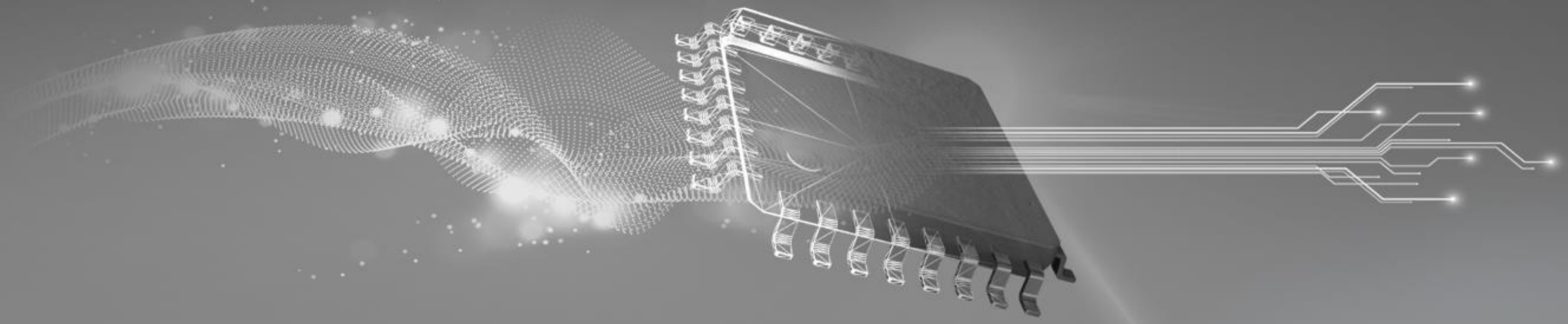
TI TECH DAYS



Sensorless stall detection

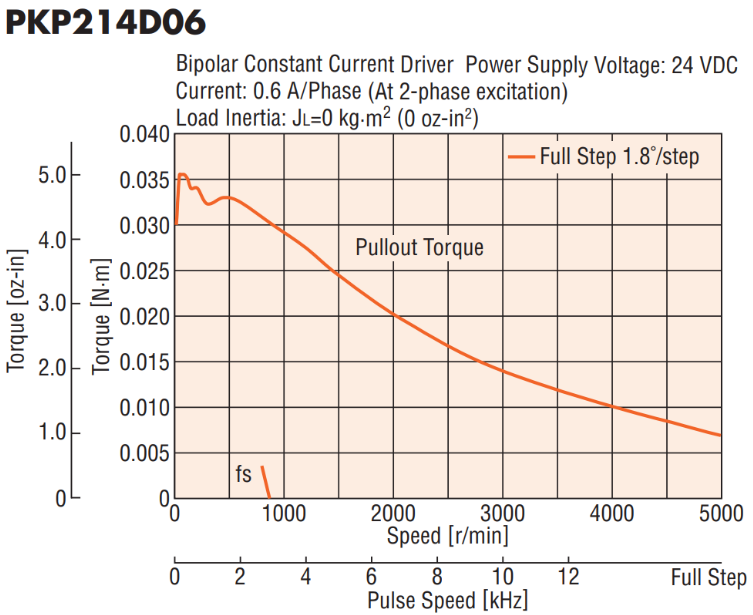
Ryan Kehr

Motor drive

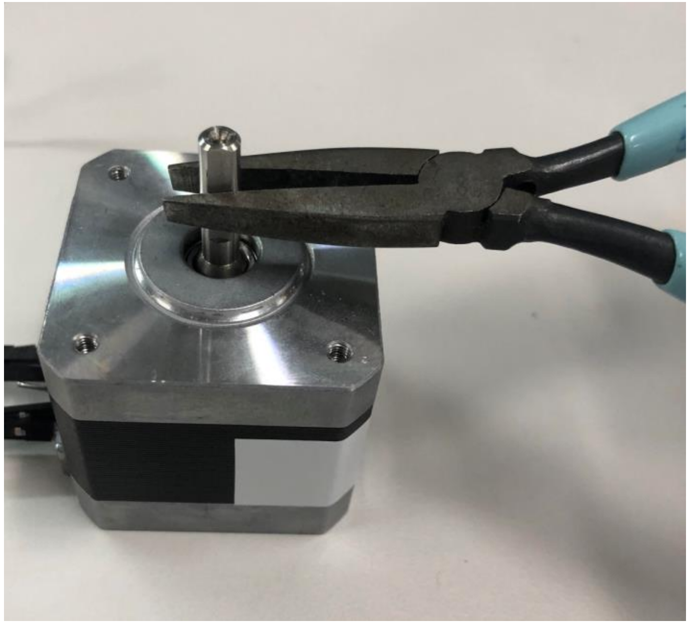
Texas Instruments

What is a stall condition?

