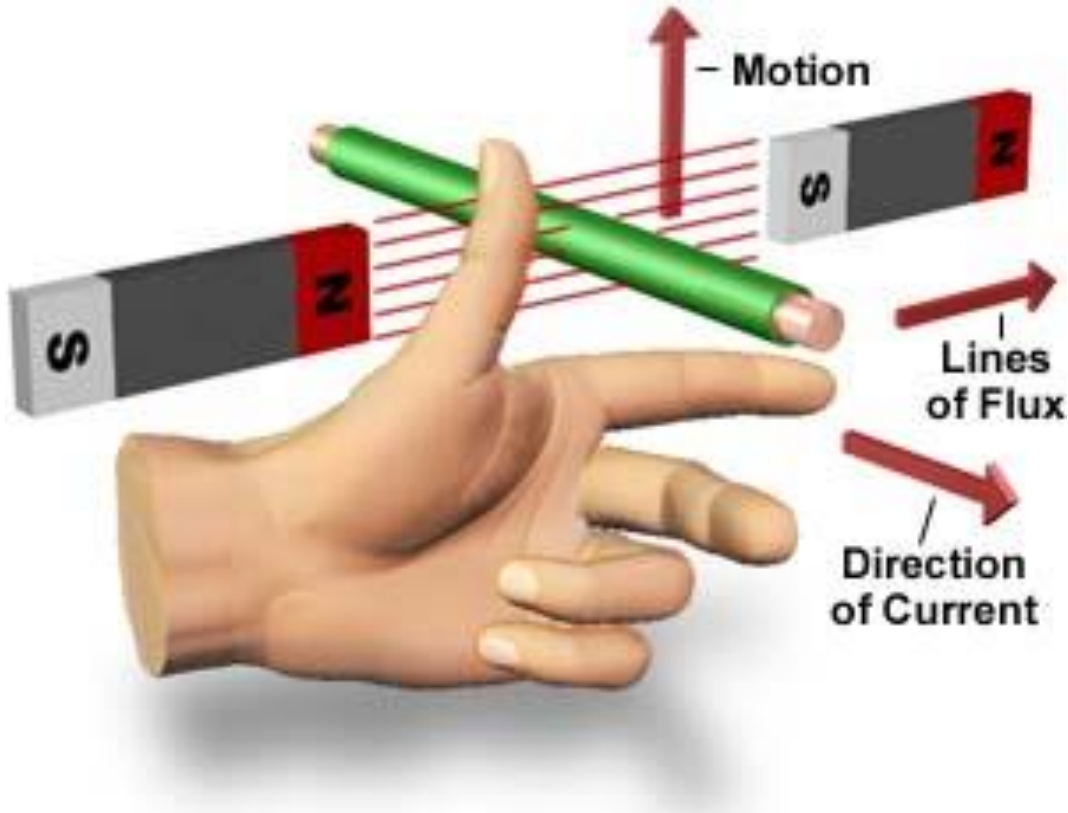
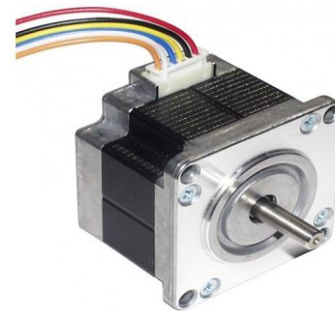


Image by Florida State University, [micro.magnet.fsu.edu](http://micro.magnet.fsu.edu)



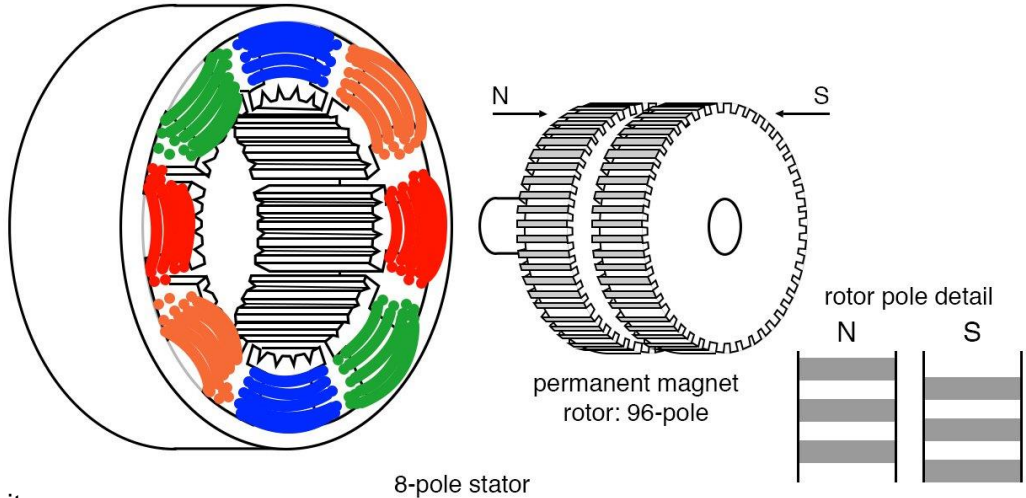
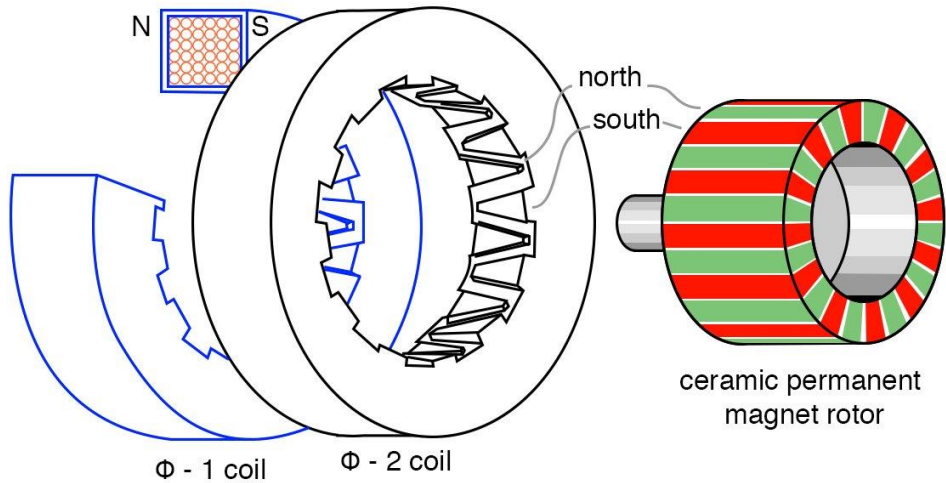
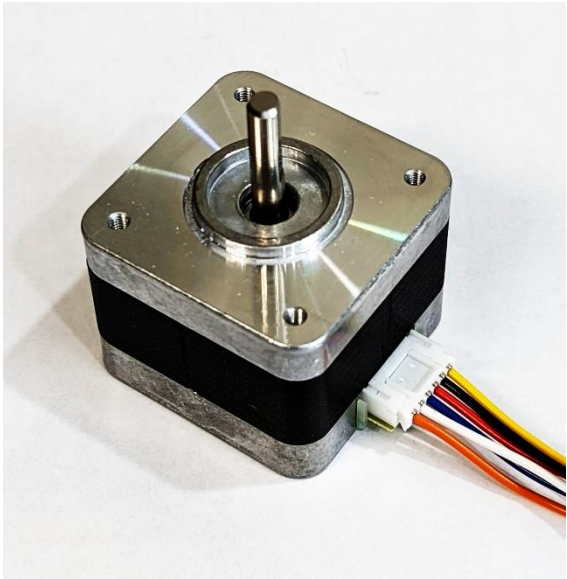
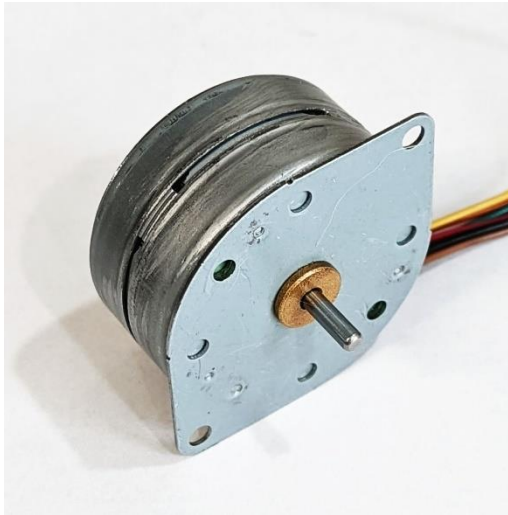
**Brushed DC Motor**

**Brushless DC Motor**



**Stepper Motor**

# Stepper Motor Construction



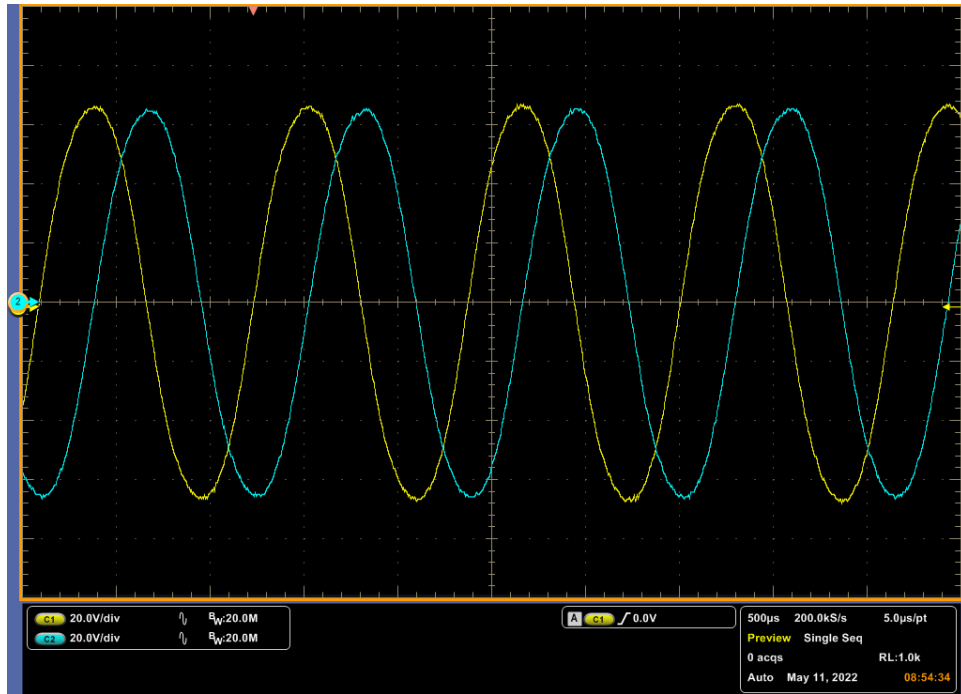
Images from [www.allaboutcircuits.com](http://www.allaboutcircuits.com)

