

DRV8234 2-A Brushed DC Motor Driver with Ripple Counting, Stall Detection, and Speed Regulation

1 Features

- N-channel H-bridge brushed DC motor driver
- 4.5-V to 38-V** operating supply voltage range
- Ripple counting** feature for:
 - On-chip **Speed and Position detection**
 - Integrated **Voltage and Speed regulation**
- Soft-Start and Stop** feature for inrush current protection
- 600-mΩ** $R_{DS(on)}$ (High-Side + Low-Side)
- High output current capability: 3.7-A Peak, 2-A RMS
- PWM with I²C control interface
 - Configuration and diagnostics on I²C registers
 - Multi-follower operation support
 - Supports standard and fast I²C mode
- Supports 3.3-V, and 5-V logic inputs
- Integrated current sensing and current regulation
- Analog current sense output (IPROPI)
- Internal charge pump with 100% duty cycle
- Long battery life with low-power sleep mode
 - < 1 μA maximum sleep current
- Small package and footprint
 - 16-Pin WQFN with PowerPAD™, 3 × 3 mm
- Integrated protection features
 - VM undervoltage lockout (UVLO)
 - Overcurrent protection (OCP)
 - Thermal shutdown (TSD)
 - Stall detection**
 - Overvoltage protection (OVP)

2 Applications

- Printers
- Vacuum Robots
- Washers and Dryers
- Coffee Machines
- POS Printers
- Electronic Hospital bed and bed control
- Fitness Machine

3 Description

The DRV8234 is a high-performance integrated H-bridge motor driver with integrated speed and position detection using ripple counting along with additional features like motor speed and voltage regulation, stall detection, current sense output, current regulation, and protection circuitry.

The integrated ripple counting algorithm counts the number of ripples in the motor current to determine

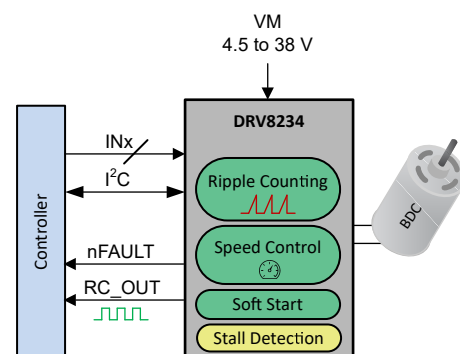
motor relative position and speed eliminating the potential need for encoders, hall sensors, or optical sensors. This reduces board space and design complexity, and saves on overall system cost. Integrated speed regulation is used to maintain constant motor speed over varying input supply voltages which minimizes current consumption and saves power over time. This is critical in applications that have different loading conditions or rely on battery power for operation where the input voltage is not constant. Soft-start and stop allows for a controlled turn-on and turn-off time, reducing large inrush currents to protect the motor windings from damage, thereby increasing system reliability and longevity.

An internal current mirror implements current sensing and regulation. This eliminates the need for a large power shunt resistor, saving board area and reducing system cost. The IPROPI current sense output allows a microcontroller to detect motor stall or changes in load conditions. Using the VREF pin, this device can regulate the motor current during startup and high-load events without interaction from a microcontroller. The device supports sensorless motor stall detection and reporting to microcontroller.

Device Information

| PART NUMBER | PACKAGE ⁽¹⁾ | BODY SIZE (NOM) |
|-------------|------------------------|-------------------|
| DRV8234 | WQFN (16) | 3.00 mm × 3.00 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.



Simplified Schematic



Table of Contents

| | | | |
|--|-----------|--|-----------|
| 1 Features | 1 | 7.4 Device Functional Modes..... | 35 |
| 2 Applications | 1 | 7.5 Programming..... | 36 |
| 3 Description | 1 | 7.6 Register Map..... | 37 |
| 4 Device Comparison | 3 | 8 Application and Implementation | 67 |
| 5 Pin Configuration and Functions | 4 | 8.1 Application Information..... | 67 |
| 6 Specifications | 5 | 8.2 Typical Application: Brushed DC Motor..... | 67 |
| 6.1 Absolute Maximum Ratings..... | 5 | 9 Power Supply Recommendations | 80 |
| 6.2 ESD Ratings..... | 5 | 9.1 Bulk Capacitance..... | 80 |
| 6.3 Recommended Operating Conditions..... | 5 | 10 Layout | 81 |
| 6.4 Thermal Information..... | 6 | 10.1 Layout Guidelines..... | 81 |
| 6.5 Electrical Characteristics..... | 6 | 11 Device and Documentation Support | 82 |
| 6.6 I2C Timing Requirements..... | 7 | 11.1 Receiving Notification of Documentation Updates.. | 82 |
| 6.7 Timing Diagrams..... | 9 | 11.2 Support Resources..... | 82 |
| 6.8 Typical Operating Characteristics..... | 10 | 11.3 Trademarks..... | 82 |
| 7 Detailed Description | 11 | 11.4 Electrostatic Discharge Caution..... | 82 |
| 7.1 Overview..... | 11 | 11.5 Glossary..... | 82 |
| 7.2 Functional Block Diagram..... | 12 | 12 Revision History | 82 |
| 7.3 Feature Description..... | 13 | | |

4 Device Comparison

Table 4-1. Device Comparison Table

| Part Number | Package | Supply VM (V) | R _{DS(ON)} (mΩ) | Current Capacity (RMS) | Ripple Counting | Speed Regulation | Stall Detection | Package Size |
|-------------------------|---------|---------------|--------------------------|------------------------|-----------------|------------------|-----------------|--------------|
| DRV8214 | RTE | 1.65 to 11 | 240 | 2 A | Yes | Yes | Yes | 3 mm × 3 mm |
| DRV8234 | RTE | 4.5 to 38 | 600 | 2 A | Yes | Yes | Yes | 3 mm × 3 mm |
| DRV8215 | RTE | 1.65 to 11 | 240 | 2 A | No | Yes | Yes | 3 mm × 3 mm |
| DRV8235 | RTE | 4.5 to 38 | 600 | 2 A | No | Yes | Yes | 3 mm × 3 mm |
| DRV8213 | RTE | 1.65 to 11 | 240 | 2 A | No | No | Yes | 3 mm × 3 mm |
| DRV8213 | DSG | 1.65 to 11 | 240 | 2 A | No | No | No | 2 mm × 2 mm |

5 Pin Configuration and Functions

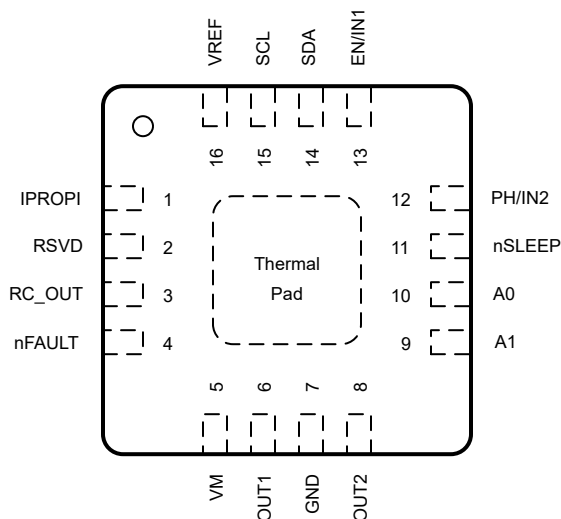


Figure 5-1. RTE Package 16-Pin WQFN Top View

Table 5-1. Pin Functions

| PIN | | TYPE ⁽¹⁾ | DESCRIPTION |
|--------|-----|---------------------|---|
| NAME | RTE | | |
| IPROPI | 1 | PWR | Analog current output proportional to load current. Connect a resistor from IPROPI to ground. |
| RSVD | 2 | — | Reserved. Leave this pin unconnected. |
| RC_OUT | 3 | OD | Output of Ripple Counting algorithm. Can be programmed by I ² C to output pulse train or logic level signal. |
| nFAULT | 4 | OD | Fault indicator output. Pulled low during a fault condition. Connect an external pullup resistor for open-drain operation. |
| VM | 5 | PWR | Motor power supply. Bypass this pin to the GND pin with a 0.1-μF ceramic capacitor as well as sufficient bulk capacitance rated for VM. |
| OUT1 | 6 | O | H-bridge output. Connect directly to the motor. |
| GND | 7 | PWR | Device ground. Connect to system ground. |
| OUT2 | 8 | O | H-bridge output. Connect directly to the motor. |
| A1 | 9 | I | I ² C base address select pin. Tri-level input. |
| A0 | 10 | I | I ² C base address select pin. Tri-level input. |
| nSLEEP | 11 | I | Sleep mode input. Logic high to enable device. Logic low to enter low-power sleep mode. Internal pulldown resistor. |
| PH/IN2 | 12 | I | Controls the H-bridge output. Has internal pulldown. |
| EN/IN1 | 13 | I | Controls the H-bridge output. Has internal pulldown. |
| SDA | 14 | I | I ² C data signal. The SDA pin requires a pullup resistor. |
| SCL | 15 | I | I ² C clock signal. |
| VREF | 16 | I | Analog input to set current regulation and stall detection level. |
| PAD | — | — | Thermal pad. Connect to board ground. For good thermal dissipation, use large ground planes on multiple layers, and multiple nearby vias connecting those planes. |

(1) I = Input, O = Output, PWR = Power, OD = Open-Drain Output

6 Specifications

6.1 Absolute Maximum Ratings

over operating temperature range (unless otherwise noted)⁽¹⁾

| | | MIN | MAX | UNIT |
|--|------------------------------------|--------------------|----------------------------------|------|
| Power supply pin voltage | VM | -0.5 | 40 | V |
| Power supply transient voltage ramp | VM | 0 | 2 | V/μs |
| Logic pin voltage | IN1, IN2, A1, A0, SDA, SCL, nSLEEP | -0.3 | 5.75 | V |
| Open-drain output pin voltage | nFAULT, RC_OUT | -0.3 | 5.75 | V |
| Proportional current output pin voltage, VM ≥ 5.45 V | IPROPI | -0.3 | 5.75 | V |
| Proportional current output pin voltage, VM < 5.45 V | | -0.3 | V _{VM} + 0.3 | V |
| Reference input pin voltage | VREF | 0.3 | 5.75 | V |
| Output pin voltage | OUTx | -V _{SD} | V _{VM} +V _{SD} | V |
| Output current | OUTx | Internally Limited | Internally Limited | A |
| Ambient temperature, T _A | | -40 | 125 | °C |
| Junction temperature, T _J | | -40 | 150 | °C |
| Storage temperature, T _{stg} | | -65 | 150 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Rating* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

| | | | VALUE | UNIT |
|--------------------|-------------------------|--|-------|------|
| V _(ESD) | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±2000 | V |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±500 | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as ± 2000 V may actually have higher performance.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Pins listed as ± 500 V may actually have higher performance.

6.3 Recommended Operating Conditions

over operating temperature range (unless otherwise noted)

| | | | MIN | NOM | MAX | UNIT |
|---------------------------------|---------------------------------|------------------------------------|-----|-----|-----|------|
| V _{VM} | Power supply voltage | VM | 4.5 | | 38 | V |
| V _{IN} | Logic input voltage | IN1, IN2, A1, A0, SDA, SCL, nSLEEP | 0 | | 5.5 | V |
| f _{PWM} | PWM frequency | INx | 0 | | 200 | kHz |
| V _{OD} | Open drain pullup voltage | nFAULT, RC_OUT | 0 | | 5.5 | V |
| I _{OD} | Open drain output current | nFAULT, RC_OUT | 0 | | 5 | mA |
| I _{OUT} ⁽¹⁾ | Peak output current | OUTx | 0 | | 3.7 | A |
| I _{IPROPI} | Current sense output current | IPROPI | 0 | | 3 | mA |
| V _{VREF} | Current limit reference voltage | VREF | 0 | | 3.3 | V |
| T _A | Operating ambient temperature | | -40 | | 125 | °C |
| T _J | Operating junction temperature | | -40 | | 150 | °C |

- (1) Power dissipation and thermal limits must be observed

6.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | DEVICE | UNIT |
|-------------------------------|--|------------|------|
| | | RTE (WQFN) | |
| | | 16 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 47.8 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 48.2 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 22.4 | °C/W |
| Ψ _{JT} | Junction-to-top characterization parameter | 1.1 | °C/W |
| Ψ _{JB} | Junction-to-board characterization parameter | 22.4 | °C/W |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | 8.6 | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

6.5 Electrical Characteristics

4.5 V ≤ V_{VM} ≤ 38 V, -40°C ≤ T_J ≤ 150°C (unless otherwise noted). Typical values are at T_J = 27°C, V_{VM} = 24 V.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---------------------------------------|--|-----|-----|-----|------|
| POWER SUPPLIES (VM) | | | | | | |
| I _{VMQ} | VM sleep mode current | nSLEEP = 0 V, V _{VM} = 24 V, T _J = 27°C | | 0.1 | 1 | μA |
| I _{VM} | VM active mode current | nSLEEP = 3.3 V, IN1 = 3.3 V, IN2 = 0 V, V _{VM} = 24 V | | 3.5 | 4 | mA |
| t _{WAKE} | Turnon time | nSLEEP = 1 to I ² C ready | | | 410 | μs |
| LOGIC-LEVEL INPUTS (IN1, IN2, SDA, SCL, nSLEEP) | | | | | | |
| V _{IL} | Input logic low voltage | | 0 | | 0.5 | V |
| V _{IH} | Input logic high voltage | | 1.5 | | 5.5 | V |
| V _{HYS} | Input hysteresis | | | 160 | | mV |
| V _{HYS} | Input hysteresis | nSLEEP pin | | 60 | | |
| I _{IL} | Input logic low current | V _I = 0 V | -1 | | 1 | μA |
| I _{IH} | Input logic high current | V _I = 5 V | | 33 | 100 | μA |
| R _{PD} | Input pulldown resistance, INx | To GND | | 100 | | kΩ |
| t _{DEGLITCH} | Input logic deglitch, INx | | | 50 | | ns |
| TRI-LEVEL INPUTS (A1, A0) | | | | | | |
| V _{TIL} | Tri-level input logic low voltage | | 0 | | 0.6 | V |
| V _{TIH} | Tri-level input Hi-Z voltage | | 1.8 | 2 | 2.2 | V |
| V _{TIH} | Tri-level input logic high voltage | | 2.7 | | 5.5 | V |
| R _{TPD} | Tri-level pulldown resistance | to GND | | 200 | | kΩ |
| I _{TPU} | Tri-level pullup current | to 3.3 V | | 10 | | μA |
| OPEN-DRAIN OUTPUTS (nFAULT, RC_OUT, SDA) | | | | | | |
| V _{OL} | Output logic low voltage | I _{OD} = 5 mA | | | 0.3 | V |
| I _{OZ} | Output logic high current | V _{OD} = 3.3 V | -1 | | 1 | μA |
| t _{PW_RC} | RC_OUT pulse width | | 30 | 50 | 70 | μs |
| t _{PW_nFAULT} | nFAULT low pulse width | RC Count overflow, RC_REP = 11b | 30 | 50 | 70 | μs |
| C _B | SDA capacitive load for each bus line | | | | 400 | pF |
| DRIVER OUTPUTS (OUTx) | | | | | | |
| R _{DS(ON)_HS} | High-side MOSFET on resistance | I _{OUTx} = 1 A; T _J = 25 °C | | 300 | 360 | mΩ |
| R _{DS(ON)_HS} | High-side MOSFET on resistance | I _{OUTx} = 1 A; T _J = 125 °C | | 450 | 540 | mΩ |
| R _{DS(ON)_HS} | High-side MOSFET on resistance | I _{OUTx} = 1 A; T _J = 150 °C | | 500 | 600 | mΩ |
| R _{DS(ON)_LS} | Low-side MOSFET on resistance | I _{OUTx} = -1 A; T _J = 25 °C | | 300 | 360 | mΩ |

$4.5\text{ V} \leq V_{VM} \leq 38\text{ V}$, $-40^\circ\text{C} \leq T_J \leq 150^\circ\text{C}$ (unless otherwise noted). Typical values are at $T_J = 27^\circ\text{C}$, $V_{VM} = 24\text{ V}$.

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------|-----------------------------------|--|-----|-----|-----|------------|
| $R_{DS(ON)_LS}$ | Low-side MOSFET on resistance | $I_{OUTx} = -1\text{ A}$; $T_J = 125^\circ\text{C}$ | | 450 | 540 | m Ω |
| $R_{DS(ON)_LS}$ | Low-side MOSFET on resistance | $I_{OUTx} = -1\text{ A}$; $T_J = 150^\circ\text{C}$ | | 500 | 600 | m Ω |
| V_{SD} | Body diode forward voltage | $I_{OUTx} = -1\text{ A}$ | | 0.8 | | V |
| t_{RISE} | Output rise time | V_{OUTx} rising from 10% to 90% of V_{VM} | | 200 | | ns |
| t_{FALL} | Output fall time | V_{OUTx} falling from 90% to 10% of V_{VM} | | 140 | | ns |
| t_{PD} | Input to output propagation delay | Input to $OUTx$ | | 650 | | ns |
| t_{DEAD} | Output dead time | | | 200 | | ns |

CURRENT SENSE AND REGULATION (IPROPI, VREF)

| | | | | | | |
|----------------|--|--|------|------|------|-----------------|
| V_{REF_INT} | Internal reference voltage | $INT_VREF = 1b$ | 2.88 | 3 | 3.12 | V |
| A_{IPROPI} | Current scaling factor | | | 1500 | | $\mu\text{A/A}$ |
| A_{ERR} | Current mirror total error | $I_{OUT} = 0.1\text{ A}$, $V_{VM} \geq 5.5\text{ V}$ | -10 | | 10 | % |
| A_{ERR} | Current mirror total error | $0.15\text{ A} \leq I_{OUT} < 0.5\text{ A}$, $V_{VM} \geq 5.5\text{ V}$ | -7 | | 7 | % |
| A_{ERR} | Current mirror total error | $I_{OUT} \geq 0.5\text{ A}$, $V_{VM} \geq 5.5\text{ V}$ | -5 | | 5 | % |
| t_{OFF} | Current regulation off time | | | 20 | | μs |
| t_{BLANK} | Current sense blanking time | $TBLANK = 0b$ | | 1.8 | | μs |
| t_{BLANK} | Current sense blanking time | $TBLANK = 1b$ | | 1 | | μs |
| t_{DEG} | Current regulation and stall detection deglitch time | $TDEG = 0b$ | | 2 | | μs |
| t_{DEG} | Current regulation and stall detection deglitch time | $TDEG = 1b$ | | 1 | | μs |
| t_{INRUSH} | Inrush time blanking for stall detection | | 5 | | 6716 | ms |

Voltage regulation

| | | | | | | |
|-------------------|-----------------|---|--|-----------|--|--|
| ΔV_{LINE} | Line regulation | $5.5\text{ V} \leq V_{VM} \leq 38\text{ V}$, $V_{OUT} = 5\text{ V}$, $I_{OUT} = 2\text{ A}$ | | $\pm 2\%$ | | |
| ΔV_{LOAD} | Load regulation | $V_{VM} = 24\text{ V}$, $V_{OUT} = 5\text{ V}$, $I_{OUT} = 100\text{ mA}$ to 2 A | | $\pm 1\%$ | | |

PROTECTION CIRCUITS

| | | | | | | |
|-----------------|---------------------------------------|--|------|-----|------|------------------|
| V_{UVLO_VM} | VM supply undervoltage lockout (UVLO) | Supply rising | 4.15 | 4.3 | 4.45 | V |
| | | Supply falling | 4.05 | 4.2 | 4.35 | V |
| V_{UVLO_HYS} | Supply UVLO hysteresis | Rising to falling threshold | | 100 | | mV |
| t_{UVLO} | Supply undervoltage deglitch time | V_{VM} falling to $OUTx$ disabled | | 10 | | μs |
| V_{RST} | VM UVLO reset | VM falling, device reset, no I^2C communications | | | 3.9 | V |
| V_{OVP_TH} | Overvoltage protection threshold | $V_{OUT} - V_{VM}$ | | 200 | | mV |
| t_{OVP_ON} | Overvoltage protection turn-on time | | | 10 | | μs |
| t_{OVP_OFF} | Overvoltage protection turn-off time | | | 250 | | μs |
| I_{OCP} | Overcurrent protection trip point | | 3.7 | | | A |
| t_{OCP} | Overcurrent protection deglitch time | | | 2 | | μs |
| t_{RETRY} | Retry time | | | 1.7 | | ms |
| T_{TSD} | Thermal shutdown temperature | | 150 | 175 | | $^\circ\text{C}$ |
| T_{HYS} | Thermal shutdown hysteresis | | | 40 | | $^\circ\text{C}$ |

6.6 I2C Timing Requirements

| | | MIN | NOM | MAX | UNIT |
|----------------------|---------------------|-----|-----|-----|------|
| STANDARD MODE | | | | | |
| f_{SCL} | SCL Clock frequency | 0 | | 100 | kHz |

| | | MIN | NOM | MAX | UNIT |
|------------------|---|-------|-----|------|---------|
| $t_{HD,STA}$ | Hold time (repeated) START condition. After this period, the first clock pulse is generated | 4 | | | μs |
| t_{LOW} | LOW period of the SCL clock | 4.7 | | | μs |
| t_{HIGH} | HIGH period of the SCL clock | 4 | | | μs |
| $t_{SU,STA}$ | Setup time for a repeated START condition | 4.7 | | | μs |
| $t_{HD,DAT}$ | Data hold time: For I2C bus devices | 0.035 | | 3.45 | μs |
| $t_{SU,DAT}$ | Data set-up time | 250 | | | ns |
| t_R | SDA and SCL rise time | | | 1000 | ns |
| t_F | SDA and SCL fall time | | | 300 | ns |
| $t_{SU,STO}$ | Set-up time for STOP condition | 4 | | | μs |
| t_{BUF} | Bus free time between a STOP and START condition | 4.7 | | | μs |
| FAST MODE | | | | | |
| f_{SCL} | SCL Clock frequency | 0 | | 400 | kHz |
| $t_{HD,STA}$ | Hold time (repeated) START condition. After this period, the first clock pulse is generated | 0.6 | | | μs |
| t_{LOW} | LOW period of the SCL clock | 1.3 | | | μs |
| t_{HIGH} | HIGH period of the SCL clock | 0.6 | | | μs |
| $t_{SU,STA}$ | Setup time for a repeated START condition | 0.6 | | | μs |
| $t_{HD,DAT}$ | Data hold time: For I2C bus devices | 0.035 | | 0.9 | μs |
| $t_{SU,DAT}$ | Data set-up time | 250 | | | ns |
| t_R | SDA and SCL rise time | | | 300 | ns |
| t_F | SDA and SCL fall time | | | 300 | ns |
| $t_{SU,STO}$ | Set-up time for STOP condition | 0.6 | | | μs |
| t_{BUF} | Bus free time between a STOP and START condition | 1.3 | | | μs |
| t_{SP} | Pulse width of spikes to be suppressed by input noise filter | | 50 | | ns |

