Application Note

Motor Pre-Startup Tuning for MCx83xx

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ABSTRACT

The BLDC motor can either be stationary or windmilling in forward or reverse direction when a motor run (non-zero reference) command is received by MCx83xx. Depending on the initial motor state (stationary or windmilling), there are different configurable options available to drive the BLDC motor to user to set reference – MCx83xx can either apply a brake to bring the motor to a stationary state before driving to set reference; alternately, MCx83xx can also resync to motor speed and direction in real time in forward direction. This application note discusses the settings available to configure the pre-start behavior of MCx83xx to achieve designed performance for start-up.

The content is applicable for MCx83xx family:

- MCF8315A
- MCF8315C
- MCF8315C-Q1
- MCF8316A
- MCF8316C
- MCF8316C-Q1
- MCF8315D
- MCF8316D
- MCF8329A
- MCT8316A
- MCT8315A
- MCT8329A

Note

- MCF83xx refers to TI's sensorless FOC based 3-phase BLDC drivers including MCF8316D, MCF8315D, MCF8316C-Q1, MCF8315C-Q1, MCF8315C, MCF8315A, MCF8316A and MCF8329A.
- MCT83xx refers to TI's sensorless trapezoidal commutation based 3-phase BLDC drivers including MCT8316A, MCT8316A-Q1, MCT8315A and MCT8329A.
- MCF83xx and MCT83xx family of devices is referred to as MCx devices in this application note.

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1 Introduction

Pre-startup refers to the stage of motor operation when the initial speed, position and direction are determined by sensing the three phase voltages when a motor run command is received.

The initial speed detection(ISD) module is used to identify the initial state of the motor and is enabled by setting ISD_EN to 1b. If the motor is coasting and sufficient back EMF is available to be sensed, the motor can be resynchronized and driven to set reference directly.

ISD can be disabled by setting ISD_EN to 0b. If ISD is disabled, the MCx83xx does not perform the initial speed detection and proceeds to the brake routine if enabled before startup irrespective of motor initial state.