**Permanent Magnet Stepper Motor**

**Hybrid Stepper Motor**

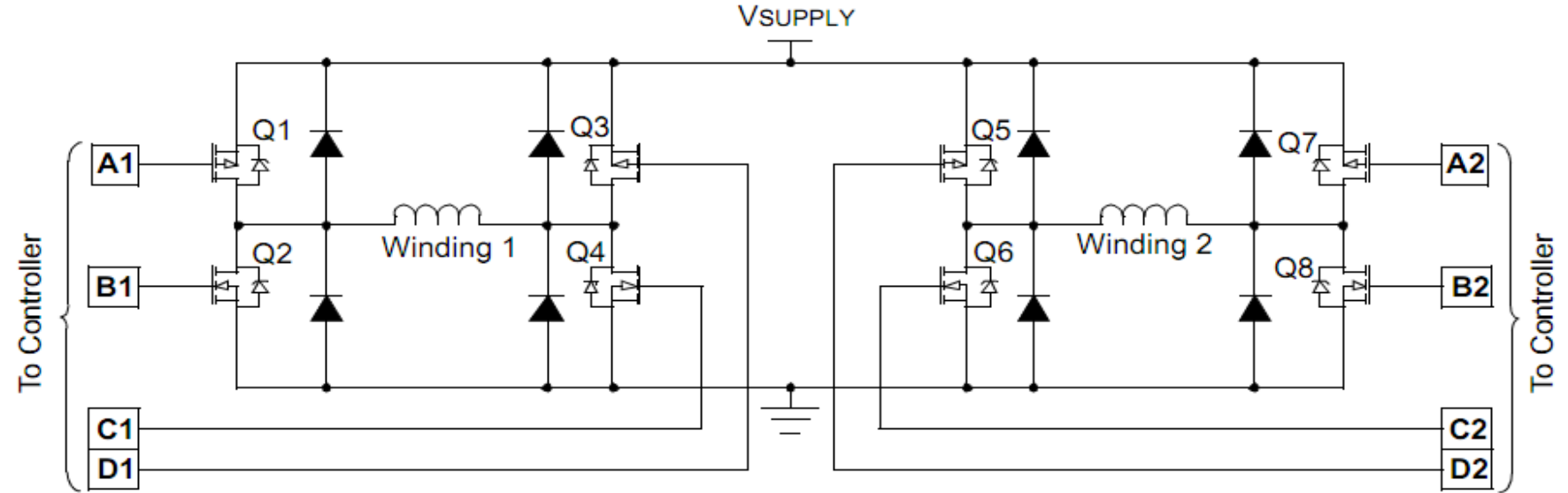
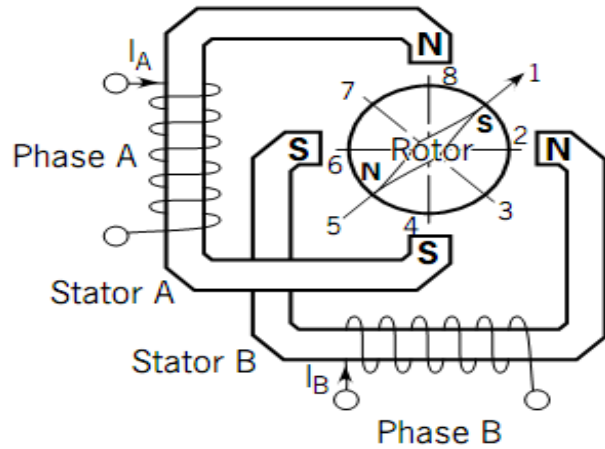