6.7 Timing Diagrams

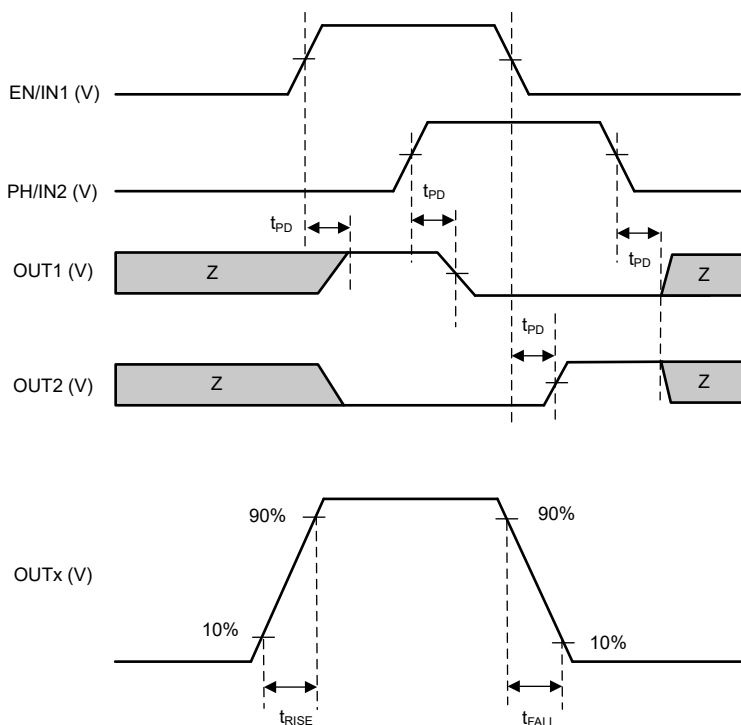


Figure 6-1. Input-to-Output Timing Diagram

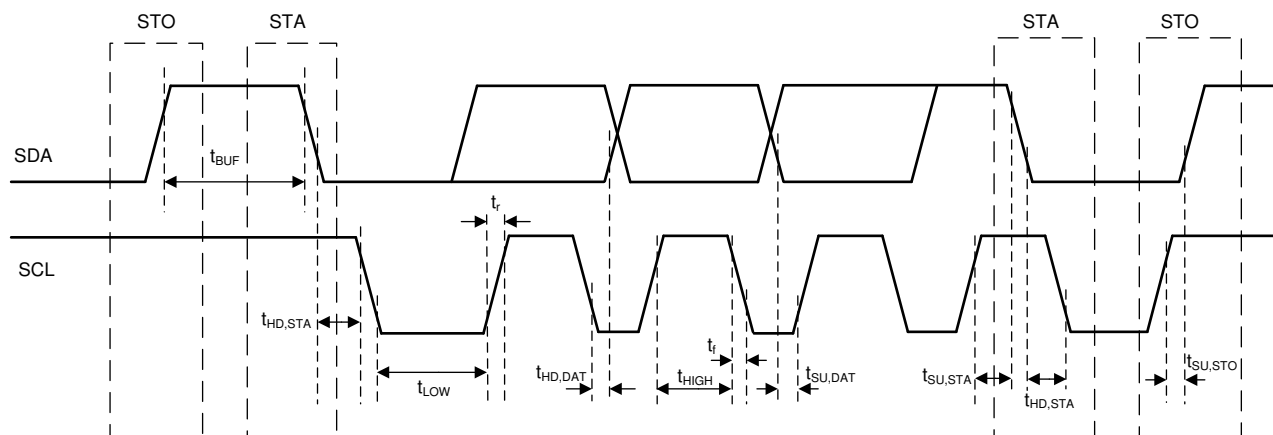


Figure 6-2. I²C Timing Diagram

6.8 Typical Operating Characteristics

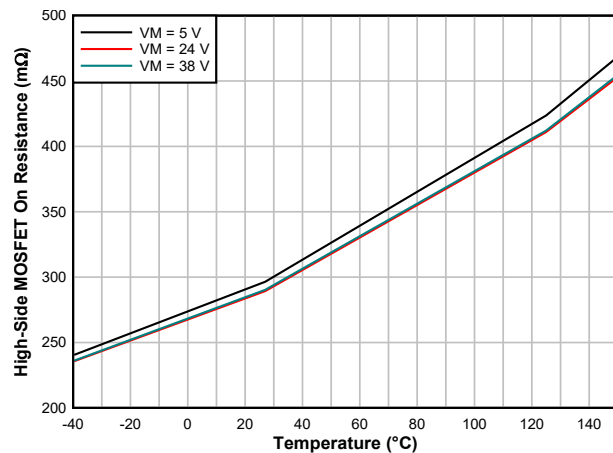


Figure 6-3. High-Side MOSFET On Resistance (mΩ)

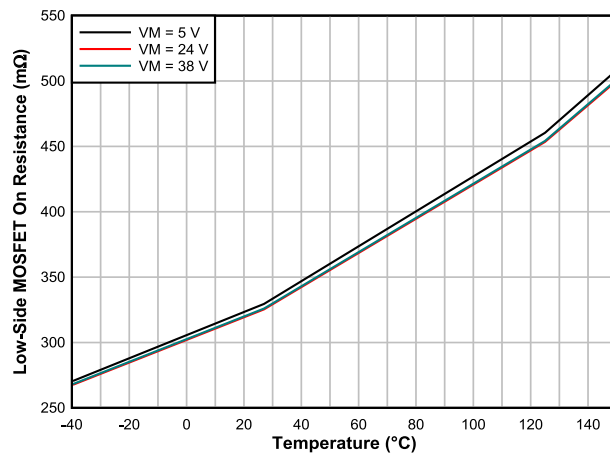


Figure 6-4. Low-Side MOSFET On Resistance (mΩ)

7 Detailed Description

7.1 Overview

The DRV8234 is a high-performance full-bridge motor driver with ripple counting for position detection, motor speed and voltage regulation, stall detection, integrated current sense, and integrated current regulation.

The Ripple Counting feature integrates DC motor relative position and speed detection in the device thereby reducing external components on a PCB and saving cost. The principle is based on counting the number of current ripples appearing in the motor current waveform due to commutations. Motor speed regulation feature maintains constant motor speed over varying battery voltages. The voltage regulation feature saves energy by driving the motor with a programmable lower terminal voltage.

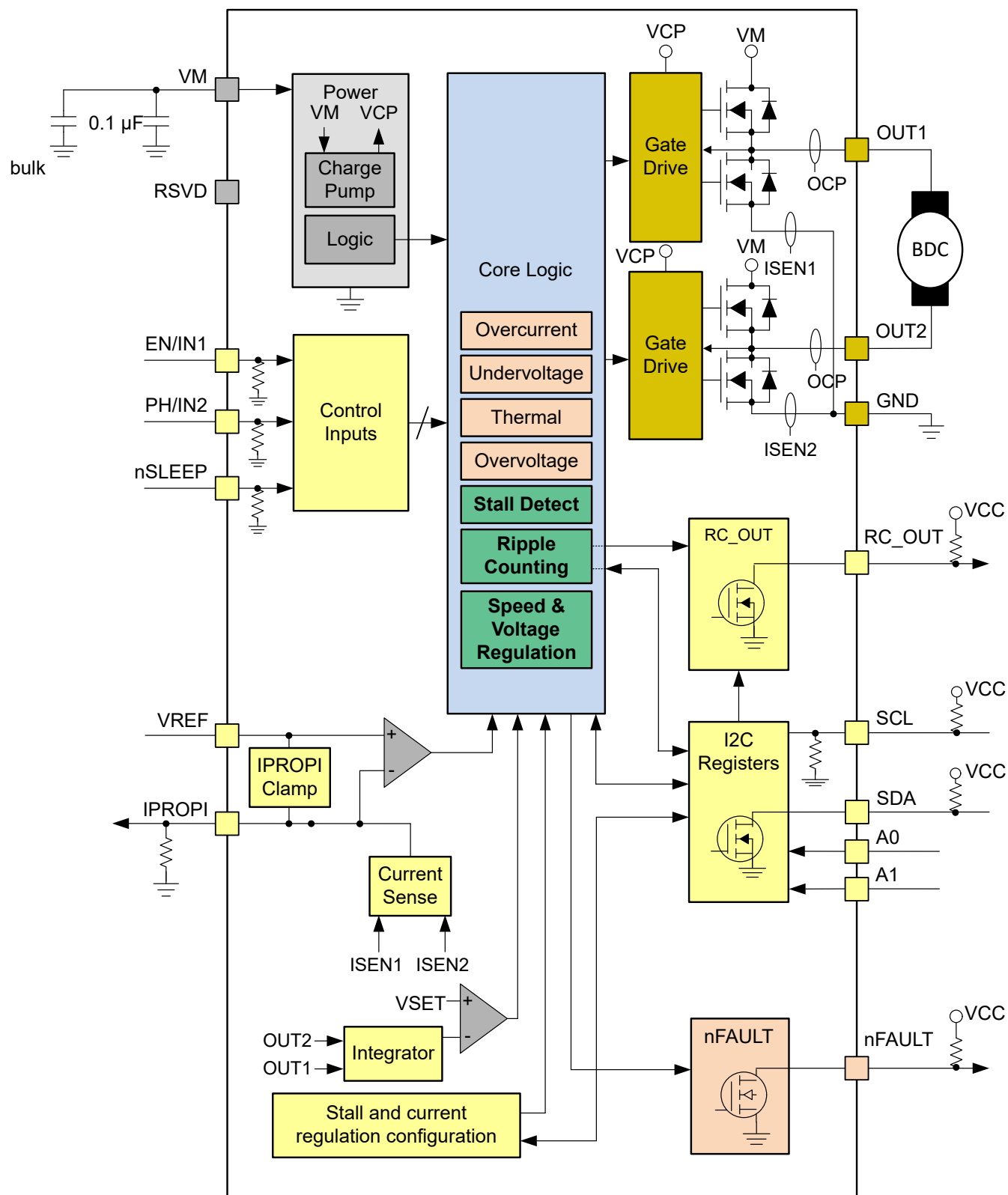
The DRV8234 uses a standard 2-pin (EN/IN1 & PH/IN2) PH/EN-PWM interface and I²C interface for configuration and detailed diagnostics. The EN/IN1 & PH/IN2 pins control the full bridge, which consists of four N-channel MOSFETs that have a typical $R_{DS(ON)}$ of 600 m Ω (including one high-side and one low-side FET). Motor speed can be controlled with pulse-width modulation (PWM), at frequencies between 0 to 200 kHz. The PMODE bit in I²C registers allow operating the H-bridge in two different control modes. I²C interface reduces number of GPIO inputs in high motor-count systems and reduces firmware control effort.

The integrated current regulation feature limits motor current to a predefined maximum based on the VREF and IPROPI settings. The IPROPI signal can provide current feedback to a microcontroller during both the drive and brake/slow-decay states of the H-bridge. The DRV8234 also has I²C programmable registers to configure a hardware stall detection feature based on the IPROPI current sensing signal.

The integrated protection features protect the device in case of a system fault. These include undervoltage lockout (UVLO), overcurrent protection (OCP), and overtemperature shutdown (TSD). Fault conditions are indicated on the nFAULT pin. Additionally, the overvoltage protection (OVP) feature puts the driver into the brake state when the motor is spun manually while the device is in sleep mode or when the H-bridge is disabled. This prevents the back EMF induced high voltages on the supply rail that could potentially damage the driver and other circuits in the system.

To reduce area and external components on a printed circuit board, the device integrates a charge pump regulator and the corresponding capacitors. The nSLEEP pin provides an ultra-low power mode to minimize current draw during system inactivity.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 External Components

Table 7-1 lists the recommended external components for the device.

Table 7-1. Recommended External Components

| COMPONENT | PIN 1 | PIN 2 | RECOMMENDED |
|--------------------------------|--------------------|--------|---|
| C _{VM1} | VM | GND | 0.1-μF, low ESR ceramic capacitor, VM-rated. |
| C _{VM2} | VM | GND | Bulk Capacitance , VM-rated. |
| R _{I_{PROPI}} | I _{PROPI} | GND | Resistor from I _{PROPI} pin to GND, sets the current regulation level. |
| R _{nFAULT} | System VCC | nFAULT | 10 kΩ |
| R _{RC_OUT} | System VCC | RC_OUT | 10 kΩ |
| R _{Pull-up} | SDA, SCL, A0, A1 | VM | 2.2 kΩ |

7.3.2 Summary of Features

This section includes a summary of the key and advanced features of DRV8234.

1. [DRV8234 Functional Block Diagram](#)
2. [Current Sense and Regulation \(I_{PROPI}\)](#)
3. [Bridge Control](#)
4. [Protection](#)
5. Advanced: [Stall Detection](#)
6. Advanced: [Ripple Counting](#)
7. Advanced: [Error Correction](#)
8. Advanced: [Speed and Voltage Regulation](#)
9. Advanced: [Soft-Start and Soft-Stop](#) using t_{INRUSH}

7.3.3 Bridge Control

The DRV8234 output consists of four N-channel MOSFETs designed to drive high current. These outputs are controlled by the two inputs EN/IN1 and PH/IN2 or the I²C bits I2C_EN_IN1 and I2C_PH_IN2.

The I2C_BC bit determines whether the bridge is controlled by the EN/IN1 and PH/IN2 pins or the I2C_EN_IN1 and I2C_PH_IN2 bits, as shown below.

Table 7-2. H-Bridge Control Interface

| I2C_BC | Description |
|--------|--|
| 0b | Bridge control configured by using the EN/IN1 and PH/IN2 pins. |
| 1b | Bridge control configured by using the I2C_EN_IN1 and I2C_PH_IN2 bits. |

The control interface is selected by the PMODE bit, as shown below.

Table 7-3. PMODE Functions

| PMODE | Control Mode |
|-------|--------------|
| 0b | PH/EN |
| 1b | PWM |

The inputs can be set to static voltages for 100% duty cycle drive, or they can be pulse-width modulated (PWM) for variable motor speed. Following diagram shows how the motor current flows through the H-bridge. The input pins can be powered before VM is applied.

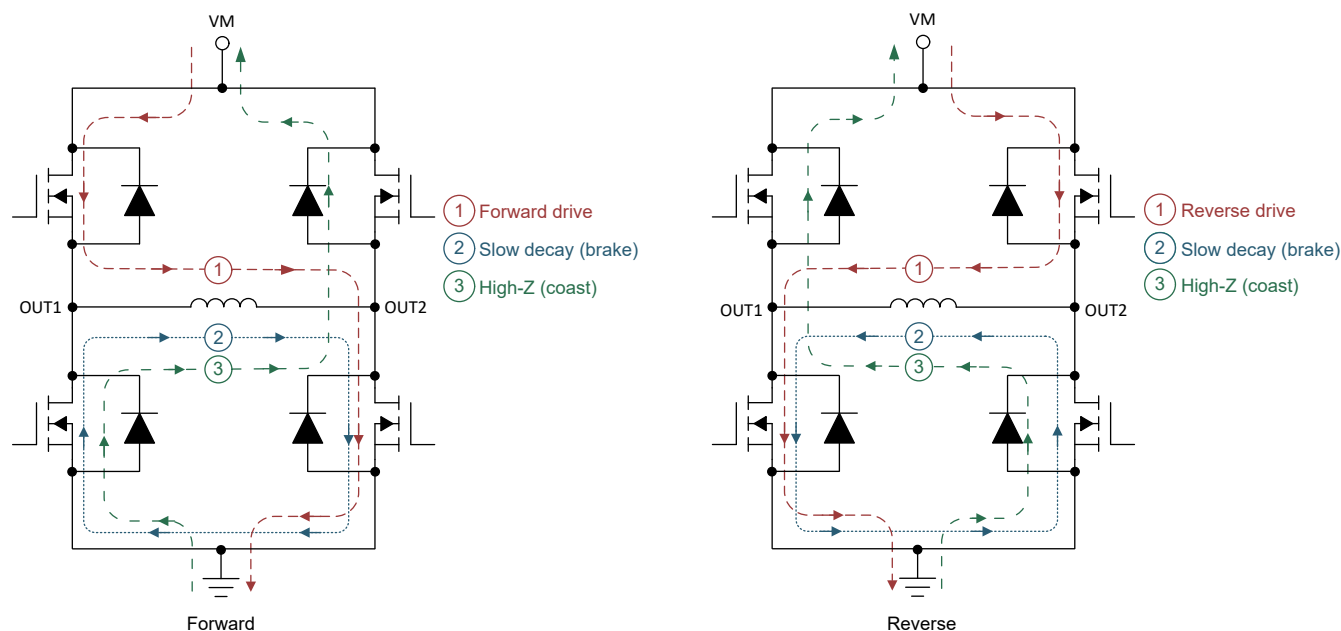


Figure 7-1. H-Bridge Current Paths

The truth tables for each control mode are shown below. Note that these tables do not take into account the internal current regulation feature. Additionally, when an output changes from driving high to driving low (or driving low to driving high), dead time is automatically inserted to prevent shoot-through.

PH/EN mode allows for the H-bridge to be controlled with a speed and direction type of interface. The truth table for PH/EN mode is shown below.

Table 7-4. PH/EN Control Mode (PMODE = 0b)

| nSLEEP | Enable | Phase | OUT1 | OUT2 | Description |
|--------|--------|-------|--------|--------|-------------------------------|
| 0 | X | X | High-Z | High-Z | Sleep Mode (H-bridge High-Z) |
| 1 | 1 | 0 | L | H | Reverse (Current OUT2 → OUT1) |
| 1 | 1 | 1 | H | L | Forward (Current OUT1 → OUT2) |
| 1 | 0 | X | L | L | Brake; low-side slow decay |

Note

Enable refers to the EN pin when bridge control is external (I2C_BC=0b), and the I2C_EN_IN1 bit when bridge control is internal (I2C_BC=1b).

Phase refers to the PH pin when bridge control is external (I2C_BC=0b), and the I2C_PH_IN2 bit when bridge control is internal (I2C_BC=1b).

PWM mode allows for the H-bridge to enter the High-Z state while the device is awake. The truth table for PWM mode is shown below.

Table 7-5. PWM Control Mode (PMODE = 1b)

| nSLEEP | Input1 | Input2 | OUT1 | OUT2 | Description |
|--------|--------|--------|--------|--------|------------------------------|
| 0 | X | X | High-Z | High-Z | Sleep Mode (H-bridge High-Z) |

Table 7-5. PWM Control Mode (PMODE = 1b) (continued)

| nSLEEP | Input1 | Input2 | OUT1 | OUT2 | Description |
|--------|--------|--------|--------|--------|-------------------------------|
| 1 | 0 | 0 | High-Z | High-Z | Coast (H-bridge High-Z) |
| 1 | 0 | 1 | L | H | Reverse (Current OUT2 → OUT1) |
| 1 | 1 | 0 | H | L | Forward (Current OUT1 → OUT2) |
| 1 | 1 | 1 | L | L | Brake; low-side slow decay |

Note

Input1 refers to the IN1 pin when bridge control is external (I2C_BC=0b), and the I2C_EN_IN1 bit when bridge control is internal (I2C_BC=1b).

Input2 refers to the IN2 pin when bridge control is external (I2C_BC=0b), and the I2C_PH_IN2 bit when bridge control is internal (I2C_BC=1b).

The following timing diagram shows the timing of the inputs and outputs of the motor driver.

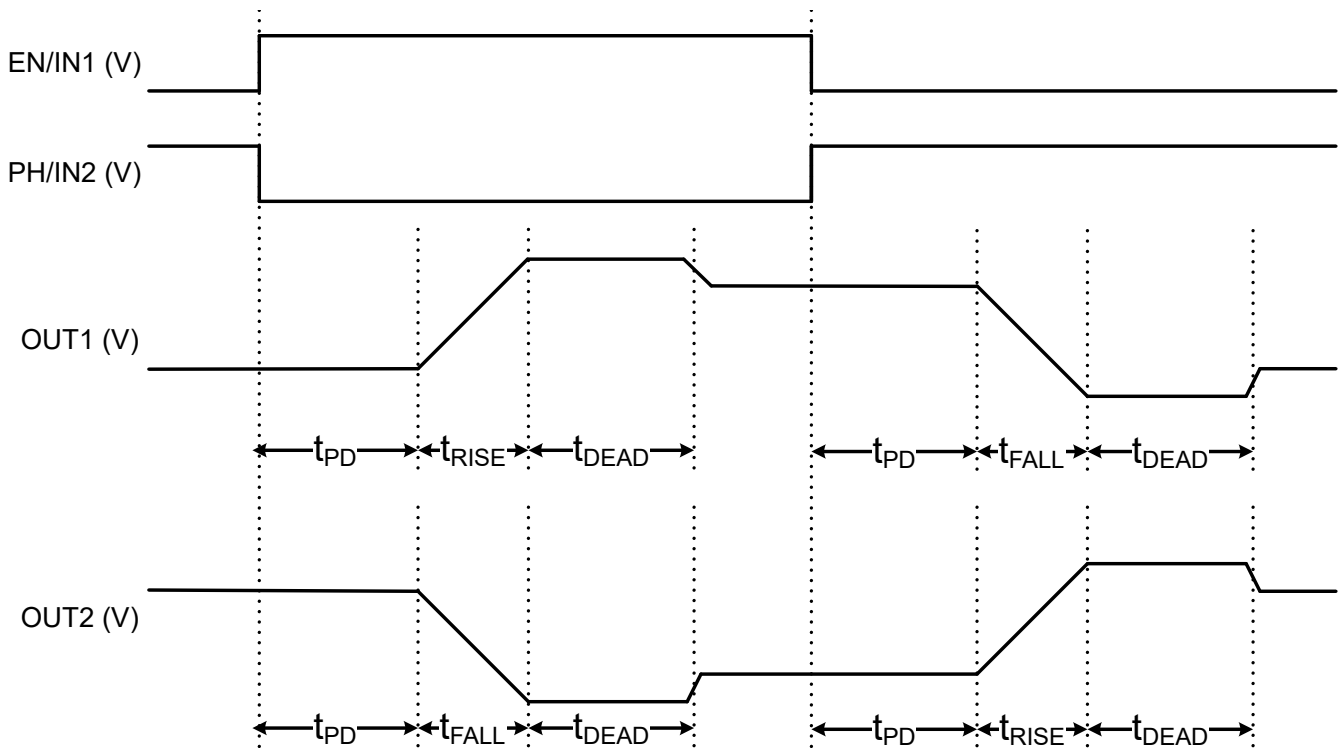


Figure 7-2. H-Bridge Timing Diagram

The t_{DEAD} time is the time in the middle when the output is High-Z. The output pin voltage during t_{DEAD} depends on the direction of the output current. If the current is sourced from the pin, the voltage is a diode voltage drop below ground. If the current is sunk to pin, the voltage is a diode voltage drop above V_M . This diode is the body diode of the high-side or low-side FET.

The propagation delay time (t_{PD}) is measured as the time between an input edge to output change. This time accounts for input deglitch time and other internal logic propagation delays. The input deglitch time prevents noise on the input pins from affecting the output state. Additional output slew delay timing accounts for FET turn on or turn off times (t_{RISE} and t_{FALL}).

7.3.4 Current Sense and Regulation (IPROPI)

The DRV8234 integrates current sensing, regulation, and current sense feedback. The internal current mirror allows the device to sense the output current without an external sense resistor or sense circuitry, thereby reducing system size, cost, and complexity. The current regulation feature allows for the device to limit the output current in case of motor stall or high load torque events. The IPROPI output provides a current output proportional to the load current. This I_{IPROPI} current can be converted to a V_{IPROPI} output voltage by connecting a suitable resistor R_{IPROPI} from this pin to the circuit ground. The following diagram shows the IPROPI timings specified in the Electrical Characteristics table.

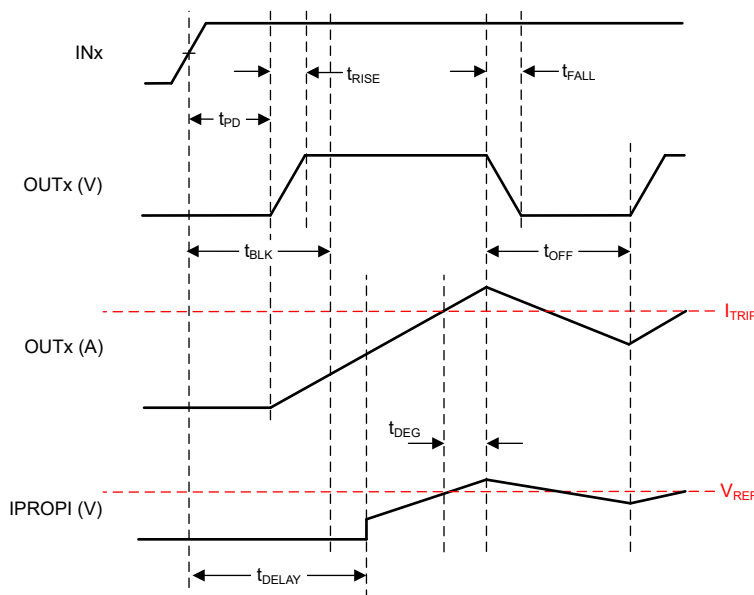


Figure 7-3. Detailed IPROPI Timing Diagram

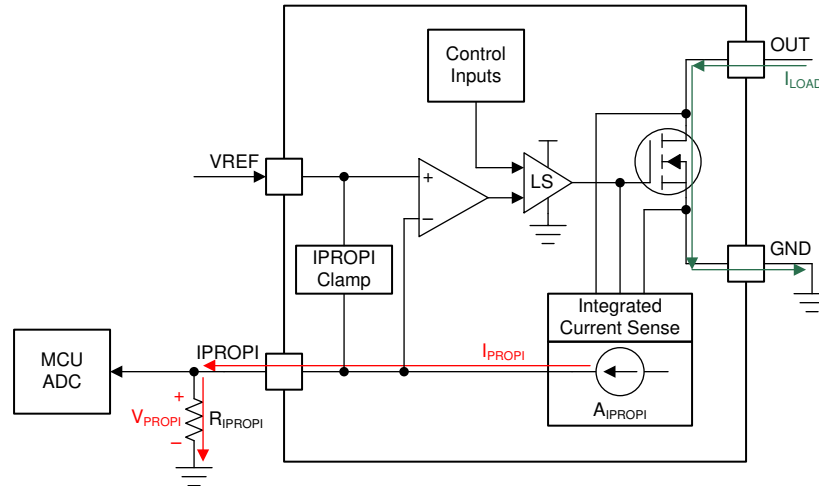
7.3.4.1 Current Sensing

The IPROPI pin outputs an analog current proportional to the current flowing through the low-side power MOSFETs in the H-bridge and scaled by the current mirror gain (A_{IPROPI}). The IPROPI output current can be calculated by the following equation. The I_{LSx} in the equation is only valid when the current flows from drain to source in the low-side MOSFET. If current flows from source to drain or through the body diode, the value of I_{LSx} for that channel is zero. For instance, if the bridge is in the brake, slow-decay state, then the current out of IPROPI is only proportional to the current in one of the low-side MOSFETs.

$$I_{IPROPI} (\mu A) = (I_{LS1} + I_{LS2}) (A) \times A_{IPROPI} (\mu A/A) \quad (1)$$

The A_{ERR} parameter in the Electrical Characteristics table is the error associated with the A_{IPROPI} gain. It indicates the combined effect of offset error added to the I_{OUT} current and gain error. The current mirror gain A_{IPROPI} is fixed at 1500 $\mu A/A$.