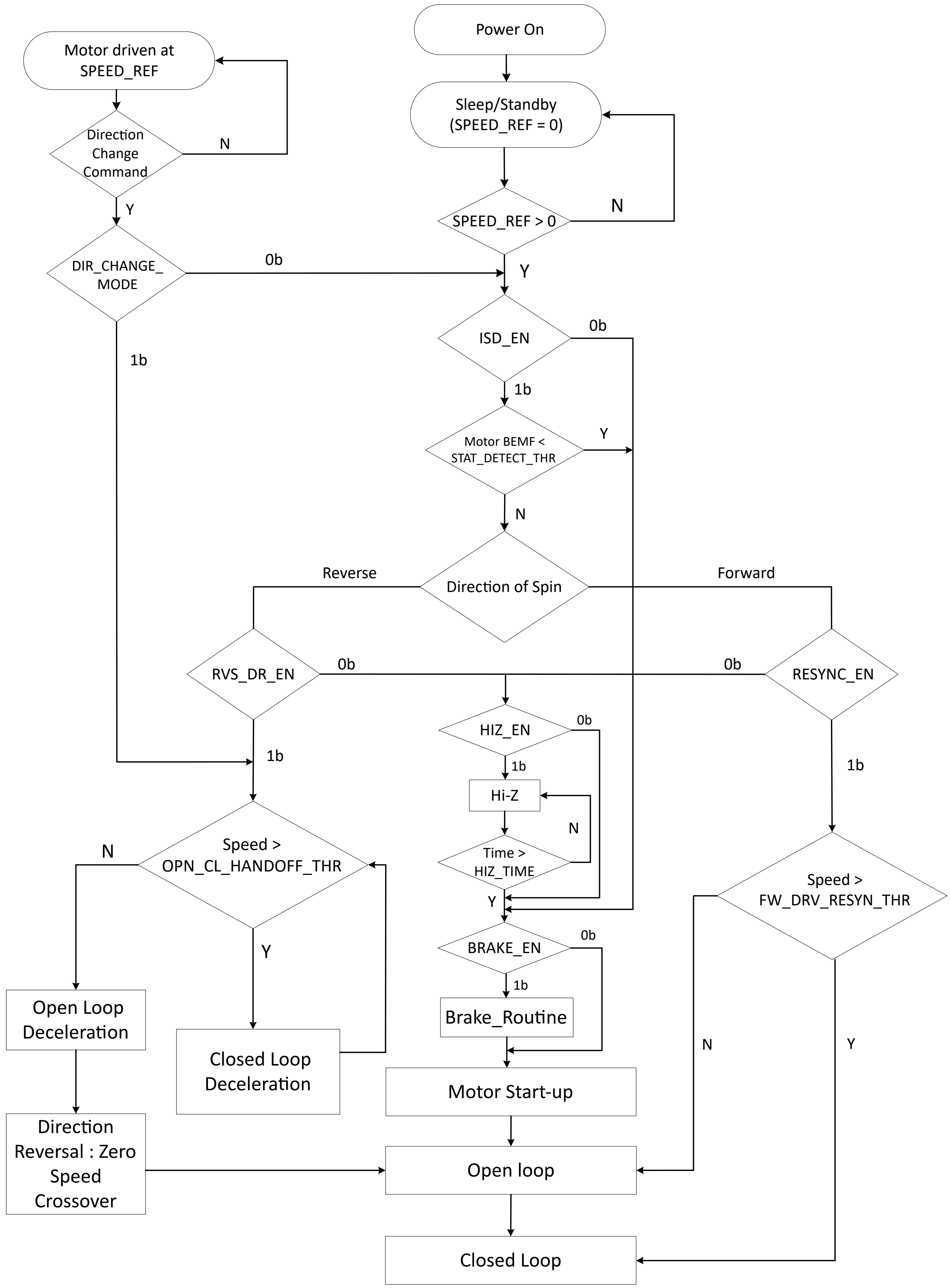

Figure 1-1. MCF83xx Pre-startup Flow Diagram

Note

There are minor differences to the pre-startup routine in MCT83xx but majority of this application note is applicable to the MCT83xx devices also.

Notable differences in the MCT83xx pre-startup flow includes (but not limited to):

- **Absence of DIR_CHANGE_MODE:** If RVS_DR_EN is set, state machine tries to reverse spin direction by decelerating to zero speed before accelerating in opposite direction. Else, motor is coasted and brake (if enabled) is applied to bring motor to standstill before accelerating in opposite direction.
- **Presence of a separate startup brake:** Even when motor is detected to be stationary, the motor can still be rotating very slowly or oscillating. A startup brake is available that can be applied to bring motor to standstill. This can be configured to be different brake time than the regular brake. Generally, startup brake time is much less than regular brake time.
- Since BEMF can be sensed in MCT83xx devices due to availability of floating phase, the threshold to resync is based on BEMF voltage magnitude unlike MCF83xx devices where the threshold is configured as a % of MAX_SPEED.

2 End Application Configuration Recommendation

Different end applications have a different set of requirements in the pre-startup stage that are critical depending on motor inertia, external factors like wind, for example. There is importance in understanding the functionality of the pre-start-up features and configure appropriately for a given end application. Table 2-1 summarizes the pre-startup configuration recommendation for common end applications.

Table 2-1. End Application Pre-startup Recommendation

Application	Resync	Reverse Drive	Hi-z	Startup Brake	Direction Change Mode	Comments
Ceiling Fans	Yes	No	Yes	Yes	0b	High inertia
Pedestal Fans	Yes	Yes	No	Yes	0b	High inertia
Server/Seat Cooling fan	Yes	No	Yes	Yes	0b	Medium inertia
Pumps/ Fuel pumps	No	No	No	Yes	0b	Low inertia
Vaccum cleaner	Yes	Yes	No	Yes	1b	High inertia
CPAP	Yes	Yes	No	Yes	1b	High inertia
Air Purifiers	Yes	No	No	Yes	0b	Medium to high inertia
Massager	No	No	No	Yes	1b	Low inertia
Brush Bar	No	No	No	Yes	0b	Geared systems
Washer Dryer pumps	No	No	No	Yes	0b	Low to Medium inertia

2.1 Resynchronization

Resynchronization or resync is a feature that allows the device to catch a windmilling motor *on-the-fly* and ramp the motor to the commanded speed when the motor was spinning in the commanded direction.

If speed is greater than FWD_DRV_RESYN_THR such that sufficient BEMF is being produced, then drive directly switches to closed loop drive else motor is ramped using open loop before handing off to closed loop.