- Stall condition: load torque exceeds the motor’s pull-out torque. [1]



Oriental motor [2]

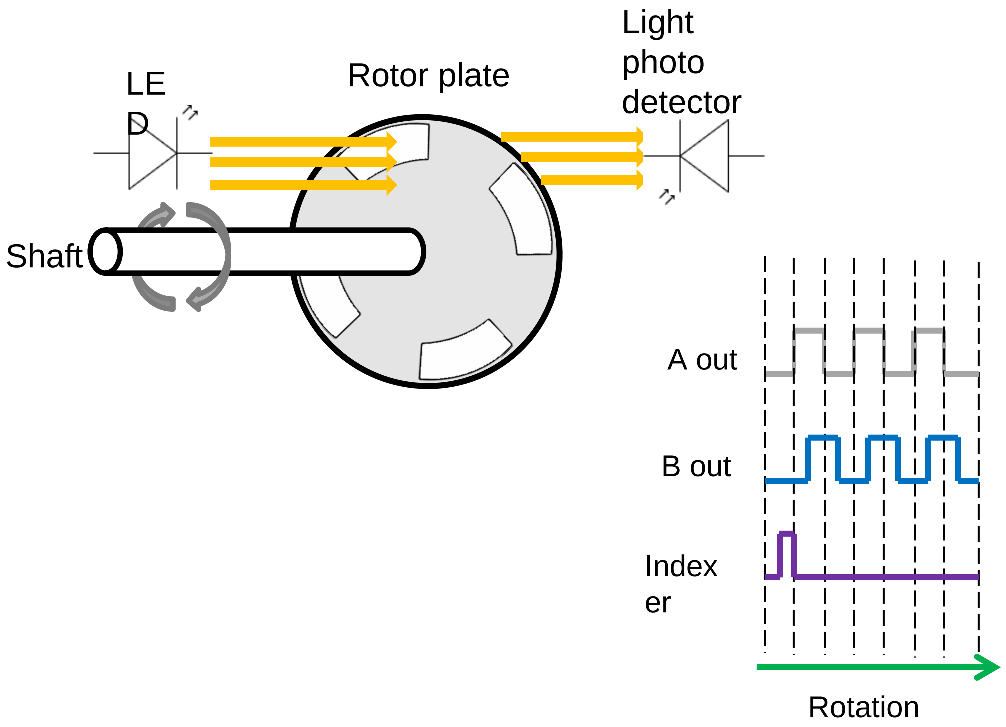


Need for sensorless stall detection

- Lack of feedback in open-loop motor systems.
- End-of-line travel and fixed mechanical stop detection.
- Helps lessen the problems that occur when a motor continues to be driven though an obstacle such as:
  - Mechanical failures
  - Audible noise
- Replaces expensive motor position modules.

Applications

Existing solution: Encoder



- Benefits:
  - Multifunctional
  - Robust
- Drawbacks:
  - High cost
  - Increase in system area

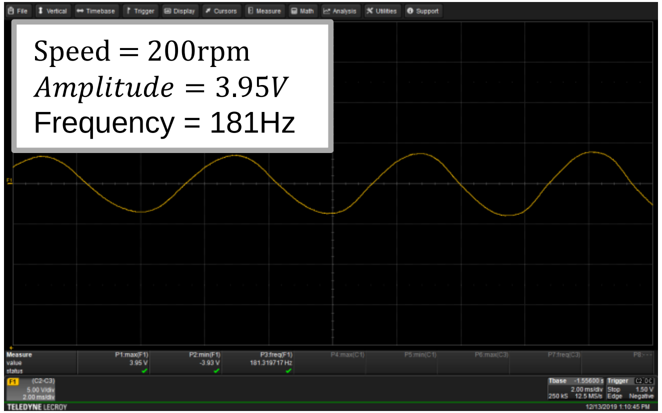
Existing solution: Sensorless back-emf measurement