# Back EMF in the Stepper Motor

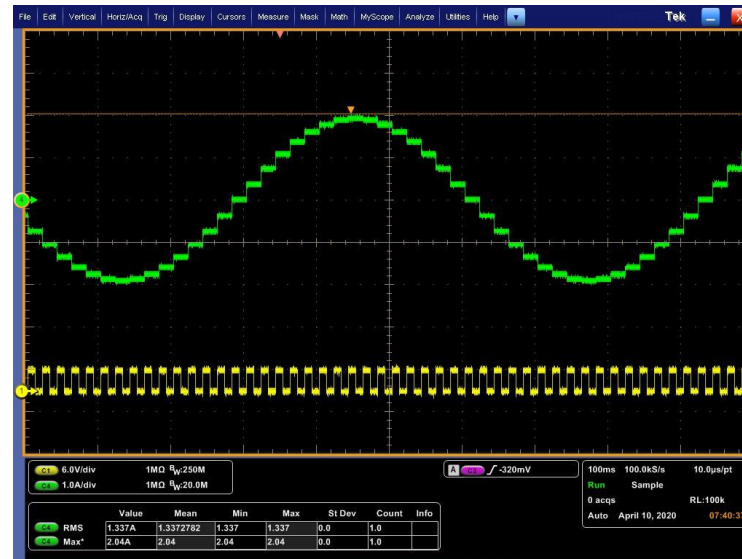




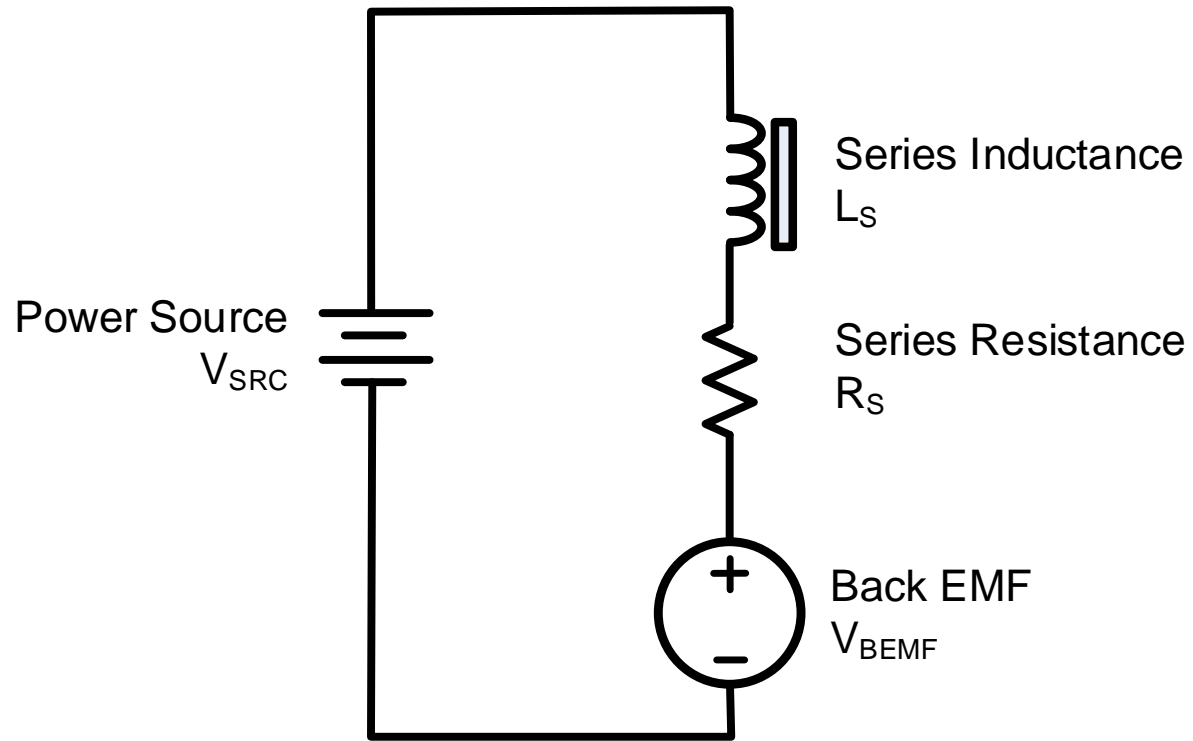
# Driving a Stepper Motor



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



# Effect of BEMF on Winding Current

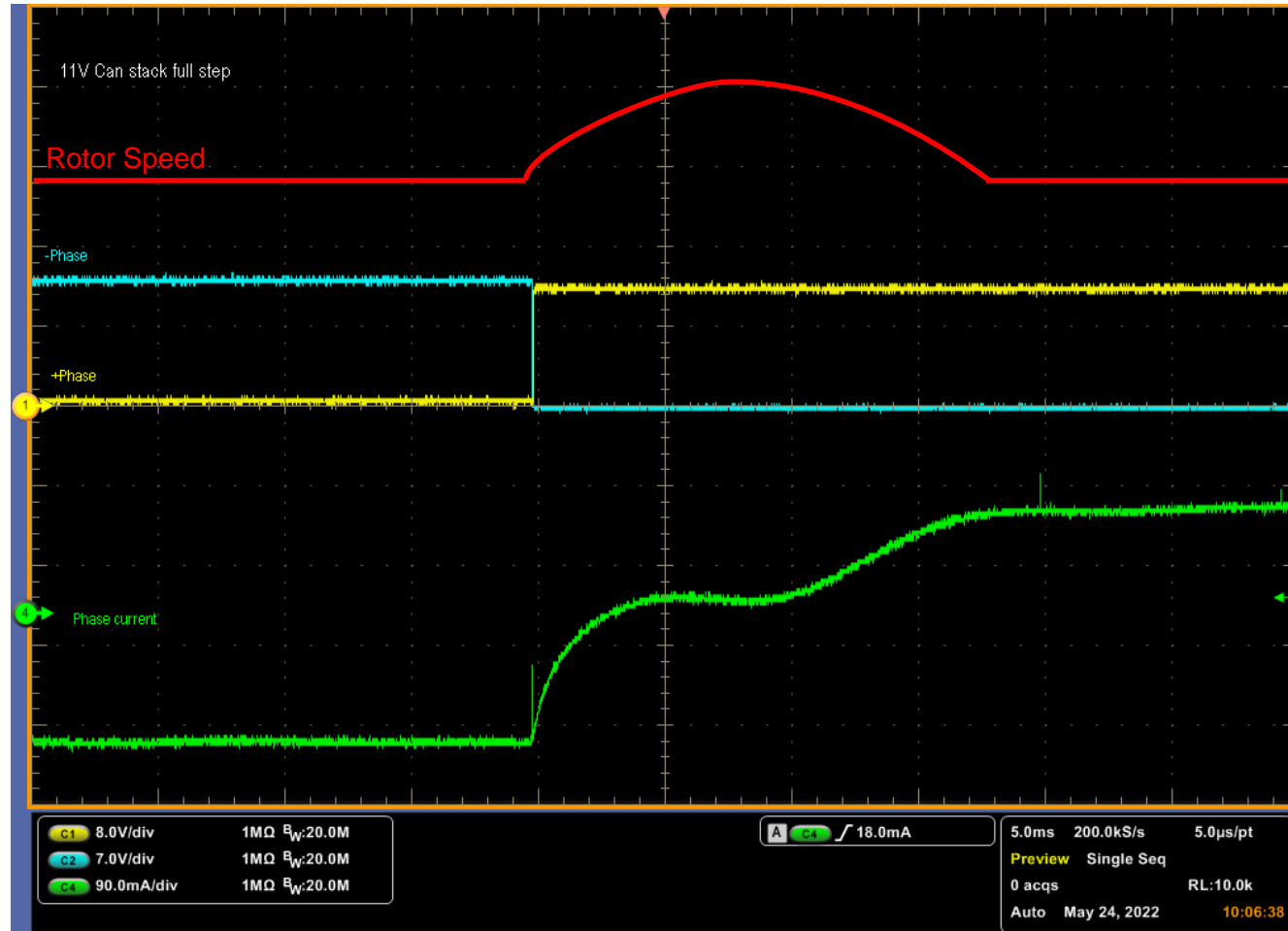


$$V = L \cdot di/dt$$



# Effect of BEMF on Winding Current

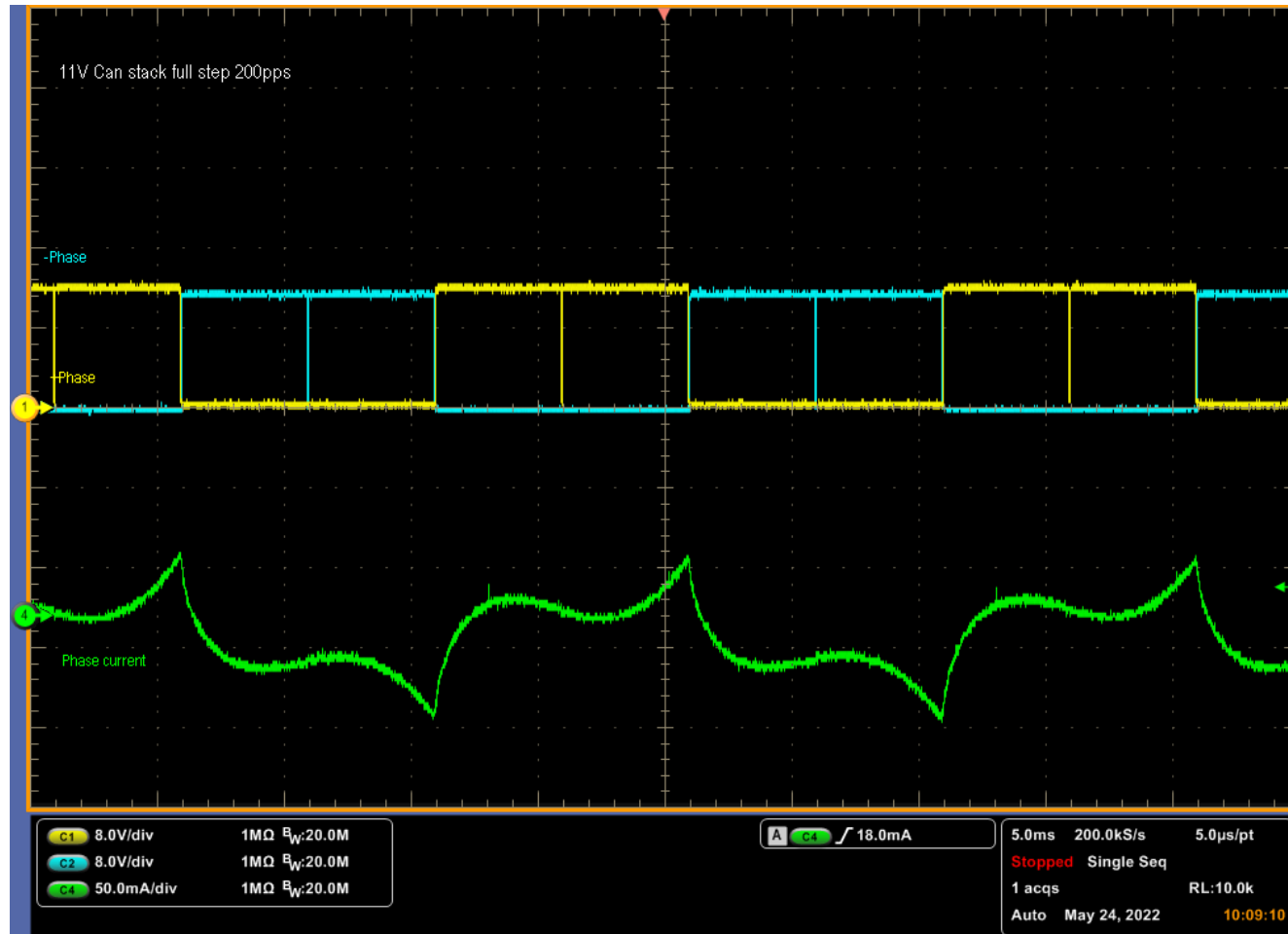
