

MCF8315C センサレス フィールド オリエンテッド コントロール (FOC)、内蔵 FET BLDC ドライバ

1 特長

- センサレス モーター制御アルゴリズムを統合した 3 相 BLDC モーター ドライバ
 - コード フリー フィールド オリエンテッド コントロール (FOC)
 - モータ パラメータ抽出ツール (MPET) を使用した オフライン モーター パラメータ測定
 - 設定可能な 5 点速度プロファイルをサポート
 - 順方向再同期と逆方向駆動による風車制御のサポート
 - アナログ、PWM、周波数、または I²C ベースの速度入力
 - モータの起動と停止に関する設定可能なオプション
 - アンチ電圧サージ (AVS) 保護機能により、
 - 自動デッドタイム補償により音響性能を向上
 - DACOUT ピンを介しての変数の監視
- 動作電圧: 4.5V ~ 35V (絶対最大定格 40V)
- 高い出力電流能力: ピーク 4A
- 低い MOSFET ON 抵抗
 - RRY: T_J = 25°Cでの R_{DS(ON)}(H+L): 250mΩ (代表値)
 - PWP: T_J = 25°Cでの R_{DS(ON)}(H+L): 265mΩ (代表値)
- 低消費電力スリープ モード: 『表 6-7』を参照してください
 - V_{VM} = 24V, T_A = 25°Cで 5μA (最大値)
- 速度ループの精度: 内部クロック使用時に 3%、外部クロックを基準とする場合は 1%
- 構成可能不揮発性メモリ (EEPROM) にデバイス構成を保存
- 低インダクタンスのモータをサポートするため、最大 60kHz の PWM 周波数に対応
- 電流センス機能を内蔵し外付け電流センス抵抗が不要
- 3.3V、20mA の LDO レギュレータを内蔵
- 3.3V/5V、170mA の降圧レギュレータを内蔵
- 専用 DRV_{OFF} ピンによる出力の無効化 (ハイインピーダンス)
- スペクトラム拡散とスルーレート設定は EMI 低減に貢献
- 各種保護機能を内蔵
 - 電源低電圧誤動作防止 (UVLO)
 - 電源の過電圧保護 (OVP)
 - モーター ロック検出 (5 つの異なる種類)
 - 過電流保護 (OCP)

- 熱警告およびシャットダウン (OTW/TSD)
- フォルト状況表示ピン (nFAULT)
- I²C インターフェイスによるフォルト診断 (オプション)

2 アプリケーション

- ブラシレス DC (BLDC) モーター モジュール
- 住宅用ファンとリビング ファン
- 空気清浄機および加湿器用ファン
- 洗濯機および食器洗い機用ポンプ
- 車載用のファンとブロワー
- CPAP 機器

3 概要

MCF8315C は、速度制御の 12~24V ブラシレス DC モーター (BLDC) または永久磁石同期モーター (PMSM) を、最大 4A のピーク電流で駆動するための、シングルチップでコード フリーのセンサレス FOC ソリューションを提供します。MCF8315C は、絶対最大定格が 40V で、R_{DS(ON)} が 250/265mΩ (ハイサイドとローサイド FET の合計) という低い値のハーフブリッジを 3 つ内蔵しています。MCF8315C には、電圧調整可能な降圧レギュレータ (3.3V/5V、170mA) および LDO (3.3V/20mA) を含む電源管理回路が内蔵されており、外部回路への電力供給に使用できます。

FOC アルゴリズムの構成は、不揮発性 EEPROM に保存されるため、構成後はデバイスをスタンドアロンで動作させることが可能です。デバイスは、PWM 入力、アナログ電圧、可変周波数の方形波、I²C コマンドによって速度コマンドを受信します。MCF8315C は、本デバイス自身、モーター、システムをフォルト イベントから保護するための多くの保護機能を内蔵しています。

MCF8315C は、32 ピン 6 × 4mm の QFN (RRY) パッケージと 24 ピン 7 × 8 × 6.4mm の HTSSOP (PWP) パッケージの 2 つで供給されます。

製品情報⁽¹⁾

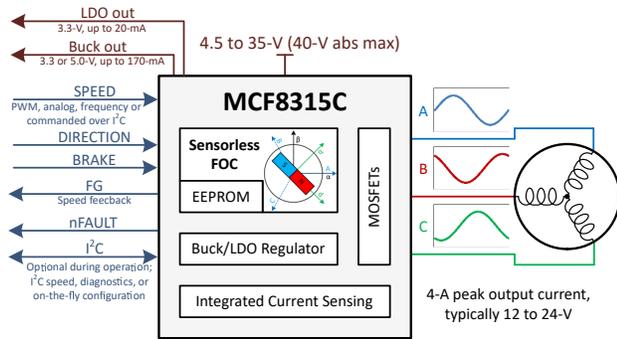
| 部品番号 | パッケージ | パッケージ サイズ ⁽²⁾ |
|------------------------------|-------------|--------------------------|
| MCF8315C1VRRYR | WQFN (32) | 6.00mm × 4.00mm |
| MCF8315C1VPWP ⁽³⁾ | HTSSOP (24) | 7.80mm × 6.40mm |

- 利用可能なすべてのパッケージについては、データシートの末尾にある注文情報を参照してください。
- パッケージ サイズ (長さ × 幅) は公称値であり、該当する場合はピンも含まれます。
- このデバイスはプレビュー版としてのみ供給されます。



MCF8315C

JAJSSQ2 – DECEMBER 2023



概略回路図

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4 Pin Configuration and Functions

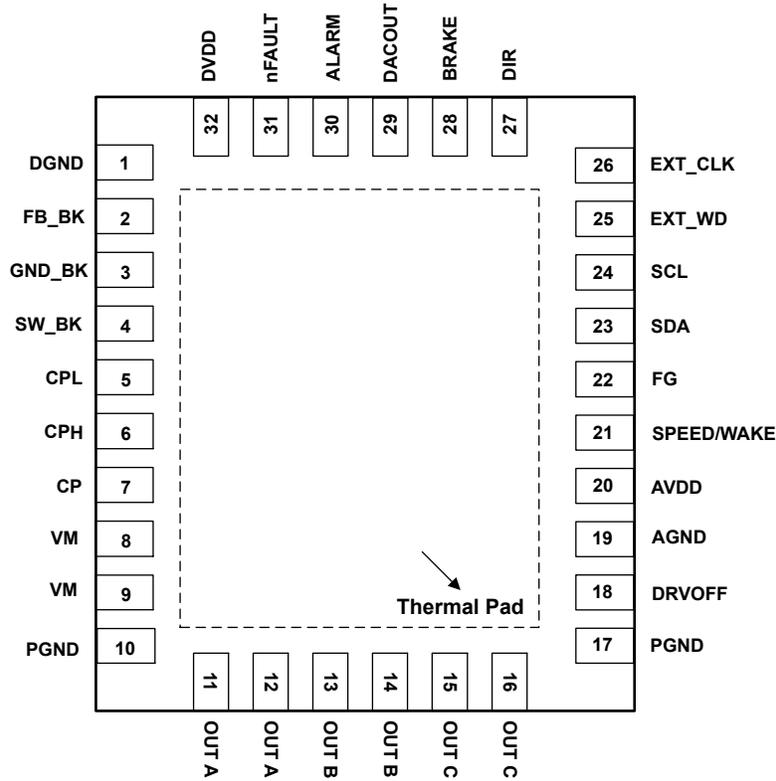


図 4-1. MCF8315C, 32-Pin WQFN With Exposed Thermal Pad, Top View

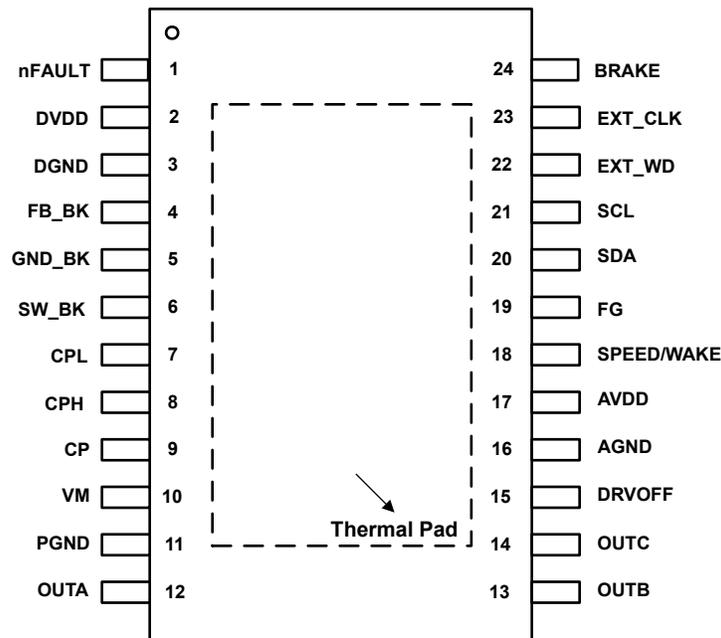


図 4-2. MCF8315C, 24-Pin HTSSOP With Exposed Thermal Pad, Top View

表 4-1. Pin Functions

| PIN | 32-pin package | 24-pin package | TYPE ⁽¹⁾ | DESCRIPTION |
|---------|----------------|----------------|---------------------|---|
| NAME | MCF8315C | MCF8315C | | |
| AGND | 19 | 16 | GND | Device analog ground. Refer Layout Guidelines for connection recommendation. |
| ALARM | 30 | - | O | Alarm signal: push-pull output. Pulled logic high during fault condition, if enabled. If ALARM pin is not used, leave it floating. |
| AVDD | 20 | 17 | PWR O | 3.3-V internal regulator output. Connect a X5R or X7R, 1- μ F, 6.3-V ceramic capacitor between the AVDD and AGND pins. This regulator can source up to 20 mA for external circuits. |
| BRAKE | 28 | 24 | I | High \rightarrow Brake the motor Low \rightarrow Normal motor operation If BRAKE pin is not used, connect to AGND directly. If BRAKE pin is used to brake the motor, use an (optional) external 10-k Ω pull-down resistor (to AGND) for better noise rejection. |
| CP | 7 | 9 | PWR | Charge pump output. Connect a X5R or X7R, 1- μ F, 16-V ceramic capacitor between the CP and VM pins. |
| CPH | 6 | 8 | PWR | Charge pump switching node. Connect a X5R or X7R, 47-nF, ceramic capacitor between the CPH and CPL pins. TI recommends a capacitor voltage rating at least twice the normal operating voltage of the device. |
| CPL | 5 | 7 | PWR | |
| DACOUT | 29 | - | O | DAC output |
| DGND | 1 | 3 | GND | Device digital ground. Refer Layout Guidelines for connection recommendation. |
| DIR | 27 | - | I | Direction of motor spinning; When low, phase driving sequence is OUT A \rightarrow OUT C \rightarrow OUT B When high, phase driving sequence is OUT A \rightarrow OUT B \rightarrow OUT C If DIR pin is not used, connect to AGND or AVDD directly (depending on phase driving sequence needed). If DIR pin is used for changing motor spin direction, use an (optional) external 10-k Ω pulldown resistor (to AGND) for better noise rejection. |
| DRVOFF | 18 | 15 | I | Coast (Hi-Z) all six MOSFETs as long as DRVOFF is high. If DRVOFF pin is not used, connect to AGND directly. If DRVOFF pin is to be used for instantly coasting (Hi-Z) the MOSFETs, use an external 10-k Ω pull-down resistor (to AGND) for better noise rejection. |
| DVDD | 32 | 2 | PWR | 1.5-V internal regulator output. Connect a X5R or X7R, 2.2- μ F, 6.3-V ceramic capacitor between the DVDD and DGND pins. |
| EXT_CLK | 26 | 23 | I | External clock reference input in external clock reference mode. |
| EXT_WD | 25 | 22 | I | External watchdog input. |
| FB_BK | 2 | 4 | PWR I/O | Feedback for buck regulator output control. Connect to buck regulator output after the inductor/resistor. |
| FG | 22 | 19 | O | Motor speed indicator : open-drain output that requires an external pull-up resistor to 1.8-V to 5.0-V. An optional internal pull-up resistor to AVDD is enabled by setting PULLUP_ENABLE to 1b; no external pull-up resistor should be used when internal pull-up resistor is enabled. |
| GND_BK | 3 | 5 | GND | Buck regulator ground. Refer Layout Guidelines for connection recommendation. |
| nFAULT | 31 | 1 | O | Fault indicator. Pulled logic-low during fault condition; open-drain output that requires an external pull-up resistor to 1.8-V to 5.0-V. An optional internal pull-up resistor to AVDD is enabled by setting PULLUP_ENABLE to 1b; no external pull-up resistor should be used when internal pull-up resistor is enabled. |
| OUTA | 11, 12 | 12 | PWR O | Half-bridge output A |
| OUTB | 13, 14 | 13 | PWR O | Half-bridge output B |
| OUTC | 15, 16 | 14 | PWR O | Half-bridge output C |
| PGND | 10, 17 | 11 | GND | Device power ground. Refer Layout Guidelines for connection recommendation. |
| SCL | 24 | 21 | I | I ² C clock input |

表 4-1. Pin Functions (続き)

| PIN | 32-pin package | 24-pin package | TYPE ⁽¹⁾ | DESCRIPTION |
|----------------|----------------|----------------|---------------------|---|
| NAME | MCF8315C | MCF8315C | | |
| SDA | 23 | 20 | I/O | I ² C data line |
| SPEED/ WAKE | 21 | 18 | I | Device speed input; supports analog, PWM or frequency based speed input. The speed pin input mode can be configured through SPEED_MODE. |
| SW_BK | 4 | 6 | PWR | Buck switch node. Connect this pin to an inductor or resistor. |
| VM | 8, 9 | 10 | PWR I | Device and motor power supply. Connect to motor supply voltage; bypass to PGND with one 0.1- μ F capacitor plus one bulk capacitor. TI recommends a capacitor voltage rating at least twice the normal operating voltage of the device. |
| Thermal pad | | | GND | Must be connected to AGND. |

(1) I = input, O = output, GND = ground, PWR = power

5 Specifications

5.1 Absolute Maximum Ratings

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

| | MIN | MAX | UNIT |
|--|------|----------------|------|
| Power supply pin voltage (VM) | -0.3 | 40 | V |
| Voltage difference between ground pins (GND_BK, DGND, PGND, AGND) | -0.3 | 0.3 | V |
| Charge pump voltage (CPH, CP) | -0.3 | $V_{VM} + 6$ | V |
| Charge pump negative switching pin voltage (CPL) | -0.3 | $V_{VM} + 0.3$ | V |
| Switching regulator pin voltage (FB_BK) | -0.3 | 6 | V |
| Switching node pin voltage (SW_BK) | -0.3 | $V_{VM} + 0.3$ | V |
| Analog regulators pin voltage (AVDD) | -0.3 | 4 | V |
| Analog regulators pin voltage (DVDD) | -0.3 | 1.7 | V |
| Logic pin input voltage (BRAKE, DRVOFF, DIR, EXT_CLK, EXT_WD, SCL, SDA, SPEED) | -0.3 | 6 | V |
| Open drain pin output voltage (nFAULT, FG) | -0.3 | 6 | V |
| Output pin voltage (OUTA, OUTB, OUTC) | -1 | $V_{VM} + 1$ | V |
| Ambient temperature, T_A | -40 | 125 | °C |
| Junction temperature, T_J | -40 | 150 | °C |
| Storage temperature, T_{stg} | -65 | 150 | °C |

- (1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime

5.2 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 JS-002 ⁽²⁾ | ±750 | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

| | | | MIN | NOM | MAX | UNIT |
|--------------------------|--------------------------------------|--|------|-----|-----|------|
| V_{VM} | Power supply voltage | V_{VM} | 4.5 | 24 | 35 | V |
| I_{OUT} ⁽¹⁾ | Peak output winding current | OUTA, OUTB, OUTC | | | 4 | A |
| V_{IN_LOGIC} | Logic input voltage | BRAKE, DRVOFF, DIR, EXT_CLK, EXT_WD, SPEED, SDA, SCL | -0.1 | | 5.5 | V |
| V_{OD} | Open drain pullup voltage | nFAULT, FG | -0.1 | | 5.5 | V |
| I_{OD} | Open drain output current capability | nFAULT, FG | | | 5 | mA |
| 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

5.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | MCF8315C | MCF8315C | UNIT |
|-------------------------------|--|------------|----------|------|
| | | RRY (WQFN) | HTSSOP | |
| | | 32 Pins | 24 Pins | |
| R _{θJA} | Junction-to-ambient thermal resistance | 30.7 | 30.5 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 18.6 | 23.7 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 9.6 | 10.1 | °C/W |
| Ψ _{JT} | Junction-to-top characterization parameter | 1.6 | 3.8 | °C/W |
| Ψ _{JB} | Junction-to-board characterization parameter | 9.6 | 10 | °C/W |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | 3.4 | 4.8 | °C/W |

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

5.5 Electrical Characteristics

T_J = -40°C to +150°C, V_{VM} = 4.5 to 35 V (unless otherwise noted). Typical limits apply for T_A = 25°C, V_{VM} = 24 V

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------|--------------------------------|---|-------|------|-------|------|
| POWER SUPPLIES | | | | | | |
| I _{VMQ} | VM sleep mode current | V _{VM} > 6 V, V _{SPEED} = 0, T _A = 25 °C | | 3 | 5 | μA |
| | | V _{SPEED} = 0, T _A = 125 °C | | 3.5 | 7 | μA |
| I _{VMS} | VM standby mode current | V _{VM} ≥ 12 V, Standby Mode, DRVOFF = High, T _A = 25 °C, L _{BK} = 47 uH, C _{BK} = 22 μF | | 8 | 16 | mA |
| | | V _{VM} ≥ 12 V, Standby Mode, DRVOFF = High, T _A = 25 °C, R _{BK} = 22 Ω, C _{BK} = 22 μF | | 25 | 29 | mA |
| | | V _{VM} ≥ 12 V, Standby Mode, DRVOFF = High, L _{BK} = 47 uH, C _{BK} = 22 μF | | 8 | 16.5 | mA |
| | | V _{VM} ≥ 12 V, Standby Mode, DRVOFF = High, R _{BK} = 22 Ω, C _{BK} = 22 μF | | 25 | 29 | mA |
| I _{VM} | VM operating mode current | V _{VM} ≥ 12 V, V _{SPEED} > V _{EX_SL} , PWM_FREQ_OUT = 0011b (25 kHz), T _A = 25 °C, L _{BK} = 47 uH, C _{BK} = 22 μF, No Motor Connected | | 11 | 18 | mA |
| | | V _{VM} ≥ 12 V, V _{SPEED} > V _{EX_SL} , PWM_FREQ_OUT = 0011b (25 kHz), T _A = 25 °C, R _{BK} = 22 Ω, C _{BK} = 22 μF, No Motor Connected | | 27 | 31.5 | mA |
| | | V _{VM} ≥ 12 V, V _{SPEED} > V _{EX_SL} , PWM_FREQ_OUT = 0011b (25 kHz), L _{BK} = 47 uH, C _{BK} = 22 μF, No Motor Connected | | 11 | 18 | mA |
| | | V _{VM} ≥ 12 V, V _{SPEED} > V _{EX_SL} , PWM_FREQ_OUT = 0011b (25 kHz), R _{BK} = 22 Ω, C _{BK} = 22 μF, No Motor Connected | | 28 | 32 | mA |
| V _{AVDD} | Analog regulator voltage | 0 mA ≤ I _{AVDD} ≤ 20 mA | 3.125 | 3.3 | 3.465 | V |
| I _{AVDD} | External analog regulator load | | | | 20 | mA |
| V _{DVDD} | Digital regulator voltage | | 1.4 | 1.55 | 1.65 | V |
| V _{VCP} | Charge pump regulator voltage | VCP with respect to VM | 4.0 | 4.7 | 5.5 | V |

$T_J = -40^\circ\text{C}$ to $+150^\circ\text{C}$, $V_{VM} = 4.5$ to 35 V (unless otherwise noted). Typical limits apply for $T_A = 25^\circ\text{C}$, $V_{VM} = 24\text{ V}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------|---|--|------|--|-----|------|
| BUCK REGULATOR | | | | | | |
| V_{BK} | Buck regulator average voltage ($L_{BK} = 47\ \mu\text{H}$, $C_{BK} = 22\ \mu\text{F}$) | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 170\text{ mA}$, BUCK_SEL = 00b | 3.1 | 3.3 | 3.5 | V |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 170\text{ mA}$, BUCK_SEL = 01b | 4.6 | 5.0 | 5.4 | V |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 170\text{ mA}$, BUCK_SEL = 10b | 3.7 | 4.0 | 4.3 | V |
| | | $V_{VM} > 6.7\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 170\text{ mA}$, BUCK_SEL = 11b | 5.2 | 5.7 | 5.8 | V |
| | | $V_{VM} < 6.0\text{ V}$ (BUCK_SEL = 00b, 01b, 10b, 11b), $0\text{ mA} \leq I_{BK} \leq 170\text{ mA}$ | | $V_{VM} - I_{BK} \cdot (R_{LBK} + 2)$ ¹ | | V |
| V_{BK} | Buck regulator average voltage ($L_{BK} = 22\ \mu\text{H}$, $C_{BK} = 22\ \mu\text{F}$) | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 20\text{ mA}$, BUCK_SEL = 00b | 3.1 | 3.3 | 3.5 | V |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 20\text{ mA}$, BUCK_SEL = 01b | 4.6 | 5.0 | 5.4 | V |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 20\text{ mA}$, BUCK_SEL = 10b | 3.7 | 4.0 | 4.3 | V |
| | | $V_{VM} > 6.7\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 20\text{ mA}$, BUCK_SEL = 11b | 5.2 | 5.7 | 5.8 | V |
| | | $V_{VM} < 6.0\text{ V}$ (BUCK_SEL = 00b, 01b, 10b, 11b), $0\text{ mA} \leq I_{BK} \leq 20\text{ mA}$ | | $V_{VM} - I_{BK} \cdot (R_{LBK} + 2)$ ¹ | | V |
| V_{BK} | Buck regulator average voltage ($R_{BK} = 22\ \Omega$, $C_{BK} = 22\ \mu\text{F}$) | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 10\text{ mA}$, BUCK_SEL = 00b | 3.1 | 3.3 | 3.5 | V |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 10\text{ mA}$, BUCK_SEL = 01b | 4.6 | 5.0 | 5.4 | V |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 10\text{ mA}$, BUCK_SEL = 10b | 3.7 | 4.0 | 4.3 | V |
| | | $V_{VM} > 6.7\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 10\text{ mA}$, BUCK_SEL = 11b | 5.2 | 5.7 | 5.8 | V |
| | | $V_{VM} < 6.0\text{ V}$ (BUCK_SEL = 00b, 01b, 10b, 11b), $0\text{ mA} \leq I_{BK} \leq 10\text{ mA}$ | | $V_{VM} - I_{BK} \cdot (R_{BK} + 2)$ | | V |
| V_{BK_RIP} | Buck regulator ripple voltage | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 170\text{ mA}$, Buck regulator with inductor, $L_{BK} = 47\ \mu\text{H}$, C_{BK} $= 22\ \mu\text{F}$ | -100 | | 100 | mV |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 20\text{ mA}$, Buck regulator with inductor, $L_{BK} = 22\ \mu\text{H}$, C_{BK} $= 22\ \mu\text{F}$ | -100 | | 100 | mV |
| | | $V_{VM} > 6\text{ V}$, $0\text{ mA} \leq I_{BK} \leq 10\text{ mA}$, Buck regulator with resistor; $R_{BK} = 22\ \Omega$, C_{BK} $= 22\ \mu\text{F}$ | -100 | | 100 | mV |

$T_J = -40^{\circ}\text{C}$ to $+150^{\circ}\text{C}$, $V_{VM} = 4.5$ to 35 V (unless otherwise noted). Typical limits apply for $T_A = 25^{\circ}\text{C}$, $V_{VM} = 24$ V

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------|---|--|-----|-----|---------------------|------------|
| I_{BK} | External buck regulator load | $L_{BK} = 47$ uH, $C_{BK} = 22$ μ F, BUCK_PS_DIS = 1b | | | 170 | mA |
| | | $L_{BK} = 47$ uH, $C_{BK} = 22$ μ F, BUCK_PS_DIS = 0b | | | 170 – I_{AVDD} | mA |
| | | $L_{BK} = 22$ uH, $C_{BK} = 22$ μ F, BUCK_PS_DIS = 1b | | | 20 | mA |
| | | $L_{BK} = 22$ uH, $C_{BK} = 22$ μ F, BUCK_PS_DIS = 0b | | | 20 – I_{AVDD} | mA |
| | | $R_{BK} = 22$ Ω , $C_{BK} = 22$ μ F, BUCK_PS_DIS = 1b | | | 10 | mA |
| | | $R_{BK} = 22$ Ω , $C_{BK} = 22$ μ F, BUCK_PS_DIS = 0b | | | 10 – I_{AVDD} | mA |
| f_{SW_BK} | Buck regulator switching frequency | Regulation Mode | 20 | | 535 | kHz |
| | | Linear Mode | 20 | | 535 | kHz |
| V_{BK_UVLO} | Buck regulator undervoltage lockout | V_{BK} rising, BUCK_SEL = 00b | 2.7 | 2.8 | 2.95 | V |
| | | V_{BK} falling, BUCK_SEL = 00b | 2.5 | 2.6 | 2.7 | V |
| | | V_{BK} rising, BUCK_SEL = 01b | 4.3 | 4.4 | 4.55 | V |
| | | V_{BK} falling, BUCK_SEL = 01b | 4.1 | 4.2 | 4.37 | V |
| | | V_{BK} rising, BUCK_SEL = 10b | 2.7 | 2.8 | 2.95 | V |
| | | V_{BK} falling, BUCK_SEL = 10b | 2.5 | 2.6 | 2.7 | V |
| | | V_{BK} rising, BUCK_SEL = 11b | 4.3 | 4.4 | 4.55 | V |
| | | V_{BK} falling, BUCK_SEL = 11b | 4.1 | 4.2 | 4.36 | V |
| $V_{BK_UVLO_HYS}$ | Buck regulator undervoltage lockout hysteresis | Rising to falling threshold, BUCK_SEL = 00b | 90 | 200 | 400 | mV |
| | | Rising to falling threshold, BUCK_SEL = 01b | 70 | 200 | 400 | mV |
| | | Rising to falling threshold, BUCK_SEL = 10b | 90 | 200 | 400 | mV |
| | | Rising to falling threshold, BUCK_SEL = 11b | 70 | 200 | 400 | mV |
| I_{BK_CL} | Buck regulator current limit threshold | BUCK_CL = 0b | 360 | 600 | 910 | mA |
| | | BUCK_CL = 1b | 80 | 150 | 250 | mA |
| I_{BK_OCP} | Buck regulator over current protection trip point | | 2 | 3 | 4 | A |
| t_{BK_RETRY} | Over current protection retry time | | 0.7 | 1 | 1.3 | ms |
| DRIVER OUTPUTS | | | | | | |
| $R_{DS(ON)}$ (RRY) | Total MOSFET on resistance (High-side + Low-side) | $V_{VM} > 6$ V, $I_{OUT} = 1$ A, $T_A = 25^{\circ}\text{C}$ | | 250 | 270 | m Ω |
| | | $V_{VM} < 6$ V, $I_{OUT} = 1$ A, $T_A = 25^{\circ}\text{C}$ | | 260 | 280 | m Ω |
| | | $V_{VM} > 6$ V, $I_{OUT} = 1$ A, $T_J = 150^{\circ}\text{C}$ | | 375 | 415 | m Ω |
| | | $V_{VM} < 6$ V, $I_{OUT} = 1$ A, $T_J = 150^{\circ}\text{C}$ | | 385 | 425 | m Ω |
| $R_{DS(ON)}$ (PW P) | Total MOSFET on resistance (High-side + Low-side) | $V_{VM} > 6$ V, $I_{OUT} = 1$ A, $T_A = 25^{\circ}\text{C}$ | | 265 | 280 | m Ω |
| | | $V_{VM} < 6$ V, $I_{OUT} = 1$ A, $T_A = 25^{\circ}\text{C}$ | | 275 | 290 | m Ω |
| | | $V_{VM} > 6$ V, $I_{OUT} = 1$ A, $T_A = 150^{\circ}\text{C}$ | | 390 | 430 | m Ω |
| | | $V_{VM} < 6$ V, $I_{OUT} = 1$ A, $T_A = 150^{\circ}\text{C}$ | | 400 | 440 | m Ω |
| SR | Phase pin slew rate switching low to high (Rising from 20 % to 80 %) | $V_{VM} = 24$ V, SLEW_RATE = 10b | 80 | 125 | 210 | V/ μ s |
| | | $V_{VM} = 24$ V, SLEW_RATE = 11b | 130 | 200 | 315 | V/ μ s |
| SR | Phase pin slew rate switching high to low (Falling from 80 % to 20 %) | $V_{VM} = 24$ V, SLEW_RATE = 10b | 80 | 125 | 235 | V/ μ s |
| | | $V_{VM} = 24$ V, SLEW_RATE = 11b | 130 | 200 | 345 | V/ μ s |

$T_J = -40^{\circ}\text{C}$ to $+150^{\circ}\text{C}$, $V_{VM} = 4.5$ to 35 V (unless otherwise noted). Typical limits apply for $T_A = 25^{\circ}\text{C}$, $V_{VM} = 24\text{ V}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------------------|--|---|-------|------|-------|---------------|
| t_{DEAD} | Output dead time (high to low / low to high) | $V_{VM} = 24\text{ V}$, SR = 125 V/ μs | | 650 | 850 | ns |
| | | $V_{VM} = 24\text{ V}$, SR = 200 V/ μs | | 500 | 550 | ns |
| SPEED INPUT - PWM MODE | | | | | | |
| f_{PWM} | PWM input frequency | | 0.01 | | 100 | kHz |
| Res_{PWM} | PWM input resolution | $f_{\text{PWM}} = 0.01$ to 0.35 kHz | 11 | 12 | 13 | bits |
| | | $f_{\text{PWM}} = 0.35$ to 2 kHz | 11 | 13 | 14 | bits |
| | | $f_{\text{PWM}} = 2$ to 3.5 kHz | 11 | 11.5 | 12 | bits |
| | | $f_{\text{PWM}} = 3.5$ to 7 kHz | 12 | 13 | 13.5 | bits |
| | | $f_{\text{PWM}} = 7$ to 14 kHz | 11 | 12 | 12.5 | bits |
| | | $f_{\text{PWM}} = 14$ to 29.2 kHz | 10 | 11.5 | 12 | bits |
| | | $f_{\text{PWM}} = 29.3$ to 60 kHz | 9 | 10.5 | 11 | bits |
| | | $f_{\text{PWM}} = 60$ to 100 kHz | 8 | 9 | 10 | bits |
| SPEED INPUT - ANALOG MODE | | | | | | |
| $V_{\text{ANA_FS}}$ | Analog full-speed voltage | | 2.95 | 3 | 3.05 | V |
| $V_{\text{ANA_RES}}$ | Analog voltage resolution | | | 732 | | μV |
| SPEED INPUT - FREQUENCY MODE | | | | | | |
| $f_{\text{PWM_FREQ}}$ | PWM input frequency range | Duty cycle = 50% | 3 | | 32767 | Hz |
| SLEEP MODE | | | | | | |
| $V_{\text{EN_SL}}$ | Analog voltage to enter sleep mode | SPEED_MODE = 00b (analog mode) | | | 40 | mV |
| $V_{\text{EX_SL}}$ | Analog voltage to exit sleep mode | SPEED_MODE = 00b (analog mode) | 2.2 | | | V |
| $t_{\text{DET_ANA}}$ | Time needed to detect wake up signal on SPEED pin | SPEED_MODE = 00b (analog mode) $V_{\text{SPEED}} > V_{\text{EX_SL}}$ | 0.5 | 1 | 1.5 | μs |
| t_{WAKE} | Wakeup time from sleep state | $V_{\text{SPEED}} > V_{\text{EX_SL}}$ to DVDD voltage available, SPEED_MODE = 00b (analog mode) | | 3 | 5 | ms |
| $t_{\text{EX_SL_DR_ANA}}$ | Time taken to drive motor after wake-up from sleep state | SPEED_MODE = 00b (analog mode), DVDD voltage available to first output PWM pulse, ISD detection disabled | | | 30 | ms |
| $t_{\text{DET_PWM}}$ | Time needed to detect wake up signal on SPEED pin | SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode), $V_{\text{SPEED}} > V_{\text{IH}}$ | 0.5 | 1 | 1.5 | μs |
| $t_{\text{WAKE_PWM}}$ | Wakeup time from sleep state | $V_{\text{SPEED}} > V_{\text{IH}}$ to DVDD voltage available, SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode) | | 3 | 5 | ms |
| $t_{\text{EX_SL_DR_PWM}}$ | Time taken to drive motor after wake-up from sleep state | SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode), DVDD voltage available to first output PWM pulse, ISD detection disabled | | | 30 | ms |
| $t_{\text{DET_SL_ANA}}$ | Time needed to detect sleep command, analog mode | SPEED_MODE = 00b (analog mode) $V_{\text{SPEED}} < V_{\text{EN_SL}}$, SLEEP_ENTRY_TIME = 00b | 0.035 | 0.05 | 0.065 | ms |
| | | SPEED_MODE = 00b (analog mode) $V_{\text{SPEED}} < V_{\text{EN_SL}}$, SLEEP_ENTRY_TIME = 00b or 01b | 0.14 | 0.2 | 0.26 | ms |
| | | SPEED_MODE = 00b (analog mode) $V_{\text{SPEED}} < V_{\text{EN_SL}}$, SLEEP_ENTRY_TIME = 10b | 14 | 20 | 26 | ms |
| | | SPEED_MODE = 00b (analog mode) $V_{\text{SPEED}} < V_{\text{EN_SL}}$, SLEEP_ENTRY_TIME = 11b | 140 | 200 | 260 | ms |

$T_J = -40^{\circ}\text{C}$ to $+150^{\circ}\text{C}$, $V_{VM} = 4.5$ to 35 V (unless otherwise noted). Typical limits apply for $T_A = 25^{\circ}\text{C}$, $V_{VM} = 24$ V

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|---|-------|------|------------------------------|---------------|
| $t_{\text{DET_SL_PWM}}$ | Time needed to detect sleep command, PWM or frequency mode | SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 00b | 0.035 | 0.05 | 0.065 | ms |
| | | SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 01b | 0.14 | 0.2 | 0.26 | ms |
| | | SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 10b | 14 | 20 | 26 | ms |
| | | SPEED_MODE = 01b (PWM mode) or 11b (Frequency mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 11b | 140 | 200 | 260 | ms |
| $t_{\text{EN_SL}}$ | Time needed to stop driving motor after detecting sleep command | SPEED < $V_{\text{EN_SL}}$ (analog mode) or $V_{\text{SPEED}} < V_{\text{IL}}$ (PWM mode or Frequency mode) or $V_{\text{SPEED}} < V_{\text{IL}}$ and DIGITAL_SPEED_CTRL = 0b (I2C mode) | | 1 | 2 | ms |
| STANDBY MODE | | | | | | |
| $t_{\text{EX_SB_DR_ANA}}$ | Time taken to drive motor after exiting standby mode, analog mode | SPEED_MODE = 00b (analog mode), $V_{\text{SPEED}} > V_{\text{EX_SB}}$, ISD detection disabled | | | 6 | ms |
| $t_{\text{EX_SB_DR_PWM}}$ | Time taken to drive motor after exiting standby mode, PWM mode | SPEED_MODE = 01b (PWM mode) $V_{\text{SPEED}} > V_{\text{IH}}$, ISD detection disabled | | | 6 | ms |
| $t_{\text{DET_SB_ANA}}$ | Time needed to detect standby command, analog mode | SPEED_MODE = 00b (analog mode), $V_{\text{SPEED}} < V_{\text{EN_SB}}$ | 0.5 | 1 | 2 | ms |
| $t_{\text{DET_SB_PWM}}$ | Time needed to detect standby command, PWM or frequency mode | SPEED_MODE = 01b (PWM mode) or SPEED_MODE = 11b (Freq mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 00b | 0.035 | 0.05 | 0.065 | ms |
| | | SPEED_MODE = 01b (PWM mode) or SPEED_MODE = 11b (Freq mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 01b | 0.14 | 0.2 | 0.26 | ms |
| | | SPEED_MODE = 01b (PWM mode) or SPEED_MODE = 11b (Freq mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 10b | 14 | 20 | 26 | ms |
| | | SPEED_MODE = 01b (PWM mode) or SPEED_MODE = 11b (Freq mode), $V_{\text{SPEED}} < V_{\text{IL}}$, SLEEP_ENTRY_TIME = 11b | 140 | 200 | 260 | ms |
| $t_{\text{DET_SB_DIG}}$ | Time needed to detect standby mode, I ² C mode | SPEED_MODE = 10b (I ² C mode), DIGITAL_SPEED_CTRL = 0b | | 1 | 2 | ms |
| $t_{\text{EN_SB}}$ | Time needed to stop driving motor after detecting standby command | All reference input modes | | 1 | 2 | ms |
| LOGIC-LEVEL INPUTS (BRAKE, DIR, EXT_CLK, EXT_WD, SPEED) | | | | | | |
| V_{IL} | Input logic low voltage | AVDD = 3 to 3.6 V | | | $0.25 \cdot V_{\text{AVDD}}$ | V |
| V_{IH} | Input logic high voltage | AVDD = 3 to 3.6 V | | | $0.65 \cdot V_{\text{AVDD}}$ | V |
| V_{HYS} | Input hysteresis | | 50 | 500 | 800 | mV |
| I_{IL} | Input logic low current | AVDD = 3 to 3.6 V | -0.15 | | 0.15 | μA |

$T_J = -40^\circ\text{C}$ to $+150^\circ\text{C}$, $V_{VM} = 4.5$ to 35 V (unless otherwise noted). Typical limits apply for $T_A = 25^\circ\text{C}$, $V_{VM} = 24\text{ V}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|------------------------------------|-----------------------------|---------------------------|---------|---------------|
| I_{IH} | Input logic high current | AVDD = 3 to 3.6 V | -0.3 | | 0 | μA |
| R_{PD_SPEED} | Input pulldown resistance | SPEED pin To GND | 0.6 | 1 | 1.4 | M Ω |
| OPEN-DRAIN OUTPUTS (nFAULT, FG) | | | | | | |
| V_{OL} | Output logic low voltage | $I_{OD} = -5\text{ mA}$ | | | 0.4 | V |
| I_{OZ} | Output logic high current | $V_{OD} = 3.3\text{ V}$ | 0 | | 0.5 | μA |
| I²C Serial Interface | | | | | | |
| V_{I2C_L} | Input logic low voltage | | -0.5 | $0.3 \cdot \frac{AVD}{D}$ | | V |
| V_{I2C_H} | Input logic high voltage | | $0.7 \cdot \frac{AVD}{D}$ | | 5.5 | V |
| V_{I2C_HYS} | Hysteresis | | $0.05 \cdot \frac{AVD}{DD}$ | | | V |
| V_{I2C_OL} | Output logic low voltage | Open-drain at 2mA sink current | 0 | | 0.4 | V |
| I_{I2C_OL} | Output logic low current | $V_{I2C_OL} = 0.6\text{ V}$ | | | 6 | mA |
| I_{I2C_IL} | Input current on SDA and SCL | | -10^2 | | 10^2 | μA |
| C_i | Capacitance for SDA and SCL | | | | 10 | pF |
| t_{of} | Output fall time from $V_{I2C_H}(\text{min})$ to $V_{I2C_L}(\text{max})$ | Standard Mode | | | 250^3 | ns |
| | | Fast Mode | | | 250^3 | ns |
| t_{SP} | Pulse width of spikes that must be suppressed by the input filter | Fast Mode | 0 | | 50^4 | ns |
| OSCILLATOR | | | | | | |
| f_{OSCREF} | External clock reference | EXT_CLK_CONFIG = 000b | | 8 | | kHz |
| | | EXT_CLK_CONFIG = 001b | | 16 | | kHz |
| | | EXT_CLK_CONFIG = 010b | | 32 | | kHz |
| | | EXT_CLK_CONFIG = 011b | | 64 | | kHz |
| | | EXT_CLK_CONFIG = 100b | | 128 | | kHz |
| | | EXT_CLK_CONFIG = 101b | | 256 | | kHz |
| | | EXT_CLK_CONFIG = 110b | | 512 | | kHz |
| | | EXT_CLK_CONFIG = 111b | | 1024 | | kHz |
| EEPROM | | | | | | |
| EE_{Prog} | Programming voltage | | 1.35 | 1.5 | 1.65 | V |
| EE_{RET} | Retention | $T_A = 25^\circ\text{C}$ | | 100 | | Years |
| | | $T_J = -40$ to 150°C | 10 | | | Years |
| EE_{END} | Endurance | $T_J = -40$ to 150°C | 1000 | | | Cycles |
| | | $T_J = -40$ to 85°C | 20000 | | | Cycles |
| PROTECTION CIRCUITS | | | | | | |
| V_{UVLO} | Supply under voltage lockout (UVLO) | VM rising | 4.3 | 4.4 | 4.51 | V |
| | | VM falling | 4.1 | 4.2 | 4.32 | V |
| V_{UVLO_HYS} | Supply under voltage lockout hysteresis | Rising to falling threshold | 90 | 200 | 350 | mV |
| t_{UVLO} | Supply under voltage deglitch time | | 3 | 5 | 7 | μs |

$T_J = -40^{\circ}\text{C}$ to $+150^{\circ}\text{C}$, $V_{VM} = 4.5$ to 35 V (unless otherwise noted). Typical limits apply for $T_A = 25^{\circ}\text{C}$, $V_{VM} = 24$ V

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|---|--|------|------|------|--------------------|
| V_{OVP} | Supply over voltage protection (OVP) threshold | Supply rising, OVP_EN = 1, OVP_SEL = 0 | 32.5 | 34 | 35 | V |
| | | Supply falling, OVP_EN = 1, OVP_SEL = 0 | 31.8 | 33 | 34.3 | V |
| | | Supply rising, OVP_EN = 1, OVP_SEL = 1 | 20 | 22 | 23 | V |
| | | Supply falling, OVP_EN = 1, OVP_SEL = 1 | 19 | 21 | 22 | V |
| V_{OVP_HYS} | Supply over voltage protection hysteresis | Rising to falling threshold, OVP_SEL = 1 | 0.9 | 1 | 1.15 | V |
| | | Rising to falling threshold, OVP_SEL = 0 | 0.7 | 0.8 | 0.9 | V |
| t_{OVP} | Supply over voltage deglitch time | | 2.5 | 5 | 7 | μs |
| V_{CPUV} | Charge pump under voltage lockout (above VM) | Supply rising | 2.25 | 2.5 | 2.75 | V |
| | | Supply falling | 2.2 | 2.4 | 2.6 | V |
| V_{CPUV_HYS} | Charge pump UVLO hysteresis | Rising to falling threshold | 65 | 100 | 150 | mV |
| V_{AVDD_UV} | Analog regulator (AVDD) under voltage lockout | Supply rising | 2.7 | 2.85 | 3 | V |
| | | Supply falling | 2.48 | 2.65 | 2.8 | V |
| $V_{AVDD_UV_HYS}$ | Analog regulator under voltage lockout hysteresis | Rising to falling threshold | 180 | 200 | 240 | mV |
| I_{OCP} | Over current protection trip point | OCP_LVL = 0b | 5.5 | 9 | 12 | A |
| | | OCP_LVL = 1b | 9 | 13 | 18 | A |
| t_{OCP} | Over current protection deglitch time | OCP_DEG = 00b | 0.02 | 0.2 | 0.4 | μs |
| | | OCP_DEG = 01b | 0.2 | 0.6 | 1.2 | μs |
| | | OCP_DEG = 10b | 0.5 | 1.2 | 1.8 | μs |
| | | OCP_DEG = 11b | 0.9 | 1.6 | 2.5 | μs |
| t_{RETRY} | Over current protection retry time | | 425 | 500 | 575 | ms |
| T_{OTW} | Thermal warning temperature | Die temperature (T_J) | 135 | 145 | 155 | $^{\circ}\text{C}$ |
| T_{OTW_HYS} | Thermal warning hysteresis | Die temperature (T_J) | 15 | 20 | 30 | $^{\circ}\text{C}$ |
| T_{TSD_BUCK} | Thermal shutdown temperature (Buck) | Die temperature (T_J) | 170 | 180 | 190 | $^{\circ}\text{C}$ |
| $T_{TSD_BUCK_HYS}$ | Thermal shutdown hysteresis (Buck) | Die temperature (T_J) | 15 | 20 | 30 | $^{\circ}\text{C}$ |
| T_{TSD} | Thermal shutdown temperature (FET) | Die temperature (T_J) | 165 | 175 | 185 | $^{\circ}\text{C}$ |
| T_{TSD_HYS} | Thermal shutdown hysteresis (FET) | Die temperature (T_J) | 15 | 20 | 30 | $^{\circ}\text{C}$ |

- (1) R_{LBK} is resistance of inductor L_{BK} .
- (2) If AVDD is switched off, I/O pins must not obstruct the SDA and SCL lines.
- (3) The maximum t_f for the SDA and SCL bus lines (300 ns) is longer than the specified maximum t_{of} for the output stages (250 ns). This allows series protection resistors (R_s) to be connected between the SDA/SCL pins and the SDA/SCL bus lines without exceeding the maximum specified t_f .
- (4) Input filters on the SDA and SCL inputs suppress noise spikes of less than 50 ns.

5.6 Characteristics of the SDA and SCL bus for Standard and Fast mode

over operating free-air temperature range (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | NOM | MAX | UNIT |
|----------------------|--------------------------------------|---|-----|-----|-----|---------------|
| Standard-mode | | | | | | |
| f_{SCL} | SCL clock frequency | | 0 | | 100 | kHz |
| 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 |

over operating free-air temperature range (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | NOM | MAX | UNIT |
|------------------|--|---|-------------------------|-----|---------------------|---------|
| t_{SU_STA} | Set-up time for a repeated START condition | | 4.7 | | | μ s |
| t_{HD_DAT} | Data hold time ⁽²⁾ | I2C bus devices | 0 ⁽³⁾ | | ⁽⁴⁾ | μ s |
| t_{SU_DAT} | Data set-up time | | 250 | | | ns |
| t_r | Rise time for both SDA and SCL signals | | | | 1000 | ns |
| t_f | Fall time of both SDA and SCL signals ⁽³⁾ ⁽⁶⁾ ⁽⁷⁾ ⁽⁸⁾ | | | | 300 | ns |
| t_{SU_STO} | Set-up time for STOP condition | | 4 | | | μ s |
| t_{BUF} | Bus free time between STOP and START condition | | 4.7 | | | μ s |
| C_b | Capacitive load for each bus line ⁽⁹⁾ | | | | 400 | pF |
| t_{VD_DAT} | Data valid time ⁽¹⁰⁾ | | | | 3.45 ⁽⁴⁾ | μ s |
| t_{VD_ACK} | Data valid acknowledge time ⁽¹¹⁾ | | | | 3.45 ⁽⁴⁾ | μ s |
| V_{nL} | Noise margin at the LOW level | For each connected device (including hysteresis) | 0.1*AVD D | | | V |
| V_{nh} | Noise margin at the HIGH level | For each connected device (including hysteresis) | 0.2*AVD D | | | V |
| 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 | | | μ s |
| t_{LOW} | LOW period of the SCL clock | | 1.3 | | | μ s |
| t_{HIGH} | HIGH period of the SCL clock | | 0.6 | | | μ s |
| t_{SU_STA} | Set-up time for a repeated START condition | | 0.6 | | | μ s |
| t_{HD_DAT} | Data hold time ⁽²⁾ | | 0 ⁽³⁾ | | ⁽⁴⁾ | μ s |
| t_{SU_DAT} | Data set-up time | | 100 ⁽⁵⁾ | | | ns |
| t_r | Rise time for both SDA and SCL signals | | 20 | | 300 | ns |
| t_f | Fall time of both SDA and SCL signals ⁽³⁾ ⁽⁶⁾ ⁽⁷⁾ ⁽⁸⁾ | | 20 x (AVDD/ 5.5V) | | 300 | ns |
| t_{SU_STO} | Set-up time for STOP condition | | 0.6 | | | μ s |
| t_{BUF} | Bus free time between STOP and START condition | | 1.3 | | | μ s |
| C_b | Capacitive load for each bus line ⁽⁹⁾ | | | | 400 | pF |
| t_{VD_DAT} | Data valid time ⁽¹⁰⁾ | | | | 0.9 ⁽⁴⁾ | μ s |
| t_{VD_ACK} | Data valid acknowledge time ⁽¹¹⁾ | | | | 0.9 ⁽⁴⁾ | μ s |
| V_{nL} | Noise margin at the LOW level | For each connected device (including hysteresis) | 0.1*AVD D | | | V |
| V_{nh} | Noise margin at the HIGH level | For each connected device (including hysteresis) | 0.2*AVD D | | | V |

- (1) All values referred to $V_{IH(min)}$ ($0.3V_{DD}$) and $V_{IL(max)}$ levels
- (2) t_{HD_DAT} is the data hold time that is measured from the falling edge of SCL, applies to data in transmission and the acknowledge.
- (3) A device must internally provide a hold time of at least 300 ns for the SDA signal (with respect to the $V_{IH(min)}$ of the SCL signal) to bridge the undefined region of the falling edge of SCL.
- (4) The maximum t_{HD_DAT} could be 3.45 μ s and .9 μ s for Standard-mode and Fast-mode, but must be less than the maximum of t_{VD_DAT} or t_{VD_ACK} by a transition time. This maximum must only be met if the device does not stretch the LOW period (t_{LOW}) of the SCL signal. If the clock stretched the SCL, the data must be valid by the set-up time before it releases the clock.
- (5) A Fast-mode I2C-bus device can be used in a Standard-mode I2C-bus system, but the requirement t_{SU_DAT} 250 ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the

LOW period of the SCL signal, it must output the next data bit to the SDA line $t_{r(max)} + t_{SU_DAT} = 1000 + 250 = 1250$ ns (according to the Standard-mode I2C-bus specification) before the SCL line is released. Also the acknowledge timing must meet this set-up time.

- (6) If mixed with HS-mode devices, faster fall times according to Table 10 are allowed.
- (7) The maximum t_f for the SDA and SCL bus lines is specified at 300 ns. The maximum fall time for the SDA output stage t_f is specified at 250 ns. This allows series protection resistors to be connected in between the SDA and the SCL pins and the SDA/SCL bus lines without exceeding the maximum specified t_f .
- (8) In Fast-mode Plus, fall time is specified the same for both output stage and bus timing. If series resistors are used, designers should allow for this when considering bus timing.
- (9) The maximum bus capacitance allowable may vary from the value depending on the actual operating voltage and frequency of the application.
- (10) t_{VD_DAT} = time for data signal from SCL LOW to SDA output (HIGH or LOW, depending on which one is worse).
- (11) t_{VD_ACK} = time for Acknowledgement signal from SCL LOW to SDA output (HIGH or LOW, depending on which one is worse).

5.7 Typical Characteristics

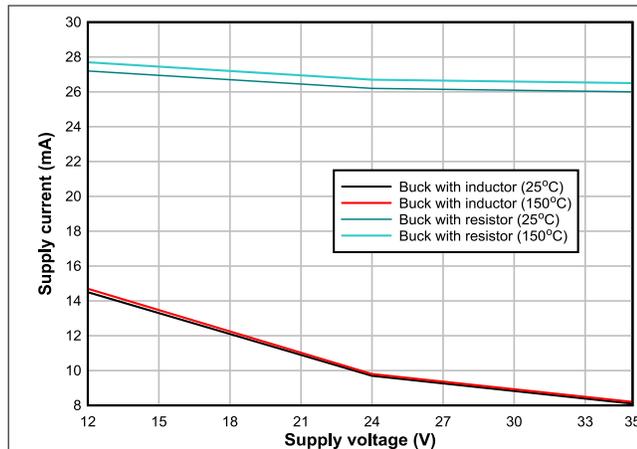


Figure 5-1. Supply current across supply voltage

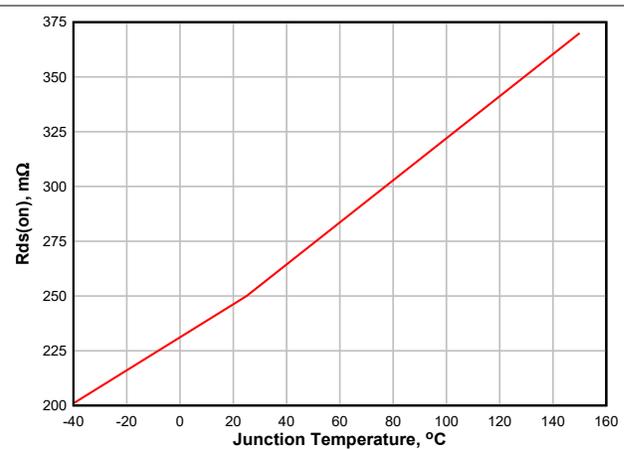


Figure 5-2. $R_{ds(on)}$ (H+L) across temperature

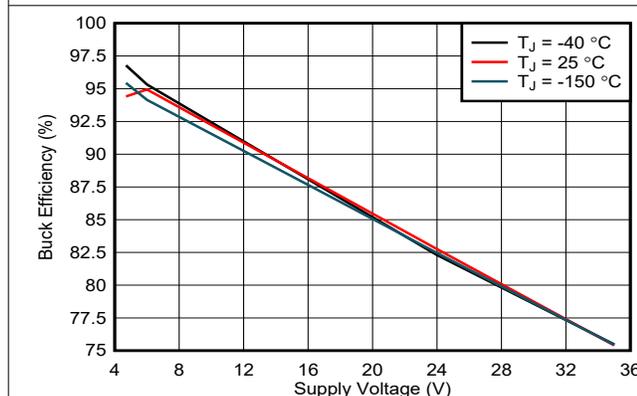


Figure 5-3. Buck regulator efficiency over supply voltage

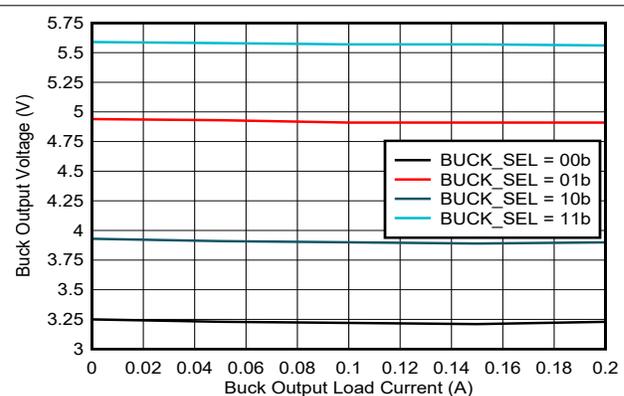


Figure 5-4. Buck regulator output voltage over load current

6 Detailed Description

6.1 Overview

The MCF8315C provides a single-chip, code-free sensorless FOC solution for customers driving speed-controlled 12- to 24-V brushless-DC motors requiring up to 4-A peak phase currents.

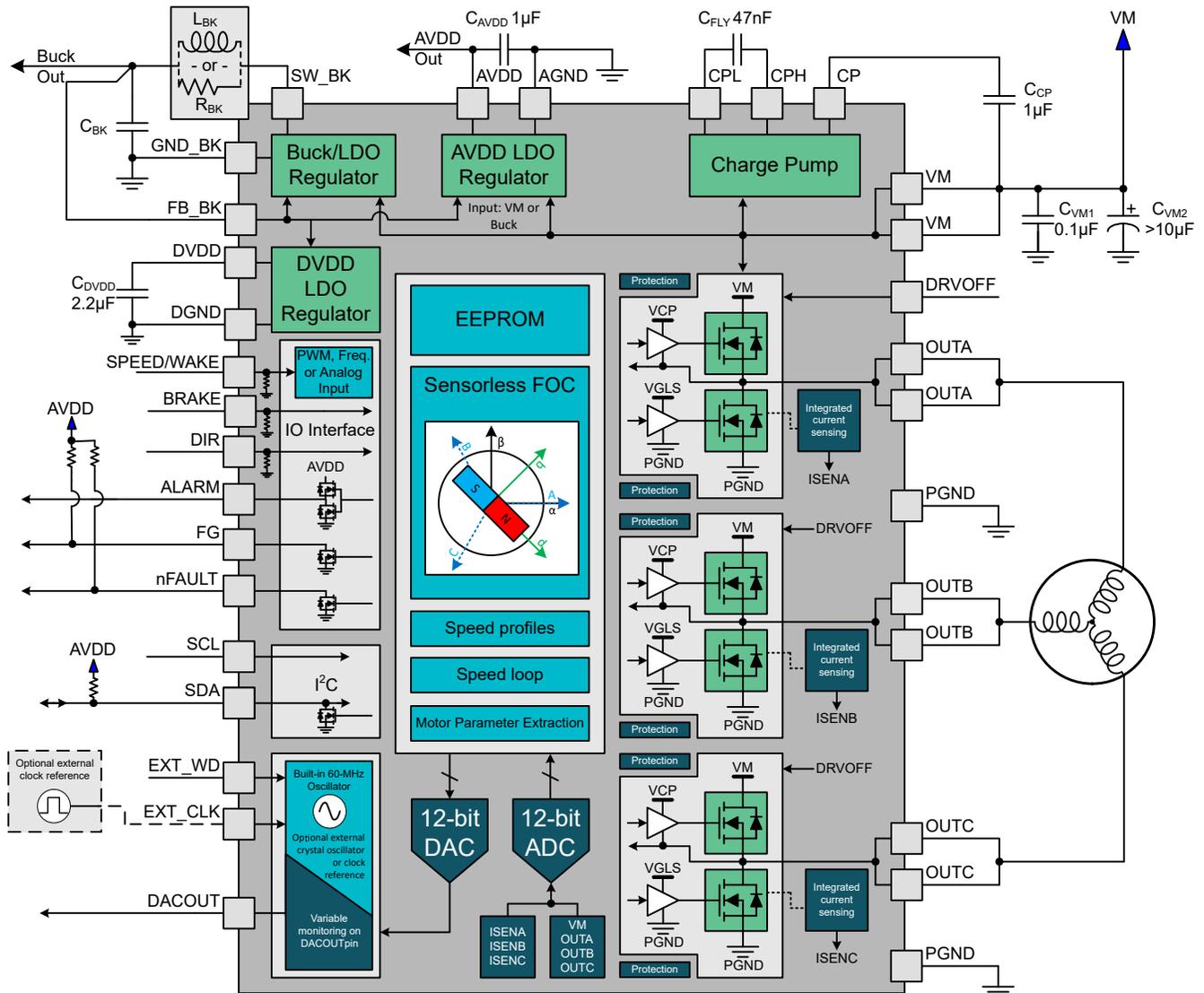
The MCF8315C integrates three $\frac{1}{2}$ -bridges with 40-V absolute maximum capability and a low $R_{DS(ON)}$ of 250-m Ω /265-m Ω (high-side + low-side) to enable high power drive capability. Current is sensed using an integrated current sensing circuit which eliminates the need for external sense resistors. Power management features of an adjustable buck regulator and LDO generate the necessary voltage rails for the device and can also be used to power external circuits.

MCF8315C implements sensorless FOC, and so an external microcontroller is not required to spin the brushless-DC motor. The algorithm is implemented in a fixed-function state machine, so no coding is needed. The algorithm is highly configurable through register settings ranging from motor start-up behavior to closed loop operation. Register settings can be stored in non-volatile EEPROM, which allows the device to operate stand-alone once it has been configured. The device receives a speed command through a PWM input, analog voltage, frequency input or I²C command.

In-built protection features include power-supply under voltage lockout (UVLO), charge-pump under voltage lockout (CPUV), over current protection (OCP), AVDD under voltage lockout (AVDD_UV), buck regulator UVLO, motor lock detection and over temperature warning and shutdown (OTW and TSD). Fault events are indicated by the nFAULT pin with detailed fault information available in the registers.

The MCF8315C device is available in 0.5-mm pin pitch, WQFN and 0.65-mm pin pitch, HTSSOP surface-mount packages. The WQFN package size is 6 mm × 4 mm with a height of 0.8 mm. The HTSSOP package size is 7.80 mm x 6.40 mm with a height of 1.2 mm.

6.2 Functional Block Diagram



6-1. MCF8315C (RRY) Functional Block Diagram

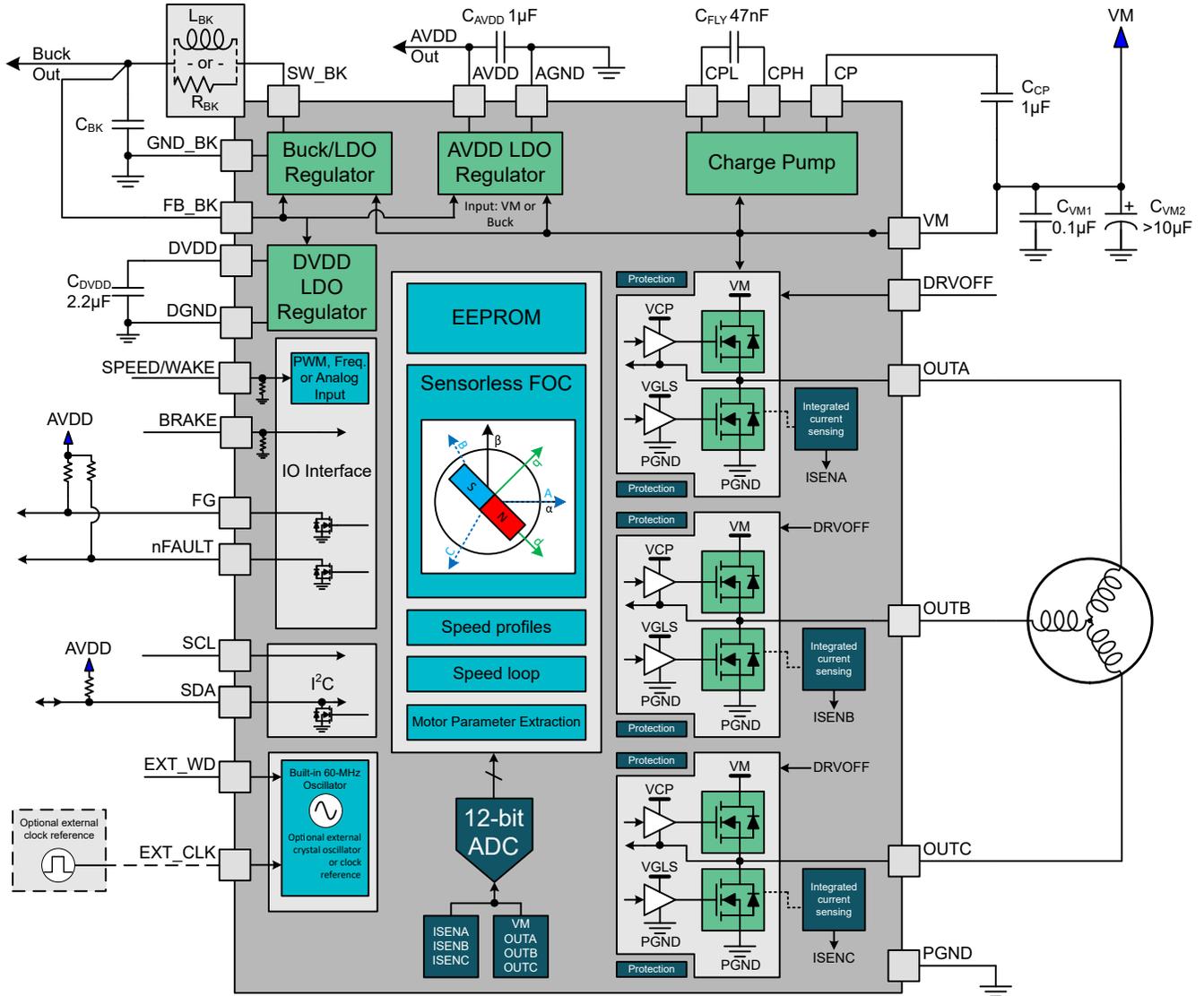


図 6-2. MCF8315C (PWP) Functional Block Diagram

6.3 Feature Description

6.3.1 Output Stage

The MCF8315C consists of integrated 250-mΩ or 265-mΩ (combined high-side and low-side FETs' on-state resistance) NMOS FETs connected in a three-phase bridge configuration. A doubler charge pump provides the proper gate-bias voltage to the high-side NMOS FETs across a wide operating voltage range in addition to providing 100% duty-cycle support. An internal linear regulator provides the gate-bias voltage for the low-side MOSFETs.

