TI Designs

Automotive Brushed Motor Drive for Power-Folding Side Mirrors Reference Design

TEXAS INSTRUMENTS

Description

This TI Design features the DRV8801EVM and the DRV8872EVM. These evaluation modules (EVMs) enable an easy-to-use platform to demonstrate the capability and performance of the DRV8801 and DRV8872 motor drivers for power-folding side mirrors. This TI Design also intends to allow easy evaluation of the automotive qualified versions of the DRV8801 and DRV8872 (DRV8801-Q1 and DRV8872-Q1). The DRV8801-Q1 is a 2.8-A peak, full-bridge, brushed DC motor driver capable of driving the retracting function of vehicle side view mirrors. With the built-in automotive protection features of overcurrent, thermal, shoot-through, UVLO, and wide-input voltage (wide V_{IN}) range, this motor driver provides the necessary features to survive a harsh automotive environment. Additionally, this TI Design provides test data to allow the designer to quickly evaluate the performance of the DRV8801-Q1 and the DRV8872-Q1 for their folding-mirror modules.

Resources

TIDA-00145	Design Folder
DRV8801	Product Folder
DRV8801-Q1	Product Folder
DRV8872	Product Folder
DRV8872-Q1	Product Folder
TPS77701	Product Folder
MSP430F1612	Product Folder

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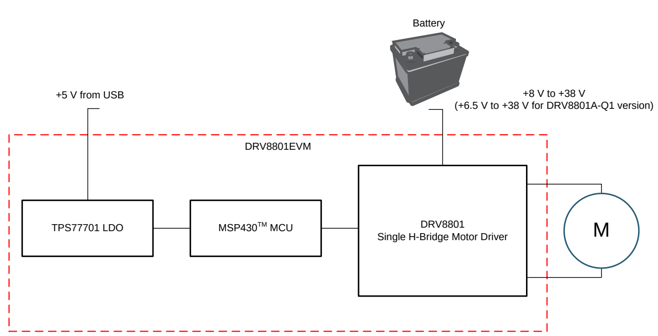
Features

- Single H-Bridge Motor Driver With Integrated Protection Features of Overcurrent, Thermal, and Undervoltage Lockout for Higher System Reliability Overvoltage Protection: 45 V
- Wide 8-V to 36-V Input Supply Range Easily Supports +12-V and +24-V Industry Standard Supplies
- High 2.8-A Peak Current Helps Support Large Startup and Stall Inrush Currents
- EVM includes easy to use GUI
- Phase and Enable Control Interface Provides Simple, 2-pin Control Interface for Motor Operation
- Brake Mode Support Allows the Motor to Stop Quickly
- Available AEC-Q100 Device Options for EVM ICs

Applications

- Automotive Body and Convenience Electronics
- Car Side-View Mirrors
- Grill Shutters



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1 System Overview

1.1 Block Diagram

Figure 1 shows the DRV8801 block diagram, and Figure 2 shows the DRV8872 block diagram.

