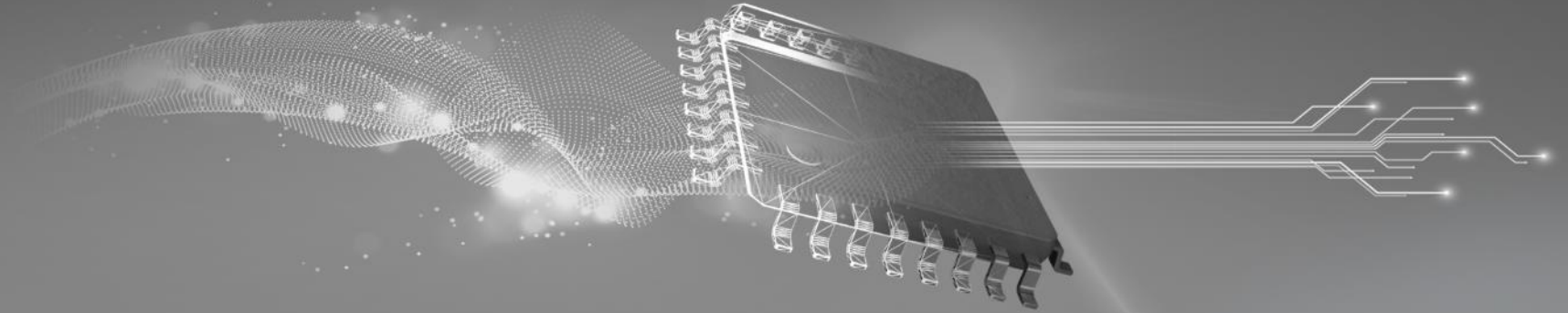


TI TECH DAYS



Sensorless stall detection

Ryan Kehr

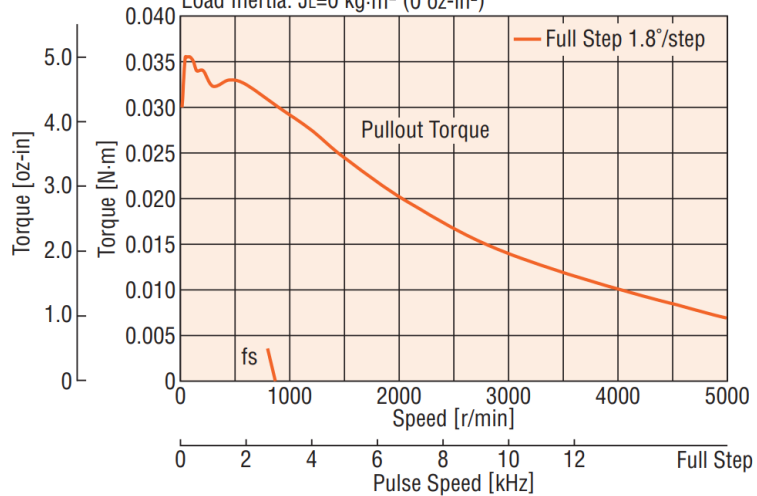
Motor drive

What is a stall condition?

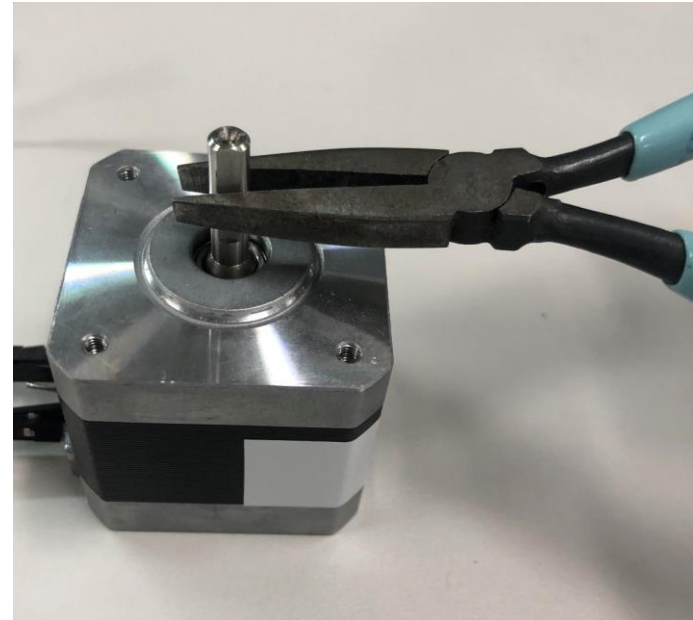
- Stall condition: load torque exceeds the motor's pull-out torque. [1]