The motor current is measured by an internal current mirror architecture on the low-side FETs which removes the need for an external power sense resistor as shown below. The current mirror architecture senses motor winding current in both the drive and brake low-side slow-decay periods, therefore allowing continuous current monitoring in typical bidirectional brushed DC motor applications. In coast mode, the current is freewheeling and cannot be sensed because it flows from source to drain. However, the current can be sampled by briefly reenabling the driver in either drive or slow-decay modes and measuring the current before switching back to coast mode again.



Copyright © 2017, Texas Instruments Incorporated

Figure 7-4. Integrated Current Sensing

The IPROPI pin should be connected to an external resistor (R_{IPROPI}) to ground in order to generate a proportional voltage (V_{IPROPI}) on the IPROPI pin with the I_{IPROPI} analog current output. This allows for the load current to be measured as the voltage drop across the R_{IPROPI} resistor with a standard analog to digital converter (ADC). The R_{IPROPI} resistor can be sized based on the expected load current in the application so that the full range of the controller ADC is utilized. Additionally, the DRV8234 implements an internal IPROPI voltage clamp circuit to limit V_{IPROPI} with respect to V_{VREF} on the VREF pin and protect the external ADC in case of output overcurrent or unexpected high current events. TI recommends designing for at least 1.25 V of headroom between V_{VM} and the maximum V_{IPROPI} voltage to be measured by the ADC, V_{IPROPI_MAX} . This ensures good accuracy across the range of V_{IPROPI} voltages measured by the ADC. For instance, if V_{VM} is 4.55 V to 11 V, V_{IPROPI_MAX} can be as high as 3.3 V. However, if V_{VM} is 3.3 V, then V_{IPROPI} will have good accuracy up to 2.05 V.

The corresponding IPROPI voltage to the output current can be calculated as shown below -

$$V_{IPROPI} (V) = I_{IPROPI} (A) \times R_{IPROPI} (\Omega) \quad (2)$$

The IPROPI output bandwidth is limited by the sense delay time (t_{DELAY}) of the internal current sensing circuit. This time is the delay from the low-side MOSFET enable command (from the INx pins) to the IPROPI output being ready.

If the device is alternating between drive and slow-decay (brake) in an H-bridge PWM pattern then the low-side MOSFET sensing the current is continuously on and the sense delay time has no impact to the IPROPI output. If a command on the INx pins disables the low-side MOSFETs (according to the truth tables), the IPROPI output will disable with the input logic signal. Although the low-side MOSFETs may still conduct current as they disable according to the device slew rate (specified in the Electrical Characteristics table by t_{RISE} time), IPROPI will not represent the current in the low-side MOSFETs during this turnoff time.

7.3.4.2 Current Regulation

The DRV8234 integrates current regulation using either a fixed off-time or a cycle-by-cycle PWM current regulation scheme. This allows the device to limit the output current in case of a motor stall, high torque, or other high current load events autonomously. The current regulation scheme is selectable by the REG_CTRL bit in I²C.

The internal current regulation can be disabled by tying IPROPI to GND and setting the VREF pin voltage greater than GND if current feedback is not required. Additionally, current regulation can also be disabled by setting IMODE to 00b as explained below. If current feedback is required and current regulation is not required, set V_{VREF} and R_{IPROPI} such that V_{IPROPI} never reaches the V_{VREF} threshold. For proper operation of the current

regulation circuit, V_{VREF} must be within the range of the VREF pin voltage specified in the Recommended Operating Conditions table.

Table 7-6. REG_CTRL Functions

| Bit* | Current Regulation Mode |
|------|-------------------------|
| 00b | Fixed Off-Time |
| 01b | Cycle-By-Cycle |

Note

*Additional REG_CTRL options 10b and 11b allow selection between motor voltage or speed regulation described in [Section 7.3.7.2.1](#).

The current regulation threshold (I_{TRIP}) is set through a combination of the VREF voltage (V_{VREF}) and IPROPI output resistor (R_{IPROPI}). This is done by comparing the voltage drop across the external R_{IPROPI} resistor to V_{VREF} with an internal comparator.

$$I_{TRIP} (A) \times A_{IPROPI} (\mu A/A) = V_{VREF} (V) / R_{IPROPI} (\Omega) \quad (3)$$

For example, if $V_{VREF} = 3.3 V$, $R_{IPROPI} = 1100 \Omega$ and $A_{IPROPI} = 1500 \mu A/A$, then I_{TRIP} will be approximately 2 A.

V_{VREF} must be lower than V_{VM} by at least 1.25 V. The maximum recommended value of V_{VREF} is 3.3 V. If INT_VREF bit is set to 1b, V_{VREF} is internally selected with a fixed value of 3 V.

The I_{TRIP} comparator has both a blanking time (t_{BLANK}) and a deglitch time (t_{DEG}). The internal blanking time helps to prevent voltage and current transients during output switching from affecting the current regulation. These transients may be caused by a capacitor inside the motor or motor terminals. The internal deglitch time ensures that transient conditions do not prematurely trigger the current regulation. In certain cases where the transient conditions are longer than the deglitch time, placing a 10-nF capacitor on the IPROPI pin, close to the device, helps filter the transients on IPROPI output so current regulation does not prematurely trigger. The capacitor value can be modified as needed, however large capacitor values may slow down the response time of the current regulation circuit.

The IMODE bits determine the behavior of current regulation for the motor driver.

- When IMODE is 00b, current regulation is disabled.
- When IMODE is 01b, the device performs current regulation only during the t_{INRUSH} time when stall detection is enabled.
- When IMODE is 10b, current regulation is enabled at all times.

The following table summarizes the IMODE bit settings.

Table 7-7. IMODE configuration

| IMODE | EN_STALL | Description |
|-------|----------|---|
| 00b | X | No current regulation at any time |
| 01b | 0b | Current regulation at all times |
| | 1b | Current regulation during t_{INRUSH} only |
| 1Xb | X | Current regulation at all times |

7.3.4.2.1 Fixed Off-Time Current Regulation

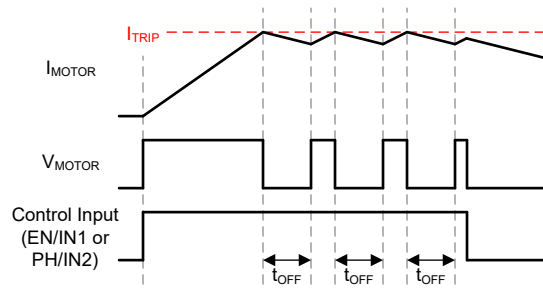


Figure 7-5. Fixed Off-Time Current Regulation

In the fixed off-time mode, the H-bridge enters a brake/low-side slow decay state (both low-side MOSFETs ON) for t_{OFF} duration after I_{OUT} exceeds I_{TRIP} . After t_{OFF} the outputs are re-enabled according to the control inputs unless I_{OUT} is still greater than I_{TRIP} . If I_{OUT} is still greater than I_{TRIP} , the H-bridge will enter another period of brake/low-side slow decay for t_{OFF} . If the state of the EN/IN1 or PH/IN2 control pin inputs or I2C_EN_IN1 or I2C_PH_IN2 bits changes during the t_{OFF} time, the remainder of the t_{OFF} time is ignored, and the outputs will again follow the inputs.

The fixed off-time mode allows for a simple current regulation scheme independent of the external controller. Fixed off-time mode will support 100% duty cycle current regulation since the H-bridge automatically enables after the t_{OFF} period and does not require a new control input edge on the control input pins or bits to reset the outputs.

7.3.4.2.2 Cycle-By-Cycle Current Regulation

In cycle-by-cycle mode, the H-bridge enters a brake, low-side slow decay state (both low-side MOSFETs ON) after I_{OUT} exceeds I_{TRIP} until the next control input edge on either the EN/IN1 or PH/IN2 pins or 0 to 1 transitions on the I2C_EN_IN1 or I2C_PH_IN2 bits. This allows for additional control of the current regulation by the external controller. This is shown in the diagram below. Cycle-by-cycle mode will not support 100% duty cycle current regulation as a new control input edge is required to reset the outputs after the brake, low-side slow decay state has been entered.

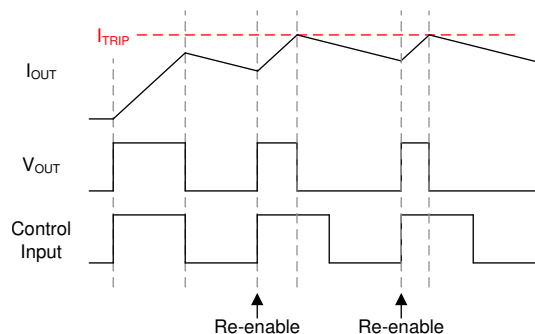


Figure 7-6. Cycle-By-Cycle Current Regulation

In cycle-by-cycle mode, the device can indicate whenever the H-bridge enters internal current regulation by pulling the nFAULT pin low. This can be used to determine when the device outputs will differ from the control inputs or the load has reached the I_{TRIP} threshold. This behavior is controlled by the CBC_REP bit. This is shown in the following diagram. In cycle-by-cycle mode, if the CBC_REP bit is 1b, nFAULT will be pulled low when the H-bridge enters internal current regulation and nFAULT will be released whenever the next control input edge is received by the device and the outputs are reset.

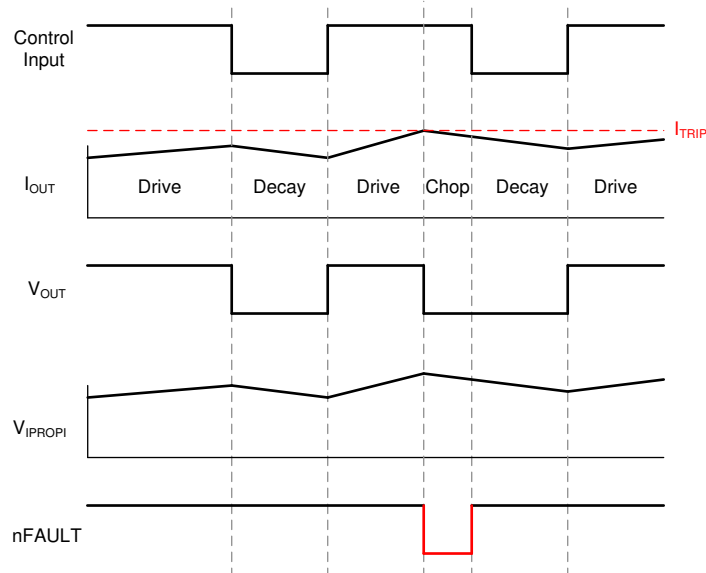


Figure 7-7. Cycle-By-Cycle Current Regulation, CBC_REP = 1b

No device functionality is affected when the nFAULT pin is pulled low for the current regulation indicator. The nFAULT pin is only used as an indicator and the device will continue normal operation. To distinguish a device fault from the current regulation indicator, the nFAULT pin can be compared with the control inputs. The current regulation indicator can only assert when the control inputs are commanding a forward or reverse drive state. If the nFAULT pin is pulled low and the control inputs are commanding the high-Z or slow-decay states, then a device fault has occurred.

7.3.5 Stall Detection

The DRV8234 integrates a stall detection feature. The principle of the stall detection scheme relies on the fact that motor current increases during stall conditions. The DRV8234 compares the voltage on the IPROPI pin to the voltage on the VREF pin or 3 V to determine whether a motor stall condition has occurred. The setting is determined by the INT_VREF register. Table 7-8 shows the configurable options for INT_VREF. The following paragraphs describe how to configure the I²C registers for the desired stall detection response.

Table 7-8. Settings for INT_VREF

| Bit | Description |
|-----|---|
| 0b | V _{VREF} not fixed |
| 1b | V _{VREF} fixed internally at 3 V |

The STALL bit in status register changes to 1b when a motor stall is detected. The EN_STALL bit is used to enable or disable stall detection. The following table summarizes the EN_STALL bit settings.

Table 7-9. EN_STALL configuration

| EN_STALL | Description |
|----------|---|
| 0b | Stall detection disabled. If IMODE = 01b, current regulation occurs at all times when V _{IPROPI} ≥ V _{VREF} . |
| 1b | Stall detection enabled. |

The IPROPI pin provides the current sense signal to the stall detection module. The VREF pin sets the I_{TRIP} current level at which a stall condition is detected. As shown in Table 7-8, V_{VREF} is internally fixed at 3 V when INT_VREF = 1b. When V_{IPROPI} ≥ V_{VREF}, it implies I_{OUT} ≥ I_{TRIP}. The device detects a stall condition here. Stall detection is blanked for a period of time, t_{INRUSH}, to avoid false detection due to high inrush currents during motor startup. The IPROPI and VREF pins also support current regulation, as described earlier.

The TINRUSH[15:0] bits set the period of time the stall detection logic will ignore the inrush current during motor startup (t_{INRUSH}). After t_{INRUSH} time expires, the DRV8234 indicates a stall condition the next instant V_{IPROP} is greater than or equal to V_{VREF} .

When voltage or speed soft-start is disabled, the t_{INRUSH} time directly reflects the setting of the TINRUSH bits. The t_{INRUSH} can be set to a value between 5 ms (corresponding to 0000h) and 6.7 s (corresponding to FFFFh), with a default value of 1 s. Each increment of LSB corresponds to 102.4 μ s of the inrush time.

When voltage or speed soft-start is enabled, target motor voltage or speed is soft-started and soft-stopped for the duration of t_{INRUSH} time. The TINRUSH bits should be setup such that the $t_{INRUSH} = \text{TINRUSH bit setting} \times \text{WSET_VSET}$. For example, if WSET_VSET = 10 and intended inrush time is 1 s, then TINRUSH bit setting should correspond to 100 ms.

The following conditions cause the stall detection scheme to ignore the inrush current for t_{INRUSH} time -

- Power-up of the DRV8234
- Recovering from faults
- After device exits from sleep mode
- After recovering from stall, as explained in [Table 7-10](#)

The SMODE bit programs the device's response to a stall condition. When SMODE = 0b, the outputs disable, and the STALL bit becomes 1b. When SMODE = 1b, the STALL bit becomes 1b, but the outputs continue to drive current into the motor. [Table 7-10](#) summarizes the SMODE bit settings.

Table 7-10. SMODE configuration

| SMODE | Description | Recovery from Stall Condition |
|-------|--|--|
| 0b | Latched disable with indication: the OUTx pins disable and the STALL bit becomes 1b. | A clear fault must be issued by writing 1b to the CLR_FLT bit. STALL bit changes to 0b after a clear fault is issued. After waking up from stall, the stall detection scheme ignores the inrush current for t_{INRUSH} time as described earlier. After t_{INRUSH} time, if motor current is still higher than I_{TRIP} , a stall condition is detected again. |
| 1b | Indication only: the OUTx pins remain active and the STALL bit becomes 1b. | A clear fault must be issued by writing 1b to the CLR_FLT bit to make STALL bit 0b. After t_{INRUSH} time, if motor current is still higher than I_{TRIP} , a stall condition is detected again. |

The **IMODE** bits determine the behavior of current regulation in the motor driver. [Table 7-7](#) summarizes the IMODE pin settings. For more details on current regulation, see [Section 7.3.4.2](#).

The STALL_REP bit determines whether stall is reported on nFAULT pin. When STALL_REP bit is 1b, nFAULT is pulled low whenever stall is detected and STALL bit is 1b. If STALL_REP bit is 0b, stall is not reported on nFAULT output.

The following diagrams show example timing diagrams for different configurations of the hardware stall detection feature.

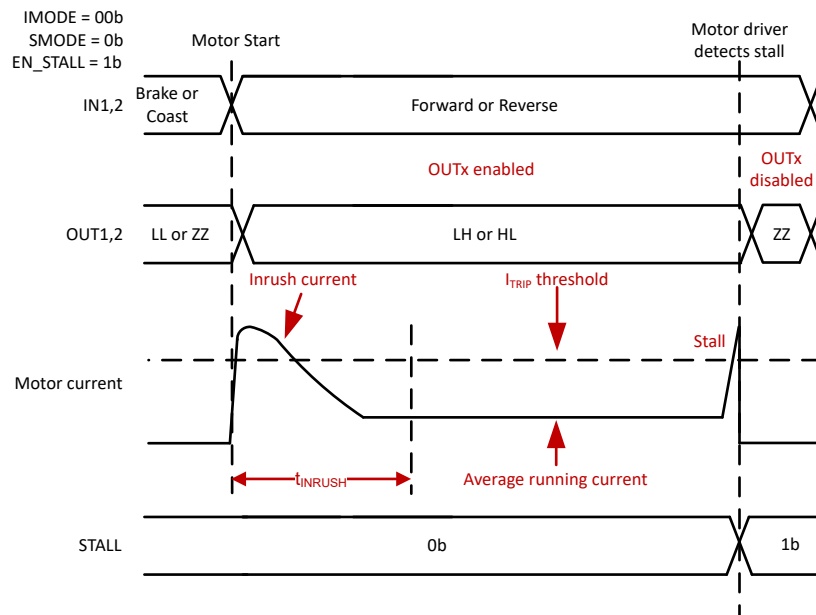


Figure 7-8. Stall Detection with Latched Disable

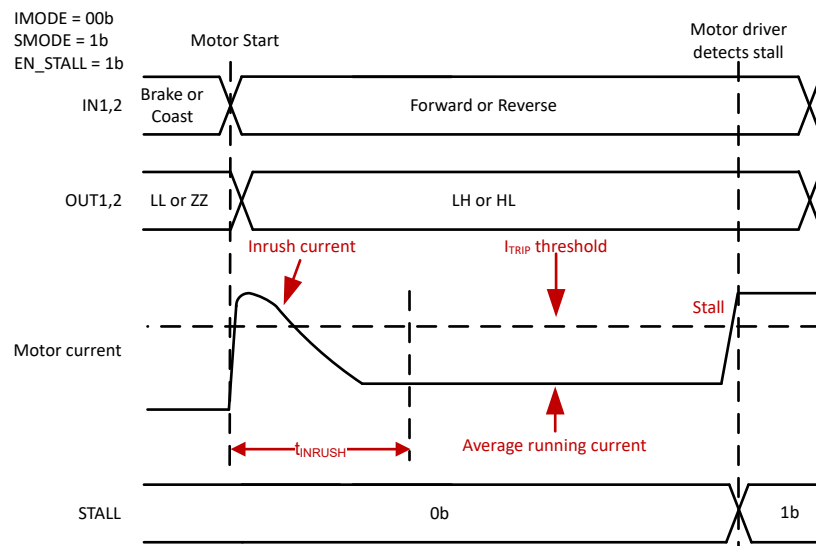


Figure 7-9. Stall Detection with STALL indication only

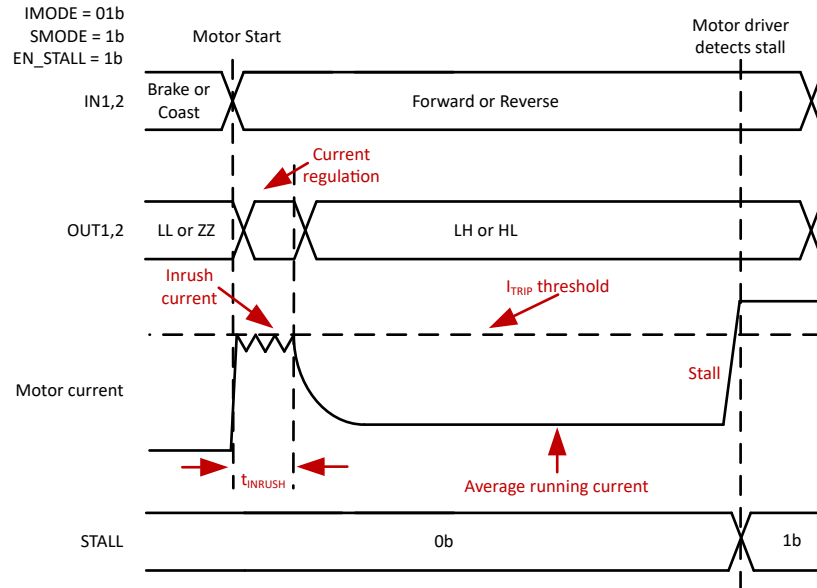


Figure 7-10. Stall Detection with current regulation during inrush

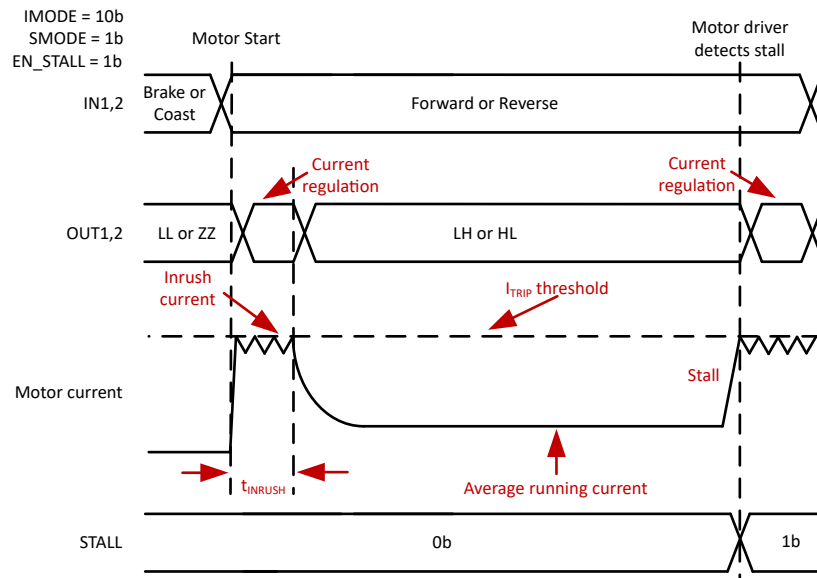


Figure 7-11. Stall Detection with current regulation

7.3.6 Ripple Counting

In applications such as electronic locks and gas valves, it may be required to identify the rotor position or speed of the brushed-DC motor to implement a variety of different functions at the system level. Most systems implement position or speed detection using encoders, limit switches or Hall sensors.

The DRV8234 supports an integrated Ripple counting algorithm to estimate motor position and speed without using any external sensors such as an encoder or a Hall sensor. This enables reduction in system BOM count, BOM cost, and design complexity.

Ripple counting with integrated stall detection allows increased system reliability. For example, in a gas valve system, although the timing of stall detection may change due to changes in temperature and gas pressure, the number of ripples before stall will be same for each actuation. If a stall occurs, but the number of ripples is less than the target value, then this may indicate a loss of position, for example due to a jammed valve.

To enable the ripple counting feature, set EN_RC to 1b.

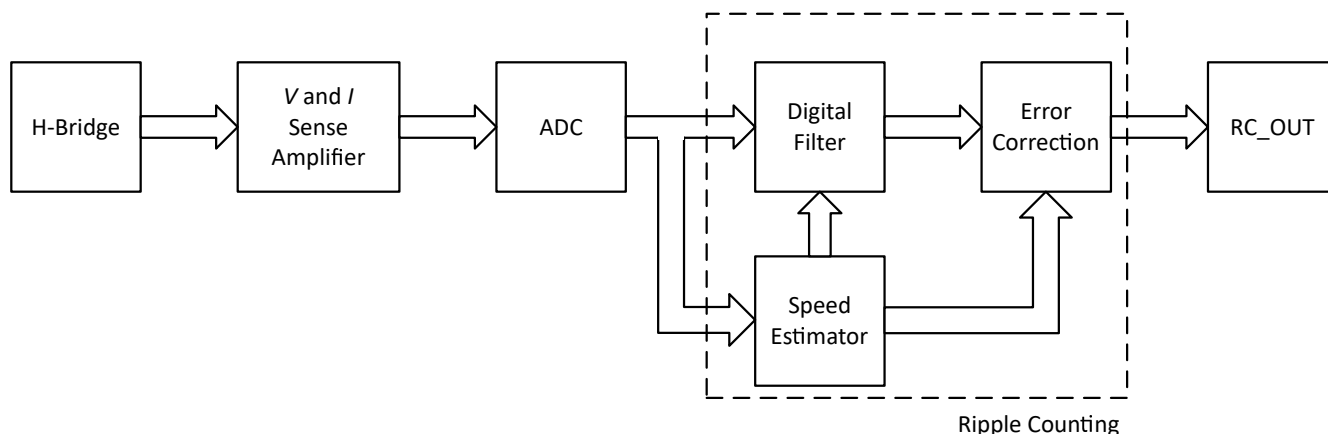


Figure 7-12. Ripple counting block diagram

7.3.6.1 Ripple Counting Parameters

To achieve an accurate ripple count, the following parameters must be configured accurately. Refer to [Section 7.6](#) for additional details. Refer to [Section 8.2.3.1](#) for the detailed tuning procedure.