When recommended:

- Resync helps significantly when motor has high inertia. High inertia motors take up a lot of time to start and stop. If a motor was already spinning in commanded direction prior to run command, resync can save the time to brake, stop and restart using motor startup methods.
  - Examples: Ceiling fans due to high inertia.
- If external factors like wind is present that rotates the motor in the commanded direction, resync is recommended to be enabled for faster and smoother startup.
  - Example: pedestal fans due to possibility of wind causing rotation.
- Repeated start-stop routine during operation in moderate to high inertia motors.
  - Example: CPAP(continuous positive airway pressure) motors.

2.2 Reverse Drive

When motor is detected to be spinning in the opposite direction, the reverse drive feature enables the user to reverse the motor direction in a controlled manner.

When recommended:

- If external factors like wind are present that rotates the motor in the opposite direction, reverse drive is recommended to be enabled for faster and smoother direction reversal and ramp in the commanded direction.
  - Example: pedestal fans due to possibility of wind causing rotation.
- Applications that require the motor to spin in both directions.
  - Example: Vacuum cleaner to suck the dust and blow the dust.

2.3 Coasting (Hi-Z)

If motor is spinning in either direction at startup, and resync or reverse drive is disabled, the device tries to brake (recommended to be enabled in all end applications as per Table 1) before starting from standstill. If the motor speed is too high while braking then high braking currents can be observed. To prevent brake current from exceeding ILIMIT, in high inertia motors when either resync or reverse drive is disabled, enable coasting to slow down the motor naturally before applying brake. Refer to Figure 1-1 for clarity.

When recommended:

- High inertia motors where resync or reverse drive is disabled.
  - Example: Ceiling fans or server fans as in these applications reverse drive feature is not recommended to be enabled due to unlikely case of reverse rotation in these end applications and the effort required to tune the reverse drive.

2.4 Startup Brake

Even when the motor is detected to be stationary, the motor can be spinning very slowly or oscillating which can result in reduction in reliability of startup methods like IPD. Startup brake is provided to make sure that the motor is stationary before initiating startup algorithms.

When recommended:

- Recommended to be enabled for all end applications.

2.5 Direction Change Mode

Decides whether direction change is executed through full pre-startup state machine or through reverse drive depending upon DIR_CHANGE_MODE configuration.

When recommended:

- In end applications where direction change is expected during operation, DIR_CHANGE_MODE is set to 1b. This requires the reverse drive parameters to be tuned as reverse drive is used to change direction.
  - Example: In massage chair motors that frequently change direction, DIR_CHANGE_MODE to 1b.
- In end applications where reverse drive is not common and can afford to stop the motor by coasting and applying brake before starting in opposite direction, set the direction change mode to 0b and disable reverse drive by setting RVS_DR_EN to 0b. This saves tuning effort for reverse drive.
  - Example: Server fans have fixed direction of spinning.
- When RVS_DR_EN is set to 1b and reverse drive is tuned, DIR_CHANGE_MODE can be set to 0b as reverse drive is executed on direction change command.

3 Tuning Guidance

Each of the modules described in the preceding section have tuning parameters that need to be configured as per motor parameters and application requirements. This section looks at the available configurations and how to tune them. Examples to recover from faults that can occur with inappropriate tuning are also provided.

3.1 Initial Speed Detection Module

When pre-startup begins, with ISD enabled, the back-EMF(BEMF) induced needs to be sensed to extract direction and speed information. The following configurations affect the robustness of the ISD module.