## Low Voltage



Yellow: Voltage Green: Current

# Effect of BEMF on Winding Current

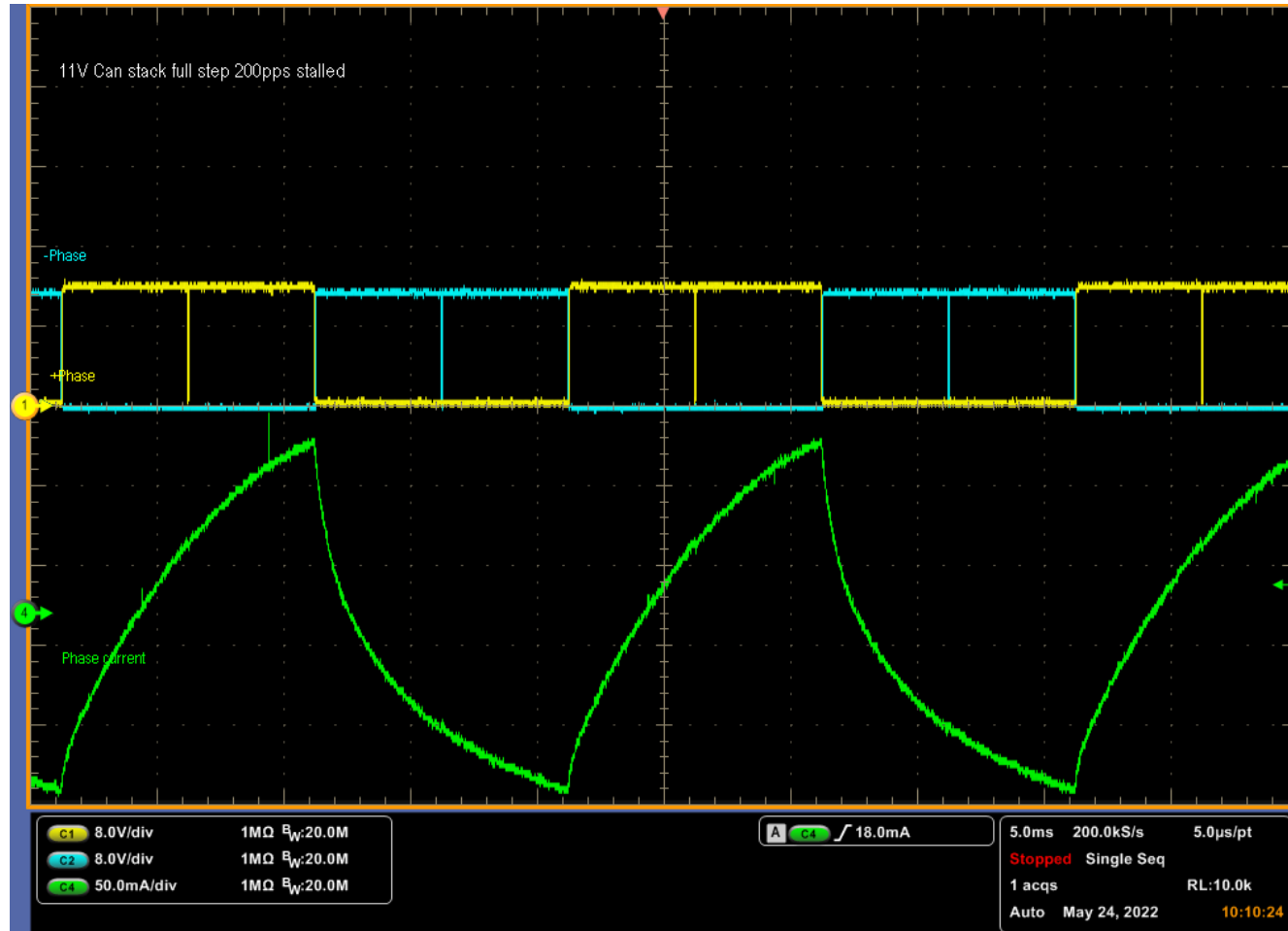
## High Step Rate



Yellow: Voltage Green: Current

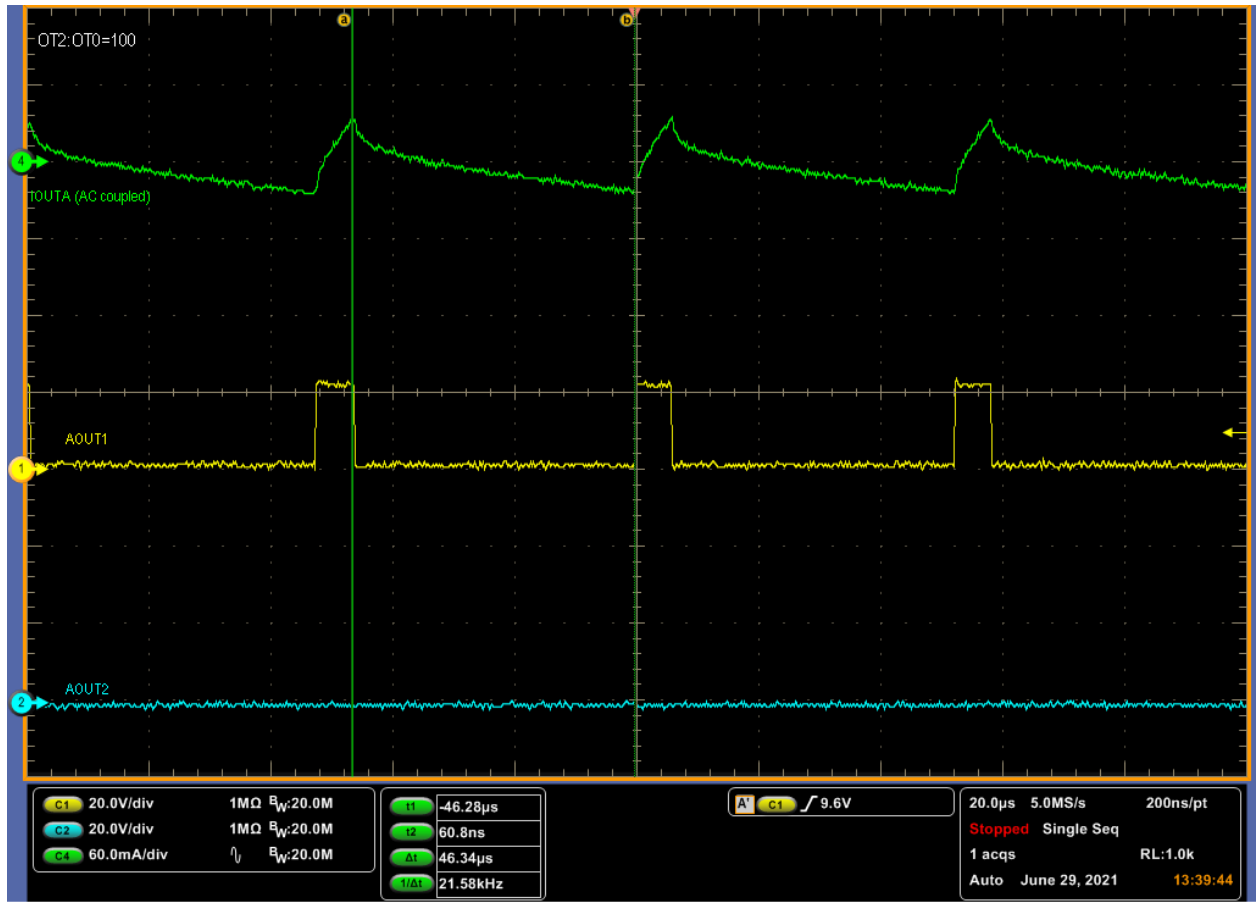
# Effect of BEMF on Winding Current

## Rotor Stalled



Yellow: Voltage Green: Current

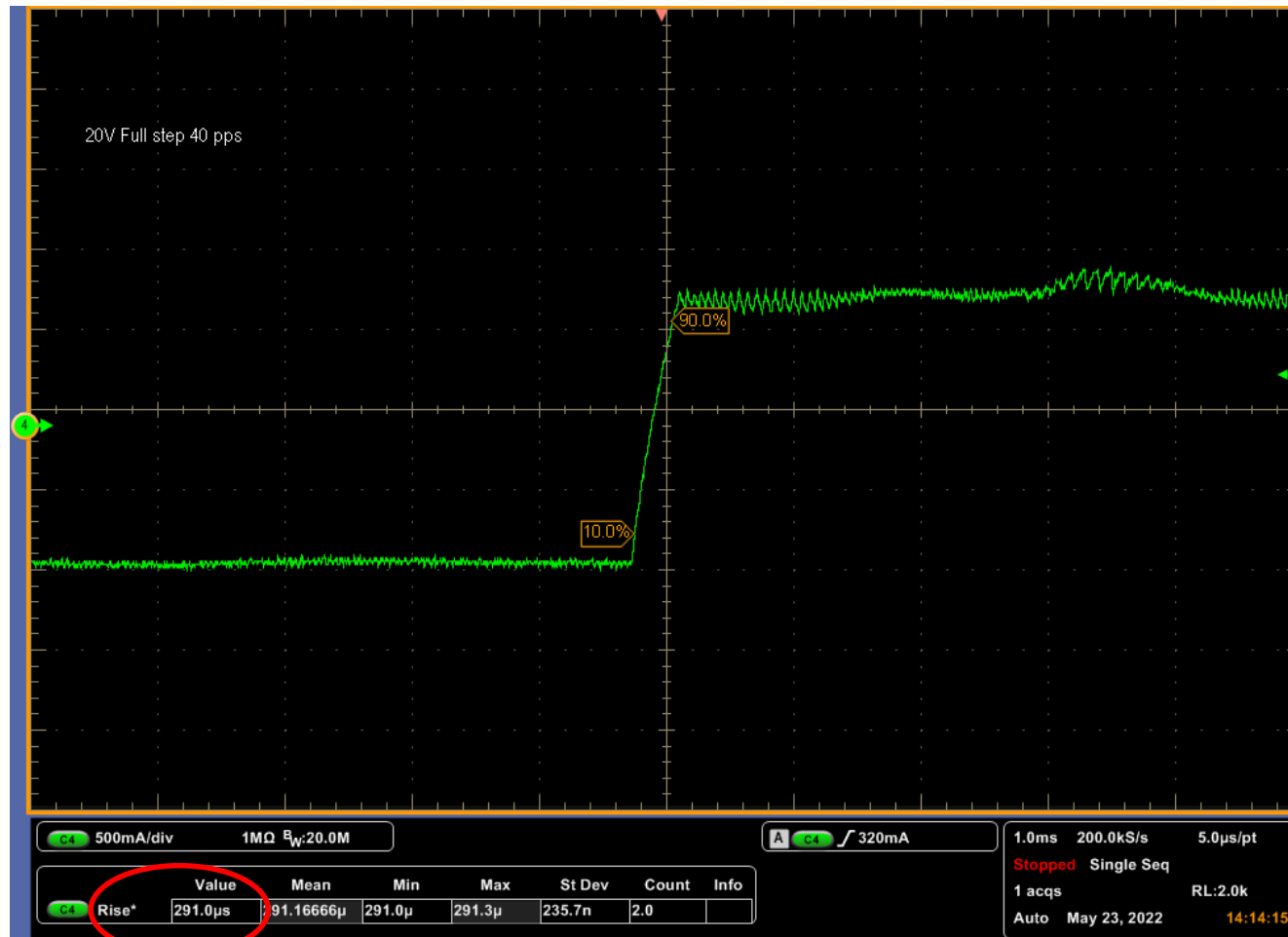