7.3.6.1.1 Motor Resistance Inverse

Denoted by INV_R, this is the equivalent of the conductance (inverse of resistance) of the motor scaled by a scaling factor, INV_R_SCALE. Scaling allows a wide range of motor resistance values to be accepted using the combination of INV_R and INV_R_SCALE.

7.3.6.1.2 Motor Resistance Inverse Scale

Denoted by INV_R_SCALE, this is the scaling factor for the inverse of motor resistance (INV_R). Since the inverse of a motor resistance is generally not an integer, the value must be rounded off to the nearest integer. Settings are described in [Section 7.3.6.1.2](#).

Table 7-11. Settings for INV_R_SCALE

| Bit | Value of INV_R_SCALE |
|-----|----------------------|
| 00b | 2 |
| 01b | 64 |
| 10b | 1024 |
| 11b | 8192 |

INV_R is represented by the equation:

$$\text{INV_R} = \frac{1}{\text{Motor Resistance}} \times \text{INV_R_SCALE} \quad (4)$$

Please note that the maximum value of INV_R is 255.

7.3.6.1.3 KMC Scaling Factor

Denoted by KMC_SCALE, this is a scaling factor for the parameter KMC. KMC is represented by the following equation:

$$\text{KMC} = \frac{K_V}{N_R} \times \text{KMC_SCALE} \quad (5)$$

Where, K_V is the motor back emf constant and N_R is the number of ripples per revolution. N_R is calculated by taking the LCM (Least Common Multiple) of the number of brushes, N_B , and the number of commutators, N_C :

$$N_R = \text{LCM}(N_B, N_C) \quad (6)$$

Please note that LCM can be easily calculated by using any online LCM calculator.

Tuning KMC appropriately is critical for the ripple counting algorithm to perform accurately. Scaling is done because the value of motor back emf constant is generally small. Scaling allows integer values to be written on to registers.

Table 7-12. Settings for KMC_SCALE

| Bit | Value of KMC_SCALE |
|-----|--------------------|
| 00b | 24×2^8 |
| 01b | 24×2^9 |
| 10b | 24×2^{12} |
| 11b | 24×2^{13} |

7.3.6.1.4 KMC

This register is a motor constant representing a proportional value of the motor back emf constant. See [KMC Tuning](#) for a detailed tuning procedure.

7.3.6.1.5 Filter Damping Constant

Denoted by FLT_K, this parameter represents the quality factor or Q-factor of the band pass filter. Tune this parameter to increase or decrease the bandwidth to accommodate a wider or narrower range of ripple frequencies around the center frequency. Center frequency of the filter is based on the frequency estimation of the ripples in the motor current waveform.

7.3.6.1.6 Filter Input Scaling Factor

Denoted by FLT_GAIN_SEL, this parameter selects the gain for the band pass filter. The gain scales the magnitude of current ripples for ease of detection and algorithmic calculation by the Ripple Counter. Settings are mentioned below.

Table 7-13. Settings for FLT_GAIN_SEL

| Bit | Value of FLT_GAIN_SEL |
|-----|-----------------------|
| 00b | 2 |
| 01b | 4 |
| 10b | 8 |
| 11b | 16 |

7.3.6.1.7 Ripple Count Threshold

Denoted by RC_THR, this parameter represents the threshold setting for the total number of ripple counts vs the total number of ripple counts estimated by the ripple counting algorithm based on the expected time of motor actuation.

Let N_{RT} be the number of ripples at threshold. Then, RC_THR is represented by the equation:

$$N_{RT} = \text{RC_THR} \times \text{RC_THR_SCALE} \quad (7)$$

The parameters further involved in ripple counting threshold are as follows:

1. [RC_CNT](#) is a 16-bit register which corresponds to the number of current ripples counted. When RC_CNT exceeds N_{RT} , CNT_DONE is latched high.
2. [CNT_DONE](#) is a status register that latches high when RC_CNT exceeds N_{RT} . This register can be cleared by using CLR_CNT.
3. [RC_REP](#) decides if nFAULT maintains previous value or is pulled low when RC_CNT exceeds N_{RT} .

4. **CLR_CNT**, when set to 1b, resets N_{RT} to 0 and CNT_DONE to 0b.

7.3.6.1.8 Ripple Count Threshold Scale

Denoted by RC_THR_SCALE, this is the scaling factor for the number of ripples for threshold. Settings are given below.

Table 7-14. Settings for RC_THR_SCALE

| Bit | Value of RC_THR_SCALE |
|-----|-----------------------|
| 00b | 2 |
| 01b | 8 |
| 10b | 16 |
| 11b | 64 |

Depending on the number of ripples per revolution, N_R , and the speed of rotations, RC_THR_SCALE can be chosen high or low based on user requirement of the nFAULT pin. If total number of ripple counts until the end of an operation cycle are low, choose a lower value of RC_THR_SCALE, otherwise a higher value is recommended.

Note

Please note that RC_THR and RC_THR_SCALE do not affect the accuracy of ripple counting.

7.3.6.1.9 T_MECH_FLT

This parameter determines the cut-off frequency of a low pass filter at the output of the ripple counter to control the response time of the ripple counter. Tune this parameter to match the inertia of the entire mechanical system. Increasing the value of this parameter slows down the ripple counter response time; decreasing the value speeds up the response time.

7.3.6.1.10 VSNS_SEL

This parameter is used to select the motor voltage output filtering method (analog or digital) during PWM. The analog filter filters out the noise based on the voltage difference between the output pins. The digital filter multiplies the PWM duty cycle with VM to render an average output voltage. Settings are shown in [Table 7-15](#). When analog filter is selected, the cut-off frequency can be selected by the **OUT_FLT** register.

Table 7-15. Settings for VSNS_SEL

| Bit | Description |
|-----|-----------------------|
| 0b | Analog Output Filter |
| 1b | Digital Output Filter |

7.3.6.1.11 Error Correction

Error correction involves the use of two registers, DIS_EC and EC_PULSE_DIS.

DIS_EC is used to enable/disable the error correction block shown in [Figure 7-12](#). [Table 7-16](#) shows the settings for DIS_EC.

Table 7-16. Settings for DIS_EC

| Bit | Description |
|-----|-------------------------------------|
| 0b | Error Correction block is enabled. |
| 1b | Error Correction block is disabled. |

EC_PULSE_DIS is used to enable/disable the output of the Error Correction block when the Error Correction block is enabled. [Table 7-17](#) describes the settings of EC_PULSE_DIS in detail.

Table 7-17. Settings for EC_PULSE_DIS

| Bit | Status of Error Correction block output |
|-----|--|
| 0b | <p>Output follows settings for DIS_EC as displayed in Table 7-16. If DIS_EC is set to 0b, RC_OUT continues to output pulses even when the motor is:</p> <ul style="list-style-type: none"> Disconnected, Connected but not rotating, or Stalled (depending on the settings for SMODE), if ripple counting is enabled. <p>Please note that the Error Correction block is active in this setting.</p> |
| 1b | <p>Output is disabled if the following two conditions are met:</p> <ol style="list-style-type: none"> Error corrector adds 12 consecutive pulses, and The bandpass filter does not give any pulse output during the time period of the 12 consecutive pulses. <p>Please note that the Error Correction block is active in this setting.</p> |

[Table 7-18](#) summarizes the settings described above.

Table 7-18. Summary of Error Correction

| DIS_EC | EC_PULSE_DIS | Error Corrector Status | Output Pulse Status |
|--------|--------------|------------------------|---|
| 0b | 0b | Enabled | Pulse train output from RC_OUT |
| 0b | 1b | Enabled | No pulses only if Error Corrector adds 12 consecutive pulses and bandpass filter gives no output. |
| 1b | X | Disabled | No Pulses |

7.3.6.1.11.1 EC_FALSE_PER

[EC_FALSE_PER](#) is a 2-bit register that allows the user to select a blanking time window **after** a current ripple is detected. During this time window, the error corrector classifies any passed ripples from the digital filter as extra ripples and does not count them. The time window is represented as a percentage of time between two successive expected current ripples.

7.3.6.1.11.2 EC_MISS_PER

[EC_MISS_PER](#) is a 2-bit register that allows the user to select a time window for when a current ripple is **expected** to be detected. During this time window, the error corrector takes action if an expected current ripple from the digital filter does not arrive. The time window is represented as a percentage of time between two successive expected current ripples.

7.3.6.2 RC_OUT Output

The RC_OUT pin has an open-drain output and is to be pulled up to a 5-V or 3.3-V supply. The RC_OUT pin outputs a pulse train corresponding to the number of ripples in the motor current. The positive pulse width of the pulse train is 50 μ s.

7.3.6.3 Ripple Counting with nFAULT

The DRV8234 allows the nFAULT pin to be configured for various settings of RC_CNT using the RC_REP register. [Table 7-19](#) lists the settings for the RC_REP register (refer to [Section 7.6](#) for details). Timing diagrams corresponding to RC_REP settings are shown in [Figure 7-13](#) and [Figure 7-14](#).

Table 7-19. RC_REP Settings

| RC_REP | nFAULT | RC_CNT |
|--------|---|---|
| 00b | Ripple counting has no effect on nFAULT | If RC_CNT reaches the maximum value of $2^{16} - 1$, it is held at that value until a CLR_CNT command is issued. |
| 01b | Ripple counting has no effect on nFAULT | If RC_CNT reaches the maximum value of $2^{16} - 1$, RC_CNT is cleared and restarted from 0. |
| 10b | nFAULT is pulled low if RC_CNT exceeds threshold | If RC_CNT reaches the maximum value of $2^{16} - 1$, it is held at that value until a CLR_CNT command is issued. |
| 11b | nFAULT is pulled low for 50 μ s if RC_CNT reaches the maximum value of $2^{16} - 1$ | If RC_CNT reaches the maximum value of $2^{16} - 1$, RC_CNT is cleared and restarted from 0. |

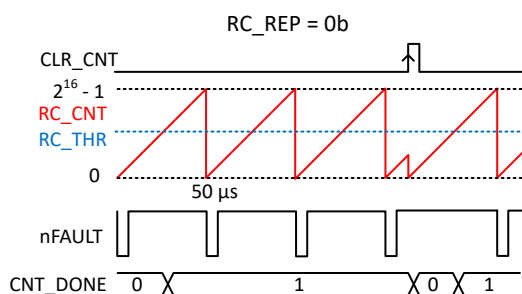


Figure 7-13. Ripple Counting Timing with RC_REP = 11b

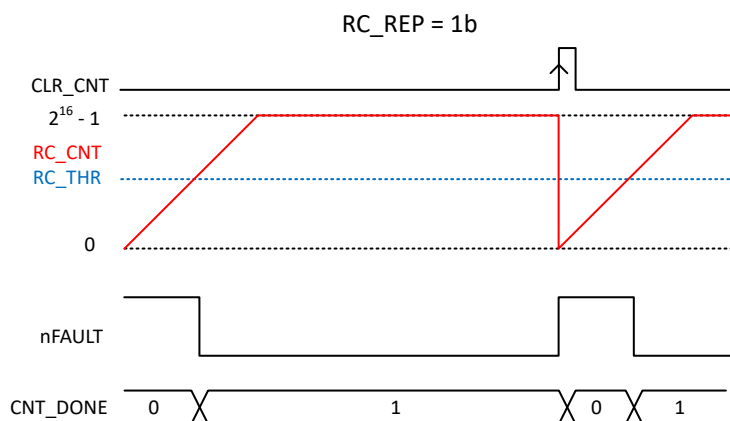


Figure 7-14. Ripple Counting Timing with RC_REP = 10b

7.3.7 Motor Voltage and Speed Regulation

The DRV8234 provides the ability to regulate the voltage applied to the motor winding or to regulate the speed of the motor. This feature allows constant motor speed to be maintained even when operating from a varying supply voltage such as a discharging battery. The DRV8234 uses a pulse-width modulation (PWM) technique instead of a linear circuit to minimize current consumption and maximize battery life.

The intended voltage or speed can be programmed by the WSET_VSET bits. Refer to [Section 7.3.7.2.1](#) for further explanation.

Four ranges of motor speed can be selected using the W_SCALE bits to support low, moderate and high speed applications. The speed regulation loop compares the motor speed estimated by the ripple counting algorithm with the user defined target speed. The following section describes the internal bridge control logic taking voltage regulation as an example, but is also applicable for speed regulation.

Figure 7-15 shows the closed loop PI control for regulating speed and voltage.

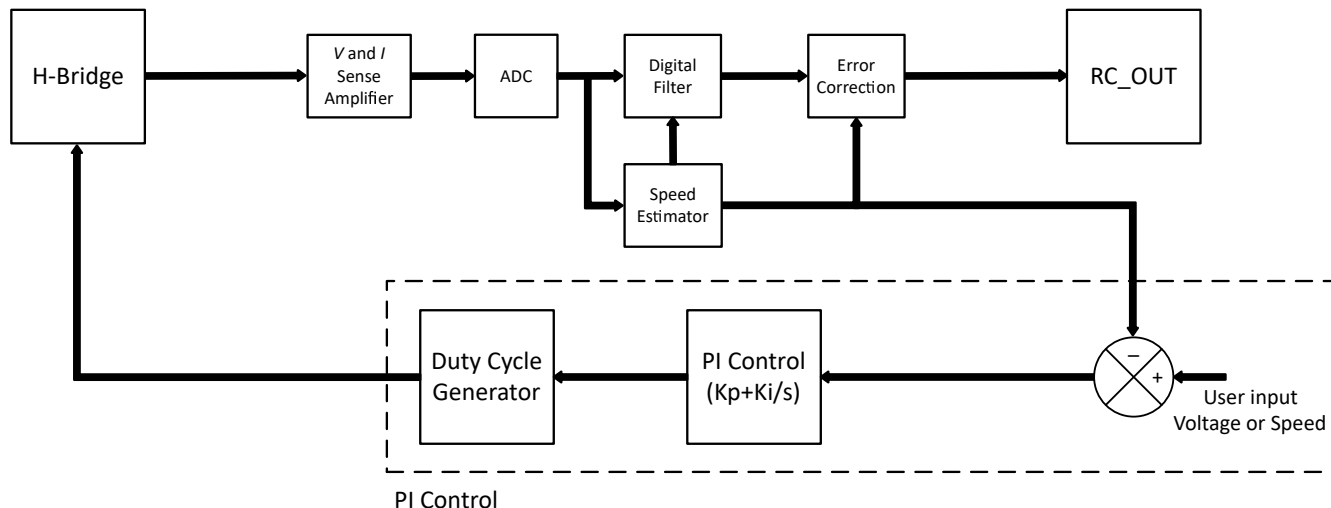


Figure 7-15. Speed and Voltage Regulation with PI Control

7.3.7.1 Internal Bridge Control

For voltage regulation, an internal circuit monitors the voltage difference between the output pins. This voltage difference is integrated over time to get an average DC voltage value. The time depends on the cut-off frequency of the output filter which can be set by the [OUT_FLT](#) register. For best results, choose a cut-off frequency setting equal to at least ten times the PWM frequency.

The DC voltage value is compared to the target motor voltage programmed by the I²C register, [VSET_VSET](#). During voltage as well as speed regulation modes, an internal bridge control scheme is employed. PMODE is used to select the PH/EN mode or the PWM mode.

When Voltage or Speed Regulation mode is active, [DUTY_CTRL](#) must be set to 0b. Bridge control is internal in this case. Duty cycle can be programmed by using the [IN_DUTY](#) register.

- If the averaged output voltage is lower than VSET, the duty cycle of the internal bridge control output is increased.
- If the averaged output voltage is higher than VSET, the duty cycle of the internal bridge control output is decreased.
- During PWM regulation, the H-bridge is enabled to drive current through the motor winding during the PWM on time. The current flow direction depends on the EN/IN1 and PH/IN2 polarity.
- During the PWM off time, winding current is recirculated by enabling both of the low-side FETs in the bridge.
- If the programmed output voltage (VSET) is greater than the VM supply voltage, the device operates at 100% duty cycle and the voltage regulation feature is disabled. In this mode, the device behaves like a conventional H-bridge driver.

Note

The [IN_DUTY](#) register outputs the actual duty cycle of the internal bridge control scheme in voltage regulation mode. [PWM_FREQ](#) sets the PWM frequency for internal PWM generation.

Setting DUTY_CTRL to 1b enables the user to program the duty cycle into EXT_DUTY for external bridge control. For using the internal bridge control scheme, DUTY_CTRL must be set to 0b. IN_DUTY can then be used to program the desired duty cycle.

Table 7-20. PWM_FREQ Settings

| Bit | Value |
|-----|--------|
| 0b | 25 kHz |
| 1b | 50 kHz |

Note

In voltage regulation mode, the motor speed can vary slightly because the voltage drop across the motor coil resistance introduces a small error. The speed regulation mode eliminates this error by directly regulating the target motor speed. To enable speed regulation, the REG_CTRL bit must be set to 10b.

7.3.7.2 Setting Speed/Voltage Regulation Parameters

For obtaining an accurate output from speed and voltage regulation, the following parameters need to be set (for an in-depth explanation, refer to [Section 7.6](#)).

7.3.7.2.1 Speed and Voltage Set

Denoted by WSET_VSET, this parameter helps set the target ripple speed or motor voltage, based on the [REG_CTRL](#) register setting.

When [REG_CTRL](#) is set to 10b, the speed regulation mode is enabled. WSET_VSET is an 8-bit register and can be set to a value between 00h (corresponds to 0 rad/s) and FFh (corresponds to the maximum speed allowable by [W_SCALE](#)). The [speed control loop](#) matches the value of the [SPEED](#) register to the target speed set by WSET_VSET. Please note that the maximum value of the [SPEED](#) register is 255. Also note that:

$$\text{Target Ripple Speed} = \text{SPEED} \times \text{W_SCALE} \quad (8)$$

When [REG_CTRL](#) is set to 11b, the motor voltage regulation mode is enabled. The motor voltage in this case can be set to a value between 0 for 0 V and 255 for approximately 42.67 V drive output voltage. Please note that the maximum value of WSET_VSET is 255. Each bit corresponds to approximately a 0.167 mV resolution of the output voltage setting. Setting WSET_VSET to 255 sets the target voltage to approximately 42.7 V.

For example, if desired target voltage is 5 V, Register Setting Value = $5 \times (255/42.67) = 29.88$. Hence, setting a value of 30 (or 1Eh) outputs approximately 5 V.

Note

1. In practice, the driver's Over Voltage Protection shuts the device down before 42.67 V.
2. The maximum voltage for VM under [Section 6.3](#) is 38 V.
 - a. Recommended to set the target voltage below 38 V for better accuracy.
3. To set the target voltage to 38 V, set WSET_VSET to 227.

7.3.7.2.2 Speed Scaling Factor

Denoted by W_SCALE, this is a scaling factor which helps in setting the target ripple speed when speed regulation mode is enabled. Settings for W_SCALE are shown below. This register also sets the maximum value of ripple speed under each setting of W_SCALE.

Table 7-21. Settings for W_SCALE

| Bit | W_SCALE | Maximum Ripple Speed |
|-----|---------|----------------------|
| 00b | 16 | 4080 rad/s |
| 01b | 32 | 8160 rad/s |
| 10b | 64 | 16320 rad/s |
| 11b | 128 | 32640 rad/s |

Example setting for W_SCALE: If **SPEED** register = 15, W_SCALE = 01b, then the actual ripple speed = $15 \times 32 = 480$ rad/s.

Note

Explanation for Maximum Ripple Speed: W_SCALE inadvertently sets the upper limit for the target ripple speed under that setting of W_SCALE. For example, if W_SCALE = 00b, then the maximum ripple speed under this setting = 255×16 rad/s = 4080 rad/s. Hence, the maximum target speed achievable under this setting is 4080 rad/s. Furthermore, under this setting of W_SCALE, FFh corresponds to 4080 rad/s for WSET_VSET when speed regulation mode is activated (**REG_CTRL**=10b).

7.3.7.3 Soft-Start and Soft-Stop

The DRV8234 integrates a soft-start and stop feature to safeguard the device from high inrush currents during start up. This feature can be activated by setting the EN_SS bit to 1b when the **REG_CTRL** register is set to 10b (Speed Regulation) or 11b (Voltage Regulation). If speed or voltage regulation modes are inactive, the EN_SS bit has no influence on the device performance.

Soft-start comes into effect during motor start up. The motor current is slowly ramped up to the current value corresponding to the target speed over the duration of t_{INRUSH} time. The inrush time t_{INRUSH} can be set by the user via the 16-bit **TINRUSH** register. During this time t_{INRUSH} , the FETs are internally PWMed with a duty cycle generated using the PI control loop.

Soft-stop results in a slow ramp down of motor current in time t_{INRUSH} . This can be triggered by the following methods:

1. The direction of rotation is changed on-the-fly. The soft stop function prevents a high current build-up through the motor windings by ramping down the current slowly and performing soft-start on the other direction.
2. Setting I2C_EN_IN1 and I2C_PH_IN2 to 0. Please note that this method sets outputs to Hi-Z after triggering soft stop, which deviates from conventional device operation where setting inputs to 0 causes the device to immediately go Hi-Z and enter coast mode.
3. Set WSET_VSET to 0x00.

A reference [block diagram](#) containing the PI loop can be found in [Section 7.3.7](#). [Figure 7-16](#) shows the motor current slow ramp up at start up and ramp down at motor stop within time t_{INRUSH} .

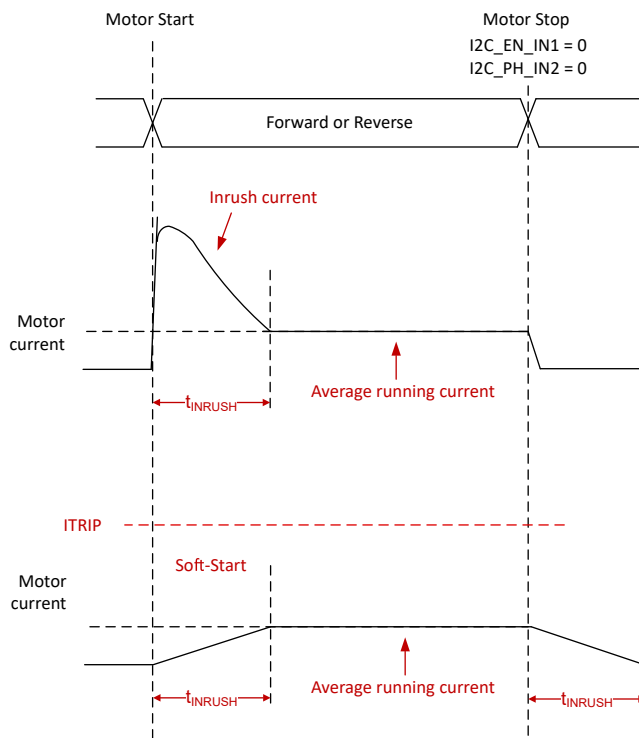


Figure 7-16. Soft Start and Soft Stop

7.3.7.3.1 t_{INRUSH}

The inrush time, t_{INRUSH} , is set using the 16-bit [TINRUSH](#) register. As described earlier, t_{INRUSH} has a dual purpose:

1. t_{INRUSH} is duration of time for which the stall detection scheme ignores the motor inrush current. This prevents false detection of stall during start up. Stall detection is blanked for this duration of time. A detailed description can be found in the [Stall Detection](#) section.
2. Additionally, t_{INRUSH} is also the duration of time for which the soft-start and stop feature ramps up the speed or voltage from 0 to a value set by [WSET_VSET](#), or ramps down the speed or voltage from the existing value to 0.
 - a. When [EN_SS](#) is set to 0b, the [TINRUSH](#) register bit settings directly reflect the t_{INRUSH} time. Time t_{INRUSH} can be set to a value between 5 ms (0000h) and 6.7 s (FFFFh). Default value is 1 s.
 - b. When [EN_SS](#) is set to 1b during motor speed or voltage regulation mode, the target motor speed or voltage is soft-started and stopped over the duration of t_{INRUSH} as describe above. In this case, $t_{INRUSH} = \text{TINRUSH} \times \text{WSET_VSET}$. As an example, if [WSET_VSET](#) = 10 and intended t_{INRUSH} time is 1 s, then [TINRUSH](#) is to be set to 100 ms.

7.3.8 Protection Circuits

The DRV8234 is fully protected against supply undervoltage, overcurrent, and overtemperature events. In addition, the device supports overvoltage protection in sleep mode and when the H-bridge is disabled.