PKP214D06

Bipolar Constant Current Driver Power Supply Voltage: 24 VDC
Current: 0.6 A/Phase (At 2-phase excitation)
Load Inertia: $J_L=0 \text{ kg}\cdot\text{m}^2$ (0 oz-in²)



Oriental motor [2]



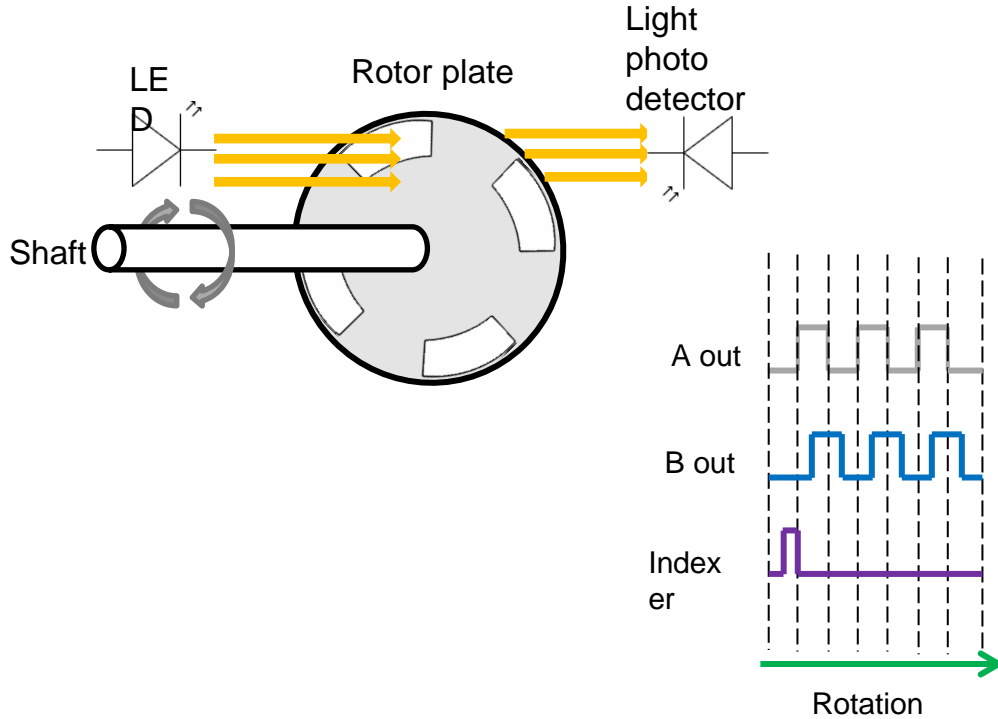
Need for sensorless stall detection

- 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:

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

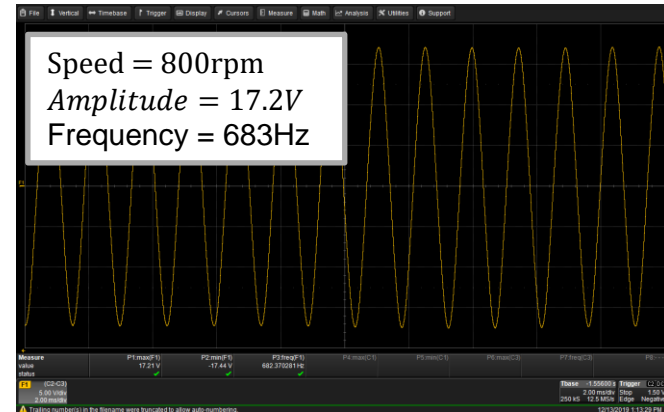
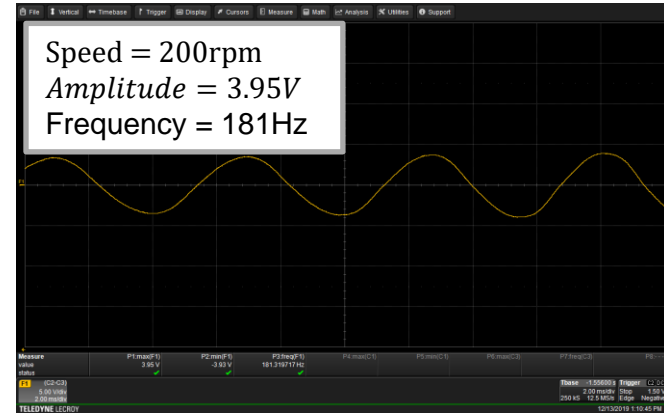
- p : number of pole pairs
- Ψ_m : maximum magnetic flux
- ω : motor angular speed