# Constant Current Drive



Yellow: Voltage Green: Current

# Effect of Supply Voltage on Constant Current

## High Voltage

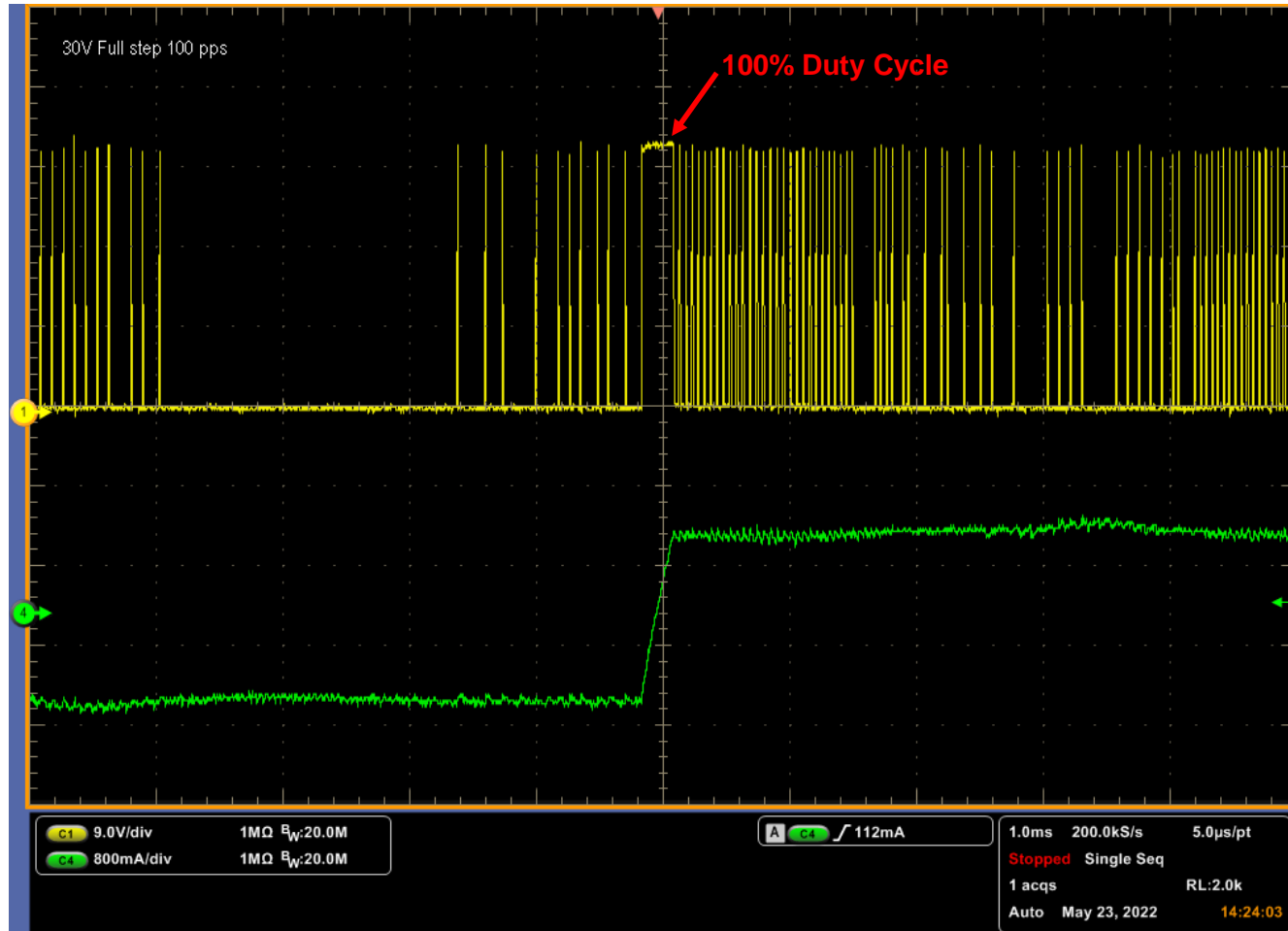


# Effect of Supply Voltage on Constant Current

## Low Voltage



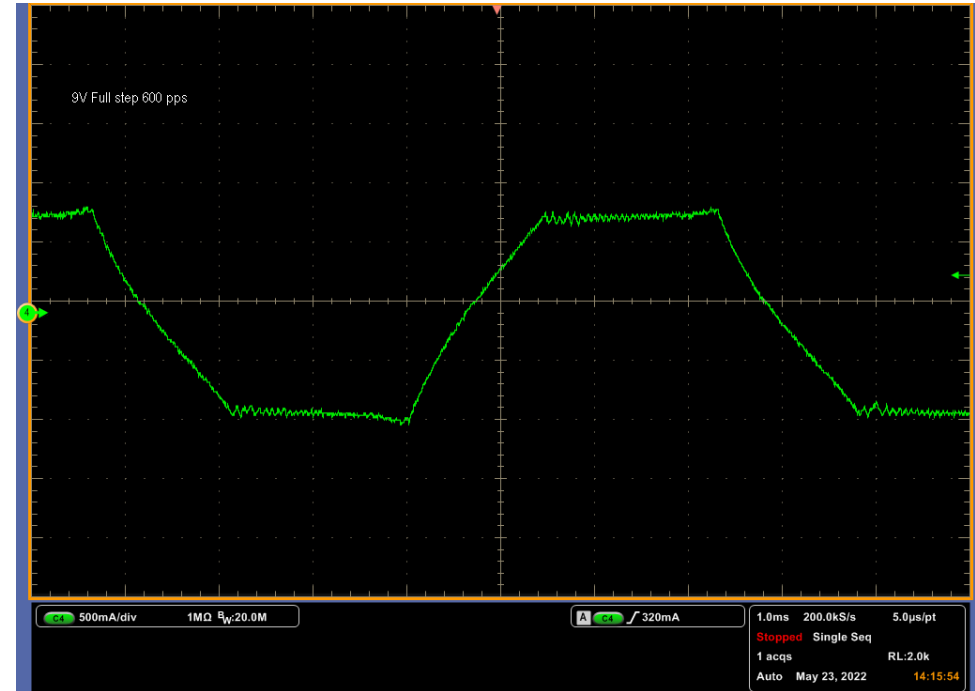
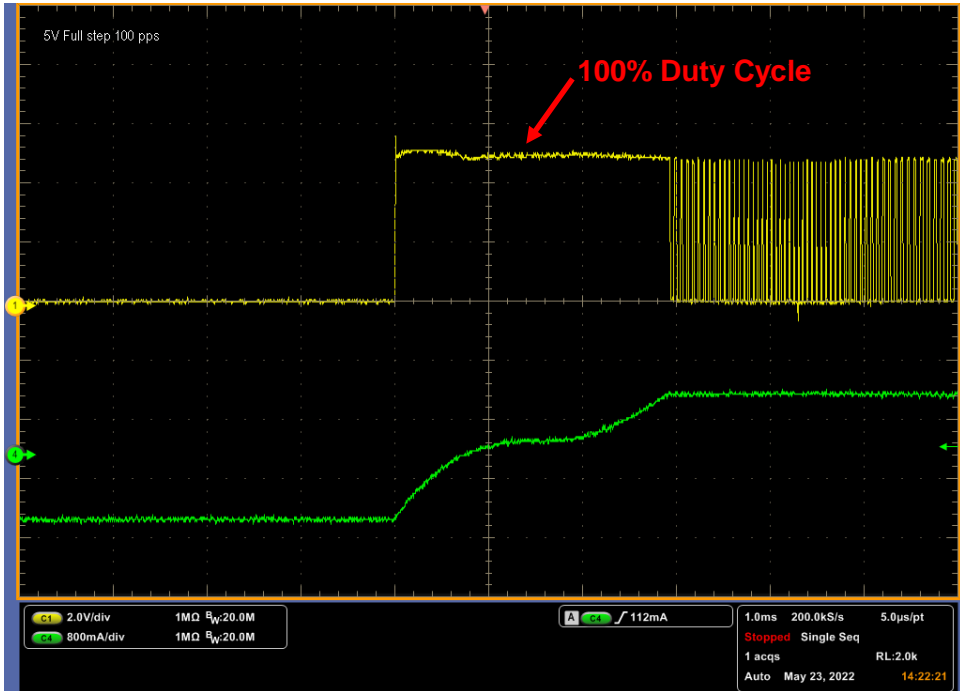
# Constant Current & BEMF