7.3.8.1 Overcurrent Protection (OCP)

An analog current limit circuit on each FET limits the current through the FET by limiting the gate drive internally. If this analog current limit persists for longer than the OCP deglitch time (t_{OCP}), all FETs in the H-bridge will disable, FAULT and OCP bits become 1b and nFAULT is pulled low.

The [OCP_MODE](#) bit programs the response of the device to overcurrent event. The device can either latch-off or perform automatic retry to recover from an overcurrent event.

In automatic retry mode, the MOSFETs will be disabled and the nFAULT pin driven low for a duration of t_{RETRY} . After t_{RETRY} , the MOSFETs are re-enabled according to the control inputs. If the overcurrent condition is still present, the cycle repeats; otherwise normal device operation resumes. This is explained by the following diagram -

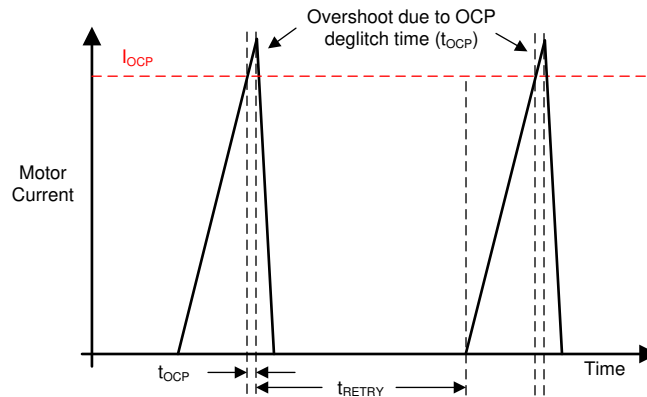


Figure 7-17. OCP Operation

In latch-off mode, the MOSFETs will remain disabled and the nFAULT pin will be driven low until the device is reset by a CLR_FLT command or by cycling the VM power supply.

Overcurrent conditions are detected independently on both high- and low-side FETs. This means that a short to ground, supply, or across the motor winding will all result in an overcurrent shutdown. Overcurrent protection does not use the current sense circuitry used for current regulation, so it functions regardless of VREF and IPROPI settings.

7.3.8.2 Thermal Shutdown (TSD)

If the die temperature exceeds the thermal shutdown temperature threshold (T_{TSD}), all FETs in the H-bridge are disabled, TSD and FAULT bits become 1b, and nFAULT is pulled low. The TSD_MODE bit programs the response of the device to overtemperature event. The device can either latch-off or perform automatic retry to recover from overtemperature.

In automatic retry mode, normal operation will resume (driver operation starts, nFAULT is released and FAULT bit changes to 0b) when the junction temperature falls below the overtemperature threshold limit minus the hysteresis ($T_{TSD} - T_{HYS}$). The TSD bit remains at 1b indicating that a thermal shutdown event occurred until a CLR_FLT command is issued.

In latch-off mode, once the overtemperature condition is removed, normal operation resumes after sending a CLR_FLT command, or a power cycling.

7.3.8.3 VM Undervoltage Lockout (VM UVLO)

If at any time the voltage on the VM pin falls below the UVLO falling threshold voltage:

- All the outputs are disabled (High-Z)
- The internal charge pump is disabled
- nFAULT is driven low

Normal operation resumes when the VM voltage recovers above the UVLO rising threshold.

If the voltage on the VM pin falls below the UVLO falling threshold voltage, but is above the V_{RST} :

- I²C communication is available and the digital core of the device is active
- The FAULT and UVLO bits are made high
- The nFAULT pin is driven low

From this condition, if the VM voltage recovers above the UVLO rising threshold voltage:

- nFAULT pin is released (is pulled-up to the external voltage)

- The FAULT bit is reset
- The UVLO bit remains latched high until cleared through the CLR_FLT command.

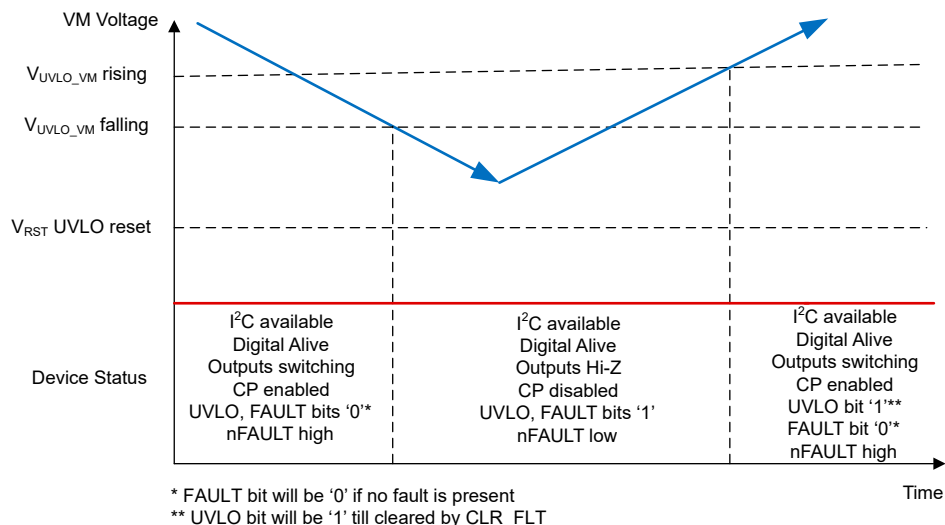


Figure 7-18. Supply Voltage Ramp Profile

When the voltage on the VM pin falls below the V_{RST} :

- I²C communication is unavailable and the digital core is shutdown
- The FAULT and UVLO bits are low
- The nFAULT pin is high

During a subsequent power-up, when the VM voltage exceeds the V_{RST} voltage:

- The digital core comes alive
- UVLO bit stays low
- The FAULT bit is made high
- The nFAULT pin is pulled low
- When the VM voltage exceeds the VM UVLO rising threshold
 - FAULT bit is reset
 - UVLO bit stays low
 - nFAULT pin is pulled high.

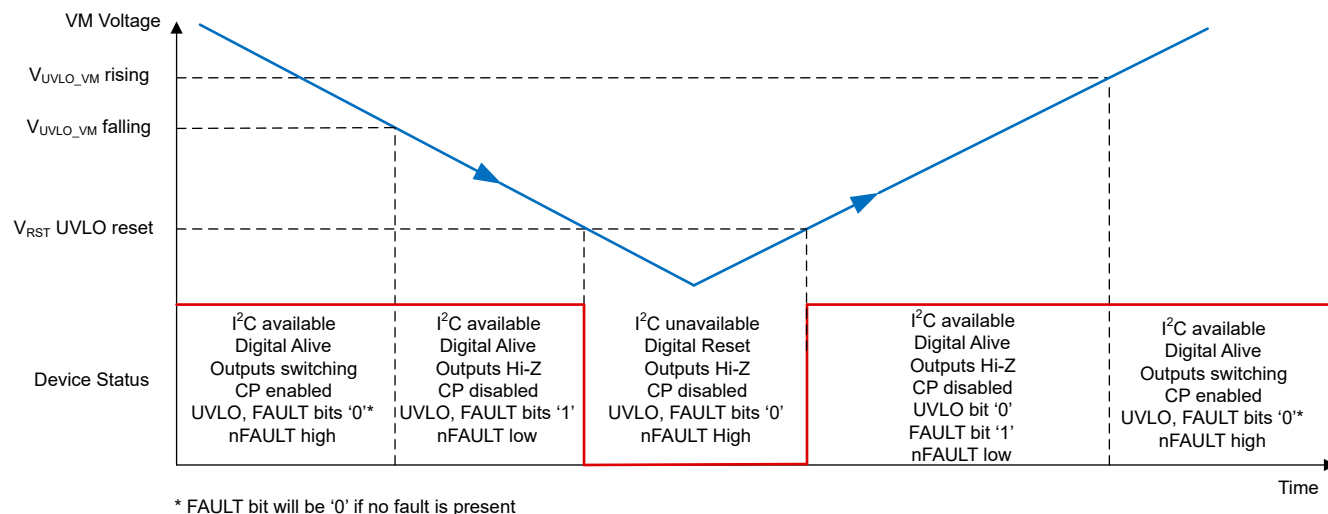


Figure 7-19. Supply Voltage Ramp Profile

7.3.8.4 Overvoltage Protection (OVP)

When the motor is driven by external force, it acts as a generator and pumps back current to the supply voltage rail. This can potentially damage other circuits connected to the supply rail. In low-power sleep mode or when the H-bridge is disabled (High-Z), if the voltage of the output nodes rise above the supply voltage by about 200 mV, the DRV8234 turns on the two low-side MOSFETs. This allows the device to actively brake a motor connected to the outputs by shorting the back emf across the motor terminals.

The overvoltage protection (OVP) function is enabled by default. After power-up, the EN_OVP bit can be made 0b to disable this feature. The EN_OVP logic state is latched, so that in sleep mode the device behaves as per the EN_OVP bit setting, even though the internal digital logic is reset.

In sleep mode, if there is a short circuit to power supply fault present in the power stage, a simple overcurrent detector circuit is provided to disable the low-side MOSFET if a high current event is detected while braking. This is needed since the normal overcurrent protection circuits are disabled during the low-power sleep mode.

7.3.8.5 nFAULT Output

The nFAULT pin has an open-drain output and should be pulled up to a 5-V or 3.3-V supply. nFAULT pin will be high after power-up. When a fault is detected, the nFAULT pin will be logic low.

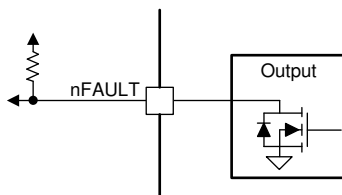


Figure 7-20. nFAULT Pin

7.4 Device Functional Modes

The following table summarizes the DRV8234 functional modes described in this section.

Table 7-22. Modes of Operation

| MODE | CONDITION | H-BRIDGE | INTERNAL CIRCUITS |
|----------------------|-------------------------|-----------|------------------------|
| Active Mode | nSLEEP = 1, EN_OUT = 1b | Operating | Operating |
| Low-Power Sleep Mode | nSLEEP = 0 | Disabled | Disabled |
| Fault Mode | Any fault condition met | Disabled | See Fault Mode section |

7.4.1 Active Mode

After the supply voltage on the VM pin has crossed the rising undervoltage threshold, if nSLEEP is logic high and t_{WAKE} has elapsed, and if the EN_OUT bit is 1b, the device enters active mode. In this mode, the full-bridge, and internal logic are active and the device is ready to receive inputs.

7.4.2 Low-Power Sleep Mode

When the nSLEEP pin is low for $t_{TURNOFF}$ time, the DRV8234 enters a low-power sleep mode. In sleep mode, the outputs remain High-Z and the device draws minimal current from the supply pin. After nSLEEP is set high for longer than the duration of t_{WAKE} , the device becomes fully operational.

7.4.3 Fault Mode

The DRV8234 enters fault mode when it encounters a fault condition. This protects the device and the load on the outputs. Table 7-23 describes the device behavior in the fault mode which depends on the fault condition.

The device will leave the fault mode and re-enter the active mode when the system meets the recovery condition.

Table 7-23. Fault Conditions Summary

| FAULT | FAULT CONDITION | CONFIGURATION | ERROR REPORT | FULL-BRIDGE | INTERNAL CIRCUITS | RECOVERY CONDITION |
|------------------------------|---|---------------|-----------------------------------|-------------|-------------------|---|
| VM undervoltage (VM UVLO) | $V_{VM} < V_{UVLO_VM}$ | – | nFAULT / I ² C | Disabled | Disabled | $V_{VM} > V_{UVLO_VM}$ |
| Overcurrent (OCP) | $I_{OUT} > I_{OCP}$ | OCP_MODE = 0b | nFAULT / I ² C | Disabled | Operating | Latched: CLR_FLT |
| | | OCP_MODE = 1b | nFAULT / I ² C | Disabled | Operating | Automatic retry: t _{RETRY} |
| Thermal Shutdown (TSD) | $T_J > T_{TSD}$ | TSD_MODE = 0b | nFAULT / I ² C | Disabled | Operating | Latched: CLR_FLT |
| | | TSD_MODE = 1b | nFAULT / I ² C | Disabled | Operating | Automatic: $T_J < T_{TSD} - T_{HYS}$ |
| Overvoltage protection (OVP) | OUTx = Hi-Z or nSLEEP = 0; $V_{VOUT} - V_{VM} > V_{SD}$ | – | I ² C when OUTx = Hi-Z | Disabled | Disabled | Automatic: $V_{VOUT} - V_{VM} < V_{SD}$ |

7.5 Programming

7.5.1 I²C Communication

The I²C interface allows control and monitoring of the DRV8234 by a microcontroller. The I²C bus consists of a data line (SDA) and a clock line (SCL) with off-chip pull-up resistors. When the bus is idle, both SDA and SCL lines are pulled high.

A leader device, usually a microcontroller or a digital signal processor, controls the bus. The leader is responsible for generating the SCL signal and device addresses. The leader also generates specific conditions that indicate the START and STOP of data transfer. A follower device receives and/or transmits data on the bus under control of the leader device. DRV8234 is a follower device.

The lower four bits of the device address are derived from the inputs from the pins A1 and A0, which can be tied to board level power supply for logic high, GND for logic low, or left open. These four address bits are latched into the device at power up, so cannot be changed dynamically. The upper address bits of the device address are fixed at 0x60h, so the device address is as follows -

Table 7-24. Device Addresses

| A1 Pin | A0 Pin | A3A2A1A0 bits | ADDRESS (WRITE) | ADDRESS (READ) |
|--------|--------|---------------|-----------------|----------------|
| 0 | 0 | 0000b | 0x60h | 0x61h |
| 0 | High-Z | 0001b | 0x62h | 0x63h |
| 0 | 1 | 0010b | 0x64h | 0x65h |
| High-Z | 0 | 0011b | 0x66h | 0x67h |
| High-Z | High-Z | 0100b | 0x68h | 0x69h |
| High-Z | 1 | 0101b | 0x6Ah | 0x6Bh |
| 1 | 0 | 0110b | 0x6Ch | 0x6Dh |
| 1 | High-Z | 0111b | 0x6Eh | 0x6Fh |
| 1 | 1 | 1000b | 0x70h | 0x71h |

Using the A0 and A1 pins, up to 9 DRV8234 follower devices can be controlled by one I²C bus. The DRV8234 does not respond to the general call address. It is recommended to use a 2.2kΩ pull-up resistor for these pins.

7.5.1.1 I²C Write

To write on the I²C bus, the leader device sends a START condition on the bus with the address of the 7-bit follower device. Also, the last bit (the R/W bit) is set to 0b, which signifies a write. After the follower sends the acknowledge bit, the leader device then sends the register address of the register to be written. The follower device sends an acknowledge (ACK) signal again which notifies the leader device that the follower device is ready. After this process, the leader device sends 8-bit write data and terminates the transmission with a STOP condition.



Figure 7-21. I²C Write Sequence

7.5.1.2 I²C Read

To read from a follower device, the leader device must first communicate to the follower device which register will be read from. This communication is done by the leader starting the transmission similarly to the write process which is by setting the address with the R/W bit equal to 0b (signifying a write). The leader device then sends the register address of the register to be read from. When the follower device acknowledges this register address, the leader device sends a START condition again, followed by the follower address with the R/W bit set to 1b (signifying a read). After this process, the follower device acknowledges the read request and the leader device releases the SDA bus, but continues supplying the clock to the follower device.

During this part of the transaction, the leader device becomes the leader-receiver, and the follower device becomes the follower-transmitter. The leader device continues sending out the clock pulses, but releases the SDA line so that the follower device can transmit data. At the end of the byte, the leader device sends a negative-acknowledge (NACK) signal, signaling to the follower device to stop communications and release the bus. The leader device then sends a STOP condition.

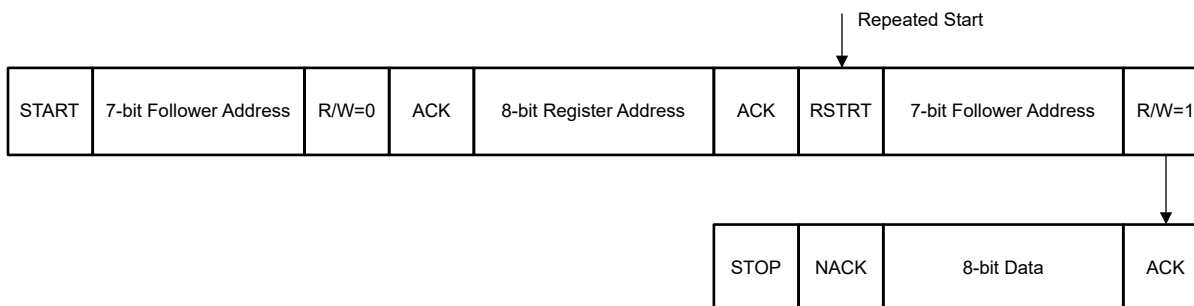


Figure 7-22. I²C Read Sequence

7.6 Register Map

The following table lists the memory-mapped I²C registers for the DRV8234. The I²C registers are used to configure the DRV8234 and for device diagnostics.

Note

Do not modify reserved registers or addresses not listed in the register map ([Table 7-25](#)). Writing to these registers can have unintended effects. For all reserved bits, the default value is 0b.

Table 7-25. I²C Registers

| Address | Name | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Access | |
|---------|-------------|------------------|------------|----------------|-------------------|-----------------------|------------------|----------------|----------------|--------|----|
| 0x00 | FAULT | FAULT | RSVD | STALL | OCP | OVP | TSD | NPOR | CNT_DO NE | R | |
| 0x01 | RC_STATUS1 | SPEED[7:0] | | | | | | | | R | |
| 0x02 | RC_STATUS2 | RC_CNT[7:0] | | | | | | | | R | |
| 0x03 | RC_STATUS3 | RC_CNT[15:8] | | | | | | | | R | |
| 0x04 | REG_STATUS1 | VMTR[7:0] | | | | | | | | R | |
| 0x05 | REG_STATUS2 | IMTR[7:0] | | | | | | | | R | |
| 0x06 | REG_STATUS3 | RSVD | | IN_DUTY[5:0] | | | | | | R | |
| 0x09 | CONFIG0 | EN_OUT | EN_OVP | EN_STAL L | VSNS_S EL* | RSVD | CLR_CN T | CLR_FLT | DUTY_C TRL* | RW | |
| 0x0A | CONFIG1 | TINRUSH[7:0] | | | | | | | | RW | |
| 0x0B | CONFIG2 | TINRUSH[15:8] | | | | | | | | RW | |
| 0x0C | CONFIG3 | IMODE[1:0]* | | SMODE* | INT_VRE F* | TBLANK* | TDEG* | OCP_MO DE* | TSD_MO DE* | RW | |
| 0x0D | CONFIG4 | RC_REP[1:0] | | STALL_R EP | CBC_RE P | PMODE* | I2C_BC* | I2C_EN_I N1 | I2C_PH_I N2 | RW | |
| 0x0E | REG_CTRL0 | RSVD | | EN_SS | REG_CTRL[1:0]* | | PWM_FR EQ* | W_SCALE[1:0] | | RW | |
| 0x0F | REG_CTRL1 | WSET_VSET[7:0] | | | | | | | | RW | |
| 0x10 | REG_CTRL2 | OUT_FLT[1:0] | | EXT_DUTY[5:0] | | | | | | RW | |
| 0x11 | RC_CTRL0 | EN_RC | DIS_EC | RC_HIZ | FLT_GAIN_SEL[1:0] | | CS_GAIN_SEL[2:0] | | | RW | |
| 0x12 | RC_CTRL1 | RC_THR[7:0] | | | | | | | | RW | |
| 0x13 | RC_CTRL2 | INV_R_SCALE[1:0] | | KMC_SCALE[1:0] | | RC_THR_SCALE[1: 0] | | RC_THR[9:8] | | RW | |
| 0x14 | RC_CTRL3 | INV_R[7:0] | | | | | | | | RW | |
| 0x15 | RC_CTRL4 | KMC[7:0] | | | | | | | | RW | |
| 0x16 | RC_CTRL5 | FLT_K[3:0] | | | | RSVD | | | | | RW |
| 0x17 | RC_CTRL6 | EC_PUL SE_DIS | T_MECH_FLT | | | EC_FALSE_PER | | EC_MISS_PER | | RW | |
| 0x18 | RC_CTRL7 | KP_DIV[2:0] | | | KP[4:0] | | | | | RW | |
| 0x19 | RC_CTRL8 | KI_DIV[2:0] | | | KI[4:0] | | | | | RW | |

Note

*Writable only when EN_OUT=0.

Table 7-26. Access Type Codes

| Access Type | Code | Description |
|------------------------|------|-------------|
| Read Type | | |
| R | R | Read |
| Write Type | | |
| W | W | Write |
| Reset or Default Value | | |

Table 7-26. Access Type Codes (continued)

| Access Type | Code | Description |
|-------------|------|--|
| -n | | Value after reset or the default value |

7.6.1 DRV8234_STATUS Registers

Table 7-27 lists the memory-mapped registers for the DRV8234_STATUS registers. All register offset addresses not listed in Table 7-27 should be considered as reserved locations and the register contents should not be modified.

Table 7-27. DRV8234_STATUS Registers

| Offset | Acronym | Register Name | Section |
|--------|-------------|---------------------------------------|---------------------------------|
| 0h | FAULT | Various fault registers' status. | Section 7.6.1.1 |
| 1h | RC_STATUS1 | Ripple Counting Status Registers - 1. | Section 7.6.1.2 |
| 2h | RC_STATUS2 | Ripple Counting Status Registers - 2. | Section 7.6.1.3 |
| 3h | RC_STATUS3 | Ripple Counting Status Registers - 3. | Section 7.6.1.4 |
| 4h | REG_STATUS1 | Regulation Status Registers - (1/3). | Section 7.6.1.5 |
| 5h | REG_STATUS2 | Regulation Status Registers - (2/3). | Section 7.6.1.6 |
| 6h | REG_STATUS3 | Regulation Status Registers - (3/3). | Section 7.6.1.7 |

Complex bit access types are encoded to fit into small table cells. Table 7-28 shows the codes that are used for access types in this section.

Table 7-28. DRV8234_STATUS Access Type Codes

| Access Type | Code | Description |
|------------------------|------|--|
| Read Type | | |
| R | R | Read |
| Reset or Default Value | | |
| -n | | Value after reset or the default value |

7.6.1.1 FAULT Register (Offset = 0h) [Reset = 00h]

FAULT is shown in [Table 7-29](#).

Return to the [Summary Table](#).

Status of various fault and protection bits.

Table 7-29. FAULT Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|----------|------|-------|--|
| 7 | FAULT | R | 0h | 0b during normal operation, 1b during a fault condition. nFAULT pin is pulled down when FAULT bit is 1b. nFAULT pin is released during normal operation. |
| 6 | RSVD | R | 0h | Reserved. |
| 5 | STALL | R | 0h | When this bit is 1b, it indicates motor stall. |
| 4 | OCP | R | 0h | 0b during normal operation, 1b if OCP event occurs. |
| 3 | OVP | R | 0h | 0b during normal operation, 1b if OVP event occurs. |
| 2 | TSD | R | 0h | 0b during normal operation, 1b if TSD event occurs. |
| 1 | NPOR | R | 0h | Reset and latched low if VM>VUVLO. Remains reset until the CLR_FLT bit is set to issue a clear fault command. After power up, automatically latched high once CLR_FLT command is issued. Refer to Section 7.3.8.3 for further explanation. |
| 0 | CNT_DONE | R | 0h | Status flag. Latched high when RC_CNT exceeds the ripple counting threshold. Can be cleared by CLR_CNT command. |

7.6.1.2 RC_STATUS1 Register (Offset = 1h) [Reset = 00h]

RC_STATUS1 is shown in [Table 7-30](#).

Return to the [Summary Table](#).

Speed estimated by the ripple counting algorithm.

Table 7-30. RC_STATUS1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|---|
| 7-0 | SPEED | R | 0h | Outputs the motor speed estimated by the ripple counting algorithm. |

7.6.1.3 RC_STATUS2 Register (Offset = 2h) [Reset = 00h]

RC_STATUS2 is shown in [Table 7-31](#).

Return to the [Summary Table](#).

Output corresponding to number of current ripples (1/2).

Table 7-31. RC_STATUS2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|--|
| 7-0 | RC_CNT_7:0 | R | 0h | Lower half 8-bit output out of the 16-bit output of the ripple counter corresponding to the number of current ripples. |

7.6.1.4 RC_STATUS3 Register (Offset = 3h) [Reset = 00h]

RC_STATUS3 is shown in [Table 7-32](#).

Return to the [Summary Table](#).

Output corresponding to number of current ripples (2/2).