6.3.2 Device Interface

The MCF8315C supports I²C interface to provide end application design with adequate flexibility. MCF8315C allows controlling the motor operation and system through BRAKE, DRVOFF, DIR, EXT_CLK, EXT_WD and SPEED/WAKE pins. MCF8315C also provides different signals for monitoring system variables, speed, fault and phase current feedback through DACOUT, FG, nFAULT and ALARM pins.

注

DIR, ALARM, DACOUT pins are available only in RRY(32-pin QFN) package.

6.3.2.1 Interface - Control and Monitoring

Motor Control Signals

- SPEED/WAKE pin is used to control the motor speed and to wake up MCF8315C from sleep. SPEED pin can be configured to accept PWM, frequency or analog input signals. It is also used to enter and exit from sleep and standby mode (see [表 6-7](#)).
- When BRAKE pin is driven 'High', MCF8315C enters brake state. MCF8315C decreases output speed to value defined by BRAKE_SPEED_THRESHOLD before entering brake state. As long as BRAKE is driven 'High', MCF8315C stays in brake state. Brake pin input can be overwritten by configuring BRAKE_INPUT over the I²C interface.
- The DIR pin decides the direction of motor spin; when driven 'High', the sequence is OUT A → OUT B → OUT C, and when driven 'Low', the sequence is OUT A → OUT C → OUT B. DIR pin input can be overwritten by configuring DIR_INPUT over the I²C interface.
- When DRVOFF pin is driven 'High', MCF8315C stops driving the motor by turning OFF all MOSFETs (coast state) - this could be accompanied by faults like no motor or abnormal BEMF. When DRVOFF is driven 'Low', MCF8315C returns to normal state of operation, as if it was restarting the motor (see [DRVOFF Functionality](#)). DRVOFF does not cause the device to go to sleep or standby mode; the digital core is still active. Entry and exit from sleep or standby condition is controlled by SPEED pin or I²C speed command.

External Oscillator and Watchdog Signals

- EXT_CLK pin can be used to provide an external clock reference (see [External Clock Source](#)).
- EXT_WD pin can be used to provide an external watchdog signal (see [External Watchdog](#)).

Output Signals

- DACOUT outputs internal variable defined by address in register DACOUT_VAR_ADDR (see [DAC output \(only in RRY package\)](#)).
- FG pin provides pulses which are proportional to motor speed (see [FG Configuration](#)).
- nFAULT (active low) pin provides fault status in device or motor operation.
- ALARM pin, if enabled using ALARM_PIN_EN, provides fault status in device or motor operation as an active high signal. When ALARM pin is enabled, report only faults are reported only on ALARM pin (as logic high) and not reported on nFAULT pin (as logic low). When ALARM pin is enabled, actionable faults are reported on ALARM pin (as logic high) as well as on nFAULT pin (as logic low). When ALARM pin is disabled, it is in Hi-Z state and all faults (actionable and report only) are reported on nFAULT as logic low. ALARM pin should be left floating when unused/disabled.

注

1. Internal pull-up resistor (to AVDD) for both FG and nFAULT pins can be enabled by configuring PULLUP_ENABLE to 1b. Any change to this bit needs to be written to EEPROM followed by a power recycle to take effect. When PULLUP_ENABLE is set to 1b, no external pull-up resistor should be provided.
2. DIR and BRAKE pins each have an internal pull-down resistor of 100-kΩ. When these pins are used, an additional pull-down resistor of 10-kΩ can be added externally for added noise immunity.
3. SPEED pin has an internal pull-down resistor of 1-MΩ. In analog speed input mode, a suitable R-C filter can be added externally for reducing noise. In PWM speed input mode, SPEED_PIN_GLITCH_FILTER can be appropriately configured for glitch rejection.

6.3.2.2 I²C Interface

The MCF8315C supports an I²C serial communication interface that allows an external controller to send and receive data. This I²C interface lets the external controller to configure the EEPROM and read detailed fault and motor state information. The pull-down strength of the I²C pins can be configured using SLEW_RATE_I2C_PINS. The I²C bus is a two-wire interface using the SCL and SDA pins which are described as follows :

- The SCL pin is the clock signal input.
- The SDA pin is the data input and output.

6.3.3 Step-Down Mixed-Mode Buck Regulator

The MCF8315C has an integrated mixed-mode buck regulator to supply regulated 3.3-V or 5-V power for an external controller or system voltage rail. Additionally, the buck output can also be configured to 4-V or 5.7-V for supporting the extra headroom for an external LDO for generating a 3.3-V or 5-V supplies. The output voltage of the buck is set by BUCK_SEL.

The buck regulator has a low quiescent current of ~1-2 mA during light loads to prolong battery life. The device improves performance during line and load transients by implementing a pulse-frequency current-mode control scheme which requires less output capacitance and simplifies frequency compensation design.

表 6-1. Recommended settings for Buck Regulator

| Buck Mode | Buck output voltage | Max output current from AVDD (I _{AVDD_MAX}) | Max output current from Buck (I _{BK_MAX}) | Buck current limit | AVDD power sequencing |
|------------------|------------------------------|---|---|-----------------------|----------------------------------|
| Inductor - 47 μH | 3.3-V or 4-V or 5-V or 5.7-V | 20 mA | 170 mA | 600 mA (BUCK_CL = 0b) | Not supported (BUCK_PS_DIS = 1b) |
| Inductor - 47 μH | 5-V or 5.7-V | 20 mA | 170 mA - I _{AVDD} | 600 mA (BUCK_CL = 0b) | Supported (BUCK_PS_DIS = 0b) |
| Inductor - 22 μH | 3.3-V or 4-V or 5-V or 5.7-V | 20 mA | 20 mA | 150 mA (BUCK_CL = 1b) | Not supported (BUCK_PS_DIS = 1b) |
| Inductor - 22 μH | 5-V or 5.7-V | 20 mA | 20 mA - I _{AVDD} | 150 mA (BUCK_CL = 1b) | Supported (BUCK_PS_DIS = 0b) |
| Resistor - 22 Ω | 3.3-V or 4-V or 5-V or 5.7-V | 20 mA | 10 mA | 150 mA (BUCK_CL = 1b) | Not supported (BUCK_PS_DIS = 1b) |
| Resistor - 22 Ω | 5-V or 5.7-V | 20 mA | 10 mA - I _{AVDD} | 150 mA (BUCK_CL = 1b) | Supported (BUCK_PS_DIS = 0b) |

6.3.3.1 Buck in Inductor Mode

The buck regulator in MCF8315C is primarily designed to support low inductance of 47-μH and 22-μH. A 47-μH inductor allows the buck regulator to operate up to 170-mA load current support, whereas applications requiring current up to 20-mA can use a 22-μH inductor which saves component size.

☒ 6-3 shows the connection of buck regulator in inductor mode.

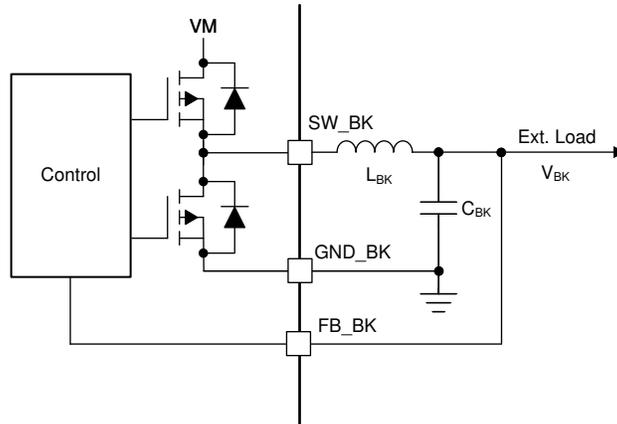


図 6-3. Buck (Inductor Mode)

6.3.3.2 Buck in Resistor mode

If the external load requirement is less than 10-mA, the inductor can be replaced with a resistor. In resistor mode the power is dissipated across the external resistor and the efficiency is lower than buck in inductor mode.

図 6-4 shows the connection of buck in resistor mode.

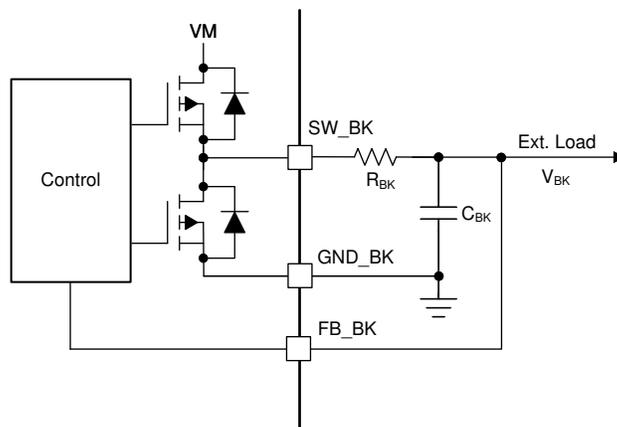


図 6-4. Buck (Resistor Mode)

6.3.3.3 Buck Regulator with External LDO

The buck regulator also supports the voltage requirement to supply an external LDO to generate standard 3.3-V or 5-V output rail with higher accuracies. The buck output voltage should be configured to 4-V or 5.7-V to provide extra headroom to support the external LDO for generating 3.3-V or 5-V rail as shown in 図 6-5. This allows for a lower-voltage LDO design to save cost and better thermal management due to low drop-out voltage.

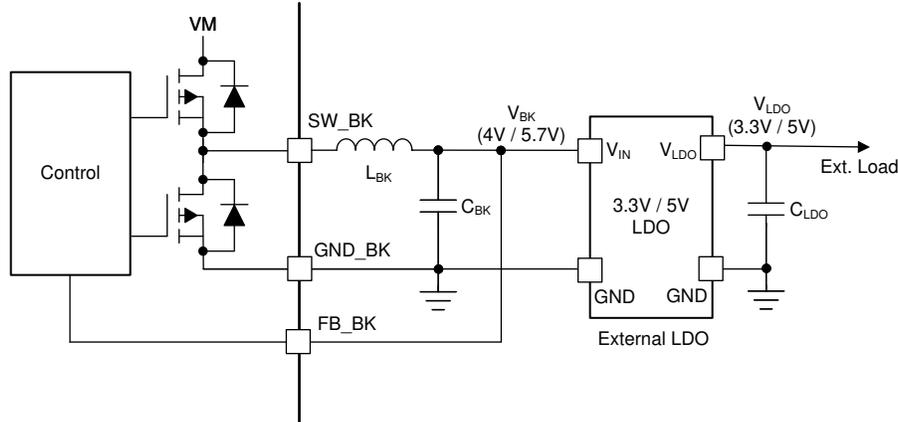


図 6-5. Buck Regulator with External LDO

6.3.3.4 AVDD Power Sequencing from Buck Regulator

The AVDD LDO has an option of using the power supply from mixed mode buck regulator to reduce the device power dissipation. The power sequencing mode allows on-the-fly changeover of AVDD LDO input from DC mains (VM) to buck output (V_{BK}) as shown in 図 6-6. This sequencing can be configured through the BUCK_PS_DIS bit . Power sequencing is supported only when buck output voltage is set to 5-V or 5.7-V.

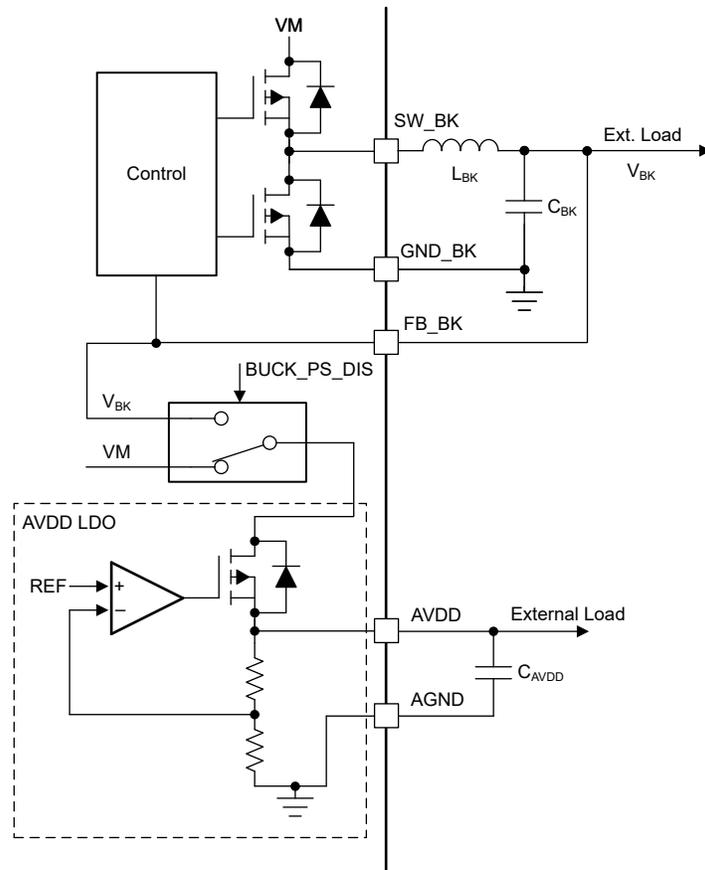
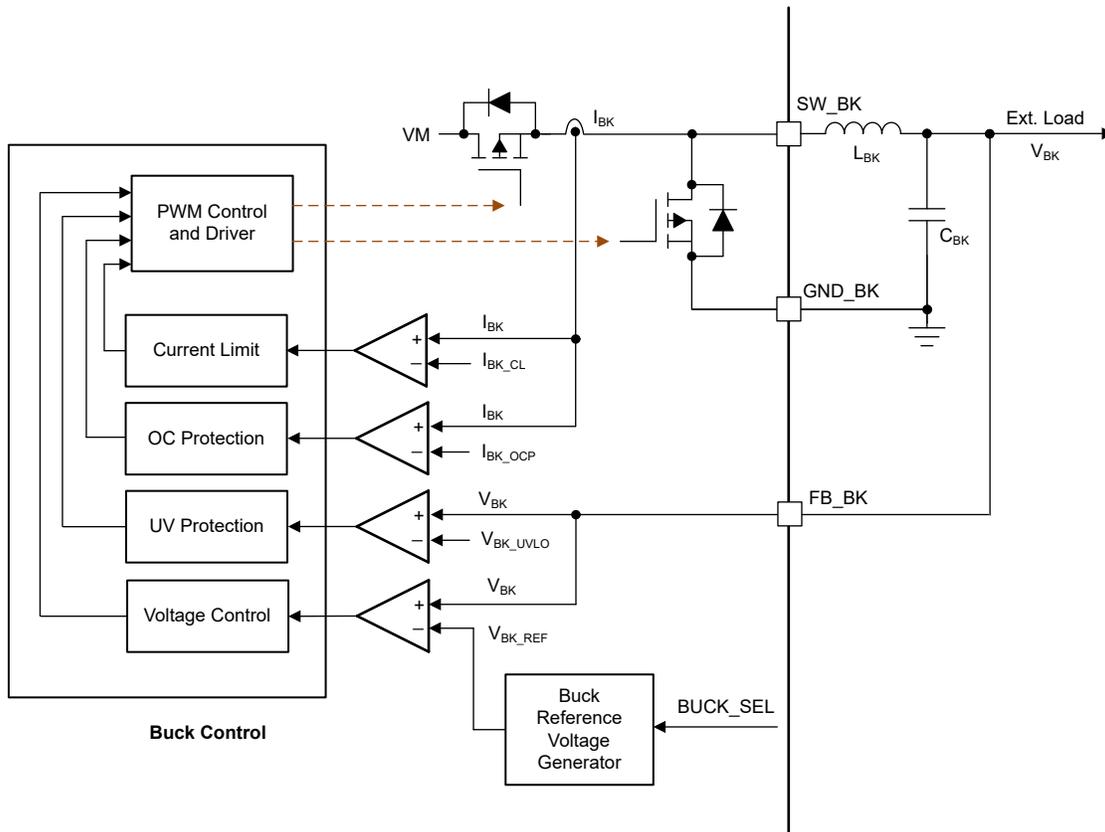


図 6-6. AVDD Power Sequencing from Mixed Mode Buck Regulator

6.3.3.5 Mixed Mode Buck Operation and Control

The buck regulator implements a pulse frequency modulation (PFM) architecture with peak current mode control. The output voltage of the buck regulator is compared with the internal reference voltage (V_{BK_REF}) which is internally generated depending on the buck output voltage setting (BUCK_SEL) which constitutes an outer voltage control loop. Depending on the comparator output going high ($V_{BK} < V_{BK_REF}$) or low ($V_{BK} > V_{BK_REF}$), the high-side power FET of the buck turns on and off respectively. An independent current control loop monitors the current in high-side power FET (I_{BK}) and turns off the high-side FET when the current becomes higher than the buck current limit (I_{BK_CL} set by BUCK_CL) - this implements a current limit control for the buck regulator.  6-7 shows the architecture of the buck and various control/protection loops.



 6-7. Buck Operation and Control Loops

6.3.3.6 Buck Under Voltage Protection

If at any time the voltage on the FB_BK pin (buck regulator output) falls lower than the V_{BK_UV} threshold, the buck regulator continues to operate but nFAULT is driven low and DRIVER_FAULT, BUCK_UV bits are set to 1b in the fault status registers. MCF8315C may go into reset state when a buck UV event occurs, since the internal circuitry in MCF8315C is powered from the buck regulator output - in this case, nFAULT and fault status registers may no longer report the buck UV fault upon reset.

6.3.3.7 Buck Over Current Protection

The buck over current event is sensed by monitoring the current flowing through high-side MOSFET of the buck regulator. If the current through the high-side MOSFET exceeds the I_{BK_OCP} threshold, a buck OCP event is recognized and both the high-side and low-side MOSFETs of the buck regulator are disabled. MCF8315C goes into reset state whenever buck OCP event occurs, since the internal circuitry in MCF8315C is powered from the buck regulator output.

6.3.4 AVDD Linear Voltage Regulator

A 3.3-V linear regulator is integrated into MCF8315C and is available for use by external circuitry. This AVDD LDO regulator is used for powering up the internal circuitry of the device and additionally, this regulator can also provide the supply voltage for a low-power MCU or other external circuitry supporting up to 20-mA. The output of the AVDD regulator should be bypassed near the AVDD pin with a X5R or X7R, 1- μ F, 6.3-V ceramic capacitor routed directly back to the adjacent AGND ground pin.

The AVDD nominal, no-load output voltage is 3.3-V.

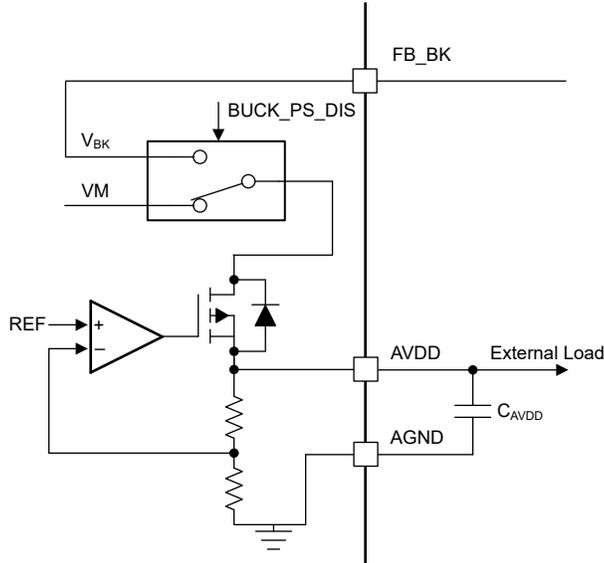


図 6-8. AVDD Linear Regulator Block Diagram

Use 式 1 to calculate the power dissipated in the device by the AVDD linear regulator with VM as supply (BUCK_PS_DIS = 1b)

$$P = (V_{VM} - V_{AVDD}) \times I_{AVDD} \quad (1)$$

For example, at a V_{VM} of 24-V, drawing 20-mA out of AVDD results in a power dissipation as shown in 式 2.

$$P_{LDO} = (V_{VM} - V_{AVDD}) \times I_{AVDD} = (24 - 3.3)V \times 20mA = 414mW \quad (2)$$

Use 式 3 to calculate the power dissipated in the device by the AVDD linear regulator with buck output as supply (BUCK_PS_DIS = 0b)

$$P = (V_{FB_BK} - V_{AVDD}) \times I_{AVDD} \quad (3)$$

For example, at a V_{FB_BK} of 5 V, drawing 20 mA out of AVDD results in a LDO power dissipation as shown in 式 4.

$$P_{LDO} = (V_{FB_BK} - V_{AVDD}) \times I_{AVDD} = (5 - 3.3)V \times 20mA = 34mW \quad (4)$$

6.3.5 Charge Pump

Since the output stages use N-channel FETs, the device requires a gate-drive voltage higher than the VM power supply to turn-on the high-side FETs. The MCF8315C integrates a charge-pump circuit that generates a voltage above the VM supply for this purpose.

The charge pump requires two external capacitors (C_{CP} , C_{FLY}) for operation. See [図 6-1](#), [図 6-2](#) and [表 4-1](#) for details on these capacitors (value, connection, and so forth).

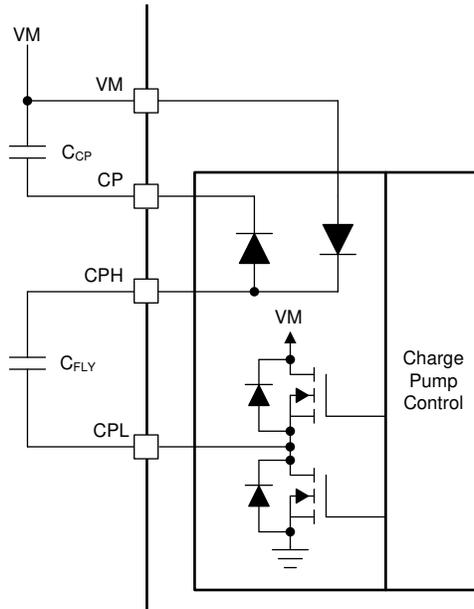


図 6-9. Charge Pump

6.3.6 Slew Rate Control

An adjustable gate-drive current control is provided for the output stage MOSFETs to achieve configurable slew rate for EMI mitigation. The MOSFET VDS slew rate is a critical factor for optimizing radiated emissions, total energy and duration of diode recovery spikes and switching voltage transients related to parasitic elements of the PCB. This slew rate is predominantly determined by the control of the internal MOSFET gate current as shown in [図 6-10](#).

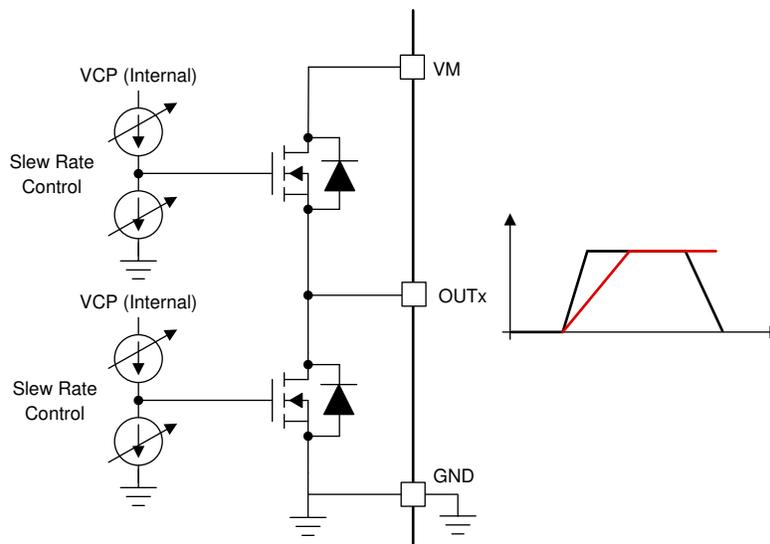
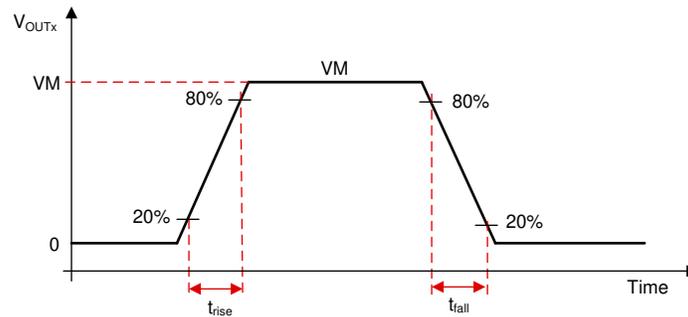


図 6-10. Slew Rate Circuit Implementation

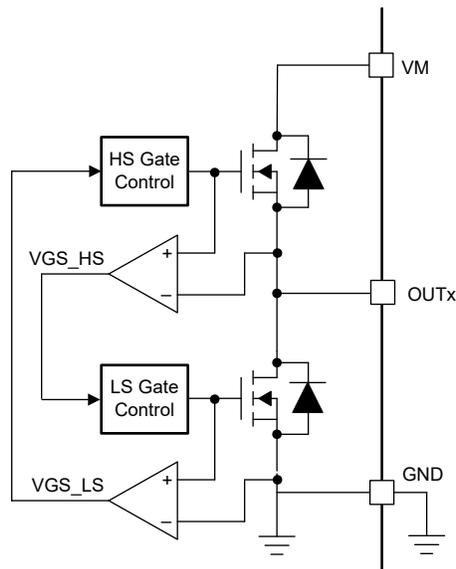
The slew rate of each half-bridge can be adjusted through SLEW_RATE settings. Slew rate can be configured as 125-V/ μ s or 200-V/ μ s. The slew rate is calculated by the rise-time and fall-time of the voltage on OUTx pin as shown in 6-11.



6-11. Slew Rate Timings

6.3.7 Cross Conduction (Dead Time)

The device is fully protected against any cross conduction of MOSFETs - during the switching of high-side and low-side MOSFETs, MCF8315C avoids shoot-through events by inserting a dead time (t_{dead}). This is implemented by sensing the gate-source voltage (V_{GS}) of the high-side and low-side MOSFETs and ensuring that V_{GS} of high-side MOSFET has dropped below turn-off level before switching on the low-side MOSFET of same half-bridge (or vice-versa) as shown in 6-12 and 6-13. The V_{GS} of the high-side and low-side MOSFETs (V_{GS_HS} and V_{GS_LS}) shown in 6-13 are internal signals.



6-12. Cross Conduction Protection

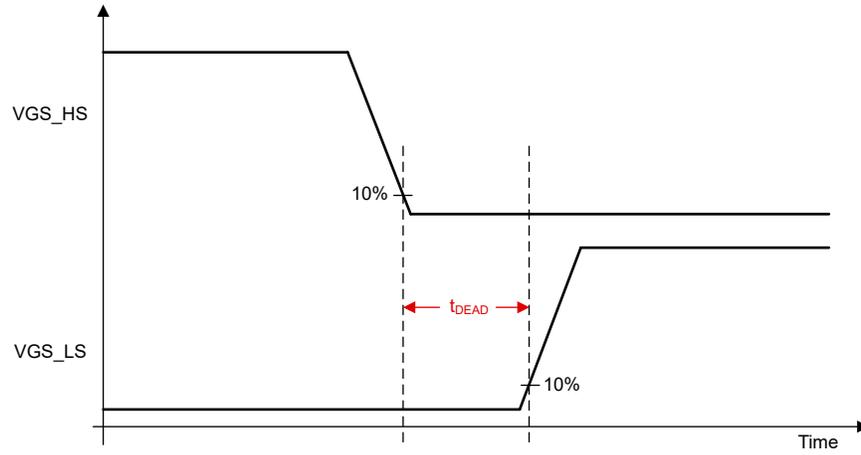


図 6-13. Dead Time

6.3.8 Motor Control Input Sources

MCF8315C provides two modes of controlling the motor based on SPEED_LOOP_DIS setting,

1. Speed control: In speed control mode (SPEED_LOOP_DIS = 0b), the speed of the motor is controlled according to the input reference using a closed loop PI control .
2. Current control: In current control mode (SPEED_LOOP_DIS = 1b), the torque controlling current (I_q) is controlled according to the input reference using a closed loop PI control.

MCF8315C offers four methods of directly controlling the input reference of the motor. The input reference source is configured by SPEED_MODE.

The input reference source can be provided in one of the following four ways,

- Analog input on SPEED pin by varying amplitude of input signal (SPEED_MODE = 00b)
- PWM input on SPEED pin by varying duty cycle of input signal (SPEED_MODE = 01b)
- Over I²C by configuring DIGITAL_SPEED_CTRL register (SPEED_MODE = 10b)
- Frequency input on SPEED pin by varying frequency of input signal (SPEED_MODE = 11b)

The signal path from SPEED pin input (or I²C based speed input) to motor control reference (SPEED_REF or CURRENT_REF in 図 6-33) is as shown in 図 6-14.

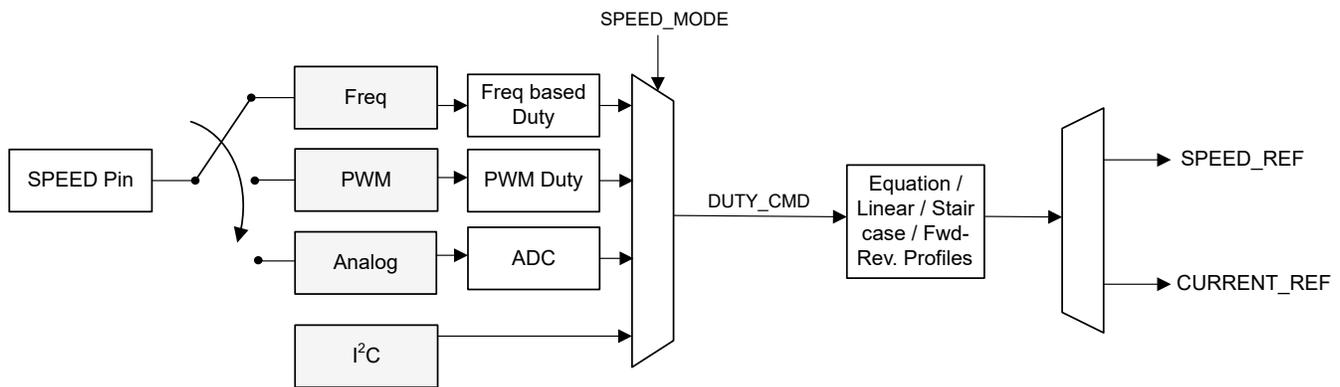


図 6-14. Multiplexing the Input Reference Source

注

When SPEED pin input is set to zero, MCF8315C will take up to SLEEP_ENTRY_TIME before starting the motor stop operation.

6.3.8.1 Analog Mode Motor Control

Analog input based motor control can be configured by setting SPEED_MODE to 00b. In this mode, the duty command (DUTY_CMD) varies with the analog voltage input on the SPEED pin (V_{SPEED}). When $0 \leq V_{SPEED} \leq V_{EN_SB}$, DUTY_CMD is set to zero and the motor is stopped. When $V_{EX_SB} \leq V_{SPEED} \leq V_{ANA_FS}$, DUTY_CMD varies linearly with V_{SPEED} as shown in 図 6-15. V_{EX_SB} and V_{EN_SB} are the standby entry and exit thresholds - refer セクション 6.4.1.2 for more information on V_{EX_SB} and V_{EN_SB} . When $V_{SPEED} > V_{ANA_FS}$, DUTY_CMD is clamped to 100%.

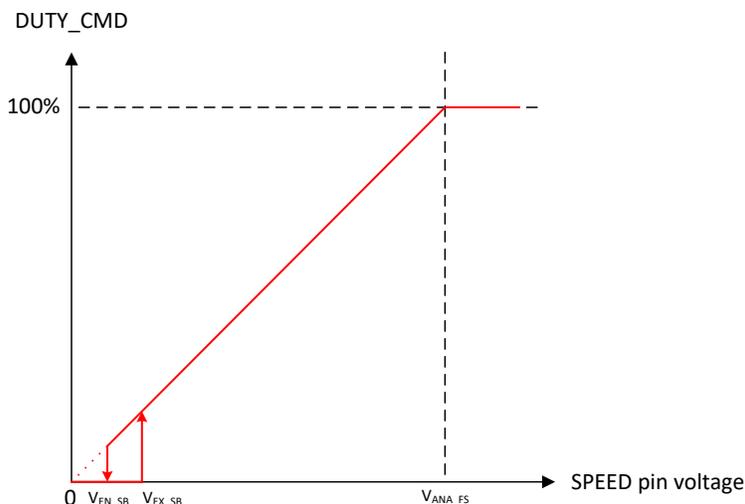


図 6-15. Analog Mode Speed Control

6.3.8.2 PWM Mode Motor Control

PWM based motor control can be configured by setting SPEED_MODE to 01b. In this mode, the PWM duty cycle applied to the SPEED pin can be varied from 0 to 100% and duty command (DUTY_CMD) varies linearly with the applied PWM duty cycle. When $0 \leq \text{Duty}_{\text{SPEED}} \leq \text{Duty}_{\text{EN_SB}}$, DUTY_CMD is set to zero and the motor is stopped. When $\text{Duty}_{\text{EX_SB}} \leq \text{Duty}_{\text{SPEED}} \leq 100\%$, DUTY_CMD varies linearly with $\text{Duty}_{\text{SPEED}}$ as shown in 図 6-16. $\text{Duty}_{\text{EX_SB}}$ and $\text{Duty}_{\text{EN_SB}}$ are the standby entry and exit thresholds - refer セクション 6.4.1.2 for more information on $\text{Duty}_{\text{EX_SB}}$ and $\text{Duty}_{\text{EN_SB}}$. The frequency of the PWM input signal applied to the SPEED pin is defined as f_{PWM} and the range for this frequency can be configured through SPEED_RANGE_SEL.

注

1. f_{PWM} is the frequency of the PWM signal the device can accept at SPEED pin to control motor speed. It does not correspond to the PWM output frequency that is applied to the motor phases. The PWM output frequency can be configured through PWM_FREQ_OUT (see セクション 6.3.17).
2. SLEEP_ENTRY_TIME should be set longer than the off time in PWM signal ($V_{\text{SPEED}} < V_{\text{IL}}$) at lowest duty input. For example, if f_{PWM} is 10 kHz and lowest duty input is 2%, SLEEP_ENTRY_TIME should be more than 98 μs to ensure there is no unintended sleep/standby entry.

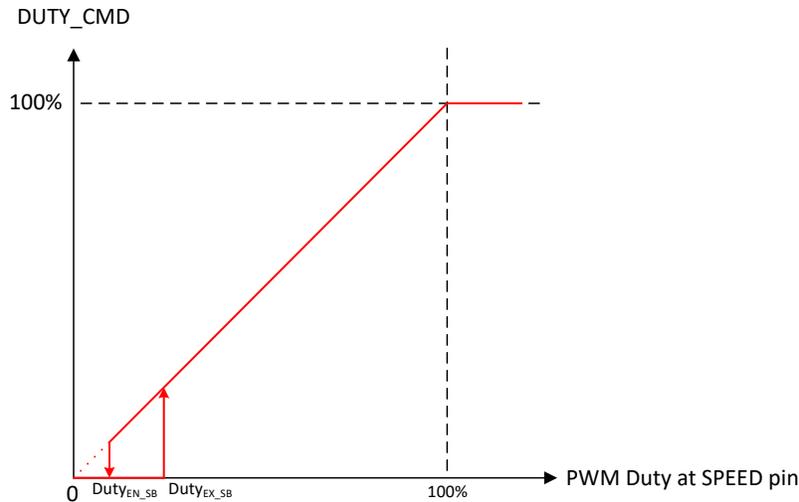


図 6-16. PWM Mode Speed Control

6.3.8.3 I²C based Motor Control

I²C based serial interface can be used for motor control by setting SPEED_MODE to 10b. In this mode, the control command can be written directly into DIGITAL_SPEED_CTRL register. The SPEED pin can be used to control the sleep entry and exit - if SPEED pin input is set to a value lower than V_{EN_SL} after DIGITAL_SPEED_CTRL register has been set to 0b for a time longer than SLEEP_ENTRY_TIME, MCF8315C enters sleep state. When SPEED pin $> V_{EX_SL}$, MCF8315C exits sleep state and speed is controlled through DIGITAL_SPEED_CTRL register. If $0 \leq \text{DIGITAL_SPEED_CTRL register} \leq \text{DIGITAL_SPEED_CTRL}_{EN_SB}$ and SPEED pin $> V_{EX_SL}$, MCF8315C is in standby state. The relationship between DUTY_CMD and DIGITAL_SPEED_CTRL register is shown in 図 6-17. Refer セクション 6.4.1.2 for more information on DIGITAL_SPEED_CTRL_{EN_SB}, EX_SB and DIGITAL_SPEED_CTRL_{EN_SB}, EN_SB.

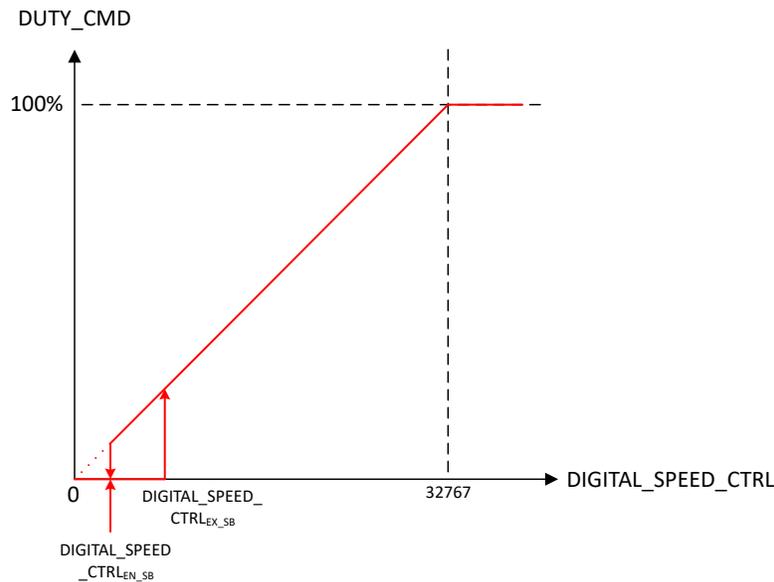


図 6-17. I2C Mode Speed Control

6.3.8.4 Frequency Mode Motor Control

Frequency based motor control is configured by setting SPEED_MODE to 11b. In this mode, duty command varies linearly as a function of the frequency of the square wave input at SPEED pin. When $0 \leq \text{Freq}_{\text{SPEED}} \leq$

When $\text{Freq}_{\text{EN_SB}}$, DUTY_CMD is set to zero and the motor is stopped. When $\text{Freq}_{\text{EX_SB}} \leq \text{Freq}_{\text{SPEED}} \leq \text{INPUT_MAXIMUM_FREQ}$, DUTY_CMD varies linearly with $\text{Freq}_{\text{SPEED}}$ as shown in [Figure 6-18](#). $\text{Freq}_{\text{EX_SB}}$ and $\text{Freq}_{\text{EN_SB}}$ are the standby entry and exit thresholds - refer [Section 6.4.1.2](#) for more information on $\text{Freq}_{\text{EX_SB}}$ and $\text{Freq}_{\text{EN_SB}}$. Input frequency greater than $\text{INPUT_MAXIMUM_FREQ}$ clamps the DUTY_CMD to 100%.

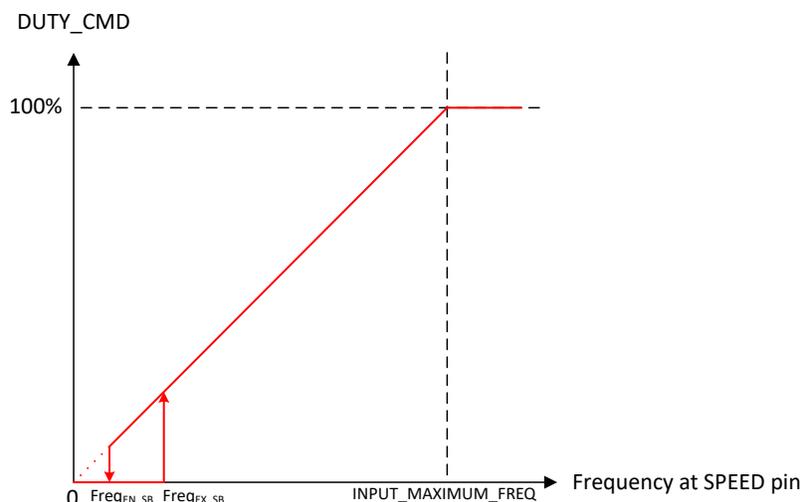


Figure 6-18. Frequency Mode Speed Control

6.3.8.5 Speed Profiles

MCF8315C supports three different kinds of input reference profiles (linear, staircase, bi-directional) to configure custom reference-duty command transfer function to meet specific application requirements. The input reference profile can be configured through $\text{REF_PROFILE_CONFIG}$.

When $\text{REF_PROFILE_CONFIG}$ is set to 00b, the input reference (SPEED_REF or CURRENT_REF) is set by the duty command (DUTY_CMD) as shown in equations [Equation 5](#) or [Equation 6](#).

$$\text{SPEED_REF (Hz)} = \text{DUTY_CMD} \times \text{MAX_SPEED (when SPEED_LOOP_DIS = 0b)} \quad (5)$$

$$\text{CURRENT_REF (A)} = \text{DUTY_CMD} \times \text{ILIMIT (when SPEED_LOOP_DIS = 1b)} \quad (6)$$

When $\text{REF_PROFILE_CONFIG}$ is set to 00b, any change in DUTY_CMD by a value less than DUTY_HYS does not produce any change in SPEED_REF or CURRENT_REF ; DUTY_HYS provides a hysteresis window around DUTY_CMD for noise immunity.

6.3.8.5.1 Linear Reference Profiles

注

1. For all types of reference profiles, a zero input reference (0-V in analog mode, 0% duty in PWM mode, $\text{DIGITAL_SPEED_CTRL} = 0b$ I²C mode or 0-Hz in frequency mode) stops the motor irrespective of the reference profile configuration.
2. The reference value in [Figure 6-19](#), [Figure 6-20](#) and [Figure 6-21](#) is decided by control mode (SPEED_LOOP_DIS) as follows,
 - Speed control mode ($\text{SPEED_LOOP_DIS} = 0b$): $\text{SPEED_REF (Hz)} = (\text{REF}_x/255) \times \text{MAX_SPEED (Hz)}$
 - Current control mode ($\text{SPEED_LOOP_DIS} = 1b$): $\text{CURRENT_REF (A)} = (\text{REF}_x/255) \times \text{ILIMIT (A)}$

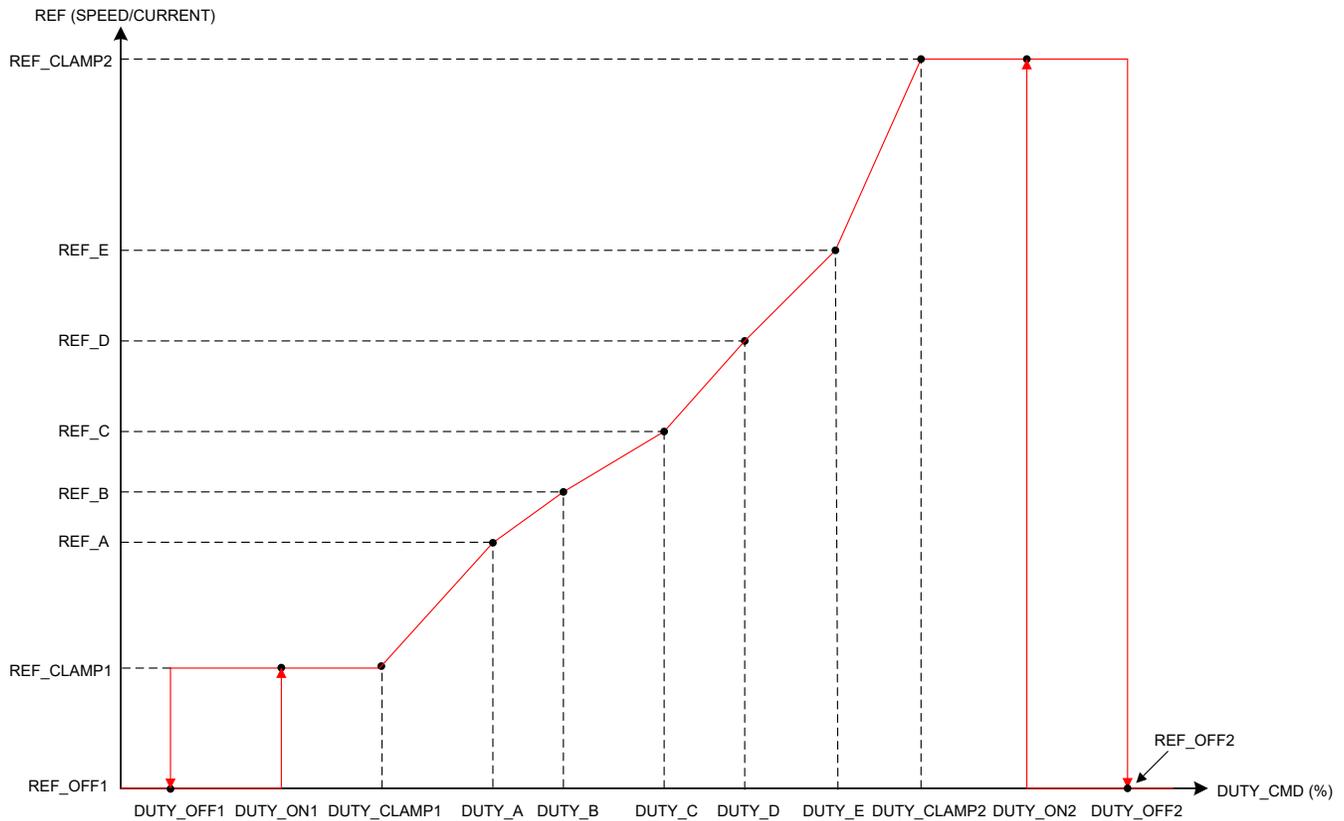


図 6-19. Linear Reference Profiles

Linear reference profiles can be configured by setting REF_PROFILE_CONFIG to 01b. Linear profiles feature input references (SPEED_REF or CURRENT_REF) which change linearly between REF_CLAMP1 and REF_CLAMP2 with different slopes which can be set by configuring DUTY_x and REF_x.

- DUTY_OFF1 configures the duty command below which the reference will be REF_OFF1.
- DUTY_OFF1 and DUTY_ON1 configure a hysteresis between reference levels, REF_CLAMP1 and REF_OFF1 as shown in 図 6-19.
- DUTY_CLAMP1 configures the duty command till which reference will be constant with a value REF_CLAMP1. DUTY_CLAMP1 can be placed anywhere between DUTY_ON1 and DUTY_A.
- DUTY_A configures the duty command for reference REF_A. The reference changes from REF_CLAMP1 to REF_A linearly between DUTY_CLAMP1 and DUTY_A. DUTY_A to DUTY_E has to be in the same order as shown in 図 6-19.
- DUTY_B configures the duty command for reference REF_B. The reference changes linearly between DUTY_A and DUTY_B.
- DUTY_C configures the duty command for reference REF_C. The reference changes linearly between DUTY_B and DUTY_C.
- DUTY_D configures the duty command for reference REF_D. The reference changes linearly between DUTY_C and DUTY_D.
- DUTY_E configures the duty command for reference REF_E. The reference changes linearly between DUTY_D and DUTY_E.
- DUTY_CLAMP2 configures the duty command above which the reference will be constant at REF_CLAMP2. REF_CLAMP2 configures this constant reference between DUTY_CLAMP2 and DUTY_OFF2. The reference changes linearly between DUTY_E and DUTY_CLAMP2. DUTY_CLAMP2 can be placed anywhere between DUTY_E and DUTY_ON2.

- DUTY_OFF2 and DUTY_ON2 configure a hysteresis between reference levels REF_CLAMP2 and REF_OFF2 as shown in [Figure 6-19](#).
- DUTY_OFF2 configures the duty command above which the reference will change from REF_CLAMP2 to REF_OFF2.

6.3.8.5.2 Staircase Reference Profiles

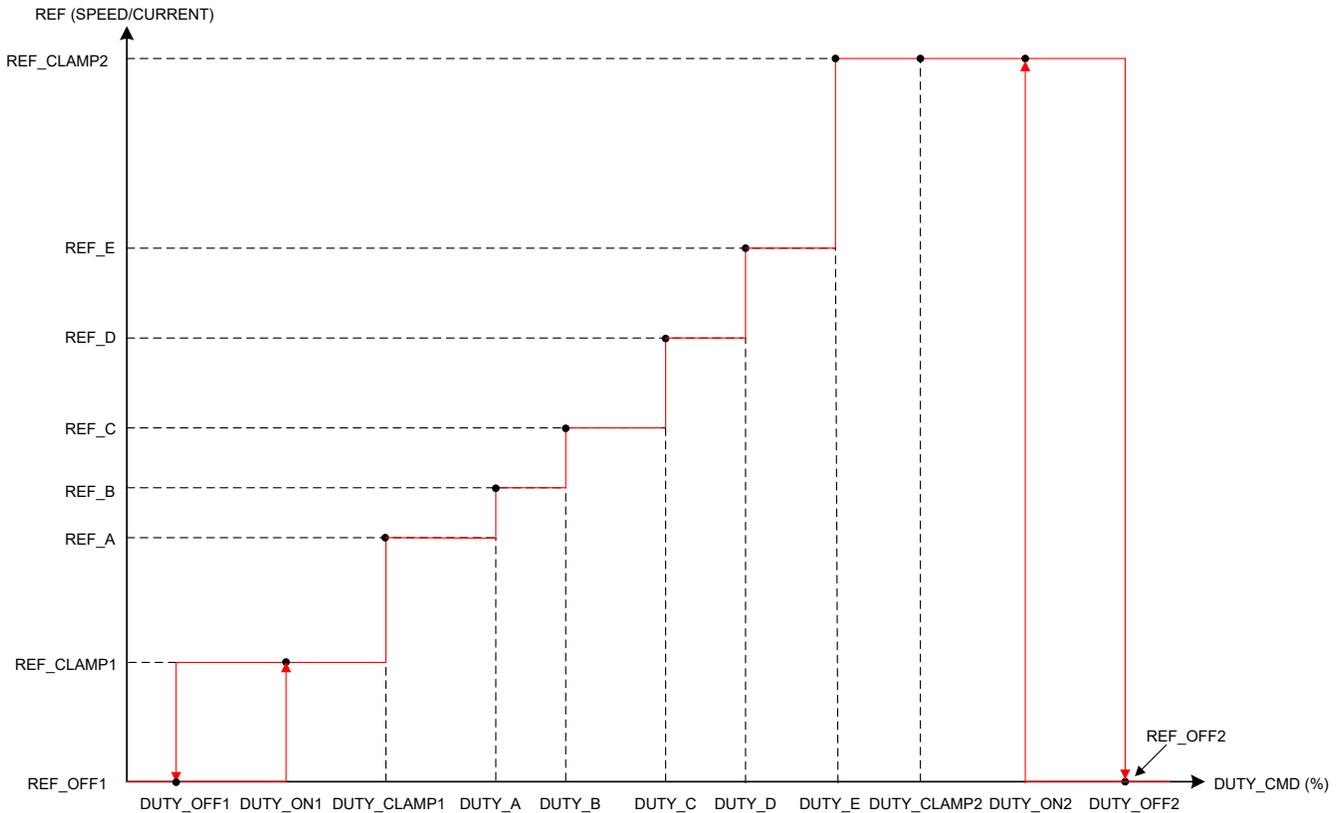


Figure 6-20. Staircase Reference Profiles

Staircase control profiles can be configured by setting REF_PROFILE_CONFIG to 10b. Staircase profiles feature input control reference changes in steps between REF_CLAMP1 and REF_CLAMP2, by configuring DUTY_x and REF_x.

- DUTY_OFF1 configures the duty command below which the reference will be REF_OFF1.
- DUTY_OFF1 and DUTY_ON1 configure a hysteresis between reference levels REF_CLAMP1 and REF_OFF1 as shown in [Figure 6-20](#).
- DUTY_CLAMP1 configures the duty command till which reference will be constant. REF_CLAMP1 configures this constant reference between DUTY_OFF1 and DUTY_CLAMP1. DUTY_CLAMP1 can be placed anywhere between DUTY_ON1 and DUTY_A.
- DUTY_A configures the duty command for reference REF_A. There is a step change in reference from REF_CLAMP1 to REF_A at DUTY_CLAMP1. DUTY_A to DUTY_E has to be in the same order as shown in [Figure 6-20](#).
- DUTY_B configures the duty command for reference REF_B. There is a step change in reference from REF_A to REF_B at DUTY_A.
- DUTY_C configures the duty command for reference REF_C. There is a step change in reference from REF_B to REF_C at DUTY_B.
- DUTY_D configures the duty command for reference REF_D. There is a step change in reference from REF_C to REF_D at DUTY_C.

- DUTY_E configures the duty command for reference REF_E. There is a step change in reference from REF_D to REF_E at DUTY_D.
- DUTY_CLAMP2 configures the duty command above which the reference will be constant at REF_CLAMP2. REF_CLAMP2 configures this constant reference between DUTY_CLAMP2 and DUTY_OFF2. There is a step change in reference from REF_E to REF_CLAMP2 at DUTY_E. DUTY_CLAMP2 can be placed anywhere between DUTY_E and DUTY_ON2.
- DUTY_OFF2 and DUTY_ON2 configure a hysteresis between reference levels REF_CLAMP2 and REF_OFF2 as shown in [Figure 6-20](#).
- DUTY_OFF2 configures the duty command above which the reference will change from REF_CLAMP2 to REF_OFF2.

6.3.8.5.3 Forward-Reverse Reference Profiles

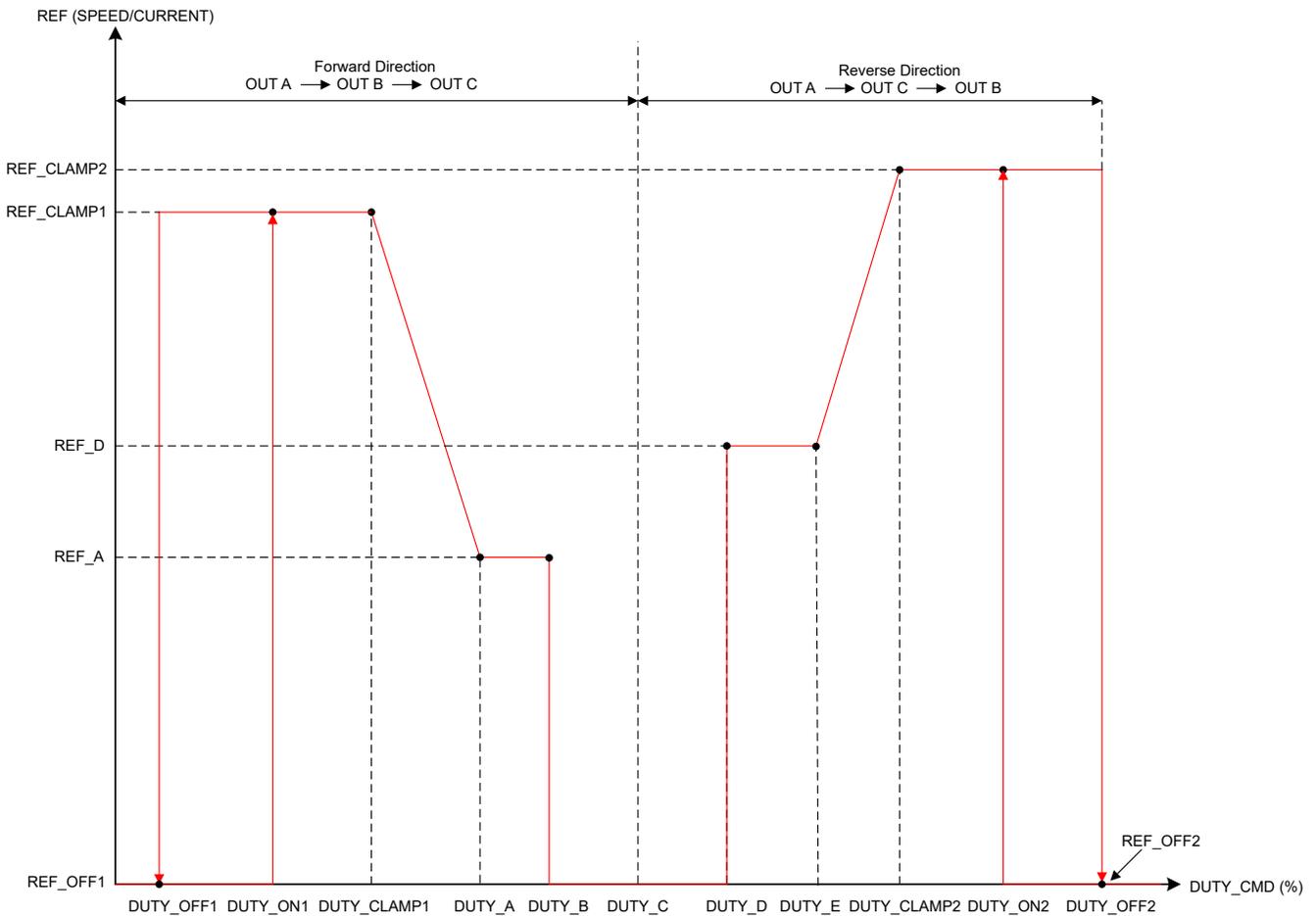


Figure 6-21. Forward-Reverse Reference Profiles

Forward-Reverse control profiles can be configured by setting REF_PROFILE_CONFIG to 11b. Forward-Reverse profiles feature direction change through adjusting the duty command. DUTY_C configures duty command at which the direction will be changed. The Forward-Reverse speed profile can be used to eliminate the separate signal used to control the motor direction.

注

The direction change functionality through DIR pin and DIR_INPUT bits are disabled in forward reverse profile mode.

- DUTY_OFF1 configures the duty command below which the reference will be REF_OFF1.
- DUTY_OFF1 and DUTY_ON1 configures a hysteresis between reference levels REF_CLAMP1 and REF_OFF1 as shown in [Figure 6-21](#).
- DUTY_CLAMP1 configures the duty command till which reference will be constant. REF_CLAMP1 configures this constant reference between DUTY_OFF1 and DUTY_CLAMP1. DUTY_CLAMP1 can be placed anywhere between DUTY_ON1 and DUTY_A.
- DUTY_A configures the duty command for reference REF_A. The reference changes linearly between DUTY_CLAMP1 and DUTY_A. DUTY_A to DUTY_E has to be in the same order as shown in [Figure 6-21](#).
- DUTY_B configures the duty command above which MCF8315C will be in idle/off state. The reference remains constant at REF_A between DUTY_A and DUTY_B.
- DUTY_C configures the duty command at which the direction is changed
- DUTY_D configures the duty command above which the MCF8315C will be in running state in the reverse direction. REF_D configures constant reference between DUTY_D and DUTY_E.
- DUTY_E configures the duty command above which reference changes linearly between DUTY_E and DUTY_CLAMP2.
- DUTY_CLAMP2 configures the duty command above which the reference will be constant at REF_CLAMP2. REF_CLAMP2 configures this constant reference between DUTY_CLAMP2 and DUTY_OFF2. DUTY_CLAMP2 can be placed anywhere between DUTY_E and DUTY_ON2.
- DUTY_OFF2 and DUTY_ON2 configure a hysteresis between reference levels REF_CLAMP2 and REF_OFF2 as shown in [Figure 6-21](#).
- DUTY_OFF2 configures the duty command above which the reference changes in the reverse direction from REF_CLAMP2 to REF_OFF2.

6.3.9 Starting the Motor Under Different Initial Conditions

The motor can be in one of three states when MCF8315C begins the start-up process. The motor may be stationary, spinning in the forward direction, or spinning in the reverse direction. The MCF8315C includes a number of features to allow for reliable motor start-up under all of these conditions. [Figure 6-22](#) shows the motor start-up flow for each of the three initial motor states.

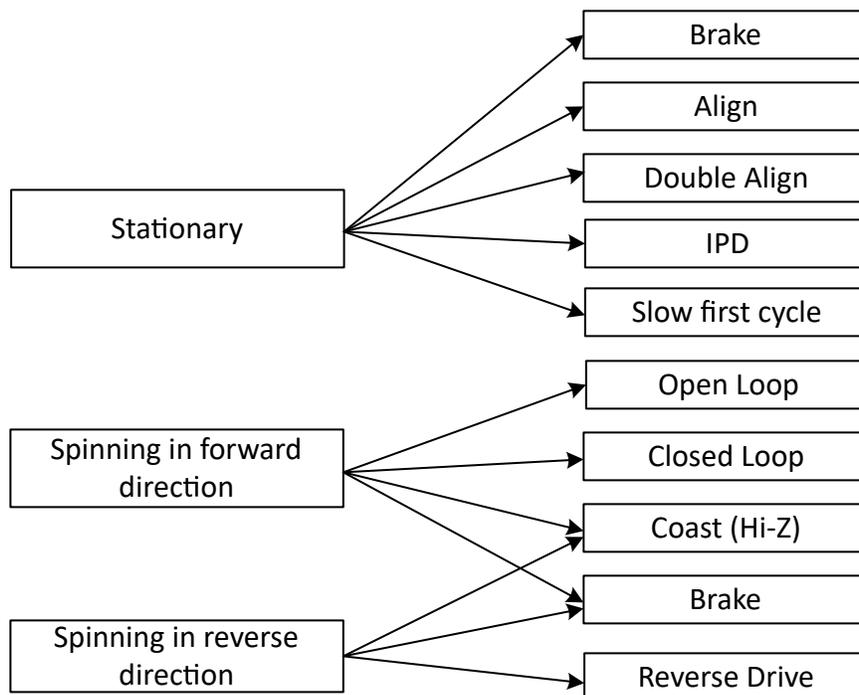


Figure 6-22. Starting the motor under different initial conditions

注

"Forward" means "spinning in the same direction as the commanded direction", and "Reverse" means "spinning in the opposite direction as the commanded direction".

6.3.9.1 Case 1 – Motor is Stationary

If the motor is stationary, the commutation must be initialized to be in phase with the position of the motor. The MCF8315C provides various options to initialize the commutation logic to the motor position and reliably start the motor.

- The align and double align techniques force the motor into alignment by applying a voltage across particular motor phases to force the motor to rotate in alignment with this phase.
- Initial position detect (IPD) determines the position of the motor based on the deterministic inductance variation, which is often present in BLDC motors.
- The slow first cycle method starts the motor by applying a low frequency cycle to align the rotor position to the applied commutation by the end of one electrical rotation.

MCF8315C also provides a configurable brake option to ensure the motor is stationary before initiating one of the above start-up methods. Device enters open loop acceleration after going through the configured start-up method.

6.3.9.2 Case 2 – Motor is Spinning in the Forward Direction

If the motor is spinning forward (same direction as the commanded direction) with sufficient speed (BEMF), the MCF8315C resynchronizes with the spinning motor and continues commutation by going directly to closed loop operation. If the motor speed is too low for closed loop operation, MCF8315C enters open loop operation to accelerate the motor till it reaches sufficient speed to enter closed loop operation. By resynchronizing to the spinning motor, the user achieves the fastest possible start-up time for this initial condition. This resynchronization feature can be enabled or disabled through RESYNC_EN. If resynchronization is disabled, the MCF8315C can be configured to wait for the motor to coast to a stop and/or apply a brake. After the motor has stopped spinning, the motor start-up sequence proceeds as in Case 1, considering the motor is stationary.