Yellow: Voltage Green: Current

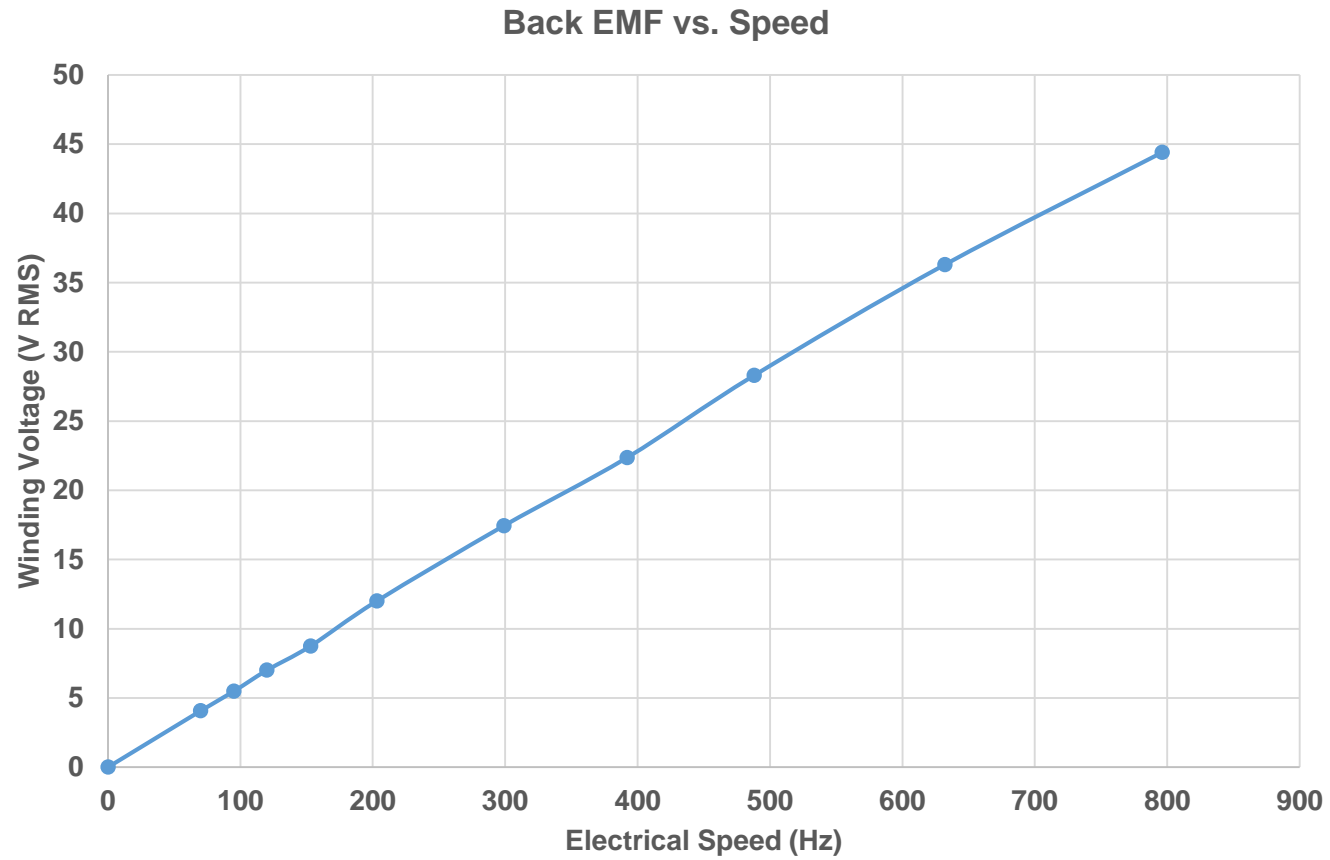


# Constant Current & BEMF

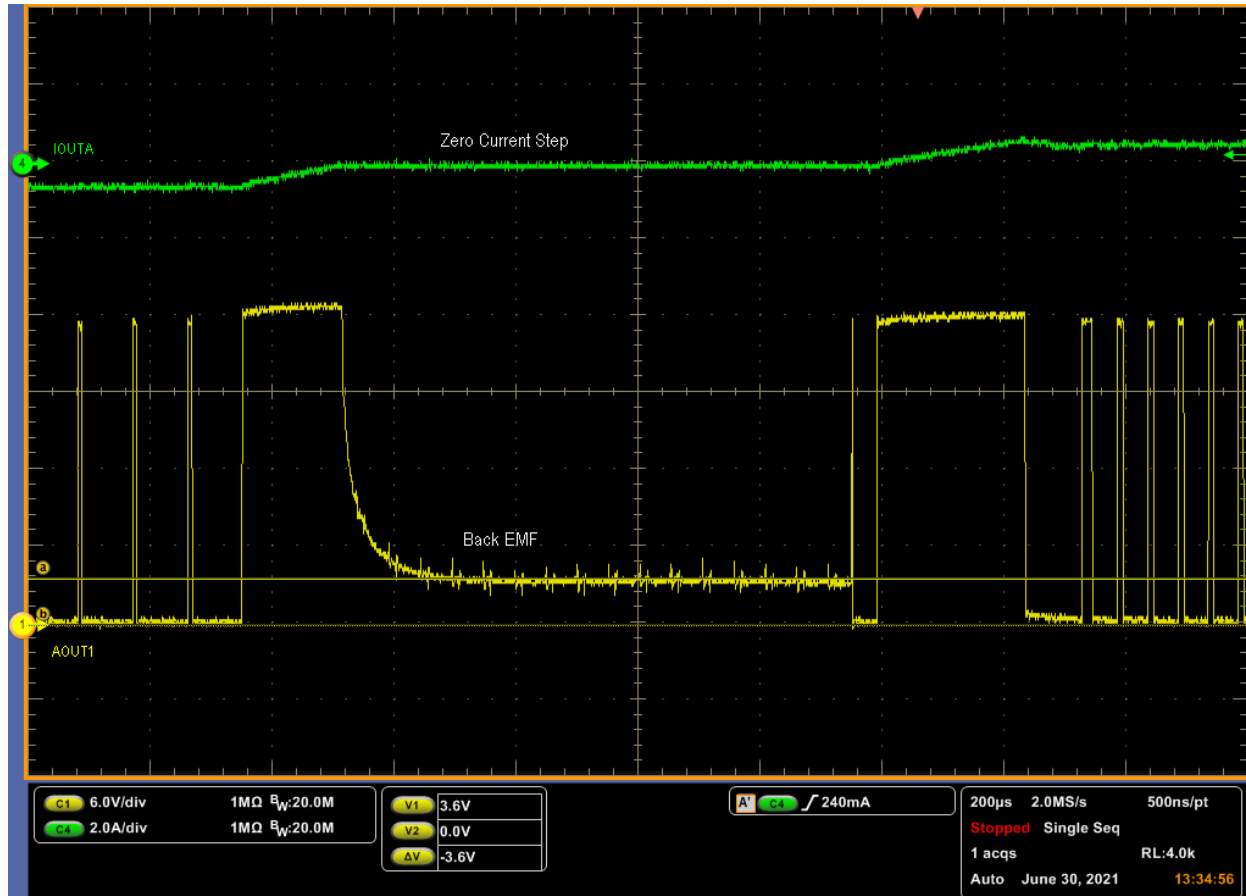


Yellow: Voltage Green: Current

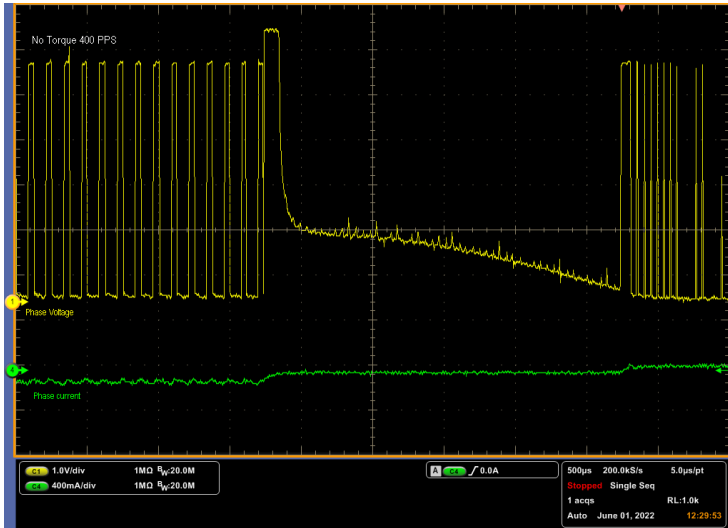
# Using Back EMF Information



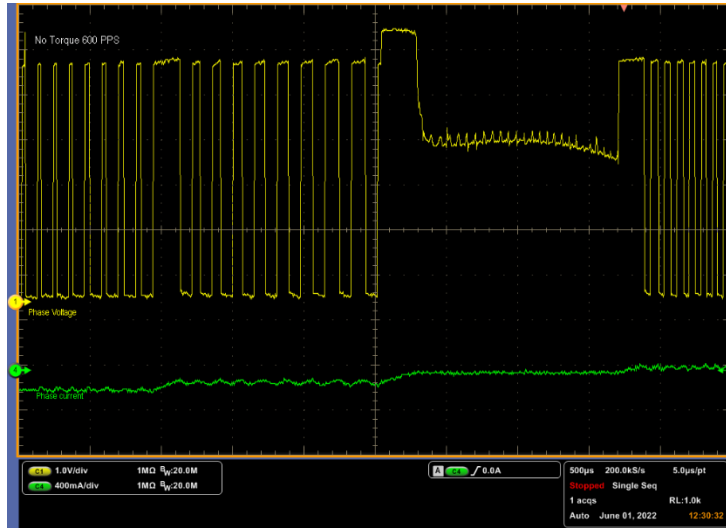