Table 3-1. ISD Tuning Parameters

Tuning Parameter	Sub-Feature Description	Tuning Considerations
ISD_EN	Enables initial motor speed and direction detection	Enable if frequent start-stop requests part of operation and there is possibility of motor windmilling at the time of start. Enable for high inertia applications like fans
FAST_ISD_EN	Enable fast speed detection during ISD.	To be enabled when fast startup time of less than 100ms is required. Due to lesser BEMF samples than normal ISD, some angle inaccuracy is observed occasionally leading to initial current spike or reverse rotation.
ISD_STOP_TIME	Persistence time for declaring motor has stopped.	Start with low persistence time settings. Noise in the sensed motor BEMF can cause erroneous motor state detection. Increase to improve reliability. Decrease for low inertia motor to allow faster speed and direction detection before the BEMF signal decays. If motor detected stationary even when run command issued with sufficient speed decrease these settings.
ISD_RUN_TIME	Persistence time for declaring motor is running	
ISD_TIMEOUT	Timeout in case ISD is unable to reliably detect speed or direction	Keep timeout times high to allow sufficient time to detect the speed of the motor if the application allows. If kept too low, ISD sometimes fails to detect speed and direction especially with high ISD_RUN_TIME settings leading to stop and start instead of resync with the drive.
ISD_BEMF_FILT_ENABLE	Enable BEMF Filter during ISD	Keep BEMF filtering enabled for reliable speed and direction detection especially for motors with non-sinusoidal BEMF.
STAT_DETECT_THR	Sets the BEMF threshold below which motor is detected to be stationary.	Set STAT_DETECT_THR with some margin to allow some time for ISD execution and persistence times. Note: BEMF generated = BEMF constant of the motor * motor speed. Speed below which the motor is detected stationary can be calculated by dividing the STAT_DETECT_THR with BEMF constant. If set too low, then motor BEMF can be unreliable after ISD is completed leading failed startup. If set too high, a motor coasting with sufficient BEMF can be detected as stationary.
DIR_CHANGE_MODE	Dictates the flow when a direction change command is received. Decides whether to go through ISD routine or use reverse drive to change motor direction while driving continuously.	Set to 1b if direction change is part of application use case to decelerate motor in a controlled manner and change direction. Otherwise the recommendation is to coast and brake to stop the motor before changing drive direction.

3.1.1 Initial Speed Detection

Initial Speed Detection (ISD_EN) decides if speed detection is required to resynchronize if the motor is spinning or to stop the motor irrespective of speed and restart from stationary state. In high inertia applications, ISD helps optimize the startup by reducing startup time significantly.

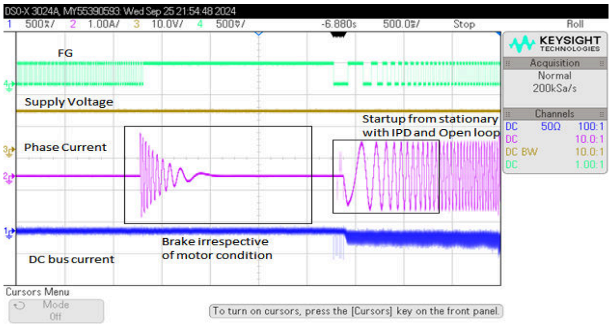

Figure 3-1. ISD_EN = 0b

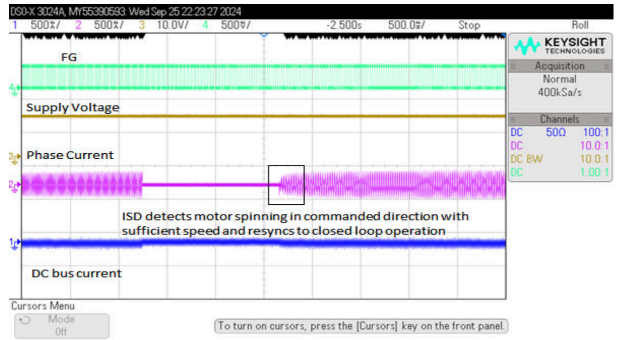

Figure 3-2. ISD_EN = 1b

In Figure 3-1, the motor was forced to brake and start from stationary even with sufficient BEMF available for direct pass-off to closed loop as ISD is disabled. In Figure 3-2, Motor resyncs with the drive and ramps up to commanded speed due to ISD being enabled.

3.1.2 ISD Times

The ISD_STOP_TIME and ISD_RUN_TIME are persistence times provided to increase robustness of motor state detection by filtering noise.

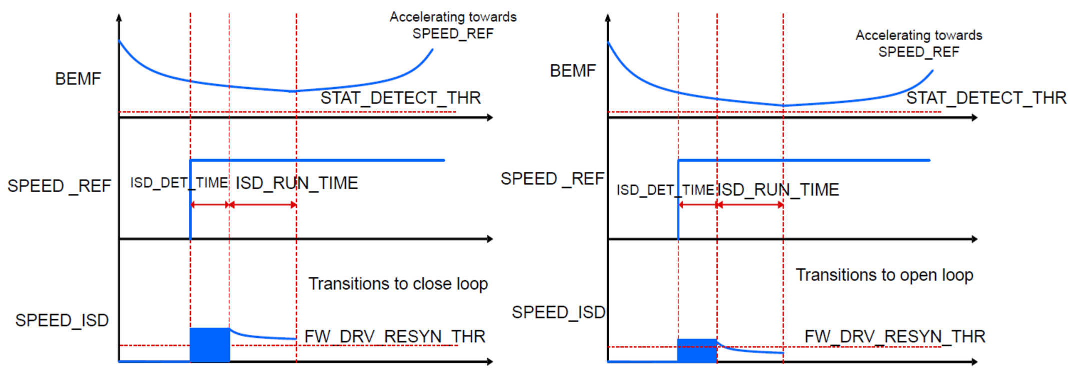

Figure 3-3. ISD_RUN_TIME Impact: Speed at Resync > FW_DRV_RESYN_THR after ISD_RUN_TIME