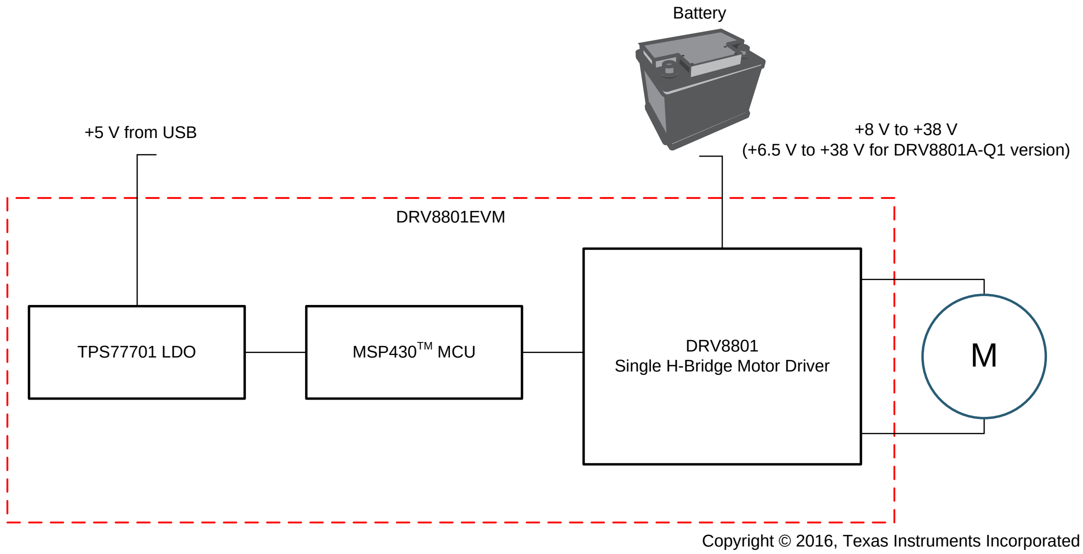

Figure 1. DRV8801 Block Diagram

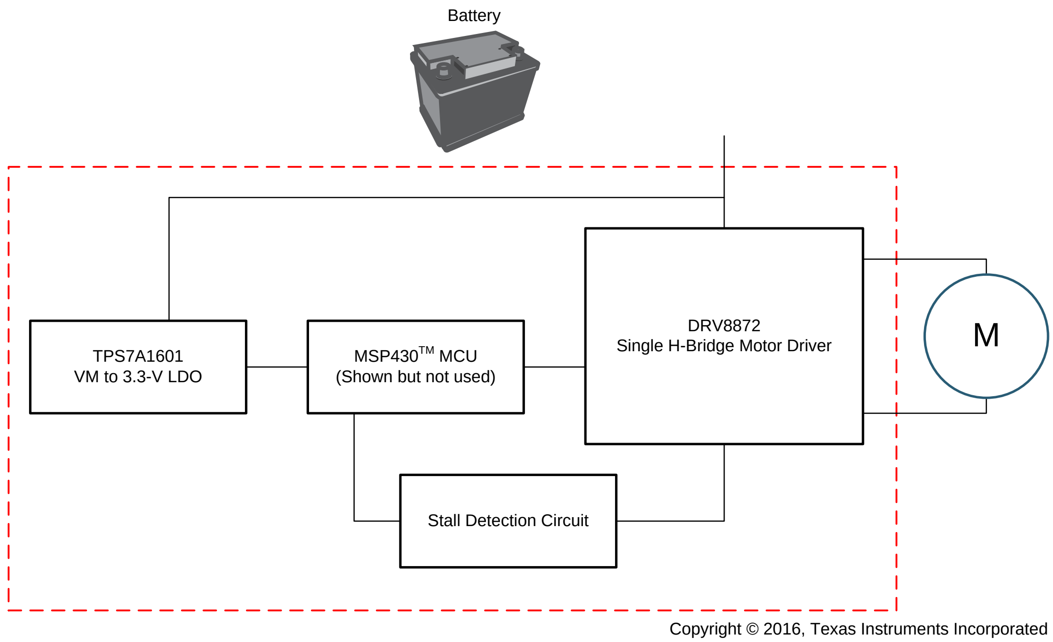

Figure 2. DRV8872 Block Diagram

1.2 Design Considerations

Linear Regulator: The EVM uses the TPS77071 LDO to power the MCU, but the designer may also consider the TPS7A66xx and TPS7A69xx LDOs from TI's automotive high-voltage LDO portfolio. LDOs in the TPS7A66xx and TPS7A69xx part families feature a low 12-µA quiescent current and short-circuit and overcurrent protection.

MCU: The motor operation through the motor driver interface of the 2-pin control is managed by the onboard MSP430™. TI has automotive qualified MSP320 devices, and TI recommends the MSP320F2272-Q1 for this design.

Motor: Because most motor-driven automotive convenience features do not require highly efficient motors and cost is typically more of a concern, a brushed motor was selected for the wing-mirror folding function.

Motor Driver, DRV8801: The DRV8801 is a single H-bridge, integrated motor driver with protection features and can handle the necessary current to fold a mirror. Also, while the DRV8801 onboard the EVM is not automotive qualified, TI has an automotive qualified version (DRV8801-Q1) available. The automotive version supports the same features and functionality.

Motor Driver, DRV8872: The DRV8872 is a single H-bridge, integrated motor driver with protection features and can handle the necessary current to fold a mirror. Also, while the DRV8872 onboard the EVM is not automotive qualified, TI has an automotive qualified version (DRV8872-Q1) available. The automotive version supports the same features and functionality.

2 Getting Started Hardware and Software

2.1 Hardware

The following list details the equipment used for testing.

- Oscilloscope
- Current probe
- 3 power supplies
  - 1 12-V power supply
  - 2 3.3-V power supplies
- DRV8801EVM (or DRV8872EVM)
- Power-folding side mirror (TYC1200142)

Figure 3 shows the power-folding mirror with the DRV8801EVM.

Figure 3. Power-Folding Mirror With DRV8801EVM

2.2 Software

Users must have the DRV8801EVM GUI installed on a PC to perform tests.

3 Testing and Results

3.1 DRV8801EVM

3.1.1 Test Setup

Figure 4 shows the board with labeled connections.