- Benefits:

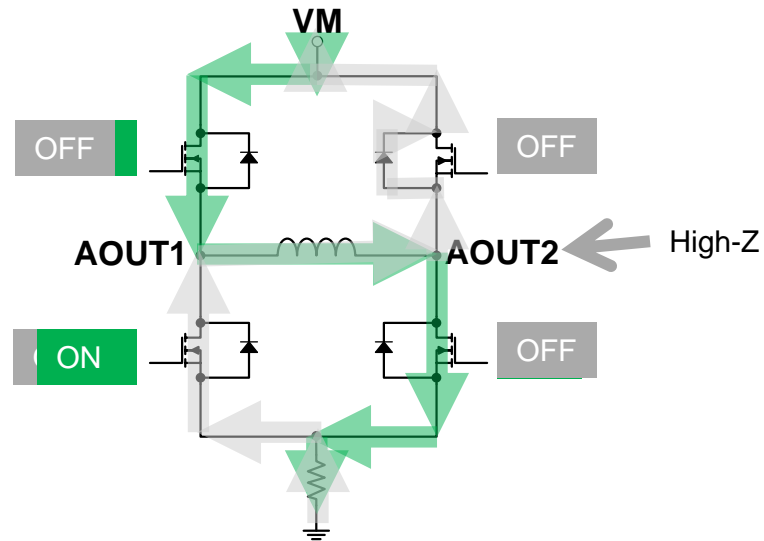
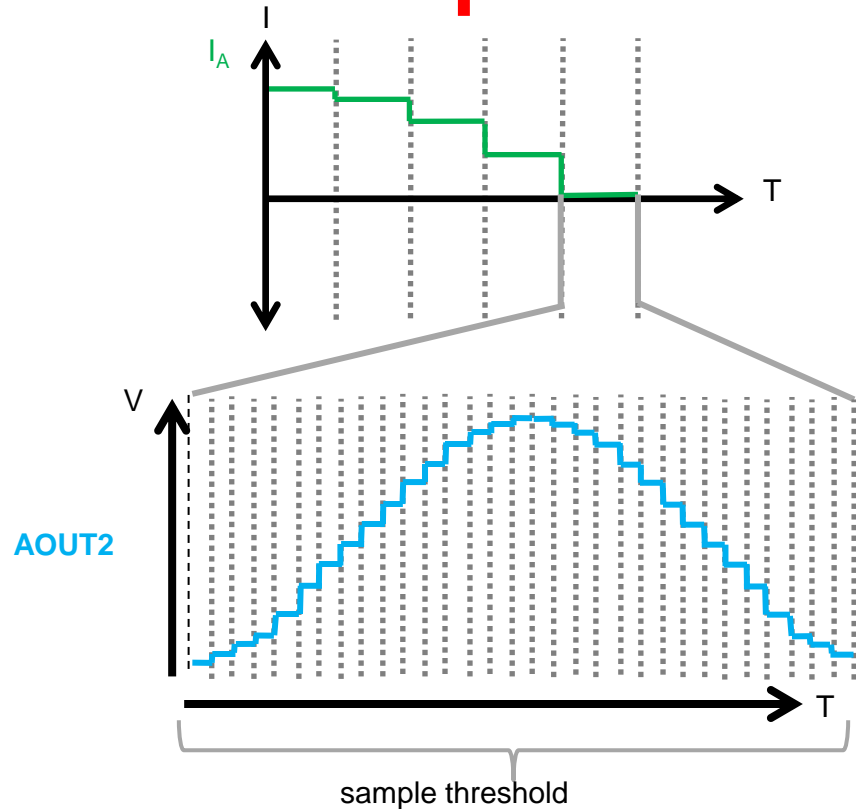
- Sensorless solution
- Reduces design cost and size

- Drawbacks:

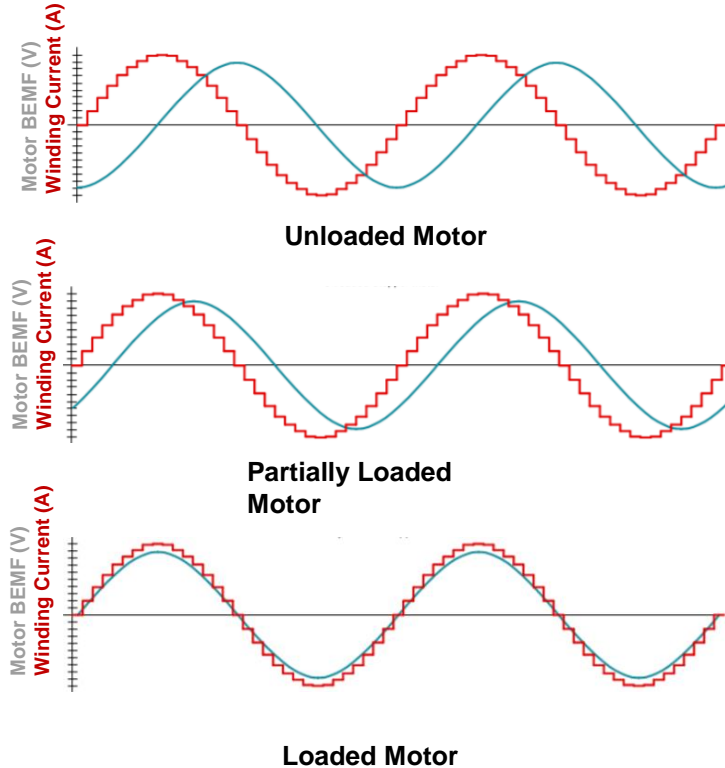
- Minimum motor running speed



Direct back-emf measurement during zero current step

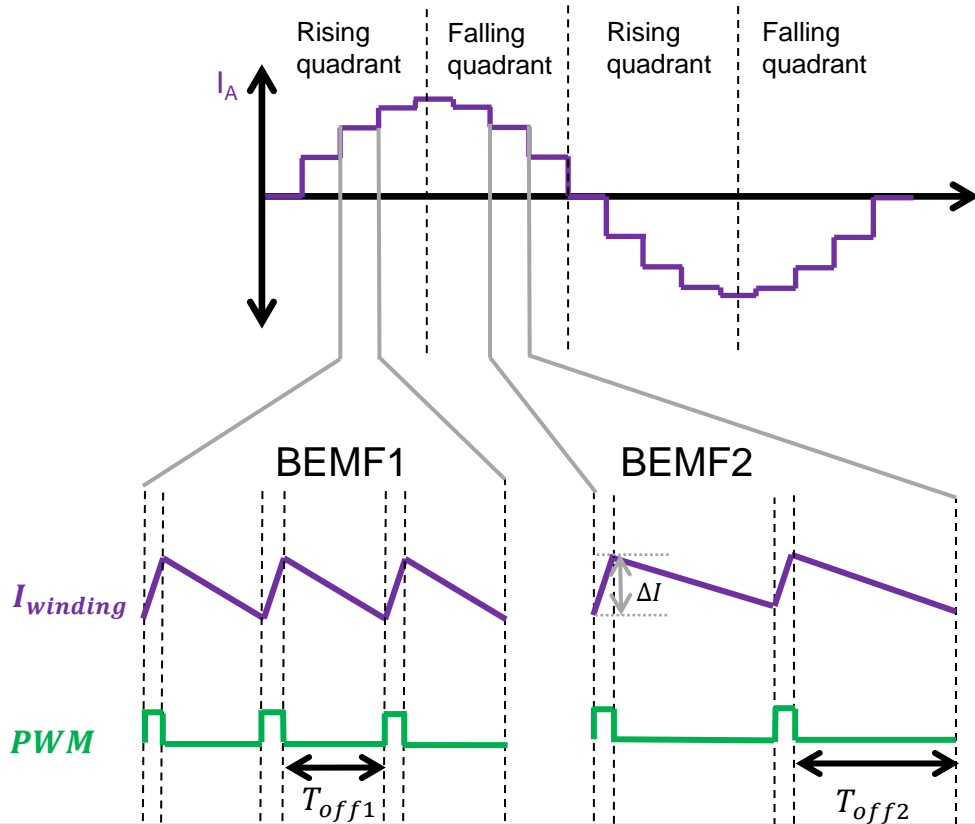


Indirect back-emf measurement



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

TI solution: Fixed current ripple method



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

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

$$\Delta BEMF = BEMF2 - BEMF1$$

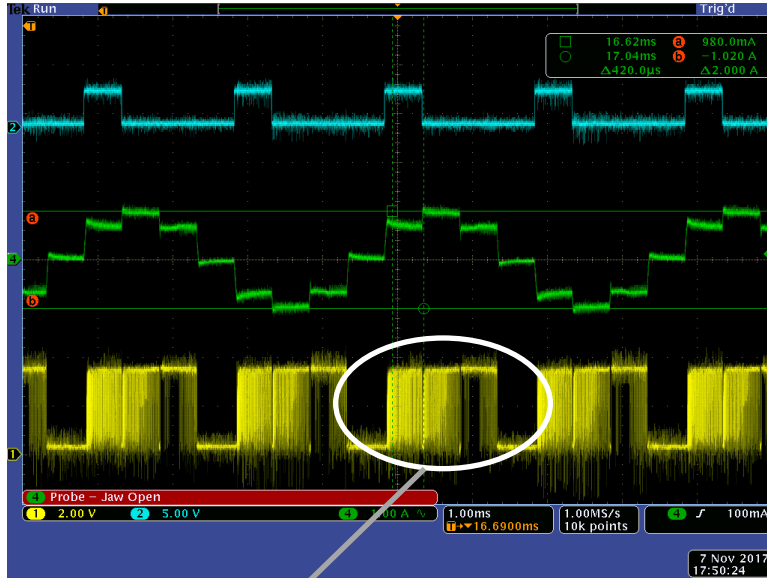
Normal operation: $\Delta BEMF > 0$

Stall condition: $\Delta BEMF = 0$

Results: Half Step

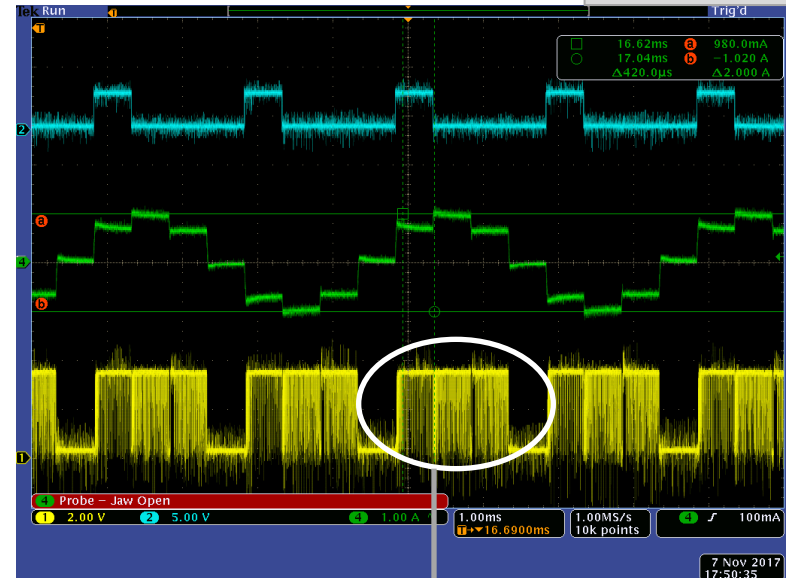
Test Conditions:
Motor = DB 1Ω
Supply = 34V
Current (Max) = 1A
Half Step @ 5 revs/sec
Abrupt Stall by holding with plier

Normal Speed

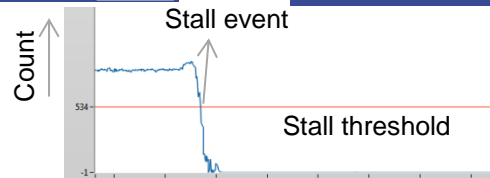


During normal speed motor operation, more back-emf in 2nd half (Q2) than 1st half (Q1) due to back-emf being 90° out of phase with current

Stalled motor



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



Summary

	Advantages	Disadvantages
Encoder	<ul style="list-style-type: none">• Precise motor position monitoring• Can work at very low speeds	<ul style="list-style-type: none">• Higher cost• Larger system area size
Direct back-emf measurement	<ul style="list-style-type: none">• Reduce design system cost and size	<ul style="list-style-type: none">• Minimum motor speed required• Does not work in full-step mode
Indirect back-emf measurement	<ul style="list-style-type: none">• Reduce system cost and size• Works for all micro-step settings	<ul style="list-style-type: none">• 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



©2020 Texas Instruments Incorporated. All rights reserved.

The material is provided strictly "as-is" for informational purposes only and without any warranty.
Use of this material is subject to TI's **Terms of Use**, viewable at [TI.com](https://www.ti.com)

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2020, Texas Instruments Incorporated