# Measuring the Back EMF



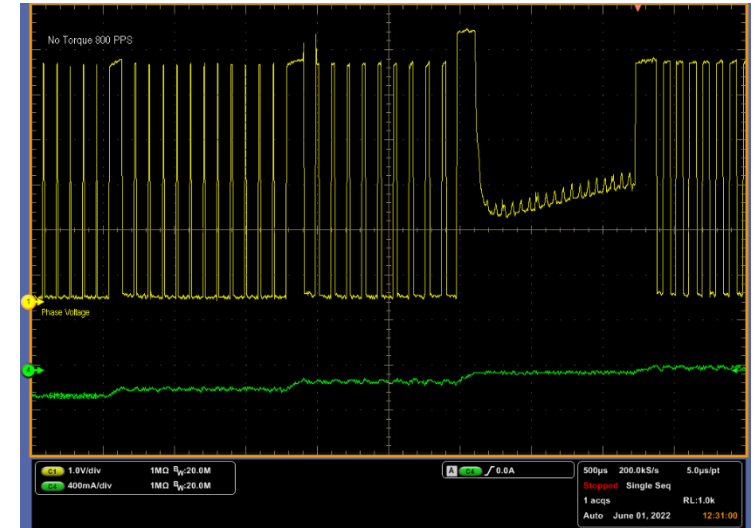
# Back EMF Measurements vs. Rotor Speed



400 PPS

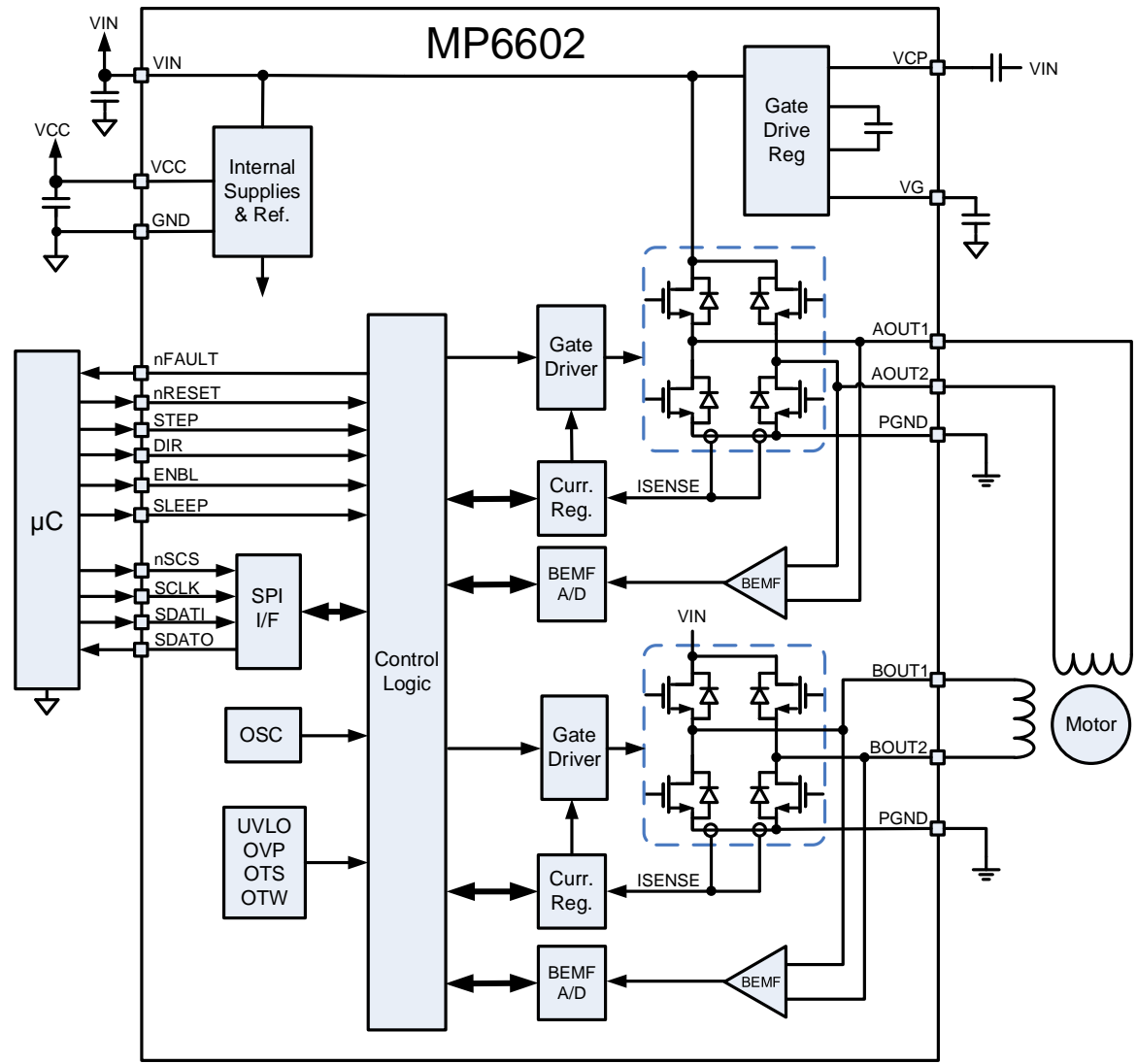


600 PPS

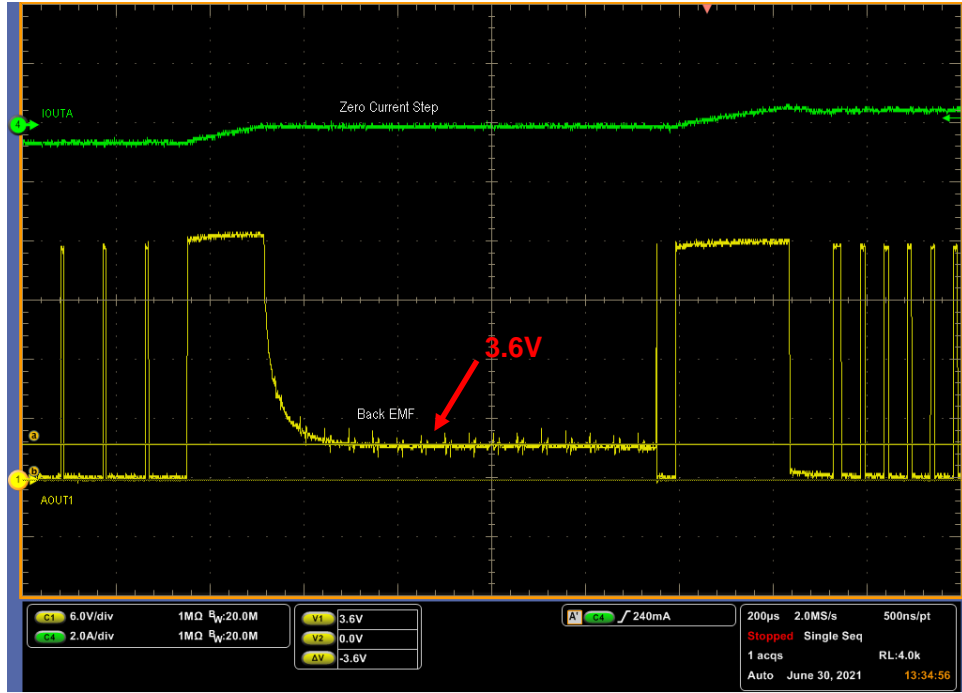


800 PPS

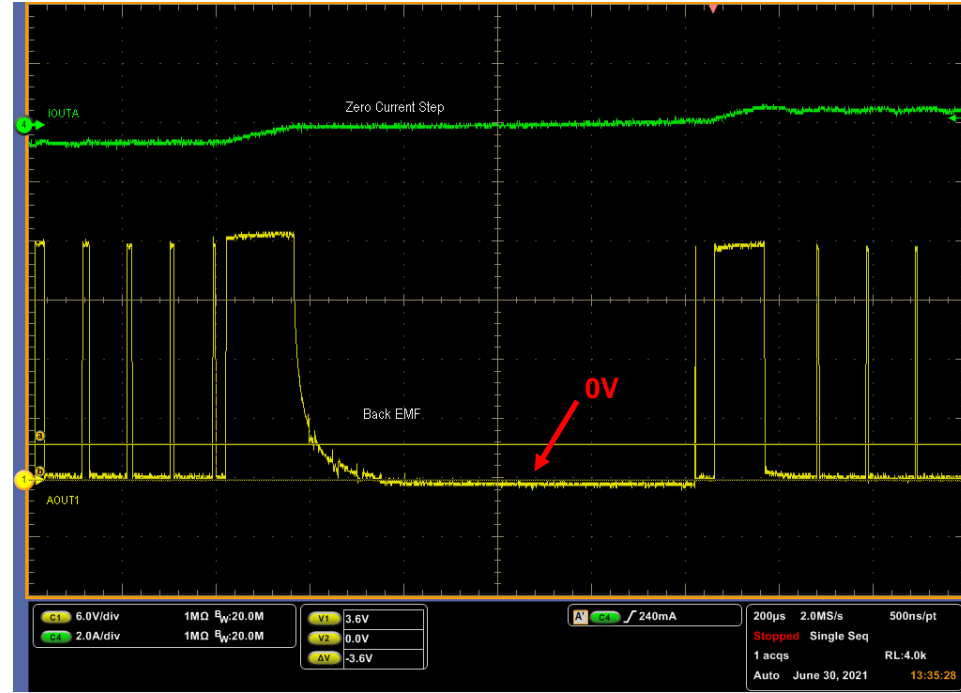
# How to Measure BEMF?