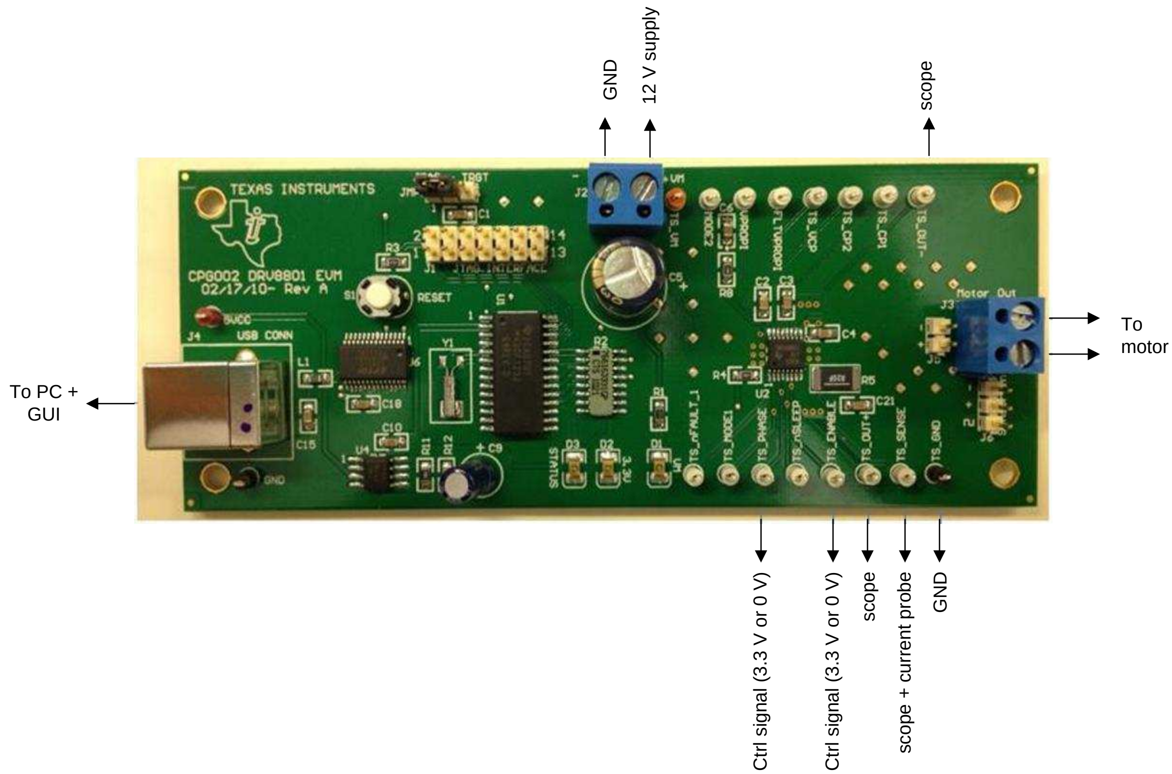

Figure 4. DRV8801EVM Board Connections

Use the following instructions for test setup.

1. Install the EVM graphics user interface (GUI), then connect the PC to the DRV8801EVM using USB CONN (J4).
2. Connect the 12-V power supply and ground to the DRV8801EVM through +VM and –VM, respectively (J2).
3. Connect the motor leads to the DRV8801EVM through Motor Out (J3).
4. Connect the TS_PHASE and TS_ENABLE pins to the 3.3-V power supplies.

   The firmware and GUI (as is) only support pulse width modulation (PWM) control, so connecting the pins to a logic supply can simplify the testing to provide 100% duty cycle signals.
5. Connect the scope leads to the DRV8801EVM at TS_OUT+ and TS_OUT–.
6. Connect the scope and current probe to the DRV8801 through TS_SENSE.

3.1.2 Motor Characterization

To measure resistance and inductance, the motor leads were probe with a multimeter.

- Motor resistance: 63.4 Ω
- Motor inductance: 127 mH

The expected current draw at an input off 12 V is approximately 200 mA (12 V / 63.4 Ω = 189 mA).

3.1.3 Start-Up

Figure 5 shows the motor moving forward from a stopped position. Though the peak current is approximately 5 A, overcurrent is not tripped because the peak lasts for less time than the overcurrent deglitch time of 3 µs (see red arrow).

See the electrical characteristics table of *DRV8801-Q1 DMOS Full-Bridge Motor Drivers* for overcurrent specifications. This motor has a large starting torque (required to overcome inertia) and consequently requires a high amount of current to initially move the motor.

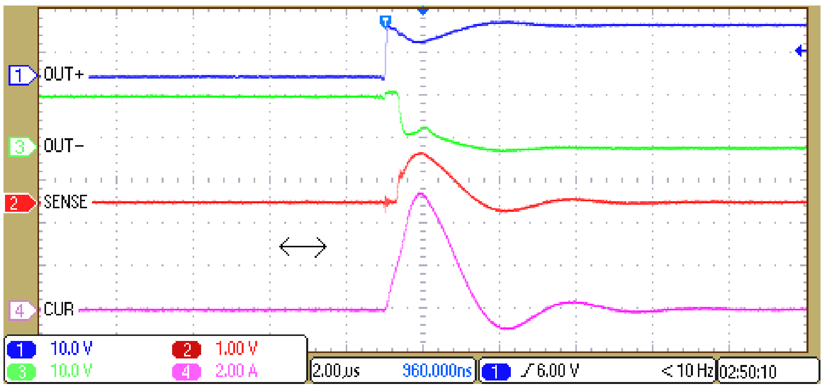

Figure 5. Motor Folding Forward From Stopped Position

Figure 6 shows the motor moving in reverse from a stopped position. Though the peak current is approximately 5 A, overcurrent is not tripped because the peak lasts for less time than the overcurrent deglitch time of 3 µs (see red arrow).