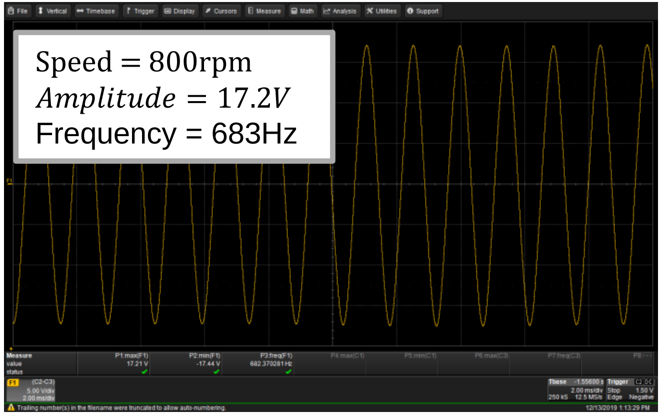
- Back-emf in stepper motors:

$$BEMF = -p * \Psi_m * \omega * \sin(p * \omega * t)$$

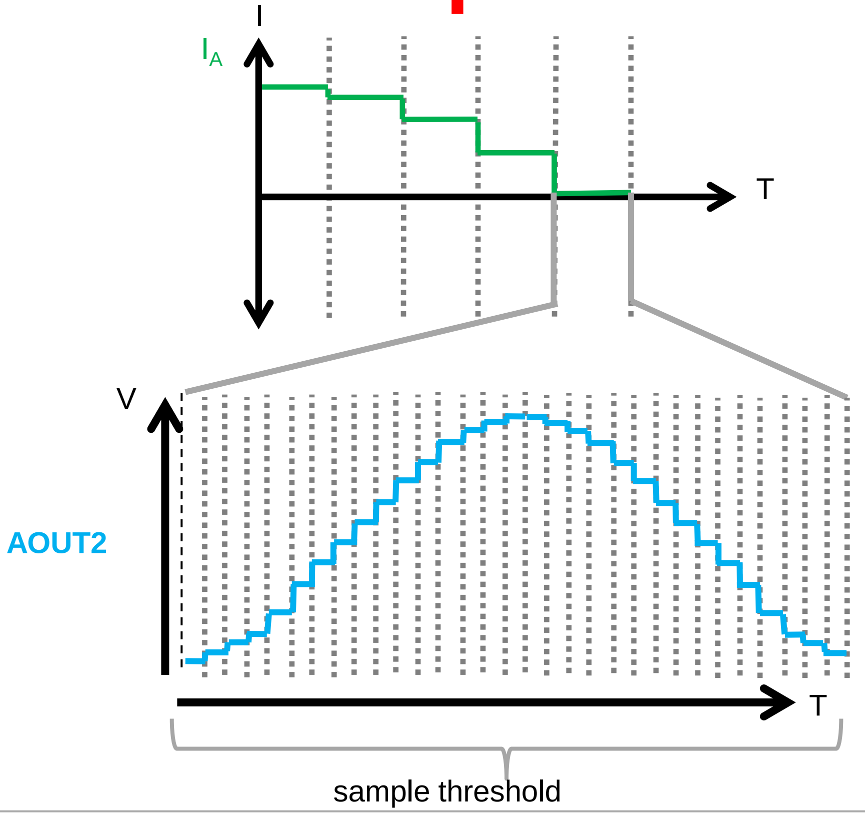
  - p: number of pole pairs
  - Ψ_m: maximum magnetic flux
  - ω: motor angular speed

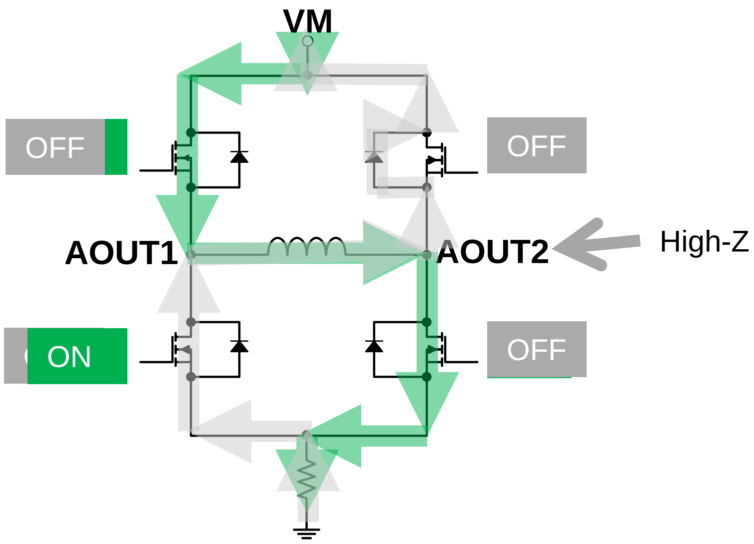
- Benefits:
  – Sensorless solution
  – Reduces design cost and size
- Drawbacks:
  – Minimum motor running speed