6.3.9.3 Case 3 – Motor is Spinning in the Reverse Direction

If the motor is spinning in the reverse direction (the opposite direction as the commanded direction), the MCF8315C provides several methods to change the direction and drive the motor to the target reference in the commanded direction.

The reverse drive method allows the motor to be driven so that it decelerates through zero speed. The motor achieves the shortest possible spin-up time when spinning in the reverse direction.

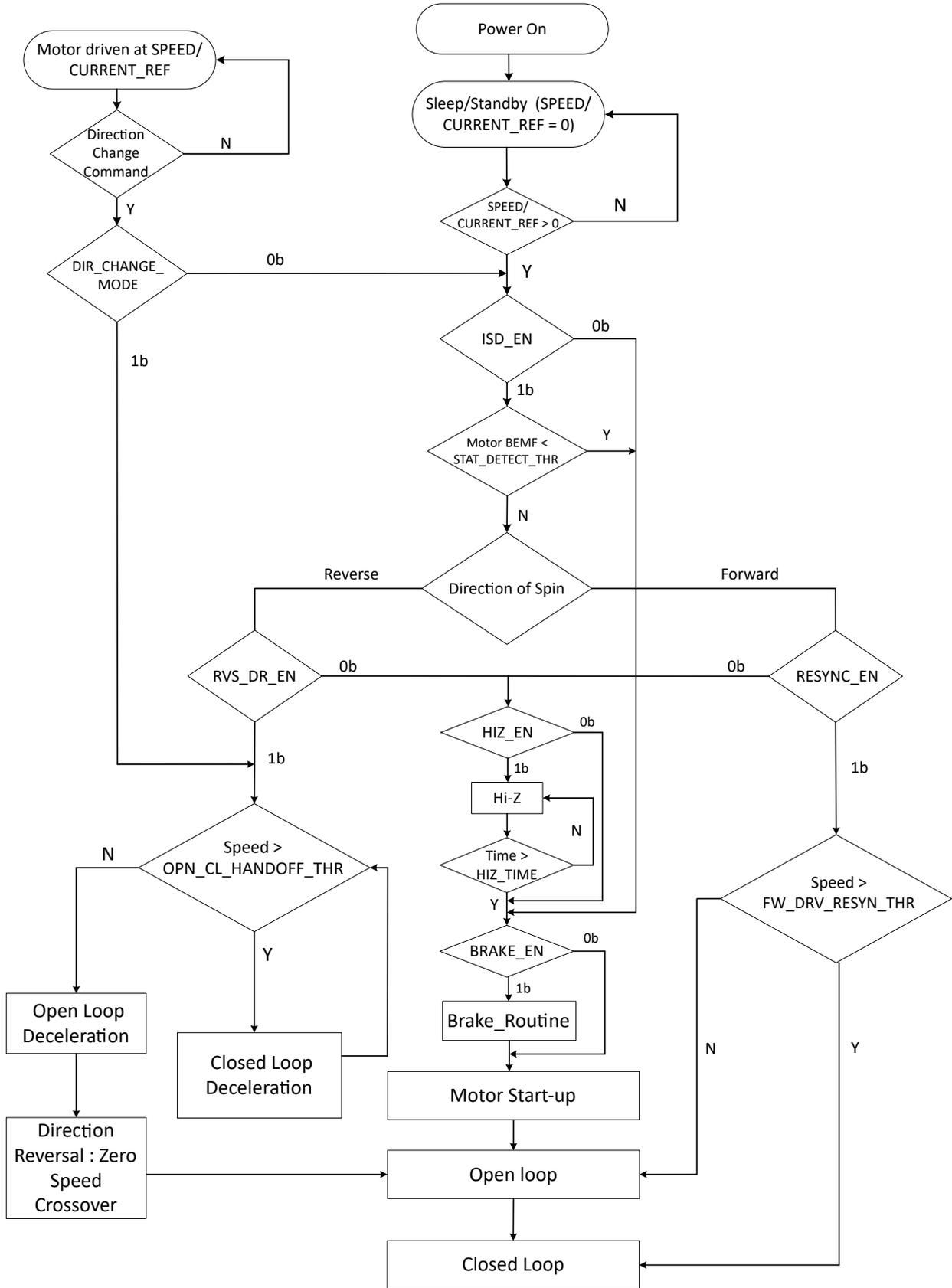
If reverse drive is not enabled, then the MCF8315C can be configured to wait for the motor to coast to a stop and/or apply a brake. After the motor has stopped spinning, the motor start-up sequence proceeds as in Case 1, considering the motor is stationary.

注

Take care when using the reverse drive or brake feature to ensure that the current is limited to an acceptable level and that the supply voltage does not surge as a result of energy being returned to the power supply.

6.3.10 Motor Start Sequence (MSS)

 [6-23](#) shows the motor-start sequence implemented in the MCF8315C device.



6-23. Motor Start Sequence

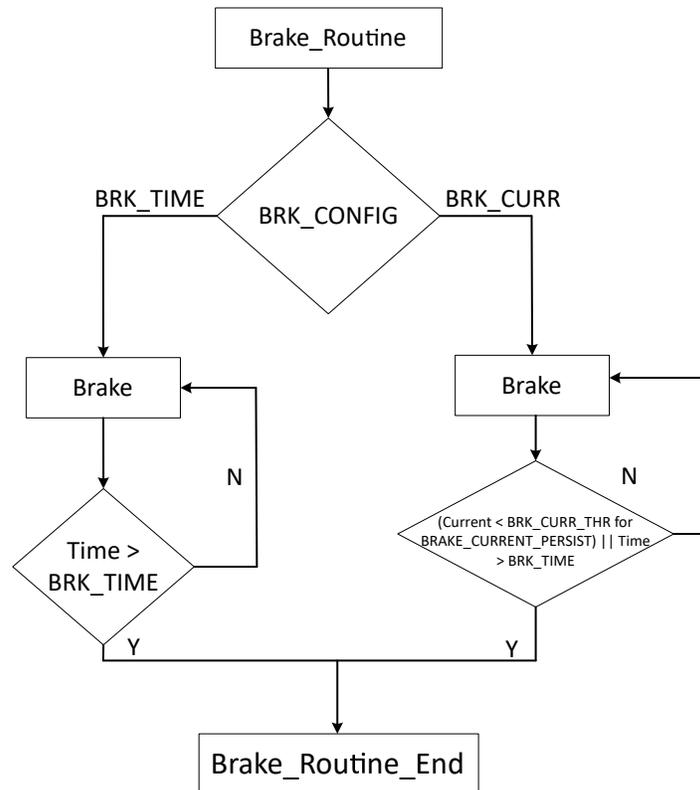


図 6-24. Brake Routine

Power-On State

This is the initial state of the Motor Start Sequence (MSS) when MCF8315C is powered on. In this state, MCF8315C configures the peripherals, initializes the algorithm parameters from EEPROM and prepares for driving the motor.

Sleep/Standby

In this state, SPEED/CURRENT_REF is set to zero and MCF8315C is either in sleep or standby mode depending on DEV_MODE and SPEED/WAKE pin voltage.

SPEED/CURRENT_REF > 0 Judgement

When SPEED/CURRENT_REF is set to greater than zero, MCF8315C exits the sleep/standby state and proceeds to ISD_EN judgement. As long as SPEED/CURRENT_REF is set to zero, MCF8315C stays in sleep/standby state.

Direction Change Command Judgement

When a direction change command is received, MCF8315C proceeds to DIR_CHANGE_MODE judgement.

DIR_CHANGE_MODE Judgement

If DIR_CHANGE_MODE is set to 0b, MCF8315C initiates direction change by proceeding to ISD_EN judgement. Instead, if DIR_CHANGE_MODE is set to 1b, MCF8315C initiates direction change by proceeding to Speed > OPN_CL_HANDOFF_THR judgement.

ISD_EN Judgement

MCF8315C checks to see if the initial speed detect (ISD) function is enabled (ISD_EN = 1b). If ISD is enabled, MSS proceeds to the BEMF < STAT_DETECT_THR judgement. Instead, if ISD is disabled, the MSS proceeds directly to the BRAKE_EN judgement.

BEMF < STAT_DETECT_THR or BEMF < FG_BEMF_THR Judgement

ISD determines the initial condition (speed, angle, direction of spin) of the motor (see セクション 6.3.10.1). If motor is deemed to be stationary (BEMF < STAT_DETECT_THR or BEMF < FG_BEMF_THR), the MSS proceeds to

| | |
|---|--|
| | BRAKE_EN judgement. If the motor is not stationary, MSS proceeds to verify the direction of spin. |
| Direction of spin Judgement | The MSS determines whether the motor is spinning in the forward or the reverse direction. If the motor is spinning in the forward direction, the MCF8315C proceeds to the RESYNC_EN judgement. If the motor is spinning in the reverse direction, the MSS proceeds to the RVS_DR_EN judgement. |
| RESYNC_EN Judgement | If RESYNC_EN is set to 1b, MCF8315C proceeds to Speed > Open to Closed Loop Handoff (Resync) judgement. If RESYNC_EN is set to 0b, MSS proceeds to HIZ_EN judgement. |
| Speed > FW_DRV_RESYN_THR Judgement | If motor speed > FW_DRV_RESYN_THR, MCF8315C uses the speed and position information from the ISD to transition to the closed loop state (see セクション 6.3.10.2) directly. If motor speed < FW_DRV_RESYN_THR, MCF8315C transitions to open loop state. |
| RVS_DR_EN Judgement | The MSS checks to see if the reverse drive function is enabled (RVS_DR_EN = 1b). If it is enabled, the MSS transitions to check speed of the motor in reverse direction. If the reverse drive function is not enabled (RVS_DR_EN = 0b), the MSS advances to the HIZ_EN judgement. |
| Speed > OPN_CL_HANDOFF_THR Judgement | The MSS checks to see if the reverse speed is high enough for MCF8315C to decelerate in closed loop. Till the speed (in reverse direction) is above OL_CL_HANDOFF_THR, MSS stays in closed loop deceleration. If speed is below OPN_CL_HANDOFF_THR, then the MSS transitions to open loop deceleration. |
| Reverse Closed Loop, Open Loop Deceleration and Zero Speed Crossover | The MCF8315C resynchronizes in the reverse direction, decelerates the motor in closed loop till motor speed falls below the handoff threshold. (see Reverse Drive). When motor speed in reverse direction is too low, the MCF8315C switches to open-loop, decelerates the motor in open-loop, crosses zero speed, and accelerates in the forward direction in open-loop before entering closed loop operation after motor speed is sufficiently high. |
| HIZ_EN Judgement | The MSS checks to determine whether the coast (Hi-Z) function is enabled (HIZ_EN = 1b). If the coast function is enabled (HIZ_EN = 1b), the MSS advances to the coast routine. If the coast function is disabled (HIZ_EN = 0b), the MSS advances to the BRAKE_EN judgement. |
| Coast (Hi-Z) Routine | The device coasts the motor by turning OFF all six MOSFETs for a certain time configured by HIZ_TIME. |
| BRAKE_EN Judgement | The MSS checks to determine whether the brake function is enabled (BRAKE_EN = 1b). If the brake function is enabled (BRAKE_EN = 1b), the MSS advances to the brake routine. If the brake function is disabled (BRAKE_EN = 0b), the MSS advances to the motor start-up state (see セクション 6.3.11). |
| Brake Routine | MCF8315C implements either a time based brake (duration configured by BRK_TIME) or a current based brake (brake applied till phase currents < BRK_CURR_THR for BRAKE_CURRENT_PERSIST) based on BRK_CONFIG. Current based brake has a timeout to ensure brake state ends in case phase currents do not drop below BRK_CURR_THR within BRK_TIME. |
| Closed Loop State | In this state, the MCF8315C drives the motor with sensorless FOC based on rotor angle estimation. |

6.3.10.1 Initial Speed Detect (ISD)

The ISD function is used to identify the initial condition of the motor and is enabled by setting ISD_EN to 1b. The initial speed, position and direction is determined by sensing the three phase voltages. ISD can be disabled by setting ISD_EN to 0b. If the function is disabled (ISD_EN set to 0b), the MCF8315C does not perform the initial speed detect function and proceeds to check if the brake routine (BRAKE_EN) is enabled.

6.3.10.2 Motor Resynchronization

The motor resynchronization function works when the ISD and resynchronization functions are both enabled and the device determines that the initial state of the motor is spinning in the forward direction (same direction as the commanded direction). The speed and position information measured during ISD are used to initialize the drive state of the MCF8315C, which can transition directly into closed loop (or open loop if motor speed is not sufficient for closed loop operation) state without needing to stop the motor. In the MCF8315C, motor resynchronization can be enabled/disabled through RESYNC_EN bit. If motor resynchronization is disabled, the device proceeds to check if the motor coast (Hi-Z) routine is enabled.

6.3.10.3 Reverse Drive

The MCF8315C uses the reverse drive function to change the direction of the motor rotation when ISD_EN and RVS_DR_EN are both set to 1b and the ISD determines the motor spin direction to be opposite to that of the commanded direction. Reverse drive includes synchronizing with the motor speed in the reverse direction, reverse decelerating the motor through zero speed, changing direction, and accelerating in open loop in forward (or commanded) direction until the device transitions into closed loop in forward direction (see [Figure 6-25](#)). MCF8315C provides the option of using the forward direction parameters or a separate set of reverse drive parameters by configuring REV_DRV_CONFIG.

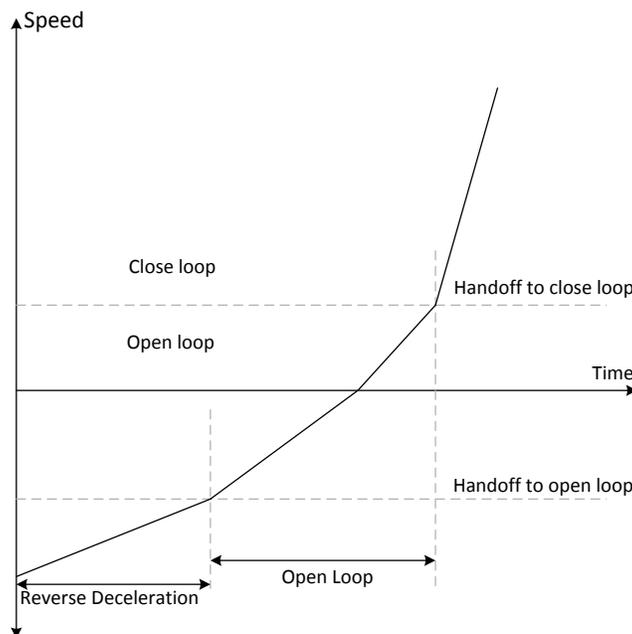


図 6-25. Reverse Drive Function

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During direction reversal, both RVS_DR_EN and ISD_EN together should either be set to 1b or 0b.

6.3.10.3.1 Reverse Drive Tuning

MCF8315C provides the option of tuning the open to closed loop handoff threshold, open loop acceleration (and deceleration) rates and open loop current limit in reverse drive to values different to those used in forward drive

operation; the reverse drive specific parameters can be used by setting REV_DRV_CONFIG to 1b. If REV_DRV_CONFIG is set to 0b, MCF8315C uses the equivalent parameters configured for forward drive operation during the reverse drive operation too.

The speed at which motor would enter the open loop in reverse direction can be configured using REV_DRV_HANDOFF_THR. For a smooth transition without jerks or loss of synchronism, user can configure an appropriate current limit when the motor is spinning in open loop during speed reversal using REV_DRV_OPEN_LOOP_CURRENT. The open loop acceleration rates for the forward direction during speed reversal are defined using REV_DRV_OPEN_LOOP_ACCEL_A1 and REV_DRV_OPEN_LOOP_ACCEL_A2. The reverse drive open loop deceleration rate, when the motor is decelerating in the opposite direction to zero speed, can be configured as a percentage of reverse drive open loop acceleration using REV_DRV_OPEN_LOOP_DEC.

6.3.11 Motor Start-up

There are different options available for motor start-up from a stationary position and these options can be configured by MTR_STARTUP. In align and double align mode, the motor is aligned to a known position by injecting a DC current. In IPD mode, the rotor position is estimated by applying 6 different high-frequency pulses. In slow first cycle mode, the motor is started by applying a low frequency cycle.

6.3.11.1 Align

Align is enabled by configuring MTR_STARTUP to 00b. The MCF8315C aligns the motor by injecting a DC current through a particular phase pattern for a certain time configured by ALIGN_TIME. The phase pattern during align is generated based on ALIGN_ANGLE. In the MCF8315C, the current limit during align is configured through ALIGN_OR_SLOW_CURRENT LIMIT.

A fast change in the phase current may result in a sudden change in the driving torque and this could result in acoustic noise. To avoid this, the MCF8315C ramps up the current from 0 to the current limit at a configurable ramp rate set by ALIGN_SLOW_RAMP_RATE. At the end of align routine, the motor will be aligned at the known position.

6.3.11.2 Double Align

Double align is enabled by configuring MTR_STARTUP to 01b. Single align is not reliable when the initial position of the rotor is 180° out of phase with the applied phase pattern. In this case, it is possible to have start-up failures using single align. In order to improve the reliability of align based start-up, the MCF8315C provides the option of double align start-up. In double align start-up, MCF8315C uses a phase pattern for the second align that is 90° ahead of the first align phase pattern. In double align, relevant parameters like align time, current limit, ramp rate are the same as in the case of single align - two different phase patterns are applied in succession with the same parameters to ensure that the motor will be aligned to a known position irrespective of initial rotor position.

6.3.11.3 Initial Position Detection (IPD)

Initial Position Detection (IPD) can be enabled by configuring MTR_STARTUP to 10b. In IPD, inductive sense method is used to determine the initial position of the motor using the spatial variation in the motor inductance.

Align or double align may result in the motor spinning in the reverse direction before starting open loop acceleration. IPD can be used in such applications where reverse rotation of the motor is unacceptable. IPD does not wait for the motor to align with the commutation and therefore can allow for a faster motor start-up sequence. IPD works well when the inductance of the motor varies as a function of position. IPD works by pulsing current in to the motor and hence can generate acoustics which must be taken into account when determining the best start-up method for a particular application.

6.3.11.3.1 IPD Operation

IPD operates by sequentially applying six different phase patterns according to the following sequence: BC-> CB-> AB-> BA-> CA-> AC (see [Figure 6-26](#)). When the current reaches the threshold configured by IPD_CURR_THR, the MCF8315C stops driving the particular phase pattern and measures the time taken to

reach the current threshold from when the particular phase pattern was applied. Thus, the time taken to reach IPD_CURR_THR is measured for all six phase patterns - this time varies as a function of the inductance in the motor windings. The state with the shortest time represents the state with the minimum inductance. The minimum inductance is because of the alignment of the north pole of the motor with this particular driving state.

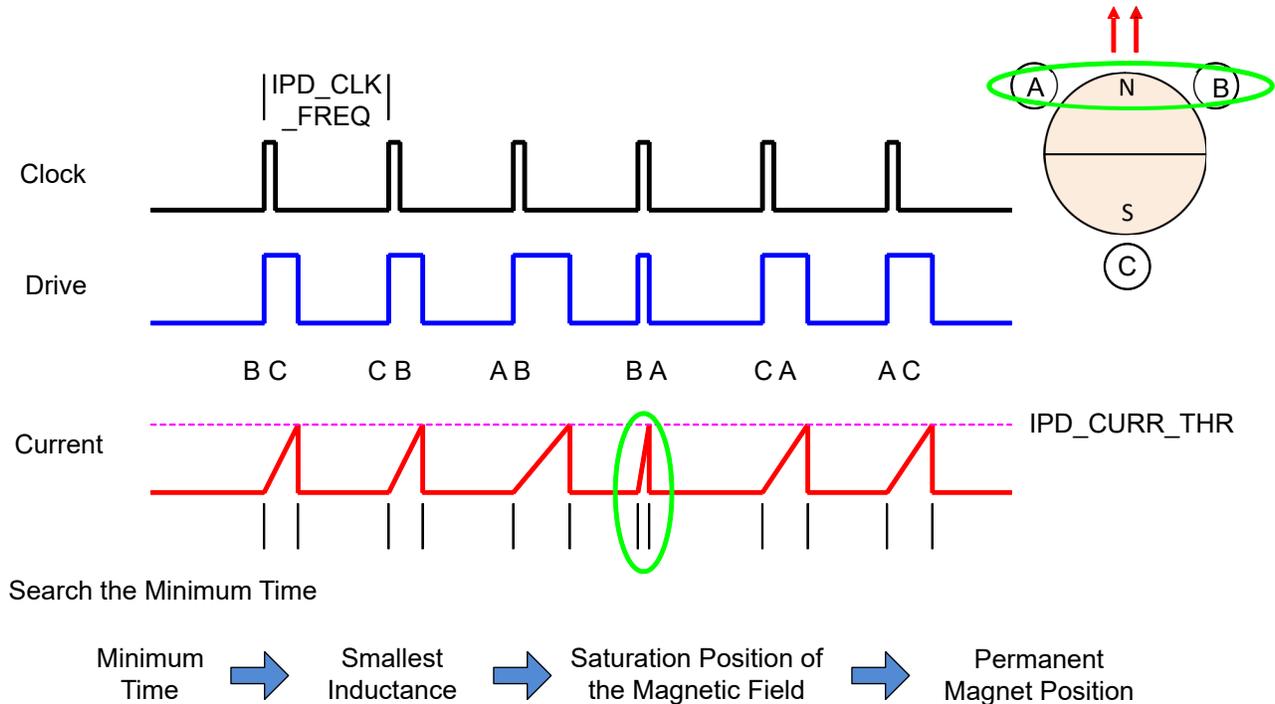


图 6-26. IPD Operation

6.3.11.3.2 IPD Release Mode

Two modes are available for configuring the way the MCF8315C stops driving the FETs when the IPD current threshold is reached. The recirculate (or brake) mode is selected if IPD_RLS_MODE = 0b. In this configuration, the low-side (LSC) MOSFET remains ON to allow the current to recirculate between the MOSFET (LSC) and body diode (LSA) (see 图 6-27). Hi-Z mode is selected if IPD_RLS_MODE = 1b. In Hi-Z mode, both the high-side (HSA) and low-side (LSC) MOSFETs are turned OFF and the current recirculates through the body diodes back to the power supply (see 图 6-28).

In the Hi-Z mode, the phase current has a faster settle-down time, but that can result in a voltage increase on V_M . The user must manage this with an appropriate selection of either a clamp circuit or by providing sufficient capacitance between V_M and PGND to absorb the energy. If the voltage surge cannot be contained or if it is unacceptable for the application, recirculate mode must be used. When using the recirculate mode, select the IPD_CLK_FREQ appropriately to give the current in the motor windings enough time to decay to 0-A before the next IPD phase pattern is applied.

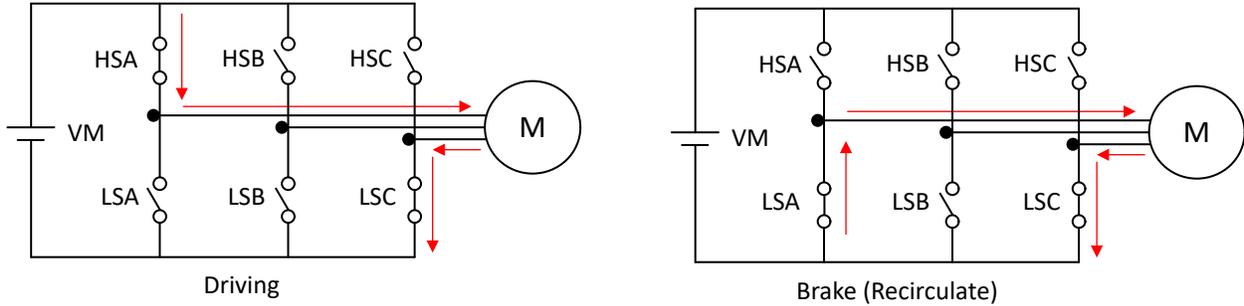


図 6-27. IPD Release Mode - Brake (0b)

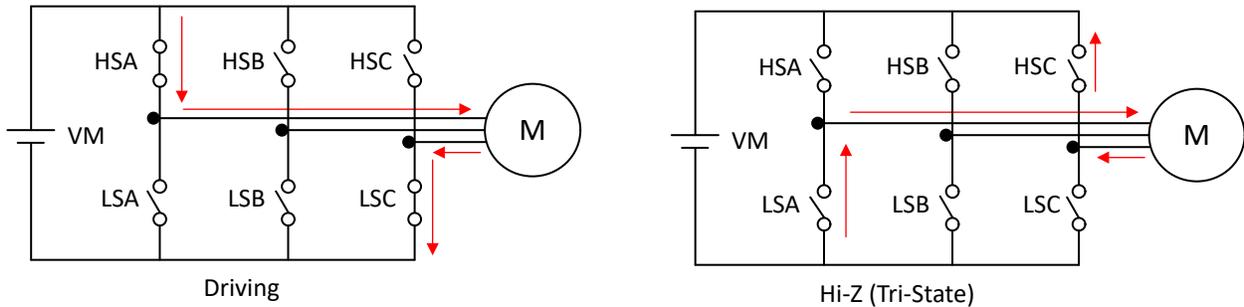


図 6-28. IPD Release Mode - Tristate (1b)

6.3.11.3.3 IPD Advance Angle

After the initial position is detected, the MCF8315C begins driving the motor in open loop at an angle specified by IPD_ADV_ANGLE.

Advancing the drive angle anywhere from 0° to 180° results in positive torque. Advancing the drive angle by 90° results in maximum initial torque. Applying maximum initial torque could result in uneven acceleration to the rotor. Select the IPD_ADV_ANGLE to allow for smooth acceleration in the application (see 図 6-29).

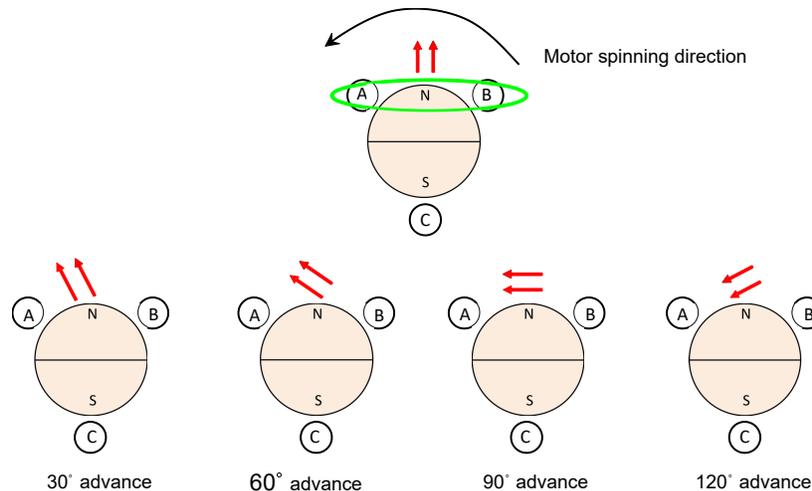


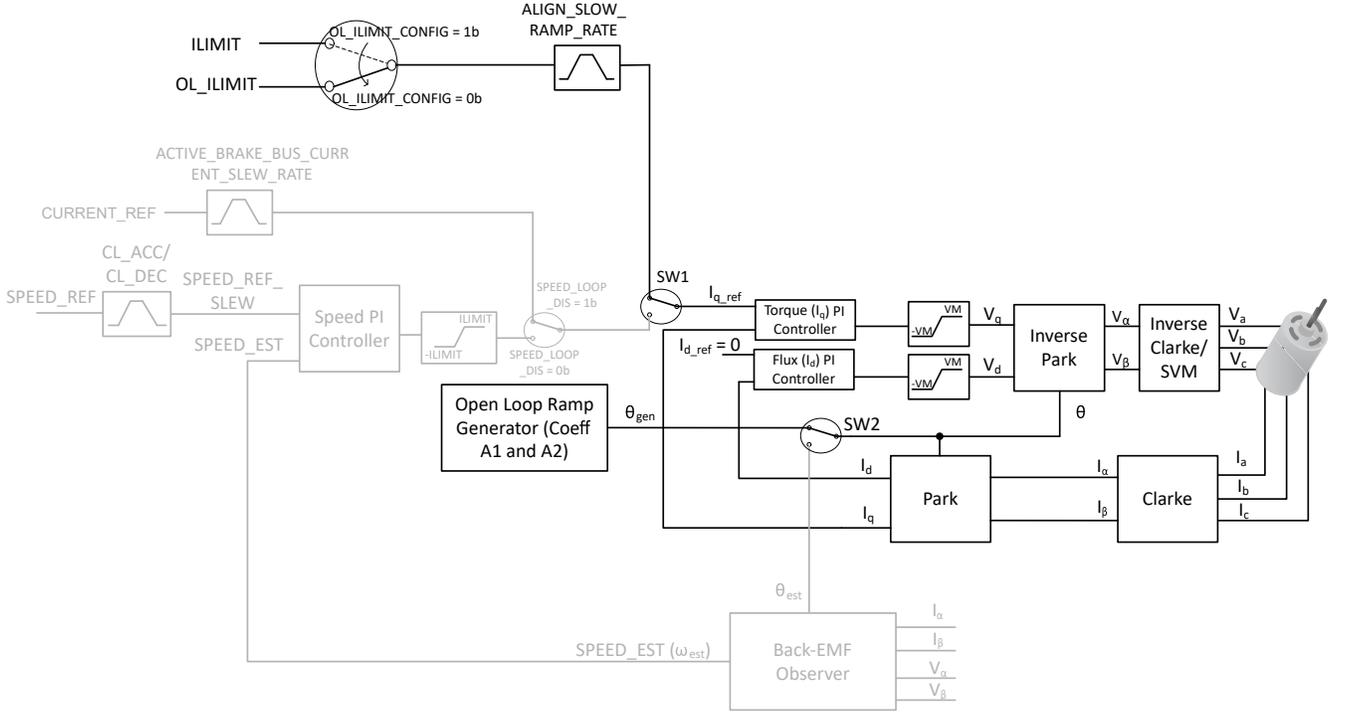
図 6-29. IPD Advance Angle

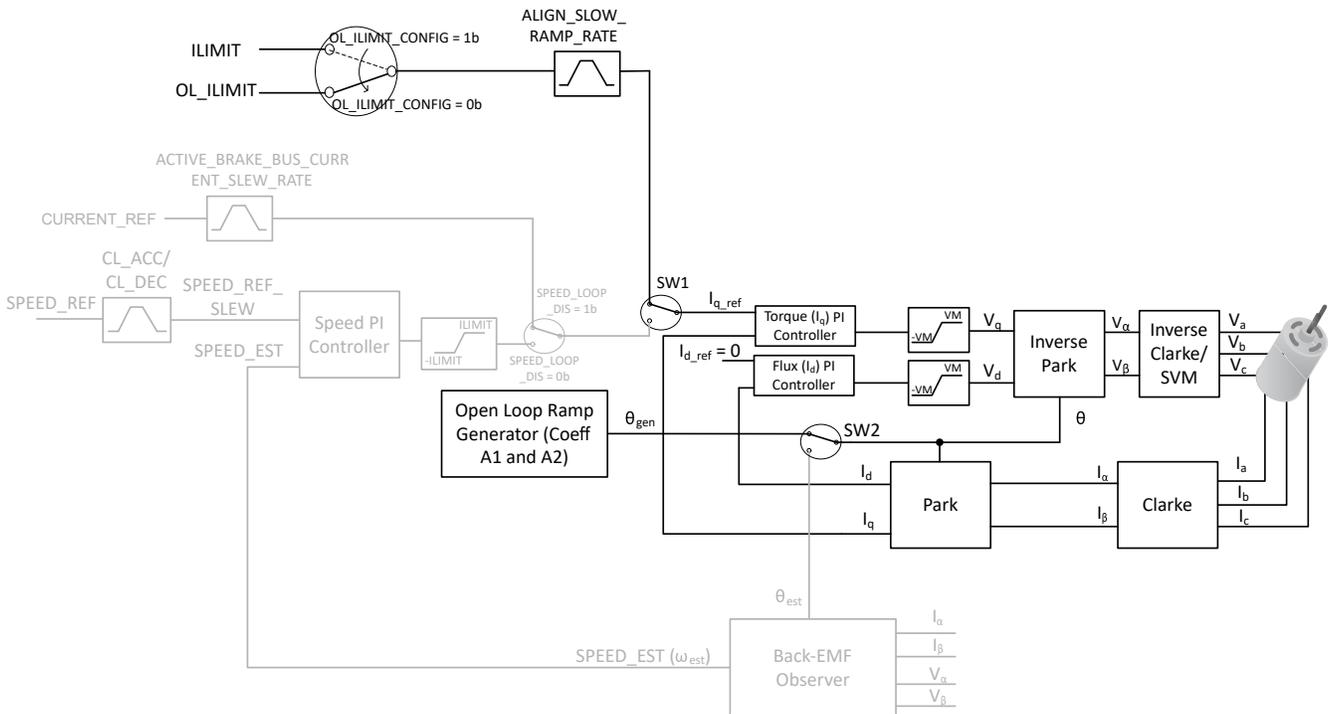
6.3.11.4 Slow First Cycle Start-up

Slow first cycle start-up is enabled by configuring MTR_STARTUP to 11b. In slow first cycle start-up, the MCF8315C starts motor commutation at a frequency defined by SLOW_FIRST_CYCLE_FREQ. The frequency

configured is used only for first cycle, and then the motor commutation follows acceleration profile configured by open loop acceleration coefficients, A1 (OL_ACC_A1) and A2 (OL_ACC_A2). The slow first cycle frequency has to be configured to be slow enough to allow motor to synchronize with the commutation sequence. This mode is useful when fast startup is desired as it significantly reduces the align time.

6.3.11.5 Open loop

Upon completing the motor position initialization with either align, double align, IPD or slow first cycle, the MCF8315C begins to accelerate the motor in open loop. In MCF8315C, the current limit in open loop is set by ILIMIT or OL_ILIMIT based on the configuration of OL_ILIMIT_CONFIG and the speed is increased using this current limit. In open loop, the control PI loops for I_q and I_d actively control the currents. The angle during open loop is provided from the ramp generator as shown in .



 6-30. Open Loop

The function of the open-loop operation is to drive the motor to a speed at which the motor generates sufficient BEMF to allow the back-EMF observer to accurately detect the position of the rotor. The motor is accelerated in open loop and speed at any given time is determined by 式 7. In MCF8315C, open loop acceleration coefficients, A1 and A2 are configured through OL_ACC_A1 and OL_ACC_A2 respectively.

$$\text{Speed}(t) = A1 * t + 0.5 * A2 * t^2 \tag{7}$$

6.3.11.6 Transition from Open to Closed Loop

Once the motor has reached a sufficient speed for the back-EMF observer to estimate the angle and speed of the motor, the MCF8315C transitions into closed loop state. This handoff speed is automatically determined based on the measured back-EMF and motor speed. Users also have an option to manually set the handoff speed by configuring OPN_CL_HANDOFF_THR and setting AUTO_HANDOFF_EN to 0b. In order to have smooth transition and avoid speed transients, the theta_error ($\Theta_{gen} - \Theta_{est}$) is decreased linearly after transition. The ramp rate of theta_error reduction can be configured using THETA_ERROR_RAMP_RATE. If the current limit set during the open loop is high and if it is not reduced before transition to closed loop, the motor speed may momentarily rise after transition into closed loop. In order to avoid such speed variations, configure the IQ_RAMP_EN to 1b, so that i_{q_ref} decreases gradually prior to transition into closed loop. However if the final

speed reference (SPEED_REF) is more than two times the open loop to closed loop hand off speed (OPN_CL_HANDOFF_THR), then i_{q_ref} is not decreased independent of the IQ_RAMP_EN setting, to enable faster motor acceleration.

After hand off to closed loop at a sufficient speed, there could be still some theta error, as the estimators may not be fully aligned. A slow acceleration can be used after the open loop to closed loop transition, ensuring that the theta error reduces to zero. The slow acceleration can be configured using CL_SLOW_ACC.

Figure 6-31 shows the control sequence in open to closed loop transition. The current i_{q_ref} reduces to a lower value in current decay region, if IQ_RAMP_EN is set to 1b. If IQ_RAMP_EN is set to 0b, then the current decay region will not be present in the transition sequence. IQ_RAMP_EN should be set to 1b only when PWM_FREQ_OUT \neq 15, 30, 45 or 60kHz.

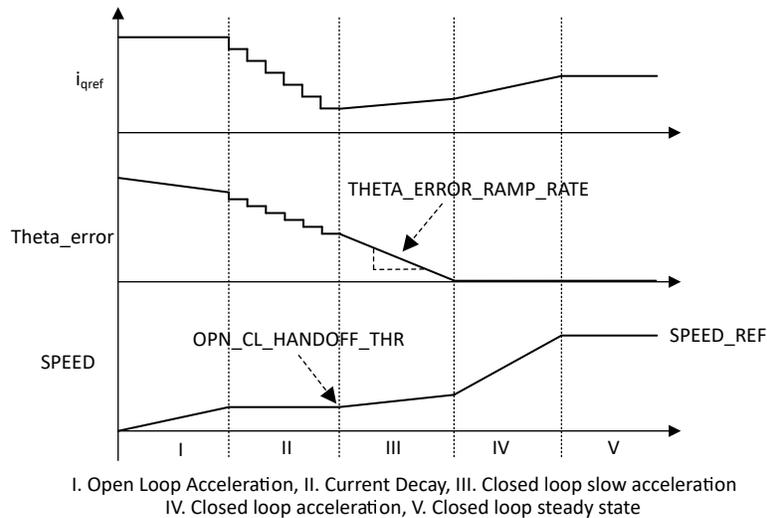


Figure 6-31. Control Sequence in Open to Closed Loop Transition

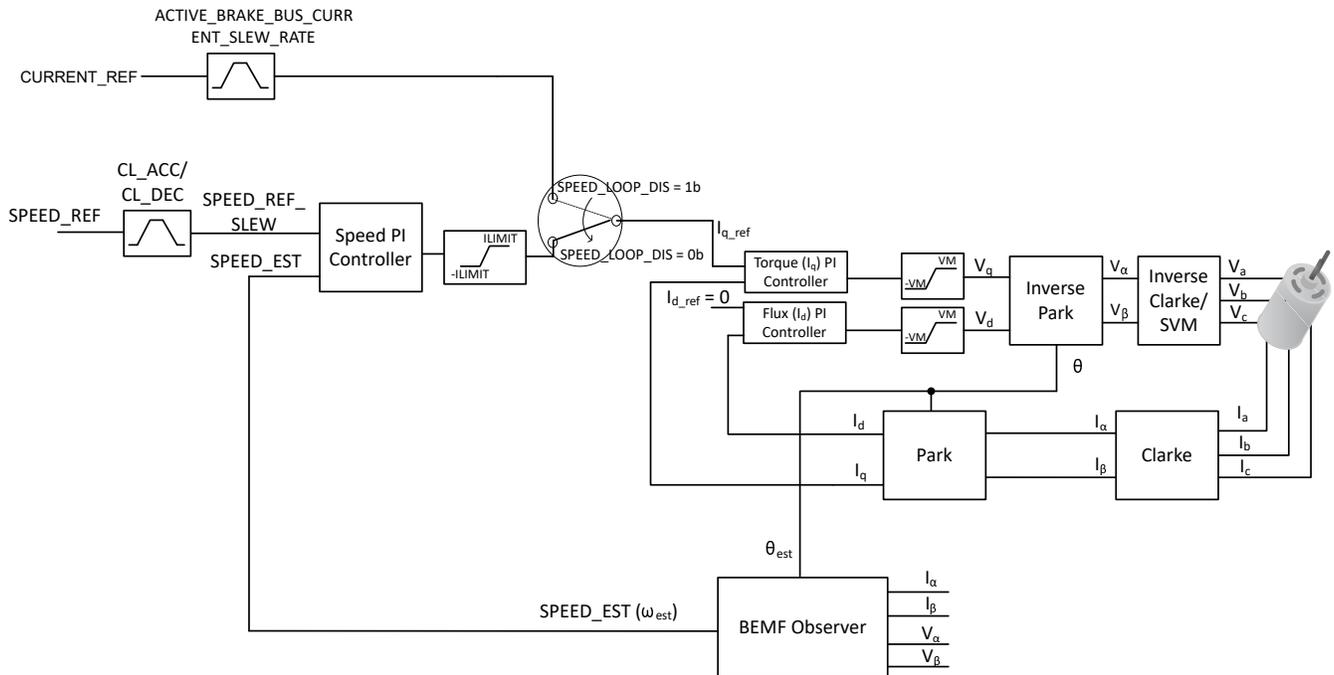


図 6-33. Closed Loop FOC Control

6.3.12.1 Closed Loop Acceleration/Deceleration Slew Rate

During closed loop acceleration/deceleration, MCF8315C provides the option of configuring the slew rate of the speed reference input to the speed PI controller (SPEED_REF_SLEW in 図 6-33). This allows for a linear change in speed reference input (SPEED_REF_SLEW) even when there is a step change in speed reference (SPEED_REF from Analog, PWM, Frequency or I²C) as seen in 図 6-34. This slew rate can be configured so as to prevent sudden changes in the torque applied to the motor which could result in acoustic noise. The closed loop acceleration/deceleration slew rate parameter, CL_ACC/CL_DEC, sets the slew rate of SPEED_REF_SLEW during acceleration and deceleration (when AVS is not active) respectively.

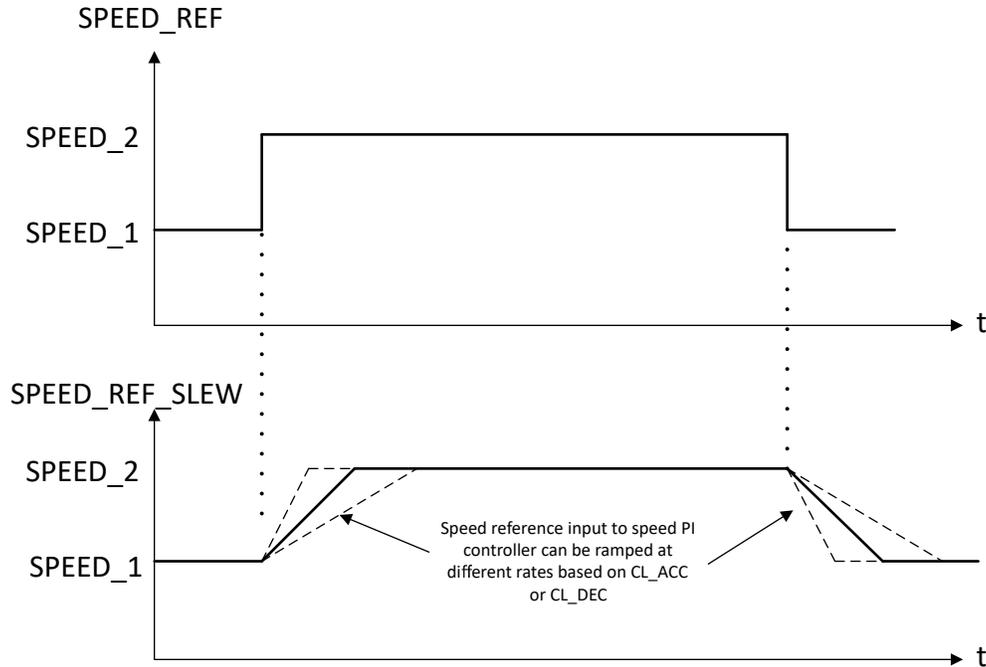


図 6-34. Closed Loop Acceleration/Deceleration Slew Rate

6.3.12.2 Speed PI Control

The integrated speed control loop helps maintain a constant speed over varying operating conditions. The K_p and K_i coefficients are configured through SPD_LOOP_KP and SPD_LOOP_KI. The output of the speed loop is used to generate the current reference for torque control (I_{q_ref}). The output of the speed loop is limited to implement a current limit. The current limit is set by configuring ILIMIT. When output of the speed loop saturates, the integrator is disabled to prevent integral wind-up.

SPEED_REF_SLEW is derived from the duty command input, speed profiles and closed loop acceleration/ deceleration rates configured by the user and SPEED_EST is the estimated speed from the back-EMF observer.

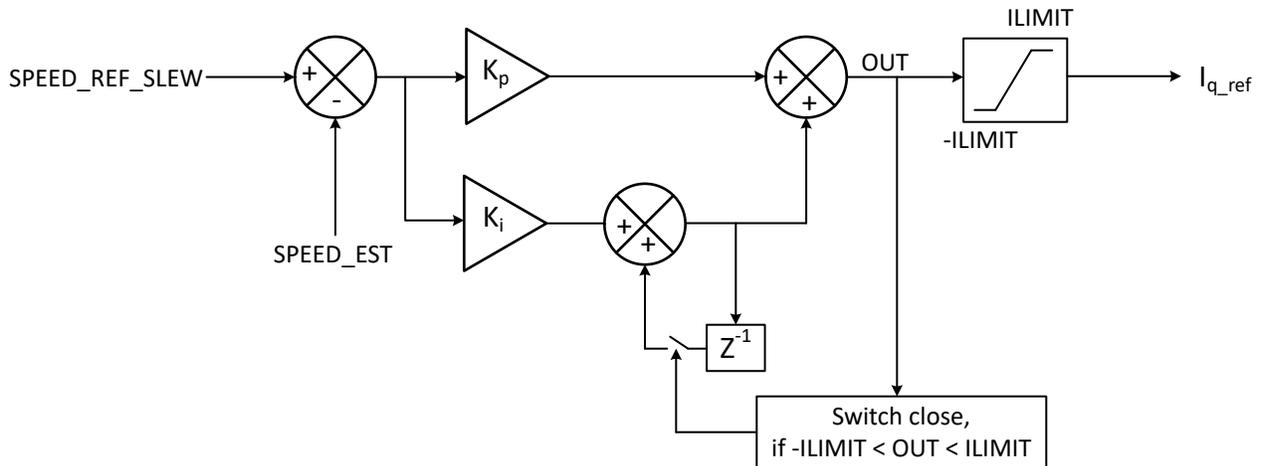


図 6-35. Speed PI Control

6.3.12.3 Current PI Control

The MCF8315C has two PI controllers, one each for I_d and I_q to control flux and torque separately. K_p and K_i coefficients are the same for both PI controllers and are configured through CURR_LOOP_KP and

CURR_LOOP_KI. The outputs of the current control loops are used to generate voltage signals V_d and V_q to be applied to the motor. The outputs of the current loops are clamped to supply voltage V_M . I_d current PI loop is executed first and output of I_d current PI loop, V_d is checked for saturation. When the output of the current loop saturates, the integration is disabled to prevent integral wind-up.

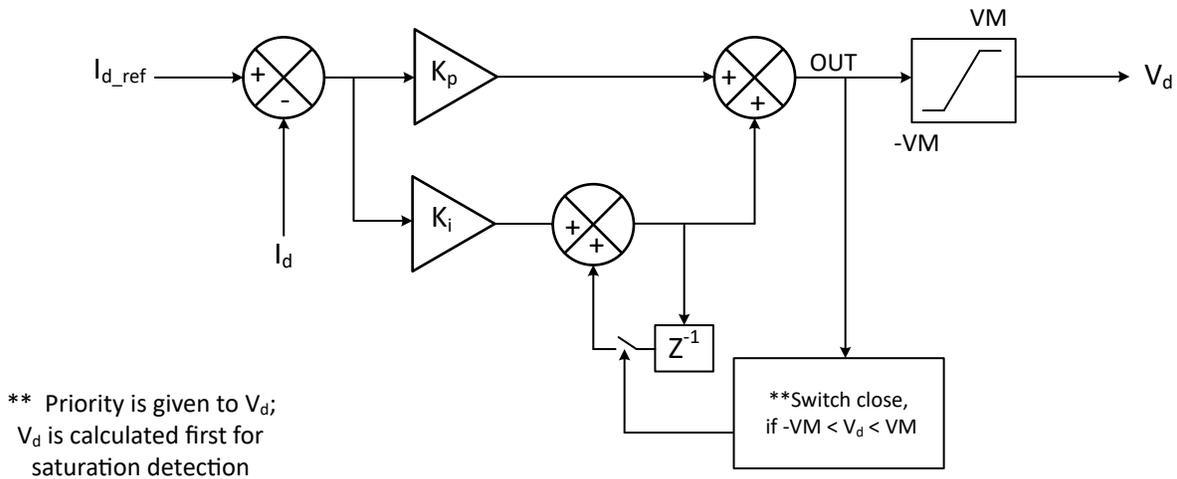


図 6-36. I_d Current PI Control

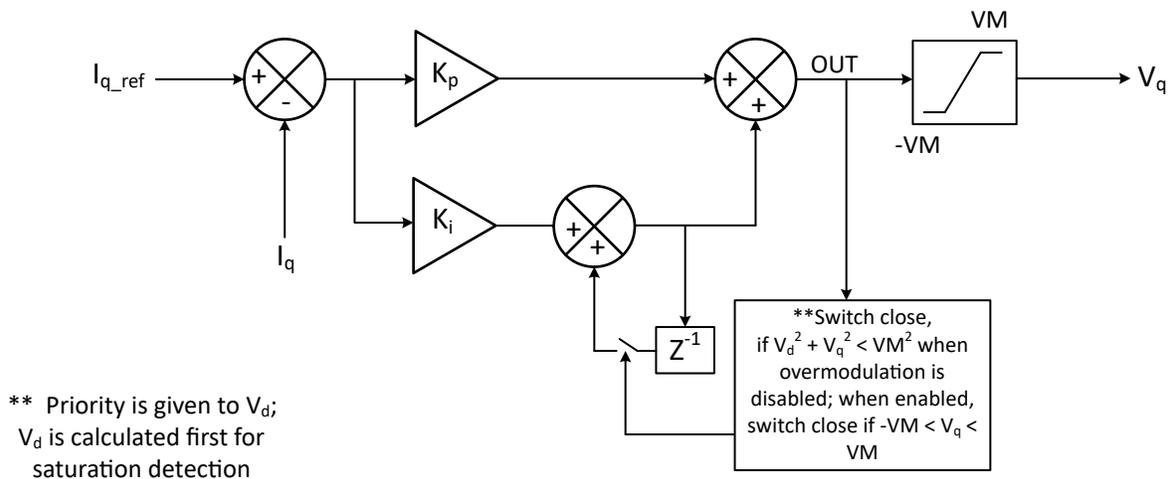


図 6-37. I_q Current PI Control

6.3.12.4 Torque Mode

MCF8315C provides the option of disabling the speed loop by setting SPEED_LOOP_DIS to 1b. In this mode, the q-axis current reference, I_{q_ref} is directly set by the product of duty cycle input, DUTY_CMD (from SPEED pin or I²C) and ILIMIT instead of the speed PI loop output as shown in 図 6-33. Thus, this mode enables torque control through setting I_{q_ref} directly and hence can be used for torque mode operation.

注

In torque mode, MTR_STOP should be configured to 000b (Hi-Z) only.

6.3.12.5 Overmodulation

MCF8315C provides an overmodulation option to operate the motor at a higher speed at the same V_M voltage by increasing the applied fundamental phase voltage by suitably modifying the applied PWM pattern - the higher

fundamental phase voltage is accompanied by an increase in higher order harmonics. This feature can be enabled by setting OVERMODULATION_ENABLE to 1b.

6.3.13 Motor Parameters

The MCF8315C uses the motor resistance, motor inductance and motor back-EMF constant to estimate motor position when operating in closed loop. The MCF8315C has the capability of measuring these motor parameters in the offline state (see [Motor Parameter Extraction Tool \(MPET\)](#)). Offline measurement of parameters, when enabled, takes place before normal motor operation. The user can also disable the offline measurement and configure motor parameters through EEPROM. This feature of offline motor parameter measurement is useful to account for motor to motor variation during manufacturing.

6.3.13.1 Motor Resistance

For a wye-connected motor, the motor phase resistance refers to the resistance from the phase output to the center tap, R_{PH} (denoted as R_{PH} in [Figure 6-38](#)). For a delta-connected motor, the motor phase resistance refers to the equivalent phase to center tap in the wye configuration in [Figure 6-38](#).

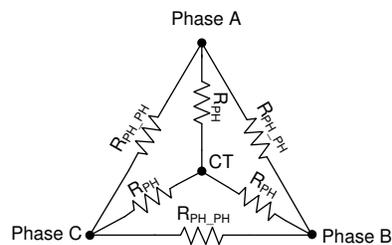


Figure 6-38. Motor Resistance

For both the delta-connected and the wye-connected motor, the easy way to get the equivalent R_{PH} is to measure the resistance between two phase terminals (R_{PH_PH}), and then divide this value by two, $R_{PH} = \frac{1}{2} R_{PH_PH}$. In wye-connected motor, if user has access to center tap (CT), R_{PH} can also be measured between center tap (CT) and phase terminal.

Configure the motor resistance (R_{PH}) to a nearest value from [Table 6-2](#).

Table 6-2. Motor Resistance Look-Up Table

| MOTOR_RES (HEX) | R_{PH} (Ω) | MOTOR_RES (HEX) | R_{PH} (Ω) | MOTOR_RES (HEX) | R_{PH} (Ω) | MOTOR_RES (HEX) | R_{PH} (Ω) |
|-----------------|--|-----------------|-----------------------|-----------------|-----------------------|-----------------|-----------------------|
| 0x00 | Self Measurement (see Motor Parameter Extraction Tool (MPET)) | 0x40 | 0.145 | 0x80 | 0.465 | 0xC0 | 2.1 |
| 0x01 | 0.006 | 0x41 | 0.150 | 0x81 | 0.470 | 0xC1 | 2.2 |
| 0x02 | 0.007 | 0x42 | 0.155 | 0x82 | 0.475 | 0xC2 | 2.3 |
| 0x03 | 0.008 | 0x43 | 0.160 | 0x83 | 0.480 | 0xC3 | 2.4 |
| 0x04 | 0.009 | 0x44 | 0.165 | 0x84 | 0.485 | 0xC4 | 2.5 |
| 0x05 | 0.010 | 0x45 | 0.170 | 0x85 | 0.490 | 0xC5 | 2.6 |
| 0x06 | 0.011 | 0x46 | 0.175 | 0x86 | 0.495 | 0xC6 | 2.7 |
| 0x07 | 0.012 | 0x47 | 0.180 | 0x87 | 0.50 | 0xC7 | 2.8 |
| 0x08 | 0.013 | 0x48 | 0.185 | 0x88 | 0.51 | 0xC8 | 2.9 |
| 0x09 | 0.014 | 0x49 | 0.190 | 0x89 | 0.52 | 0xC9 | 3.0 |
| 0x0A | 0.015 | 0x4A | 0.195 | 0x8A | 0.53 | 0xCA | 3.2 |
| 0x0B | 0.016 | 0x4B | 0.200 | 0x8B | 0.54 | 0xCB | 3.4 |
| 0x0C | 0.017 | 0x4C | 0.205 | 0x8C | 0.55 | 0xCC | 3.6 |

表 6-2. Motor Resistance Look-Up Table (続き)

| MOTOR_RES (HEX) | R _{PH} (Ω) |
|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|
| 0x0D | 0.018 | 0x4D | 0.210 | 0x8D | 0.56 | 0xCD | 3.8 |
| 0x0E | 0.019 | 0x4E | 0.215 | 0x8E | 0.57 | 0xCE | 4.0 |
| 0x0F | 0.020 | 0x4F | 0.220 | 0x8F | 0.58 | 0xCF | 4.2 |
| 0x10 | 0.022 | 0x50 | 0.225 | 0x90 | 0.59 | 0xD0 | 4.4 |
| 0x11 | 0.024 | 0x51 | 0.230 | 0x91 | 0.60 | 0xD1 | 4.6 |
| 0x12 | 0.026 | 0x52 | 0.235 | 0x92 | 0.61 | 0xD2 | 4.8 |
| 0x13 | 0.028 | 0x53 | 0.240 | 0x93 | 0.62 | 0xD3 | 5.0 |
| 0x14 | 0.030 | 0x54 | 0.245 | 0x94 | 0.63 | 0xD4 | 5.2 |
| 0x15 | 0.032 | 0x55 | 0.250 | 0x95 | 0.64 | 0xD5 | 5.4 |
| 0x16 | 0.034 | 0x56 | 0.255 | 0x96 | 0.65 | 0xD6 | 5.6 |
| 0x17 | 0.036 | 0x57 | 0.260 | 0x97 | 0.66 | 0xD7 | 5.8 |
| 0x18 | 0.038 | 0x58 | 0.265 | 0x98 | 0.67 | 0xD8 | 6.0 |
| 0x19 | 0.040 | 0x59 | 0.270 | 0x99 | 0.68 | 0xD9 | 6.2 |
| 0x1A | 0.042 | 0x5A | 0.275 | 0x9A | 0.69 | 0xDA | 6.4 |
| 0x1B | 0.044 | 0x5B | 0.280 | 0x9B | 0.70 | 0xDB | 6.6 |
| 0x1C | 0.046 | 0x5C | 0.285 | 0x9C | 0.72 | 0xDC | 6.8 |
| 0x1D | 0.048 | 0x5D | 0.290 | 0x9D | 0.74 | 0xDD | 7.0 |
| 0x1E | 0.050 | 0x5E | 0.295 | 0x9E | 0.76 | 0xDE | 7.2 |
| 0x1F | 0.052 | 0x5F | 0.300 | 0x9F | 0.78 | 0xDF | 7.4 |
| 0x20 | 0.054 | 0x60 | 0.305 | 0xA0 | 0.80 | 0xE0 | 7.6 |
| 0x21 | 0.056 | 0x61 | 0.310 | 0xA1 | 0.82 | 0xE1 | 7.8 |
| 0x22 | 0.058 | 0x62 | 0.315 | 0xA2 | 0.84 | 0xE2 | 8.0 |
| 0x23 | 0.060 | 0x63 | 0.320 | 0xA3 | 0.86 | 0xE3 | 8.2 |
| 0x24 | 0.062 | 0x64 | 0.325 | 0xA4 | 0.88 | 0xE4 | 8.4 |
| 0x25 | 0.064 | 0x65 | 0.330 | 0xA5 | 0.90 | 0xE5 | 8.6 |
| 0x26 | 0.066 | 0x66 | 0.335 | 0xA6 | 0.92 | 0xE6 | 8.8 |
| 0x27 | 0.068 | 0x67 | 0.340 | 0xA7 | 0.94 | 0xE7 | 9 |
| 0x28 | 0.070 | 0x68 | 0.345 | 0xA8 | 0.96 | 0xE8 | 9.2 |
| 0x29 | 0.072 | 0x69 | 0.350 | 0xA9 | 0.98 | 0xE9 | 9.4 |
| 0x2A | 0.074 | 0x6A | 0.355 | 0xAA | 1.00 | 0xEA | 9.6 |
| 0x2B | 0.076 | 0x6B | 0.360 | 0xAB | 1.05 | 0xEB | 9.8 |
| 0x2C | 0.078 | 0x6C | 0.365 | 0xAC | 1.10 | 0xEC | 10.0 |
| 0x2D | 0.080 | 0x6D | 0.370 | 0xAD | 1.15 | 0xED | 10.5 |
| 0x2E | 0.082 | 0x6E | 0.375 | 0xAE | 1.20 | 0xEE | 11.0 |
| 0x2F | 0.084 | 0x6F | 0.380 | 0xAF | 1.25 | 0xEF | 11.5 |
| 0x30 | 0.086 | 0x70 | 0.385 | 0xB0 | 1.30 | 0xF0 | 12.0 |
| 0x31 | 0.088 | 0x71 | 0.390 | 0xB1 | 1.35 | 0xF1 | 12.5 |
| 0x32 | 0.090 | 0x72 | 0.395 | 0xB2 | 1.40 | 0xF2 | 13.0 |
| 0x33 | 0.092 | 0x73 | 0.400 | 0xB3 | 1.45 | 0xF3 | 13.5 |
| 0x34 | 0.094 | 0x74 | 0.405 | 0xB4 | 1.50 | 0xF4 | 14.0 |
| 0x35 | 0.096 | 0x75 | 0.410 | 0xB5 | 1.55 | 0xF5 | 14.5 |
| 0x36 | 0.098 | 0x76 | 0.415 | 0xB6 | 1.60 | 0xF6 | 15.0 |
| 0x37 | 0.100 | 0x77 | 0.420 | 0xB7 | 1.65 | 0xF7 | 15.5 |
| 0x38 | 0.105 | 0x78 | 0.425 | 0xB8 | 1.70 | 0xF8 | 16.0 |

表 6-2. Motor Resistance Look-Up Table (続き)

| MOTOR_RES (HEX) | R _{PH} (Ω) |
|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|-----------------|---------------------|
| 0x39 | 0.110 | 0x79 | 0.430 | 0xB9 | 1.75 | 0xF9 | 16.5 |
| 0x3A | 0.115 | 0x7A | 0.435 | 0xBA | 1.80 | 0xFA | 17.0 |
| 0x3B | 0.120 | 0x7B | 0.440 | 0xBB | 1.85 | 0xFB | 17.5 |
| 0x3C | 0.125 | 0x7C | 0.445 | 0xBC | 1.90 | 0xFC | 18.0 |
| 0x3D | 0.130 | 0x7D | 0.450 | 0xBD | 1.95 | 0xFD | 18.5 |
| 0x3E | 0.135 | 0x7E | 0.455 | 0xBE | 2.00 | 0xFE | 19.0 |
| 0x3F | 0.140 | 0x7F | 0.460 | 0xBF | 2.05 | 0xFF | 20.0 |

6.3.13.2 Motor Inductance

For a wye-connected motor, the motor phase inductance refers to the inductance from the phase output to the center tap, L_{PH} (denoted as L_{PH} in [図 6-39](#)). For a delta-connected motor, the motor phase inductance refers to the equivalent phase to center tap in the wye configuration in [図 6-39](#).

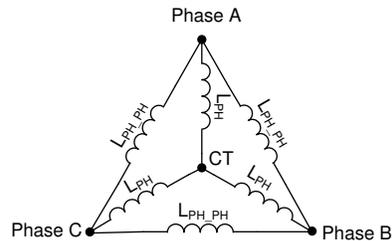


図 6-39. Motor Inductance

For both the delta-connected motor and the wye-connected motor, the easy way to get the equivalent L_{PH} is to measure the inductance between two phase terminals (L_{PH_PH}), and then divide this value by two, $L_{PH} = \frac{1}{2} L_{PH_PH}$. In wye-connected motor, if user has access to center tap (CT), L_{PH} can also be measured between center tap (CT) and phase terminal.

Configure the motor inductance (L_{PH}) to a nearest value from [表 6-3](#).