See the electrical characteristics table of *DRV8801-Q1 DMOS Full-Bridge Motor Drivers* for overcurrent specifications. Notice that OUT+, OUT–, and CUR are inverted from Figure 5.

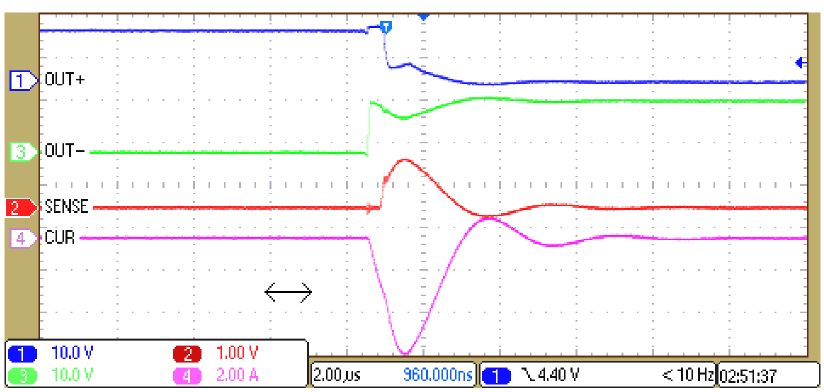

Figure 6. Motor Folding in Reverse From Stopped Position

3.1.4 Steady State

Figure 7 shows the motor moving forward in steady state. Starting torque requirements have been met. The current is low in this region of operation. In Figure 7, the forward steady state DC current (with enable at 100% duty cycle), is 375 mA.

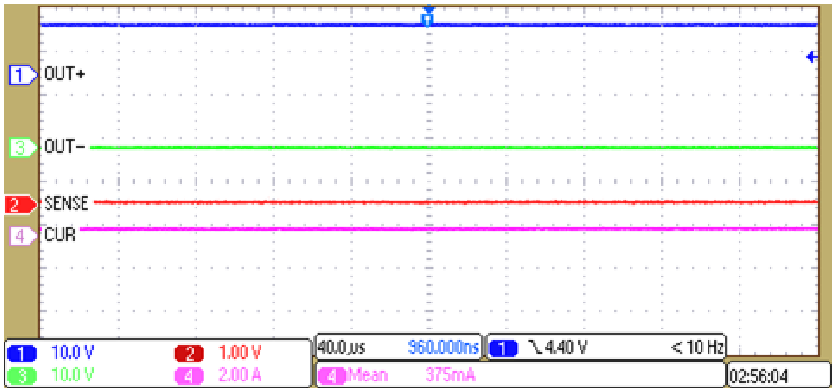

Figure 7. Motor Folding Forward in Steady State

In Figure 8, the reverse steady state DC current (with enable at 100% duty cycle) is –211 mA.

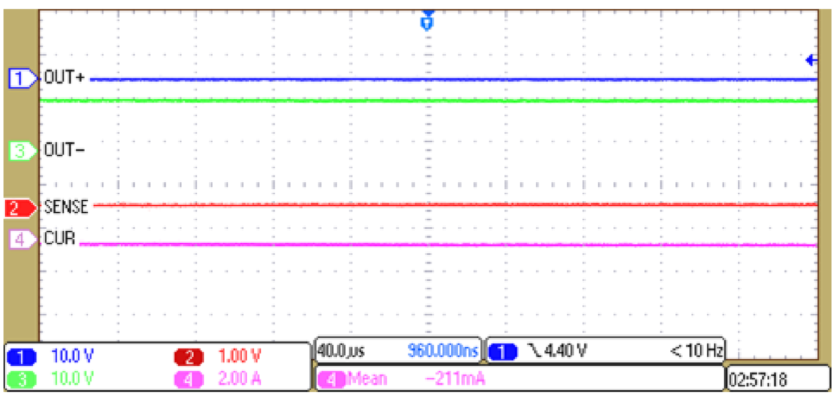

Figure 8. Motor Folding Reverse in Steady State

3.1.5 Track Resistance (Near end of Track)

Before the motor stall, the motor encounter mechanical resistance along the track. This resistance is dependant upon the housing and mechanical surroundings of the motor. In Figure 9, the pink curved pulses (CUR) represent the track resistance.

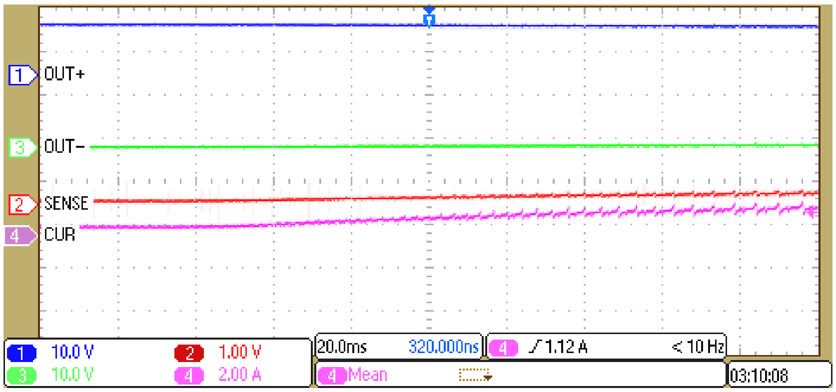

Figure 9. Track Resistance (Pink) for Forward Direction

Figure 10 shows the track resistance in reverse. Based on the steepness of the pink signal (CUR), the motor hits more resistance quicker than when moving forward.