# Stall Detection

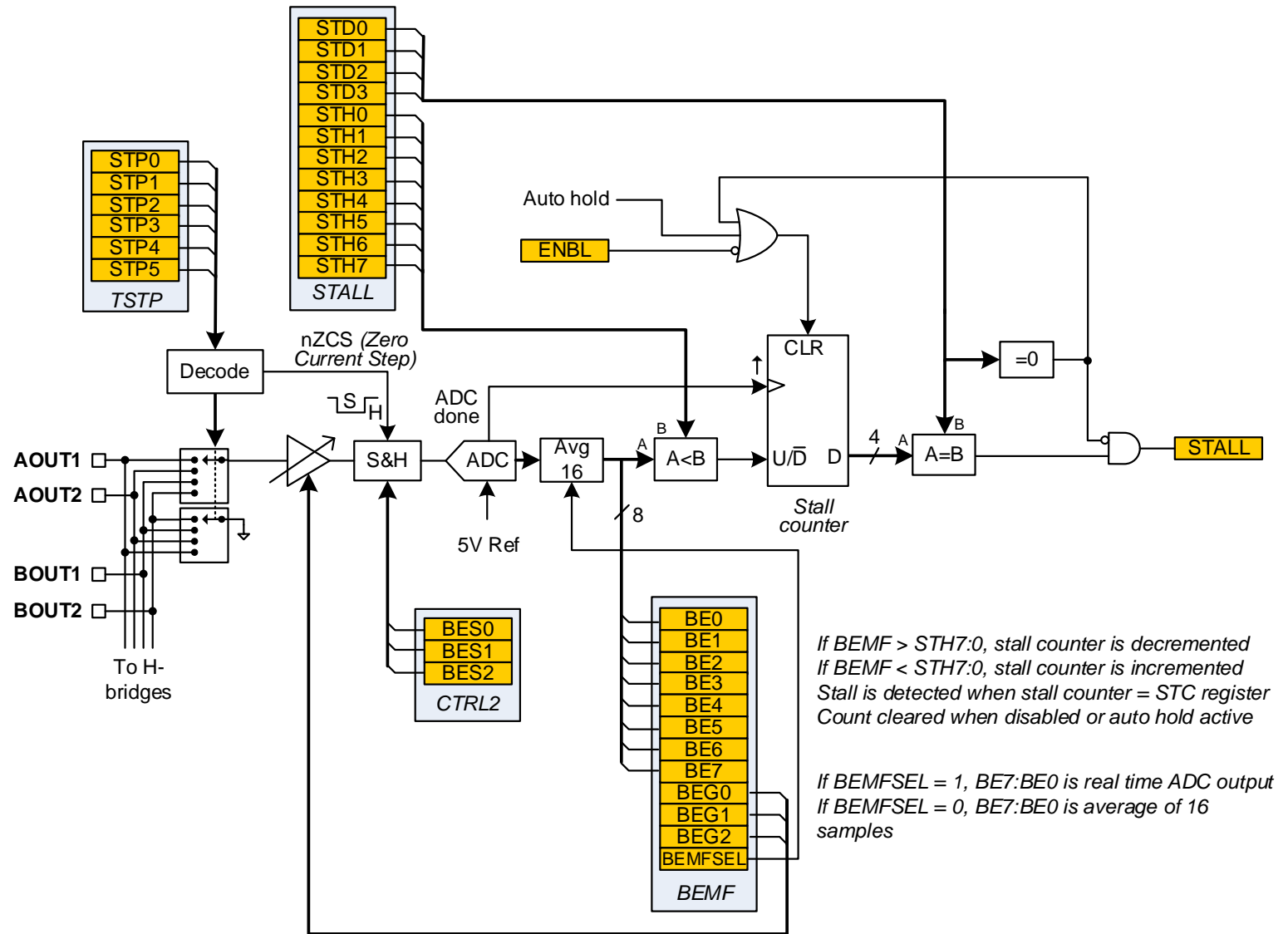


**Rotating**  
**Back EMF = 3.6V**



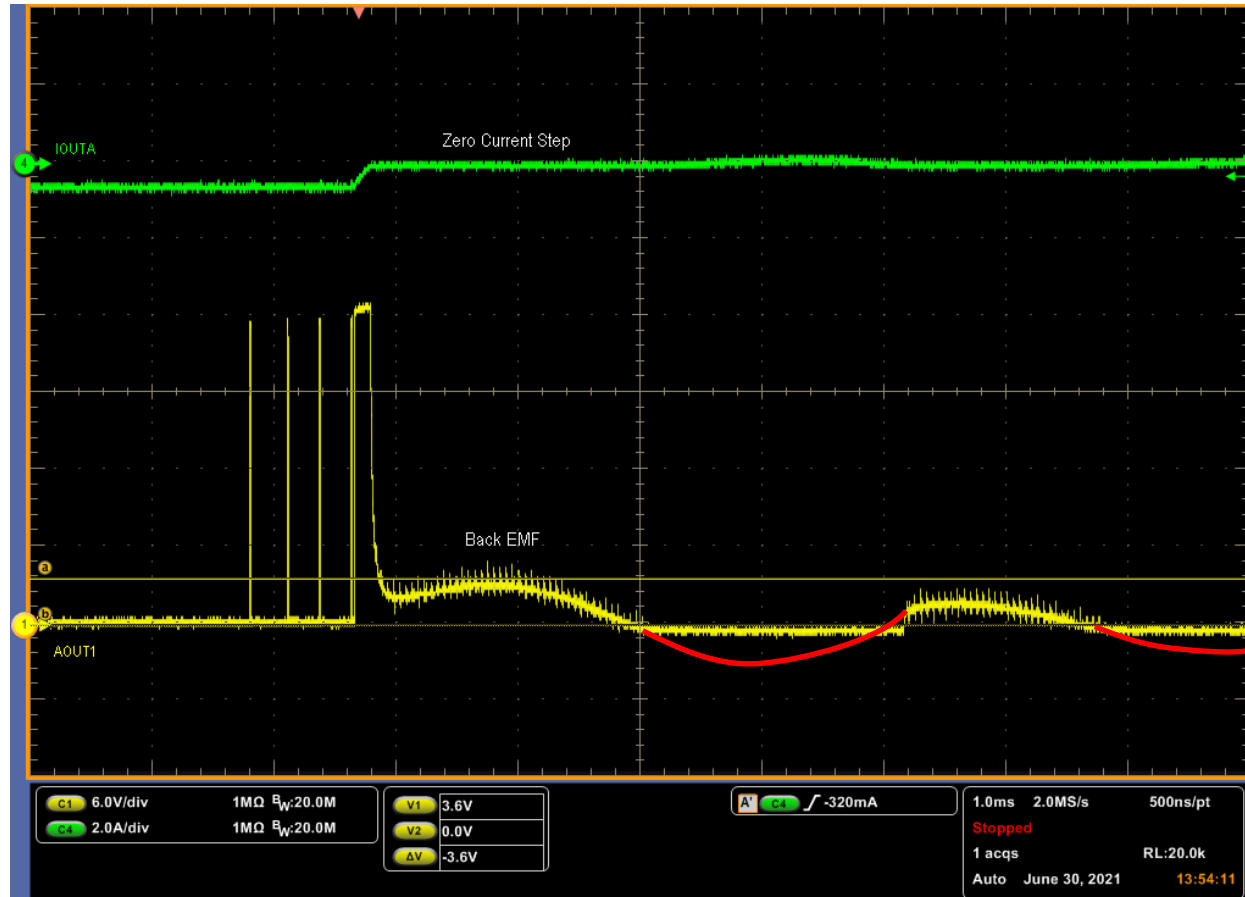
**Stalled**  
**Back EMF = 0**

# MP6602 Stall Detection





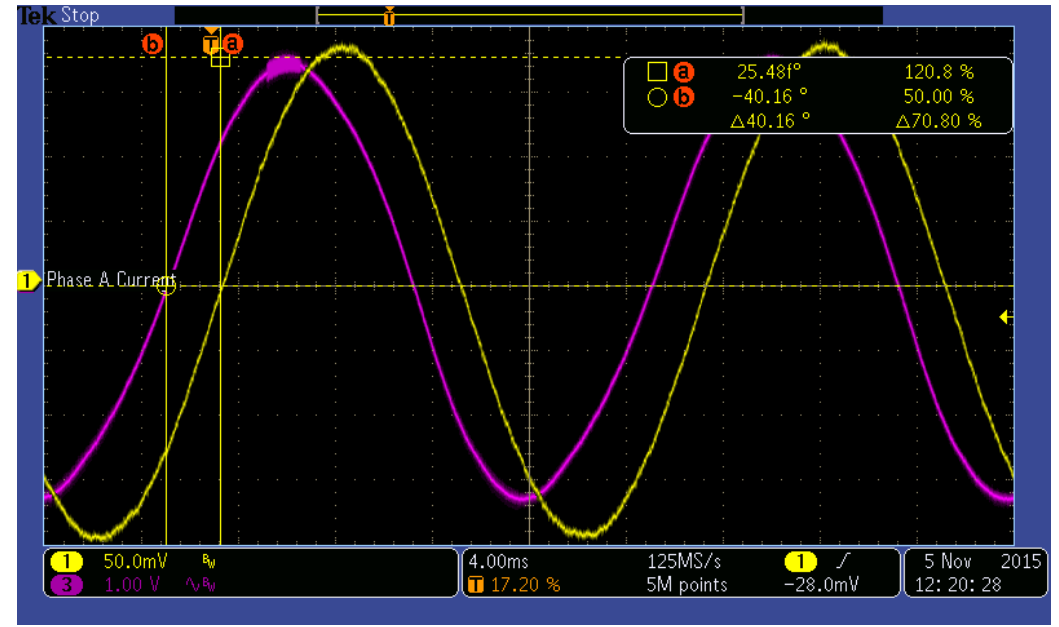
# Low Step Rates



# Load Torque Estimation



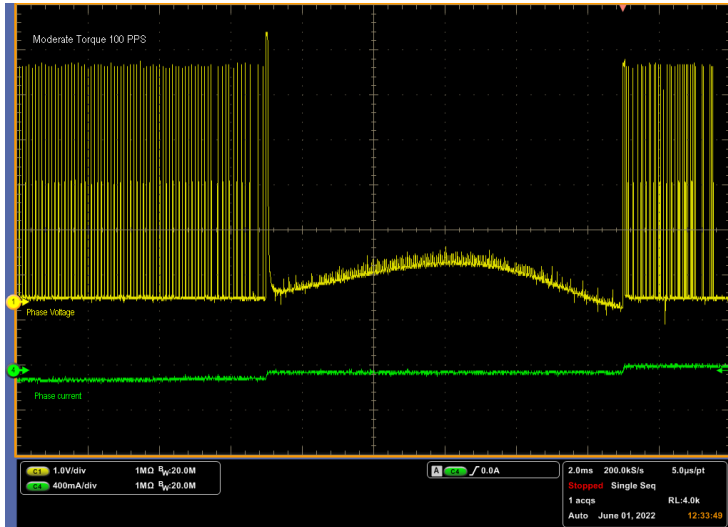
Unloaded



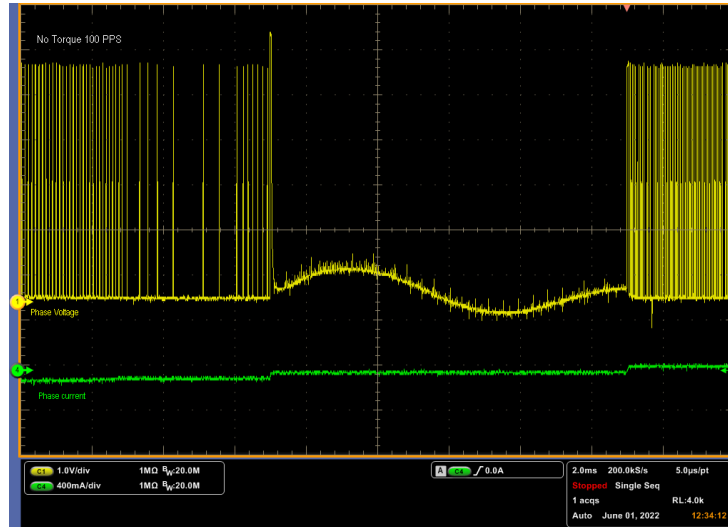
Loaded

Magenta: Voltage Yellow: Current

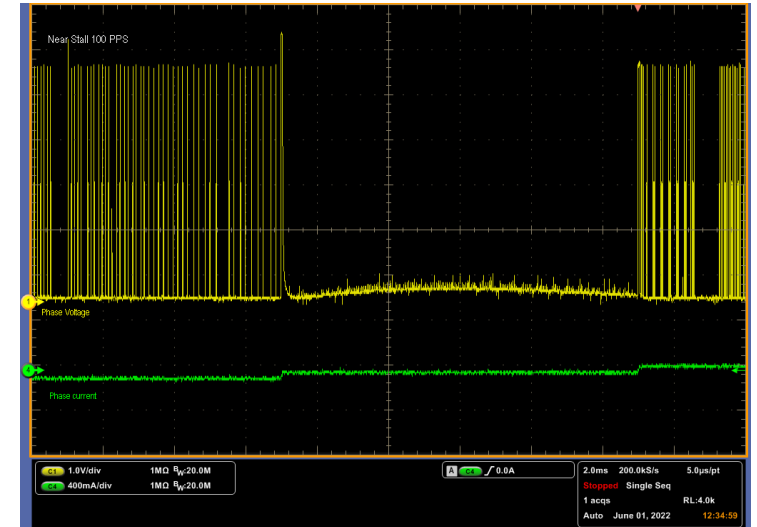
# Load Torque Estimation via BEMF Measurement



No Torque

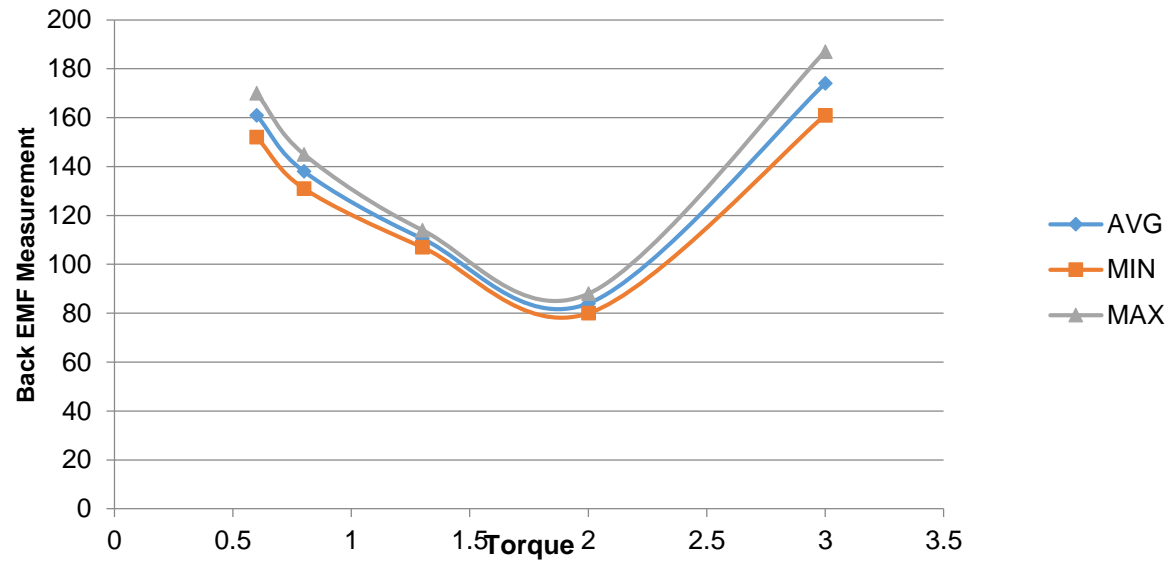
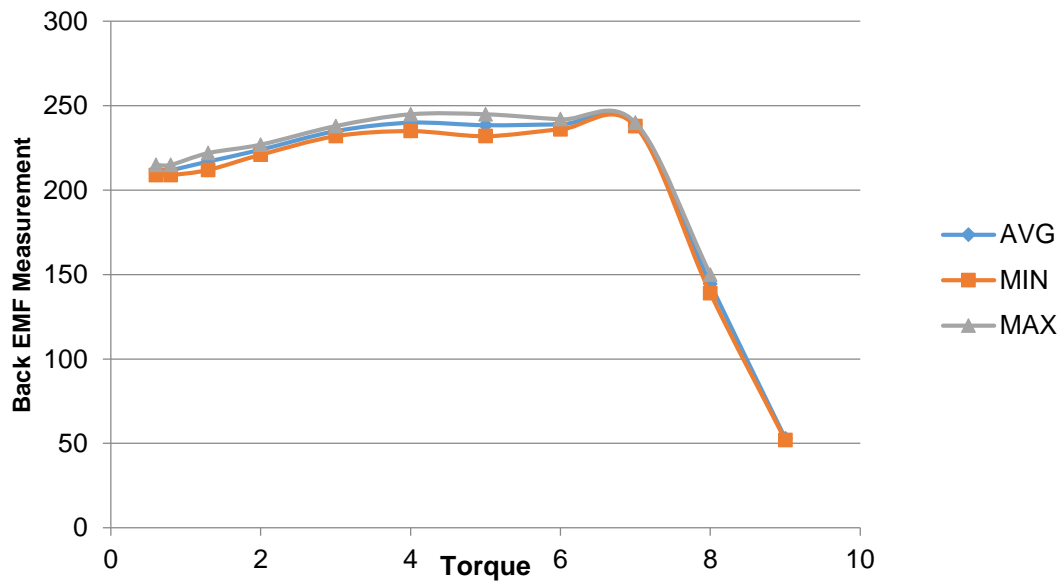


Moderate Torque



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

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