表 6-3. Motor Inductance Look-Up Table

| MOTOR_IND (HEX) | L _{PH} (mH) | MOTOR_IND (HEX) | L _{PH} (mH) | MOTOR_IND (HEX) | L _{PH} (mH) | MOTOR_IND (HEX) | L _{PH} (mH) |
|-----------------|---|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|
| 0x00 | Self Measurement (see Motor Parameter Extraction Tool (MPET)) | 0x40 | 0.145 | 0x80 | 0.465 | 0xC0 | 2.1 |
| 0x01 | 0.006 | 0x41 | 0.150 | 0x81 | 0.470 | 0xC1 | 2.2 |
| 0x02 | 0.007 | 0x42 | 0.155 | 0x82 | 0.475 | 0xC2 | 2.3 |
| 0x03 | 0.008 | 0x43 | 0.160 | 0x83 | 0.480 | 0xC3 | 2.4 |
| 0x04 | 0.009 | 0x44 | 0.165 | 0x84 | 0.485 | 0xC4 | 2.5 |
| 0x05 | 0.010 | 0x45 | 0.170 | 0x85 | 0.490 | 0xC5 | 2.6 |
| 0x06 | 0.011 | 0x46 | 0.175 | 0x86 | 0.495 | 0xC6 | 2.7 |
| 0x07 | 0.012 | 0x47 | 0.180 | 0x87 | 0.50 | 0xC7 | 2.8 |
| 0x08 | 0.013 | 0x48 | 0.185 | 0x88 | 0.51 | 0xC8 | 2.9 |
| 0x09 | 0.014 | 0x49 | 0.190 | 0x89 | 0.52 | 0xC9 | 3.0 |
| 0x0A | 0.015 | 0x4A | 0.195 | 0x8A | 0.53 | 0xCA | 3.2 |
| 0x0B | 0.016 | 0x4B | 0.200 | 0x8B | 0.54 | 0xCB | 3.4 |
| 0x0C | 0.017 | 0x4C | 0.205 | 0x8C | 0.55 | 0xCC | 3.6 |
| 0x0D | 0.018 | 0x4D | 0.210 | 0x8D | 0.56 | 0xCD | 3.8 |
| 0x0E | 0.019 | 0x4E | 0.215 | 0x8E | 0.57 | 0xCE | 4.0 |
| 0x0F | 0.020 | 0x4F | 0.220 | 0x8F | 0.58 | 0xCF | 4.2 |
| 0x10 | 0.022 | 0x50 | 0.225 | 0x90 | 0.59 | 0xD0 | 4.4 |
| 0x11 | 0.024 | 0x51 | 0.230 | 0x91 | 0.60 | 0xD1 | 4.6 |
| 0x12 | 0.026 | 0x52 | 0.235 | 0x92 | 0.61 | 0xD2 | 4.8 |
| 0x13 | 0.028 | 0x53 | 0.240 | 0x93 | 0.62 | 0xD3 | 5.0 |
| 0x14 | 0.030 | 0x54 | 0.245 | 0x94 | 0.63 | 0xD4 | 5.2 |
| 0x15 | 0.032 | 0x55 | 0.250 | 0x95 | 0.64 | 0xD5 | 5.4 |
| 0x16 | 0.034 | 0x56 | 0.255 | 0x96 | 0.65 | 0xD6 | 5.6 |
| 0x17 | 0.036 | 0x57 | 0.260 | 0x97 | 0.66 | 0xD7 | 5.8 |
| 0x18 | 0.038 | 0x58 | 0.265 | 0x98 | 0.67 | 0xD8 | 6.0 |
| 0x19 | 0.040 | 0x59 | 0.270 | 0x99 | 0.68 | 0xD9 | 6.2 |
| 0x1A | 0.042 | 0x5A | 0.275 | 0x9A | 0.69 | 0xDA | 6.4 |
| 0x1B | 0.044 | 0x5B | 0.280 | 0x9B | 0.70 | 0xDB | 6.6 |
| 0x1C | 0.046 | 0x5C | 0.285 | 0x9C | 0.72 | 0xDC | 6.8 |
| 0x1D | 0.048 | 0x5D | 0.290 | 0x9D | 0.74 | 0xDD | 7.0 |
| 0x1E | 0.050 | 0x5E | 0.295 | 0x9E | 0.76 | 0xDE | 7.2 |
| 0x1F | 0.052 | 0x5F | 0.300 | 0x9F | 0.78 | 0xDF | 7.4 |
| 0x20 | 0.054 | 0x60 | 0.305 | 0xA0 | 0.80 | 0xE0 | 7.6 |
| 0x21 | 0.056 | 0x61 | 0.310 | 0xA1 | 0.82 | 0xE1 | 7.8 |
| 0x22 | 0.058 | 0x62 | 0.315 | 0xA2 | 0.84 | 0xE2 | 8.0 |
| 0x23 | 0.060 | 0x63 | 0.320 | 0xA3 | 0.86 | 0xE3 | 8.2 |
| 0x24 | 0.062 | 0x64 | 0.325 | 0xA4 | 0.88 | 0xE4 | 8.4 |
| 0x25 | 0.064 | 0x65 | 0.330 | 0xA5 | 0.90 | 0xE5 | 8.6 |
| 0x26 | 0.066 | 0x66 | 0.335 | 0xA6 | 0.92 | 0xE6 | 8.8 |
| 0x27 | 0.068 | 0x67 | 0.340 | 0xA7 | 0.94 | 0xE7 | 9 |
| 0x28 | 0.070 | 0x68 | 0.345 | 0xA8 | 0.96 | 0xE8 | 9.2 |

表 6-3. Motor Inductance Look-Up Table (続き)

| MOTOR_IND (HEX) | L _{PH} (mH) |
|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|
| 0x29 | 0.072 | 0x69 | 0.350 | 0xA9 | 0.98 | 0xE9 | 9.4 |
| 0x2A | 0.074 | 0x6A | 0.355 | 0xAA | 1.00 | 0xEA | 9.6 |
| 0x2B | 0.076 | 0x6B | 0.360 | 0xAB | 1.05 | 0xEB | 9.8 |
| 0x2C | 0.078 | 0x6C | 0.365 | 0xAC | 1.10 | 0xEC | 10.0 |
| 0x2D | 0.080 | 0x6D | 0.370 | 0xAD | 1.15 | 0xED | 10.5 |
| 0x2E | 0.082 | 0x6E | 0.375 | 0xAE | 1.20 | 0xEE | 11.0 |
| 0x2F | 0.084 | 0x6F | 0.380 | 0xAF | 1.25 | 0xEF | 11.5 |
| 0x30 | 0.086 | 0x70 | 0.385 | 0xB0 | 1.30 | 0xF0 | 12.0 |
| 0x31 | 0.088 | 0x71 | 0.390 | 0xB1 | 1.35 | 0xF1 | 12.5 |
| 0x32 | 0.090 | 0x72 | 0.395 | 0xB2 | 1.40 | 0xF2 | 13.0 |
| 0x33 | 0.092 | 0x73 | 0.400 | 0xB3 | 1.45 | 0xF3 | 13.5 |
| 0x34 | 0.094 | 0x74 | 0.405 | 0xB4 | 1.50 | 0xF4 | 14.0 |
| 0x35 | 0.096 | 0x75 | 0.410 | 0xB5 | 1.55 | 0xF5 | 14.5 |
| 0x36 | 0.098 | 0x76 | 0.415 | 0xB6 | 1.60 | 0xF6 | 15.0 |
| 0x37 | 0.100 | 0x77 | 0.420 | 0xB7 | 1.65 | 0xF7 | 15.5 |
| 0x38 | 0.105 | 0x78 | 0.425 | 0xB8 | 1.70 | 0xF8 | 16.0 |
| 0x39 | 0.110 | 0x79 | 0.430 | 0xB9 | 1.75 | 0xF9 | 16.5 |
| 0x3A | 0.115 | 0x7A | 0.435 | 0xBA | 1.80 | 0xFA | 17.0 |
| 0x3B | 0.120 | 0x7B | 0.440 | 0xBB | 1.85 | 0xFB | 17.5 |
| 0x3C | 0.125 | 0x7C | 0.445 | 0xBC | 1.90 | 0xFC | 18.0 |
| 0x3D | 0.130 | 0x7D | 0.450 | 0xBD | 1.95 | 0xFD | 18.5 |
| 0x3E | 0.135 | 0x7E | 0.455 | 0xBE | 2.00 | 0xFE | 19.0 |
| 0x3F | 0.140 | 0x7F | 0.460 | 0xBF | 2.05 | 0xFF | 20.0 |

6.3.13.3 Motor Back-EMF constant

The back-EMF constant describes the motor phase-to-neutral back-EMF voltage as a function of the motor speed. For a wye-connected motor, the motor BEMF constant refers to the BEMF as a function of time from the phase output to the center tap, $K_{t_{PH_N}}$ (denoted as $K_{t_{PH_N}}$ in [図 6-40](#)). For a delta-connected motor, the motor BEMF constant refers to the equivalent phase to center tap in the wye configuration in [図 6-40](#).

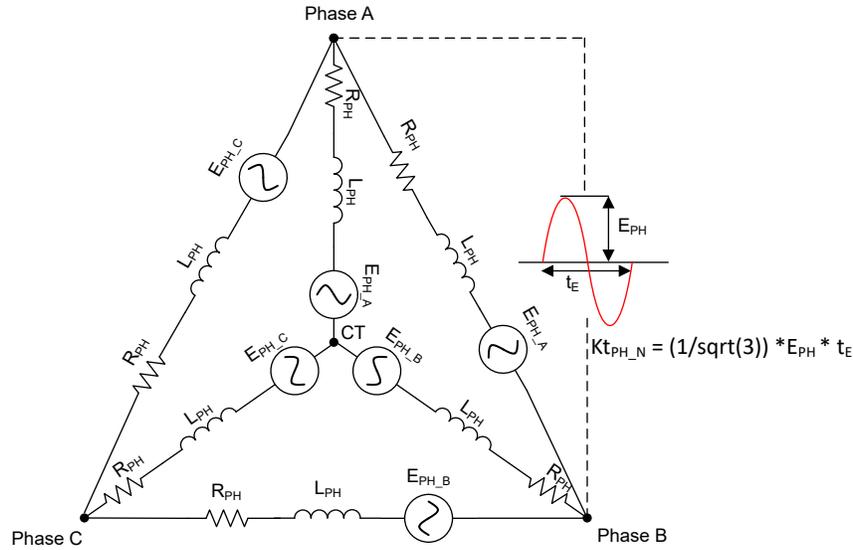


図 6-40. Motor back-EMF constant

For both the delta-connected motor and the wye-connected motor, the easy way to get the equivalent Kt_{PH_N} is to measure the peak value of BEMF on scope for one electrical cycle between two phase terminals (E_{PH}), and then multiply by time duration of one electrical cycle and in order to convert from phase-to-phase to phase-to-neutral divide by $\sqrt{3}$ as shown in 式 8 .

$$Kt_{PH_N} = \frac{1}{\sqrt{3}} \times E_{PH} \times t_E \quad (8)$$

Configure the motor BEMF constant (Kt_{PH_N}) to a nearest value from 表 6-4.

表 6-4. Motor BEMF constant Look-Up Table

| MOTOR_BEMF_CONST (HEX) | Kt_{PH_N} (mV/Hz) | MOTOR_BEMF_CONST (HEX) | Kt_{PH_N} (mV/Hz) | MOTOR_BEMF_CONST (HEX) | Kt_{PH_N} (mV/Hz) | MOTOR_BEMF_CONST (HEX) | Kt_{PH_N} (mV/Hz) |
|------------------------|---|------------------------|----------------------|------------------------|----------------------|------------------------|----------------------|
| 0x00 | Self Measurement (see Motor Parameter Extraction Tool (MPET)) | 0x40 | 14.5 | 0x80 | 46.5 | 0xC0 | 210 |
| 0x01 | 0.6 | 0x41 | 15.0 | 0x81 | 47.0 | 0xC1 | 220 |
| 0x02 | 0.7 | 0x42 | 15.5 | 0x82 | 47.5 | 0xC2 | 230 |
| 0x03 | 0.8 | 0x43 | 16.0 | 0x83 | 48.0 | 0xC3 | 240 |
| 0x04 | 0.9 | 0x44 | 16.5 | 0x84 | 48.5 | 0xC4 | 250 |
| 0x05 | 1.0 | 0x45 | 17.0 | 0x85 | 49.0 | 0xC5 | 260 |
| 0x06 | 1.1 | 0x46 | 17.5 | 0x86 | 49.5 | 0xC6 | 270 |
| 0x07 | 1.2 | 0x47 | 18.0 | 0x87 | 50.0 | 0xC7 | 280 |
| 0x08 | 1.3 | 0x48 | 18.5 | 0x88 | 51 | 0xC8 | 290 |
| 0x09 | 1.4 | 0x49 | 19.0 | 0x89 | 52 | 0xC9 | 300 |
| 0x0A | 1.5 | 0x4A | 19.5 | 0x8A | 53 | 0xCA | 320 |
| 0x0B | 1.6 | 0x4B | 20.0 | 0x8B | 54 | 0xCB | 340 |
| 0x0C | 1.7 | 0x4C | 20.5 | 0x8C | 55 | 0xCC | 360 |
| 0x0D | 1.8 | 0x4D | 21.0 | 0x8D | 56 | 0xCD | 380 |
| 0x0E | 1.9 | 0x4E | 21.5 | 0x8E | 57 | 0xCE | 400 |

表 6-4. Motor BEMF constant Look-Up Table (続き)

| MOTOR_BEMF_ CONST (HEX) | Kt _{PH_N} (mV/Hz) | MOTOR_BEMF_ CONST (HEX) | Kt _{PH_N} (mV/Hz) | MOTOR_BEMF_ CONST (HEX) | Kt _{PH_N} (mV/Hz) | MOTOR_BEM F_CONST (HEX) | Kt _{PH_N} (mV/Hz) |
|----------------------------|-------------------------------|----------------------------|-------------------------------|----------------------------|-------------------------------|-------------------------------|-------------------------------|
| 0x0F | 2.0 | 0x4F | 22.0 | 0x8F | 58 | 0xCF | 420 |
| 0x10 | 2.2 | 0x50 | 22.5 | 0x90 | 59 | 0xD0 | 440 |
| 0x11 | 2.4 | 0x51 | 23.0 | 0x91 | 60 | 0xD1 | 460 |
| 0x12 | 2.6 | 0x52 | 23.5 | 0x92 | 61 | 0xD2 | 480 |
| 0x13 | 2.8 | 0x53 | 24.0 | 0x93 | 62 | 0xD3 | 500 |
| 0x14 | 3.0 | 0x54 | 24.5 | 0x94 | 63 | 0xD4 | 520 |
| 0x15 | 3.2 | 0x55 | 25.0 | 0x95 | 64 | 0xD5 | 540 |
| 0x16 | 3.4 | 0x56 | 25.5 | 0x96 | 65 | 0xD6 | 560 |
| 0x17 | 3.6 | 0x57 | 26.0 | 0x97 | 66 | 0xD7 | 580 |
| 0x18 | 3.8 | 0x58 | 26.5 | 0x98 | 67 | 0xD8 | 600 |
| 0x19 | 4.0 | 0x59 | 27.0 | 0x99 | 68 | 0xD9 | 620 |
| 0x1A | 4.2 | 0x5A | 27.5 | 0x9A | 69 | 0xDA | 640 |
| 0x1B | 4.4 | 0x5B | 28.0 | 0x9B | 70 | 0xDB | 660 |
| 0x1C | 4.6 | 0x5C | 28.5 | 0x9C | 72 | 0xDC | 680 |
| 0x1D | 4.8 | 0x5D | 29.0 | 0x9D | 74 | 0xDD | 700 |
| 0x1E | 5.0 | 0x5E | 29.5 | 0x9E | 76 | 0xDE | 720 |
| 0x1F | 5.2 | 0x5F | 30.0 | 0x9F | 78 | 0xDF | 740 |
| 0x20 | 5.4 | 0x60 | 30.5 | 0xA0 | 80 | 0xE0 | 760 |
| 0x21 | 5.6 | 0x61 | 31.0 | 0xA1 | 82 | 0xE1 | 780 |
| 0x22 | 5.8 | 0x62 | 31.5 | 0xA2 | 84 | 0xE2 | 800 |
| 0x23 | 6.0 | 0x63 | 32.0 | 0xA3 | 86 | 0xE3 | 820 |
| 0x24 | 6.2 | 0x64 | 32.5 | 0xA4 | 88 | 0xE4 | 840 |
| 0x25 | 6.4 | 0x65 | 33.0 | 0xA5 | 90 | 0xE5 | 860 |
| 0x26 | 6.6 | 0x66 | 33.5 | 0xA6 | 92 | 0xE6 | 880 |
| 0x27 | 6.8 | 0x67 | 34.0 | 0xA7 | 94 | 0xE7 | 900 |
| 0x28 | 7.0 | 0x68 | 34.5 | 0xA8 | 96 | 0xE8 | 920 |
| 0x29 | 7.2 | 0x69 | 35.0 | 0xA9 | 98 | 0xE9 | 940 |
| 0x2A | 7.4 | 0x6A | 35.5 | 0xAA | 100 | 0xEA | 960 |
| 0x2B | 7.6 | 0x6B | 36.0 | 0xAB | 105 | 0xEB | 980 |
| 0x2C | 7.8 | 0x6C | 36.5 | 0xAC | 110 | 0xEC | 1000 |
| 0x2D | 8.0 | 0x6D | 37.0 | 0xAD | 115 | 0xED | 1050 |
| 0x2E | 8.2 | 0x6E | 37.5 | 0xAE | 120 | 0xEE | 1100 |
| 0x2F | 8.4 | 0x6F | 38.0 | 0xAF | 125 | 0xEF | 1150 |
| 0x30 | 8.6 | 0x70 | 38.5 | 0xB0 | 130 | 0xF0 | 1200 |
| 0x31 | 8.8 | 0x71 | 39.0 | 0xB1 | 135 | 0xF1 | 1250 |
| 0x32 | 9.0 | 0x72 | 39.5 | 0xB2 | 140 | 0xF2 | 1300 |
| 0x33 | 9.2 | 0x73 | 40.0 | 0xB3 | 145 | 0xF3 | 1350 |
| 0x34 | 9.4 | 0x74 | 40.5 | 0xB4 | 150 | 0xF4 | 1400 |
| 0x35 | 9.6 | 0x75 | 41.0 | 0xB5 | 155 | 0xF5 | 1450 |
| 0x36 | 9.8 | 0x76 | 41.5 | 0xB6 | 160 | 0xF6 | 1500 |
| 0x37 | 10.0 | 0x77 | 42.0 | 0xB7 | 165 | 0xF7 | 1550 |
| 0x38 | 10.5 | 0x78 | 42.5 | 0xB8 | 170 | 0xF8 | 1600 |
| 0x39 | 11.0 | 0x79 | 43.0 | 0xB9 | 175 | 0xF9 | 1650 |

表 6-4. Motor BEMF constant Look-Up Table (続き)

| MOTOR_BEMF_CONST (HEX) | Kt _{PH_N} (mV/Hz) |
|------------------------|----------------------------|------------------------|----------------------------|------------------------|----------------------------|------------------------|----------------------------|
| 0x3A | 11.5 | 0x7A | 43.5 | 0xBA | 180 | 0xFA | 1700 |
| 0x3B | 12.0 | 0x7B | 44.0 | 0xBB | 185 | 0xFB | 1750 |
| 0x3C | 12.5 | 0x7C | 44.5 | 0xBC | 190 | 0xFC | 1800 |
| 0x3D | 13.0 | 0x7D | 45.0 | 0xBD | 195 | 0xFD | 1850 |
| 0x3E | 13.5 | 0x7E | 45.5 | 0xBE | 200 | 0xFE | 1900 |
| 0x3F | 14.0 | 0x7F | 46.0 | 0xBF | 205 | 0xFF | 2000 |

6.3.14 Motor Parameter Extraction Tool (MPET)

The MCF8315C uses motor winding resistance, motor winding inductance and Back-EMF constant to estimate motor position in closed loop operation. The MCF8315C has capability of automatically measuring motor parameters in offline state, rather than having the user enter the values themselves. The MPET routine measures motor winding resistance, inductance, back EMF constant and mechanical load inertia and frictional coefficients. Offline measurement of parameters takes place before normal motor operation. TI recommends to estimate the motor parameters before motor start-up to minimize the impact caused due to possible parameter variations.

図 6-41 shows the sequence of operation in the MPET routine. The MPET routine is entered when either the MPET_CMD bit is set to 1b or a non-zero target speed is set. The MPET routine consists of four steps namely, IPD, Open Loop Acceleration, Current Ramp Down and Coasting. Each one of these steps are executed if the condition shown below the step evaluates to TRUE; if the condition evaluates to FALSE, the algorithm bypasses that particular step and moves on to the next step in the sequence. Once all the 4 steps are completed (or bypassed), the algorithm exits the MPET routine. If target speed is set to a non-zero value, the algorithm begins the start-up and acceleration sequence (to target speed reference) once MPET routine is exited.

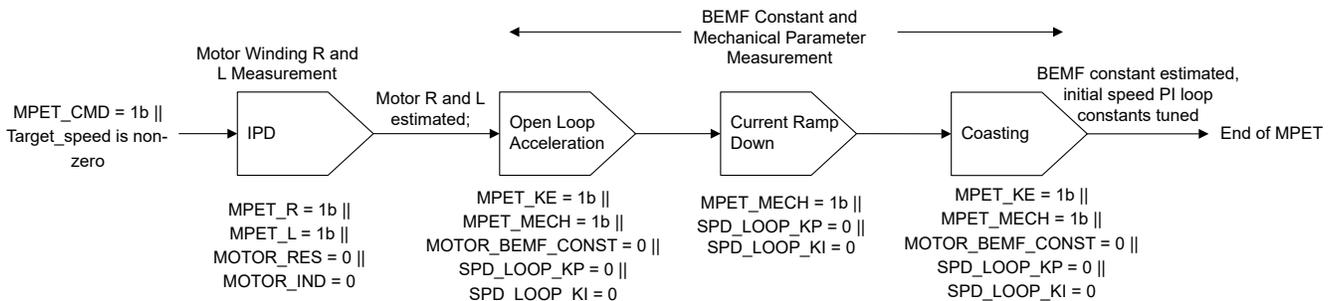


図 6-41. MPET Sequence

TI proprietary MPET routine includes following sequence of operation.

- **IPD:** The MPET routine starts with IPD, if the user enables motor winding resistance or inductance measurement by setting MPET_R = 1b and MPET_L = 1b or if the user defines MOTOR_RES = 0 or MOTOR_IND = 0. The IPD during MPET can be configured using MPET specific configuration parameters or using the normal motor operation IPD configuration parameters. The IPD configuration selection is done using MPET_IPD_SELECT. With MPET_IPD_SELECT = 1b, the IPD current limit is configured using MPET_IPD_CURRENT_LIMIT and the IPD repeat number is configured using MPET_IPD_FREQ. With MPET_IPD_SELECT = 0b, the IPD current limit and the repeat number is configured using IPD_CURR_THR and IPD_REPEAT. The IPD timer over flow or the IPD current decay time more than three times the current ramp up time can result in MPET_IPD_FAULT. TI recommends to run the MPET multiple times to observe for consistent resistance and inductance reading.
- **Open loop Acceleration:**

After IPD, the MPET routine run align and then open loop acceleration if the back-EMF constant or mechanical parameter measurement are enabled by setting MPET_KE = 1b and MPET_MECH = 1b. The MPET routine incorporates the sequences for mechanical parameter measurement, if the speed loop PI constants are defined as zero, even if MPET_MECH = 0b. User can configure MPET specific open loop configuration parameters or use normal motor operation open loop configuration parameters. The open loop configuration selection is done using MPET_KE_MEAS_PARAMETER_SELECT. With MPET_KE_MEAS_PARAMETER_SELECT = 1b, the speed slew rate is defined using MPET_OPEN_LOOP_SLEW_RATE, the open loop current reference is defined using MPET_OPEN_LOOP_CURR_REF and the open loop speed reference is defined using MPET_OPEN_LOOP_SPEED_REF. With MPET_KE_MEAS_PARAMETER_SELECT = 0b, the speed slew rate is defined using OL_ACC_A1 and OL_ACC_A2, 80% of I_LIMIT for current reference and 50% of MAX_SPEED for speed reference.

- **Current Ramp Down:** After open loop acceleration, if the mechanical parameter measurement is enabled, then the MPET routine optimizes the motor current to lower value sufficient to support the load. If mechanical parameter measurement is disabled (MPET_MECH = 0b, or non-zero speed loop PI parameters) then the MPET will not have the current ramp down sequence.
- **Coasting:** MPET routine completes the sequence by allowing the motor to coast by enabling Hi-Z. The motor back EMF and indicative values of mechanical parameters are measured during the motor coasting period. If the motor back EMF is lower than the threshold defined in STAT_DETECT_THR, the MPET_BEMF_FAULT is generated.

Selecting the parameters from EEPROM or MPET

The MPET estimated values are available in the MTR_PARAMS Register. Setting the MPET_WRITE_SHADOW bit to 1, writes the MPET estimated values to the shadow registers and the user-configured (from EEPROM) values in MOTOR_RES, MOTOR_IND, MOTOR_BEMF_CONST, CURR_LOOP_KP, CURR_LOOP_KI, SPD_LOOP_KP and SPD_LOOP_KI shadow registers will be overwritten by the estimated values from MPET. If any of the shadow registers are initialized to zero (from EEPROM registers), the MPET estimated values are used for those registers independent of the MPET_WRITE_SHADOW setting. The MPET calculates the current loop KP and KI by using the measured resistance and inductance. The MPET does an estimation of the mechanical parameters including the inertia and frictional coefficient at the shaft (includes both motor and shaft coupled load). These values are used to set an initial values speed loop KP and KI. The estimated speed loop KP and KI setting can be used as an initial setting only and TI recommends to tune these parameters on application by the user based on the performance requirement.

注

Set VDC_FILT_DIS to 1b before running MPET.

6.3.15 Anti-Voltage Surge (AVS)

When a motor is driven, energy is transferred from the power supply into the motor. Some of this energy is stored in the form of inductive and mechanical energy. If the speed command suddenly drops such that the BEMF voltage generated by the motor is greater than the voltage that is applied to the motor, then the mechanical energy of the motor is returned to the power supply and the V_M voltage surges. The AVS feature works to prevent this voltage surge on V_M and can be enabled by setting AVS_EN to 1b. AVS can be disabled by setting AVS_EN to 0b. When AVS is disabled, the deceleration rate is configured through CL_DEC_CONFIG

6.3.16 Active Braking

Decelerating the motor quickly requires the motor mechanical energy to be extracted from the rotor in a fast and controlled manner. However, the supply voltage (V_M) increases if the motor mechanical energy is returned to the power supply during the deceleration process. MCF8315C is capable of decelerating the motor quickly without pumping energy back into the supply voltage by using a novel technique called active braking. ACTIVE_BRAKE_EN should be set to 1b to enable active braking and prevent DC bus voltage (V_M) spike during fast motor deceleration. Active braking can also be used during reverse drive (see [セクション 6.3.10.3](#)) or motor stop (see [セクション 6.3.20.3](#)) to reduce the motor speed quickly without DC bus voltage (V_M) spike.

The maximum limit on the current sourced from the DC bus (i_{dc_ref}) during active braking can be configured using ACTIVE_BRAKE_CURRENT_LIMIT. The D-axis current reference (i_{d_ref}) is generated from the error between DC bus current limit (i_{dc_ref}) and the estimated DC bus current (i_{dc}) using a PI controller as shown in 6-42. The gain constants of PI controller can be configured using ACTIVE_BRAKE_KP and ACTIVE_BRAKE_KI. During active braking, the DC bus current limit (i_{dc_ref}) starts from zero and linearly increases to ACTIVE_BRAKE_CURRENT_LIMIT with current slew rate as defined by ACTIVE_BRAKE_BUS_CURRENT_SLEW_RATE.

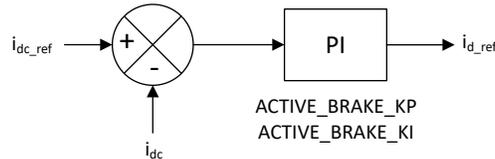


図 6-42. Active Braking Current Control Loop for i_{d_ref}

ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY sets the minimum difference between the initial and target speed above which active braking will be entered. For example, consider ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY is set to 10%; if the initial speed is 100% and target speed is set to 95%, MCF8315C uses AVS instead of active braking to reach 95% speed since the difference in commanded speed change (5%) is less than ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY (10%).

ACTIVE_BRAKE_SPEED_DELTA_LIMIT_EXIT sets the difference between the current and target speed below which active braking will be exited. For example, consider ACTIVE_BRAKE_SPEED_DELTA_LIMIT_EXIT is set to 5%; if the initial motor speed is 100% and target speed is set to 10%, MCF8315C uses active braking to reduce the motor speed to 15%; upon reaching 15% speed, MCF8315C exits active braking and uses AVS to decelerate the motor speed to 10%.

ACTIVE_BRAKE_MOD_INDEX_LIMIT sets the modulation index below which active braking will be used. For example, consider ACTIVE_BRAKE_MOD_INDEX_LIMIT is set to 50%, ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY is set to 5%, ACTIVE_BRAKE_SPEED_DELTA_LIMIT_EXIT is set to 2.5%. If the initial motor speed is at 70% (corresponding modulation index is 90%) and target speed is 40% (corresponding modulation index is 60%), MCF8315C uses AVS to decelerate the motor till target speed of 40% since the modulation index (60%) corresponding to final speed is higher than ACTIVE_BRAKE_MOD_INDEX_LIMIT of 50%. In the same case, if final speed command is 10% (corresponding modulation index is 30%), MCF8315C uses AVS till 30% speed (corresponding modulation index is 50%), switches to active braking from 30% to 15% speed (final speed of 10% + ACTIVE_BRAKE_SPEED_DELTA_LIMIT_EXIT of 5%) and uses AVS again from 15% to 10% speed to complete the active braking. TI recommends starting active braking tuning with ACTIVE_BRAKE_MOD_INDEX_LIMIT set to 100%; if there is a DC bus voltage (VM) spike observed during active braking, reduce ACTIVE_BRAKE_MOD_INDEX_LIMIT in steps so as to eliminate this voltage spike. If ACTIVE_BRAKE_MOD_INDEX_LIMIT is set to 0%, MCF8315C decelerates in AVS (even when ACTIVE_BRAKE_EN is set to 1b) in the forward direction; in reverse direction (during direction change), ACTIVE_BRAKE_MOD_INDEX_LIMIT is not applicable and therefore MCF8315C decelerates in active braking.

注

1. ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY, ACTIVE_BRAKE_SPEED_DELTA_LIMIT_EXIT and ACTIVE_BRAKE_MOD_INDEX_LIMIT are applicable only during deceleration in forward direction and not used during direction change.
2. ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY should be set higher than ACTIVE_BRAKE_SPEED_DELTA_LIMIT_EXIT for active braking operation.
3. During active (or closed loop) braking, I_{q_ref} is clamped to -ILIMIT. This (I_{q_ref} being clamped to -ILIMIT) may result in the speed PI loop getting saturated and SPEED_LOOP_SATURATION bit getting set to 1b during deceleration. This bit is automatically set to 0b once the deceleration is completed and the speed PI loop is out of saturation. Hence, speed loop saturation fault should be ignored during deceleration.
4. Active braking is not available in torque mode.

6.3.17 Output PWM Switching Frequency

The MCF8315C provides the option to configure the output PWM switching frequency of the MOSFETs through PWM_FREQ_OUT. PWM_FREQ_OUT has configurable range of 15-60 kHz. In order to select optimal output PWM switching frequency, user has to make tradeoff between the current ripple and the switching losses. Generally, motors having lower L/R ratio require higher PWM switching frequency to reduce current ripple.

6.3.18 PWM Modulation Schemes

The MCF8315C supports two different modulation schemes, namely, continuous and discontinuous space vector PWM modulation schemes. In continuous PWM modulation, all the three phases switch all the time as per the defined switching frequency. In discontinuous PWM modulation, one of the phases is clamped to ground for 120° electrical period, and the other two phases are pulse width modulated. The modulation scheme is configured using PWM_MODE. [図 6-43](#) shows the modulated average phase voltages for different modulation schemes.

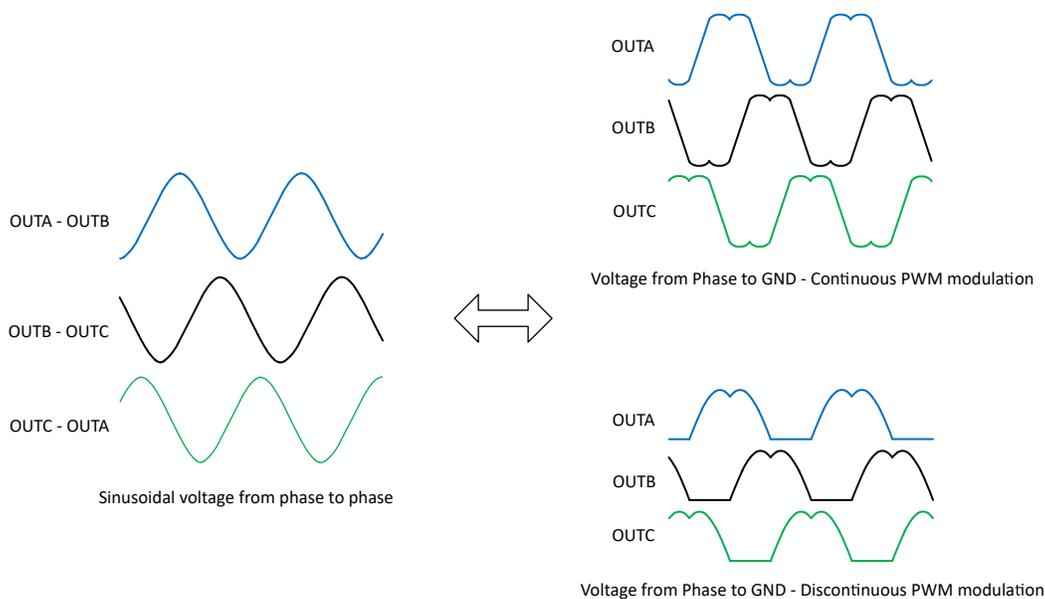


図 6-43. Continuous and Discontinuous PWM Modulation Phase Voltages

Continuous modulation helps in reducing current ripple for motors having low inductance but it results in higher switching losses because all three phases are switching. Discontinuous modulation has lower switching losses due to only two phases switching at a time, but higher current ripple.

6.3.19 Dead Time Compensation

Dead time is inserted between the switching instants of high-side and low-side MOSFETs in a half-bridge leg to avoid shoot-through condition. Due to dead time insertion, the expected voltage and applied voltage at the phase node differ based on the phase current direction. The phase node voltage distortion introduces undesired distortion in the phase current causing audible noise. MCF8315C integrates a proprietary dead time compensation technique to remove this phase current distortion and greatly reduce the audible noise, thereby significantly improving the acoustic performance of the FOC in MCF8315C. This dead time compensation can be enabled or disabled by configuring DEADTIME_COMP_EN. Even when DEADTIME_COMP_EN is set to 1b (compensation enabled), dead time compensation is disabled when motor electrical frequency exceeds 135-Hz and re-enabled when motor electrical frequency drops below 127-Hz.

6.3.20 Motor Stop Options

The MCF8315C provides different options for stopping the motor which can be configured by MTR_STOP.

6.3.20.1 Coast (Hi-Z) Mode

Coast (Hi-Z) mode is configured by setting MTR_STOP to 000b. When motor stop command is received, the MCF8315C will transition into a high impedance (Hi-Z) state by turning off all MOSFETs. When the MCF8315C transitions from driving the motor into a Hi-Z state, the inductive current in the motor windings continues to flow and the energy returns to the power supply through the body diodes in the MOSFET output stage (see example [Figure 6-44](#)).

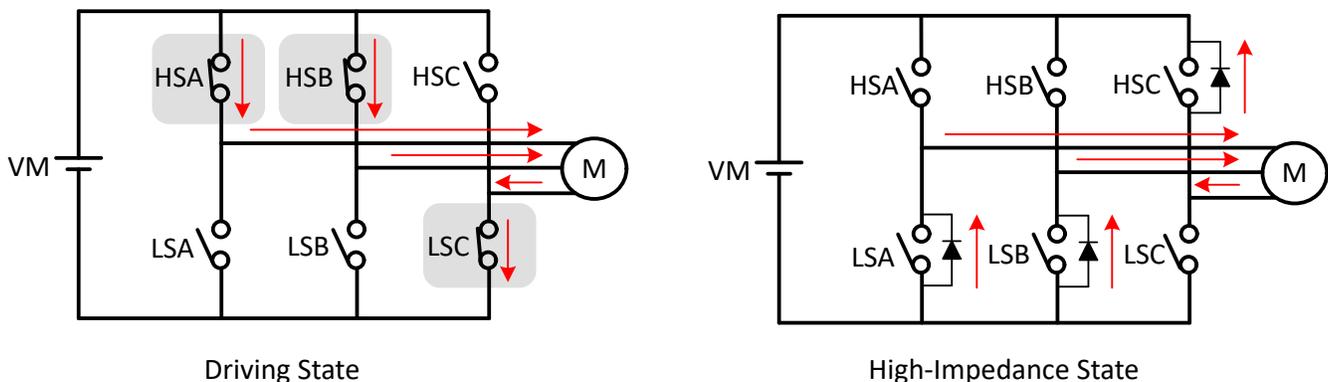


Figure 6-44. Coast (Hi-Z) Mode

In this example, current is applied to the motor through the high-side phase-A MOSFET (HSA), high-side phase-B MOSFET (HSB) and returned through the low-side phase-C MOSFET (LSC). When motor stop command is received all 6 MOSFETs transition to Hi-Z state and the inductive energy returns to supply through body diodes of MOSFETs LSA, LSB and HSC.

6.3.20.2 Low-Side Braking

注

Low-side braking is to be used as stop option only when MCF8315C is configured as a standby device.

Low-side braking mode is configured by setting MTR_STOP to 010b. When a motor stop command is received, the output speed is reduced to a value defined by BRAKE_SPEED_THRESHOLD prior to turning all low-side MOSFETs ON (see example [Figure 6-45](#)) for a time configured by MTR_STOP_BRK_TIME. If the motor speed is below BRAKE_SPEED_THRESHOLD prior to receiving stop command, then the MCF8315C transitions directly into the brake state. After applying the brake for MTR_STOP_BRK_TIME, the MCF8315C transitions into the Hi-Z state by turning OFF all MOSFETs.

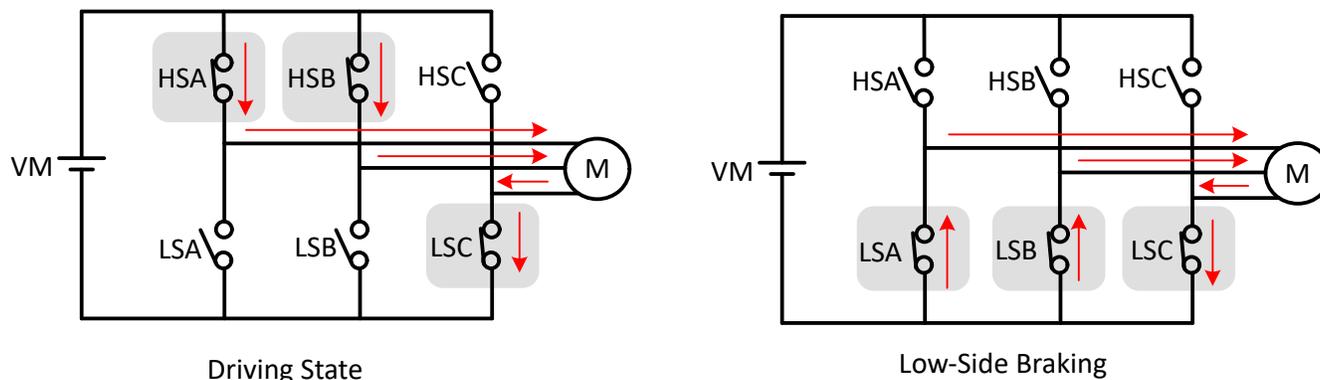


图 6-45. Low-Side Braking

The MCF8315C can also enter low-side braking through BRAKE pin input. When BRAKE pin is pulled to HIGH state, the output speed is reduced to a value defined by BRAKE_SPEED_THRESHOLD prior to turning all low-side MOSFETs ON. In this case, MCF8315C stays in low-side brake state till BRAKE pin changes to LOW state.

6.3.20.3 Active Spin-Down

Active spin down mode is configured by setting MTR_STOP to 100b. When a motor stop command is received, the output speed is reduced to a value defined by ACT_SPIN_THR and then MCF8315C transitions to Hi-Z state by turning all MOSFETs OFF. The advantage of this mode is that by reducing motor speed, the phase currents are reduced before entering Hi-Z. Now, when the motor transitions into Hi-Z state, the energy transfer to the power supply is reduced. The threshold ACT_SPIN_THR needs to be configured high enough for MCF8315C to not lose synchronization with the motor.

6.3.21 FG Configuration

The MCF8315C provides information about the motor speed through the Frequency Generate (FG) pin. In MCF8315C, the FG pin output is configured through FG_CONFIG. When FG_CONFIG is configured to 0b, the FG output is active as long as the MCF8315C is driving the motor. When FG_CONFIG is configured to 1b, the MCF8315C provides an FG output until the motor back-EMF falls below FG_BEMF_THR.

6.3.21.1 FG Output Frequency

The FG output frequency can be configured by FG_DIV. Many applications require the FG output to provide a pulse for every mechanical rotation of the motor. Different FG_DIV configurations can accomplish this for 2-pole up to 30-pole motors.

图 6-46 shows the FG output when MCF8315C has been configured to provide FG pulses once every electrical cycle (2 poles), once every two electrical cycle (4 poles), once every three electrical cycles (6 poles), once every four electrical cycles (8 poles), and so on.

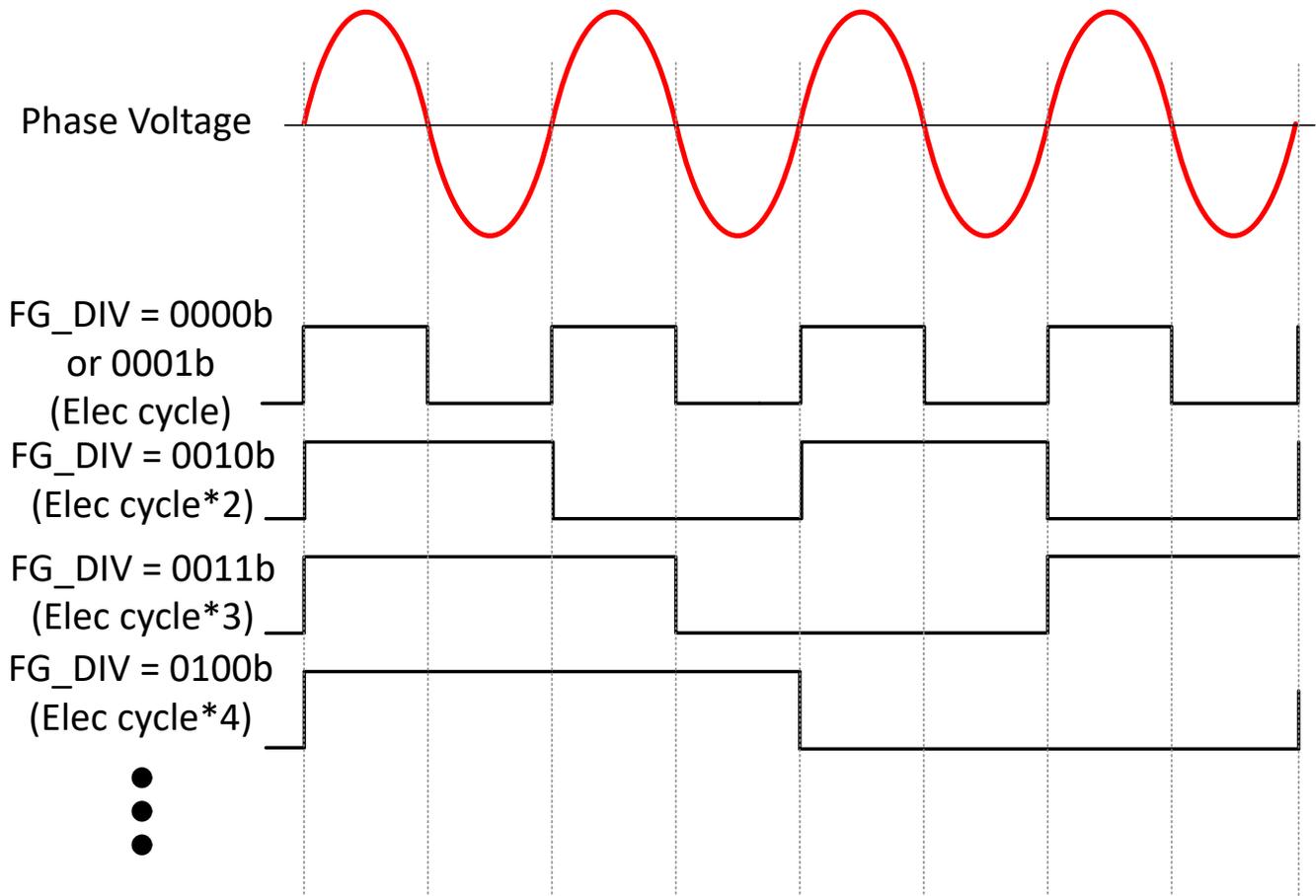


図 6-46. FG Frequency Divider

6.3.21.2 FG during open loop

During closed loop operation, the driving speed (FG output frequency) and the actual motor speed are synchronized. During open-loop operation, however, FG may not reflect the actual motor speed.

The MCF8315C provides three options for controlling the FG output during open loop, as shown in 図 6-47. The selection of these options is configured through FG_SEL.

If FG_SEL is set to,

- 00b: When in open loop, the FG output is based on the driving frequency.
- 01b: When in open loop, the FG output will be driven high.
- 10b: The FG output will reflect the driving frequency during open loop operation in the first motor start-up cycle after power-on, sleep/standby; FG will be held high during open loop operation in subsequent start-up cycles.

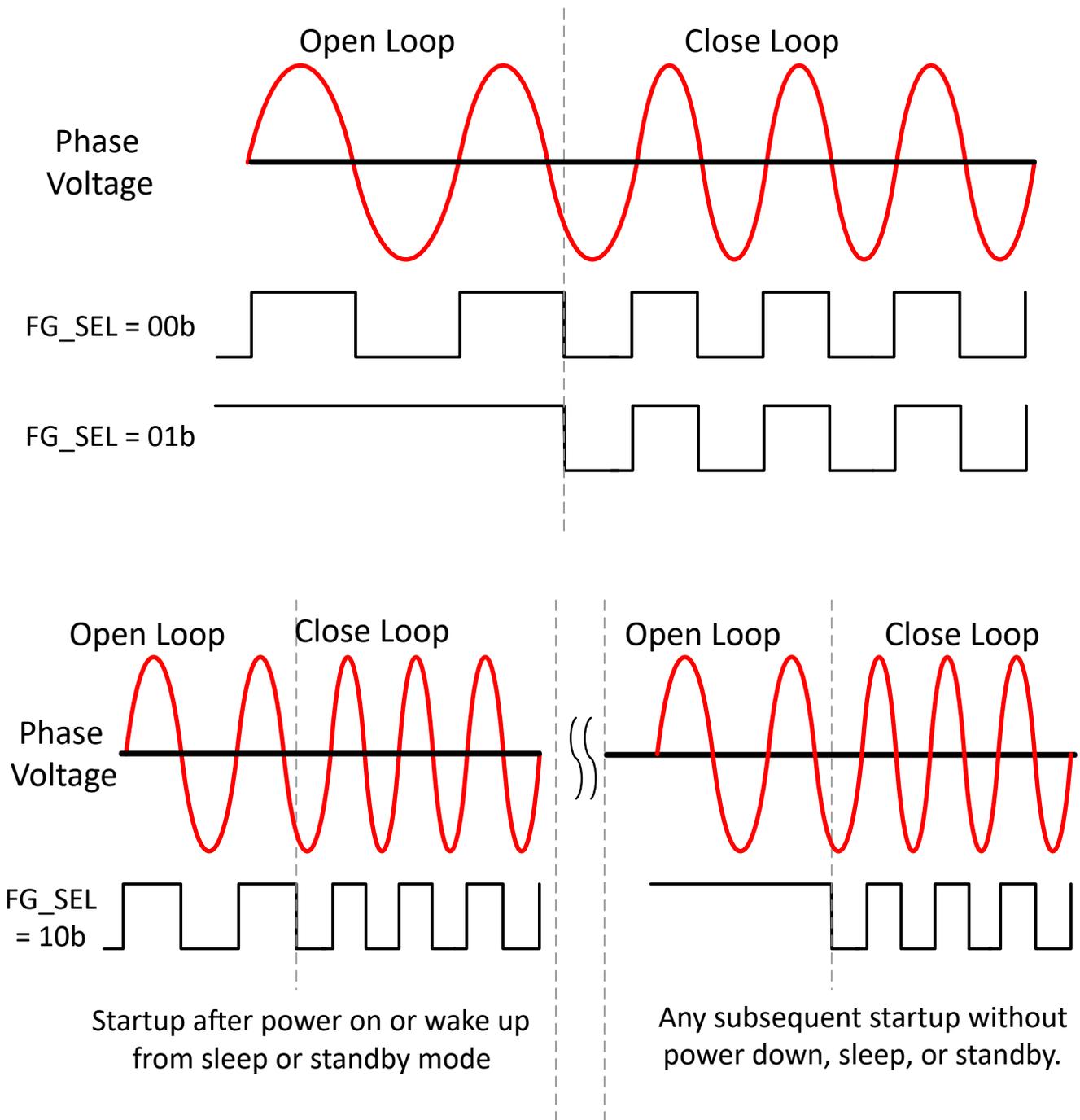


図 6-47. FG Behavior During Open Loop

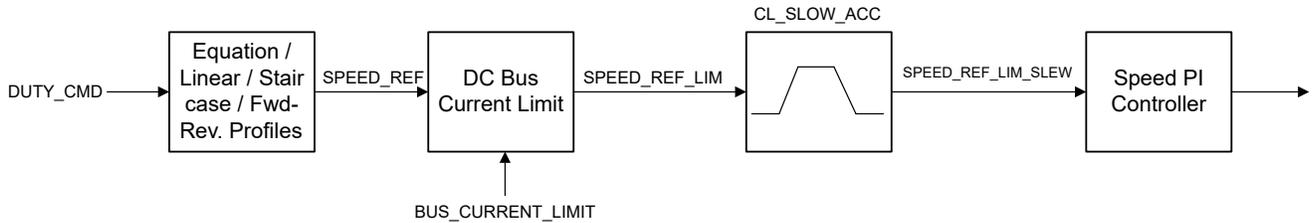
6.3.21.3 FG during idle and fault

FG output during fault condition can be configured using FG_FAULT_CONFIG. FG output during motor idle (stopped) state can be configured using FG_IDLE_CONFIG. These two configurations can be used to identify the motor idle and fault states while FG frequency (during open and closed loop) can be used to estimate the motor speed.

6.3.22 DC Bus Current Limit

The DC bus current limit feature can be used to limit the current supplied by the DC input source (VM). This feature can be enabled by setting `BUS_CURRENT_LIMIT_ENABLE` to 1b. The DC bus current limit can be configured using `BUS_CURRENT_LIMIT`. This feature limits the DC bus current by limiting the speed (`SPEED_REF_LIM`)/current (`CURRENT_REF_LIM`) reference as shown in 図 6-48. Enabling this feature may restrict the speed/phase current of the motor from reaching the set point (`SPEED_REF` or `CURRENT_REF`) in order to limit the DC bus current. The DC bus current limit status is reported on `BUS_CURRENT_LIMIT_STATUS`.

Speed Control Mode



Current Control Mode

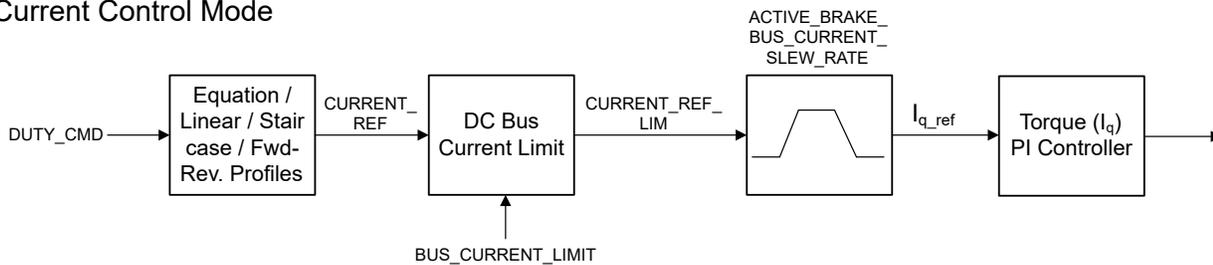


図 6-48. DC Bus Current Limit

注

1. DC bus current limit feature is not available when active braking is enabled.
2. MCF8315C implements a 5% hysteresis around `BUS_CURRENT_LIMIT` to avoid chattering around this set-point.

6.3.23 Protections

The MCF8315C is protected from a host of fault events including motor lock, VM undervoltage, AVDD undervoltage, buck undervoltage, charge pump undervoltage, overtemperature and overcurrent events. 表 6-5 summarizes the response, recovery modes, power stage status, reporting mechanism for different faults.

注

1. Actionable faults (latched or retry) are always reported on nFAULT pin (as logic low).
2. Actionable faults (latched or retry) are reported on ALARM pin (as logic high) when ALARM_PIN_EN is set to 1b.
3. Report only faults are reported on nFAULT (as logic low) only when ALARM_PIN_EN is set to 0b. When ALARM_PIN_EN is set to 1b, report only faults are reported only on ALARM pin (as logic high) while nFAULT stays high (via pull-up).
4. Priority order for multi-fault scenarios is latched > slower retry time fault > faster retry time fault > report only fault. For example, if a latched and retry fault happen simultaneously, the device stays latched in fault mode until user issues clear fault command by writing 1b to CLR_FLT. If two retry faults with different retry times happen simultaneously, the device retries only after the longer (slower) retry time lapses.
5. Recovery refers only to state of FETs (Hi-Z or active) after the fault condition is removed. Automatic indicates that the device automatically recovers (and FETs are active) when retry time lapses after the fault condition is removed. Latched indicates that the device waits for clearing of fault condition (by writing 1b to CLR_FLT bit) to make the FETs active again.
6. Actionable (latched or retry) faults can take up to 200-ms after fault response (FETs in Hi-Z) to be reported on nFAULT pin (as logic low), ALARM pin (as logic high) and fault status registers.
7. Latched faults can take up to 200-ms after CLR_FLT command is issued (over I²C) to be cleared.

表 6-5. Fault Action and Response

| FAULT | CONDITION | CONFIGURATION | REPORT | FETs | DIGITAL | RECOVERY |
|--|-------------------------------------|----------------|--|-------------|-----------------|--|
| VM undervoltage | $V_{VM} < V_{UVLO}$ (falling) | — | — | Hi-Z | Disabled | Automatic: $V_{VM} > V_{UVLO}$ (rising) |
| AVDD undervoltage | $V_{AVDD} < V_{AVDD_UV}$ (falling) | — | — | Hi-Z | Disabled | Automatic: $V_{AVDD} > V_{AVDD_UV}$ (rising) |
| Buck undervoltage (BUCK_UV) | $V_{FB_BK} < V_{BK_UV}$ (falling) | — | — | Active/Hi-Z | Active/Disabled | Automatic: $V_{FB_BK} > V_{BK_UV}$ (rising) |
| Charge pump undervoltage (VCP_UV) | $V_{CP} < V_{CPLV}$ (falling) | — | nFAULT and GATE_DRIVER_FAULT_STATUS register | Hi-Z | Active | Automatic: $V_{VCP} > V_{CPLV}$ (rising) |
| Over Voltage Protection (OVP) | $V_{VM} > V_{OVP}$ (rising) | OVP_EN = 0b | None | Active | Active | No action |
| | | OVP_EN = 1b | nFAULT and GATE_DRIVER_FAULT_STATUS register | Hi-Z | Active | Automatic: $V_{VM} < V_{OVP}$ (falling) |
| Over Current Protection (OCP) | $I_{PHASE} > I_{OCP}$ | OCP_MODE = 00b | nFAULT and GATE_DRIVER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| | | OCP_MODE = 01b | nFAULT and GATE_DRIVER_FAULT_STATUS register | Hi-Z | Active | Retry: t_{RETRY} |
| Buck Overcurrent Protection (BUCK_OCP) | $I_{BK} > I_{BK_OCP}$ | — | — | Hi-Z | Disabled | Automatic |

表 6-5. Fault Action and Response (続き)

| FAULT | CONDITION | CONFIGURATION | REPORT | FETs | DIGITAL | RECOVERY |
|--|--|--------------------------------------|---|-----------------|---------|-------------------------------|
| Motor Lock (MTR_LCK) | Motor lock: Abnormal Speed; No Motor Lock; Abnormal BEMF | MTR_LCK_MODE = 0000b or 0001b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| | | MTR_LCK_MODE = 0010b | nFAULT and CONTROLLER_FAULT_STATUS register | High side brake | Active | Latched: CLR_FLT |
| | | MTR_LCK_MODE = 0011b | nFAULT and CONTROLLER_FAULT_STATUS register | Low side brake | Active | Latched: CLR_FLT |
| | | MTR_LCK_MODE = 0100b or 0101b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Retry: t _{LCK_RETRY} |
| | | MTR_LCK_MODE = 0110b | nFAULT and CONTROLLER_FAULT_STATUS register | High side brake | Active | Retry: t _{LCK_RETRY} |
| | | MTR_LCK_MODE = 0111b | nFAULT and CONTROLLER_FAULT_STATUS register | Low side brake | Active | Retry: t _{LCK_RETRY} |
| | | MTR_LCK_MODE = 1000b | nFAULT and CONTROLLER_FAULT_STATUS register | Active | Active | No action |
| | | MTR_LCK_MODE = 1xx1b | None | Active | Active | No action |
| Hardware Lock-Detection Current Limit (HW_LOCK_LIMIT) | V _{sox} > HW_LOCK_ILIMIT | HW_LOCK_ILIMIT_MODE = 0000b or 0001b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| | | HW_LOCK_ILIMIT_MODE = 0010b | nFAULT and CONTROLLER_FAULT_STATUS register | High-side brake | Active | Latched: CLR_FLT |
| | | HW_LOCK_ILIMIT_MODE = 0011b | nFAULT and CONTROLLER_FAULT_STATUS register | Low-side brake | Active | Latched: CLR_FLT |
| | | HW_LOCK_ILIMIT_MODE = 0100b or 0101b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Retry: t _{LCK_RETRY} |
| | | HW_LOCK_ILIMIT_MODE = 0110b | nFAULT and CONTROLLER_FAULT_STATUS register | High-side brake | Active | Retry: t _{LCK_RETRY} |
| | | HW_LOCK_ILIMIT_MODE = 0111b | nFAULT and CONTROLLER_FAULT_STATUS register | Low-side brake | Active | Retry: t _{LCK_RETRY} |
| | | HW_LOCK_ILIMIT_MODE = 1000b | nFAULT and CONTROLLER_FAULT_STATUS register | Active | Active | No action |
| | | HW_LOCK_ILIMIT_MODE = 1xx1b | None | Active | Active | No action |

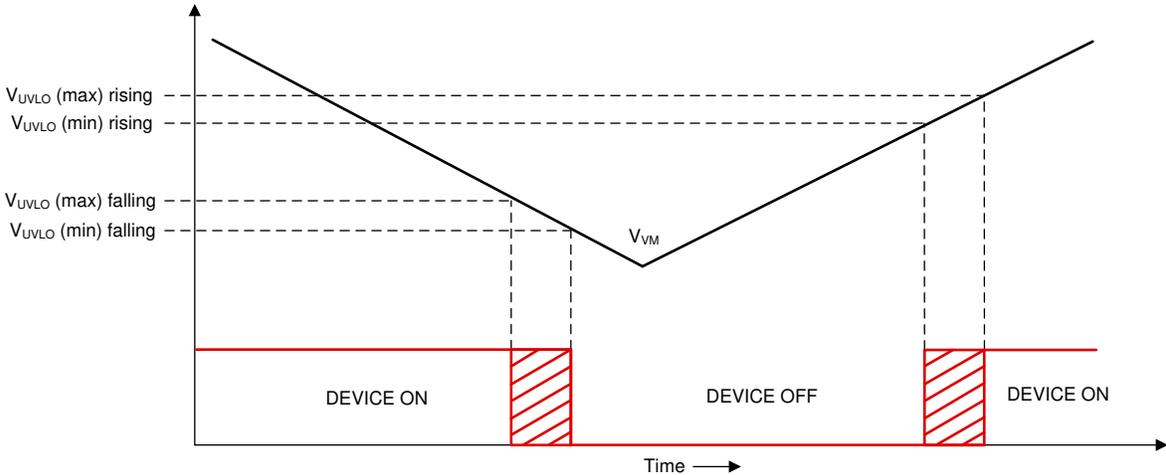
表 6-5. Fault Action and Response (続き)

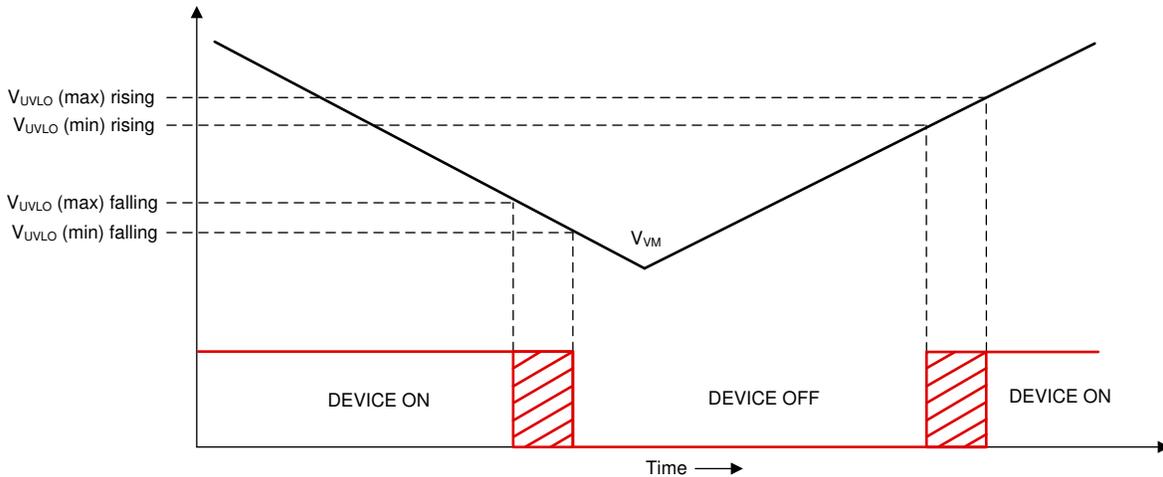
| FAULT | CONDITION | CONFIGURATION | REPORT | FETs | DIGITAL | RECOVERY |
|--|---|-----------------------------------|---|-----------------|---------|--|
| Software Lock-Detection Current Limit (LOCK_LIMIT) | $V_{SOX} > LOCK_LIMIT$ | LOCK_ILIMIT_MODE = 0000b or 0001b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| | | LOCK_ILIMIT_MODE = 0010b | nFAULT and CONTROLLER_FAULT_STATUS register | High-side brake | Active | Latched: CLR_FLT |
| | | LOCK_ILIMIT_MODE = 0011b | nFAULT and CONTROLLER_FAULT_STATUS register | Low-side brake | Active | Latched: CLR_FLT |
| | | LOCK_ILIMIT_MODE = 0100b or 0101b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Retry: t_{LCK_RETRY} |
| | | LOCK_ILIMIT_MODE = 0110b | nFAULT and CONTROLLER_FAULT_STATUS register | High-side brake | Active | Retry: t_{LCK_RETRY} |
| | | LOCK_ILIMIT_MODE = 0111b | nFAULT and CONTROLLER_FAULT_STATUS register | Low-side brake | Active | Retry: t_{LCK_RETRY} |
| | | LOCK_ILIMIT_MODE = 1000b | nFAULT and CONTROLLER_FAULT_STATUS register | Active | Active | No action |
| | | LOCK_ILIMIT_MODE = 1xx1b | None | Active | Active | No action |
| IPD Timeout Fault (IPD_T1_FAULT and IPD_T2_FAULT) | IPD TIME > 500ms (approx.), during IPD current ramp up or ramp down | IPD_TIMEOUT_FAULT_EN = 0b | — | Active | Active | No action |
| | | IPD_TIMEOUT_FAULT_EN = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Retry: t_{LCK_RETRY} |
| IPD Frequency Fault (IPD_FREQ_FAULT) | IPD pulse before the current decay in previous IPD pulse | IPD_FREQ_FAULT_EN = 0b | — | Active | Active | No action |
| | | IPD_FREQ_FAULT_EN = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Retry: t_{LCK_RETRY} |
| MPET IPD Fault (MPET_IPD_FAULT) | Same as IPD timeout fault during MPET R, L measurement | — | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| MPET Back-EMF Fault (MPET_BEMF_FAULT) | Motor back-EMF < STAT_DETECT_THR during MPET Ke and mechanical parameters measurement | — | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| Maximum VM (overvoltage) fault | $V_{VM} > MAX_VM_MOTOR$, if MAX_VM_MOTOR ≠ 000b | MAX_VM_MODE = 0b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| | | MAX_VM_MODE = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Automatic: $(V_{VM} < MAX_VM_MOTOR - 1)-V$ |
| Minimum VM (undervoltage) fault | $V_{VM} < MIN_VM_MOTOR$, if MIN_VM_MOTOR ≠ 000b | MIN_VM_MODE = 0b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |
| | | MIN_VM_MODE = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Automatic: $(V_{VM} > MIN_VM_MOTOR + 0.5)-V$ |
| External Watchdog | Watchdog tickle does not arrive before configured time interval when EXT_WDT_EN = 1b. Refer セクション 6.5.4 | EXT_WDT_FAULT_MODE = 0b | nFAULT and CONTROLLER_FAULT_STATUS register | Active | Active | No action |
| | | EXT_WDT_FAULT_MODE = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Hi-Z | Active | Latched: CLR_FLT |

表 6-5. Fault Action and Response (続き)

| FAULT | CONDITION | CONFIGURATION | REPORT | FETs | DIGITAL | RECOVERY |
|--------------------------------|--|-------------------------------|--|--|---------|--|
| Bus Current Limit | $I_{VM} > \text{BUS_CURRENT_LIMIT}$. Refer セクション 6.3.22 | BUS_CURRENT_LIMIT_ENABLE = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Active; motor speed/current will be restricted to limit DC bus current | Active | Automatic: Speed restriction is removed when $I_{VM} < \text{BUS_CURRENT_LIMIT}$ |
| Current Loop Saturation | Indication of current loop saturation due to lower V_{VM} | SATURATION_FLAGS_EN = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Active; motor speed may not reach speed reference | Active | Automatic: motor will reach reference operating point upon exiting saturation |
| Speed Loop Saturation | Indication of speed loop saturation due to lower V_{VM} , lower ILIMIT setting etc., | SATURATION_FLAGS_EN = 1b | nFAULT and CONTROLLER_FAULT_STATUS register | Active; motor speed may not reach speed reference | Active | Automatic: motor will reach reference operating point upon exiting saturation |
| Thermal warning (OTW) | $T_J > T_{OTW}$ | OTW_REP = 0b | — | Active | Active | No action |
| | | OTW_REP = 1b | nFAULT and GATE_DRIVER_FAULT_STATUS register | Active | Active | No action |
| FET thermal shutdown (TSD_FET) | $T_J > T_{TSD_FET}$ | — | nFAULT and GATE_DRIVER_FAULT_STATUS register | Hi-Z | Active | Automatic: $T_J < T_{TSD_FET} - T_{TSD_FET_HYS}$ |

6.3.23.1 VM Supply Undervoltage Lockout

If at any time the input supply voltage on the VM pin falls lower than the V_{UVLO} threshold (VM UVLO falling threshold), all the integrated FETs, driver charge-pump and digital logic are disabled as shown in  6-49. MCF8315C goes into reset state whenever VM UVLO event occurs.