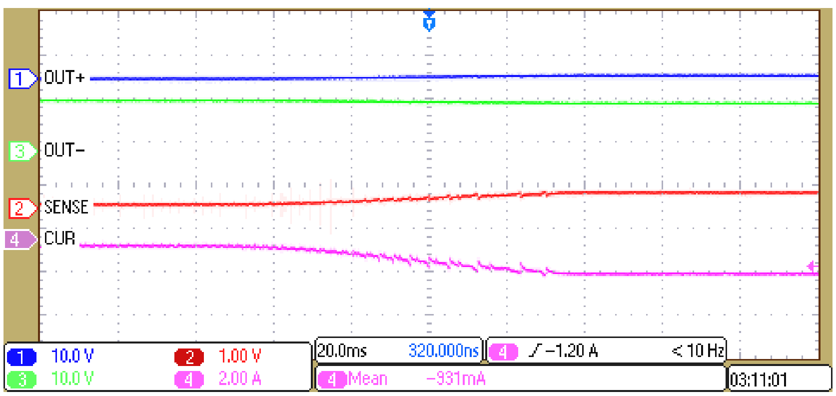

Figure 10. Track Resistance (Pink) for Reverse Direction

3.1.6 Stall

When the motor reaches the end of the track, the motor continues to move forward and eventually stalls when a fault or overcurrent detection is tripped (depending on the motor driver). After the motor stalls, the current drops. Figure 11 through Figure 13 shows the motor stall behavior.

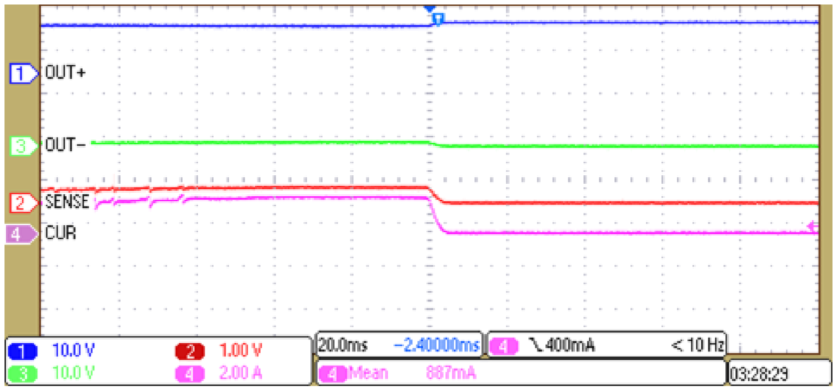

Figure 11. Forward Direction Motor Stalling

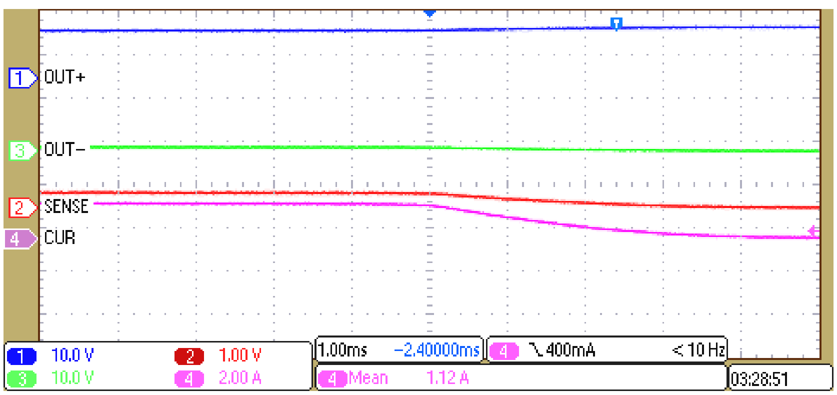

Figure 12. Zoomed-in Image of Figure 11

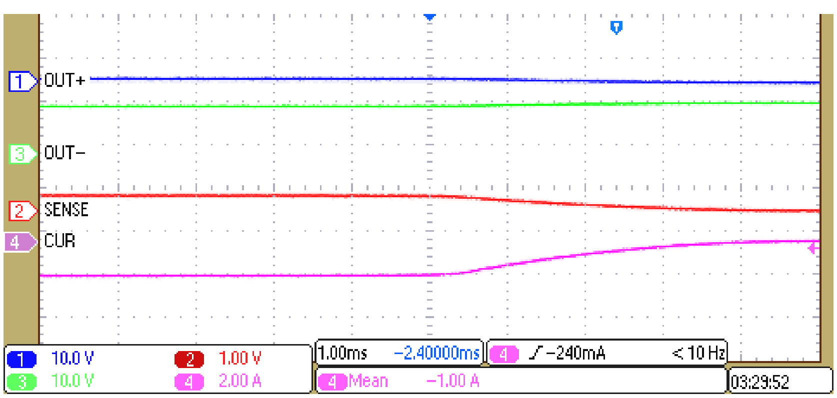

Figure 13. Reverse Direction Motor Stalling

3.1.7 Thermal Imaging

Figure 14 shows the thermal image of the board taken with an FLIR thermal camera. The power folding side mirror was repeatedly opened and closed for 10 minutes before the thermal image was taken. Additionally, Figure 14 shows most of the heat (red) dissipated through the DRV8801 and the corresponding sense resistor.