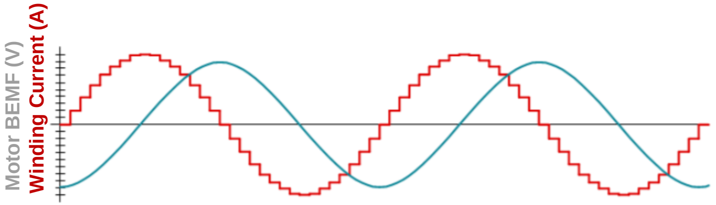


Direct back-emf measurement during zero current step

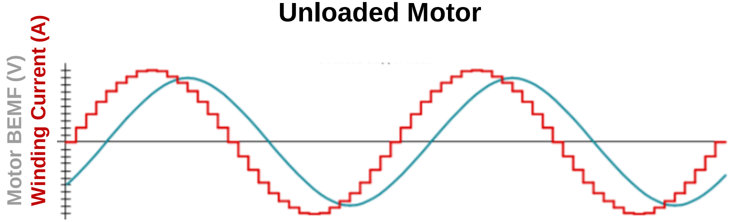




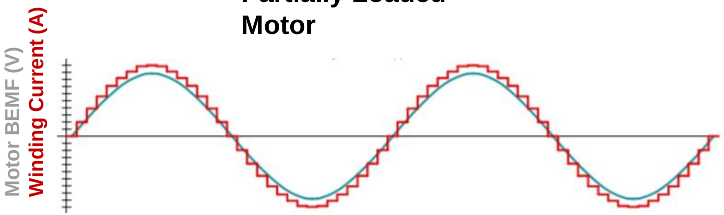
Indirect back-emf measurement



Unloaded Motor



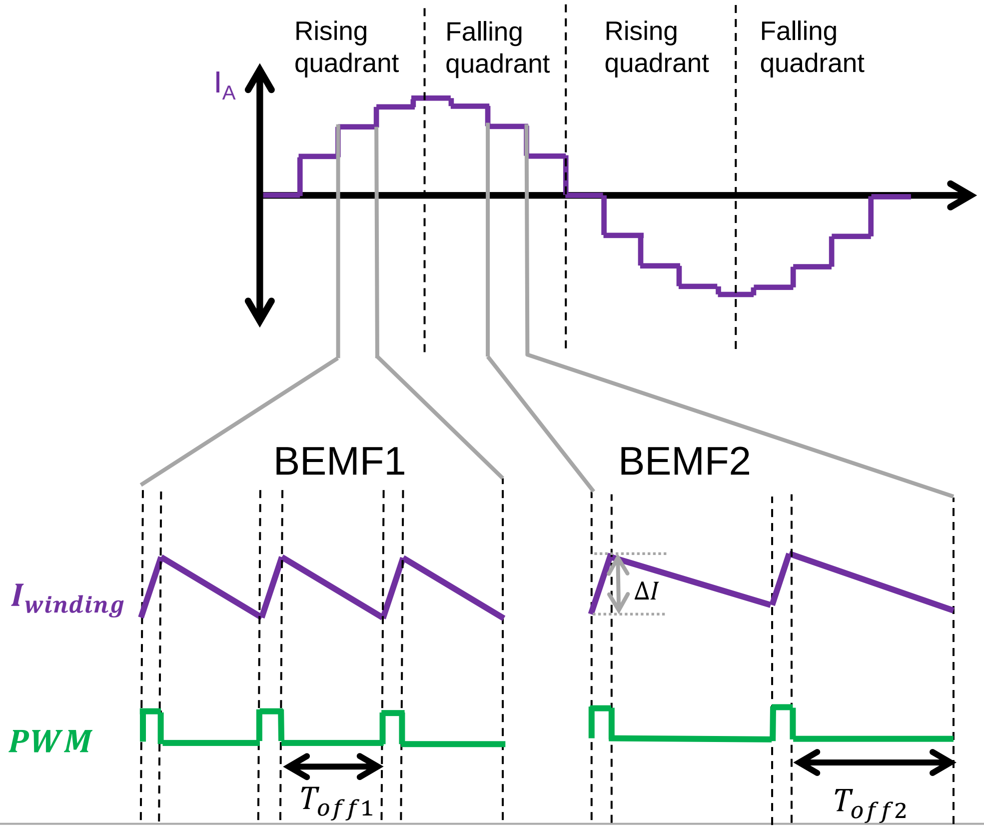
Partially Loaded Motor



Loaded Motor

- Benefits:
  - Constant back-emf monitoring
- Drawbacks:
  - Current regulation waveform dependencies on supply voltage, motor current, and motor resistance

TI solution: Fixed current ripple method



$$T_{off} = \frac{L*\Delta I}{I*R-BEMF}$$

$$\frac{1}{T_{off1}} - \frac{1}{T_{off2}} = \frac{\Delta BEMF}{L*\Delta I}$$

$$\Delta BEMF = BEMF2 - BEMF1$$

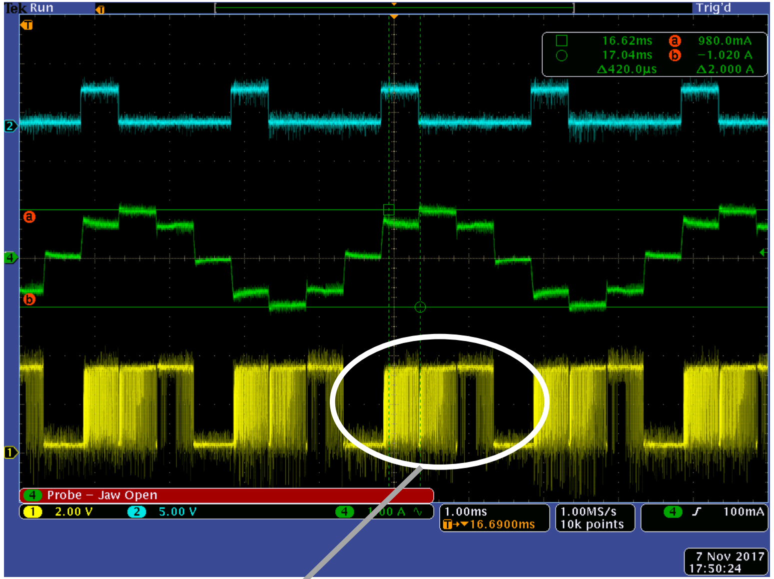
Normal operation: $\Delta BEMF > 0$

Stall condition: $\Delta BEMF = 0$

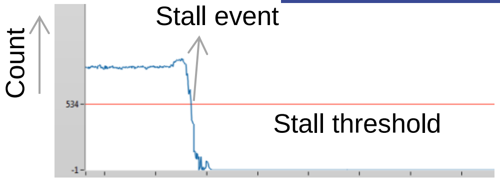
Results: Half Step

Test Conditions:
Motor = DB 1Ω
Supply = 34V
Current (Max) = 1A
Half Step @ 5 revs/sec
Abrupt Stall by holding with plier

Normal Speed



Stalled motor



During normal speed motor operation, more back-emf in 2nd half (Q2) than 1st half (Q1) due to back-emf being 90º out of phase with current

When motor stalls, back-emf shifts left to evenly balance out in in 2nd half (Q2) and 1st half (Q1).

Summary

	Advantages	Disadvantages
Encoder	• Precise motor position monitoring • Can work at very low speeds	• Higher cost • Larger system area size
Direct back-emf measurement	• Reduce design system cost and size	• Minimum motor speed required • Does not work in full-step mode
Indirect back-emf measurement	• Reduce system cost and size • Works for all micro-step settings	• Minimum motor speed required • Can be affected by supply voltage, motor current, and motor resistance variations

Resources

- [1] Acarnley, Paul P. *Stepping motors: a guide to theory and practice.* 4th ed., Institution of Engineering and Technology, 2007.
- [2] "PKP Series Product Catalog", orientalmotor.com
- [3] "Closed Loop Stepper Motor Design with Encoder for Stall-Detection Reference Design", ti.com

- DRV8889-Q1
- DRV8434A
- DRV8434S

Texas Instruments