 6-49. VM Supply Undervoltage Lockout

6.3.23.2 AVDD Undervoltage Lockout (AVDD_UV)

If at any time the voltage on the AVDD pin falls lower than the V_{AVDD_UV} threshold, all the integrated FETs, driver charge-pump and digital logic controller are disabled. Since internal circuitry in MCF8315C is powered through the AVDD regulator, MCF8315C goes into reset state whenever AVDD UV event occurs.

6.3.23.3 BUCK Under Voltage Lockout (BUCK_UV)

If at any time the voltage on the FB_BK pin falls lower than the V_{BK_UVLO} threshold, a buck UV fault is recognized - MCF8315C continues to attempt regulating the FB_BK voltage to set value. Since internal circuitry in MCF8315C is powered through the buck regulator, MCF8315C may go into reset state if FB_BK voltage drops low enough to trigger UV on the internal circuits.

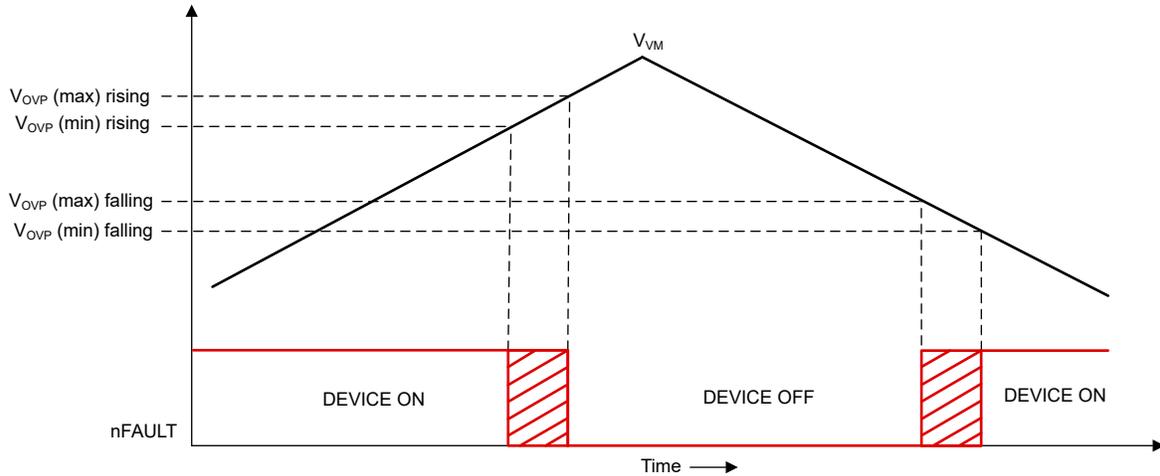
6.3.23.4 VCP Charge Pump Undervoltage Lockout (CPUV)

If at any time the voltage on the VCP pin (charge pump) falls lower than the V_{CPUV} threshold, all the integrated FETs are disabled and the nFAULT pin is driven low. The DRIVER_FAULT and VCP_UV bits are set to 1b in the status registers. Normal operation resumes (driver operation and the nFAULT pin is released) when the VCP undervoltage condition clears. The VCP_UV bit stays set until cleared through the CLR_FLT bit.

6.3.23.5 Overvoltage Protection (OVP)

If at any time input supply voltage on the VM pins rises higher than V_{OVP} , all the integrated FETs are disabled and the nFAULT pin is driven low. The DRIVER_FAULT and OVP bits are set to 1b in the status registers. Normal operation resumes (driver operation and the nFAULT pin is released) when the OVP condition clears. The OVP bit stays set until cleared through the CLR_FLT bit. Setting the OVP_EN to 0b disables this protection feature.

The OVP threshold can be set to 22-V or 34-V based on the OVP_SEL bit.



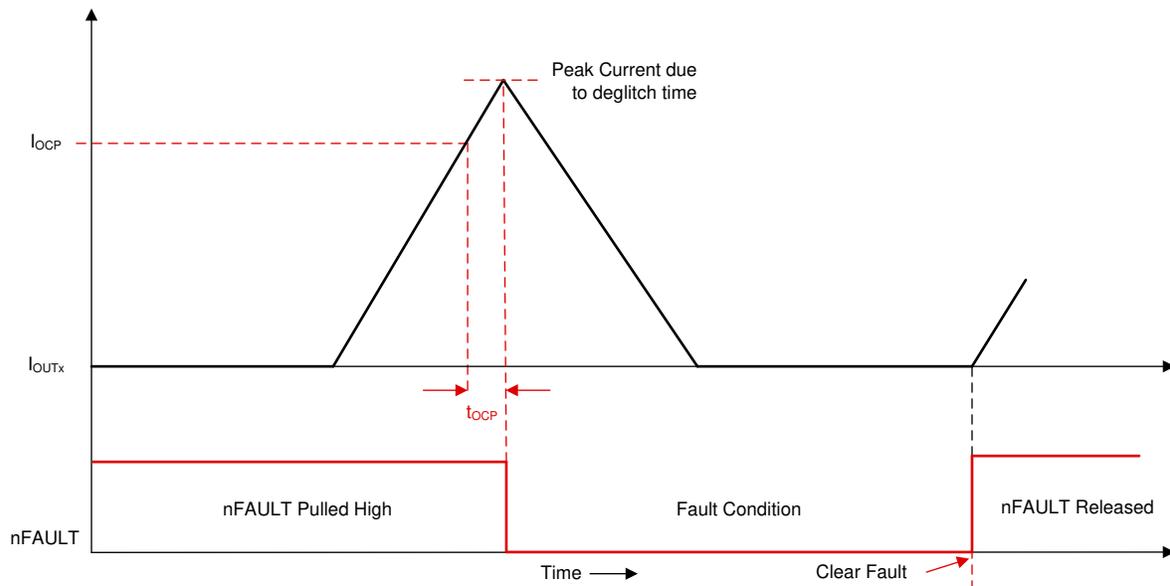
6-50. Over Voltage Protection

6.3.23.6 Overcurrent Protection (OCP)

MOSFET overcurrent event is sensed by monitoring the current flowing through the FETs. If the current across a FET exceeds the I_{OCP} threshold for longer than the deglitch time t_{OCP} , an OCP event is recognized and action is taken according to OCP_MODE. The I_{OCP} threshold is set through the OCP_LVL, t_{OCP} is set through OCP_DEG and the OCP_MODE can be configured in four different modes: latched shutdown, automatic retry, report only and disabled.

6.3.23.6.1 OCP Latched Shutdown (OCP_MODE = 00b)

When an OCP event happens in this mode, all MOSFETs are disabled and the nFAULT pin is driven low. The DRIVER_FAULT, OCP and corresponding FET's OCP bits are set to 1b in the status registers. Normal operation resumes (driver operation and the nFAULT pin is released) when the OCP condition clears and a clear fault command is issued through the CLR_FLT bit.



6-51. Overcurrent Protection - Latched Shutdown Mode

6.3.23.6.2 OCP Automatic Retry (OCP_MODE = 01b)

When an OCP event happens in this mode, all the FETs are disabled and the nFAULT pin is driven low. The DRIVER_FAULT, OCP and corresponding FET's OCP bits are set to 1b in the fault status registers. Normal operation resumes automatically (gate driver operation and the nFAULT pin is released) after the t_{RETRY} (T_RETRY) time elapses. The DRIVER_FAULT bit is reset to 0b after the t_{RETRY} period expires. The OCP and corresponding FET's OCP bits are set to 1b until cleared through the CLR_FLT bit.

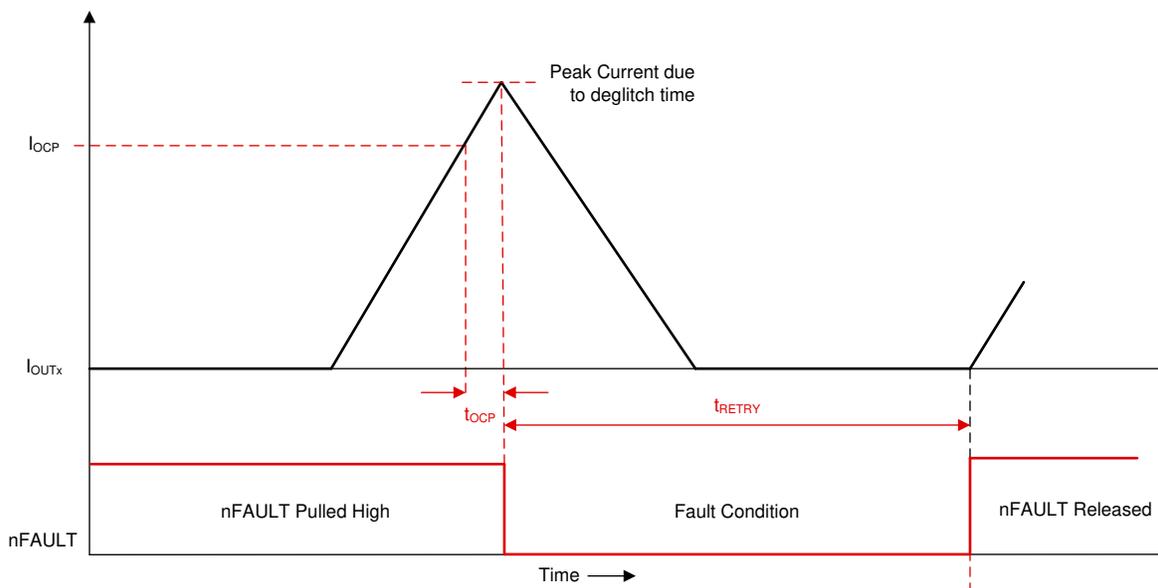


図 6-52. Overcurrent Protection - Automatic Retry Mode

6.3.23.7 Buck Overcurrent Protection

The buck overcurrent event is sensed by monitoring the current flowing through high-side MOSFET of the buck regulator. If the current through the high-side MOSFET exceeds the I_{BK_OCP} threshold for a time longer than the deglitch time, a buck OCP event is recognized and the buck regulator MOSFETs are disabled (Hi-Z). MCF8315C goes into reset state whenever buck OCP event occurs, since the internal circuitry in MCF8315C is powered from the buck regulator output.

6.3.23.8 Hardware Lock Detection Current Limit (HW_LOCK_ILIMIT)

The hardware lock detection current limit function provides a configurable threshold for limiting the current to prevent damage to the system. The output of current sense amplifier is connected to hardware comparator. If at any time, the voltage on the output of CSA exceeds HW_LOCK_ILIMIT threshold for a time longer than $t_{HW_LOCK_ILIMIT}$, a HW_LOCK_ILIMIT event is recognized and action is taken according to the HW_LOCK_ILIMIT_MODE. The threshold is set through HW_LOCK_ILIMIT, the $t_{HW_LCK_ILIMIT}$ is set through the HW_LOCK_ILIMIT_DEG. HW_LOCK_ILIMIT_MODE bit can operate in four different modes: HW_LOCK_ILIMIT latched shutdown, HW_LOCK_ILIMIT automatic retry, HW_LOCK_ILIMIT report only, and HW_LOCK_ILIMIT disabled.

6.3.23.8.1 HW_LOCK_ILIMIT Latched Shutdown (HW_LOCK_ILIMIT_MODE = 00xxb)

When a HW_LOCK_ILIMIT event happens in this mode, the status of MOSFET will be configured by HW_LOCK_ILIMIT_MODE and nFAULT is driven low. Status of MOSFETs during HW_LOCK_ILIMIT:

- HW_LOCK_ILIMIT_MODE = 0000b or 0001b: All MOSFETs are turned OFF.
- HW_LOCK_ILIMIT_MODE = 0010b: All-high side MOSFETs are turned ON.
- HW_LOCK_ILIMIT_MODE = 0011b: All-low side MOSFETs are turned ON.

The CONTROLLER_FAULT and HW_LOCK_ILIMIT bits are set to 1b in the fault status registers. Normal operation resumes (gate driver operation and the nFAULT pin is released) when the HW_LOCK_ILIMIT condition clears and a clear fault command is issued through the CLR_FLT bit.

6.3.23.8.2 HW_LOCK_ILIMIT Automatic recovery (HW_LOCK_ILIMIT_MODE = 01xxb)

When a HW_LOCK_ILIMIT event happens in this mode, the status of MOSFET will be configured by HW_LOCK_ILIMIT_MODE and nFAULT is driven low. Status of MOSFET during HW_LOCK_ILIMIT:

- HW_LOCK_ILIMIT_MODE = 0100b or 0101b: All MOSFETs are turned OFF.
- HW_LOCK_ILIMIT_MODE = 0110b: All high-side MOSFETs are turned ON
- HW_LOCK_ILIMIT_MODE = 0111b: All low-side MOSFETs are turned ON

The CONTROLLER_FAULT and HW_LOCK_ILIMIT bits are set to 1b in the fault status registers. Normal operation resumes automatically (gate driver operation and the nFAULT pin is released) after the t_{LCK_RETRY} (configured by LCK_RETRY) time lapses. The CONTROLLER_FAULT and HW_LOCK_ILIMIT bits are reset to 0b after the t_{LCK_RETRY} period expires.

6.3.23.8.3 HW_LOCK_ILIMIT Report Only (HW_LOCK_ILIMIT_MODE = 1000b)

No protective action is taken when a HW_LOCK_ILIMIT event happens in this mode. The hardware lock detection current limit event is reported by setting the CONTROLLER_FAULT and HW_LOCK_ILIMIT bits to 1b in the fault status registers. The gate drivers continue to operate. The external controller manages this condition by acting appropriately. The reporting clears when the HW_LOCK_ILIMIT condition clears and a clear fault command is issued through the CLR_FLT bit.

6.3.23.8.4 HW_LOCK_ILIMIT Disabled (HW_LOCK_ILIMIT_MODE= 1xx1b)

No action is taken when a HW_LOCK_ILIMIT event happens in this mode.

6.3.23.9 Motor Lock (MTR_LCK)

The MCF8315C continuously checks for different motor lock conditions (see [Motor Lock Detection](#)) during motor operation. When one of the enabled lock condition happens, a MTR_LCK event is recognized and action is taken according to the MTR_LCK_MODE.

All locks can be enabled or disabled individually and retry times can be configured through LCK_RETRY. MTR_LCK_MODE bit can operate in four different modes: MTR_LCK latched shutdown, MTR_LCK automatic retry, MTR_LCK report only and MTR_LCK disabled.

6.3.23.9.1 MTR_LCK Latched Shutdown (MTR_LCK_MODE = 00xxb)

When a MTR_LCK event happens in this mode, the status of MOSFETs will be configured by MTR_LCK_MODE and nFAULT is driven low. Status of MOSFETs during MTR_LCK:

- MTR_LCK_MODE = 0000b or 0001b: All MOSFETs are turned OFF.
- MTR_LCK_MODE = 0010b: All high-side MOSFETs are turned ON.
- MTR_LCK_MODE = 0011b: All low-side MOSFETs are turned ON.

The CONTROLLER_FAULT, MTR_LCK and respective motor lock condition bits are set to 1b in the fault status registers. Normal operation resumes (gate driver operation and the nFAULT pin is released) when the MTR_LCK condition clears and a clear fault command is issued through the CLR_FLT bit.

6.3.23.9.2 MTR_LCK Automatic Recovery (MTR_LCK_MODE= 01xxb)

When a MTR_LCK event happens in this mode, the status of MOSFETs will be configured by MTR_LCK_MODE and nFAULT is driven low. Status of MOSFETs during MTR_LCK:

- MTR_LCK_MODE = 0100b or 0101b: All MOSFETs are turned OFF.
- MTR_LCK_MODE = 0110b: All high-side MOSFETs are turned ON.
- MTR_LCK_MODE = 0111b: All low-side MOSFETs are turned ON.

The CONTROLLER_FAULT, MTR_LCK and respective motor lock condition bits are set to 1b in the fault status registers. Normal operation resumes automatically (gate driver operation and the nFAULT pin is released) after

the t_{LCK_RETRY} (configured by LCK_RETRY) time lapses. The CONTROLLER_FAULT, MTR_LCK and respective motor lock condition bits are reset to 0b after the t_{LCK_RETRY} period expires.

6.3.23.9.3 MTR_LCK Report Only (MTR_LCK_MODE = 1000b)

No protective action is taken when a MTR_LCK event happens in this mode. The motor lock event is reported by setting the CONTROLLER_FAULT, MTR_LCK and respective motor lock condition bits to 1b in the fault status registers. The gate drivers continue to operate. The external controller manages this condition by acting appropriately. The reporting clears when the MTR_LCK condition clears and a clear fault command is issued through the CLR_FLT bit.

6.3.23.9.4 MTR_LCK Disabled (MTR_LCK_MODE = 1xx1b)

No action is taken when a MTR_LCK event happens in this mode.

6.3.23.10 Motor Lock Detection

The MCF8315C provides different lock detect mechanisms to determine if the motor is in a locked state. Multiple detection mechanisms work together to ensure the lock condition is detected quickly and reliably. In addition to detecting if there is a locked motor condition, the MCF8315C can also identify and take action if there is no motor connected to the system. Each of the lock detect mechanisms and the no-motor detection can be disabled by their respective register bits (LOCK1/2/3_EN).

6.3.23.10.1 Lock 1: Abnormal Speed (ABN_SPEED)

MCF8315C monitors the speed continuously and at any time the speed exceeds LOCK_ABN_SPEED, an ABN_SPEED lock event is recognized and action is taken according to the MTR_LCK_MODE. The threshold is set through the LOCK_ABN_SPEED register. ABN_SPEED lock can be enabled/disabled by LOCK1_EN.

6.3.23.10.2 Lock 2: Abnormal BEMF (ABN_BEMF)

MCF8315C estimates back-EMF in order to run motor optimally in closed loop. This estimated back-EMF is compared against the expected back-EMF calculated using the estimated speed and the BEMF constant. Whenever motor is stalled the estimated back-EMF is inaccurate due to lower back-EMF at low speed. When the difference between estimated and expected back-EMF exceeds ABNORMAL_BEMF_THR, an abnormal BEMF fault is triggered and action is taken according to the MTR_LCK_MODE.

ABN_BEMF lock can be enabled/disabled by LOCK2_EN.

6.3.23.10.3 Lock3: No-Motor Fault (NO_MTR)

The MCF8315C continuously monitors phase currents on all three phases; if any phase current stays below NO_MTR_THR for 500ms, a NO_MTR event is recognized. The response to the NO_MTR event is configured through MTR_LCK_MODE. NO_MTR lock can be enabled/disabled by LOCK3_EN.

6.3.23.11 Minimum VM (undervoltage) Protection

MCF8315C provides the option of a configurable VM undervoltage protection. The VM level at which MCF8315C triggers the undervoltage fault is set by MIN_VM_MOTOR and the fault response to VM undervoltage is set by MIN_VM_MODE. If MIN_VM_MODE is set to 0b, VM undervoltage fault (at MIN_VM_MOTOR) is latched and the FETs are in Hi-Z until the fault condition is cleared by writing 1b to CLR_FIT bit. If MIN_VM_MODE is set to 1b, VM undervoltage fault (at MIN_VM_MOTOR) automatically clears and the device starts motor operation once $VM > (MIN_VM_MODE + 0.5) \cdot V$.

注

When MIN_VM_MOTOR (\neq 000b) is set to a finite limit, MAX_VM_MOTOR should not be set to 000b.

6.3.23.12 Maximum VM (overvoltage) Protection

MCF8315C provides the option of a configurable VM overvoltage protection. The VM level at which MCF8315C triggers the overvoltage fault is set by MAX_VM_MOTOR and the fault response to VM overvoltage is set by MAX_VM_MODE. If MAX_VM_MODE is set to 0b, VM overvoltage fault (at MAX_VM_MOTOR) is latched and

the FETs are in Hi-Z until the fault condition is cleared by writing 1b to CLR_FIT bit. If MAX_VM_MODE is set to 1b, VM overvoltage fault (at MAX_VM_MOTOR) automatically clears and the device starts motor operation once $VM < (MAX_VM_MODE - 1) \cdot V$.

6.3.23.13 MPET Faults

An error during resistance and inductance measurement is reported using MPET_IPD_FAULT. The MPET_IPD_FAULT gets triggered when the IPD timer overflows due to unsuccessful attempt to ramp up the current to the threshold value, same as explained in [セクション 6.3.23.14](#). The fault typically gets triggered when there is no motor connected to MCF8315C or when the MPET IPD current threshold is set high for motors with high resistance.

An error during BEMF constant measurement is reported using MPET_BEMF_FAULT. This fault gets triggered when the measured back EMF is less than the threshold set in STAT_DETECT_THR. One example of such fault scenario can be the motor stall while running in open loop due to incorrect open loop configuration used.

6.3.23.14 IPD Faults

The MCF8315C uses 12-bit timers to estimate the time during the current ramp up and ramp down during IPD, when the motor start-up is configured as IPD (MTR_STARTUP is set to 10b). During IPD, the algorithm checks for a successful current ramp-up to IPD_CURR_THR, starting with an IPD clock of 10MHz; if unsuccessful (timer overflow before current reaches IPD_CURR_THR), IPD is repeated with lower frequency clocks of 1MHz, 100kHz, and 10kHz sequentially. If the IPD timer overflows (current does not reach IPD_CURR_THR) with all the four clock frequencies, then the IPD_T1_FAULT gets triggered. Similarly the algorithm checks for a successful current decay to zero during IPD current ramp down using all the mentioned IPD clock frequencies. If the IPD timer overflows (current does not ramp down to zero) in all the four attempts, then the IPD_T2_FAULT gets triggered. The user can enable IPD timeout (IPD timer overflow) by setting IPD_TIMEOUT_FAULT_EN to 1b.

IPD gives incorrect results if the next IPD pulse is commanded before the complete decay of current due to present IPD pulse. The MCF8315C can generate a fault called IPD_FREQ_FAULT during such a scenario by setting IPD_FREQ_FAULT_EN to 1b. The IPD_FREQ_FAULT maybe triggered if the IPD frequency is too high for the IPD current limit and the IPD release mode or if the motor inductance is too high for the IPD frequency, IPD current limit and IPD release mode.

On the occurrence of any IPD fault, MCF8315C stops the IPD based start-up process and FETs are in Hi-Z. MCF8315C automatically retries IPD based start-up after t_{LCK_RETRY} elapses.

6.3.23.15 Thermal Warning (OTW)

If the die temperature exceeds the thermal warning limit (T_{OTW}), nFAULT is pulled low and the OT and OTW bits in the gate driver status register are set to 1b. The reporting of OTW (on nFAULT and status bits) can be enabled by setting OTW_REP to 1b. The device performs no additional action and continues to function. In this case, the nFAULT pin is released when the die temperature decreases below the hysteresis point of the thermal warning limit ($T_{OTW} - T_{OTW_HYS}$). The OTW bit remains set until cleared through the CLR_FLT bit and the die temperature is lower than thermal warning limit. ($T_{OTW} - T_{OTW_HYS}$).

6.3.23.16 Thermal Shutdown (TSD)

If the die temperature exceeds the thermal shutdown limit (T_{TSD}), all the FETs are disabled, the charge pump is shut down, and the nFAULT pin is driven low. In addition, the DRIVER_FAULT, OT and OTS bit in the status register are set to 1b. Normal operation resumes (driver operation and the nFAULT pin is released) when the die temperature decreases below the hysteresis point of the thermal shutdown limit ($T_{TSD} - T_{TSD_HYS}$). The OTS bit stays latched high indicating that a thermal event occurred until a clear fault command is issued through the CLR_FLT bit. This protection feature cannot be disabled.

6.4 Device Functional Modes

6.4.1 Functional Modes

6.4.1.1 Sleep Mode

In sleep mode, the MOSFETs, sense amplifiers, buck regulator, charge pump, AVDD LDO regulator and the I²C bus are disabled. The device can be configured to enter sleep (instead of standby) mode by configuring DEV_MODE to 1b. SPEED pin and I²C speed command determine entry and exit from sleep state as described in 表 6-7.

6.4.1.2 Standby Mode

The device can be configured to operate as a standby device by setting DEV_MODE to 0b. In standby mode, the charge pump, AVDD LDO, buck regulator and I²C bus are active while the motor is in stopped state waiting for a suitable non-zero speed command. SPEED pin (analog, PWM or frequency based speed input) or I²C speed command (I²C based speed input) determines entry and exit from standby state as described in 表 6-7.

The thresholds for entering and exiting standby mode in different speed input modes are as follows,

表 6-6. Standby Mode Entry/Exit Thresholds

| Input Source (SPEED_MODE) | Standby entry/exit thresholds | REF_PROFILE_CONFIG = 00b | REF_PROFILE_CONFIG ≠ 00b |
|---------------------------|---|--|--------------------------|
| Analog (00b) | V _{EN_SB} | 1% x V _{ANA_FS} | 1% x V _{ANA_FS} |
| | V _{EX_SB} | 5% x V _{ANA_FS} | 5% x V _{ANA_FS} |
| PWM (01b) | Duty _{EX_SB/EN_SB} | Maximum of (1%, DUTY_HYS) | 0% |
| I ² C (10b) | DIGITAL_SPEED_CTRL _{EX_SB/EN_SB} | Maximum of (1%, DUTY_HYS) x 32767 | 0 |
| Frequency (11b) | Freq _{EX_SB/EN_SB} | Maximum of (1%, DUTY_HYS) x INPUT_MAXIMUM_FREQ (subject to minimum of 3Hz) | < 3Hz |

表 6-7. Conditions to Enter or Exit Sleep or Standby Modes

| SPEED COMMAND MODE | ENTER STANDBY CONDITION | EXIT FROM STANDBY CONDITION | ENTER SLEEP CONDITION | EXIT FROM SLEEP CONDITION |
|--------------------|--|--|---|--|
| Analog | V _{SPEED} < V _{EN_SB} | V _{SPEED} > V _{EX_SB} | V _{SPEED} < V _{EN_SL} for t _{DET_SL_ANA} | V _{SPEED} > V _{EX_SL} for t _{DET_ANA} |
| PWM | Duty _{SPEED} < Duty _{EN_SB} | Duty _{SPEED} > Duty _{EX_SB} | V _{SPEED} < V _{IL} for t _{DET_SL_PWM} | V _{SPEED} > V _{IH} for t _{DET_PWM} |
| I ² C | DIGITAL_SPEED_CTRL < DIGITAL_SPEED_CTRL _{EN_SB} | DIGITAL_SPEED_CTRL > DIGITAL_SPEED_CTRL _{EX_SB} | DIGITAL_SPEED_CTRL is set to 0b for SLEEP_ENTRY_TIME and V _{SPEED} < V _{IL} | V _{SPEED} > V _{IH} for t _{DET_PWM} |
| Frequency | Freq _{SPEED} < Freq _{EN_SB} | Freq _{SPEED} > Freq _{EX_SB} | V _{SPEED} < V _{IL} for t _{DET_SL_PWM} | V _{SPEED} > V _{IH} for t _{DET_PWM} |

注

V_{SPEED} : SPEED pin input voltage, Duty_{SPEED} : SPEED pin input PWM duty, Freq_{SPEED} : SPEED pin input frequency

6.4.1.3 Fault Reset (CLR_FLT)

In the case of latched faults, the device goes into a partial shutdown state to help protect the power MOSFETs and system. When the fault condition clears, the device can go to the operating state again by setting the CLR_FLT to 1b.

6.5 External Interface

6.5.1 DRVOFF Functionality

When DRVOFF pin is driven high, all six MOSFETs are put in Hi-Z state, irrespective of speed command. If motor speed command is non-zero when DRVOFF is driven high, device may encounter a fault like no motor or abnormal BEMF. Whenever DRVOFF is driven high, it should be held high for a minimum of 10s for safe operation.

6.5.2 DAC output (only in RRY package)

MCF8315C has a 12-bit DAC which outputs analog voltage equivalent of digital variables on the DACOUT pin. The maximum DAC output voltage is 3-V. Signals available on DACOUT pin are useful in tracking internal variables in real-time and can be used for tuning speed controller or motor acceleration time. The address for variable to be tracked on DACOUT pin is configured using DACOUT_VAR_ADDR. DACOUT is available on pin 29 by setting DAC_ENABLE to 1b.

6.5.3 Oscillator Source

MCF8315C has a built-in oscillator that is used as the clock source for all digital peripherals and timing measurements. Default configuration for MCF8315C is to use the internal oscillator and it is sufficient to drive the motor without need for any external crystal or clock sources.

In case MCF8315C does not meet accuracy requirements of timing measurement or speed loop, then MCF8315C has an option to support an external clock reference.

In order to improve EMI performance, MCF8315C provides the option of modulating the clock frequency by enabling Spread Spectrum Modulation (SSM) through SPREAD_SPECTRUM_MODULATION_DIS.

6.5.3.1 External Clock Source

Speed loop accuracy of MCF8315C over the operating temperature range can be improved by providing a more accurate clock reference on EXT_CLK pin as shown in [Figure 6-53](#). EXT_CLK will be used to calibrate the internal clock oscillator - this will help match the accuracy of the internal clock oscillator to that of the external clock. External clock source can be selected by configuring CLK_SEL to 11b and setting EXT_CLK_EN to 1b. The external clock source frequency can be configured through EXT_CLK_CONFIG.

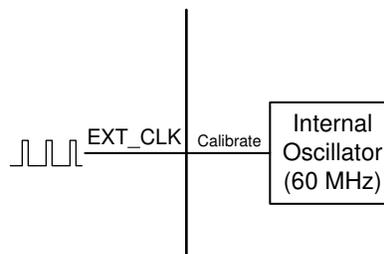


Figure 6-53. External Clock Reference

注

External clock is optional and can be used when higher clock accuracy is needed. MCF8315C will always power up using the internal oscillator in all modes.

6.5.4 External Watchdog

MCF8315C provides an external watchdog feature - EXT_WDT_EN bit should be set to 1b to enable the external watchdog. When this feature is enabled, the device waits for a tickle (low to high transition in EXT_WD pin, WATCHDOG_TICKLE set to 1b in I²C mode) from the external watchdog input for a configured time interval; if the time interval between two consecutive tickles is higher than the configured time, a watchdog fault is

triggered. This fault can be configured using EXT_WDT_FAULT_MODE either as a report only fault or as a latched fault with outputs in Hi-Z state. The latched fault can be cleared by writing 1b to CLR_FLT. When a watchdog timeout occurs, WATCHDOG_FAULT bit is set to 1b. In case, the next tickle arrives before the configured time interval elapses, the watchdog timer is reset and it begins to wait for the next tickle. This can be used to continuously monitor the health of an external MCU (which is the external watchdog input) and put the MCF8315C outputs in Hi-Z in case the external MCU is in a fault/hang state.

The external watchdog input is selected using EXT_WDT_INPUT_MODE and can either be the EXT_WD pin or the I²C interface. The time interval between two tickles to trigger a watchdog fault is configured by EXT_WDT_CONFIG; there are 4 time settings - 100, 200, 500 and 1000ms for the EXT_WD pin based watchdog and 4 time settings - 1, 2, 5 and 10s for the I²C based watchdog.

注

Watchdog should be disabled by setting EXT_WDT_EN to 0b before changing EXT_WDT_CONFIG configuration.

6.6 EEPROM access and I²C interface

6.6.1 EEPROM Access

MCF8315C has 1024 bits (16 rows of 64 bits each) of EEPROM, which are used to store the motor configuration parameters. Erase operations are row-wise (all 64 bits are erased in a single erase operation), but 32-bit write and read operations are supported. EEPROM can be written and read using the I²C serial interface but erase cannot be performed using I²C serial interface. The shadow registers corresponding to the EEPROM are located at addresses 0x000080-0x0000AE.

注

MCF8315C allows EEPROM write and read operations only when the motor is not spinning.

6.6.1.1 EEPROM Write

In MCF8315C, EEPROM write procedure is as follows,

1. Write register 0x000080 (ISD_CONFIG) with ISD and reverse drive configuration like resync enable, reverse drive enable, stationary detect threshold, reverse drive handoff threshold etc.
2. Write register 0x000082 (REV_DRIVE_CONFIG) with reverse drive and active brake configuration like reverse drive open loop acceleration, active brake current limit, Kp, Ki values etc.
3. Write register 0x000084 (MOTOR_STARTUP1) with motor start-up configuration like start-up method, IPD parameters, align parameters etc.
4. Write register 0x000086 (MOTOR_STARTUP2) with motor start-up configuration like open loop acceleration, open loop current limit, first cycle frequency etc.
5. Write register 0x000088 (CLOSED_LOOP1) with motor control configuration like closed loop acceleration, overmodulation enable, PWM frequency, FG signal parameters etc.
6. Write register 0x00008A (CLOSED_LOOP2) with motor control configuration like motor winding resistance and inductance, motor stop options, brake speed threshold etc.
7. Write register 0x00008C (CLOSED_LOOP3) with motor control configuration like motor BEMF constant, current loop Kp, Ki etc.
8. Write register 0x00008E (CLOSED_LOOP4) with motor control configuration like speed loop Kp, Ki and maximum speed.
9. Write register 0x000090 (FAULT_CONFIG1) with fault control configuration software and hardware current limits, lock current limit and actions, retry times etc.
10. Write register 0x000092 (FAULT_CONFIG2) with fault control configuration like hardware current limit actions, OV, UV limits and actions, abnormal speed level, no motor threshold etc.
11. Write registers 0x000094 – 0x00009E (SPEED_PROFILES1-6) with speed profile configuration like profile type, duty cycle, speed clamp level, duty cycle clamp level etc.
12. Write register 0x0000A0 (INT_ALGO_1) with miscellaneous configuration like ISD run time and timeout, MPET parameters etc.
13. Write register 0x0000A2 (INT_ALGO_2) with miscellaneous configuration like additional MPET parameters, IPD high resolution enable, active brake current slew rate, closed loop slow acceleration etc.
14. Write registers 0x0000A4 (PIN_CONFIG1) with pin configuration for speed input mode (analog or PWM), BRAKE pin mode etc.
15. Write registers 0x0000A6 and 0x0000A8 (DEVICE_CONFIG1 and DEVICE_CONFIG2) with device configuration like pins 36, 37 configuration, pin 38 configuration, dynamic CSA gain enable, dynamic voltage gain enable, clock source select, speed range select etc.
16. Write register 0x0000AA (PERI_CONFIG1) with peripheral configuration like dead time, bus current limit, DIR input, SSM enable etc.
17. Write registers 0x0000AC and 0x0000AE (GD_CONFIG1 and GD_CONFIG2) with gate driver configuration like slew rate, CSA gain, OCP level, mode, OVP enable, level, buck voltage level, buck current limit etc.
18. Write 0x8A500000 into register 0x0000EA to write the shadow register(0x000080-0x0000AE) values into the EEPROM.
19. Wait for 300ms for the EEPROM write operation to complete

Steps 1-17 can be selectively executed based on registers/parameters that need to be modified. After all shadow registers have been updated with the required values, step 18 should be executed to copy the contents of the shadow registers into the EEPROM.

6.6.1.2 EEPROM Read

In MCF8315C, EEPROM read procedure is as follows,

1. Write 0x40000000 into register 0x0000EA to read the EEPROM data into the shadow registers (0x000080-0x0000AE).
2. Wait for 100ms for the EEPROM read operation to complete.
3. Read the shadow register values, 1 or 2 registers at a time, using the I²C read command as explained in [セクション 6.6.2](#). Shadow register addresses are in the range of 0x000080-0x0000AE. Register address increases in steps of 2 for 32-bit read operation (since each address is a 16-bit location).

6.6.1.3 EEPROM Security

MCF8315C provides configurable read and write protection to EEPROM registers. The level of protection can be configured using EEPROM_RW_PROTECTION as per following list,

- 000b : EEPROM read and write are allowed without a passcode
- 001b : EEPROM read is allowed without a passcode; EEPROM write needs a valid passcode
- 010b : EEPROM read is allowed without a passcode; EEPROM write is locked permanently
- 011b : EEPROM read and write needs a valid passcode
- 1xxb : EEPROM read and write are locked permanently

Passcode is a 30-bit number composed from the EEPROM section as shown in [図 6-54](#).



図 6-54. Passcode for EEPROM Read/Write Protection

When passcode based read/write protection is enabled, every EEPROM read/write transaction has to be preceded by a valid passcode write to appropriate address. EEPROM read/write transaction has to be initiated within 500-ms of valid passcode write - once 500-ms lapses, valid passcode has to be written again to the appropriate address to enable subsequent EEPROM read/write transaction. If an invalid passcode is written, the subsequent EEPROM read/write transaction is rejected, number of consecutive invalid passcode attempts logged and nFAULT is pulled low to indicate failed EEPROM transaction. Number of consecutive invalid passcode attempts is reset to zero and nFAULT is cleared on subsequent valid passcode write as long as the number of consecutive invalid passcode attempts is < 3. On the third consecutive invalid passcode attempt, the EEPROM is locked permanently and no further EEPROM read/write transactions are allowed even with valid passcode. The read/write protection is applicable to EEPROM as well as corresponding shadow RAM locations. The EEPROM_RW_PROTECTION as well as the passcode are part of the EEPROM registers and hence same level of read/write protection applies to these bit fields as configured by EEPROM_RW_PROTECTION.

6.6.2 I²C Serial Interface

MCF8315C interfaces with an external MCU over an I²C serial interface. MCF8315C is an I²C target to be interfaced with a controller. External MCU can use this interface to read/write from/to any non-reserved register in MCF8315C.

注

For reliable communication, a 100- μ s delay should be used between every byte transferred over the I²C bus.

6.6.2.1 I²C Data Word

The I²C data word format is shown in [表 6-8](#).

表 6-8. I²C Data Word Format

| TARGET_ID | R/W | CONTROL WORD | DATA | CRC-8 |
|-----------|-----|--------------|---------------------|---------|
| A6 - A0 | W0 | CW23 - CW0 | D15 / D31/ D63 - D0 | C7 - C0 |

Target ID and R/W Bit: The first byte includes the 7-bit I²C target ID, followed by the read/write command bit. Every packet in MCF8315C the communication protocol starts with writing a 24-bit control word and hence the R/W bit is always 0.

24-bit Control Word: The Target Address is followed by a 24-bit control bit. The control word format is shown in [表 6-9](#).

表 6-9. 24-bit Control Word Format

| OP_R/W | CRC_EN | DLEN | MEM_SEC | MEM_PAGE | MEM_ADDR |
|--------|--------|------------|-------------|-------------|------------|
| CW23 | CW22 | CW21- CW20 | CW19 - CW16 | CW15 - CW12 | CW11 - CW0 |

Each field in the control word is explained in detail below.

OP_R/W – Read/Write: R/W bit gives information on whether this is a read (1b) operation or write (0b) operation. For write operation, MCF8315C will expect data bytes to be sent after the 24-bit control word. For read operation, MCF8315C will expect an I²C read request with repeated start or normal start after the 24-bit control word.

CRC_EN – Cyclic Redundancy Check(CRC) Enable: MCF8315C supports CRC to verify the data integrity. This bit controls whether the CRC feature is enabled or not.

DLEN – Data Length: DLEN field determines the length of the data that will be sent by external MCU to MCF8315C. MCF8315C protocol supports three data lengths: 16-bit, 32-bit and 64-bit.

表 6-10. Data Length Configuration

| DLEN Value | Data Length |
|------------|-------------|
| 00b | 16-bit |
| 01b | 32-bit |
| 10b | 64-bit |
| 11b | Reserved |

MEM_SEC – Memory Section: Each memory location in MCF8315C is addressed using three separate entities in the control word – Memory Section, Memory Page, Memory Address. Memory Section is a 4-bit field which denotes the memory section to which the memory location belongs like RAM, ROM etc.

MEM_PAGE – Memory Page: Memory page is a 4-bit field which denotes the memory page to which the memory location belongs.

MEM_ADDR – Memory Address: Memory address is the last 12-bits of the address. The complete 22-bit address is constructed internally by MCF8315C using all three fields – Memory Section, Memory Page, Memory Address. For memory locations 0x000000-0x000800, memory section is 0x0, memory page is 0x0 and memory address is the lowest 12 bits(0x000 for 0x000000, 0x080 for 0x000080 and 0x800 for 0x000800). All relevant memory locations (EEPROM and RAM variables) have MEM_SEC and MEM_PAGE values both corresponding to 0x0. All other MEM_SEC, MEM_PAGE values are reserved and not for external use.

Data Bytes: For a write operation to MCF8315C, the 24-bit control word is followed by data bytes. The DLEN field in the control word should correspond with the number of bytes sent in this section. In case of mismatch between number of data bytes and DLEN, the write operation is discarded.

CRC Byte: If the CRC feature is enabled in the control word, CRC byte has to be sent at the end of a write transaction. Refer to [セクション 6.6.2.6](#) for detailed information on CRC byte calculation.

6.6.2.2 I²C Write Transaction

MCF8315C write transaction over I²C involves the following sequence (see [Figure 6-55](#)).

1. I²C start condition.
2. Start is followed by the I²C target ID byte, made up of 7-bit target ID along with the R/W bit set to 0b. ACK in yellow box indicates that MCF8315C has processed the received target ID which has matched with its I²C target ID and therefore will proceed with this transaction. If target ID received does not match with the I²C ID of MCF8315C, then the transaction is ignored. and no ACK is sent by MCF8315C.
3. The target ID byte is followed by the 24-bit control word sent one byte at a time. Bit 23 in the control word is 0b as it is a write transaction. ACK in blue boxes correspond to acknowledgements sent by MCF8315C to the controller that the previous byte (of control word) has been received and next byte can be sent.
4. The 24-bit control word is then followed by the data bytes. The number of data bytes sent by the controller depends on the DLEN field in the control word.
 - a. While sending data bytes, the LSB byte is sent first. Refer to [Section 6.6.2.4](#) for more details.
 - b. 16-bit/32-bit write – The data sent is written to the address mentioned in control word.
 - c. 64-bit Write – 64-bit is treated as two successive 32-bit writes. The address mentioned in control word is taken as Addr_1. Addr_2 is internally calculated by MCF8315C by incrementing Addr_1 by 0x2. A total of 8 data bytes are sent. The first 4 bytes (sent in LSB first) are written to Addr_1 and the next 4 bytes are written to Addr_2.
 - d. ACK in blue boxes (after every data byte) correspond to the acknowledgement sent by MCF8315C to the controller that the previous data byte has been received and next data byte can be sent.
5. If CRC is enabled, the packet ends with a CRC byte. CRC is calculated for the entire packet (Target ID + W bit, Control Word, Data Bytes). MCF8315C will send an ACK on receiving the CRC byte.
6. I²C Stop condition from the controller to terminate the transaction.

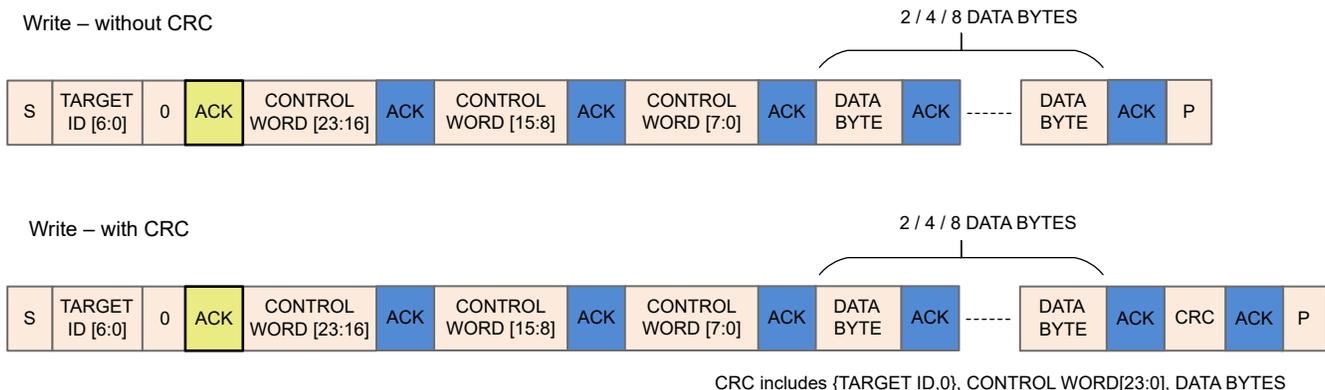


Figure 6-55. I²C Write Transaction Sequence

6.6.2.3 I²C Read Transaction

MCF8315C read transaction over I²C involves the following sequence (see [Figure 6-56](#)).

1. I²C Start condition from the controller to initiate the transaction.
2. Start is followed by the I²C target ID byte, made up of 7-bit target ID along with the R/W bit set to 0b. ACK (in yellow box) indicates that MCF8315C has processed the received target ID which has matched with its I²C target ID and therefore will proceed with this transaction. If target ID received does not match with the I²C ID of MCF8315C, then the transaction is ignored and no ACK is sent by MCF8315C.
3. The target ID byte is followed by the 24-bit control word sent one byte at a time. Bit 23 in the control word is set to 1b as it is a read transaction. ACK (in blue boxes) correspond to acknowledgements sent by MCF8315C to the controller that the previous byte (of control word) has been received and next byte can be sent.
4. The control word is followed by a Repeated Start (RS, start without a preceding stop) or normal Start (P followed by S) to initiate the data (to be read back) transfer from MCF8315C to I²C controller. RS or S is

- followed by the 7-bit target ID along with R/W bit set to 1b to initiate the read transaction. MCF8315C sends an ACK (in grey box after RS) to the controller to acknowledge the receipt of read transaction request.
5. Post acknowledgement of read transaction request, MCF8315C sends the data bytes on SDA one byte at a time. The number of data bytes sent by MCF8315C depends on the DLEN field in the control word.
 - a. While sending data bytes, the LSB byte is sent first. Refer the examples in [セクション 6.6.2.4](#) for more details.
 - b. 16-bit/32-bit Read – The data from the address mentioned in control word is sent back to the controller.
 - c. 64-bit Read – 64-bit is treated as two successive 32-bit reads. The address mentioned in control word is taken as Addr_1. Addr_2 is internally calculated by MCF8315C by incrementing Addr_1 by 0x2. A total of 8 data bytes are sent by MCF8315C. The first 4 bytes (sent in LSB first) are read from Addr_1 and the next 4 bytes are read from Addr_2.
 - d. ACK in orange boxes correspond to acknowledgements sent by the controller to MCF8315C that the previous byte has been received and next byte can be sent.
 6. If CRC is enabled in the control word, then MCF8315C sends an additional CRC byte at the end. Controller has to read the CRC byte and then send the last ACK (in orange). CRC is calculated for the entire packet (Target ID + W bit, Control Word, Target ID + R bit, Data Bytes).
 7. I²C Stop condition from the controller to terminate the transaction.

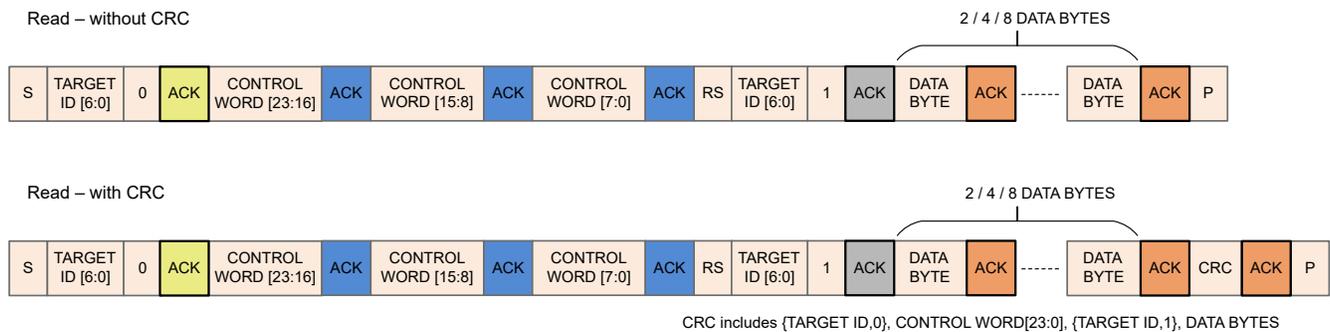


図 6-56. I²C Read Transaction Sequence

6.6.2.4 I²C Communication Protocol Packet Examples

All values used in this example section are in hex format. I²C target ID used in the examples is 0x60.

Example for 32-bit Write Operation: Address – 0x00000080, Data – 0x1234ABCD, CRC Byte – 0x45 (Sample value; does not match with the actual CRC calculation)

表 6-11. Example for 32-bit Write Operation Packet

| Start Byte | | Control Word 0 | | | | Control Word 1 | | Control Word 2 | Data Bytes | | | | CRC |
|------------|------------------------|----------------|--------|-----------|-----------|----------------|----------|----------------|------------|-------|-------|-------|----------|
| Target ID | I ² C Write | OP_R/W | CRC_EN | DLEN | MEM_SEC | MEM_PAGE | MEM_ADDR | MEM_ADDR | DB0 | DB1 | DB2 | DB3 | CRC Byte |
| A6-A0 | W0 | CW23 | CW22 | CW21-CW20 | CW19-CW16 | CW15-CW12 | CW11-CW8 | CW7-CW0 | D7-D0 | D7-D0 | D7-D0 | D7-D0 | C7-C0 |
| 0x60 | 0x0 | 0x0 | 0x1 | 0x1 | 0x0 | 0x0 | 0x0 | 0x80 | 0xCD | 0xAB | 0x34 | 0x12 | 0x45 |
| 0xC0 | | 0x50 | | | | 0x00 | | 0x80 | 0xCD | 0xAB | 0x34 | 0x12 | 0x45 |

Example for 64-bit Write Operation: Address - 0x00000080, Data Address 0x00000080 - Data 0x01234567, Data Address 0x00000082 – Data 0x89ABCDEF, CRC Byte – 0x45 (Sample value; does not match with the actual CRC calculation)

表 6-12. Example for 64-bit Write Operation Packet

| Start Byte | Control Word 0 | | | | Control Word 1 | | Control Word 2 | Data Bytes | CRC |
|------------|----------------|--|--|--|----------------|--|----------------|------------|-----|
|------------|----------------|--|--|--|----------------|--|----------------|------------|-----|

表 6-12. Example for 64-bit Write Operation Packet (続き)

| Target ID | I ² C Write | OP_R/W | CRC_EN | DLEN | MEM_SEC | MEM_PAGE | MEM_ADDR | MEM_ADDR | DB0 - DB7 | CRC Byte |
|-----------|------------------------|--------|--------|-----------|-----------|-----------|----------|----------|-------------------|----------|
| A6-A0 | W0 | CW23 | CW22 | CW21-CW20 | CW19-CW16 | CW15-CW12 | CW11-CW8 | CW7-CW0 | [D7-D0] x 8 | C7-C0 |
| 0x60 | 0x0 | 0x0 | 0x1 | 0x2 | 0x0 | 0x0 | 0x0 | 0x80 | 0x67452301EFCDA89 | 0x45 |
| 0xC0 | | 0x60 | | | | 0x00 | | 0x80 | 0x67452301EFCDA89 | 0x45 |

Example for 32-bit Read Operation: Address – 0x00000080, Data – 0x1234ABCD, CRC Byte – 0x56 (Sample value; does not match with the actual CRC calculation)

表 6-13. Example for 32-bit Read Operation Packet

| Start Byte | | Control Word 0 | | | | Control Word 1 | | | Control Word 2 | Start Byte | | Byte 0 | Byte 1 | Byte 2 | Byte 3 | Byte 4 |
|------------|------------------------|----------------|--------|-----------|-----------|----------------|----------|----------|----------------|-----------------------|-------|--------|--------|--------|----------|--------|
| Target ID | I ² C Write | R/W | CRC_EN | DLEN | MEM_SEC | MEM_PAGE | MEM_ADDR | MEM_ADDR | Target ID | I ² C Read | DB0 | DB1 | DB2 | DB3 | CRC Byte | |
| A6-A0 | W0 | CW23 | CW22 | CW21-CW20 | CW19-CW16 | CW15-CW12 | CW11-CW8 | CW7-CW0 | A6-A0 | W0 | D7-D0 | D7-D0 | D7-D0 | D7-D0 | C7-C0 | |
| 0x60 | 0x0 | 0x1 | 0x1 | 0x1 | 0x0 | 0x0 | 0x0 | 0x80 | 0x60 | 0x1 | 0xCD | 0xAB | 0x34 | 0x12 | 0x56 | |
| 0xC0 | | 0xD0 | | | | 0x00 | | 0x80 | 0xC1 | | 0xCD | 0xAB | 0x34 | 0x12 | 0x56 | |

6.6.2.5 I²C Clock Stretching

The I²C peripheral in MCF8315C implements clock stretching under certain conditions when there are pending I²C interrupts waiting to be processed. During clock stretching, MCF8315C pulls SCL low and the I²C bus is unavailable for use by other devices. The following is a list of conditions under which clock stretching can occur:

- Start interrupt pending:** There are two scenarios when a start interrupt can result in clock stretching,
 - When target ID is a match, I²C peripheral in MCF8315C raises a start interrupt request. Until this start interrupt request is processed, clock is stretched. Upon processing this request, clock is released and an ACK (marked in yellow or grey in [図 6-55](#) and [図 6-56](#)) is sent to the controller for continuing with the transaction.
 - If Start (followed by target ID match) for a new transaction is received when a receive interrupt from previous transaction is yet to be processed, clock is stretched until both the receive interrupt and start interrupt are processed in chronological order. This process ensures that previous transaction is executed correctly before initiating the next transaction.
- Receive interrupt pending:** When a receive interrupt is waiting to be processed and the receive register is full which occurs when two successive bytes (data or control) have been received by MCF8315C (separated by one ACK shown as blue boxes in [図 6-55](#) and [図 6-56](#)) without the receive interrupt generated by the first byte being processed. Upon receive of second byte, clock is stretched until receive interrupt generated by the first byte is processed.
- Transmit buffer is empty:** In case of a transmit interrupt pending (to send data back to controller), if the transmit buffer is waiting to be populated with data to be read back to the controller, clock stretching is done until the transmit buffer is populated with requested data. After the buffer is populated, clock is released and data is sent to controller.

注

I²C clock stretching is timed out after 5 ms by MCF8315C to allow I²C bus access for other devices on the same bus.

6.6.2.6 CRC Byte Calculation

An 8-bit CCIT polynomial ($x^8 + x^2 + x + 1$) is used for CRC computation.

CRC Calculation in Write Operation: When the external MCU writes to MCF8315C, if the CRC is enabled, the external MCU has to compute an 8-bit CRC byte and add the CRC byte at the end of the data. MCF8315C will compute CRC using the same polynomial internally and if there is a mismatch, the write request is discarded. Input data for CRC calculation by external MCU for write operation are listed below:

1. Target ID + write bit.
2. Control word – 3 bytes
3. Data bytes – 2/4/8 bytes

CRC Calculation in Read Operation: When the external MCU reads from MCF8315C, if the CRC is enabled, MCF8315C sends the CRC byte at the end of the data. The CRC computation in read operation involves the start byte, control words sent by external MCU along with data bytes sent by MCF8315C. Input data for CRC calculation by external MCU to verify the data sent by MCF8315C are listed below :

1. Target ID + write bit
2. Control word – 3 bytes
3. Target ID + read bit
4. Data bytes – 2/4/8 bytes

6.7 EEPROM (Non-Volatile) Register Map

6.7.1 Algorithm_Configuration Registers

表 6-14 lists the memory-mapped registers for the Algorithm_Configuration registers. All register offset addresses not listed in 表 6-14 should be considered as reserved locations and the register contents should not be modified.

表 6-14. ALGORITHM_CONFIGURATION Registers

| Offset | Acronym | Register Name | Section |
|--------|------------------|------------------------------|--------------------------------|
| 80h | ISD_CONFIG | ISD Configuration | セクション 6.7.1.1 |
| 82h | REV_DRIVE_CONFIG | Reverse Drive Configuration | セクション 6.7.1.2 |
| 84h | MOTOR_STARTUP1 | Motor Startup Configuration1 | セクション 6.7.1.3 |
| 86h | MOTOR_STARTUP2 | Motor Startup Configuration2 | セクション 6.7.1.4 |
| 88h | CLOSED_LOOP1 | Close Loop Configuration1 | セクション 6.7.1.5 |
| 8Ah | CLOSED_LOOP2 | Close Loop Configuration2 | セクション 6.7.1.6 |
| 8Ch | CLOSED_LOOP3 | Close Loop Configuration3 | セクション 6.7.1.7 |
| 8Eh | CLOSED_LOOP4 | Close Loop Configuration4 | セクション 6.7.1.8 |
| 94h | SPEED_PROFILES1 | Speed Profile Configuration1 | セクション 6.7.1.9 |
| 96h | SPEED_PROFILES2 | Speed Profile Configuration2 | セクション 6.7.1.10 |
| 98h | SPEED_PROFILES3 | Speed Profile Configuration3 | セクション 6.7.1.11 |
| 9Ah | SPEED_PROFILES4 | Speed Profile Configuration4 | セクション 6.7.1.12 |
| 9Ch | SPEED_PROFILES5 | Speed Profile Configuration5 | セクション 6.7.1.13 |
| 9Eh | SPEED_PROFILES6 | Speed Profile Configuration6 | セクション 6.7.1.14 |

Complex bit access types are encoded to fit into small table cells. 表 6-15 shows the codes that are used for access types in this section.

表 6-15. Algorithm_Configuration 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 |

6.7.1.1 ISD_CONFIG Register (Offset = 80h) [Reset = 0000000h]

ISD_CONFIG is shown in [図 6-57](#) and described in [表 6-16](#).

Return to the [Summary Table](#).

Register to configure initial speed detect settings

図 6-57. ISD_CONFIG Register

| | | | | | | | |
|------------------|--------|---------------------|------------|--------------|-----------|----------------------------|-----------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | ISD_EN | BRAKE_EN | HIZ_EN | RVS_DR_EN | RESYNC_EN | FW_DRV_RESYN_THR | |
| R-0h | R/W-0h | R/W-0h | R/W-0h | R/W-0h | R/W-0h | R/W-0h | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| FW_DRV_RESYN_THR | | BRK_MODE | BRK_CONFIG | BRK_CURR_THR | | | BRK_TIME |
| R/W-0h | | R/W-0h | R/W-0h | R/W-0h | | | R/W-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| BRK_TIME | | | HIZ_TIME | | | | STAT_DETECT_THR |
| R/W-0h | | | R/W-0h | | | | R/W-0h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| STAT_DETECT_THR | | REV_DRV_HANDOFF_THR | | | | REV_DRV_OPEN_LOOP_CURR_ENT | |
| R/W-0h | | R/W-0h | | | | R/W-0h | |

表 6-16. ISD_CONFIG Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-----------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30 | ISD_EN | R/W | 0h | ISD enable 0h = Disable 1h = Enable |
| 29 | BRAKE_EN | R/W | 0h | ISD brake enable 0h = Disable 1h = Enable |
| 28 | HIZ_EN | R/W | 0h | ISD Hi-Z enable 0h = Disable 1h = Enable |
| 27 | RVS_DR_EN | R/W | 0h | Reverse Drive Enable 0h = Disable 1h = Enable |
| 26 | RESYNC_EN | R/W | 0h | Resynchronization Enable 0h = Disable 1h = Enable |

表 6-16. ISD_CONFIG Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|------------------|------|-------|---|
| 25-22 | FW_DRV_RESYN_THR | R/W | 0h | Minimum speed threshold to resynchronize to close loop (% of MAX_SPEED) 0h = 5% 1h = 10% 2h = 15% 3h = 20% 4h = 25% 5h = 30% 6h = 35% 7h = 40% 8h = 45% 9h = 50% Ah = 55% Bh = 60% Ch = 70% Dh = 80% Eh = 90% Fh = 100% |
| 21 | BRK_MODE | R/W | 0h | Brake mode 0h = Reserved 1h = All three low side FETs turned ON |
| 20 | BRK_CONFIG | R/W | 0h | Brake configuration 0h = Brake time is used to come out of Brake state 1h = Brake current threshold and Brake time is used to come out of Brake state |
| 19-17 | BRK_CURR_THR | R/W | 0h | Brake current threshold 0h = 0.0625 A 1h = 0.125 A 2h = 0.1875 A 3h = 0.3125 A 4h = 0.625 A 5h = 1.25 A 6h = 2.5 A 7h = 5.0 A |
| 16-13 | BRK_TIME | R/W | 0h | Brake time 0h = 10 ms 1h = 50 ms 2h = 100 ms 3h = 200 ms 4h = 300 ms 5h = 400 ms 6h = 500 ms 7h = 750 ms 8h = 1 s 9h = 2 s Ah = 3 s Bh = 4 s Ch = 5 s Dh = 7.5 s Eh = 10 s Fh = 15 s |

表 6-16. ISD_CONFIG Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|---------------------------|------|-------|---|
| 12-9 | HIZ_TIME | R/W | 0h | Hi-Z time 0h = 10 ms 1h = 50 ms 2h = 100 ms 3h = 200 ms 4h = 300 ms 5h = 400 ms 6h = 500 ms 7h = 750 ms 8h = 1 s 9h = 2 s Ah = 3 s Bh = 4 s Ch = 5 s Dh = 7.5 s Eh = 10 s Fh = 15 s |
| 8-6 | STAT_DETECT_THR | R/W | 0h | BEMF threshold to detect if motor is stationary 0h = 50 mV 1h = 75 mV 2h = 100 mV 3h = 250 mV 4h = 500 mV 5h = 750 mV 6h = 1000 mV 7h = 1500 mV |
| 5-2 | REV_DRV_HANDOFF_THR | R/W | 0h | Speed threshold used to transition to open loop during reverse declaration (% of MAX_SPEED) 0h = 2.5% 1h = 5% 2h = 7.5% 3h = 10% 4h = 12.5% 5h = 15% 6h = 20% 7h = 25% 8h = 30% 9h = 40% Ah = 50% Bh = 60% Ch = 70% Dh = 80% Eh = 90% Fh = 100% |
| 1-0 | REV_DRV_OPEN_LOOP_CURRENT | R/W | 0h | Open loop current limit during speed reversal 0h = 0.9375 A 1h = 1.5625 A 2h = 2.1875 A 3h = 3.125 A |

6.7.1.2 REV_DRIVE_CONFIG Register (Offset = 82h) [Reset = 0000000h]

REV_DRIVE_CONFIG is shown in [図 6-58](#) and described in [表 6-17](#).