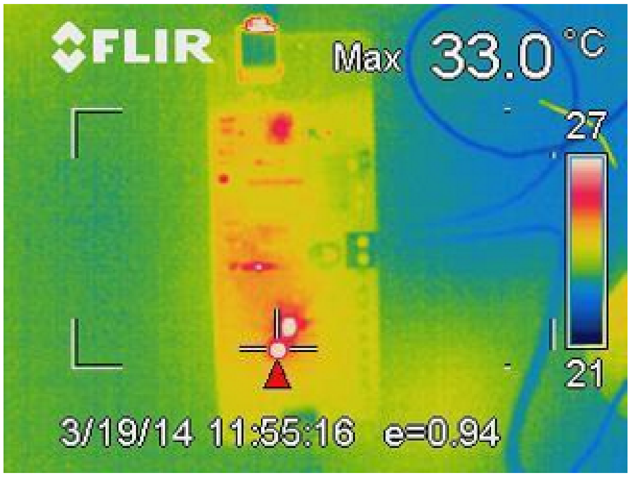

Figure 14. DRV8801EVM After 10 Minutes of Continual Operation

3.2 DRV8872EVM

3.2.1 Test Setup

Figure 15 shows the DRV8872EVM device.

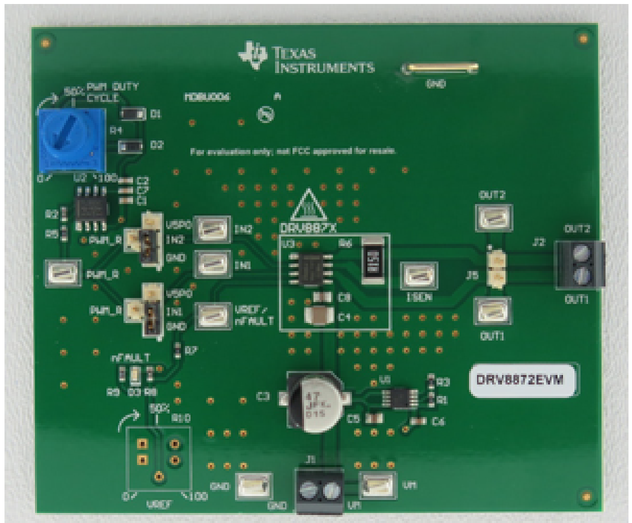

Figure 15. DRV8872EVM

Use the following instructions for test setup.

1. Create a stall detection circuit (see Figure 16).
2. Connect the 12-V power supply and ground to the DRV8872EVM through VM and GND, respectively.
3. Connect the motor leads to the DRV8872EVM through OUT1 and OUT2.
4. Connect the scope leads to the DRV8872EVM at OUT1, OUT2, and nSTALL.
5. Connect the scope and current probe to the DRV8872 through OUT1.
6. Control the forward or reverse direction by connecting IN1 or IN2 to V5P0.

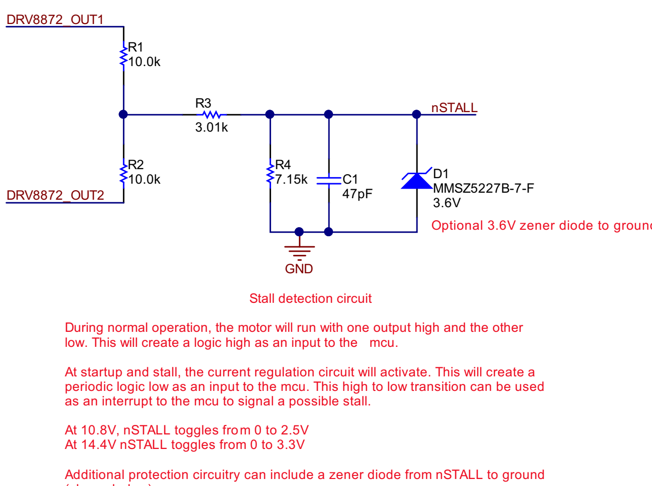

Figure 16. Stall Detection Circuit

3.2.2 Start-Up

Figure 17 shows the motor moving forward from a stopped position. The peak current is limited by the current sense resistor (a 0.3-Ω resistor limits the current to 700 mA). During start up, the current is limited and the output toggles between drive forward and slow decay. The stall detection current can be ignored during this time.