Table 7-32. RC_STATUS3 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------------|------|-------|--|
| 7-0 | RC_CNT_15:8 | R | 0h | Upper half 8-bit output out of the 16-bit output of the ripple counter corresponding to the number of current ripples. |

7.6.1.5 REG_STATUS1 Register (Offset = 4h) [Reset = 00h]

REG_STATUS1 is shown in [Table 7-33](#).

Return to the [Summary Table](#).

Value corresponding to the output voltage across the motor terminals.

Table 7-33. REG_STATUS1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|--|
| 7-0 | VMTR | R | 0h | Outputs the voltage across the motor terminals, maximum value FFh. 00h corresponds to 0 V and E4h corresponds to 38 V. |

7.6.1.6 REG_STATUS2 Register (Offset = 5h) [Reset = 00h]

REG_STATUS2 is shown in [Table 7-34](#).

Return to the [Summary Table](#).

Output corresponding to current flowing through the motor.

Table 7-34. REG_STATUS2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|---|
| 7-0 | IMTR | R | 0h | Outputs the current flowing through the motor. 00h corresponds to 0 A and C0h corresponds to the maximum value set by the CS_GAIN_SEL bits. |

7.6.1.7 REG_STATUS3 Register (Offset = 6h) [Reset = 00h]

REG_STATUS3 is shown in [Table 7-35](#).

Return to the [Summary Table](#).

Internal pwm duty cycle and device id.

Table 7-35. REG_STATUS3 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|---------|------|-------|--|
| 7-6 | RSVD | R | 0h | Reserved. |
| 5-0 | IN_DUTY | R | 0h | Represents the bridge control duty cycle generated by an internal regulation logic. This register is applicable when speed or voltage regulation is activated. When speed or voltage regulation is inactive, set DUTY_CTRL to 1b and program the duty cycle in EXT_DUTY explained later. The range of duty cycle is 0% (000000b) to 100% (111111b). Refer to Section 7.3.7.1 for further explanation on the internal PWM generation scheme. |

7.6.2 DRV8234_CONFIG Registers

Table 7-36 lists the memory-mapped registers for the DRV8234_CONFIG registers. All register offset addresses not listed in Table 7-36 should be considered as reserved locations and the register contents should not be modified.

Table 7-36. DRV8234_CONFIG Registers

| Offset | Acronym | Register Name | Section |
|--------|---------|---|---------------------------------|
| 9h | CONFIG0 | Configuration Registers - Faults (1/5). | Section 7.6.2.1 |
| Ah | CONFIG1 | Configuration Registers - (2/5). | Section 7.6.2.2 |
| Bh | CONFIG2 | Configuration Registers - (3/5). | Section 7.6.2.3 |
| Ch | CONFIG3 | Configuration Registers - (4/5). | Section 7.6.2.4 |
| Dh | CONFIG4 | Configuration Registers - (5/5). | Section 7.6.2.5 |

Complex bit access types are encoded to fit into small table cells. Table 7-37 shows the codes that are used for access types in this section.

Table 7-37. DRV8234_CONFIG Access Type Codes

| Access Type | Code | Description |
|------------------------|------|--|
| Read Type | | |
| R | R | Read |
| Write Type | | |
| W | W | Write |
| Reset or Default Value | | |
| -n | | Value after reset or the default value |

7.6.2.1 CONFIG0 Register (Offset = 9h) [Reset = 60h]

CONFIG0 is shown in [Table 7-38](#).

Return to the [Summary Table](#).

Enable/Disable various faults like OCP, OVP, STALL, etc.

Table 7-38. CONFIG0 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-----------|------|-------|--|
| 7 | EN_OUT | R/W | 0h | 0b: All driver FETs are Hi-Z. 1b: Enables the driver outputs. |
| 6 | EN_OVP | R/W | 1h | Enables the OVP feature. 1b by default, can be made 0b after power-up to disable the OVP feature. Refer to Section 7.3.8.4 for further explanation. |
| 5 | EN_STALL | R/W | 1h | Enables the Stall Detection feature. Stall detection feature can be disabled by setting this bit to 0b. Refer to EN_STALL configuration under Section 7.3.5 for further explanation. |
| 4 | VSNS_SEL | R/W | 0h | 0b: Use the analog low-pass filter to average out the output voltage for voltage regulation. Refer to OUT_FLT for further description of the analog low-pass filter. 0b is the recommended value. 1b: Use the digital low-pass filter for voltage regulation. This option performs multiplication of the duty cycle with VM to obtain the output voltage. |
| 3 | RSVD | R | 0h | Reserved |
| 2 | CLR_CNT | R/W | 0h | Resets the ripple counter to 0, and resets CNT_DONE. Also releases nFAULT when RC_REP = 10b. CLR_CNT is automatically reset. |
| 1 | CLR_FLT | R/W | 0h | Clears all latched faults when set to 1b. CLR_FLT is automatically reset. |
| 0 | DUTY_CTRL | R/W | 0h | When speed regulation is disabled and the DUTY_CTRL bit is 1b, user can write desired PWM duty to EXT_DUTY bits. The range of duty is 0% (000000b) to 100% (111111b). |

7.6.2.2 CONFIG1 Register (Offset = Ah) [Reset = 00h]

CONFIG1 is shown in [Table 7-39](#).

Return to the [Summary Table](#).

Configure the inrush time (1/2).

Table 7-39. CONFIG1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------------|------|-------|---|
| 7-0 | TINRUSH_7:0 | R/W | 0h | Lower half 8-bit output out of the total 16-bit output for inrush time blanking for stall detection. Sets the amount of time for which the stall detection scheme ignores motor inrush current. Refer to Section 7.3.7.3.1 for further explanation. |

7.6.2.3 CONFIG2 Register (Offset = Bh) [Reset = 00h]

CONFIG2 is shown in [Table 7-40](#).

Return to the [Summary Table](#).

Configure the inrush time (2/2).

Table 7-40. CONFIG2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------------|------|-------|---|
| 7-0 | TINRUSH_15:8 | R/W | 0h | Upper half 8-bit output out of the total 16-bit output for inrush time blanking for stall detection. Sets the amount of time for which the stall detection scheme ignores motor inrush current. Refer to Section 7.3.7.3.1 for further explanation. |

7.6.2.4 CONFIG3 Register (Offset = Ch) [Reset = 63h]

CONFIG3 is shown in [Table 7-41](#).

Return to the [Summary Table](#).

Enable/Disable various device modes like IMODE, SMODE and parameters like blanking time.

Table 7-41. CONFIG3 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|----------|------|-------|--|
| 7-6 | IMODE | R/W | 1h | Determines the behavior of current regulation. Refer to IMODE configuration under Section 7.3.4.2 for further explanation. |
| 5 | SMODE | R/W | 1h | Programs device response to a stall condition. Refer to SMODE configuration under Section 7.3.5 for further explanation. |
| 4 | INT_VREF | R/W | 0h | If set to 1b, sets VREF voltage to 3 V internally. Voltage is not fixed if INT_VREF is set to 0b. Refer to Section 7.3.5 for further explanation. |
| 3 | TBLANK | R/W | 0h | Sets the current sense blanking time. If set to 0b, $t_{BLANK}=1.8\mu s$. If set to 1b, $t_{BLANK}=1.0\mu s$. |
| 2 | TDEG | R/W | 0h | Sets the current regulation and stall detection deglitch time. If set to 0b, $t_{DEG}=2\mu s$. If set to 1b, $t_{DEG}=1\mu s$. |
| 1 | OCP_MODE | R/W | 1h | Programs device response to an overcurrent event. If set to 0b, device is latched off in case of an OCP event. Can be cleared using CLR_FLT. If set to 1b, device performs auto-retry after time t_{retry} in case of an OCP event. Refer to Section 7.3.8.1 for further explanation. |
| 0 | TSD_MODE | R/W | 1h | Programs device response to an overtemperature event. If set to 0b, device is latched off in case of a TSD event. If set to 1b, device performs auto-retry when $T_J < T_{TSD} - T_{HYS}$. |

7.6.2.5 CONFIG4 Register (Offset = Dh) [Reset = 38h]

CONFIG4 is shown in [Table 7-42](#).

Return to the [Summary Table](#).

Configure the report registers like RC_REP and STALL_REP.

Table 7-42. CONFIG4 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|--|
| 7-6 | RC_REP | R/W | 0h | Determines whether nFAULT is pulled low when RC_CNT exceeds threshold, and the behavior of RC_CNT when it reaches maximum value of ($2^{16}-1$). Refer to RC_REP Settings under Section 7.3.6.3 for further explanation. |
| 5 | STALL_REP | R/W | 1h | Determines whether stall is reported on the nFAULT pin. When set to 1b, nFAULT is low whenever stall is detected. When set to 0b, stall is not reported on nFAULT output. Refer to Section 7.3.5 for further explanation. |
| 4 | CBC_REP | R/W | 1h | When REG_CTRL is set to 01b, the device enters cycle-by-cycle mode of current regulation. In this mode, the device can indicate whenever the H-bridge enters internal current regulation. CBC_REP bit is used to determine device outputs' behavior in the cycle-by-cycle mode. 1b: nFAULT is pulled low when H-Bridge enters internal current regulation. 0b: nFAULT is not pulled low when H-Bridge enters internal current regulation. Refer to Section 7.3.4.2.2 for further explanation. |
| 3 | PMODE | R/W | 1h | Switch between phase/enable mode and PWM mode. 0b: PH/EN. 1b: PWM. |
| 2 | I2C_BC | R/W | 0h | Decides the H-Bridge Control Interface. 0b: Bridge control configured by INx pins. 1b: Bridge control configured by I2C bits I2C_EN_IN1 and I2C_PH_IN2. |
| 1 | I2C_EN_IN1 | R/W | 0h | Enable/PWM Input Bit 1 for internal bridge control. Used when I2C_BC=1b. Ignored when I2C_BC=0b. |
| 0 | I2C_PH_IN2 | R/W | 0h | Phase/PWM Input Bit 2 for internal bridge control. Used when I2C_BC=1b. Ignored when I2C_BC=0b. |

7.6.3 DRV8234_CTRL Registers

Table 7-43 lists the memory-mapped registers for the DRV8234_CTRL registers. All register offset addresses not listed in Table 7-43 should be considered as reserved locations and the register contents should not be modified.

Table 7-43. DRV8234_CTRL Registers

| Offset | Acronym | Register Name | Section |
|--------|-----------|--|----------------------------------|
| Eh | REG_CTRL0 | Regulation control registers (1/3). | Section 7.6.3.1 |
| Fh | REG_CTRL1 | Regulation control registers (2/3). | Section 7.6.3.2 |
| 10h | REG_CTRL2 | Regulation control registers (3/3). | Section 7.6.3.3 |
| 11h | RC_CTRL0 | Ripple Counting Control Registers - (1/9). | Section 7.6.3.4 |
| 12h | RC_CTRL1 | Ripple Counting Control Registers - (2/9). | Section 7.6.3.5 |
| 13h | RC_CTRL2 | Ripple Counting Control Registers - (3/9). | Section 7.6.3.6 |
| 14h | RC_CTRL3 | Ripple Counting Control Registers - (4/9). | Section 7.6.3.7 |
| 15h | RC_CTRL4 | Ripple Counting Control Registers - (5/9). | Section 7.6.3.8 |
| 16h | RC_CTRL5 | Ripple Counting Control Registers - (6/9). | Section 7.6.3.9 |
| 17h | RC_CTRL6 | Ripple Counting Control Registers - (7/9). | Section 7.6.3.10 |
| 18h | RC_CTRL7 | Ripple Counting Control Registers - (8/9). | Section 7.6.3.11 |
| 19h | RC_CTRL8 | Ripple Counting Control Registers - (9/9). | Section 7.6.3.12 |

Complex bit access types are encoded to fit into small table cells. Table 7-44 shows the codes that are used for access types in this section.

Table 7-44. DRV8234_CTRL Access Type Codes

| Access Type | Code | Description |
|------------------------|------|--|
| Read Type | | |
| R | R | Read |
| Write Type | | |
| W | W | Write |
| Reset or Default Value | | |
| -n | | Value after reset or the default value |

7.6.3.1 REG_CTRL0 Register (Offset = Eh) [Reset = 27h]

REG_CTRL0 is shown in [Table 7-45](#).

Return to the [Summary Table](#).

Set features like Soft Start/Stop, speed scaling factor, etc.

Table 7-45. REG_CTRL0 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|----------|------|-------|---|
| 7-6 | RSVD | R | 0h | Reserved. |
| 5 | EN_SS | R/W | 1h | Used to enable/disable soft start/stop. 1b: Target motor voltage or speed is soft-started and soft-stopped over the duration of t_{INRUSH} time. 0b: Soft-start/stop feature is disabled. Refer to Section 7.3.7.3 for further explanation. |
| 4-3 | REG_CTRL | R/W | 0h | Selects the current regulation scheme (fixed off-time or cycle-by-cycle) or motor speed and voltage regulation. 00b: Fixed Off-Time Current Regulation. 01b: Cycle-By-Cycle Current Regulation. 10b: Motor speed is regulated. Ripple counting must be enabled in this mode by setting EN_RC to 1b. 11b: Motor voltage is regulated. Refer to Section 7.3.4.2 for further explanation. |
| 2 | PWM_FREQ | R/W | 1h | Sets the PWM frequency when bridge control is configured by INx bits (I2C_BC=1b). 0b: PWM frequency is set to 50kHz. 1b: PWM frequency is set to 25kHz. |
| 1-0 | W_SCALE | R/W | 3h | Scaling factor that helps in setting the target ripple speed. 00b: 16 01b: 32 10b: 64 11b: 128 Refer to Section 7.3.7.2.2 for further explanation. |

7.6.3.2 REG_CTRL1 Register (Offset = Fh) [Reset = FFh]

REG_CTRL1 is shown in [Table 7-46](#).

Return to the [Summary Table](#).

Set the target motor voltage and speed.

Table 7-46. REG_CTRL1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-----------|------|-------|---|
| 7-0 | WSET_VSET | R/W | FFh | Sets the target motor voltage or ripple speed. A detailed explanation is provided in Section 7.3.7.2.1 . |

7.6.3.3 REG_CTRL2 Register (Offset = 10h) [Reset = 00h]

REG_CTRL2 is shown in [Table 7-47](#).

Return to the [Summary Table](#).

Set the duty cycle and cut-off frequency for output voltage filtering.

Table 7-47. REG_CTRL2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|----------|------|-------|--|
| 7-6 | OUT_FLT | R/W | 0h | Programs the cut-off frequency of the output voltage filtering. 00b: 250Hz 01b: 500Hz 10b: 750Hz 11b: 1000Hz For best results, choose a cut-off frequency equal to a value at least 20 times lower than the PWM frequency. Eg, if you PWM at 20kHz, OUT_FLT=11b (1000Hz) is sufficient. |
| 5-0 | EXT_DUTY | R/W | 0h | Available when using external bridge control (I2C_BC=0b). DUTY_CTRL must be set to 1b. Speed and voltage regulation modes are inactive in this case. User can program the desired duty cycle in the EXT_DUTY bits. The range of duty cycle is 0% (000000b) to 100% (111111b). |

7.6.3.4 RC_CTRL0 Register (Offset = 11h) [Reset = 88h]

RC_CTRL0 is shown in [Table 7-48](#).

Return to the [Summary Table](#).

Set various functions for RC including enable/disable.

Table 7-48. RC_CTRL0 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------------|------|-------|--|
| 7 | EN_RC | R/W | 1h | Enable/Disable Ripple Counting. 0b: Disable 1b: Enable |
| 6 | DIS_EC | R/W | 0h | Enable/Disable the Error Correction module. 0b: Error Correction is enabled. 1b: Error Correction is disabled. Please note that this is different from the EC_PULSE_DIS described earlier. |
| 5 | RC_HIZ | R/W | 0h | 0b: H-bridge stays enabled when RC_CNT exceeds threshold. 1b: H-bridge is disabled (High-Z) when RC_CNT exceeds threshold. |
| 4-3 | FLT_GAIN_SEL | R/W | 1h | Filter input scaling factor. This factor scales the magnitude of current ripples for ease of detection and algorithmic calculation by the Ripple Counter. The options are: 00b: 2 01b: 4 10b: 8 11b: 16 Refer to Section 8.2.3.1.3.1.1 for further explanation. |
| 2-0 | CS_GAIN_SEL | R/W | 0h | Used to select the current scaling options. Settings are as follows: X00b: 4 A X01b: 2 A X10b: 1 A X11b: 0.5 A |

7.6.3.5 RC_CTRL1 Register (Offset = 12h) [Reset = FFh]

RC_CTRL1 is shown in [Table 7-49](#).

Return to the [Summary Table](#).

Threshold for ripple counting.

Table 7-49. RC_CTRL1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------|------|-------|--|
| 7-0 | RC_THR | R/W | FFh | Lower 8 bits of the 10-bit RC_THR Register. Threshold level to compare against the RC_CNT based on the expected time of motor actuation. Ripple counting threshold = RC_THR x RC_THR_SCALE |

7.6.3.6 RC_CTRL2 Register (Offset = 13h) [Reset = 7Fh]

RC_CTRL2 is shown in [Table 7-50](#).

Return to the [Summary Table](#).

Set values of various scaling parameters.

Table 7-50. RC_CTRL2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------------|------|-------|--|
| 7-6 | INV_R_SCALE | R/W | 1h | Scaling factor for the INV_R parameter. 00b: INV_R_SCALE = 2 01b: INV_R_SCALE = 64 10b: INV_R_SCALE = 1024 11b: INV_R_SCALE = 8192 Refer to Section 7.3.6.1.2 for further explanation. |
| 5-4 | KMC_SCALE | R/W | 3h | Scaling factor for KMC parameter. 00b: KMC_SCALE = 24×2^8 01b: KMC_SCALE = 24×2^9 10b: KMC_SCALE = 24×2^{12} 11b: KMC_SCALE = 24×2^{13} Refer to Section 7.3.6.1.3 for further explanation. |
| 3-2 | RC_THR_SCALE | R/W | 3h | Scaling factor for RC_THR. 00b: RC_THR_SCALE = 2 01b: RC_THR_SCALE = 8 10b: RC_THR_SCALE = 16 11b: RC_THR_SCALE = 64 |
| 1-0 | RC_THR_9:8 | R/W | 3h | Upper two bits of the 10-bit RC_THR Register. Threshold level to compare against RC_CNT based on the expected time of motor actuation. Ripple counting threshold = RC_THR x RC_THR_SCALE |

7.6.3.7 RC_CTRL3 Register (Offset = 14h) [Reset = 00h]

RC_CTRL3 is shown in [Table 7-51](#).

Return to the [Summary Table](#).

Set the INV_R parameter.

Table 7-51. RC_CTRL3 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|--|
| 7-0 | INV_R | R/W | 0h | User input based on motor coil resistance. INV_R = INV_R_SCALE / Motor Resistance. Must not be set to 0. Refer to Section 7.3.6.1.1 for further explanation. |

7.6.3.8 RC_CTRL4 Register (Offset = 15h) [Reset = 00h]

RC_CTRL4 is shown in [Table 7-52](#).

Return to the [Summary Table](#).

Set the KMC parameter.

Table 7-52. RC_CTRL4 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|--|
| 7-0 | KMC | R/W | 0h | Represents a proportional value of the motor back emf constant. $KMC = (K_V) / N_R * KMC_SCALE$. Refer to Section 7.3.6.1.4 for further explanation. |

7.6.3.9 RC_CTRL5 Register (Offset = 16h) [Reset = 00h]

RC_CTRL5 is shown in [Table 7-53](#).

Return to the [Summary Table](#).

Set the filter damping constant.

Table 7-53. RC_CTRL5 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-------|------|-------|--|
| 7-4 | FLT_K | R/W | 0h | Bandpass filter 1/Q factor. Sets the bandwidth of the bandpass filter. Recommended value is the default value: 6d. Refer to Section 8.2.3.1.3.1.2 for further explanation. |
| 3-0 | RSVD | R | 0h | Reserved |

7.6.3.10 RC_CTRL6 Register (Offset = 17h) [Reset = 45h]

RC_CTRL6 is shown in [Table 7-54](#).

Return to the [Summary Table](#).

Disable the Error Correction pulses for Ripple Counting.

Table 7-54. RC_CTRL6 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------------|------|-------|--|
| 7 | EC_PULSE_DIS | R/W | 0h | Disable the Error Correction Pulses. Differs from the EN_EC bit described previously. 0b: Error correction is always enabled. 1b: Error correction will stop giving pulses under certain conditions described in Section 7.3.6.1.11 . |
| 6-4 | T_MECH_FLT | R/W | 4h | This parameter determines the cut-off frequency of a low pass filter at the output of the ripple counter to control the response time of the ripple counter to match the inertia of the mechanical system. Increase this value to for a slower response and decrease it for a faster response. |
| 3-2 | EC_FALSE_PER | R/W | 1h | Sets the window during which the error corrector classifies a current ripple as an extra ripple. 00b: 20% 01b: 30% 10b: 40% 11b: 50% |
| 1-0 | EC_MISS_PER | R/W | 1h | Sets the window during which the error corrector adds a missed ripple. 00b: 20% 01b: 30% 10b: 40% 11b: 50% |

7.6.3.11 RC_CTRL7 Register (Offset = 18h) [Reset = 21h]

RC_CTRL7 is shown in [Table 7-55](#).

Return to the [Summary Table](#).

Set the proportional constant in PI control loop.

Table 7-55. RC_CTRL7 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------|------|-------|--|
| 7-5 | KP_DIV | R/W | 1h | Used to select a division value for calculating the actual proportional constant for the PI control loop. Actual proportional constant = KP/KP_DIV . Settings are as follows: 000b: 32 001b: 64 010b: 128 011b: 256 100b: 512 101b: 16 110b: 1 |
| 4-0 | KP | R/W | 1h | Represents the PI loop KP constant. This is not the actual proportional constant that is fed into the gain block of the PI control loop. Rather, the actual proportional constant can be calculated using this value of the KP register. Actual Proportional Constant = KP/KP_DIV . For example, if actual proportional constant is 0.0625, then KP can be set to 1 (00001b), and KP_DIV can be set to 16 (corresponds to 101b), hence, Actual proportional constant = $1/16 = 0.0625$. |

7.6.3.12 RC_CTRL8 Register (Offset = 19h) [Reset = 21h]

RC_CTRL8 is shown in [Table 7-56](#).

Return to the [Summary Table](#).

Set the integral constant in PI control loop.

Table 7-56. RC_CTRL8 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------|------|-------|--|
| 7-5 | KI_DIV | R/W | 1h | Used to select a division value for calculating the actual integral constant for the PI control loop. Actual integral constant = KI/KI_DIV . Settings are as follows: 000b: 32 001b: 64 010b: 128 011b: 256 100b: 512 101b: 16 110b: 1 |
| 4-0 | KI | R/W | 1h | Represents the PI loop KI constant. This is not the actual integral constant that is fed into the gain block of the PI control loop. Rather, the actual integral constant can be calculated using this value of the KI register. Actual Integral Constant = KI/KI_DIV . For example, if actual integral constant is 0.90625, then KI can be set to 29 (11101b), and KI_DIV can be set to 32 (corresponds to 000b), hence, Actual integral constant = $29/32 = 0.90625$. |

8 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The DRV8234 is intended to drive one brushed DC motor.

8.2 Typical Application: Brushed DC Motor

A typical application for the DRV8234 is to drive a brushed DC motor using the full-bridge outputs. [Figure 8-1](#) shows a schematic example. The resistor on the IPROPI pin can provide a voltage signal to the microcontroller analog-to-digital converter (ADC).

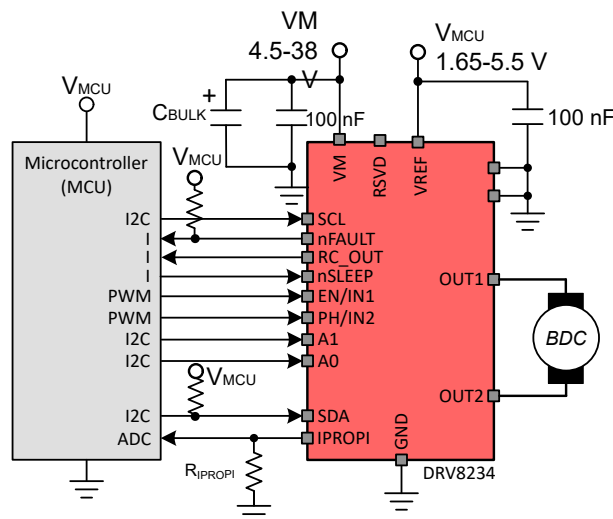


Figure 8-1. Typical Connections with stall detection disabled

8.2.1 Design Requirements

[Table 8-1](#) lists example design parameters.