Return to the [Summary Table](#).

Register to configure reverse drive settings

図 6-58. REV_DRIVE_CONFIG Register

| | | | | | | | |
|----------------------------|----------------------------|----|----|----|----------------------------|-----------------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | REV_DRV_OPEN_LOOP_ACCEL_A1 | | | | REV_DRV_OPEN_LOOP_ACCEL_A2 | | |
| R-0h | R/W-0h | | | | R/W-0h | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| REV_DRV_OPEN_LOOP_ACCEL_A2 | ACTIVE_BRAKE_CURRENT_LIMIT | | | | ACTIVE_BRAKE_KP | | |
| R/W-0h | R/W-0h | | | | R/W-0h | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| ACTIVE_BRAKE_KP | | | | | | ACTIVE_BRAKE_KI | |
| R/W-0h | | | | | | R/W-0h | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ACTIVE_BRAKE_KI | | | | | | | |
| R/W-0h | | | | | | | |

表 6-17. REV_DRIVE_CONFIG Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|----------------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-27 | REV_DRV_OPEN_LOOP_ACCEL_A1 | R/W | 0h | Open loop acceleration coefficient A1 during reverse drive 0h = 0.01 Hz/s 1h = 0.05 Hz/s 2h = 1 Hz/s 3h = 2.5 Hz/s 4h = 5 Hz/s 5h = 10 Hz/s 6h = 25 Hz/s 7h = 50 Hz/s 8h = 75 Hz/s 9h = 100 Hz/s Ah = 250 Hz/s Bh = 500 Hz/s Ch = 750 Hz/s Dh = 1000 Hz/s Eh = 5000 Hz/s Fh = 10000 Hz/s |

表 6-17. REV_DRIVE_CONFIG Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|----------------------------|------|-------|---|
| 26-23 | REV_DRV_OPEN_LOOP_ACCEL_A2 | R/W | 0h | Open loop acceleration coefficient A2 during reverse drive 0h = 0.0 Hz/s ² 1h = 0.05 Hz/s ² 2h = 1 Hz/s ² 3h = 2.5 Hz/s ² 4h = 5 Hz/s ² 5h = 10 Hz/s ² 6h = 25 Hz/s ² 7h = 50 Hz/s ² 8h = 75 Hz/s ² 9h = 100 Hz/s ² Ah = 250 Hz/s ² Bh = 500 Hz/s ² Ch = 750 Hz/s ² Dh = 1000 Hz/s ² Eh = 5000 Hz/s ² Fh = 10000 Hz/s ² |
| 22-20 | ACTIVE_BRAKE_CURRENT_LIMIT | R/W | 0h | Bus current limit during active braking 0h = 0.3125 A 1h = 0.625 A 2h = 1.25 A 3h = 1.875 A 4h = 2.5 A 5h = 3.125 A 6h = 3.75 A 7h = 4.375 A |
| 19-10 | ACTIVE_BRAKE_KP | R/W | 0h | 10-bit value for active braking loop Kp. $K_p = \text{ACTIVE_BRAKE_KP} / 2^7$ |
| 9-0 | ACTIVE_BRAKE_KI | R/W | 0h | 10-bit value for active braking loop Ki. $K_i = \text{ACTIVE_BRAKE_KI} / 2^9$ |

6.7.1.3 MOTOR_STARTUP1 Register (Offset = 84h) [Reset = 0000000h]

MOTOR_STARTUP1 is shown in [図 6-59](#) and described in [表 6-18](#).

Return to the [Summary Table](#).

Register to configure motor startup settings1

図 6-59. MOTOR_STARTUP1 Register

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
|---------------|-------------|--------------|------------------------------|------------------|------------|-----------------|----------------|
| RESERVED | MTR_STARTUP | | ALIGN_SLOW_RAMP_RATE | | | ALIGN_TIME | |
| R-0h | R/W-0h | | R/W-0h | | | R/W-0h | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| ALIGN_TIME | | | ALIGN_OR_SLOW_CURRENT_ILIMIT | | | IPD_CLK_FREQ | |
| R/W-0h | | | R/W-0h | | | R/W-0h | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| IPD_CLK_FREQ | | IPD_CURR_THR | | | | IPD_RLS_MODE | |
| R/W-0h | | R/W-0h | | | | R/W-0h | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IPD_ADV_ANGLE | | IPD_REPEAT | | OL_ILIMIT_CONFIG | IQ_RAMP_EN | ACTIVE_BRAKE_EN | REV_DRV_CONFIG |
| R/W-0h | | R/W-0h | | R/W-0h | R/W-0h | R/W-0h | R/W-0h |

表 6-18. MOTOR_STARTUP1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|----------------------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-29 | MTR_STARTUP | R/W | 0h | Motor start-up options 0h = Align 1h = Double Align 2h = IPD 3h = Slow first cycle |
| 28-25 | ALIGN_SLOW_RAMP_RATE | R/W | 0h | Align, slow first cycle and open loop current ramp rate 0h = 0.1 A/s 1h = 1 A/s 2h = 5 A/s 3h = 10 A/s 4h = 15 A/s 5h = 25 A/s 6h = 50 A/s 7h = 100 A/s 8h = 150 A/s 9h = 200 A/s Ah = 250 A/s Bh = 500 A/s Ch = 1000 A/s Dh = 2000 A/s Eh = 5000 A/s Fh = No Limit A/s |

表 6-18. MOTOR_STARTUP1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|------------------------------|------|-------|--|
| 24-21 | ALIGN_TIME | R/W | 0h | Align time 0h = 10 ms 1h = 50 ms 2h = 100 ms 3h = 200 ms 4h = 300 ms 5h = 400 ms 6h = 500 ms 7h = 750 ms 8h = 1 s 9h = 1.5 s Ah = 2 s Bh = 3 s Ch = 4 s Dh = 5 s Eh = 7.5 s Fh = 10 s |
| 20-17 | ALIGN_OR_SLOW_CURRENT_ILIMIT | R/W | 0h | Align or slow first cycle current limit 0h = 0.078125 A 1h = 0.15625 A 2h = 0.3125 A 3h = 0.625 A 4h = 0.9375 A 5h = 1.25 A 6h = 1.5625 A 7h = 1.875 A 8h = 2.1875 A 9h = 2.5 A Ah = 2.8125 A Bh = 3.125 A Ch = 3.4375 A Dh = 3.75 A Eh = 4.375 A Fh = 5.0 A |
| 16-14 | IPD_CLK_FREQ | R/W | 0h | IPD clock frequency 0h = 50 Hz 1h = 100 Hz 2h = 250 Hz 3h = 500 Hz 4h = 1000 Hz 5h = 2000 Hz 6h = 5000 Hz 7h = 10000 Hz |

表 6-18. MOTOR_STARTUP1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|------------------|------|-------|--|
| 13-9 | IPD_CURR_THR | R/W | 0h | IPD current threshold 0h = 0.15625 A 1h = 0.3125 A 2h = 0.468 A 3h = 0.625 A 4h = 0.78125 A 5h = 0.9375 A 6h = 1.25 A 7h = 1.5625 A 8h = 1.875 A 9h = 2.291 A Ah = 2.5 A Bh = 2.916 A Ch = 3.125 A Dh = 3.333 A Eh = 3.75 A Fh = 4.166 A 10h = 4.583 A 11h = 5 A 12h = NA 13h = NA 14h = NA 15h = NA 16h = NA 17h = NA 18h = NA 19h = NA 1Ah = NA 1Bh = NA 1Ch = NA 1Dh = NA 1Eh = NA 1Fh = NA |
| 8 | IPD_RLS_MODE | R/W | 0h | IPD release mode 0h = Brake 1h = Tristate |
| 7-6 | IPD_ADV_ANGLE | R/W | 0h | IPD advance angle 0h = 0° 1h = 30° 2h = 60° 3h = 90° |
| 5-4 | IPD_REPEAT | R/W | 0h | Number of times IPD is executed 0h = 1 time 1h = average of 2 times 2h = average of 3 times 3h = average of 4 times |
| 3 | OL_ILIMIT_CONFIG | R/W | 0h | Open loop current limit configuration 0h = Open loop current limit defined by OL_ILIMIT 1h = Open loop current limit defined by ILIMIT |
| 2 | IQ_RAMP_EN | R/W | 0h | Iq ramp down after transition to close loop enable 0h = Disable Iq ramp down 1h = Enable Iq ramp down |
| 1 | ACTIVE_BRAKE_EN | R/W | 0h | Enables active braking during deceleration 0h = Disable Active Brake Reverse Drive 1h = Enable Active Brake Reverse Drive |
| 0 | REV_DRV_CONFIG | R/W | 0h | Chooses between forward and reverse drive setting for reverse drive 0h = Open loop current, A1, A2 based on forward drive 1h = Open loop current, A1, A2 based on reverse drive |

6.7.1.4 MOTOR_STARTUP2 Register (Offset = 86h) [Reset = 0000000h]

MOTOR_STARTUP2 is shown in [図 6-60](#) and described in [表 6-19](#).

Return to the [Summary Table](#).

Register to configure motor startup settings2

図 6-60. MOTOR_STARTUP2 Register

| | | | | | | | |
|---------------------|-----------|----|----|----------------------|-----------------------|--------------------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | OL_ILIMIT | | | | OL_ACC_A1 | | |
| R-0h | R/W-0h | | | | R/W-0h | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| OL_ACC_A1 | OL_ACC_A2 | | | | AUTO_HANDOFF_FF_EN | OPN_CL_HANDOFF_THR | |
| R/W-0h | R/W-0h | | | | R/W-0h | R/W-0h | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| OPN_CL_HANDOFF_THR | | | | ALIGN_ANGLE | | | |
| R/W-0h | | | | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SLOW_FIRST_CYC_FREQ | | | | FIRST_CYCLE_FREQ_SEL | THETA_ERROR_RAMP_RATE | | |
| R/W-0h | | | | R/W-0h | R/W-0h | | |

表 6-19. MOTOR_STARTUP2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-----------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-27 | OL_ILIMIT | R/W | 0h | Open loop current limit 0h = 0.078125 A 1h = 0.15625 A 2h = 0.3125 A 3h = 0.625 A 4h = 0.9375 A 5h = 1.25 A 6h = 1.5625 A 7h = 1.875 A 8h = 2.1875 A 9h = 2.5 A Ah = 2.8125 A Bh = 3.125 A Ch = 3.4375 A Dh = 3.75 A Eh = 4.375 A Fh = 5.0 A |

表 6-19. MOTOR_STARTUP2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|-----------------|------|-------|--|
| 26-23 | OL_ACC_A1 | R/W | 0h | Open loop acceleration coefficient A1 0h = 0.01 Hz/s 1h = 0.05 Hz/s 2h = 1 Hz/s 3h = 2.5 Hz/s 4h = 5 Hz/s 5h = 10 Hz/s 6h = 25 Hz/s 7h = 50 Hz/s 8h = 75 Hz/s 9h = 100 Hz/s Ah = 250 Hz/s Bh = 500 Hz/s Ch = 750 Hz/s Dh = 1000 Hz/s Eh = 5000 Hz/s Fh = 10000 Hz/s |
| 22-19 | OL_ACC_A2 | R/W | 0h | Open loop acceleration coefficient A2 0h = 0.0 Hz/s ² 1h = 0.05 Hz/s ² 2h = 1 Hz/s ² 3h = 2.5 Hz/s ² 4h = 5 Hz/s ² 5h = 10 Hz/s ² 6h = 25 Hz/s ² 7h = 50 Hz/s ² 8h = 75 Hz/s ² 9h = 100 Hz/s ² Ah = 250 Hz/s ² Bh = 500 Hz/s ² Ch = 750 Hz/s ² Dh = 1000 Hz/s ² Eh = 5000 Hz/s ² Fh = 10000 Hz/s ² |
| 18 | AUTO_HANDOFF_EN | R/W | 0h | Auto handoff enable 0h = Disable Auto Handoff (and use OPN_CL_HANDOFF_THR) 1h = Enable Auto Handoff |

表 6-19. MOTOR_STARTUP2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|--------------------|------|-------|--|
| 17-13 | OPN_CL_HANDOFF_THR | R/W | 0h | Open to close loop handoff threshold (% of MAX_SPEED) 0h = 1% 1h = 2% 2h = 3% 3h = 4% 4h = 5% 5h = 6% 6h = 7% 7h = 8% 8h = 9% 9h = 10% Ah = 11% Bh = 12% Ch = 13% Dh = 14% Eh = 15% Fh = 16% 10h = 17% 11h = 18% 12h = 19% 13h = 20% 14h = 22.5% 15h = 25% 16h = 27.5% 17h = 30% 18h = 32.5% 19h = 35% 1Ah = 37.5% 1Bh = 40% 1Ch = 42.5% 1Dh = 45% 1Eh = 47.5% 1Fh = 50% |

表 6-19. MOTOR_STARTUP2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|-----------------------|------|-------|---|
| 12-8 | ALIGN_ANGLE | R/W | 0h | Align angle 0h = 0° 1h = 10° 2h = 20° 3h = 30° 4h = 45° 5h = 60° 6h = 70° 7h = 80° 8h = 90° 9h = 110° Ah = 120° Bh = 135° Ch = 150° Dh = 160° Eh = 170° Fh = 180° 10h = 190° 11h = 210° 12h = 225° 13h = 240° 14h = 250° 15h = 260° 16h = 270° 17h = 280° 18h = 290° 19h = 315° 1Ah = 330° 1Bh = 340° 1Ch = 350° 1Dh = Reserved 1Eh = Reserved 1Fh = Reserved |
| 7-4 | SLOW_FIRST_CYC_FREQ_Q | R/W | 0h | Frequency of first cycle in close loop start-up (% of MAX_SPEED) 0h = 1% 1h = 2% 2h = 3% 3h = 5% 4h = 7.5% 5h = 10% 6h = 12.5% 7h = 15% 8h = 17.5% 9h = 20% Ah = 25% Bh = 30% Ch = 35% Dh = 40% Eh = 45% Fh = 50% |
| 3 | FIRST_CYCLE_FREQ_SEL | R/W | 0h | First cycle frequency in open loop for align, double align and IPD start-up options 0h = 0 Hz 1h = Defined by SLOW_FIRST_CYC_FREQ |

表 6-19. MOTOR_STARTUP2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|-----------------------|------|-------|--|
| 2-0 | THETA_ERROR_RAMP_RATE | R/W | 0h | Ramp rate for reducing difference between estimated theta and open loop theta 0h = 0.01 deg/ms 1h = 0.05 deg/ms 2h = 0.1 deg/ms 3h = 0.15 deg/ms 4h = 0.2 deg / ms 5h = 0.5 deg/ms 6h = 1 deg/ms 7h = 2 deg/ms |

6.7.1.5 CLOSED_LOOP1 Register (Offset = 88h) [Reset = 00000000h]

CLOSED_LOOP1 is shown in [図 6-61](#) and described in [表 6-20](#).

Return to the [Summary Table](#).

Register to configure close loop settings1

図 6-61. CLOSED_LOOP1 Register

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
|--------------|-----------------------|--------|--------|------------------|----------------|---------------|------|
| RESERVED | OVERMODULATION_ENABLE | CL_ACC | | | | CL_DEC_CONFIG | |
| R-0h | R/W-0h | R/W-0h | | | | R/W-0h | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| CL_DEC | | | | PWM_FREQ_OUT | | | |
| R/W-0h | | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PWM_FREQ_OUT | PWM_MODE | FG_SEL | | FG_DIV | | | |
| R/W-0h | R/W-0h | R/W-0h | | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FG_CONFIG | FG_BEMF_THR | | AVS_EN | DEADTIME_COMP_EN | SPEED_LOOP_DIS | RESERVED | |
| R/W-0h | R/W-0h | | R/W-0h | R/W-0h | R/W-0h | R/W-0h | R-0h |

表 6-20. CLOSED_LOOP1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|-----------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30 | OVERMODULATION_ENABLE | R/W | 0h | Overmodulation enable 0h = Disable overmodulation 1h = Enable overmodulation |

表 6-20. CLOSED_LOOP1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|---------------|------|-------|--|
| 29-25 | CL_ACC | R/W | 0h | Closed loop acceleration 0h = 0.5 Hz/s 1h = 1 Hz/s 2h = 2.5 Hz/s 3h = 5 Hz/s 4h = 7.5 Hz/s 5h = 10 Hz/s 6h = 20 Hz/s 7h = 40 Hz/s 8h = 60 Hz/s 9h = 80 Hz/s Ah = 100 Hz/s Bh = 200 Hz/s Ch = 300 Hz/s Dh = 400 Hz/s Eh = 500 Hz/s Fh = 600 Hz/s 10h = 700 Hz/s 11h = 800 Hz/s 12h = 900 Hz/s 13h = 1000 Hz/s 14h = 2000 Hz/s 15h = 4000 Hz/s 16h = 6000 Hz/s 17h = 8000 Hz/s 18h = 10000 Hz/s 19h = 20000 Hz/s 1Ah = 30000 Hz/s 1Bh = 40000 Hz/s 1Ch = 50000 Hz/s 1Dh = 60000 Hz/s 1Eh = 70000 Hz/s 1Fh = No limit |
| 24 | CL_DEC_CONFIG | R/W | 0h | Closed loop deceleration configuration 0h = Closed loop deceleration defined by CL_DEC 1h = Closed loop deceleration defined by CL_ACC |

表 6-20. CLOSED_LOOP1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|--------------|------|-------|--|
| 23-19 | CL_DEC | R/W | 0h | Closed loop deceleration. This register is used only if AVS is disabled and CL_DEC_CONFIG is set to '0b' 0h = 0.5 Hz/s 1h = 1 Hz/s 2h = 2.5 Hz/s 3h = 5 Hz/s 4h = 7.5 Hz/s 5h = 10 Hz/s 6h = 20 Hz/s 7h = 40 Hz/s 8h = 60 Hz/s 9h = 80 Hz/s Ah = 100 Hz/s Bh = 200 Hz/s Ch = 300 Hz/s Dh = 400 Hz/s Eh = 500 Hz/s Fh = 600 Hz/s 10h = 700 Hz/s 11h = 800 Hz/s 12h = 900 Hz/s 13h = 1000 Hz/s 14h = 2000 Hz/s 15h = 4000 Hz/s 16h = 6000 Hz/s 17h = 8000 Hz/s 18h = 10000 Hz/s 19h = 20000 Hz/s 1Ah = 30000 Hz/s 1Bh = 40000 Hz/s 1Ch = 50000 Hz/s 1Dh = 60000 Hz/s 1Eh = 70000 Hz/s 1Fh = No limit |
| 18-15 | PWM_FREQ_OUT | R/W | 0h | PWM output frequency 0h = Reserved 1h = 15 kHz 2h = 20 kHz 3h = 25 kHz 4h = 30 kHz 5h = 35 kHz 6h = 40 kHz 7h = 45 kHz 8h = 50 kHz 9h = 55 kHz Ah = 60 kHz Bh = Reserved Ch = Reserved Dh = Reserved Eh = Reserved Fh = Reserved |
| 14 | PWM_MODE | R/W | 0h | PWM modulation 0h = Continuous Space Vector Modulation 1h = Discontinuous Space Vector Modulation |
| 13-12 | FG_SEL | R/W | 0h | FG select 0h = Output FG in open loop and closed loop 1h = Output FG in only closed loop 2h = Output FG in open loop for the first try. 3h = Reserved |

表 6-20. CLOSED_LOOP1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|------------------|------|-------|--|
| 11-8 | FG_DIV | R/W | 0h | FG division factor 0h = Divide by 1 (2-pole motor mechanical speed) 1h = Divide by 1 (2-pole motor mechanical speed) 2h = Divide by 2 (4-pole motor mechanical speed) 3h = Divide by 3 (6-pole motor mechanical speed) 4h = Divide by 4 (8-pole motor mechanical speed) ... Fh = Divide by 15 (30-pole motor mechanical speed) |
| 7 | FG_CONFIG | R/W | 0h | FG output configuration 0h = FG active as long as motor is driven 1h = FG active till BEMF drops below BEMF threshold defined by FG_BEMF_THR |
| 6-4 | FG_BEMF_THR | R/W | 0h | FG output BEMF threshold 0h = +/- 1mV 1h = +/- 2mV 2h = +/- 5mV 3h = +/- 10mV 4h = +/- 20mV 5h = +/- 30mV 6h = Reserved 7h = Reserved |
| 3 | AVS_EN | R/W | 0h | AVS enable 0h = Disable 1h = Enable |
| 2 | DEADTIME_COMP_EN | R/W | 0h | Deadtime compensation enable 0h = Disable 1h = Enable |
| 1 | SPEED_LOOP_DIS | R/W | 0h | Speed loop disable 0h = Enable 1h = Disable |
| 0 | RESERVED | R | 0h | Reserved |

6.7.1.6 CLOSED_LOOP2 Register (Offset = 8Ah) [Reset = 0000XXXh]

CLOSED_LOOP2 is shown in [図 6-62](#) and described in [表 6-21](#).

Return to the [Summary Table](#).

Register to configure close loop settings2

図 6-62. CLOSED_LOOP2 Register

| | | | | | | | |
|--------------|----------|----|----|-----------------------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | MTR_STOP | | | MTR_STOP_BRK_TIME | | | |
| R-0h | R/W-0h | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| ACT_SPIN_THR | | | | BRAKE_SPEED_THRESHOLD | | | |
| R/W-0h | | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| MOTOR_RES | | | | | | | |
| R/W-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MOTOR_IND | | | | | | | |
| R/W-0h | | | | | | | |

表 6-21. CLOSED_LOOP2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-------------------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-28 | MTR_STOP | R/W | 0h | Motor stop mode 0h = Hi-Z 1h = Reserved 2h = Low side braking 3h = Reserved 4h = Active spin down 5h = Reserved 6h = Reserved 7h = Reserved |
| 27-24 | MTR_STOP_BRK_TIME | R/W | 0h | Brake time during motor stop 0h = 1 ms 1h = 1 ms 2h = 1 ms 3h = 1 ms 4h = 1 ms 5h = 5 ms 6h = 10 ms 7h = 50 ms 8h = 100 ms 9h = 250 ms Ah = 500 ms Bh = 1000 ms Ch = 2500 ms Dh = 5000 ms Eh = 10000 ms Fh = 15000 ms |

表 6-21. CLOSED_LOOP2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|---------------------------|------|-------|--|
| 23-20 | ACT_SPIN_THR | R/W | 0h | Speed threshold for active spin down (% of MAX_SPEED) 0h = 100 % 1h = 90 % 2h = 80 % 3h = 70 % 4h = 60% 5h = 50 % 6h = 45 % 7h = 40 % 8h = 35 % 9h = 30 % Ah = 25 % Bh = 20 % Ch = 15 % Dh = 10 % Eh = 5 % Fh = 2.5 % |
| 19-16 | BRAKE_SPEED_THRES HOLD | R/W | 0h | Speed threshold for BRAKE pin and motor stop options (low side braking or high side braking) (% of MAX_SPEED) 0h = 100 % 1h = 90 % 2h = 80 % 3h = 70 % 4h = 60% 5h = 50 % 6h = 45 % 7h = 40 % 8h = 35 % 9h = 30 % Ah = 25 % Bh = 20 % Ch = 15 % Dh = 10 % Eh = 5 % Fh = 2.5 % |
| 15-8 | MOTOR_RES | R/W | 0h | 8-bit values for motor phase resistance See 表 6-2 for values of phase resistance |
| 7-0 | MOTOR_IND | R/W | 0h | 8-bit values for motor phase inductance See 表 6-3 for values of phase inductance |

6.7.1.7 CLOSED_LOOP3 Register (Offset = 8Ch) [Reset = XXX0000h]

CLOSED_LOOP3 is shown in [図 6-63](#) and described in [表 6-22](#).

Return to the [Summary Table](#).

Register to configure close loop settings3

図 6-63. CLOSED_LOOP3 Register

| | | | | | | | |
|------------------|------------------|----|----|--------------|-------------|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | MOTOR_BEMF_CONST | | | | | | |
| R-0h | | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| MOTOR_BEMF_CONST | CURR_LOOP_KP | | | | | | |
| R/W-0h | | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| CURR_LOOP_KP | | | | CURR_LOOP_KI | | | |
| R/W-0h | | | | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CURR_LOOP_KI | | | | | SPD_LOOP_KP | | |
| R/W-0h | | | | | R/W-0h | | |

表 6-22. CLOSED_LOOP3 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-23 | MOTOR_BEMF_CONST | R/W | 0h | 8-bit values for motor BEMF Constant See 表 6-4 for values of BEMF constant |
| 22-13 | CURR_LOOP_KP | R/W | 0h | 10-bit value for current Iq and Id loop Kp. $K_p = 8\text{LSB of CURR_LOOP_KP} / 10^2\text{MSB of CURR_LOOP_KP}$. Set to 0 for auto calculation of current Kp and Ki |
| 12-3 | CURR_LOOP_KI | R/W | 0h | 10-bit value for current Iq and Id loop Ki. $K_i = 1000 * 8\text{LSB of CURR_LOOP_KI} / 10^2\text{MSB of CURR_LOOP_KI}$. Set to 0 for auto calculation of current Kp and Ki |
| 2-0 | SPD_LOOP_KP | R/W | 0h | 3 MSB bits for speed loop Kp. $K_p = 0.01 * 8\text{LSB of SPD_LOOP_KP} / 10^2\text{MSB of SPD_LOOP_KP}$ |

6.7.1.8 CLOSED_LOOP4 Register (Offset = 8Eh) [Reset = 0000XXXXh]

CLOSED_LOOP4 is shown in [図 6-64](#) and described in [表 6-23](#).

Return to the [Summary Table](#).

Register to configure close loop settings4

図 6-64. CLOSED_LOOP4 Register

| | | | | | | | |
|-------------|----|-------------|----|-----------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | | SPD_LOOP_KP | | | | | |
| R-0h | | R/W-0h | | | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| SPD_LOOP_KI | | | | | | | |
| R/W-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SPD_LOOP_KI | | | | MAX_SPEED | | | |
| R/W-0h | | | | R/W-X | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MAX_SPEED | | | | | | | |
| R/W-X | | | | | | | |

表 6-23. CLOSED_LOOP4 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-------------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-24 | SPD_LOOP_KP | R/W | 0h | 7 LSB bits for speed loop Kp. $K_p = 0.01 * 8\text{LSB of SPD_LOOP_KP} / 10^2\text{MSB of SPD_LOOP_KP}$ |
| 23-14 | SPD_LOOP_KI | R/W | 0h | 10 bit value for speed loop Ki. $K_i = 0.1 * 8\text{LSB of SPD_LOOP_KI} / 10^2\text{MSB of SPD_LOOP_KI}$ |
| 13-0 | MAX_SPEED | R/W | X | 14-bit value for setting maximum value of Speed in electrical Hz Maximum motor electrical speed (Hz): $\{\text{MOTOR_SPEED}/6\}$ For example: if MOTOR_SPEED is 0x2710, then maximum motor speed (Hz) = $10000(0x2710)/6 = 1666$ Hz |

6.7.1.9 SPEED_PROFILES1 Register (Offset = 94h) [Reset = 0000000h]

SPEED_PROFILES1 is shown in [図 6-65](#) and described in [表 6-24](#).

Return to the [Summary Table](#).

Register to configure speed profile1

図 6-65. SPEED_PROFILES1 Register

| | | | | | | | |
|-------------|--------------------|----|-------------|----------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | REF_PROFILE_CONFIG | | | DUTY_ON1 | | | |
| R-0h | R/W-0h | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| DUTY_ON1 | | | DUTY_OFF1 | | | | |
| R/W-0h | | | R/W-0h | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DUTY_OFF1 | | | DUTY_CLAMP1 | | | | |
| R/W-0h | | | R/W-0h | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DUTY_CLAMP1 | | | DUTY_A | | | | |
| R/W-0h | | | R/W-0h | | | | |

表 6-24. SPEED_PROFILES1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|--------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-29 | REF_PROFILE_CONFIG | R/W | 0h | Configuration for reference profiles 0h = Speed/current reference mode 1h = Linear profile 2h = Staircase profile 3h = Forward-reverse profile |
| 28-21 | DUTY_ON1 | R/W | 0h | Duty_ON1 configuration Turn-on duty cycle (%) = {(DUTY_ON1/255)*100} |
| 20-13 | DUTY_OFF1 | R/W | 0h | Duty_OFF1 configuration Turn-off duty cycle (%) = {(DUTY_OFF1/255)*100} |
| 12-5 | DUTY_CLAMP1 | R/W | 0h | Duty_CLAMP1 configuration Duty cycle for clamping speed (%) = {(DUTY_CLAMP1/255)*100} |
| 4-0 | DUTY_A | R/W | 0h | 5 MSB bits for duty cycle A |

6.7.1.10 SPEED_PROFILES2 Register (Offset = 96h) [Reset = 0000000h]

SPEED_PROFILES2 is shown in [図 6-66](#) and described in [表 6-25](#).

Return to the [Summary Table](#).

Register to configure speed profile2

図 6-66. SPEED_PROFILES2 Register

| | | | | | | | |
|----------|--------|----|--------|--------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | DUTY_A | | | DUTY_B | | | |
| R-0h | R/W-0h | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| DUTY_B | | | DUTY_C | | | | |
| R/W-0h | | | R/W-0h | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DUTY_C | | | DUTY_D | | | | |
| R/W-0h | | | R/W-0h | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DUTY_D | | | DUTY_E | | | | |
| R/W-0h | | | R/W-0h | | | | |

表 6-25. SPEED_PROFILES2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|----------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-28 | DUTY_A | R/W | 0h | 3 LSB bits for duty cycle A Duty_A configuration Duty cycle A (%) = $\{(DUTY_A/255)*100\}$ |
| 27-20 | DUTY_B | R/W | 0h | Duty_B configuration Duty cycle B (%) = $\{(DUTY_B/255)*100\}$ |
| 19-12 | DUTY_C | R/W | 0h | Duty_C configuration Duty cycle C (%) = $\{(DUTY_C/255)*100\}$ |
| 11-4 | DUTY_D | R/W | 0h | Duty_D configuration Duty cycle D (%) = $\{(DUTY_D/255)*100\}$ |
| 3-0 | DUTY_E | R/W | 0h | 4 MSB bits for Duty cycle E |

6.7.1.11 SPEED_PROFILES3 Register (Offset = 98h) [Reset = 0000000h]

SPEED_PROFILES3 is shown in [図 6-67](#) and described in [表 6-26](#).

Return to the [Summary Table](#).

Register to configure speed profile3

図 6-67. SPEED_PROFILES3 Register

| | | | | | | | |
|-------------|--------|----|----|-------------|----------|----------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | DUTY_E | | | | DUTY_ON2 | | |
| R-0h | R/W-0h | | | | R/W-0h | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| DUTY_ON2 | | | | DUTY_OFF2 | | | |
| R/W-0h | | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DUTY_OFF2 | | | | DUTY_CLAMP2 | | | |
| R/W-0h | | | | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DUTY_CLAMP2 | | | | DUTY_HYS | | RESERVED | |
| R/W-0h | | | | R/W-0h | | R-0h | |

表 6-26. SPEED_PROFILES3 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-27 | DUTY_E | R/W | 0h | 4 LSB bits for Duty cycle E Duty_E configuration Duty cycle E (%) = $\{(DUTY_E/255)*100\}$ |
| 26-19 | DUTY_ON2 | R/W | 0h | Duty_ON2 configuration Turn-on duty cycle (%) = $\{(DUTY_ON2/255)*100\}$ |
| 18-11 | DUTY_OFF2 | R/W | 0h | Duty_OFF2 configuration Turn-off duty cycle (%) = $\{(DUTY_OFF2/255)*100\}$ |
| 10-3 | DUTY_CLAMP2 | R/W | 0h | Duty_CLAMP2 configuration Duty cycle for clamping speed (%) = $\{(DUTY_CLAMP1/255)*100\}$ |
| 2-1 | DUTY_HYS | R/W | 0h | Duty hysteresis for speed/current reference mode 0h = 0% 1h = 0.5% 2h = 1% 3h = 2% |
| 0 | RESERVED | R | 0h | Reserved |

6.7.1.12 SPEED_PROFILES4 Register (Offset = 9Ah) [Reset = 0000000h]

SPEED_PROFILES4 is shown in [図 6-68](#) and described in [表 6-27](#).

Return to the [Summary Table](#).

Register to configure speed profile4

図 6-68. SPEED_PROFILES4 Register

| | | | | | | | |
|--------------|--------------|----|----|--------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | SPEED_OFF1 | | | | | | |
| R-0h | | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| SPEED_OFF1 | SPEED_CLAMP1 | | | | | | |
| R/W-0h | | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SPEED_CLAMP1 | SPEED_A | | | | | | |
| R/W-0h | | | | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SPEED_A | SPEED_B | | | | | | |
| R/W-0h | | | | R/W-0h | | | |

表 6-27. SPEED_PROFILES4 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|--------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-23 | SPEED_OFF1 | R/W | 0h | Turn off speed configuration Turn off speed (% of MAX_SPEED) = $\{(SPEED_OFF1/255)*100\}$ |
| 22-15 | SPEED_CLAMP1 | R/W | 0h | Clamp speed configuration Clamp speed (% of MAX_SPEED) = $\{(SPEED_CLAMP1/255)*100\}$ |
| 14-7 | SPEED_A | R/W | 0h | Speed A configuration SPEED A (% of MAX_SPEED) = $\{(SPEED_A/255)*100\}$ |
| 6-0 | SPEED_B | R/W | 0h | 7 MSB of SPEED_B configuration |

6.7.1.13 SPEED_PROFILES5 Register (Offset = 9Ch) [Reset = 0000000h]

SPEED_PROFILES5 is shown in [図 6-69](#) and described in [表 6-28](#).

Return to the [Summary Table](#).

Register to configure speed profile5

図 6-69. SPEED_PROFILES5 Register

| | | | | | | | |
|----------|---------|----------|----|----|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | SPEED_B | SPEED_C | | | | | |
| R-0h | R/W-0h | R/W-0h | | | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| SPEED_C | | SPEED_D | | | | | |
| R/W-0h | | R/W-0h | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SPEED_D | | SPEED_E | | | | | |
| R/W-0h | | R/W-0h | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SPEED_E | | RESERVED | | | | | |
| R/W-0h | | R-0h | | | | | |

表 6-28. SPEED_PROFILES5 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|----------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30 | SPEED_B | R/W | 0h | 1 LSB of SPEED_B configuration Speed B configuration $SPEED_B(\% \text{ of } MAX_SPEED) = \{(SPEED_B/255)*100\}$ |
| 29-22 | SPEED_C | R/W | 0h | Speed C configuration SPEED C (% of MAX_SPEED) = $\{(SPEED_A/255)*100\}$ |
| 21-14 | SPEED_D | R/W | 0h | Speed D configuration SPEED D (% of MAX_SPEED) = $\{(SPEED_D/255)*100\}$ |
| 13-6 | SPEED_E | R/W | 0h | Speed E configuration SPEED E(% of MAX_SPEED) = $\{(SPEED_E/255)*100\}$ |
| 5-0 | RESERVED | R | 0h | Reserved |

6.7.1.14 SPEED_PROFILES6 Register (Offset = 9Eh) [Reset = 0000000h]

SPEED_PROFILES6 is shown in 図 6-70 and described in 表 6-29.

Return to the [Summary Table](#).

Register to configure speed profile6

図 6-70. SPEED_PROFILES6 Register

| | | | | | | | |
|--------------|--------------|----|----|--------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | SPEED_OFF2 | | | | | | |
| R-0h | | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| SPEED_OFF2 | SPEED_CLAMP2 | | | | | | |
| R/W-0h | | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SPEED_CLAMP2 | RESERVED | | | | | | |
| R/W-0h | | | | R-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |

表 6-29. SPEED_PROFILES6 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|--------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-23 | SPEED_OFF2 | R/W | 0h | Turn off speed configuration Turn off speed (% of MAX_SPEED) = $\{(SPEED_OFF2/255)*100\}$ |
| 22-15 | SPEED_CLAMP2 | R/W | 0h | Clamp speed configuration Clamp Speed (% of MAX_SPEED) = $\{(SPEED_CLAMP2/255)*100\}$ |
| 14-0 | RESERVED | R | 0h | Reserved |

6.7.2 Fault_Configuration Registers

表 6-30 lists the memory-mapped registers for the Fault_Configuration registers. All register offset addresses not listed in 表 6-30 should be considered as reserved locations and the register contents should not be modified.

表 6-30. FAULT_CONFIGURATION Registers

| Offset | Acronym | Register Name | Section |
|--------|---------------|----------------------|-------------------------------|
| 90h | FAULT_CONFIG1 | Fault Configuration1 | セクション 6.7.2.1 |
| 92h | FAULT_CONFIG2 | Fault Configuration2 | セクション 6.7.2.2 |

Complex bit access types are encoded to fit into small table cells. 表 6-31 shows the codes that are used for access types in this section.

表 6-31. Fault_Configuration Access Type Codes

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

表 6-31. Fault_Configuration Access Type Codes (続
き)

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

6.7.2.1 FAULT_CONFIG1 Register (Offset = 90h) [Reset = 00000000h]

FAULT_CONFIG1 is shown in [図 6-71](#) and described in [表 6-32](#).

Return to the [Summary Table](#).

Register to configure fault settings1

図 6-71. FAULT_CONFIG1 Register

| | | | | | | | |
|------------------|-----------------|----|----|----------------------|-------------------|---------------------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | ILIMIT | | | HW_LOCK_ILIMIT | | | |
| R-0h | R/W-0h | | | R/W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| HW_LOCK_ILIMIT | LOCK_ILIMIT | | | LOCK_ILIMIT_MODE | | | |
| R/W-0h | R/W-0h | | | R/W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| LOCK_ILIMIT_MODE | LOCK_ILIMIT_DEG | | | LCK_RETRY | | | |
| R/W-0h | R/W-0h | | | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| LCK_RETRY | MTR_LCK_MODE | | | IPD_TIMEOUT_FAULT_EN | IPD_FREQ_FAULT_EN | SATURATION_FLAGS_EN | |
| R/W-0h | R/W-0h | | | R/W-0h | R/W-0h | R/W-0h | |

表 6-32. FAULT_CONFIG1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|----------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-27 | ILIMIT | R/W | 0h | Reference for torque PI loop 0h = 0.078125 A 1h = 0.15625 A 2h = 0.3125 A 3h = 0.625 A 4h = 0.9375 A 5h = 1.25 A 6h = 1.5625 A 7h = 1.875 A 8h = 2.1875 A 9h = 2.5 A Ah = 2.8125 A Bh = 3.125 A Ch = 3.4375 A Dh = 3.75 A Eh = 4.375 A Fh = 5.0 A |

表 6-32. FAULT_CONFIG1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|----------------|------|-------|--|
| 26-23 | HW_LOCK_ILIMIT | R/W | 0h | Comparator based lock detection current limit 0h = 0.078125 A 1h = 0.15625 A 2h = 0.3125 A 3h = 0.625 A 4h = 0.9375 A 5h = 1.25 A 6h = 1.5625 A 7h = 1.875 A 8h = 2.1875 A 9h = 2.5 A Ah = 2.8125 A Bh = 3.125 A Ch = 3.4375 A Dh = 3.75 A Eh = 4.375 A Fh = 5.0 A |
| 22-19 | LOCK_ILIMIT | R/W | 0h | ADC based lock detection current threshold 0h = 0.078125 A 1h = 0.15625 A 2h = 0.3125 A 3h = 0.625 A 4h = 0.9375 A 5h = 1.25 A 6h = 1.5625 A 7h = 1.875 A 8h = 2.1875 A 9h = 2.5 A Ah = 2.8125 A Bh = 3.125 A Ch = 3.4375 A Dh = 3.75 A Eh = 4.375 A Fh = 5.0 A |

表 6-32. FAULT_CONFIG1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|------------------|------|-------|--|
| 18-15 | LOCK_ILIMIT_MODE | R/W | 0h | <p>Lock current limit mode</p> <p>0h = Ilimit lock detection causes latched fault; nFAULT active; Gate driver is tristated</p> <p>1h = Ilimit lock detection causes latched fault; nFAULT active; Gate driver is tristated</p> <p>2h = Ilimit lock detection causes latched fault; nFAULT active; Gate driver is in high side brake mode (all high side FETs are turned ON)</p> <p>3h = Ilimit lock detection causes latched fault; nFAULT active; Gate driver is in low side brake mode (all low side FETs are turned ON)</p> <p>4h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is tristated; nFAULT active</p> <p>5h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is tristated; nFAULT active</p> <p>6h = Fault automatically cleared for AUTO_RETRY_TIMES after LCK_RETRY time; Gate driver is in high side brake mode (All high side FETs are turned ON); nFAULT active</p> <p>7h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is in low side brake mode (All low side FETs are turned ON); nFAULT active</p> <p>8h = Ilimit lock detection current limit is in report only but no action is taken; nFAULT active</p> <p>9h = ILIMIT LOCK is disabled</p> <p>Ah = ILIMIT LOCK is disabled</p> <p>Bh = ILIMIT LOCK is disabled</p> <p>Ch = ILIMIT LOCK is disabled</p> <p>Dh = ILIMIT LOCK is disabled</p> <p>Eh = ILIMIT LOCK is disabled</p> <p>Fh = ILIMIT LOCK is disabled</p> |
| 14-11 | LOCK_ILIMIT_DEG | R/W | 0h | <p>Lock current limit detection deglitch time</p> <p>0h = 0.05 ms</p> <p>1h = 0.1 ms</p> <p>2h = 0.2 ms</p> <p>3h = 0.5 ms</p> <p>4h = 1 ms</p> <p>5h = 2.5 ms</p> <p>6h = 5 ms</p> <p>7h = 7.5 ms</p> <p>8h = 10 ms</p> <p>9h = 25 ms</p> <p>Ah = 50 ms</p> <p>Bh = 75 ms</p> <p>Ch = 100 ms</p> <p>Dh = 200 ms</p> <p>Eh = 500 ms</p> <p>Fh = 1000 ms</p> |

表 6-32. FAULT_CONFIG1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|----------------------|------|-------|---|
| 10-7 | LCK_RETRY | R/W | 0h | Lock detection retry time 0h = 300 ms 1h = 500 ms 2h = 1 s 3h = 2 s 4h = 3 s 5h = 4 s 6h = 5 s 7h = 6 s 8h = 7 s 9h = 8 s Ah = 9 s Bh = 10 s Ch = 11 s Dh = 12 s Eh = 13 s Fh = 14 s |
| 6-3 | MTR_LCK_MODE | R/W | 0h | Motor lock mode 0h = Motor lock detection causes latched fault; nFAULT active; Gate driver is tristated 1h = Motor lock detection causes latched fault; nFAULT active; Gate driver is tristated 2h = Motor lock detection causes latched fault; nFAULT active; Gate driver is in high side brake mode (All high side FETs are turned ON) 3h = Motor lock detection causes latched fault; nFAULT active; Gate driver is in low side brake mode (All low side FETs are turned ON) 4h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is tristated; nFAULT active 5h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is tristated; nFAULT active 6h = Fault automatically cleared for AUTO_RETRY_TIMES after LCK_RETRY time; Gate driver is in high side brake mode (All high side FETs are turned ON); nFAULT active 7h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is in low side brake mode (All low side FETs are turned ON); nFAULT active 8h = Motor lock detection current limit is in report only but no action is taken; nFAULT active 9h = Motor lock detection is disabled Ah = Motor lock detection is disabled Bh = Motor lock detection is disabled Ch = Motor lock detection is disabled Dh = Motor lock detection is disabled Eh = Motor lock detection is disabled Fh = Motor lock detection is disabled |
| 2 | IPD_TIMEOUT_FAULT_EN | R/W | 0h | IPD timeout fault enable 0h = Disable 1h = Enable |
| 1 | IPD_FREQ_FAULT_EN | R/W | 0h | IPD frequency fault enable 0h = Disable 1h = Enable |
| 0 | SATURATION_FLAGS_EN | R/W | 0h | Enable indication of current loop and speed loop saturation 0h = Disable 1h = Enable |

6.7.2.2 FAULT_CONFIG2 Register (Offset = 92h) [Reset = 0000000h]

FAULT_CONFIG2 is shown in [図 6-72](#) and described in [表 6-33](#).

Return to the [Summary Table](#).

Register to configure fault settings2

図 6-72. FAULT_CONFIG2 Register

| | | | | | | | |
|---------------------|--------------------|------------|----------|----------------|---------------------|----|-------------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | LOCK1_EN | LOCK2_EN | LOCK3_EN | LOCK_ABN_SPEED | | | ABNORMAL_BEMF_THR |
| R-0h | R/W-0h | R/W-0h | R/W-0h | R/W-0h | | | R/W-0h |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| ABNORMAL_BEMF_THR | | NO_MTR_THR | | | HW_LOCK_ILIMIT_MODE | | |
| R/W-0h | | R/W-0h | | | R/W-0h | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| HW_LOCK_ILIMIT_MODE | HW_LOCK_ILIMIT_DEG | | | RESERVED | MIN_VM_MOTOR | | |
| R/W-0h | R/W-0h | | | R-0h | R/W-0h | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MIN_VM_MODE | MAX_VM_MOTOR | | | MAX_VM_MODE | AUTO_RETRY_TIMES | | |
| R/W-0h | R/W-0h | | | R/W-0h | R/W-0h | | |

表 6-33. FAULT_CONFIG2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30 | LOCK1_EN | R/W | 0h | Lock 1 (Abnormal Speed) Enable 0h = Disable 1h = Enable |
| 29 | LOCK2_EN | R/W | 0h | Lock 2 (Abnormal BEMF) Enable 0h = Disable 1h = Enable |
| 28 | LOCK3_EN | R/W | 0h | Lock 3 (No Motor) Enable 0h = Disable 1h = Enable |
| 27-25 | LOCK_ABN_SPEED | R/W | 0h | Abnormal speed lock threshold (% of MAX_SPEED) 0h = 130% 1h = 140% 2h = 150% 3h = 160% 4h = 170% 5h = 180% 6h = 190% 7h = 200% |
| 24-22 | ABNORMAL_BEMF_THR | R/W | 0h | Abnormal BEMF lock threshold (% of expected BEMF) 0h = 40% 1h = 45% 2h = 50% 3h = 55% 4h = 60% 5h = 65% 6h = 67.5% 7h = 70% |

表 6-33. FAULT_CONFIG2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|---------------------|------|-------|---|
| 21-19 | NO_MTR_THR | R/W | 0h | No motor lock threshold 0h = 0.0468 A 1h = 0.0468 A 2h = 0.0625A 3h = 0.078 A 4h = 0.156 A 5h = 0.312 A 6h = 0.468 A 7h = 0.625 A |
| 18-15 | HW_LOCK_ILIMIT_MODE | R/W | 0h | Hardware lock current limit mode 0h = Hardware Ilimit lock detection causes latched fault; nFAULT active; Gate driver is tristated 1h = Hardware Ilimit lock detection causes latched fault; nFAULT active; Gate driver is tristated 2h = Hardware Ilimit lock detection causes latched fault; nFAULT active; Gate driver is in high side brake mode (All high side FETs are turned ON) 3h = Hardware Ilimit lock detection causes latched fault; nFAULT active; Gate driver is in low side brake mode (All low side FETs are turned ON) 4h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is tristated 5h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is tristated 6h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is in high side brake mode (All high side FETs are turned ON) 7h = Fault automatically cleared after LCK_RETRY time. Number of retries limited to AUTO_RETRY_TIMES. If number of retries exceed AUTO_RETRY_TIMES, fault is latched; Gate driver is in low side brake mode (All low side FETs are turned ON) 8h = Hardware ILIMIT lock detection is in report only but no action is taken 9h = Hardware ILIMIT lock detection is disabled Ah = Hardware ILIMIT lock detection is disabled Bh = Hardware ILIMIT lock detection is disabled Ch = Hardware ILIMIT lock detection is disabled Dh = Hardware ILIMIT lock detection is disabled Eh = Hardware ILIMIT lock detection is disabled Fh = Hardware ILIMIT lock detection is disabled |
| 14-12 | HW_LOCK_ILIMIT_DEG | R/W | 0h | Hardware lock current limit detection deglitch time 0h = No deglitch 1h = 1 μ s 2h = 2 μ s 3h = 3 μ s 4h = 4 μ s 5h = 5 μ s 6h = 6 μ s 7h = 7 μ s |
| 11 | RESERVED | R | 0h | Reserved |
| 10-8 | MIN_VM_MOTOR | R/W | 0h | Minimum voltage for running motor 0h = No Limit 1h = 4.5 V 2h = 5 V 3h = 5.5 V 4h = 6 V 5h = 7.5 V 6h = 10 V 7h = 12.5 V |

表 6-33. FAULT_CONFIG2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|------------------|------|-------|---|
| 7 | MIN_VM_MODE | R/W | 0h | Undervoltage fault recovery mode 0h = Latch on undervoltage 1h = Automatic clear if voltage in bounds |
| 6-4 | MAX_VM_MOTOR | R/W | 0h | Maximum voltage for running motor 0h = No Limit 1h = 20 V 2h = 22.5 V 3h = 25 V 4h = 27.5 V 5h = 30 V 6h = 32.5 V 7h = 35 V |
| 3 | MAX_VM_MODE | R/W | 0h | Overvoltage fault recovery mode 0h = Latch on overvoltage 1h = Automatic clear if voltage in bounds |
| 2-0 | AUTO_RETRY_TIMES | R/W | 0h | Automatic retry attempts 0h = No Limit 1h = 2 2h = 3 3h = 5 4h = 7 5h = 10 6h = 15 7h = 20 |

6.7.3 Hardware_Configuration Registers

表 6-34 lists the memory-mapped registers for the Hardware_Configuration registers. All register offset addresses not listed in 表 6-34 should be considered as reserved locations and the register contents should not be modified.

表 6-34. HARDWARE_CONFIGURATION Registers

| Offset | Acronym | Register Name | Section |
|--------|----------------|----------------------------|-------------------------------|
| A4h | PIN_CONFIG | Hardware Pin Configuration | セクション 6.7.3.1 |
| A6h | DEVICE_CONFIG1 | Device configuration1 | セクション 6.7.3.2 |
| A8h | DEVICE_CONFIG2 | Device configuration2 | セクション 6.7.3.3 |
| AAh | PERI_CONFIG1 | Peripheral Configuration1 | セクション 6.7.3.4 |
| ACh | GD_CONFIG1 | Gate Driver Configuration1 | セクション 6.7.3.5 |
| A Eh | GD_CONFIG2 | Gate Driver Configuration2 | セクション 6.7.3.6 |

Complex bit access types are encoded to fit into small table cells. 表 6-35 shows the codes that are used for access types in this section.

表 6-35. Hardware_Configuration Access Type Codes

| Access Type | Code | Description |
|------------------------|---------|---------------------|
| Read Type | | |
| R | R | Read |
| Write Type | | |
| W | W | Write |
| W1C | W 1C | Write 1 to clear |
| Reset or Default Value | | |

表 6-35. Hardware_Configuration Access Type
Codes (続き)

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

6.7.3.1 PIN_CONFIG Register (Offset = A4h) [Reset = 0000000h]

PIN_CONFIG is shown in [図 6-73](#) and described in [表 6-36](#).

Return to the [Summary Table](#).

Register to configure hardware pins

図 6-73. PIN_CONFIG Register

| | | | | | | | |
|-----------------|--------------|----------|----------|--------------|----------------|-----------------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | RESERVED | | | VDC_FILT_DIS | RESERVED | | |
| R-0h | R-0h | | | R/W-0h | R-0h | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | RESERVED | | FG_IDLE_CONFIG | FG_FAULT_CONFIG | |
| R-0h | | | R-0h | | R/W-0h | R/W-0h | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FG_FAULT_CONFIG | ALARM_PIN_EN | RESERVED | RESERVED | BRAKE_INPUT | | SPEED_MODE | |
| R/W-0h | R/W-0h | R-0h | R-0h | R/W-0h | | R/W-0h | |

表 6-36. PIN_CONFIG Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-----------------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-28 | RESERVED | R | 0h | Reserved |
| 27 | VDC_FILT_DIS | R/W | 0h | Vdc filter disable 0h = Enable 1h = Disable |
| 26-13 | RESERVED | R | 0h | Reserved |
| 12-11 | RESERVED | R | 0h | Reserved |
| 10-9 | FG_IDLE_CONFIG | R/W | 0h | FG configuration during motor stopped/idle state 0h = FG continues and end state depends on FG_CONFIG and last state before motor stops 1h = FG is pulled High 2h = FG is pulled Low 3h = FG is pulled High |
| 8-7 | FG_FAULT_CONFIG | R/W | 0h | FG configuration during fault state 0h = Use last FG signal when motor is driving 1h = FG is pulled High 2h = FG is pulled Low |
| 6 | ALARM_PIN_EN | R/W | 0h | Alarm pin enable 0h = Disable 1h = Enable |
| 5 | RESERVED | R | 0h | Reserved |
| 4 | RESERVED | R | 0h | Reserved |
| 3-2 | BRAKE_INPUT | R/W | 0h | Brake pin override 0h = Hardware pin (BRAKE) 1h = Override pin and apply low-side brake 2h = Override pin and do not brake 3h = Hardware pin (BRAKE) |

表 6-36. PIN_CONFIG Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|--|
| 1-0 | SPEED_MODE | R/W | 0h | Configure input reference mode from SPEED pin 0h = Controlled by amplitude of SPEED pin (analog mode) 1h = Controlled by duty cycle of SPEED pin (PWM mode) 2h = Controlled by DIGITAL_SPEED_CTRL register (I2C mode) 3h = Controlled by frequency of SPEED pin (freq. mode) |

6.7.3.2 DEVICE_CONFIG1 Register (Offset = A6h) [Reset = 0XXXXXX0h]

DEVICE_CONFIG1 is shown in [図 6-74](#) and described in [表 6-37](#).

Return to the [Summary Table](#).

Register to configure device

図 6-74. DEVICE_CONFIG1 Register

| | | | | | | | |
|-----------------|----------|----------|--------------------|------------|-----------------|----------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | RESERVED | RESERVED | | DAC_ENABLE | I2C_TARGET_ADDR | | |
| R-0h | R-0h | R-0h | | R/W-0h | R/W-X | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| I2C_TARGET_ADDR | | | | RESERVED | | | |
| R/W-X | | | | R-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | SLEW_RATE_I2C_PINS | | PULLUP_ENABLE | BUS_VOLT | |
| R-0h | | | R/W-0h | | R/W-0h | R/W-0h | |

表 6-37. DEVICE_CONFIG1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|--------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30 | RESERVED | R | 0h | Reserved |
| 29-28 | RESERVED | R | 0h | Reserved |
| 27 | DAC_ENABLE | R/W | 0h | DAC enable 0h = DACOUT disabled 1h = DACOUT enabled |
| 26-20 | I2C_TARGET_ADDR | R/W | X | I2C target address |
| 19-5 | RESERVED | R | 0h | Reserved |
| 4-3 | SLEW_RATE_I2C_PINS | R/W | 0h | Slew rate control for I2C pins 0h = 4.8 mA 1h = 3.9 mA 2h = 1.86 mA 3h = 30.8 mA |
| 2 | PULLUP_ENABLE | R/W | 0h | Internal pull-up enable for nFAULT and FG pins 0h = Disable 1h = Enable |
| 1-0 | BUS_VOLT | R/W | 0h | Maximum DC bus voltage configuration 0h = 15 V 1h = 30 V 2h = 60 V 3h = Reserved |

6.7.3.3 DEVICE_CONFIG2 Register (Offset = A8h) [Reset = 0000000h]

DEVICE_CONFIG2 is shown in [図 6-75](#) and described in [表 6-38](#).

Return to the [Summary Table](#).

Register to configure device

図 6-75. DEVICE_CONFIG2 Register

| | | | | | | | |
|--------------------|---------------------|-------------------------|----------------|---------|------------------|--------------------|--------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | INPUT_MAXIMUM_FREQ | | | | | | |
| R-0h | | R/W-0h | | | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| INPUT_MAXIMUM_FREQ | | | | | | | |
| R/W-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SLEEP_ENTRY_TIME | DYNAMIC_CSA_GAIN_EN | DYNAMIC_VOLTAGE_GAIN_EN | DEV_MODE | CLK_SEL | | EXT_CLK_EN | |
| R/W-0h | | R/W-0h | R/W-0h | R/W-0h | R/W-0h | | R/W-0h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| EXT_CLK_CONFIG | | EXT_WDT_EN | EXT_WDT_CONFIG | | EXT_WDT_INP_MODE | EXT_WDT_FAULT_MODE | |
| R/W-0h | | R/W-0h | R/W-0h | | R/W-0h | R/W-0h | |

表 6-38. DEVICE_CONFIG2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-------------------------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-16 | INPUT_MAXIMUM_FREQ | R/W | 0h | Input frequency on speed pin for input reference mode as "controlled by frequency of SPEED pin" that corresponds to 100% duty cycle. Duty cycle = Input frequency / INPUT_MAXIMUM_FREQ |
| 15-14 | SLEEP_ENTRY_TIME | R/W | 0h | Device enters sleep mode when SPEED input is held continuously below threshold for SLEEP_ENTRY_TIME 0h = Sleep Entry when SPEED pin remains low for 50 μ s 1h = Sleep Entry when SPEED pin remains low for 200 μ s 2h = Sleep Entry when SPEED pin remains low for 20 ms 3h = Sleep Entry when SPEED pin remains low for 200 ms |
| 13 | DYNAMIC_CSA_GAIN_EN | R/W | 0h | Adjust CSA gain automatically for optimal current resolution at all current levels 0h = Disable 1h = Enable |
| 12 | DYNAMIC_VOLTAGE_GAIN_EN | R/W | 0h | Adjust voltage gain automatically for optimal voltage resolution at all voltage levels 0h = Disable 1h = Enable |
| 11 | DEV_MODE | R/W | 0h | Device mode select 0h = Standby Mode 1h = Sleep Mode |
| 10-9 | CLK_SEL | R/W | 0h | Clock source 0h = Internal oscillator 1h = Reserved 2h = Reserved 3h = External clock input |
| 8 | EXT_CLK_EN | R/W | 0h | Enable external clock mode 0h = Disable 1h = Enable |

表 6-38. DEVICE_CONFIG2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|--------------------|------|-------|--|
| 7-5 | EXT_CLK_CONFIG | R/W | 0h | External Clock Configuration 0h = 8 kHz 1h = 16 kHz 2h = 32 kHz 3h = 64 kHz 4h = 128 kHz 5h = 256 kHz 6h = 512 kHz 7h = 1024 kHz |
| 4 | EXT_WDT_EN | R/W | 0h | Enable external watchdog 0h = Disable 1h = Enable |
| 3-2 | EXT_WDT_CONFIG | R/W | 0h | Time between watchdog tickles (GPIO/I2C) 0h = 100ms/1s 1h = 200ms/2s 2h = 500ms/3s 3h = 1000ms/10s |
| 1 | EXT_WDT_INPUT_MODE | R/W | 0h | External watchdog input source 0h = Watchdog tickle over I2C 1h = Watchdog tickle over GPIO |
| 0 | EXT_WDT_FAULT_MODE | R/W | 0h | External watchdog fault mode 0h = Report only 1h = Latch with MOSFETs in Hi-Z |

6.7.3.4 PERI_CONFIG1 Register (Offset = AAh) [Reset = 4000000h]

PERI_CONFIG1 is shown in [図 6-76](#) and described in [表 6-39](#).

Return to the [Summary Table](#).

Register to peripheral1

図 6-76. PERI_CONFIG1 Register

| | | | | | | | |
|--------------------------------------|--------------------------------|--------------------------|------------------------------|----|-----------------|-------------------|--------------------------------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | SPREAD_SPECTRUM_MODULATION_DIS | RESERVED | | | | BUS_CURRENT_LIMIT | |
| R-0h | R/W-1h | R-0h | | | | R/W-0h | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BUS_CURRENT_LIMIT | | BUS_CURRENT_LIMIT_ENABLE | DIR_INPUT | | DIR_CHANGE_MODE | RESERVED | ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY |
| R/W-0h | | R/W-0h | R/W-0h | | R/W-0h | R-0h | R/W-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY | | | ACTIVE_BRAKE_MOD_INDEX_LIMIT | | | SPEED_RANGE_SEL | RESERVED |
| R/W-0h | | | R/W-0h | | | R/W-0h | R-0h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |

表 6-39. PERI_CONFIG1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|--------------------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30 | SPREAD_SPECTRUM_MODULATION_DIS | R/W | 1h | Spread spectrum modulation disable 0h = SSM is enabled 1h = SSM is disabled |
| 29-26 | RESERVED | R | 0h | Reserved |
| 25-22 | BUS_CURRENT_LIMIT | R/W | 0h | Bus current limit 0h = 0.078125 A 1h = 0.15625 A 2h = 0.3125 A 3h = 0.625 A 4h = 0.9375 A 5h = 1.25 A 6h = 1.5625 A 7h = 1.875 A 8h = 2.1875 A 9h = 2.5 A Ah = 2.8125 A Bh = 3.125 A Ch = 3.4375 A Dh = 3.75 A Eh = 4.375 A Fh = 5.0 A |
| 21 | BUS_CURRENT_LIMIT_ENABLE | R/W | 0h | Bus current limit enable 0h = Disable 1h = Enable |

表 6-39. PERI_CONFIG1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|--------------------------------------|------|-------|--|
| 20-19 | DIR_INPUT | R/W | 0h | DIR pin override 0h = Hardware pin (DIR) 1h = Override DIR pin with clockwise rotation OUTA-OUTB-OUTC 2h = Override DIR pin with counter clockwise rotation OUTA-OUTC-OUTB 3h = Hardware pin (DIR) |
| 18 | DIR_CHANGE_MODE | R/W | 0h | Response to change of DIR pin status 0h = Follow motor stop options and ISD routine on detecting DIR change 1h = Change the direction through reverse drive while continuously driving the motor |
| 17 | RESERVED | R | 0h | Reserved |
| 16-13 | ACTIVE_BRAKE_SPEED_DELTA_LIMIT_ENTRY | R/W | 0h | Difference between final speed and present speed below which active braking will be applied 0h = reserved 1h = 5% 2h = 10% 3h = 15% 4h = 20% 5h = 25% 6h = 30% 7h = 35% 8h = 40% 9h = 45% Ah = 50% Bh = 60% Ch = 70% Dh = 80% Eh = 90% Fh = 100% |
| 12-10 | ACTIVE_BRAKE_MOD_INDEX_LIMIT | R/W | 0h | Modulation index limit below which active braking will be applied 0h = 0% 1h = 40% 2h = 50% 3h = 60% 4h = 70% 5h = 80% 6h = 90% 7h = 100% |
| 9 | SPEED_RANGE_SEL | R/W | 0h | Frequency range selection for PWM duty mode reference input 0h = 325Hz to 100kHz 1h = 10Hz to 325Hz |
| 8 | RESERVED | R | 0h | Reserved |
| 7-0 | RESERVED | R | 0h | Reserved |

6.7.3.5 GD_CONFIG1 Register (Offset = ACh) [Reset = 10228100h]

GD_CONFIG1 is shown in [図 6-77](#) and described in [表 6-40](#).

Return to the [Summary Table](#).