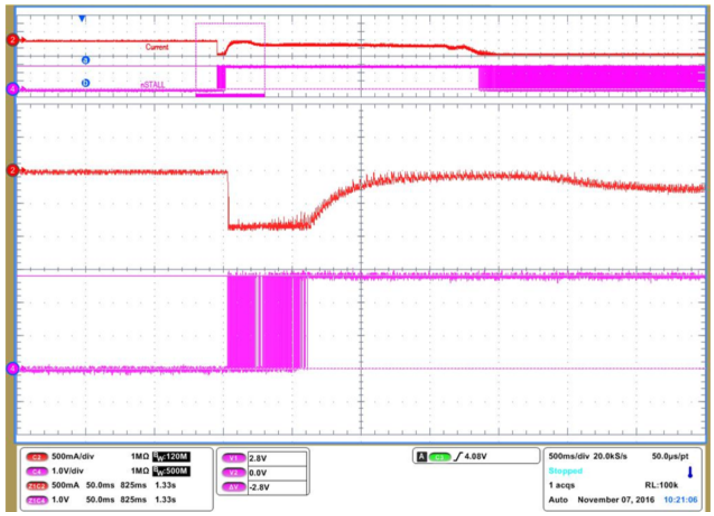

Figure 17. Motor Folding Forward From Stopped Position (Zoom-in is Start-up Position Showing Current Regulation)

Figure 18 shows the motor moving in reverse from a stopped position. Like Figure 17, the current is limited by the current sense resistor.

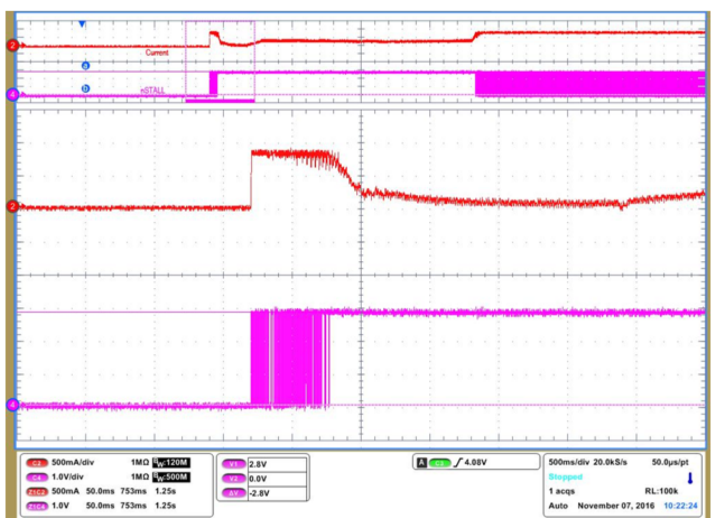

Figure 18. Motor Folding in Reverse From Stopped Position (Zoom-in is Start-up Position Showing Current Regulation)

3.2.3 Steady State

Figure 19 shows the motor moving forward in steady state. The starting torque requirements have been met. The current is low and current regulation is not required in this region of operation. In Figure 19, the forward steady state DC current (with enable at 100% duty cycle), 375 mA.

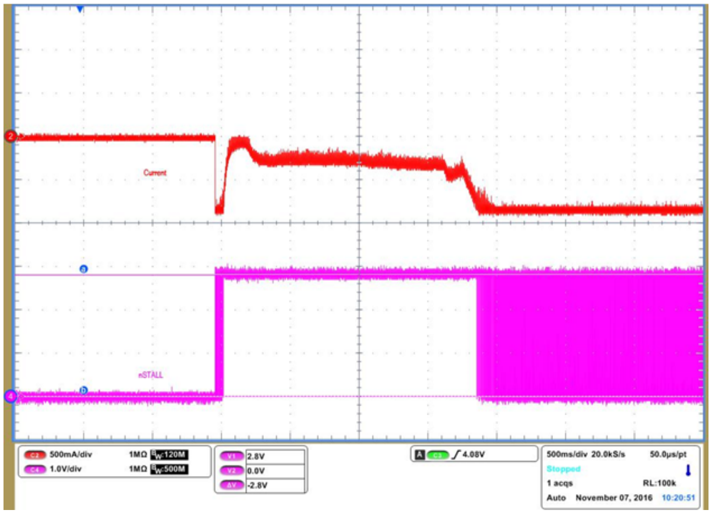

Figure 19. Motor Folding Forward in Steady State

In Figure 20, the reverse steady-state DC current (with enable at 100% duty cycle) is –211 mA.