Table 8-1. Design Parameters

| DESIGN PARAMETER | REFERENCE | EXAMPLE VALUE |
|--------------------------------|--------------|---------------|
| Motor voltage | V_{VM} | 8 V |
| Average motor current | I_{AVG} | 0.8 A |
| Motor inrush (startup) current | I_{INRUSH} | 2. A |
| Motor stall current | I_{STALL} | 2.1 A |
| Motor current trip point | I_{TRIP} | 1.9 A |
| VREF voltage | VREF | 3.3 V |
| IPROPI resistance | R_{IPROPI} | 8.45 kΩ |
| PWM frequency | f_{PWM} | 20 kHz |
| Bulk Capacitance | C_{BULK} | 50μF |

8.2.2 Stall Detection

Some applications require stall detection to notify the microcontroller of a locked-rotor/stall condition. A stall could be caused by one of two things: unintended mechanical blockage or the load reaching an end-stop in a constrained travel path. The DRV8234 supports hardware stall detection by comparing the IPROPI pin voltage to the VREF pin voltage or 3 V as applicable.

8.2.2.1 Application Description

The principle of this stall detection scheme relies on the fact that motor current increases during stall conditions as shown in [Figure 8-2](#). The DRV8234 compares the voltage on the IPROPI pin to the voltage on the VREF pin to determine whether a stall condition has occurred. The TINRUSH register sets the timing, t_{INRUSH} , so the DRV8234 ignores the inrush current at motor startup. The SMODE pin configures how the DRV8234 responds to a stall condition. The IMODE pin configures whether the device regulates current during inrush and stall currents. When a stall condition occurs, nFAULT pin becomes low and the appropriate registers indicate stall to the microcontroller using the I²C pins. [Section 7.3.5](#) provides all the details for configuring the stall detection feature.

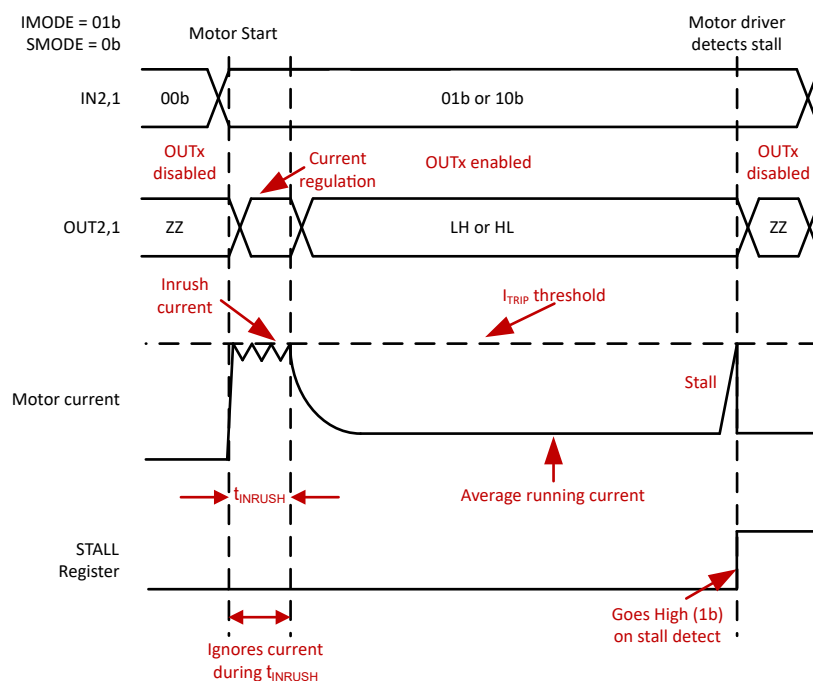


Figure 8-2. Example timing diagram for stall detection

8.2.2.1.1 Stall Detection Timing

Large inrush current occurs during motor start up because motor speed is low. As the motor accelerates, the motor current drops to an average level because the back electromotive force (EMF) in the motor increases with speed. The inrush current should not be mistaken for a stall condition, so the DRV8234 uses the TINRUSH register to ignore the inrush current during the startup time, t_{INRUSH} . [Section 7.3.5](#) describes the overall details for using the stall detection feature.

When designing for the t_{INRUSH} time, it is important to include enough margin to account for tolerances and variation in the DRV8234 and the system overall.

8.2.2.1.2 Hardware Stall Threshold Selection

The voltage on the VREF pin selects I_{TRIP} threshold which sets the current level for stall detection and current regulation. This threshold should be chosen such that I_{TRIP} is less than the stall current of the motor when current regulation is not used. It should also be set low enough to account for variation in the stall current due to changes in the motor supply voltage, V_{VM} , and temperature.

8.2.3 Ripple Counting Application

This section describes Ripple Counting and the associated tuning procedure using an example.

8.2.3.1 Tuning Ripple Counting Parameters

This section explains the tuning process for the Ripple Counting parameters described in [Section 7.3.6.1](#).

8.2.3.1.1 Resistance Parameters

This section describes how to select INV_R and INV_R_SCALE. The first step is to find the motor resistance. This can be done in three ways:

1. Use the motor resistance value mentioned in the data sheet of the motor. If this is not available, use one of the other methods listed below.
2. Perform a voltage sweep at the motor terminals, stall the motor at each voltage level, and measure the motor current. Please note that at least 10 measurements are required at every voltage level whilst rotating the motor by approximately 30° for each measurement. This is because it is unknown if the commutator segments are in contact with the brushes in a particular motor position which renders a lower, incorrect motor resistance value. **If motor resistance from the motor's data sheet is unavailable, then this method is recommended to obtain the value of motor resistance.** Take the average of all values to calculate motor resistance.
3. Measure the motor resistance using a digital multimeter. Please note that this process also needs to be done at every voltage level for 10 measurements each and then averaged out at the end for the same reason as mentioned above.

Once the motor resistance value is found, select an appropriate value of INV_R_SCALE and calculate INV_R. The formula to calculate INV_R is:

$$\text{INV_R} = \frac{1}{\text{Motor Resistance}} \times \text{INV_R_SCALE} \quad (9)$$

For example, if the motor resistance is **25 Ω**, we have the following possible results based on the choice of INV_R_SCALE:

Table 8-2. Selection Example for INV_R_SCALE and INV_R

| Bit | INV_R_SCALE value | INV_R_SCALE/Motor Resistance (Actual Value) | Rounded Value INV_R | Comment |
|------------|-------------------|---|---------------------|---|
| 00b | 2 | 2/25=0.08 | 0 | Do not select, since output is 0. |
| 01b | 64 | 64/25=2.56 | 3 | Avoid selecting, since low bit precision. |
| 10b | 1024 | 1024/25=40.96 | 41 | Can select this value. |
| 11b | 8192 | 8192/25=327.68 | 328 | Cannot select this value because 328 exceeds the maximum limit for INV_R (255). |

8.2.3.1.2 KMC and KMC_SCALE

Selection of KMC_SCALE and KMC can be divided into two cases based on [Equation 5](#):

1. Value of the motor back emf constant, K_v is known to the user from the data sheet of the motor.
2. Value of the motor back emf constant, K_v is unknown to the user.

8.2.3.1.2.1 Case I

In case 1, [Equation 5](#) can be used. Choose the value of KMC_SCALE such that KMC is within the range of 0 to 255 with highest bit resolution. As an example, if $K_V = 0.01$ and number of ripples per revolution, $N_R = 10$, $K_V/N_R = 10^{-3}$. The following table lists the available options:

Table 8-3. Selection Example for KMC_SCALE

| Bit | KMC_SCALE value | $K_V/N_R \times \text{KMC_SCALE}$ (Actual Value) | Rounded Value (KMC) | Comment |
|-----|--------------------|--|------------------------|---|
| 00b | 24×2^8 | 6.144 | 6 | Avoid selecting, since low bit precision. |
| 01b | 24×2^9 | 12.288 | 12 | Avoid selecting, since low bit precision. |
| 10b | 24×2^{12} | 98.304 | 98 | Avoid selecting, since low bit precision. |
| 11b | 24×2^{13} | 196.608 | 197 | Can select this value as this has the highest bit precision. |

8.2.3.1.2.2 Case II

In case 2, KMC and KMC_SCALE need to be tuned manually using either of the two methods:

8.2.3.1.2.2.1 Method 1: Tuning from Scratch

This method resets both parameters in the beginning before arriving at tuned values. [Figure 8-3](#) displays a flowchart for tuning KMC_SCALE using this method. KMC can be found using Binary Search as shown in [Figure 8-4](#)

8.2.3.1.2.2.1.1 Tuning KMC_SCALE

- Obtain the value of actual ripple speed in rad/s using either of the two methods:
 - Use an oscilloscope to observe motor current waveform to measure the ripple frequency. This can be done in two ways:
 - Through the IPROPI pin which provides an output proportional to the motor current.
 - Through a current probe.

The frequency of ripples is observed in Hz on the oscilloscope. Please consider at least 20 ripples while calculating frequency. Divide the number of ripples by the time taken for calculating the frequency in Hz. Convert into rad/s using [Equation 11](#). Please note that **this is the recommended method**.

- Use a tachometer to obtain the motor speed in rpm. Convert the motor speed into ripple speed using [Equation 10](#). Finally, convert the ripple speed in rpm to ripple speed in rad/s using [Equation 12](#).

$$\text{Ripple Speed} = \text{Motor Speed} \times N_R \quad (10)$$

$$\text{Ripple Speed (in rad/s)} = \text{Ripple Speed (in Hz)} \times 2\pi \quad (11)$$

$$\text{Ripple Speed (in rad/s)} = \text{Ripple Speed (in rpm)} \times \frac{2\pi}{60} \quad (12)$$

Where N_R is the number of ripples per revolution. Let this value be called OBS_SPEED.

- Select the lowest value of KMC_SCALE, 00b. Set KMC to the highest possible value, 255.
- Refer to [Table 7-21](#) to set W_SCALE to a value where maximum ripple speed is more than OBS_SPEED. For example, if OBS_SPEED is 6000 rad/s, set W_SCALE to 01b allowing a maximum speed of 8160 rad/s.
- Convert the ripple speed on the [SPEED](#) register into rad/s by multiplying [SPEED](#) with [W_SCALE](#). For example, if SPEED reads 0x04 and W_SCALE is set to 10b (corresponds to 64 rad/s), then ripple speed in rad/s = $4 \times 64 = 256$ rad/s. Let this value be called EST_SPEED.
- If EST_SPEED is lower than OBS_SPEED, increase KMC_SCALE by one bit.
- Repeat steps 4-5 until EST_SPEED is higher than OBS_SPEED.

7. Set KMC_SCALE to the previous value. For example, if 11b was obtained in the previous step, set KMC_SCALE to 10b. This is the tuned value of KMC_SCALE.

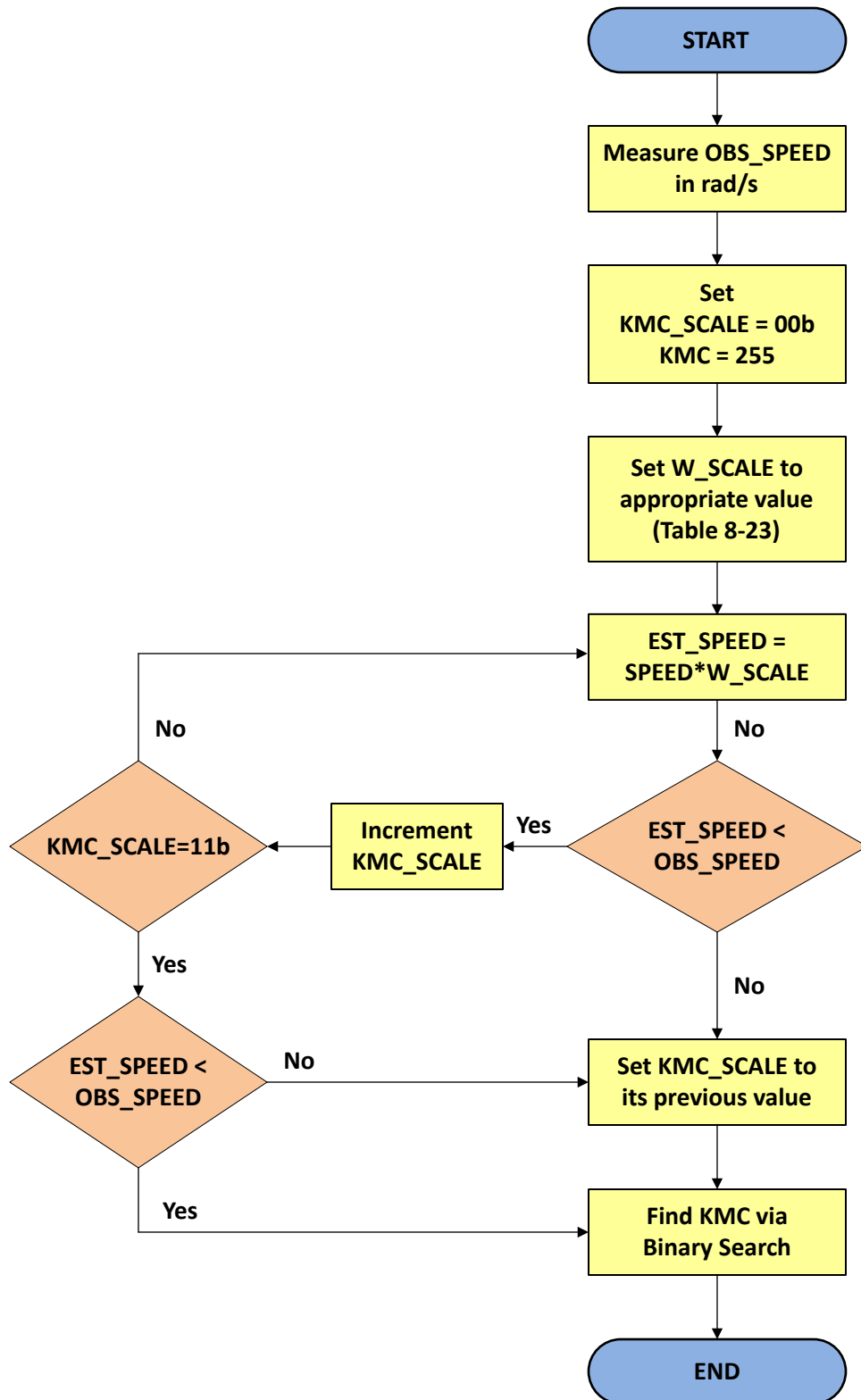


Figure 8-3. KMC_SCALE Tuning Procedure

8.2.3.1.2.2.1.2 Tuning KMC

1. Verify that $EST_SPEED < OBS_SPEED$ and value of KMC is 255. If this is not the case, please restart the tuning process.
2. Let $START = 0$ and $END = 255$.
3. Set KMC to START and obtain the value of OBS_SPEED in rad/s **from step 1 of the KMC_SCALE tuning procedure**.
4. If EST_SPEED is within $OBS_SPEED \pm W_SCALE$ value from [Table 7-21](#), stop the tuning process and record the value of KMC. For example, if $W_SCALE = 10b$ (corresponds to 64 rad/s), $OBS_SPEED = 6000$ rad/s, and $EST_SPEED = 5937$ rad/s, stop the tuning process.
5. Let $MID = (START + END) / 2$, rounded off to the nearest integer.
6. If EST_SPEED is higher than OBS_SPEED in this step, set KMC to MID. If EST_SPEED is lower than OBS_SPEED in this step, decrement KMC_SCALE by one bit and repeat the binary search procedure to tune KMC.
7. If EST_SPEED is higher than OBS_SPEED , update $START = MID$. If EST_SPEED is lower than OBS_SPEED , update $END = MID$.
8. Repeat steps 4-7 until EST_SPEED is within $OBS_SPEED \pm W_SCALE$ value from [Table 7-21](#). Record the value of KMC.

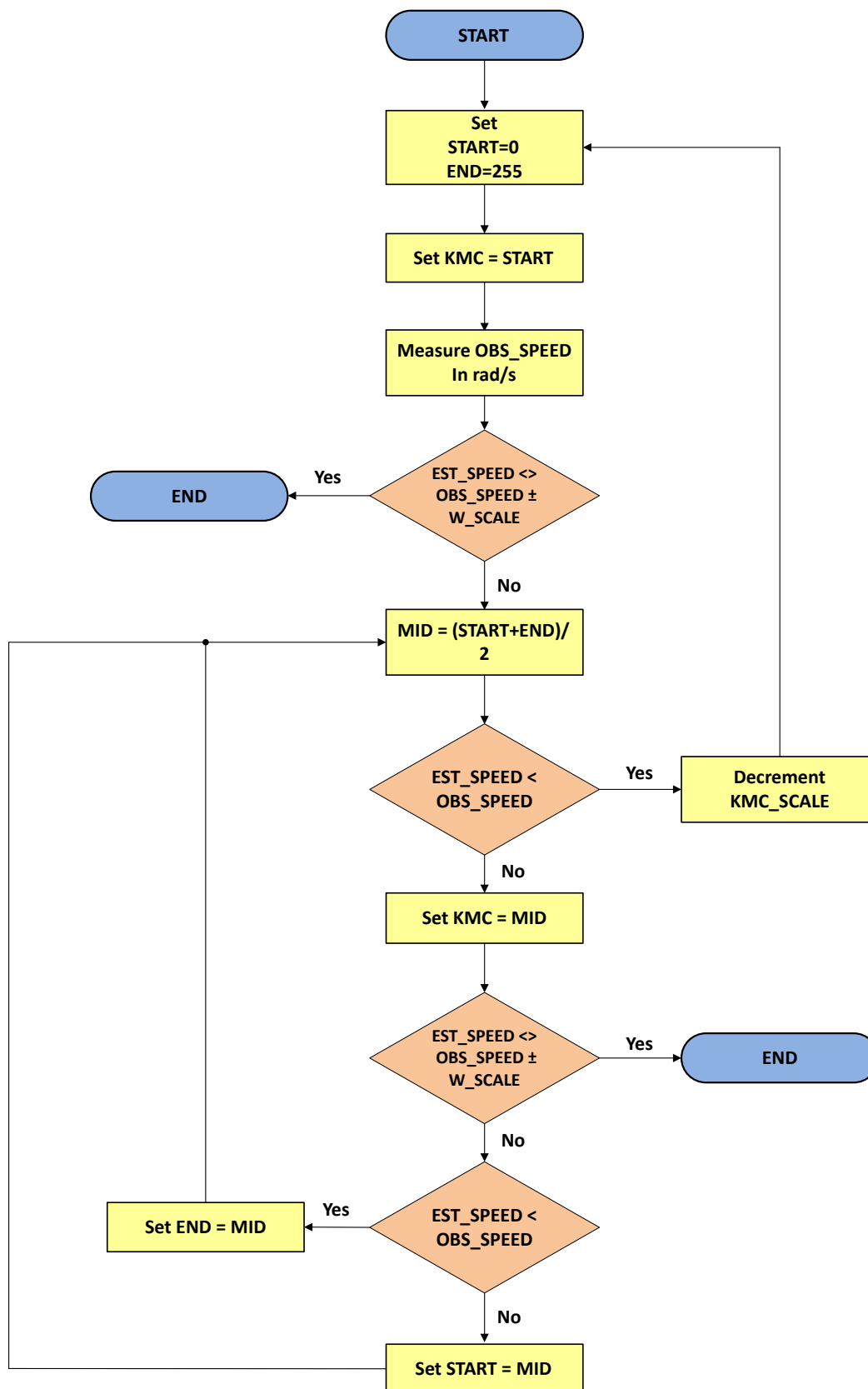


Figure 8-4. Binary Search Algorithm to Find KMC

Note

1. Tuning is not possible in the following cases:
 - a. EST_SPEED is higher than OBS_SPEED after step 4 in the KMC_SCALE tuning process (KMC_SCALE = 00b; KMC = 255), or
 - b. EST_SPEED is lower than OBS_SPEED after step 3 in the Binary Search Method for KMC (KMC_SCALE = 11b, KMC = 0).
2. Multiple sets of KMC and KMC_SCALE exist. If found, then choose the set with highest bit resolution.

8.2.3.1.2.2.2 Method 2: Using the Proportionality factor

This method utilises the factor of proportionality that associates KMC and KMC_SCALE with the ripple speed, ω_{ripple} . ω_{ripple} is directly proportional to KMC_SCALE but varies inversely with KMC. Let k_d be a dummy constant. We have:

$$\omega_{\text{ripple}} = k_d \frac{\text{KMC_SCALE}}{\text{KMC}} \quad (13)$$

Using the subscript 'def' to denote default, we have the following equation for default values of KMC and KMC_SCALE:

$$\omega_{\text{def}} = k_d \frac{\text{KMC_SCALE}_{\text{def}}}{\text{KMC}_{\text{def}}} \quad (14)$$

Using the subscript 'tuned', we similarly have the following equation for tuned values of KMC and KMC_SCALE:

$$\omega_{\text{tuned}} = k_d \frac{\text{KMC_SCALE}_{\text{tuned}}}{\text{KMC}_{\text{tuned}}} \quad (15)$$

Taking the ratio of the two equations above, the dummy constant, k_d , cancels out:

$$\frac{\omega_{\text{tuned}}}{\omega_{\text{def}}} = \frac{\text{KMC_SCALE}_{\text{tuned}}}{\text{KMC}_{\text{tuned}}} \times \frac{\text{KMC}_{\text{def}}}{\text{KMC_SCALE}_{\text{def}}} \quad (16)$$

At this point, the following is known:

1. $\text{KMC_SCALE}_{\text{def}} = 11\text{b}$ (24×2^{13}) is the default value of KMC_SCALE from the register map.
2. $\text{KMC}_{\text{def}} = 163$ is the default value of KMC from the register map.
3. ω_{tuned} is the actual value of the ripple speed in rad/s. Please refer to step 1 of the [KMC_SCALE Tuning Method 1](#) for obtaining this value.

To obtain ω_{def} , select a value of W_SCALE based on step 3 of [KMC_SCALE Tuning Method 1](#). Next, convert the ripple speed on the [SPEED](#) register obtained using $\text{KMC_SCALE}_{\text{def}}$ and KMC_{def} into rad/s by multiplying [SPEED](#) with [W_SCALE](#). For example, if [SPEED](#) reads 0x04 and W_SCALE is set to 10b (corresponds to 64 rad/s), then ripple speed in rad/s = $4 \times 64 = 256$ rad/s.

Plugging the four values above and simplifying, we get a ratio of $\text{KMC_SCALE}_{\text{tuned}}$ and $\text{KMC}_{\text{tuned}}$ as a constant number. Select $\text{KMC_SCALE}_{\text{tuned}}$ from the four available values such that $\text{KMC}_{\text{tuned}}$ has the highest bit precision within limits (0 to 255). A working example is shown below.

8.2.3.1.2.2.2.1 Working Example

As a working example, let $\omega_{\text{tuned}} = 500$ rad/s. Thus,

- W_SCALE is chosen as 00b (16 rad/s) since $500 < 4080$, the maximum value allowable by W_SCALE based on [Table 7-21](#).
- Let [SPEED](#) = 0x30. Thus, $\omega_{\text{def}} = 48 \times 16 = 768$ rad/s.
- Plugging these values into [Equation 17](#), we have:

$$\frac{500}{768} = \frac{KMC_SCALE_{tuned}}{KMC_{tuned}} \times \frac{163}{24 \times 2^{13}} \quad (17)$$

- Simplifying, we get:

$$785.276 = \frac{KMC_SCALE_{tuned}}{KMC_{tuned}} \quad (18)$$

- The final step is to choose KMC_SCALE_{tuned} such that KMC_{tuned} has the highest precision within limits (0 to 255). The following table illustrates the possible choices:

Table 8-4. Selection Example for KMC_SCALE

| Bit | KMC_SCALE _{tuned} value | KMC_SCALE _{tuned} / 785.276 (Actual Value) | KMC _{tuned} (Rounded Value) | Comment |
|-----|----------------------------------|---|---|---|
| 00b | 24 x 2 ⁸ | 7.82 | 8 | Avoid selecting, since low precision. |
| 01b | 24 x 2 ⁹ | 15.64 | 16 | Avoid selecting, since low precision. |
| 10b | 24 x 2 ¹² | 125.18 | 125 | Avoid selecting, since low precision. |
| 11b | 24 x 2 ¹³ | 250.36 | 250 | Can select this value, since highest precision. |

8.2.3.1.3 Advanced Parameters

8.2.3.1.3.1 Filter Constants

This section describes how to tune the two filter constants: FLT_K and FLT_GAIN_SEL.

8.2.3.1.3.1.1 FLT_GAIN_SEL

Denoted by FLT_GAIN_SEL, this parameter selects the gain for the band pass filter. The gain scales the magnitude of current ripples for ease of detection and algorithmic calculation by the Ripple Counter. Recommended to set this to the maximum value (11b) to utilize the full signal range. Settings are as shown in [Table 7-13](#).

8.2.3.1.3.1.2 FLT_K

Denoted by FLT_K, this parameter represents the quality factor or Q-factor of the band pass filter. Tune this parameter to increase or decrease the bandwidth to accommodate a wider or narrower range of ripple frequencies around the center frequency. Center frequency of the filter is based on the frequency estimation of the motor for the ripples.