Register to configure gated driver settings1

図 6-77. GD_CONFIG1 Register

| | | | | | | | |
|----------|----------|----------|----------|-----------|----------|----------|----------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| PARITY | RESERVED | RESERVED | RESERVED | SLEW_RATE | RESERVED | RESERVED | RESERVED |
| R/W-0h | R-0h | R-0h | R-0h | R/W-0h | R-0h | R-0h | R-0h |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| RESERVED | RESERVED | RESERVED | RESERVED | OVP_SEL | OVP_EN | RESERVED | RESERVED |
| R-0h | R-0h | R-0h | R-0h | R/W-0h | R/W-0h | R-0h | R-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | RESERVED | OCP_DEG | RESERVED | OCP_LVL | OCP_MODE | RESERVED | RESERVED |
| R-0h | R-0h | R/W-0h | R-0h | R/W-0h | R/W-1h | R-0h | R-0h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | RESERVED | RESERVED | RESERVED | RESERVED | RESERVED | CSA_GAIN | RESERVED |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R/W-0h | R-0h |

表 6-40. GD_CONFIG1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-----------|------|-------|---|
| 31 | PARITY | R/W | 0h | Parity bit |
| 30-29 | RESERVED | R | 0h | Reserved |
| 28 | RESERVED | R | 0h | Reserved |
| 27-26 | SLEW_RATE | R/W | 0h | Slew rate 0h = Reserved 1h = Reserved 2h = Slew rate is 125 V/μs 3h = Slew rate is 200 V/μs |
| 25-24 | RESERVED | R | 0h | Reserved |
| 23 | RESERVED | R | 0h | Reserved |
| 22 | RESERVED | R | 0h | Reserved |
| 21 | RESERVED | R | 0h | Reserved |
| 20 | RESERVED | R | 0h | Reserved |
| 19 | OVP_SEL | R/W | 0h | Overvoltage level 0h = VM overvoltage level is 34-V 1h = VM overvoltage level is 22-V |
| 18 | OVP_EN | R/W | 0h | Overvoltage enable 0h = Overvoltage protection is disabled 1h = Overvoltage protection is enabled |
| 17 | RESERVED | R | 0h | Reserved |
| 16 | RESERVED | R | 0h | Reserved |
| 15 | RESERVED | R | 0h | Reserved |
| 14 | RESERVED | R | 0h | Reserved |
| 13-12 | OCP_DEG | R/W | 0h | OCP deglitch time 0h = OCP deglitch time is 0.2 μs 1h = OCP deglitch time is 0.6 μs 2h = OCP deglitch time is 1.2 μs 3h = OCP deglitch time is 1.6 μs |

表 6-40. GD_CONFIG1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|----------|------|-------|--|
| 11 | RESERVED | R | 0h | Reserved |
| 10 | OCP_LVL | R/W | 0h | Overcurrent level 0h = OCP level is 9 A (Typical) 1h = OCP level is 13 A (Typical) |
| 9-8 | OCP_MODE | R/W | 1h | OCP fault mode 0h = Overcurrent causes a latched fault 1h = Overcurrent causes an automatic retrying fault after 500ms 2h = Reserved 3h = Reserved |
| 7 | RESERVED | R | 0h | Reserved |
| 6 | RESERVED | R | 0h | Reserved |
| 5 | RESERVED | R | 0h | Reserved |
| 4 | RESERVED | R | 0h | Reserved |
| 3 | RESERVED | R | 0h | Reserved |
| 2 | RESERVED | R | 0h | Reserved |
| 1-0 | CSA_GAIN | R/W | 0h | Current sense amplifier's gain (used only if DYNAMIC_CSA_GAIN_EN = 0) 0h = CSA gain is 0.24 V/A 1h = CSA gain is 0.48 V/A 2h = CSA gain is 0.96 V/A 3h = CSA gain is 1.92 V/A |

6.7.3.6 GD_CONFIG2 Register (Offset = AEh) [Reset = 01200000h]

GD_CONFIG2 is shown in [図 6-78](#) and described in [表 6-41](#).

Return to the [Summary Table](#).

Register to configure gated driver settings2

図 6-78. GD_CONFIG2 Register

| | | | | | | | |
|----------|---------------|--------------|----------|-------------|----|----------|-------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| PARITY | DELAY_COMP_EN | TARGET_DELAY | | | | RESERVED | BUCK_PS_DIS |
| R/W-0h | R/W-0h | R/W-0h | | | | R-0h | R/W1C-1h |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BUCK_CL | BUCK_SEL | | BUCK_DIS | MIN_ON_TIME | | | RESERVED |
| R/W-0h | R/W-1h | | R/W-0h | R/W-0h | | | R-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |

表 6-41. GD_CONFIG2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|---------------|-------|-------|---|
| 31 | PARITY | R/W | 0h | Parity bit |
| 30 | DELAY_COMP_EN | R/W | 0h | Driver delay compensation enable 0h = Disable 1h = Enable |
| 29-26 | TARGET_DELAY | R/W | 0h | Delay target for driver delay compensation 0h = Automatic based on slew rate 1h = 0.4 μ s 2h = 0.6 μ s 3h = 0.8 μ s 4h = 1 μ s 5h = 1.2 μ s 6h = 1.4 μ s 7h = 1.6 μ s 8h = 1.8 μ s 9h = 2 μ s Ah = 2.2 μ s Bh = 2.4 μ s Ch = 2.6 μ s Dh = 2.8 μ s Eh = 3 μ s Fh = 3.2 μ s |
| 25 | RESERVED | R | 0h | Reserved |
| 24 | BUCK_PS_DIS | R/W1C | 1h | Buck power sequencing disable 0h = Buck power sequencing is enabled 1h = Buck power sequencing is disabled |
| 23 | BUCK_CL | R/W | 0h | Buck current limit 0h = Buck regulator current limit is set to 600 mA 1h = Buck regulator current limit is set to 150 mA |

表 6-41. GD_CONFIG2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|-------------|------|-------|--|
| 22-21 | BUCK_SEL | R/W | 1h | Buck output voltage 0h = Buck voltage is 3.3 V 1h = Buck voltage is 5.0 V 2h = Buck voltage is 4.0 V 3h = Buck voltage is 5.7 V |
| 20 | BUCK_DIS | R/W | 0h | Buck disable 0h = Buck regulator is enabled 1h = Buck regulator is disabled |
| 19-17 | MIN_ON_TIME | R/W | 0h | Minimum ON time for low side MOSFET 0h = 0 μ s 1h = Automatic based on slew rate 2h = 0.5 μ s 3h = 0.75 μ s 4h = 1 μ s 5h = 1.25 μ s 6h = 1.5 μ s 7h = 2 μ s |
| 16-0 | RESERVED | R | 0h | Reserved |

6.7.4 Internal_Algorithm_Configuration Registers

表 6-42 lists the memory-mapped registers for the Internal_Algorithm_Configuration registers. All register offset addresses not listed in 表 6-42 should be considered as reserved locations and the register contents should not be modified.

表 6-42. INTERNAL_ALGORITHM_CONFIGURATION Registers

| Offset | Acronym | Register Name | Section |
|--------|------------|-----------------------------------|-------------------------------|
| A0h | INT_ALGO_1 | Internal Algorithm Configuration1 | セクション 6.7.4.1 |
| A2h | INT_ALGO_2 | Internal Algorithm Configuration2 | セクション 6.7.4.2 |

Complex bit access types are encoded to fit into small table cells. 表 6-43 shows the codes that are used for access types in this section.

表 6-43. Internal_Algorithm_Configuration 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 |

6.7.4.1 INT_ALGO_1 Register (Offset = A0h) [Reset = 0000000h]

INT_ALGO_1 is shown in [図 6-79](#) and described in [表 6-44](#).

Return to the [Summary Table](#).

Register to configure internal algorithm parameters1

図 6-79. INT_ALGO_1 Register

| | | | | | | | |
|--------------------------|--------------------------------------|--------------------------|---------------|-----------------------|----------------------------|----|-----------------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | ACTIVE_BRAKE_SPEED__DELTA_LIMIT_EXIT | SPEED_PIN_GLITCH_FILTER | | FAST_ISD_EN | ISD_STOP_TIME | | |
| R-0h | R/W-0h | R/W-0h | | R/W-0h | R/W-0h | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| ISD_RUN_TIME | | ISD_TIMEOUT | | AUTO_HANDOFF_MIN_BEMF | | | BRAKE_CURRENT_PERSIST |
| R/W-0h | | R/W-0h | | R/W-0h | | | R/W-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| BRAKE_CURRENT_PERSIST | MPET_IPD_CURRENT_LIMIT | | MPET_IPD_FREQ | | MPET_OPEN_LOOP_CURRENT_REF | | |
| R/W-0h | R/W-0h | | R/W-0h | | R/W-0h | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MPET_OPEN_LOOP_SPEED_REF | | MPET_OPEN_LOOP_SLEW_RATE | | | REV_DRV_OPEN_LOOP_DEC | | |
| R/W-0h | | R/W-0h | | | R/W-0h | | |

表 6-44. INT_ALGO_1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|--------------------------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-29 | ACTIVE_BRAKE_SPEED__DELTA_LIMIT_EXIT | R/W | 0h | Difference between final speed and present speed below which active braking will be stopped 0h = 2.5% 1h = 5% 2h = 7.5% 3h = 10% |
| 28-27 | SPEED_PIN_GLITCH_FILTER | R/W | 0h | Glitch filter applied on speed pin input 0h = No Glitch Filter 1h = 0.2 μ s 2h = 0.5 μ s 3h = 1.0 μ s |
| 26 | FAST_ISD_EN | R/W | 0h | Enable fast speed detection during ISD 0h = Disable fast ISD 1h = Enable fast ISD |
| 25-24 | ISD_STOP_TIME | R/W | 0h | Persistence time for declaring motor has stopped 0h = 1 ms 1h = 5 ms 2h = 50 ms 3h = 100 ms |
| 23-22 | ISD_RUN_TIME | R/W | 0h | Persistence time for declaring motor is running 0h = 1 ms 1h = 5 ms 2h = 50 ms 3h = 100 ms |

表 6-44. INT_ALGO_1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-------|----------------------------|------|-------|--|
| 21-20 | ISD_TIMEOUT | R/W | 0h | Timeout in case ISD is unable to reliably detect speed or direction 0h = 500ms 1h = 750 ms 2h = 1000 ms 3h = 2000 ms |
| 19-17 | AUTO_HANDOFF_MIN_BEMF | R/W | 0h | Minimum BEMF for handoff 0h = 0 mV 1h = 50 mV 2h = 100 mV 3h = 250 mV 4h = 500 mV 5h = 1000 mV 6h = 1250 mV 7h = 1500 mV |
| 16-15 | BRAKE_CURRENT_PERSIST | R/W | 0h | Persistence time for current below threshold during low side brake 0h = 50 ms 1h = 100 ms 2h = 250 ms 3h = 500 ms |
| 14-13 | MPET_IPD_CURRENT_LIMIT | R/W | 0h | IPD current limit for MPET 0h = 0.0625 A 1h = 0.3125 A 2h = 0.625 A 3h = 1.25 A |
| 12-11 | MPET_IPD_FREQ | R/W | 0h | Number of times IPD is executed for MPET 0h = 1 1h = 2 2h = 4 3h = 8 |
| 10-8 | MPET_OPEN_LOOP_CURRENT_REF | R/W | 0h | MPET open loop current reference 0h = 0.625 A 1h = 1.25 A 2h = 1.875 A 3h = 2.5 A 4h = 3.125 A 5h = 3.75 A 6h = 4.375 A 7h = 5 A |
| 7-6 | MPET_OPEN_LOOP_SPEED_REF | R/W | 0h | MPET open loop speed reference (% of MAX_SPEED) 0h = 15% 1h = 25% 2h = 35% 3h = 50% |
| 5-3 | MPET_OPEN_LOOP_SLEW_RATE | R/W | 0h | MPET open loop slew rate 0h = 0.1 Hz/s 1h = 0.5 Hz/s 2h = 1 Hz/s 3h = 2 Hz/s 4h = 3 Hz/s 5h = 5 Hz/s 6h = 10 Hz/s 7h = 20 Hz/s |

表 6-44. INT_ALGO_1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|-----------------------|------|-------|---|
| 2-0 | REV_DRV_OPEN_LOOP_DEC | R/W | 0h | % of open loop acceleration to be applied during open loop deceleration in reverse drive 0h = 50% 1h = 60% 2h = 70% 3h = 80% 4h = 90% 5h = 100% 6h = 125% 7h = 150% |

6.7.4.2 INT_ALGO_2 Register (Offset = A2h) [Reset = 0000000h]

INT_ALGO_2 is shown in [図 6-80](#) and described in [表 6-45](#).

Return to the [Summary Table](#).

Register to configure internal algorithm parameters2

図 6-80. INT_ALGO_2 Register

| | | | | | | | |
|-------------|----|------------------------------------|----|------|-----------------|--------------------------------|------------------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | | RESERVED | | | | | |
| R-0h | | | | R-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | CL_SLOW_ACC | |
| R-0h | | | | | | R/W-0h | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CL_SLOW_ACC | | ACTIVE_BRAKE_BUS_CURRENT_SLEW_RATE | | | MPET_IPD_SELECT | MPET_KEY_MEAS_PARAMETER_SELECT | IPD_HIGH_RESOLUTION_EN |
| R/W-0h | | R/W-0h | | | R/W-0h | R/W-0h | R/W-0h |

表 6-45. INT_ALGO_2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|------------------------------------|------|-------|--|
| 31 | RESERVED | R | 0h | Reserved |
| 30-10 | RESERVED | R | 0h | Reserved |
| 9-6 | CL_SLOW_ACC | R/W | 0h | Close loop acceleration when estimator is not yet fully aligned 0h = 0.1 Hz/s 1h = 1 Hz/s 2h = 2 Hz/s 3h = 3 Hz/s 4h = 5 Hz/s 5h = 10 Hz/s 6h = 20 Hz/s 7h = 30 Hz/s 8h = 40 Hz/s 9h = 50 Hz/s Ah = 100 Hz/s Bh = 200 Hz/s Ch = 500 Hz/s Dh = 750 Hz/s Eh = 1000 Hz/s Fh = 2000 Hz/s |
| 5-3 | ACTIVE_BRAKE_BUS_CURRENT_SLEW_RATE | R/W | 0h | Bus current slew rate during active braking 0h = 10 A/s 1h = 50 A/s 2h = 100 A/s 3h = 250 A/s 4h = 500 A/s 5h = 1000 A/s 6h = 5000 A/s 7h = No Limit |

表 6-45. INT_ALGO_2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|-------------------------------|------|-------|--|
| 2 | MPET_IPD_SELECT | R/W | 0h | Selection between MPET_IPD_CURRENT_LIMIT for IPD current limit, MPET_IPD_FREQ for IPD Repeat OR IPD_CURR_THR for IPD current limit, IPD_REPEAT for IPD Repeat 0h = Configured parameters for normal motor operation 1h = MPET specific parameters |
| 1 | MPET_KE_MEAS_PARAMETER_SELECT | R/W | 0h | Selection between MPET_OPEN_LOOP_SLEW_RATE for slew rate, MPET_OPEN_LOOP_CURR_REF for current reference, MPET_OPEN_LOOP_SPEED_REF for speed reference OR OL_ACC_A1, OL_ACC_A2 for slew rate, open loop current reference for current reference and open to closed loop speed threshold for speed reference 0h = Configured parameters for normal motor operation 1h = MPET specific parameters |
| 0 | IPD_HIGH_RESOLUTION_EN | R/W | 0h | IPD high resolution enable 0h = Disable 1h = Enable |

6.8 RAM (Volatile) Register Map

6.8.1 Fault_Status Registers

表 6-46 lists the memory-mapped registers for the Fault_Status registers. All register offset addresses not listed in 表 6-46 should be considered as reserved locations and the register contents should not be modified.

表 6-46. FAULT_STATUS Registers

| Offset | Acronym | Register Name | Section |
|--------|--------------------------|-----------------------|-------------------------------|
| E0h | GATE_DRIVER_FAULT_STATUS | Fault Status Register | セクション 6.8.1.1 |
| E2h | CONTROLLER_FAULT_STATUS | Fault Status Register | セクション 6.8.1.2 |

Complex bit access types are encoded to fit into small table cells. 表 6-47 shows the codes that are used for access types in this section.

表 6-47. Fault_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 |

6.8.1.1 GATE_DRIVER_FAULT_STATUS Register (Offset = E0h) [Reset = 0000000h]

GATE_DRIVER_FAULT_STATUS is shown in [Figure 6-81](#) and described in [Table 6-48](#).

Return to the [Summary Table](#).

Status of various gate driver faults

Figure 6-81. GATE_DRIVER_FAULT_STATUS Register

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
|--------------|---------|----------|---------|----------|----------|--------|----------|
| DRIVER_FAULT | BK_FLT | RESERVED | OCP | RESERVED | OVP | OT | RESERVED |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| OTW | OTS | OCP_HC | OCP_LC | OCP_HB | OCP_LB | OCP_HA | OCP_LA |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | OTP_ERR | BUCK_OCP | BUCK_UV | VCP_UV | RESERVED | | |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |

Table 6-48. GATE_DRIVER_FAULT_STATUS Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------------|------|-------|---|
| 31 | DRIVER_FAULT | R | 0h | Logic OR of gate driver fault status registers |
| 30 | BK_FLT | R | 0h | Buck fault status 0h = No buck regulator fault condition is detected 1h = Buck regulator fault condition is detected |
| 29 | RESERVED | R | 0h | Reserved |
| 28 | OCP | R | 0h | Overcurrent protection status 0h = No overcurrent condition is detected 1h = Overcurrent condition is detected |
| 27 | RESERVED | R | 0h | Reserved |
| 26 | OVP | R | 0h | Supply overvoltage protection status 0h = No overvoltage condition is detected on VM 1h = Overvoltage condition is detected on VM |
| 25 | OT | R | 0h | Overtemperature fault status 0h = No overtemperature warning / shutdown is detected 1h = Overtemperature warning / shutdown is detected |
| 24 | RESERVED | R | 0h | Reserved |
| 23 | OTW | R | 0h | Overtemperature warning status 0h = No overtemperature warning is detected 1h = Overtemperature warning is detected |
| 22 | OTS | R | 0h | Overtemperature shutdown status 0h = No overtemperature shutdown is detected 1h = Overtemperature shutdown is detected |
| 21 | OCP_HC | R | 0h | Overcurrent status on high-side switch of OUTC 0h = No overcurrent detected on high-side switch of OUTC 1h = Overcurrent detected on high-side switch of OUTC |
| 20 | OCP_LC | R | 0h | Overcurrent status on low-side switch of OUTC 0h = No overcurrent detected on low-side switch of OUTC 1h = Overcurrent detected on low-side switch of OUTC |

表 6-48. GATE_DRIVER_FAULT_STATUS Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|----------|------|-------|---|
| 19 | OCP_HB | R | 0h | Overcurrent status on high-side switch of OUTB 0h = No overcurrent detected on high-side switch of OUTB 1h = Overcurrent detected on high-side switch of OUTB |
| 18 | OCP_LB | R | 0h | Overcurrent status on low-side switch of OUTB 0h = No overcurrent detected on low-side switch of OUTB 1h = Overcurrent detected on low-side switch of OUTB |
| 17 | OCP_HA | R | 0h | Overcurrent status on high-side switch of OUTA 0h = No overcurrent detected on high-side switch of OUTA 1h = Overcurrent detected on high-side switch of OUTA |
| 16 | OCP_LA | R | 0h | Overcurrent status on low-side switch of OUTA 0h = No overcurrent detected on low-side switch of OUTA 1h = Overcurrent detected on low-side switch of OUTA |
| 15 | RESERVED | R | 0h | Reserved |
| 14 | OTP_ERR | R | 0h | OTP error 0h = No OTP error is detected 1h = OTP Error is detected |
| 13 | BUCK_OCP | R | 0h | Buck regulator overcurrent status 0h = No buck regulator overcurrent is detected 1h = Buck regulator overcurrent is detected |
| 12 | BUCK_UV | R | 0h | Buck regulator undervoltage status 0h = No buck regulator undervoltage is detected 1h = Buck regulator undervoltage is detected |
| 11 | VCP_UV | R | 0h | Charge pump undervoltage status 0h = No charge pump undervoltage is detected 1h = Charge pump undervoltage is detected |
| 10-0 | RESERVED | R | 0h | Reserved |

6.8.1.2 CONTROLLER_FAULT_STATUS Register (Offset = E2h) [Reset = 0000000h]

CONTROLLER_FAULT_STATUS is shown in [Figure 6-82](#) and described in [Table 6-49](#).

Return to the [Summary Table](#).

Status of various controller faults

Figure 6-82. CONTROLLER_FAULT_STATUS Register

| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
|-----------------------|-------------------------|----------------|--------------|----------------|--------------------------|-------------------|------------------|
| CONTROLLER_FAULT | RESERVED | IPD_FREQ_FAULT | IPD_T1_FAULT | IPD_T2_FAULT | BUS_CURRENT_LIMIT_STATUS | MPET_IPD_FAULT | MPET_BEMF_FAULT |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| ABN_SPEED | ABN_BEMF | NO_MTR | MTR_LCK | LOCK_LIMIT | HW_LOCK_LIMIT | MTR_UNDER_VOLTAGE | MTR_OVER_VOLTAGE |
| R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h | R-0h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SPEED_LOOP_SATURATION | CURRENT_LOOP_SATURATION | RESERVED | | | | | |
| R-0h | R-0h | R-0h | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | WATCHDOG_FAULT | RESERVED | RESERVED | RESERVED |
| R-0h | | | | R-0h | R-0h | R-0h | R-0h |

Table 6-49. CONTROLLER_FAULT_STATUS Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-----|--------------------------|------|-------|---|
| 31 | CONTROLLER_FAULT | R | 0h | Logic OR of Controller fault status registers |
| 30 | RESERVED | R | 0h | Reserved |
| 29 | IPD_FREQ_FAULT | R | 0h | Indicates IPD frequency fault 0h = No IPD frequency fault is detected 1h = IPD frequency fault is detected |
| 28 | IPD_T1_FAULT | R | 0h | Indicates IPD T1 fault 0h = No IPD T1 fault is detected 1h = IPD T1 fault is detected |
| 27 | IPD_T2_FAULT | R | 0h | Indicates IPD T2 fault 0h = No IPD T2 fault is detected 1h = IPD T2 fault is detected |
| 26 | BUS_CURRENT_LIMIT_STATUS | R | 0h | Indicates bus current limit status 0h = Bus current limit is not active 1h = Bus current limit is active |
| 25 | MPET_IPD_FAULT | R | 0h | Indicates error during resistance and inductance measurement 0h = No MPET IPD fault is detected 1h = MPET IPD fault is detected |
| 24 | MPET_BEMF_FAULT | R | 0h | Indicates error during BEMF constant measurement 0h = No MPET BEMF fault is detected 1h = MPET BEMF fault is detected |
| 23 | ABN_SPEED | R | 0h | Indicates abnormal speed motor lock condition 0h = No abnormal speed fault is detected 1h = Abnormal speed fault is detected |
| 22 | ABN_BEMF | R | 0h | Indicates abnormal BEMF motor lock condition 0h = No abnormal BEMF fault is detected 1h = Abnormal BEMF fault is detected |

表 6-49. CONTROLLER_FAULT_STATUS Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|-----------------------------|------|-------|---|
| 21 | NO_MTR | R | 0h | Indicates no motor fault 0h = No no motor fault is detected 1h = No motor fault is detected |
| 20 | MTR_LCK | R | 0h | Indicates when one of the motor lock is triggered 0h = No motor lock fault is detected 1h = Motor lock fault is detected |
| 19 | LOCK_LIMIT | R | 0h | Indicates lock llimit fault 0h = No lock current limit fault is detected 1h = Lock current limit fault is detected |
| 18 | HW_LOCK_LIMIT | R | 0h | Indicates hardware lock llimit fault 0h = No HW lock current limit fault is detected 1h = HW lock current limit fault is detected |
| 17 | MTR_UNDER_VOLTAGE | R | 0h | Indicates motor undervoltage fault 0h = No undervoltage fault is detected 1h = Undervoltage fault is detected |
| 16 | MTR_OVER_VOLTAGE | R | 0h | Indicates motor overvoltage fault 0h = No overvoltage fault is detected 1h = Overvoltage fault is detected |
| 15 | SPEED_LOOP_SATURAT ION | R | 0h | Indicates speed loop saturation 0h = No speed loop saturation is detected 1h = Speed loop saturation is detected |
| 14 | CURRENT_LOOP_SATU RATION | R | 0h | Indicates current loop saturation 0h = No current loop saturation is detected 1h = Current loop saturation is detected |
| 13-4 | RESERVED | R | 0h | Reserved |
| 3 | WATCHDOG_FAULT | R | 0h | Indicates watchdog fault 0h = No watchdog timeout is detected 1h = Watchdog timeout is detected |
| 2 | RESERVED | R | 0h | Reserved |
| 1 | RESERVED | R | 0h | Reserved |
| 0 | RESERVED | R | 0h | Reserved |

6.8.2 System_Status Registers

表 6-50 lists the memory-mapped registers for the System_Status registers. All register offset addresses not listed in 表 6-50 should be considered as reserved locations and the register contents should not be modified.

表 6-50. SYSTEM_STATUS Registers

| Offset | Acronym | Register Name | Section |
|--------|------------------|------------------------|-------------------------------|
| E4h | ALGO_STATUS | System Status Register | セクション 6.8.2.1 |
| E6h | MTR_PARAMS | System Status Register | セクション 6.8.2.2 |
| E8h | ALGO_STATUS_MPET | System Status Register | セクション 6.8.2.3 |

Complex bit access types are encoded to fit into small table cells. 表 6-51 shows the codes that are used for access types in this section.

表 6-51. System_Status Access Type Codes

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

表 6-51. System_Status Access Type Codes (続き)

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

6.8.2.1 ALGO_STATUS Register (Offset = E4h) [Reset = 0000000h]

ALGO_STATUS is shown in [図 6-83](#) and described in [表 6-52](#).

Return to the [Summary Table](#).

Status of various system and algorithm parameters

図 6-83. ALGO_STATUS Register

| | | | | | | | |
|----------|----|----|----|----------|-----------------|----------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| VOLT_MAG | | | | | | | |
| R-0h | | | | | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| VOLT_MAG | | | | | | | |
| R-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DUTY_CMD | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DUTY_CMD | | | | RESERVED | SYS_ENABLE_FLAG | RESERVED | |
| R-0h | | | | R-0h | R-0h | R-0h | |

表 6-52. ALGO_STATUS Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-----------------|------|-------|---|
| 31-16 | VOLT_MAG | R | 0h | 16-bit value indicating applied modulation index. Modulation index (%) = (VOLT_MAG/32768 * 100) % |
| 15-4 | DUTY_CMD | R | 0h | 12-bit value indicating decoded duty command in PWM/freq./analog mode DUTY_CMD (%) = (DUTY_CMD/4096 * 100)%. |
| 3 | RESERVED | R | 0h | Reserved |
| 2 | SYS_ENABLE_FLAG | R | 0h | 1 indicates GUI can control the register 0 indicates GUI is still copying default parameters from shadow memory |
| 1-0 | RESERVED | R | 0h | Reserved |

6.8.2.2 MTR_PARAMS Register (Offset = E6h) [Reset = 0000000h]

MTR_PARAMS is shown in [Figure 6-84](#) and described in [Table 6-53](#).

Return to the [Summary Table](#).

Status of various motor parameters

Figure 6-84. MTR_PARAMS Register

| | | | | | | | | | | | | | | | |
|---------|----|----|----|----|----|----|----|------------------|----|----|----|----|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| MOTOR_R | | | | | | | | MOTOR_BEMF_CONST | | | | | | | |
| R-0h | | | | | | | | R-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| MOTOR_L | | | | | | | | RESERVED | | | | | | | |
| R-0h | | | | | | | | R-0h | | | | | | | |

Table 6-53. MTR_PARAMS Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|------------------|------|-------|---|
| 31-24 | MOTOR_R | R | 0h | 8-bit value indicating MPET measured motor resistance |
| 23-16 | MOTOR_BEMF_CONST | R | 0h | 8-bit value indicating MPET measured BEMF constant |
| 15-8 | MOTOR_L | R | 0h | 8-bit value indicating MPET measured motor inductance |
| 7-0 | RESERVED | R | 0h | Reserved |

6.8.2.3 ALGO_STATUS_MPET Register (Offset = E8h) [Reset = 0000000h]

ALGO_STATUS_MPET is shown in [図 6-85](#) and described in [表 6-54](#).

Return to the [Summary Table](#).

Status of various MPET parameters

図 6-85. ALGO_STATUS_MPET Register

| | | | | | | | |
|-------------------|-------------------|--------------------|----------------------|---------------|----|----|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| MPET_R_STAT US | MPET_L_STAT US | MPET_KE_STA TUS | MPET_MECH_ STATUS | MPET_PWM_FREQ | | | |
| R-0h | R-0h | R-0h | R-0h | R-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |

表 6-54. ALGO_STATUS_MPET Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|------------------|------|-------|---|
| 31 | MPET_R_STATUS | R | 0h | Indicates status of resistance measurement |
| 30 | MPET_L_STATUS | R | 0h | Indicates status of inductance measurement |
| 29 | MPET_KE_STATUS | R | 0h | Indicates status of BEMF constant measurement |
| 28 | MPET_MECH_STATUS | R | 0h | Indicates status of mechanical parameter measurement |
| 27-24 | MPET_PWM_FREQ | R | 0h | 4-bit value indicating MPET recommended PWM switching frequency based on electrical time constant |
| 23-0 | RESERVED | R | 0h | Reserved |

6.8.3 Device_Control Registers

[表 6-55](#) lists the memory-mapped registers for the Device_Control registers. All register offset addresses not listed in [表 6-55](#) should be considered as reserved locations and the register contents should not be modified.

表 6-55. DEVICE_CONTROL Registers

| Offset | Acronym | Register Name | Section |
|--------|------------|-------------------------|-------------------------------|
| EAh | ALGO_CTRL1 | Device Control Register | セクション 6.8.3.1 |

Complex bit access types are encoded to fit into small table cells. [表 6-56](#) shows the codes that are used for access types in this section.

表 6-56. Device_Control Access Type Codes

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

表 6-56. Device_Control Access Type Codes (続き)

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

6.8.3.1 ALGO_CTRL1 Register (Offset = EAh) [Reset = 0000000h]

ALGO_CTRL1 is shown in [図 6-86](#) and described in [表 6-57](#).

Return to the [Summary Table](#).

Control settings

図 6-86. ALGO_CTRL1 Register

| | | | | | | | |
|-------------------------|-------------|---------|---------------------|-------------------------|-----------------|----------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| EEPROM_WRT | EEPROM_READ | CLR_FLT | CLR_FLT_RETRY_COUNT | EEPROM_WRITE_ACCESS_KEY | | | |
| R/W-0h | R/W-0h | W-0h | W-0h | W-0h | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| EEPROM_WRITE_ACCESS_KEY | | | | FORCED_ALIGN_ANGLE | | | |
| W-0h | | | | W-0h | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| FORCED_ALIGN_ANGLE | | | | | WATCHDOG_TICKLE | RESERVED | |
| W-0h | | | | | R/W-0h | R-0h | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |

表 6-57. ALGO_CTRL1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-------------------------|------|-------|--|
| 31 | EEPROM_WRT | R/W | 0h | Write the configuration to EEPROM |
| 30 | EEPROM_READ | R/W | 0h | Read the default configuration from EEPROM |
| 29 | CLR_FLT | W | 0h | Clear all faults |
| 28 | CLR_FLT_RETRY_COUNT | W | 0h | Clears fault retry count |
| 27-20 | EEPROM_WRITE_ACCESS_KEY | W | 0h | EEPROM write access key |
| 19-11 | FORCED_ALIGN_ANGLE | W | 0h | 9-bit value (in degrees) used during forced Align state (FORCE_ALIGN_EN = 1) Angle applied = (FORCED_ALIGN_ANGLE % 360)deg |
| 10 | WATCHDOG_TICKLE | R/W | 0h | RAM bit to tickle watchdog in I2C mode. This bit should be written with 1b by external controller within every EXT_WDT_CONFIG. MCF8315C will reset this bit to 0b. |
| 9-0 | RESERVED | R | 0h | Reserved |

6.8.4 Algorithm_Control Registers

[表 6-58](#) lists the memory-mapped registers for the Algorithm_Control registers. All register offset addresses not listed in [表 6-58](#) should be considered as reserved locations and the register contents should not be modified.

表 6-58. ALGORITHM_CONTROL Registers

| Offset | Acronym | Register Name | Section |
|--------|-------------|----------------------------|-------------------------------|
| ECh | ALGO_DEBUG1 | Algorithm Control Register | セクション 6.8.4.1 |
| EEh | ALGO_DEBUG2 | Algorithm Control Register | セクション 6.8.4.2 |
| F0h | CURRENT_PI | Current PI Controller used | セクション 6.8.4.3 |
| F2h | SPEED_PI | Speed PI controller used | セクション 6.8.4.4 |

表 6-58. ALGORITHM_CONTROL Registers (続き)

| Offset | Acronym | Register Name | Section |
|--------|---------|-----------------------|-------------------------------|
| F4h | DAC | DAC1 Control Register | セクション 6.8.4.5 |

Complex bit access types are encoded to fit into small table cells. 表 6-59 shows the codes that are used for access types in this section.

表 6-59. Algorithm_Control 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 |

6.8.4.1 ALGO_DEBUG1 Register (Offset = ECh) [Reset = 0000000h]

ALGO_DEBUG1 is shown in 図 6-87 and described in 表 6-60.

Return to the [Summary Table](#).

Algorithm control register for debug

図 6-87. ALGO_DEBUG1 Register

| | | | | | | | |
|-----------------------------|----------------|---------------------------|--------------|--------------|---------------------------|-----------------------------|----|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| OVERRIDE | | DIGITAL_SPEED_CTRL | | | | | |
| W-0h | | W-0h | | | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| DIGITAL_SPEED_CTRL | | | | | | | |
| W-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| CLOSED_LOOP_DIS | FORCE_ALIGN_EN | FORCE_SLOW_FIRST_CYCLE_EN | FORCE_IPD_EN | FORCE_ISD_EN | FORCE_ALIGN_ANGLE_SRC_SEL | FORCE_IQ_REF_SPEED_LOOP_DIS | |
| W-0h | W-0h | W-0h | W-0h | W-0h | W-0h | W-0h | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FORCE_IQ_REF_SPEED_LOOP_DIS | | | | | | | |
| W-0h | | | | | | | |

表 6-60. ALGO_DEBUG1 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|---------------------------|------|-------|---|
| 31 | OVERRIDE | W | 0h | Use to control the reference input mode. If OVERRIDE = 1b, speed command can be written by the user through I2C interface. 0h = Reference input based on SPEED_MODE 1h = Reference input based on DIGITAL_SPEED_CTRL |
| 30-16 | DIGITAL_SPEED_CTRL | W | 0h | If OVERRIDE = 1b or SPEED_MODE = 10b, then reference input is from DIGITAL_SPEED_CTRL |
| 15 | CLOSED_LOOP_DIS | W | 0h | Use to disable closed loop 0h = Enable closed loop 1h = Disable closed loop, motor commutation in open loop |
| 14 | FORCE_ALIGN_EN | W | 0h | Force align state 0h = Disable force align state, device comes out of align state if MTR_STARTUP is selected as ALIGN or DOUBLE ALIGN 1h = Enable force align state, device stays in align state if MTR_STARTUP is selected as ALIGN or DOUBLE ALIGN |
| 13 | FORCE_SLOW_FIRST_CYCLE_EN | W | 0h | Force slow first cycle 0h = Disable force slow first cycle state, device comes out of slow first cycle state if MTR_STARTUP is selected as SLOW FIRST CYCLE 1h = Enable force slow first cycle state, device stays in slow first cycle state if MTR_STARTUP is selected as SLOW FIRST CYCLE |
| 12 | FORCE_IPD_EN | W | 0h | Force IPD 0h = Disable force IPD state, device comes out of IPD state if MTR_STARTUP is selected as IPD 1h = Enable force IPD state, device stays in IPD state if MTR_STARTUP is selected as IPD |
| 11 | FORCE_ISD_EN | W | 0h | Force ISD enable 0h = Disable force ISD state, device comes out of ISD state if ISD_EN is set 1h = Enable force ISD state, device stays in ISD state if ISD_EN is set |

表 6-60. ALGO_DEBUG1 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|-----------------------------|------|-------|--|
| 10 | FORCE_ALIGN_ANGLE_SRC_SEL | W | 0h | Force align angle state source 0h = Force align angle defined by ALIGN_ANGLE 1h = Force align angle defined by FORCED_ALIGN_ANGLE |
| 9-0 | FORCE_IQ_REF_SPEED_LOOP_DIS | W | 0h | Sets IQ ref (% of BASE_CURRENT) when speed loop is disabled. If SPEED_LOOP_DIS = 1b, then Iq_ref is control using $\text{IQ_REF_SPEED_LOOP_DIS } iqRef = \begin{cases} (\text{FORCE_IQ_REF_SPEED_LOOP_DIS} / 500) * \text{BASE_CURRENT} & \text{if } \text{FORCE_IQ_REF_SPEED_LOOP_DIS} < 500 \\ (\text{FORCE_IQ_REF_SPEED_LOOP_DIS} - 1024) / 500 * \text{BASE_CURRENT} & \text{if } \text{FORCE_IQ_REF_SPEED_LOOP_DIS} > 512 \end{cases}$ Valid values are 0 to 500 and 512 to 1000 |

6.8.4.2 ALGO_DEBUG2 Register (Offset = EEh) [Reset = 0000000h]

ALGO_DEBUG2 is shown in [図 6-88](#) and described in [表 6-61](#).

Return to the [Summary Table](#).

Algorithm control register for debug

図 6-88. ALGO_DEBUG2 Register

| | | | | | | | |
|---------------------------|----------|--------|--------|----------|------------------|---------------------------|------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | RESERVED | | | RESERVED | CURRENT_LOOP_DIS | FORCE_VD_CURRENT_LOOP_DIS | |
| R-0h | R-0h | | | R-0h | W-0h | W-0h | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| FORCE_VD_CURRENT_LOOP_DIS | | | | | | | |
| W-0h | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| FORCE_VQ_CURRENT_LOOP_DIS | | | | | | | |
| W-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FORCE_VQ_CURRENT_LOOP_DIS | MPET_CMD | MPET_R | MPET_L | MPET_KE | MPET_MECH | MPET_WRITE_SHADOW | |
| W-0h | W-0h | W-0h | W-0h | W-0h | W-0h | W-0h | W-0h |

表 6-61. ALGO_DEBUG2 Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|---------------------------|------|-------|---|
| 31 | RESERVED | R | 0h | Reserved |
| 30-28 | RESERVED | R | 0h | Reserved |
| 27 | RESERVED | R | 0h | Reserved |
| 26 | CURRENT_LOOP_DIS | W | 0h | Use to control the FORCE_VD_CURRENT_LOOP_DIS and FORCE_VQ_CURRENT_LOOP_DIS. If CURRENT_LOOP_DIS = '1', Current loop and speed loop is disabled 0h = Enable current loop 1h = Disable current loop |
| 25-16 | FORCE_VD_CURRENT_LOOP_DIS | W | 0h | Sets Vd when current and speed loops are disabled If CURRENT_LOOP_DIS = 1b, then Vd is control using FORCE_VD_CURRENT_LOOP_DIS mdRef = (FORCE_VD_CURRENT_LOOP_DIS /500) if FORCE_VD_CURRENT_LOOP_DIS < 500 (FORCE_VD_CURRENT_LOOP_DIS - 1024)/500 if FORCE_VD_CURRENT_LOOP_DIS > 512 Valid values: 0 to 500 and 512 to 1000 |
| 15-6 | FORCE_VQ_CURRENT_LOOP_DIS | W | 0h | Sets Vq when current and speed loops are disabled If CURRENT_LOOP_DIS = 1b, then Vq is control using FORCE_VQ_CURRENT_LOOP_DIS mqRef = (FORCE_VQ_CURRENT_LOOP_DIS /500) if FORCE_VQ_CURRENT_LOOP_DIS < 500 (FORCE_VQ_CURRENT_LOOP_DIS - 1024)/500 if FORCE_VQ_CURRENT_LOOP_DIS > 512 Valid values: 0 to 500 and 512 to 1000 |
| 5 | MPET_CMD | W | 0h | Initiates motor parameter measurement routine when set to 1b |

表 6-61. ALGO_DEBUG2 Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|-----|-------------------|------|-------|---|
| 4 | MPET_R | W | 0h | Enables motor resistance measurement during motor parameter measurement routine 0h = Disables motor resistance measurement during motor parameter measurement routine 1h = Enable motor resistance measurement during motor parameter measurement routine |
| 3 | MPET_L | W | 0h | Enables motor inductance measurement during motor parameter measurement routine 0h = Disables motor inductance measurement during motor parameter measurement routine 1h = Enable motor inductance measurement during motor parameter measurement routine |
| 2 | MPET_KE | W | 0h | Enables motor BEMF constant measurement during motor parameter measurement routine 0h = Disables motor BEMF constant measurement during motor parameter measurement routine 1h = Enable motor BEMF constant measurement during motor parameter measurement routine |
| 1 | MPET_MECH | W | 0h | Enables motor mechanical parameter measurement during motor parameter measurement routine 0h = Disables motor mechanical parameter measurement during motor parameter measurement routine 1h = Enable motor mechanical parameter measurement during motor parameter measurement routine |
| 0 | MPET_WRITE_SHADOW | W | 0h | Write measured parameters to shadow register when set to 1b |

6.8.4.3 CURRENT_PI Register (Offset = F0h) [Reset = 0000000h]

CURRENT_PI is shown in [図 6-89](#) and described in [表 6-62](#).

Return to the [Summary Table](#).

Current PI controller used

図 6-89. CURRENT_PI Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----------------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CURRENT_LOOP_KI | | | | | | | | | | | | | | | | CURRENT_LOOP_KP | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | R-0h | | | | | | | | | | | | | | | |

表 6-62. CURRENT_PI Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|-----------------|------|-------|--|
| 31-16 | CURRENT_LOOP_KI | R | 0h | 10-bit register for current loop Ki Same scaling as CURR_LOOP_KI |
| 15-0 | CURRENT_LOOP_KP | R | 0h | 10-bit register for current loop Kp Same scaling as CURR_LOOP_KP |

6.8.4.4 SPEED_PI Register (Offset = F2h) [Reset = 0000000h]

SPEED_PI is shown in [図 6-90](#) and described in [表 6-63](#).

Return to the [Summary Table](#).

Speed PI controller used

図 6-90. SPEED_PI Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SPEED_LOOP_KI | | | | | | | | | | | | | | | SPEED_LOOP_KP | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | R-0h | | | | | | | | | | | | | | | | |

表 6-63. SPEED_PI Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|---------------|------|-------|---|
| 31-16 | SPEED_LOOP_KI | R | 0h | 10-bit register for speed loop Ki Same Scaling as SPD_LOOP_KI |
| 15-0 | SPEED_LOOP_KP | R | 0h | 10-bit register for speed loop Kp Same Scaling as SPD_LOOP_KP |

6.8.4.5 DAC Register (Offset = F4h) [Reset = 00110000h]

DAC is shown in [図 6-91](#) and described in [表 6-64](#).

Return to the [Summary Table](#).

DAC Control Register

図 6-91. DAC Register

| | | | | | | | |
|-----------------|----|----|---------------------|-----------------|----|----|----------------|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 |
| RESERVED | | | | | | | |
| R-0h | | | | | | | |
| 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| RESERVED | | | DACOUT_ENUM_SCALING | | | | DACOUT_SCALING |
| R-0h | | | W-8h | | | | W-8h |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| DACOUT_SCALING | | | DACOUT_UNIPOLAR | DACOUT_VAR_ADDR | | | |
| W-8h | | | W-0h | R/W-0h | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| DACOUT_VAR_ADDR | | | | | | | |
| R/W-0h | | | | | | | |

表 6-64. DAC Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|-------|---------------------|------|-------|---|
| 31-21 | RESERVED | R | 0h | Reserved |
| 20-17 | DACOUT_ENUM_SCALING | W | 8h | Multiplication Factor for DACOUT Algorithm variable extracted from the address contained in DACOUT_VAR_ADDR multiplied with $2^{\text{DACOUT_ENUM_SCALING}}$. DACOUT_ENUM_SCALING comes into effect only if DACOUT_SCALING is zero |
| 16-13 | DACOUT_SCALING | W | 8h | Scaling factor for DACOUT Algorithm variable extracted from the address contained in DACOUT_VAR_ADDR scaled with DACOUT_SCALING / 8. Actual voltage depends on DACOUT_UNIPOLAR. If DACOUT_UNIPOLAR = 1b, 0V == 0pu of algorithmVariable * DACOUT_SCALING / 8, 3V == 1pu of algorithmVariable * DACOUT_SCALING / 8 If DACOUT_UNIPOLAR = 0b, 0V == -1pu of algorithmVariable * DACOUT_SCALING / 8, 3V == 1pu of algorithmVariable * DACOUT_SCALING / 8 0h = Treated s Enum with max value being 31 1h = 1 / 8 2h = 2 / 8 3h = 3 / 8 4h = 4 / 8 5h = 5 / 8 6h = 6 / 8 7h = 7 / 8 8h = 8 / 8 9h = 9 / 8 Ah = 10 / 8 Bh = 11 / 8 Ch = 12 / 8 Dh = 13 / 8 Eh = 14 / 8 Fh = 15 / 8 |

表 6-64. DAC Register Field Descriptions (続き)

| Bit | Field | Type | Reset | Description |
|------|-----------------|------|-------|---|
| 12 | DACOUT_UNIPOLAR | W | 0h | Configures output of DACOUT If DACOUT_UNIPOLAR = 1, 0V == 0pu of algorithmVariable * DACOUT_SCALING / 16, 3V == 1pu of algorithmVariable * DACOUT_SCALING / 16 If DACOUT_UNIPOLAR = 0, 0V == -1pu of algorithmVariable * DACOUT_SCALING / 16, 3V == 1pu of algorithmVariable * DACOUT_SCALING / 16 0h = Bipolar (Offset of 1.5 V) 1h = Unipolar (No Offset) |
| 11-0 | DACOUT_VAR_ADDR | R/W | 0h | 12-bit address of variable to be monitored |

6.8.5 Algorithm_Variables Registers

表 6-65 lists the memory-mapped registers for the Algorithm_Variables registers. All register offset addresses not listed in 表 6-65 should be considered as reserved locations and the register contents should not be modified.

表 6-65. ALGORITHM_VARIABLES Registers

| Offset | Acronym | Register Name | Section |
|--------|-----------------------|--------------------------------------|--------------------------------|
| 190h | ALGORITHM_STATE | Current Algorithm State Register | セクション 6.8.5.1 |
| 196h | FG_SPEED_FDBK | FG Speed Feedback Register | セクション 6.8.5.2 |
| 410h | BUS_CURRENT | Calculated DC Bus Current Register | セクション 6.8.5.3 |
| 440h | PHASE_CURRENT_A | Measured Current on Phase A Register | セクション 6.8.5.4 |
| 442h | PHASE_CURRENT_B | Measured Current on Phase B Register | セクション 6.8.5.5 |
| 444h | PHASE_CURRENT_C | Measured Current on Phase C Register | セクション 6.8.5.6 |
| 468h | CSA_GAIN_FEEDBACK | CSA Gain Register | セクション 6.8.5.7 |
| 472h | VOLTAGE_GAIN_FEEDBACK | Voltage Gain Register | セクション 6.8.5.8 |
| 474h | VM_VOLTAGE | VM Voltage Register | セクション 6.8.5.9 |
| 47Ah | PHASE_VOLTAGE_VA | Phase A Voltage Register | セクション 6.8.5.10 |
| 47Ch | PHASE_VOLTAGE_VB | Phase B Voltage Register | セクション 6.8.5.11 |
| 47Eh | PHASE_VOLTAGE_VC | Phase C Voltage Register | セクション 6.8.5.12 |
| 4B6h | SIN_COMMUTATION_ANGLE | Sine of Commutation Angle | セクション 6.8.5.13 |
| 4B8h | COS_COMMUTATION_ANGLE | Cosine of Commutation Angle | セクション 6.8.5.14 |
| 4D2h | IALPHA | IALPHA Current Register | セクション 6.8.5.15 |
| 4D4h | IBETA | IBETA Current Register | セクション 6.8.5.16 |
| 4D6h | VALPHA | VALPHA Voltage Register | セクション 6.8.5.17 |
| 4D8h | VBETA | VBETA Voltage Register | セクション 6.8.5.18 |
| 4E2h | ID | Measured d-axis Current Register | セクション 6.8.5.19 |
| 4E4h | IQ | Measured q-axis Current Register | セクション 6.8.5.20 |
| 4E6h | VD | VD Voltage Register | セクション 6.8.5.21 |
| 4E8h | VQ | VQ Voltage Register | セクション 6.8.5.22 |
| 524h | IQ_REF_ROTOR_ALIGN | Align Current Reference | セクション 6.8.5.23 |
| 53Ch | SPEED_REF_OPEN_LOOP | Open Loop Speed Register | セクション 6.8.5.24 |
| 54Ch | IQ_REF_OPEN_LOOP | Open Loop Current Reference | セクション 6.8.5.25 |
| 5D2h | SPEED_REF_CLOSED_LOOP | Speed Reference Register | セクション 6.8.5.26 |
| 604h | ID_REF_CLOSED_LOOP | Reference for Current Loop Register | セクション 6.8.5.27 |
| 606h | IQ_REF_CLOSED_LOOP | Reference for Current Loop Register | セクション 6.8.5.28 |
| 680h | ISD_STATE | ISD State Register | セクション 6.8.5.29 |
| 68Ah | ISD_SPEED | ISD Speed Register | セクション 6.8.5.30 |

表 6-65. ALGORITHM_VARIABLES Registers (続き)

| Offset | Acronym | Register Name | Section |
|--------|------------|-----------------------------------|--------------------------------|
| 6BEh | IPD_STATE | IPD State Register | セクション 6.8.5.31 |
| 702h | IPD_ANGLE | Calculated IPD Angle Register | セクション 6.8.5.32 |
| 748h | ED | Estimated BEMF EQ Register | セクション 6.8.5.33 |
| 74Ah | EQ | Estimated BEMF ED Register | セクション 6.8.5.34 |
| 758h | SPEED_FDBK | Speed Feedback Register | セクション 6.8.5.35 |
| 75Ch | THETA_EST | Estimated rotor Position Register | セクション 6.8.5.36 |

Complex bit access types are encoded to fit into small table cells. [表 6-66](#) shows the codes that are used for access types in this section.

表 6-66. Algorithm_Variables Access Type Codes

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

6.8.5.1 ALGORITHM_STATE Register (Offset = 190h) [Reset = 0000h]

ALGORITHM_STATE is shown in [図 6-92](#) and described in [表 6-67](#).

Return to the [Summary Table](#).

Current Algorithm State Register

図 6-92. ALGORITHM_STATE Register

| | | | | | | | |
|-----------------|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| ALGORITHM_STATE | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ALGORITHM_STATE | | | | | | | |
| R-0h | | | | | | | |

表 6-67. ALGORITHM_STATE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------|------|-------|--|
| 15-0 | ALGORITHM_STATE | R | 0h | 16-bit value indicating current state of device 0h = MOTOR_IDLE 1h = MOTOR_ISD 2h = MOTOR_TRISTATE 3h = MOTOR_BRAKE_ON_START 4h = MOTOR_IPD 5h = MOTOR_SLOW_FIRST_CYCLE 6h = MOTOR_ALIGN 7h = MOTOR_OPEN_LOOP 8h = MOTOR_CLOSED_LOOP_UNALIGNED 9h = MOTOR_CLOSED_LOOP_ALIGNED Ah = MOTOR_CLOSED_LOOP_ACTIVE_BRAKING Bh = MOTOR_SOFT_STOP Ch = MOTOR_RECIRCULATE_STOP Dh = MOTOR_BRAKE_ON_STOP Eh = MOTOR_FAULT Fh = MOTOR_MPET_MOTOR_STOP_CHECK 10h = MOTOR_MPET_MOTOR_STOP_WAIT 11h = MOTOR_MPET_MOTOR_BRAKE 12h = MOTOR_MPET_ALGORITHM_PARAMETERS_INIT 13h = MOTOR_MPET_RL_MEASURE 14h = MOTOR_MPET_KE_MEASURE 15h = MOTOR_MPET_STALL_CURRENT_MEASURE 16h = MOTOR_MPET_TORQUE_MODE 17h = MOTOR_MPET_DONE 18h = MOTOR_MPET_FAULT |

6.8.5.2 FG_SPEED_FDBK Register (Offset = 196h) [Reset = 0000000h]

FG_SPEED_FDBK is shown in [図 6-93](#) and described in [表 6-68](#).

Return to the [Summary Table](#).

Speed Feedback from FG

図 6-93. FG_SPEED_FDBK Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| FG_SPEED_FDBK | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-68. FG_SPEED_FDBK Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|---------------|------|-------|--|
| 31-0 | FG_SPEED_FDBK | R | 0h | 32-bit value indicating estimated rotor speed $estimatedSpeed = (FG_SPEED_FDBK / 2^{27}) * MAX_SPEED$ in Hz |

6.8.5.3 BUS_CURRENT Register (Offset = 410h) [Reset = 00000000h]

BUS_CURRENT is shown in [図 6-94](#) and described in [表 6-69](#).

Return to the [Summary Table](#).

Calculated Supply Current Register

図 6-94. BUS_CURRENT Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BUS_CURRENT | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-69. BUS_CURRENT Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------------|------|-------|--|
| 31-0 | BUS_CURRENT | R | 0h | 32-bit value indicating DC bus current $i_{Bus} = (BUS_CURRENT / 2^{27}) * Base_Current/8$ |

6.8.5.4 PHASE_CURRENT_A Register (Offset = 440h) [Reset = 00000000h]

PHASE_CURRENT_A is shown in [図 6-95](#) and described in [表 6-70](#).

Return to the [Summary Table](#).

Measured current on Phase A Register

図 6-95. PHASE_CURRENT_A Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PHASE_CURRENT_A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-70. PHASE_CURRENT_A Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------|------|-------|---|
| 31-0 | PHASE_CURRENT_A | R | 0h | 32-bit value indicating measured current on Phase A iA = $(\text{PHASE_CURRENT_A} / 2^{27}) * \text{Base_Current}/8$ |

6.8.5.5 PHASE_CURRENT_B Register (Offset = 442h) [Reset = 00000000h]

PHASE_CURRENT_B is shown in [図 6-96](#) and described in [表 6-71](#).

Return to the [Summary Table](#).

Measured current on Phase B Register

図 6-96. PHASE_CURRENT_B Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PHASE_CURRENT_B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-71. PHASE_CURRENT_B Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------|------|-------|---|
| 31-0 | PHASE_CURRENT_B | R | 0h | 32-bit value indicating measured current on Phase B iB = $(\text{PHASE_CURRENT_B} / 2^{27}) * \text{Base_Current}/8$ |

6.8.5.6 PHASE_CURRENT_C Register (Offset = 444h) [Reset = 00000000h]

PHASE_CURRENT_C is shown in [図 6-97](#) and described in [表 6-72](#).

Return to the [Summary Table](#).

Measured current on Phase C Register

図 6-97. PHASE_CURRENT_C Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PHASE_CURRENT_C | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-72. PHASE_CURRENT_C Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------|------|-------|--|
| 31-0 | PHASE_CURRENT_C | R | 0h | 32-bit value indicating measured current on Phase C iC = (PHASE_CURRENT_C / 2 ²⁷) * Base_Current/8 |

6.8.5.7 CSA_GAIN_FEEDBACK Register (Offset = 468h) [Reset = 0000h]

CSA_GAIN_FEEDBACK is shown in [図 6-98](#) and described in [表 6-73](#).

Return to the [Summary Table](#).

VM Voltage Register

図 6-98. CSA_GAIN_FEEDBACK Register

| | | | | | | | |
|-------------------|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| CSA_GAIN_FEEDBACK | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CSA_GAIN_FEEDBACK | | | | | | | |
| R-0h | | | | | | | |

表 6-73. CSA_GAIN_FEEDBACK Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------------------|------|-------|--|
| 15-0 | CSA_GAIN_FEEDBACK | R | 0h | 16-bit value indicating current sense gain 0h = MAX_CSA_GAIN * 8 1h = MAX_CSA_GAIN * 4 2h = MAX_CSA_GAIN * 2 3h = MAX_CSA_GAIN * 1 |

6.8.5.8 VOLTAGE_GAIN_FEEDBACK Register (Offset = 472h) [Reset = 0000h]

VOLTAGE_GAIN_FEEDBACK is shown in [図 6-99](#) and described in [表 6-74](#).

Return to the [Summary Table](#).

Voltage Gain Register

図 6-99. VOLTAGE_GAIN_FEEDBACK Register

| | | | | | | | |
|-----------------------|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| VOLTAGE_GAIN_FEEDBACK | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| VOLTAGE_GAIN_FEEDBACK | | | | | | | |
| R-0h | | | | | | | |

表 6-74. VOLTAGE_GAIN_FEEDBACK Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------------|------|-------|--|
| 15-0 | VOLTAGE_GAIN_FEEDBACK | R | 0h | 16-bit value indicating voltage gain 0h = 60V 1h = 30V 2h = 15V |

6.8.5.9 VM_VOLTAGE Register (Offset = 474h) [Reset = 0000000h]

VM_VOLTAGE is shown in [図 6-100](#) and described in [表 6-75](#).

Return to the [Summary Table](#).

Supply voltage register

図 6-100. VM_VOLTAGE Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| VM_VOLTAGE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-75. VM_VOLTAGE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|------------|------|-------|---|
| 31-0 | VM_VOLTAGE | R | 0h | 32-bit value indicating DC bus voltage DC Bus Voltage = $VM_VOLTAGE * 60 / 2^{27}$ |

6.8.5.10 PHASE_VOLTAGE_VA Register (Offset = 47Ah) [Reset = 0000000h]

PHASE_VOLTAGE_VA is shown in [図 6-101](#) and described in [表 6-76](#).

Return to the [Summary Table](#).

Phase A Voltage Register

図 6-101. PHASE_VOLTAGE_VA Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PHASE_VOLTAGE_VA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-76. PHASE_VOLTAGE_VA Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|------------------|------|-------|--|
| 31-0 | PHASE_VOLTAGE_VA | R | 0h | 32-bit value indicating phase voltage Va during ISD Phase A voltage = PHASE_VOLTAGE_VA * 60 / (sqrt(3) * 2 ²⁷) |

6.8.5.11 PHASE_VOLTAGE_VB Register (Offset = 47Ch) [Reset = 0000000h]

PHASE_VOLTAGE_VB is shown in [図 6-102](#) and described in [表 6-77](#).

Return to the [Summary Table](#).

Phase B Voltage Register

図 6-102. PHASE_VOLTAGE_VB Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PHASE_VOLTAGE_VB | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-77. PHASE_VOLTAGE_VB Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|------------------|------|-------|---|
| 31-0 | PHASE_VOLTAGE_VB | R | 0h | 32-bit value indicating phase voltage Vb during ISD Phase B voltage = PHASE_VOLTAGE_VB * 60 / (sqrt(3) * 2 ²⁷) |

6.8.5.12 PHASE_VOLTAGE_VC Register (Offset = 47Eh) [Reset = 0000000h]

PHASE_VOLTAGE_VC is shown in [図 6-103](#) and described in [表 6-78](#).

Return to the [Summary Table](#).

Phase C Voltage Register

図 6-103. PHASE_VOLTAGE_VC Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PHASE_VOLTAGE_VC | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-78. PHASE_VOLTAGE_VC Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|------------------|------|-------|--|
| 31-0 | PHASE_VOLTAGE_VC | R | 0h | 32-bit value indicating phase voltage Vc during ISD Phase C voltage = PHASE_VOLTAGE_VC * 60 / (sqrt(3) * 2 ²⁷) |

6.8.5.13 SIN_COMMUTATION_ANGLE Register (Offset = 4B6h) [Reset = 0000000h]

SIN_COMMUTATION_ANGLE is shown in [Figure 6-104](#) and described in [Table 6-79](#).

Return to the [Summary Table](#).

Sine of Commutation Angle

Figure 6-104. SIN_COMMUTATION_ANGLE Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SIN_COMMUTATION_ANGLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 6-79. SIN_COMMUTATION_ANGLE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------------|------|-------|---|
| 31-0 | SIN_COMMUTATION_ANGLE | R | 0h | 32-bit value indicating sine of commutation Angle $\text{sinCommutationAngle} = (\text{SIN_COMMUTATION_ANGLE} / 2^{27})$ |

6.8.5.14 COS_COMMUTATION_ANGLE Register (Offset = 4B8h) [Reset = 00000000h]

COS_COMMUTATION_ANGLE is shown in [図 6-105](#) and described in [表 6-80](#).

Return to the [Summary Table](#).

Cosine of Commutation Angle

図 6-105. COS_COMMUTATION_ANGLE Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| COS_COMMUTATION_ANGLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-80. COS_COMMUTATION_ANGLE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------------|------|-------|---|
| 31-0 | COS_COMMUTATION_ANGLE | R | 0h | 32-bit value indicating cosine of commutation Angle $\text{cosCommutationAngle} = (\text{COS_COMMUTATION_ANGLE} / 2^{27})$ |

6.8.5.15 IALPHA Register (Offset = 4D2h) [Reset = 0000000h]

IALPHA is shown in [図 6-106](#) and described in [表 6-81](#).

Return to the [Summary Table](#).

IALPHA Current Register

図 6-106. IALPHA Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IALPHA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-81. IALPHA Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|--------|------|-------|---|
| 31-0 | IALPHA | R | 0h | 32-bit value indicating calculated IALPHA $i\alpha = (IALPHA / 2^{27}) * Base_Current/8$ |

6.8.5.16 IBETA Register (Offset = 4D4h) [Reset = 0000000h]

IBETA is shown in [Figure 6-107](#) and described in [Table 6-82](#).

Return to the [Summary Table](#).

IBETA Current Register

Figure 6-107. IBETA Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | | | | | | | | | | | | | | | | IBETA | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | R-0h | | | | | | | | | | | | | | | |

Table 6-82. IBETA Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|---|
| 31-0 | IBETA | R | 0h | 32-bit value indicating calculated IBETA $iBeta = (IBETA / 2^{27}) * Base_Current/8$ |

6.8.5.17 VALPHA Register (Offset = 4D6h) [Reset = 0000000h]

VALPHA is shown in [図 6-108](#) and described in [表 6-83](#).

Return to the [Summary Table](#).

VALPHA Voltage Register

図 6-108. VALPHA Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| VALPHA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-83. VALPHA Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|--------|------|-------|--|
| 31-0 | VALPHA | R | 0h | 32-bit value indicating calculated VALPHA $vAlpha = (VALPHA / 2^{27}) * 60 / \sqrt{3}$ |

6.8.5.18 VBETA Register (Offset = 4D8h) [Reset = 0000000h]

VBETA is shown in [図 6-109](#) and described in [表 6-84](#).

Return to the [Summary Table](#).

VBETA Voltage Register

図 6-109. VBETA Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| VBETA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-84. VBETA Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|--|
| 31-0 | VBETA | R | 0h | 32-bit value indicating calculated VBETA $v_{\text{Beta}} = (\text{VBETA} / 2^{27}) * 60 / \text{sqrt}(3)$ |

6.8.5.19 ID Register (Offset = 4E2h) [Reset = 0000000h]

ID is shown in [図 6-110](#) and described in [表 6-85](#).

Return to the [Summary Table](#).

Measured d-axis Current Register

図 6-110. ID Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | | | | | | | | | | | | | | | | ID | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | R-0h | | | | | | | | | | | | | | | |

表 6-85. ID Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|--|
| 31-0 | ID | R | 0h | 32-bit value indicating estimated Id id = (ID / 2 ²⁷) * Base_Current/8 |

6.8.5.20 IQ Register (Offset = 4E4h) [Reset = 0000000h]

IQ is shown in [図 6-111](#) and described in [表 6-86](#).

Return to the [Summary Table](#).

Measured q-axis Current Register

図 6-111. IQ Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | | | | | | | | | | | | | | | | IQ | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-86. IQ Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|---|
| 31-0 | IQ | R | 0h | 32-bit value indicating estimated Iq $iq = (IQ / 2^{27}) * Base_Current/8$ |

6.8.5.21 VD Register (Offset = 4E6h) [Reset = 0000000h]

VD is shown in [図 6-112](#) and described in [表 6-87](#).