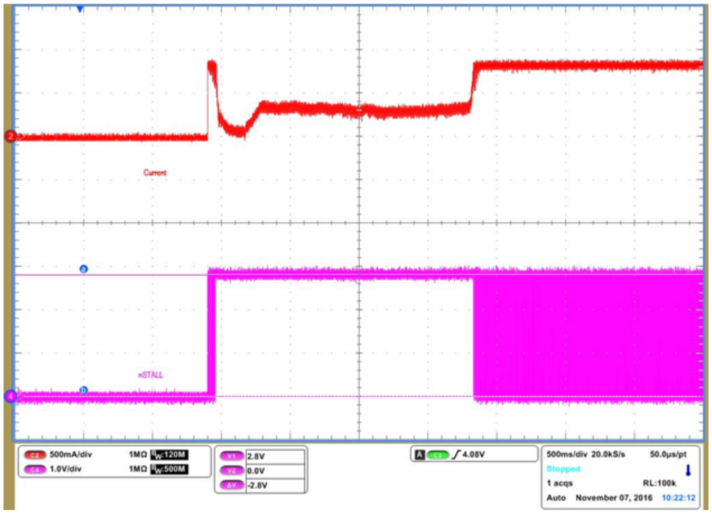

Figure 20. Motor Folding in Reverse in Steady State

3.2.4 Stall

When the motor reaches the end of the track, the motor continues to move forward and eventually stalls. As the current increases above the 700-mA threshold, current regulation begins and can be used to detect the stall. The stall detector circuit begins to toggle between logic 0 and logic 1. See Figure 21 and Figure 22.

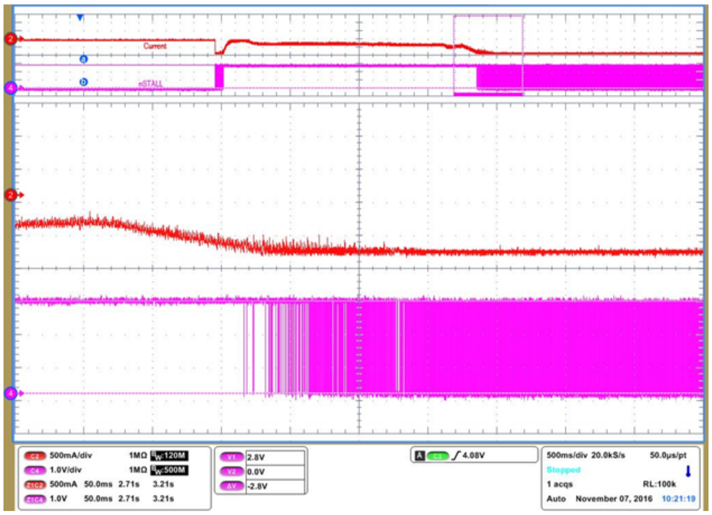

Figure 21. Forward-Direction Motor Stalling (Zoom-in is Stalled Position Showing Current Regulation)

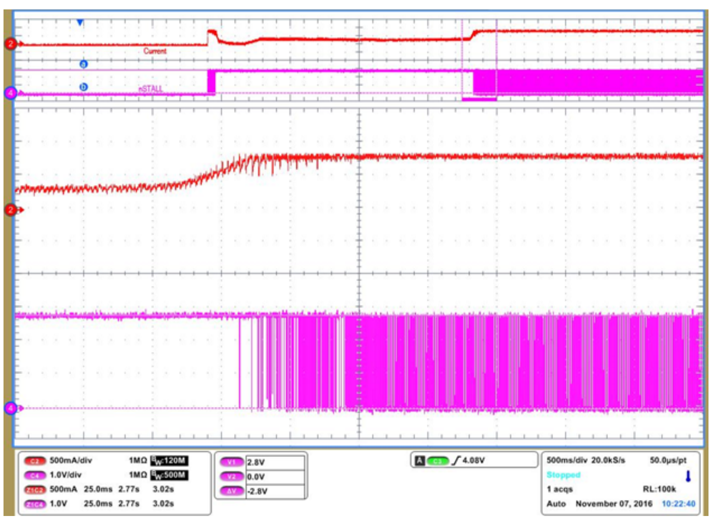

Figure 22. Reverse-Direction Motor Stalling (Zoom-in is Stalled Position Showing Current Regulation)

3.2.5 DRV8872 Code

The DRV8872 in this TI Design does not use an MCU to control the opening and closing of the mirror. If an MCU is used, the following pseudocode could be implemented to determine when to stop driving the motor after a stall is detected.

```
1) Set direction to fold out // place mirror in drive position
2) Enable the motor
3) Ignore PWM for 200 ms (low voltage is longer)
4) Enable interrupt and start timer
5) When interrupt, check time
    If < 1 sec (higher voltage is shorter), problem encountered, could be blocked
        Reverse for time recorded plus 200 ms, then restart
    If < 1 sec
        Count interrupts for 200 ms, then
        Stop motor
        Enter sleep mode
        Set direction to opposite
            If fold out, set direction to fold in
            Otherwise set direction to fold out
6) Wait until awakened
7) Go to Step 2
```

4 Design Files

4.1 Schematics

To download the schematics, see the design files at TIDA-00145.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-00145.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints

To download the layer plots, see the design files at TIDA-00145.

4.4 Altium Project

To download the Altium project files, see the design files at TIDA-00145.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDA-00145.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-00145.

5 Software Files

To download the software files, see the design files at TIDA-00145.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (April 2014) to A Revision **Page**

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