Settings are shown in [Table 8-5](#). Recommended value is the default value: 0110b.

Table 8-5. Settings for FLT_K

| Bit | Decimal | Value |
|------|---------|----------|
| 0000 | 0 | 0.007813 |
| 0001 | 1 | 0.015265 |
| 0010 | 2 | 0.03125 |
| 0011 | 3 | 0.0625 |
| 0100 | 4 | 0.125 |
| 0101 | 5 | 0.25 |
| 0110 | 6 | 0.5 |
| 0111 | 7 | 0.625 |
| 1000 | 8 | 0.75 |
| 1001 | 9 | 0.825 |

Table 8-5. Settings for FLT_K (continued)

| Bit | Decimal | Value |
|-------------|---------|-------|
| 1010 - 1111 | 10-15 | 1 |

8.2.3.1.3.2 T_MECH_FLT

This parameter determines the cut-off frequency of a low pass filter at the output of the ripple counter to control the response time of the ripple counter. Tune this parameter to match the inertia of the entire mechanical system. This can be done by observing the ripple counter response during dynamic speed events such as inrush or transient loading. Increasing the value of this parameter slows down the ripple counter response time; decreasing the value speeds up the response time. Setting this parameter to the default value (100b) is recommended since that suffices for most mechanical systems.

8.2.3.1.3.3 VSNS_SEL

This parameter is used to select the motor voltage output filtering method (analog or digital) during PWM. The analog filter (0b) filters out the noise based on the voltage difference between the output pins. The digital filter (1b) multiplies the PWM duty cycle with VM to render an average output voltage. Settings are shown in [Table 7-15](#). When analog filter is selected, the cut-off frequency can be selected using the [OUT_FLT](#) register. Recommended setting is the analog filter (0b).

8.2.3.1.3.4 Additional Error Corrector Parameters

This section describes two additional parameters, EC_FALSE_PER and EC_MISS_PER. Please note that these are advanced parameters used for fine tuning the error corrector and used only in extreme scenarios. The default settings work in most cases.

8.2.3.1.3.4.1 EC_FALSE_PER

[EC_FALSE_PER](#) is a 2-bit register that allows the user to select a blanking time window **after** a current ripple is detected. During this time window, the error corrector classifies any passed ripples from the digital filter as extra ripples and does not count them. The time window is represented as a percentage of time between two successive expected current ripples. The settings are shown in [Table 8-6](#):

Table 8-6. Settings for EC_FALSE_PER

| Bit | Value |
|-----|-------|
| 00b | 20% |
| 01b | 30% |
| 10b | 40% |
| 11b | 50% |

8.2.3.1.3.4.2 EC_MISS_PER

[EC_MISS_PER](#) is a 2-bit register that allows the user to select a time window for when a current ripple is **expected** to be detected. During this time window, the error corrector identifies any ripples filtered out from the digital filter to classify them as missed and adds them manually. The time window is represented as a percentage of time between two successive expected current ripples. During this time window, the error corrector takes action if an expected ripple from the digital filter does not arrive. The time window is represented as a percentage of time between two successive expected current ripples. The settings are shown in [Table 8-7](#):

Table 8-7. Settings for EC_MISS_PER

| Bit | Value |
|-----|-------|
| 00b | 20% |
| 01b | 30% |
| 10b | 40% |
| 11b | 50% |

8.2.4 Motor Voltage

The motor voltage to use depends on the ratings of the motor selected and the desired RPM. A higher voltage spins a brushed DC motor faster with the same PWM duty cycle applied to the power FETs. A higher voltage also increases the rate of current change through the inductive motor windings.

8.2.5 Motor Current

Motors experience large currents at low speed, initial startup, and stalled rotor conditions. The large current at motor startup is sometimes called inrush current. The current regulation feature in the DRV8234 can help to limit these large currents. Additionally, DRV8234's soft-start feature can be used to limit the inrush current by ramping the PWM duty cycle during startup time. Alternatively, the microcontroller may limit the inrush current via a similar procedure.

8.2.6 Application Curves

RC_OUT denotes the pulse train output of the RC_OUT pin

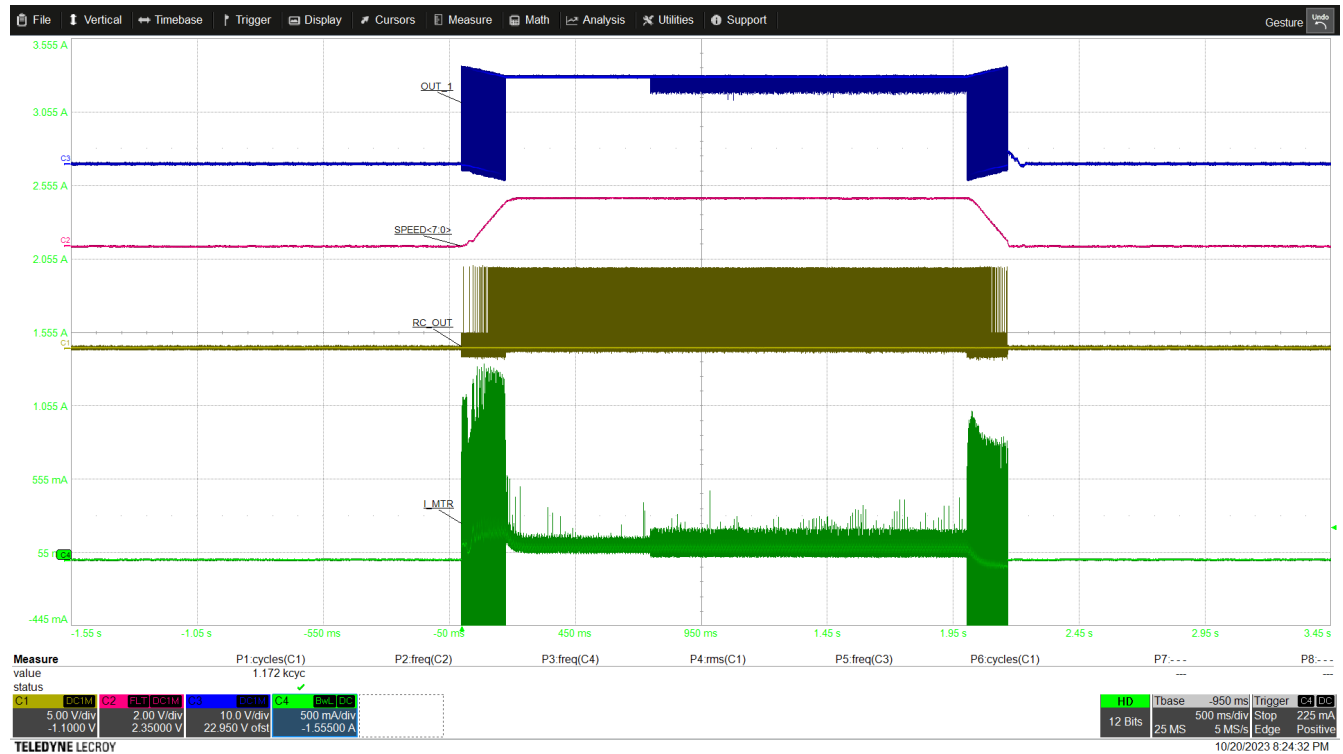


Figure 8-5. Example Operation at VM = 12 V

RC_OUT denotes the pulse train output of the RC_OUT pin

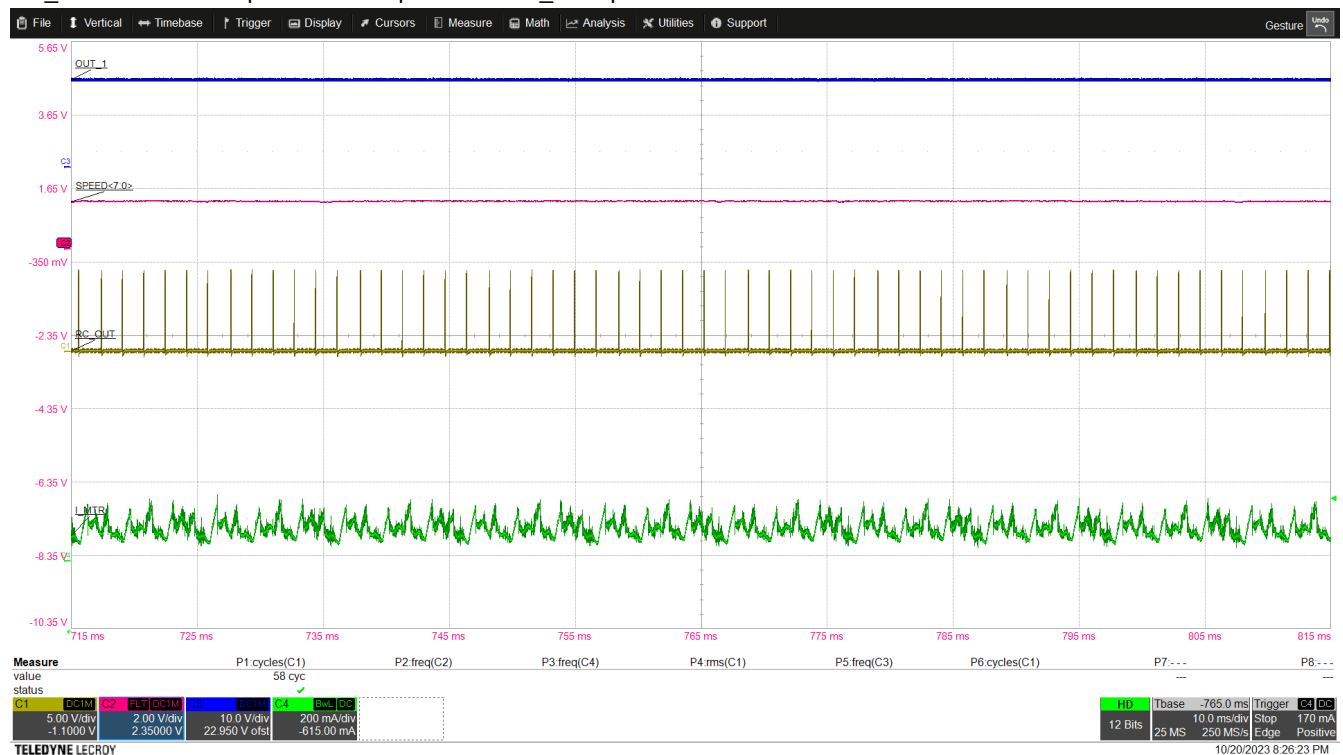


Figure 8-6. Steady State Operation at VM = 12 V

RC_OUT denotes the pulse train output of the RC_OUT pin

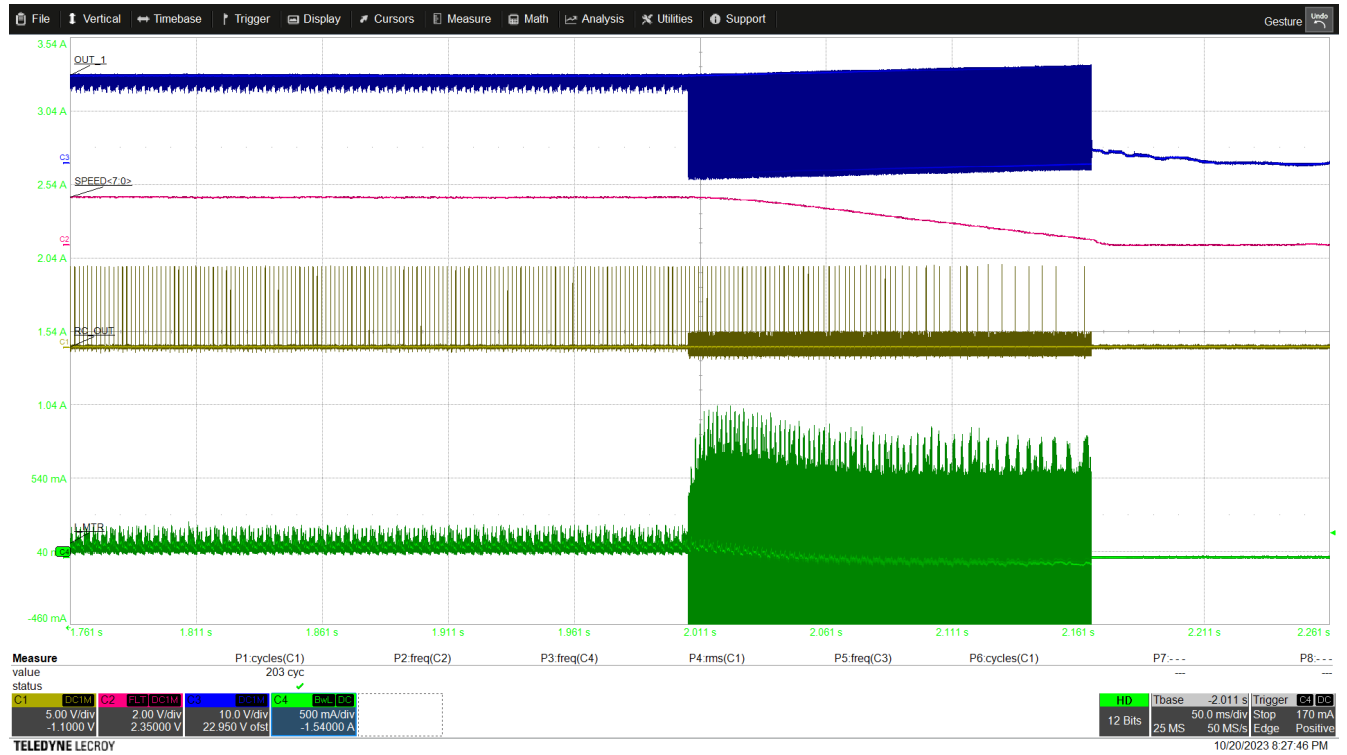


Figure 8-7. Soft Stop at VM = 12 V

RC_OUT denotes the pulse train output of the RC_OUT pin

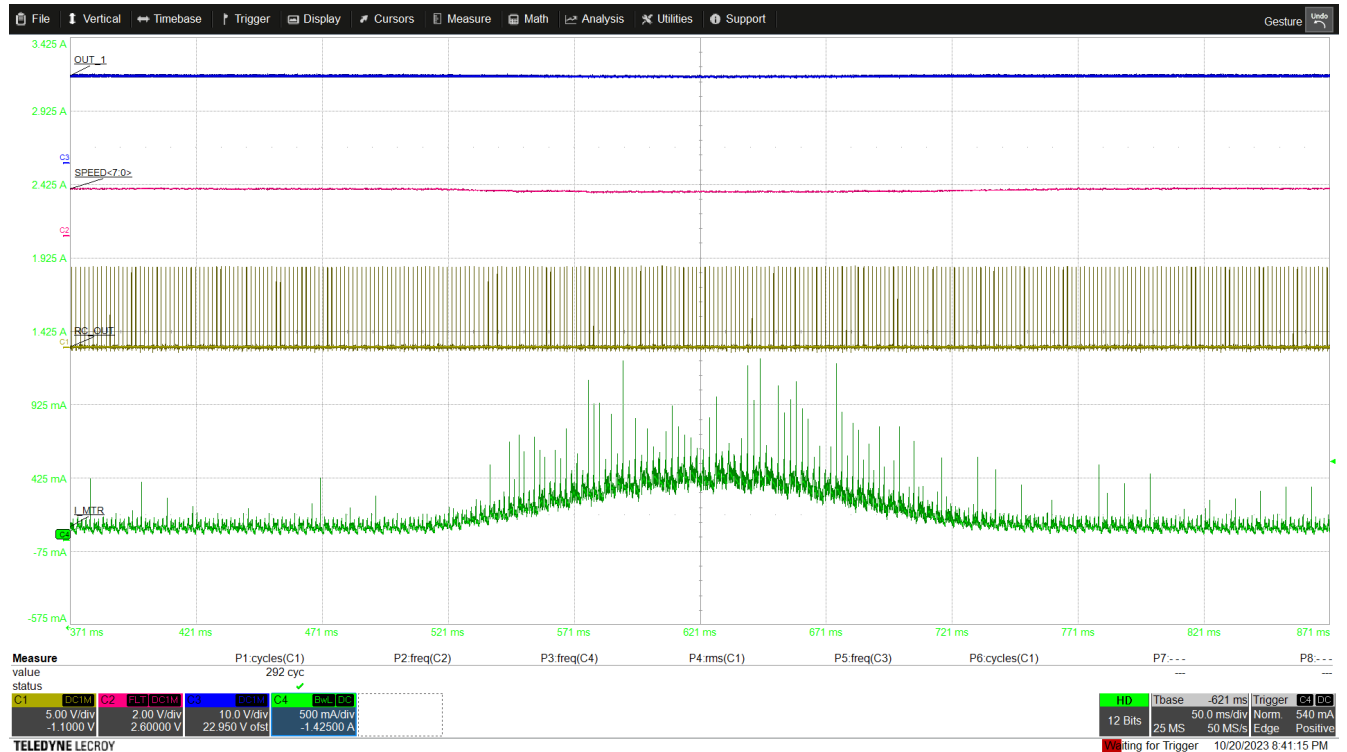


Figure 8-8. Transient Loading Conditions - Full Profile

9 Power Supply Recommendations

9.1 Bulk Capacitance

Having appropriate local bulk capacitance is an important factor in motor drive system design. Having more bulk capacitance is generally beneficial, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:

- The highest current required by the motor system
- The capacitance of the power supply and ability to source current
- The amount of parasitic inductance between the power supply and motor system
- The acceptable voltage ripple
- The type of motor used (brushed DC, brushless DC, stepper)
- The motor braking method

The inductance between the power supply and motor drive system limits how the rate current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

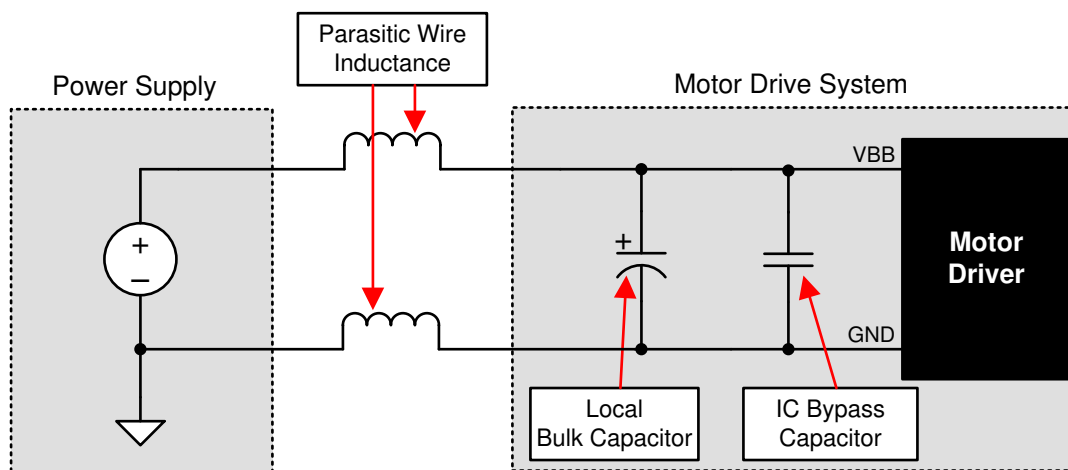


Figure 9-1. Example Setup of Motor Drive System With External Power Supply

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

10 Layout

10.1 Layout Guidelines

Since the DRV8234 integrates power MOSFETs capable of driving high current, careful attention should be paid to the layout design and external component placement. Some design and layout guidelines are provided below.

- Low ESR ceramic capacitors should be utilized for the VM to GND bypass capacitor. X5R and X7R types are recommended.
- The VM power supply capacitors should be placed as close to the device as possible to minimize the loop inductance.
- The VM power supply bulk capacitor can be of ceramic or electrolytic type, but should also be placed as close as possible to the device to minimize the loop inductance.
- VM, OUT1, OUT2, and GND carry the high current from the power supply to the outputs and back to ground. Thick metal routing should be utilized for these traces as is feasible.
- The device thermal pad should be attached to the PCB top layer ground plane and internal ground plane (when available) through thermal vias to maximize the PCB heat sinking.
- A recommended land pattern for the thermal vias is provided in the package drawing section.
- The copper plane area attached to the thermal pad should be maximized to ensure optimal heat sinking.

11 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

11.3 Trademarks

PowerPAD™ is a trademark of Texas Instruments.

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

12 Revision History

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

| DATE | REVISION | NOTES |
|---------------|----------|-----------------|
| December 2023 | * | Initial Release |

PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|-----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| DRV8234RTER | Active | Production | WQFN (RTE) 16 | 3000 LARGE T&R | Yes | FULL NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 8234 |
| DRV8234RTER.A | Active | Production | WQFN (RTE) 16 | 3000 LARGE T&R | Yes | FULL NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 8234 |

- (1) Status:** For more details on status, see our [product life cycle](#).
- (2) Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.
- (3) RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.
- (4) Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.
- (5) MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.
- (6) Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| DRV8234RTER | WQFN | RTE | 16 | 3000 | 330.0 | 12.4 | 3.3 | 3.3 | 1.1 | 8.0 | 12.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| DRV8234RTER | WQFN | RTE | 16 | 3000 | 367.0 | 367.0 | 35.0 |

GENERIC PACKAGE VIEW

RTE 16

WQFN - 0.8 mm max height

3 x 3, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.





4219117/B 04/2022

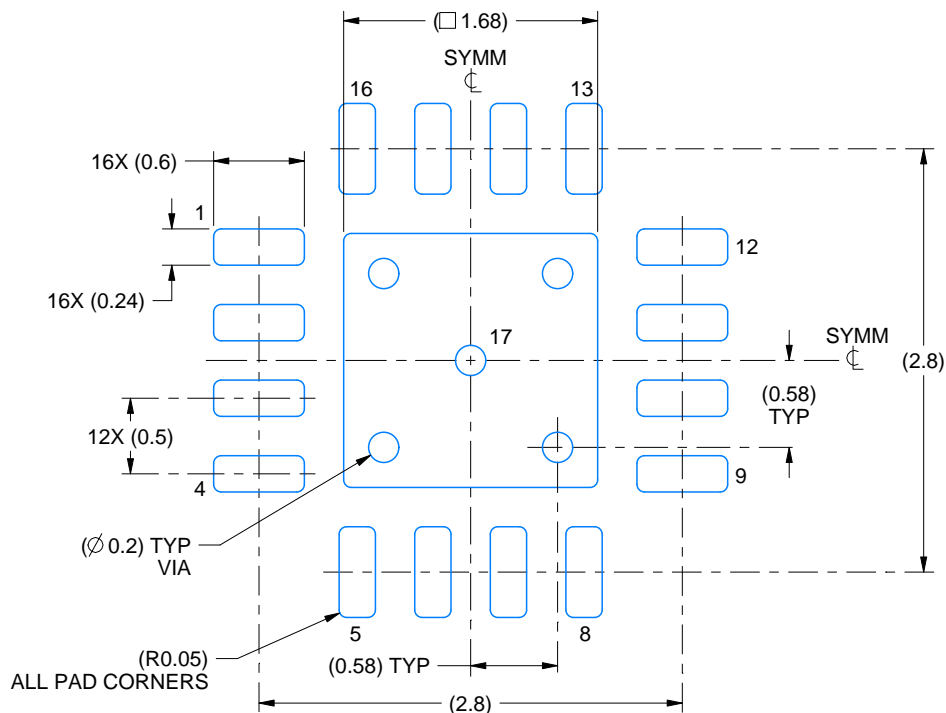
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

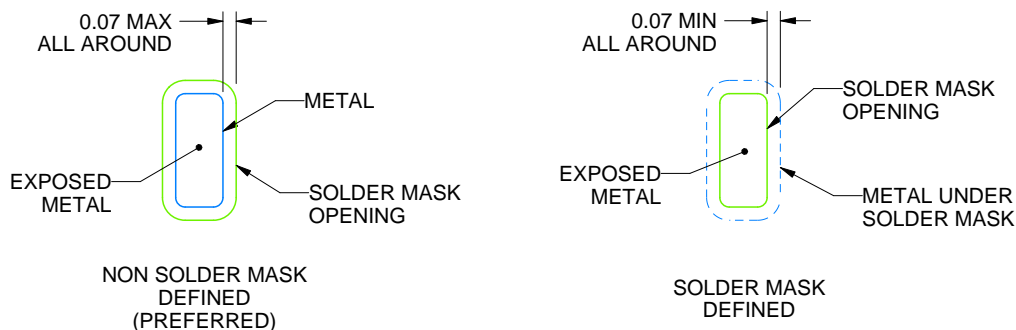
RTE0016C

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:20X



SOLDER MASK DETAILS

4219117/B 04/2022

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

RTE0016C

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 17:
85% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:25X

4219117/B 04/2022

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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, regulatory 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 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](#), [TI's General Quality Guidelines](#), 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. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2025, Texas Instruments Incorporated

Last updated 10/2025