Return to the [Summary Table](#).

VD Voltage Register

図 6-112. VD Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| VD | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-87. VD Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|---|
| 31-0 | VD | R | 0h | 32-bit value indicating applied Vd $vd = (VD / 2^{27}) * 60 / \text{sqrt}(3)$ |

6.8.5.22 VQ Register (Offset = 4E8h) [Reset = 00000000h]

VQ is shown in [図 6-113](#) and described in [表 6-88](#).

Return to the [Summary Table](#).

VQ Voltage Register

図 6-113. VQ Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | | | | | | | | | | | | | | | | VQ | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | R-0h | | | | | | | | | | | | | | | |

表 6-88. VQ Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|---|
| 31-0 | VQ | R | 0h | 32-bit value indicating applied Vq $vq = (VQ / 2^{27}) * 60 / \text{sqrt}(3)$ |

6.8.5.23 IQ_REF_ROTATOR_ALIGN Register (Offset = 524h) [Reset = 00000000h]

IQ_REF_ROTATOR_ALIGN is shown in [図 6-114](#) and described in [表 6-89](#).

Return to the [Summary Table](#).

Align Current Reference

図 6-114. IQ_REF_ROTATOR_ALIGN Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IQ_REF_ROTATOR_ALIGN | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-89. IQ_REF_ROTATOR_ALIGN Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|----------------------|------|-------|--|
| 31-0 | IQ_REF_ROTATOR_ALIGN | R | 0h | 32-bit value indicating align current reference $iqRefRotorAlign = (IQ_REF_ROTATOR_ALIGN / 2^{27}) * Base_Current/8$ |

6.8.5.24 SPEED_REF_OPEN_LOOP Register (Offset = 53Ch) [Reset = 0000000h]

SPEED_REF_OPEN_LOOP is shown in [図 6-115](#) and described in [表 6-90](#).

Return to the [Summary Table](#).

Speed at which motor transitions to close loop

図 6-115. SPEED_REF_OPEN_LOOP Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SPEED_REF_OPEN_LOOP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-90. SPEED_REF_OPEN_LOOP Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|---------------------|------|-------|---|
| 31-0 | SPEED_REF_OPEN_LOOP | R | 0h | 32-bit value indicating open loop speed openLoopSpeedRef = (SPEED_REF_OPEN_LOOP / 2 ²⁷) * MAX_SPEED in Hz |

6.8.5.25 IQ_REF_OPEN_LOOP Register (Offset = 54Ch) [Reset = 0000000h]

IQ_REF_OPEN_LOOP is shown in [図 6-116](#) and described in [表 6-91](#).

Return to the [Summary Table](#).

Open Loop Current Reference

図 6-116. IQ_REF_OPEN_LOOP Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IQ_REF_OPEN_LOOP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-91. IQ_REF_OPEN_LOOP Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|------------------|------|-------|--|
| 31-0 | IQ_REF_OPEN_LOOP | R | 0h | 32-bit value indicating open loop current reference $iqRefOpenLoop = (IQ_REF_OPEN_LOOP / 2^{27}) * Base_Current/8$ |

6.8.5.26 SPEED_REF_CLOSED_LOOP Register (Offset = 5D2h) [Reset = 0000000h]

SPEED_REF_CLOSED_LOOP is shown in [図 6-117](#) and described in [表 6-92](#).

Return to the [Summary Table](#).

Speed Reference Register

図 6-117. SPEED_REF_CLOSED_LOOP Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SPEED_REF_CLOSED_LOOP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-92. SPEED_REF_CLOSED_LOOP Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------------------|------|-------|---|
| 31-0 | SPEED_REF_CLOSED_LOOP | R | 0h | 32-bit value indicating reference for speed loop Speed reference in closed loop (Hz) = (SPEED_REF_CLOSED_LOOP / 2 ²⁷) * MAX_SPEED in Hz |

6.8.5.27 ID_REF_CLOSED_LOOP Register (Offset = 604h) [Reset = 0000000h]

ID_REF_CLOSED_LOOP is shown in [図 6-118](#) and described in [表 6-93](#).

Return to the [Summary Table](#).

Reference for Current Loop Register

図 6-118. ID_REF_CLOSED_LOOP Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ID_REF_CLOSED_LOOP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-93. ID_REF_CLOSED_LOOP Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|--------------------|------|-------|---|
| 31-0 | ID_REF_CLOSED_LOOP | R | 0h | 32-bit value indicating Id_ref for flux loop idRefClosedLoop = (ID_REF_CLOSED_LOOP / 2 ²⁷) * Base_Current/8 |

6.8.5.28 IQ_REF_CLOSED_LOOP Register (Offset = 606h) [Reset = 0000000h]

IQ_REF_CLOSED_LOOP is shown in [図 6-119](#) and described in [表 6-94](#).

Return to the [Summary Table](#).

Reference for Current Loop Register

図 6-119. IQ_REF_CLOSED_LOOP Register

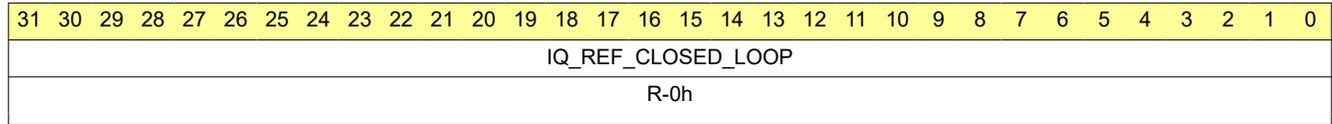


表 6-94. IQ_REF_CLOSED_LOOP Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|--------------------|------|-------|---|
| 31-0 | IQ_REF_CLOSED_LOOP | R | 0h | 32-bit value indicating Iq_ref for torque loop iqRefClosedLoop = (IQ_REF_CLOSED_LOOP / 2 ²⁷) * Base_Current/8 |

6.8.5.29 ISD_STATE Register (Offset = 680h) [Reset = 0000h]

ISD_STATE is shown in [図 6-120](#) and described in [表 6-95](#).

Return to the [Summary Table](#).

ISD state Register

図 6-120. ISD_STATE Register

| | | | | | | | |
|-----------|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| ISD_STATE | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ISD_STATE | | | | | | | |
| R-0h | | | | | | | |

表 6-95. ISD_STATE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------|------|-------|---|
| 15-0 | ISD_STATE | R | 0h | 16-bit value indicating current ISD state 0h = ISD_INIT 1h = ISD_MOTOR_STOP_CHECK 2h = ISD_ESTIM_INIT 3h = ISD_RUN_MOTOR_CHECK 4h = ISD_MOTOR_DIRECTION_CHECK 5h = ISD_COMPLETE 6h = ISD_FAULT |

6.8.5.30 ISD_SPEED Register (Offset = 68Ah) [Reset = 0000000h]

ISD_SPEED is shown in [図 6-121](#) and described in [表 6-96](#).

Return to the [Summary Table](#).

ISD Speed Register

図 6-121. ISD_SPEED Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ISD_SPEED | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-96. ISD_SPEED Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------|------|-------|---|
| 31-0 | ISD_SPEED | R | 0h | 32-bit value indicating calculated speed during ISD state $isdSpeed = (ISD_SPEED / 2^{27}) * MAX_SPEED$ in Hz |

6.8.5.31 IPD_STATE Register (Offset = 6BEh) [Reset = 0000h]

IPD_STATE is shown in [図 6-122](#) and described in [表 6-97](#).

Return to the [Summary Table](#).

IPD state Register

図 6-122. IPD_STATE Register

| | | | | | | | |
|-----------|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| IPD_STATE | | | | | | | |
| R-0h | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IPD_STATE | | | | | | | |
| R-0h | | | | | | | |

表 6-97. IPD_STATE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------|------|-------|--|
| 15-0 | IPD_STATE | R | 0h | 16-bit value indicating current IPD state 0h = IPD_INIT 1h = IPD_VECTOR_CONFIG 2h = IPD_RUN 3h = IPD_SLOW_RISE_CLOCK 4h = IPD_SLOW_FALL_CLOCK 5h = IPD_WAIT_CURRENT_DECAY 6h = IPD_GET_TIMES 7h = IPD_SET_NEXT_VECTOR 8h = IPD_CALC_SECTOR_RISE 9h = IPD_CALC_ROTOR_POSITION Ah = IPD_CALC_ANGLE Bh = IPD_COMPLETE Ch = IPD_FAULT |

6.8.5.32 IPD_ANGLE Register (Offset = 702h) [Reset = 0000000h]

IPD_ANGLE is shown in [図 6-123](#) and described in [表 6-98](#).

Return to the [Summary Table](#).

Calculated IPD Angle Register

図 6-123. IPD_ANGLE Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IPD_ANGLE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-98. IPD_ANGLE Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------|------|-------|---|
| 31-0 | IPD_ANGLE | R | 0h | 32-bit value indicating measured IPD angle ipdAngle = (IPD_ANGLE / 2 ²⁷) * 360 (Degree) |

6.8.5.33 ED Register (Offset = 748h) [Reset = 0000000h]

ED is shown in [図 6-124](#) and described in [表 6-99](#).

Return to the [Summary Table](#).

Estimated BEMF EQ Register

図 6-124. ED Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | | | | | | | | | | | | | | | | ED | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | R-0h | | | | | | | | | | | | | | | |

表 6-99. ED Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|--|
| 31-0 | ED | R | 0h | 32-bit value indicating estimated ED $E_d = (ED / 2^{27}) * 60 / \text{sqrt}(3)$ |

6.8.5.34 EQ Register (Offset = 74Ah) [Reset = 0000000h]

EQ is shown in [図 6-125](#) and described in [表 6-100](#).

Return to the [Summary Table](#).

Estimated BEMF ED Register

図 6-125. EQ Register

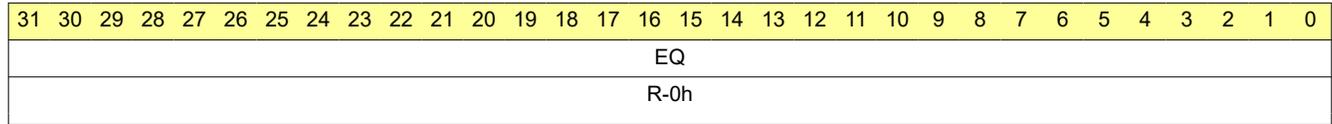


表 6-100. EQ Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-------|------|-------|--|
| 31-0 | EQ | R | 0h | 32-bit value indicating estimated EQ $E_q = (EQ / 2^{27}) * 60 / \text{sqrt}(3)$ |

6.8.5.35 SPEED_FDBK Register (Offset = 758h) [Reset = 0000000h]

SPEED_FDBK is shown in [図 6-126](#) and described in [表 6-101](#).

Return to the [Summary Table](#).

Speed Feedback Register

図 6-126. SPEED_FDBK Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SPEED_FDBK | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-101. SPEED_FDBK Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|------------|------|-------|---|
| 31-0 | SPEED_FDBK | R | 0h | 32-bit value indicating estimated rotor speed $\text{estimatedSpeed} = (\text{SPEED_FDBK} / 2^{27}) * \text{MAX_SPEED}$ in Hz |

6.8.5.36 THETA_EST Register (Offset = 75Ch) [Reset = 0000000h]

THETA_EST is shown in [図 6-127](#) and described in [表 6-102](#).

Return to the [Summary Table](#).

Estimated rotor Position Register

図 6-127. THETA_EST Register

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| THETA_EST | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| R-0h | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

表 6-102. THETA_EST Register Field Descriptions

| Bit | Field | Type | Reset | Description |
|------|-----------|------|-------|--|
| 31-0 | THETA_EST | R | 0h | 32-bit value indicating estimated rotor angle estimatedAngle = (THETA_EST / 2 ²⁷)*360 (Degree) |

7 Application and Implementation

注

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.

7.1 Application Information

The MCF8315C device is used in sensorless 3-phase BLDC motor control. The driver provides a high performance, high-reliability, flexible solution for appliances, fans, pumps, residential and living fans, seat cooling fans, automotive fans and blowers. The following section shows a common application of the MCF8315C device.

7.2 Typical Applications

図 7-1 shows the typical schematic of MCF8315C.

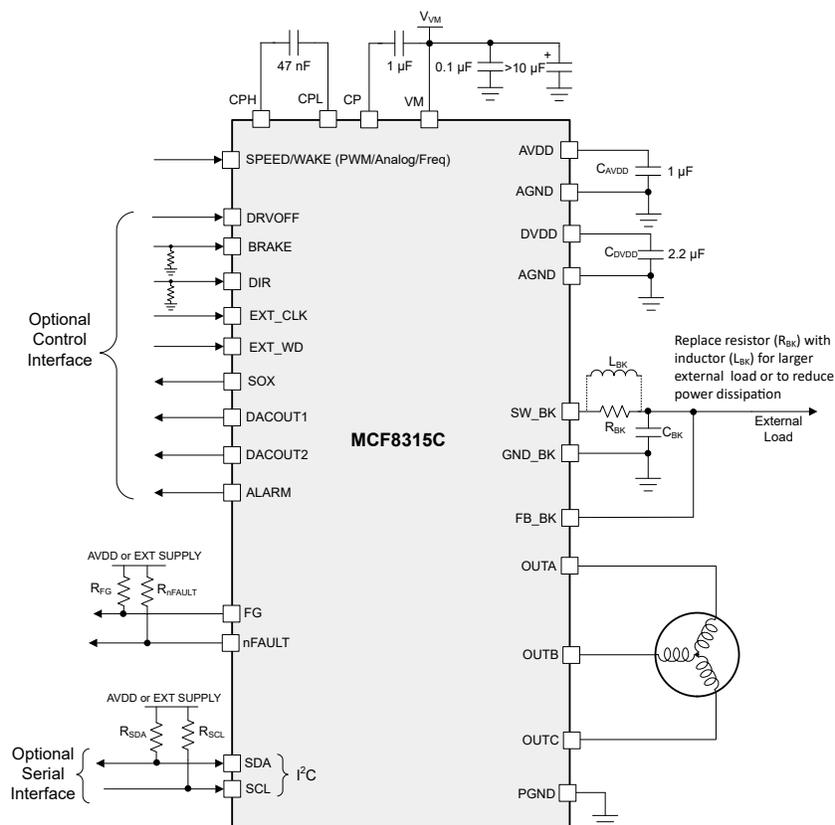


図 7-1. Example Application Schematic

表 7-1 lists the recommended values of the external components for MCF8315C.

表 7-1. MCF8315C External Components

| COMPONENTS | PIN 1 | PIN 2 | RECOMMENDED |
|------------|-------|-------|--|
| C_{VM1} | VM | PGND | X5R or X7R, 0.1- μ F, TI recommends a capacitor voltage rating at least twice the normal operating voltage of the device |
| C_{VM2} | VM | PGND | ≥ 10 - μ F, TI recommends a capacitor voltage rating at least twice the normal operating voltage of the device |

表 7-1. MCF8315C External Components (続き)

| COMPONENTS | PIN 1 | PIN 2 | RECOMMENDED |
|---------------------|---------------------|--------|---|
| C _{CP} | CP | VM | X5R or X7R, 16-V, 1-μF capacitor |
| C _{FLY} | CPH | CPL | X5R or X7R, 47-nF, TI recommends a capacitor voltage rating at least twice the normal operating voltage of the pin |
| C _{AVDD} | AVDD | AGND | X5R or X7R, 1-μF, ≥ 6.3-V. In order for AVDD to accurately regulate output voltage, capacitor should have effective capacitance between 0.7-μF to 1.3-μF at 3.3-V across operating temperature. |
| C _{DVDD} | DVDD | DGND | X5R or X7R, 2.2-μF, ≥ 6.3-V. In order for DVDD to accurately regulate output voltage, capacitor should have effective capacitance between 1.1-μF to 2.5-μF at 1.5-V across operating temperature. |
| C _{BK} | FB_BK | GND_BK | X5R or X7R, buck-output rated capacitor |
| L _{BK} | SW_BK | FB_BK | Buck-output inductor |
| R _{FG} | 1.8 to 5-V Supply | FG | 5.1-kΩ, Pull-up resistor |
| R _{nFAULT} | 1.8 to 5-V Supply | nFAULT | 5.1-kΩ, Pull-up resistor |
| R _{SDA} | 1.8 to 3.3-V Supply | SDA | 5.1-kΩ, Pull-up resistor |
| R _{SCL} | 1.8 to 3.3-V Supply | SCL | 5.1-kΩ, Pull-up resistor |

Recommended application range for MCF8315C is shown in 表 7-2.

表 7-2. Recommended Application Range

| Parameter | Min | Max | Unit |
|--|-------|------|-------|
| Motor voltage | 4.5 | 35 | V |
| Back-EMF constant (see セクション 6.3.13.3) | 0.6 | 2000 | mV/Hz |
| Motor resistance (see セクション 6.3.13.1) | 0.006 | 20 | Ω |
| Motor inductance (see セクション 6.3.13.2) | 0.006 | 20 | mH |
| Motor electrical speed | - | 1500 | Hz |
| Peak motor phase current | - | 4 | A |

Once the device EEPROM is programmed with the desired configuration, device can be operated stand-alone and I²C serial interface is not required anymore. Speed can be commanded using SPEED pin.

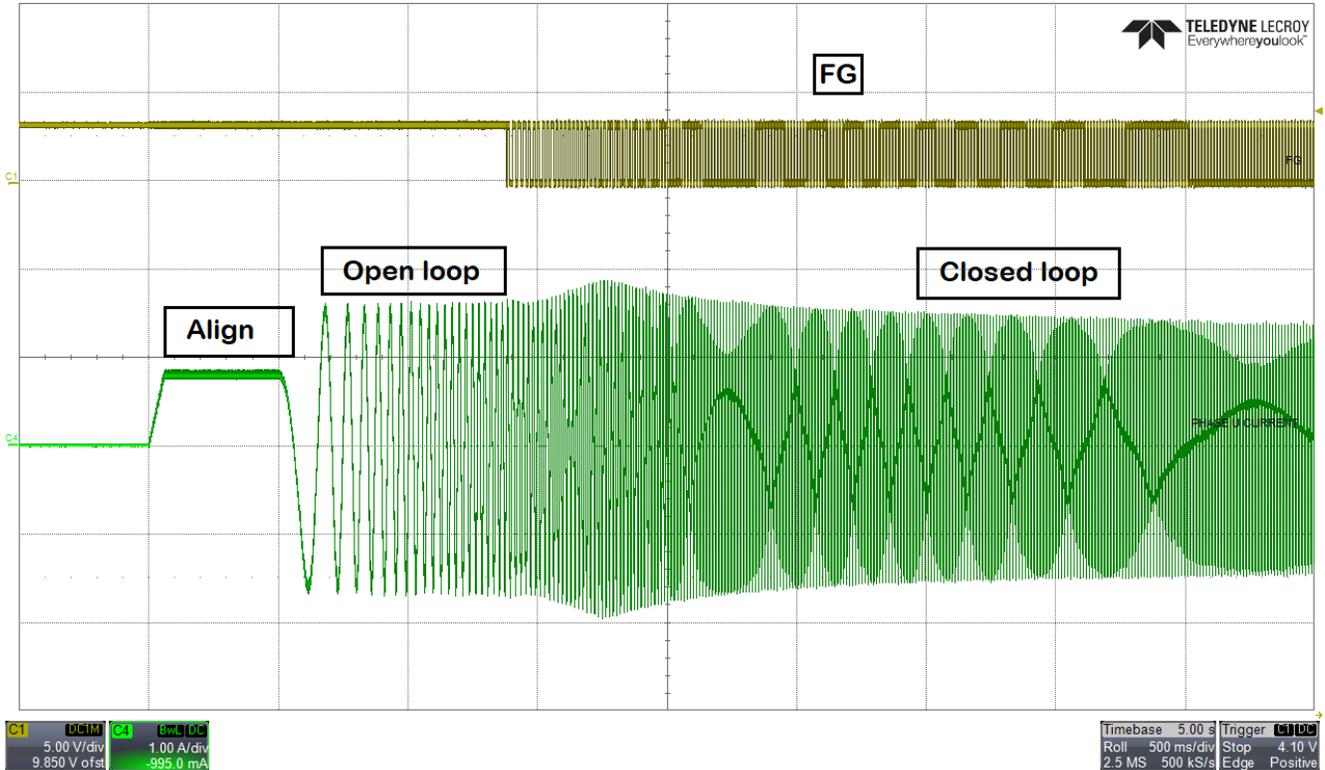
Below are the two essential parameters that are required to spin the motor in closed loop.

1. Maximum motor speed.
2. Current limit for torque PI loop.

7.2.1 Application Curves

7.2.1.1 Motor startup

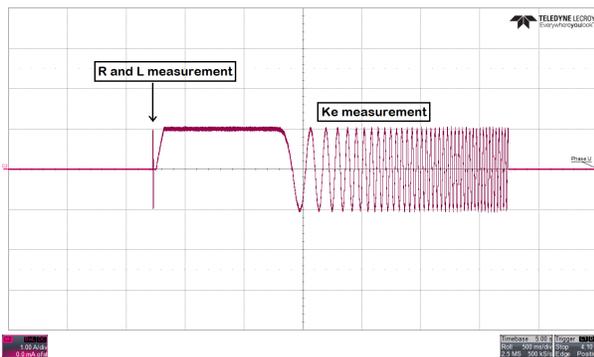
図 7-2 shows the FG waveform and the phase current waveform at different motor operations.



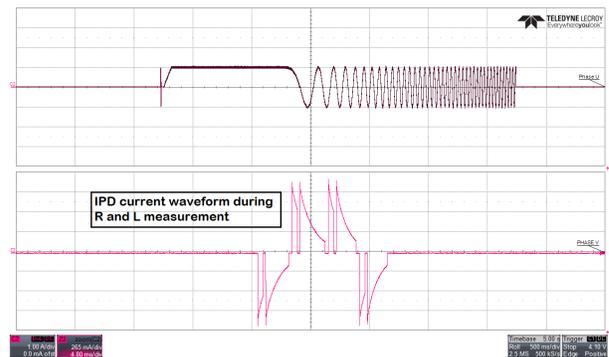
7-2. Motor Startup - FG and Phase current

7.2.1.2 MPET

7-3 shows the phase current waveform during motor parameter measurement. 7-4 shows the IPD current waveform during R, L and Ke measurement. Bottom half of 7-4 shows the IPD current waveform during R and L measurement. R is measured during the rising of phase current and L is measured during the falling of phase current. After R and L measurement, motor spins in open loop. Once the speed reaches MPET open loop speed reference [MPET_OPEN_LOOP_SPEED_REF], motor is coasted. BEMF voltage of all three phases are measured and Ke is calculated.



7-3. MPET - Phase current

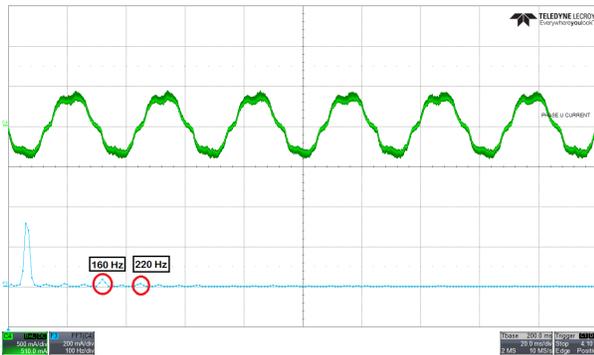


7-4. IPD current waveform during R and L measurement

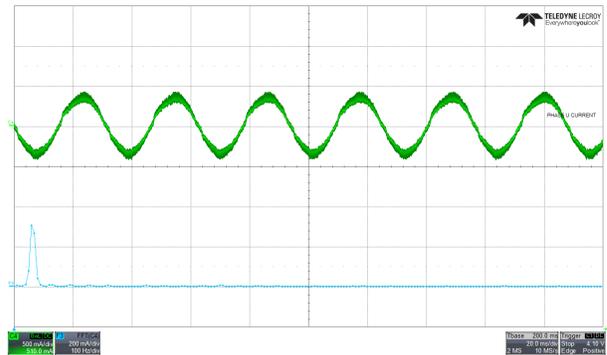
7.2.1.3 Dead time compensation

7-5 shows the phase current waveform when dead time compensation is disabled. Fundamental frequency of phase current is 40 Hz. Fast Fourier transform (FFT) of phase current plot shows harmonics at 160 Hz and 220

Hz.  7-6 shows the phase current waveform when dead time compensation is enabled. Phase current looks more sinusoidal and the FFT of phase current plot does not have any harmonics.



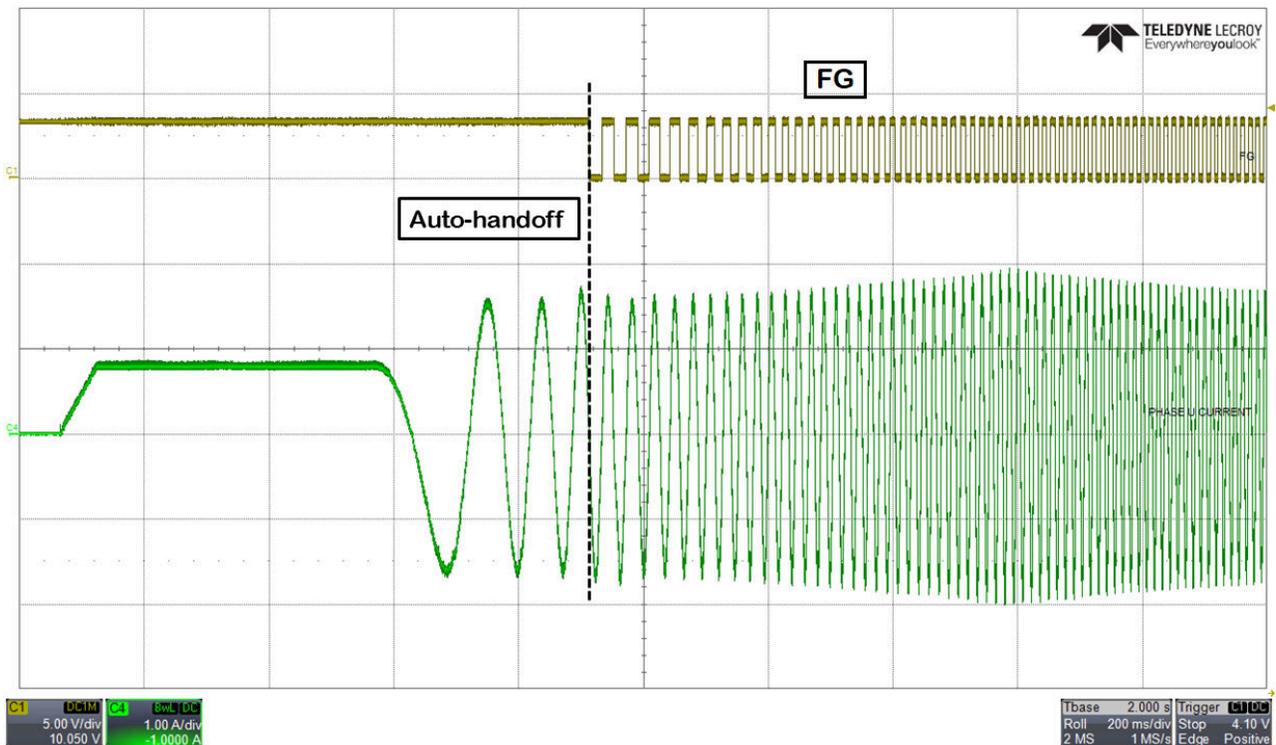
 7-5. Phase current and FFT - Dead time compensation disabled



 7-6. Phase current and FFT - Dead time compensation enabled

7.2.1.4 Auto handoff

 7-7 shows the auto handoff feature in MCF8315C where the motor transitions seamlessly from open loop to closed loop.

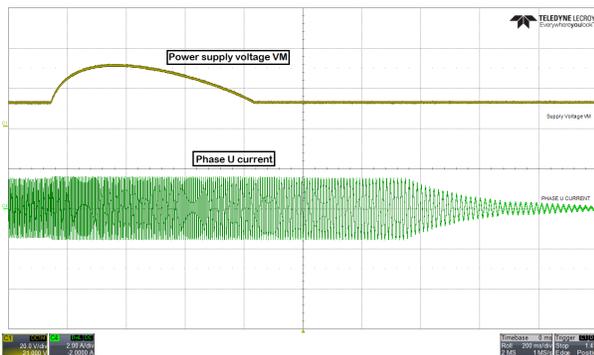


 7-7. Auto-handoff

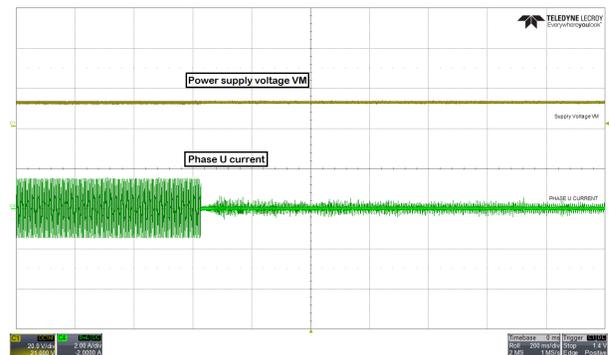
7.2.1.5 Anti voltage surge (AVS)

When motor speed decelerates at a very high deceleration rate, mechanical energy from the motor returns to the power supply which could result in pumping up the supply voltage, VM.  7-8 shows overshoot in power supply

voltage when AVS is disabled. Motor decelerates from 100% duty cycle to 10% duty cycle at a deceleration rate of 70,000 Hz/sec.  7-9 shows no overshoot in power supply voltage when AVS is enabled.



 7-8. Power supply voltage and phase current waveform when AVS is disabled



 7-9. Power supply voltage and phase current waveform when AVS is enabled

7.2.1.6 Real time variable tracking using DACOUT

MCF8315C has one 12-bit DAC which outputs analog voltage equivalent of digital variables on DACOUT pin with resolution of 12 bits and max voltage of 3V. Signals available on DACOUT pin can be used for tuning speed controller or other driver configuration or bus current monitoring. Check algorithm variable registers in datasheet for list of all internal algorithm variables.

The address for variables for DACOUT is configured using DACOUT_VAR_ADDR. This is useful in applications which require tracking algorithm variable in real time without having any delay from the communication bus. Pin 29 should be configured as DACOUT by setting DAC_ENABLE to 1b.

For example, if the user wants to read phase A current from pin 29, set DAC_ENABLE to 1b and program the phase A current register address (0x00000440) in Hex in [DACOUT_VAR_ADDR].

8 Power Supply Recommendations

8.1 Bulk Capacitance

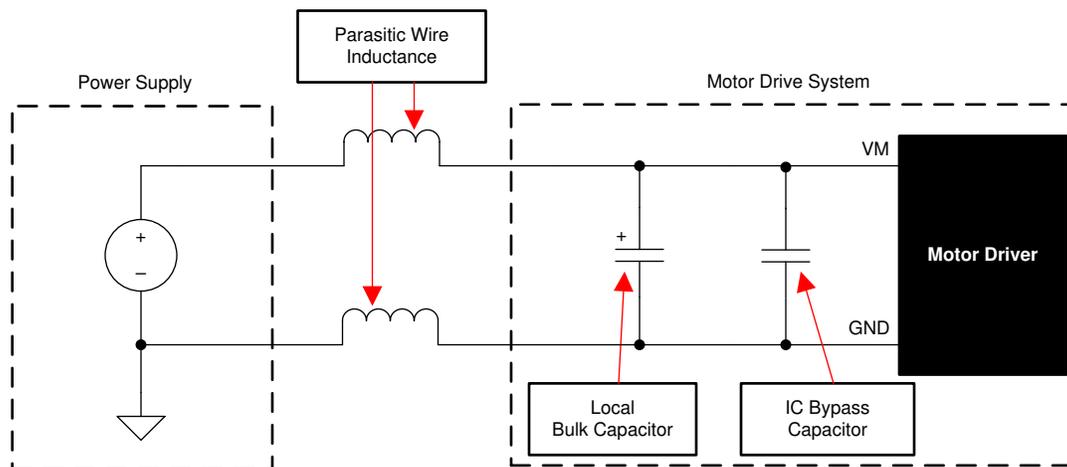
Having an appropriate local bulk capacitance is an important factor in motor drive system design. It is generally beneficial to have more bulk capacitance, while the disadvantages are increased cost and physical size.

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

- The highest current required by the motor system
- The capacitance and current capability of the power supply
- 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 the motor drive system limits the rate at which 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 VM voltage. When adequate bulk capacitance is used, the VM 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 bulk capacitor.



8-1. 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.

9 Layout

9.1 Layout Guidelines

The bulk capacitor should be placed to minimize the distance of the high-current path through the motor driver device. The connecting metal trace widths should be as wide as possible, and numerous vias should be used when connecting PCB layers. These practices minimize parasitic inductance and allow the bulk capacitor to deliver high current.

Small-value capacitors should be ceramic, and placed closely to device pins.

The high-current device outputs should use wide metal traces.

To reduce noise coupling and EMI interference from large transient currents into small-current signal paths, grounding should be partitioned between PGND and AGND. TI recommends connecting all non-power stage circuitry (including the thermal pad) to AGND to reduce parasitic effects and improve power dissipation from the device. Optionally, GND_BK can be split. Ensure grounds are connected through net-ties or wide resistors to reduce voltage offsets and maintain gate driver performance.

The device thermal pad should be soldered to the PCB top-layer ground plane. Multiple vias should be used to connect to a large bottom-layer ground plane. The use of large metal planes and multiple vias helps dissipate the $I^2 \times R_{DS(on)}$ heat that is generated in the device.

To improve thermal performance, maximize the ground area that is connected to the thermal pad ground across all possible layers of the PCB. Using thick copper pours can lower the junction-to-air thermal resistance and improve thermal dissipation from the die surface.

Separate the SW_BK and FB_BK traces with ground separation to reduce buck switching from coupling as noise into the buck outer feedback loop. Widen the FB_BK trace as much as possible to allow for faster load switching.

9.2 Thermal Considerations

The MCF8315C has thermal shutdown (TSD) as previously described. A die temperature in excess of 150°C (minimally) disables the device until the temperature drops to a safe level.

Any tendency of the device to enter thermal shutdown is an indication of excessive power dissipation, insufficient heatsinking, or too high an ambient temperature.

9.2.1 Power Dissipation

The power dissipated in the output FET resistance ($R_{DS(on)}$) dominates power dissipation in MCF8315C.

At start-up and fault conditions, the FET current is much higher than normal operating FET current; remember to take these peak currents and their duration into consideration.

The total device power dissipation is the power dissipated in each of the three half-bridges added together along with standby power, LDO and buck regulator losses.

The maximum amount of power that the device can dissipate depends on ambient temperature and heatsinking.

Note that $R_{DS(on)}$ increases with temperature, so as the device heats, the power dissipation increases. Take this into consideration when sizing the heatsink.

A summary of equations for calculating each loss is shown below in [表 9-1](#).

表 9-1. Power Losses for MCF8315C

| Loss type | MCF8315C |
|----------------|--|
| Standby power | $P_{standby} = VM \times I_{VM_TA}$ |
| LDO | $P_{LDO} = (VM - V_{AVDD}) \times I_{AVDD}$, if BUCK_PS_DIS = 1b $P_{LDO} = (V_{BK} - V_{AVDD}) \times I_{AVDD}$, if BUCK_PS_DIS = 0b |
| FET conduction | $P_{CON} = 3 \times (I_{RMS(FOC)})^2 \times R_{ds,on(TA)}$ |
| FET switching | $P_{SW} = 3 \times I_{PK(FOC)} \times V_{PK(FOC)} \times t_{rise/fall} \times f_{PWM}$ |
| Diode | $P_{diode} = 3 \times I_{PK(FOC)} \times V_{diode} \times t_{dead} \times f_{PWM}$ |
| Buck | $P_{BK} = 0.11 \times V_{BK} \times I_{BK}$ ($\eta_{BK} = 90\%$) |

10 Device and Documentation Support

10.1 サポート・リソース

テキサス・インスツルメンツ E2E™ サポート・フォーラムは、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計に必要な支援を迅速に得ることができます。

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10.4 用語集

[テキサス・インスツルメンツ用語集](#) この用語集には、用語や略語の一覧および定義が記載されています。

11 Revision History

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

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most-current data available for the designated device. This data is subject to change without notice and without revision of this document. For browser-based versions of this data sheet, see the left-hand navigation pane.

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) |
|--------------------------------|---------------|----------------------|-------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| MCF8315C1VPWPR | Active | Production | HTSSOP (PWP) 24 | 2000 LARGE T&R | Yes | NIPDAU | Level-3-260C-168 HR | -40 to 125 | MCF15C1V |
| MCF8315C1VPWPR.A | Active | Production | HTSSOP (PWP) 24 | 2000 LARGE T&R | Yes | NIPDAU | Level-3-260C-168 HR | -40 to 125 | MCF15C1V |
| MCF8315C1VRRYR | Active | Production | WQFN (RRY) 32 | 3000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | MCF8315 C1VRRYR |
| MCF8315C1VRRYR.A | Active | Production | WQFN (RRY) 32 | 3000 LARGE T&R | Yes | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | MCF8315 C1VRRYR |

(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.

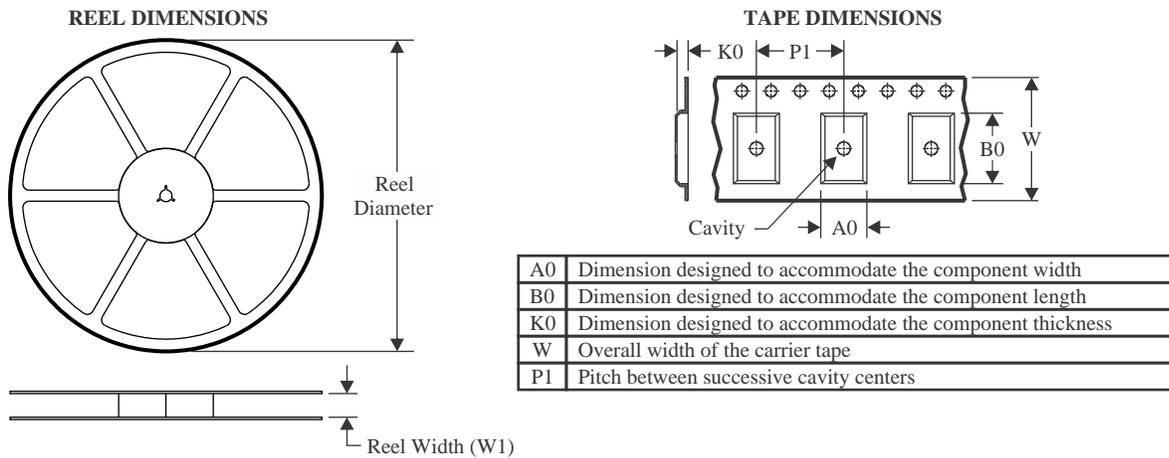
OTHER QUALIFIED VERSIONS OF MCF8315C :

- Automotive : [MCF8315C-Q1](#)

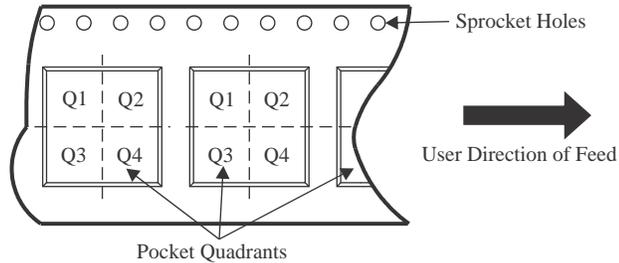
NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

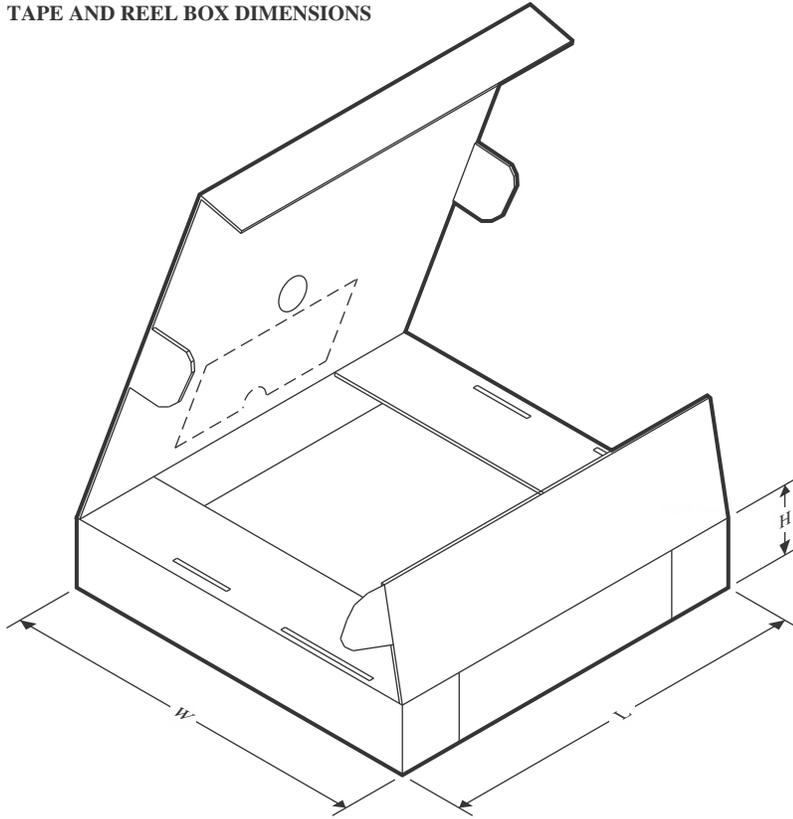


QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MCF8315C1VPWPR | HTSSOP | PWP | 24 | 2000 | 330.0 | 16.4 | 6.95 | 8.3 | 1.6 | 8.0 | 16.0 | Q1 |
| MCF8315C1VRRYR | WQFN | RRY | 32 | 3000 | 330.0 | 12.4 | 4.3 | 6.3 | 1.1 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MCF8315C1VPWPR | HTSSOP | PWP | 24 | 2000 | 350.0 | 350.0 | 43.0 |
| MCF8315C1VRRYR | WQFN | RRY | 32 | 3000 | 367.0 | 367.0 | 35.0 |

GENERIC PACKAGE VIEW

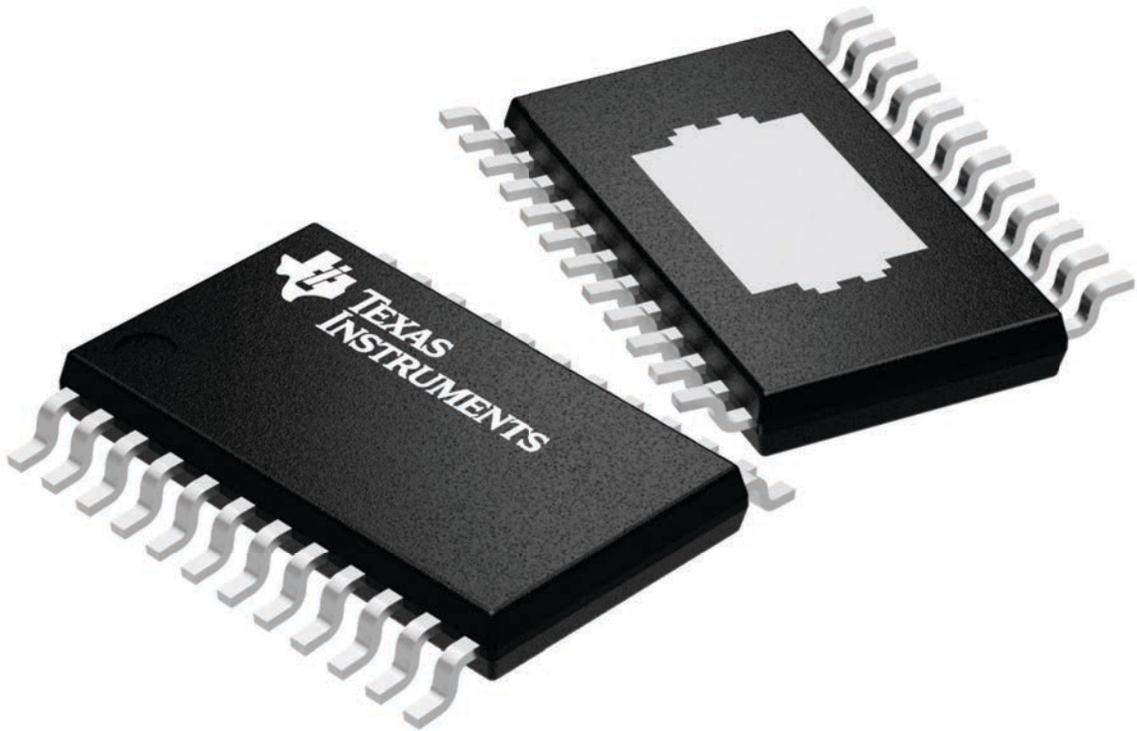
PWP 24

PowerPAD™ TSSOP - 1.2 mm max height

4.4 x 7.6, 0.65 mm pitch

PLASTIC SMALL OUTLINE

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



4224742/B

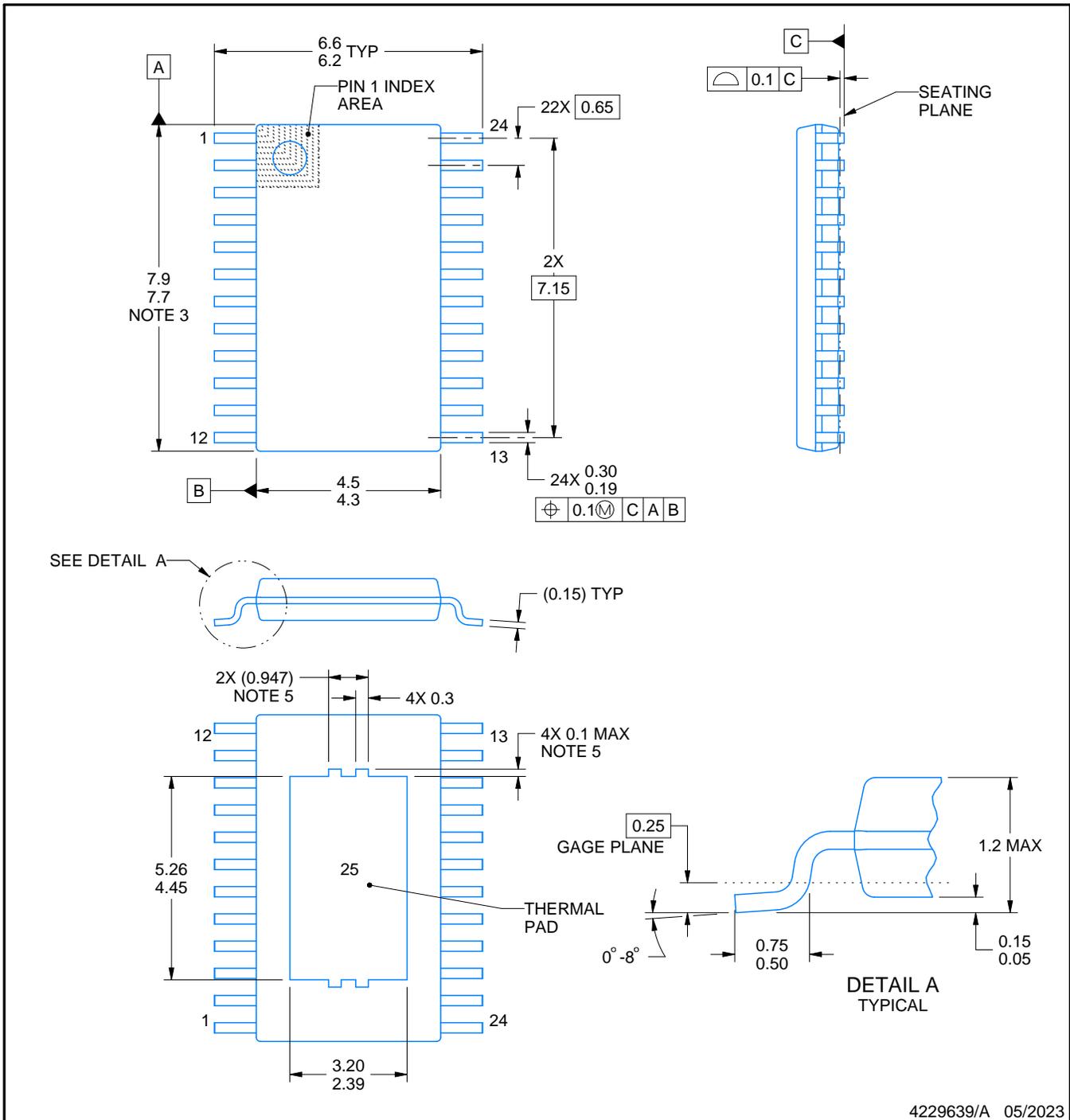
PWP0024R



PACKAGE OUTLINE

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4229639/A 05/2023

NOTES:

PowerPAD is a trademark of Texas Instruments.

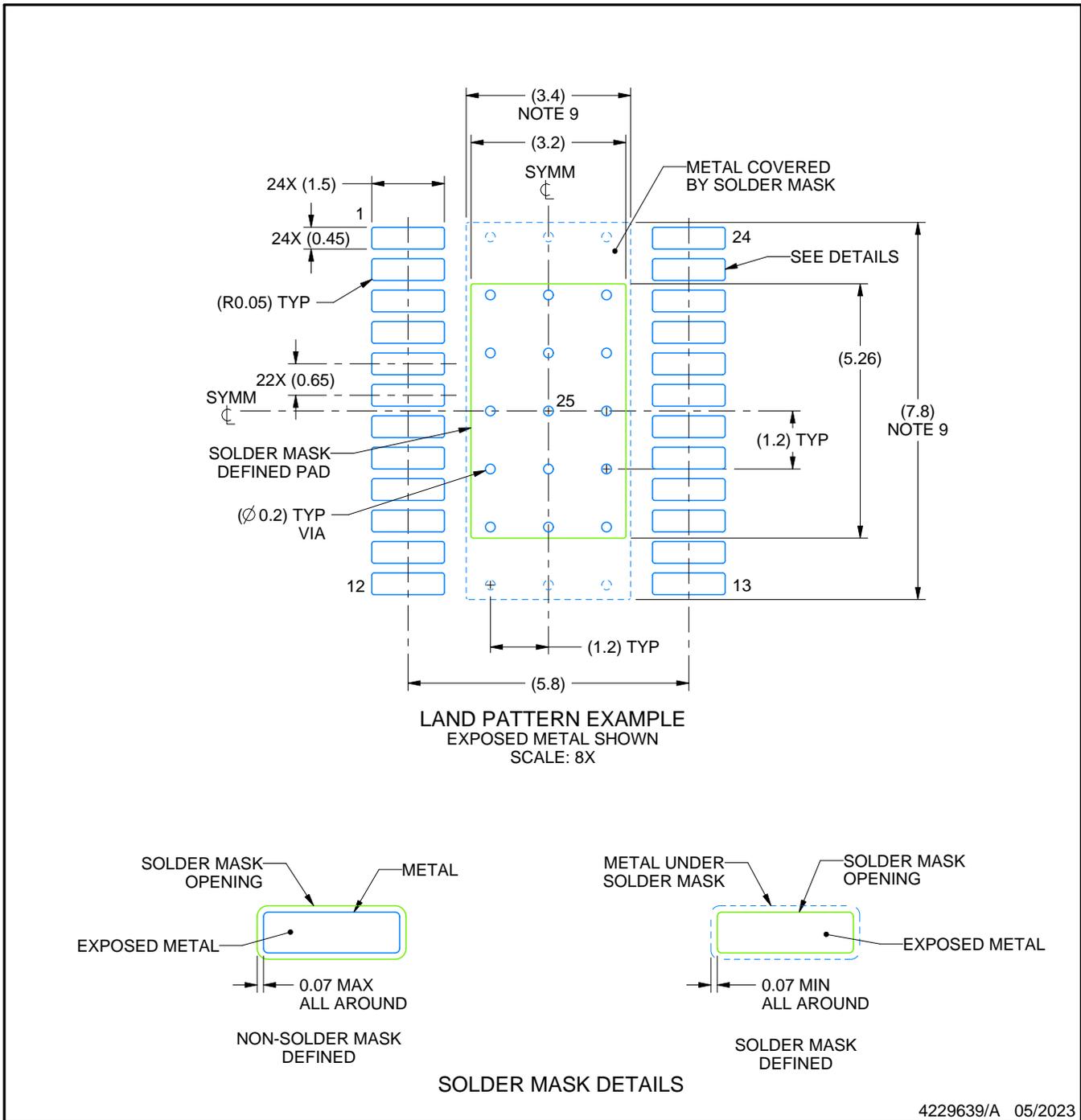
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-153.
5. Features may differ or may not be present.

EXAMPLE BOARD LAYOUT

PWP0024R

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



NOTES: (continued)

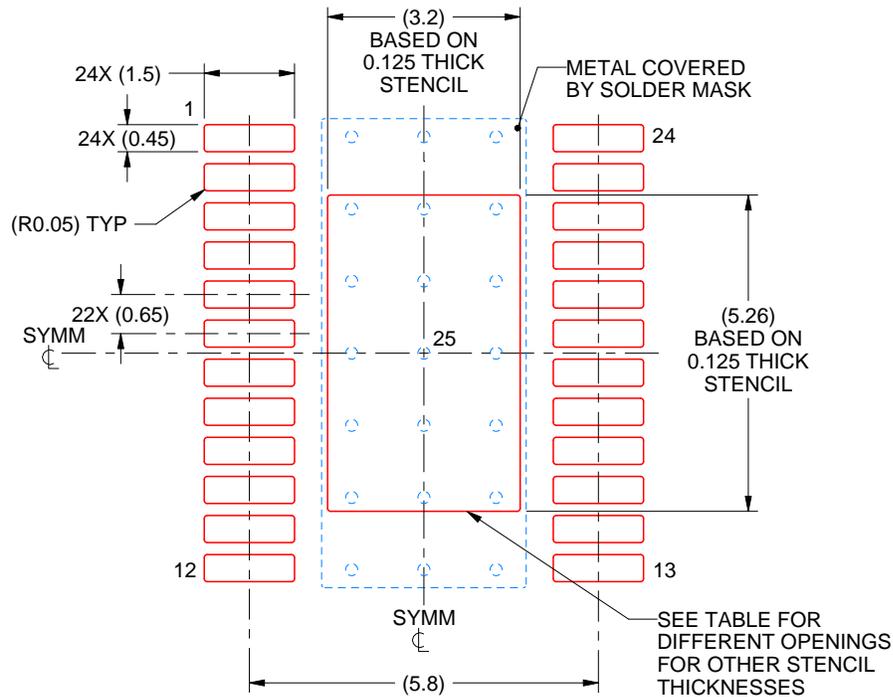
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Size of metal pad may vary due to creepage requirement.
10. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

PWP0024R

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 8X

| STENCIL THICKNESS | SOLDER STENCIL OPENING |
|-------------------|------------------------|
| 0.1 | 3.58 X 5.88 |
| 0.125 | 3.20 X 5.26 (SHOWN) |
| 0.15 | 2.92 X 4.80 |
| 0.175 | 2.70 X 4.45 |

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NOTES: (continued)

11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

GENERIC PACKAGE VIEW

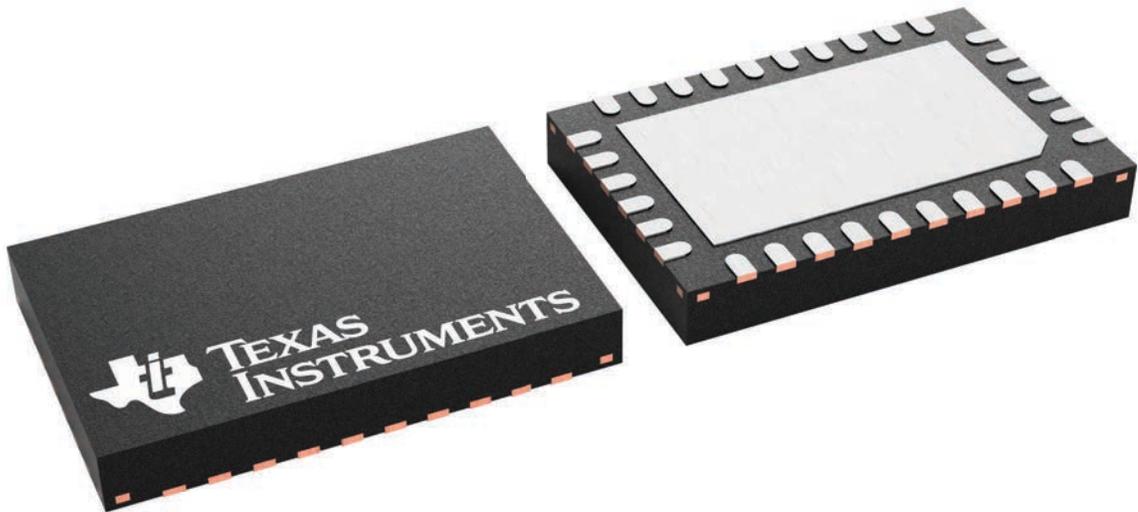
RRY 32

WQFN - 0.8 mm max height

4 x 6, 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.



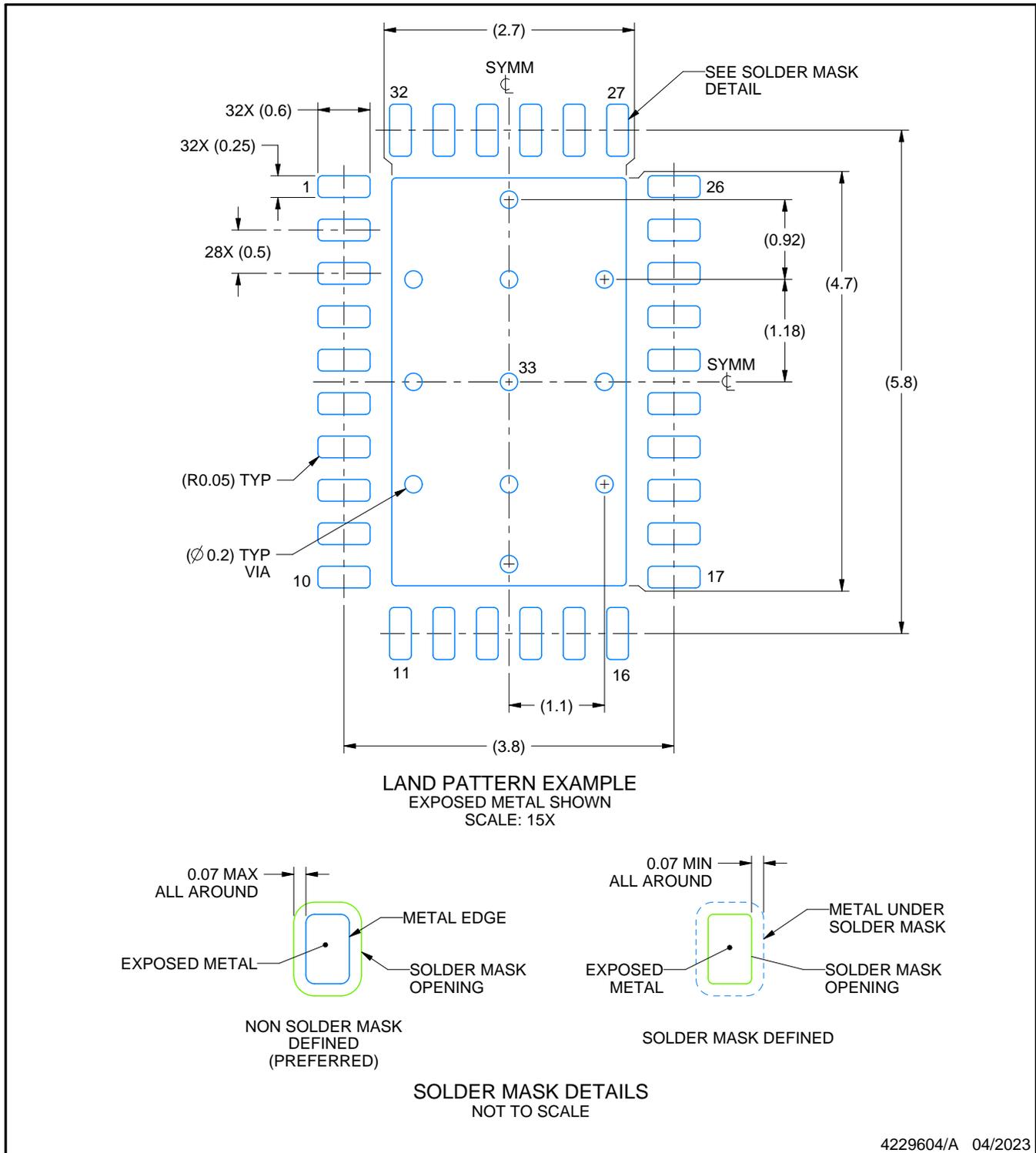
4229624/A

EXAMPLE BOARD LAYOUT

RRY0032B

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

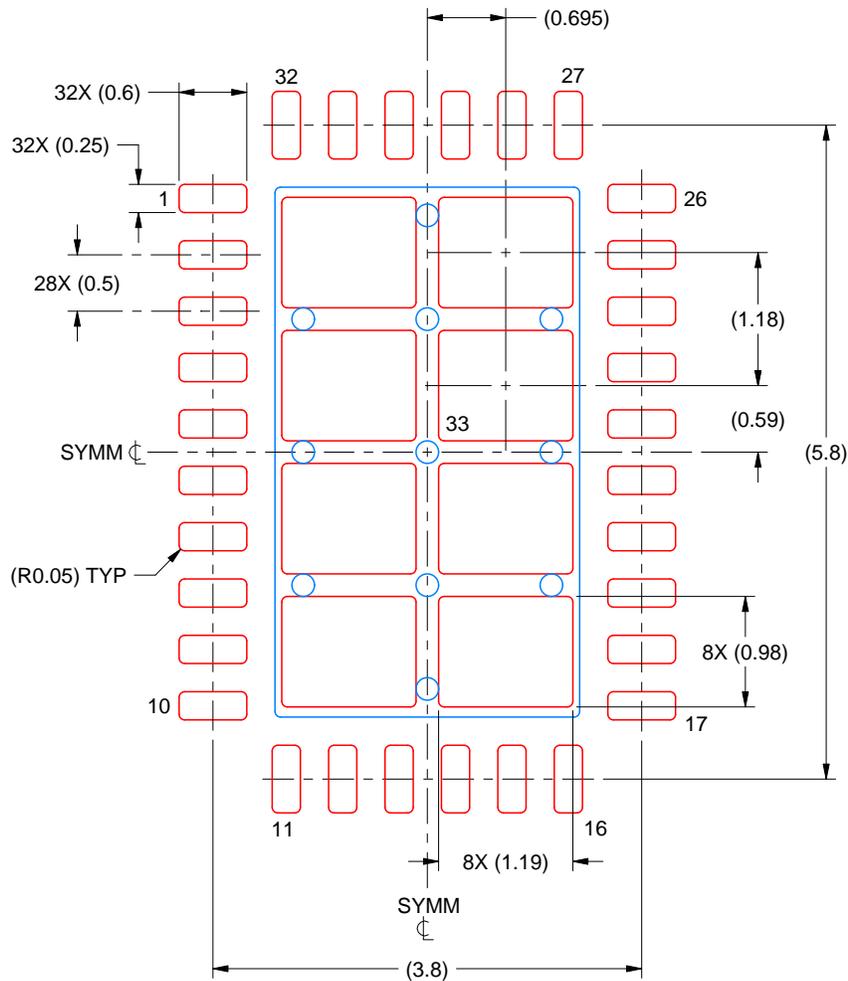
- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown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

EXAMPLE STENCIL DESIGN

RRY0032B

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 15X

EXPOSED PAD 33
74% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

4229604/A 04/2023

NOTES: (continued)

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

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