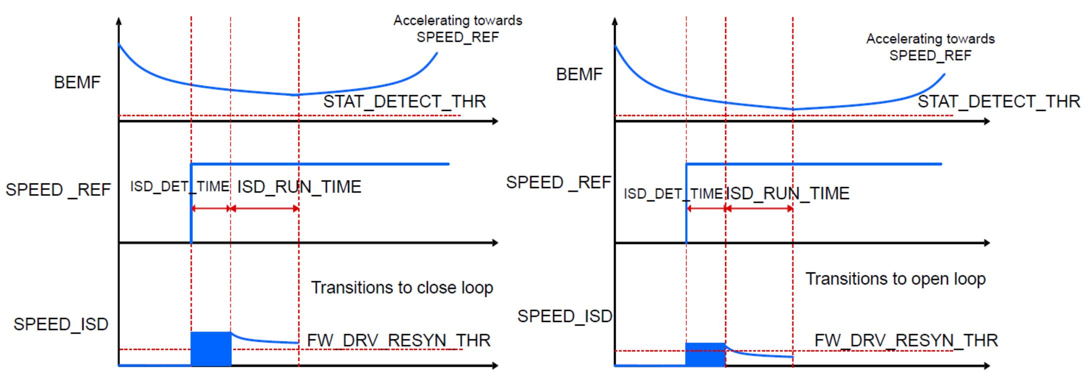

Figure 3-4. ISD_RUN_TIME Impact: Speed at Resync < FW_DRV_RESYN_THR After ISD_RUN_TIME After ISD_RUN_TIME

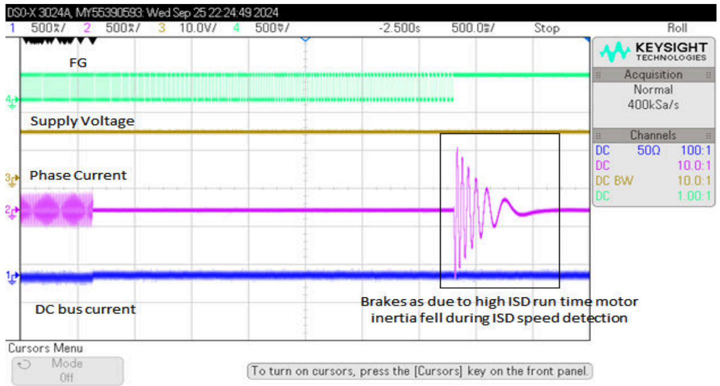

Figure 3-5. ISD_RUN_TIME of 100ms Leads to BEMF Fall Below STAT_DETECT_THR and Results in Brake Instead of Resynchronization

In Figure 3-5, high ISD run time increases the ISD detection time leading to fall of speed in motor especially in low inertia motors. This can lead to motor brake and restart even if sufficient speed was available when run command was issued.

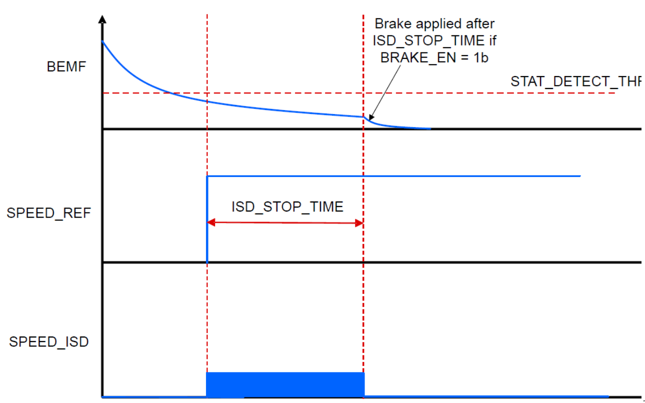

Figure 3-6. ISD_STOP_TIME Impact: Brake Applied to Stop Motor as Speed Below STAT_DETECT_THR for ISD_STOP_TIME

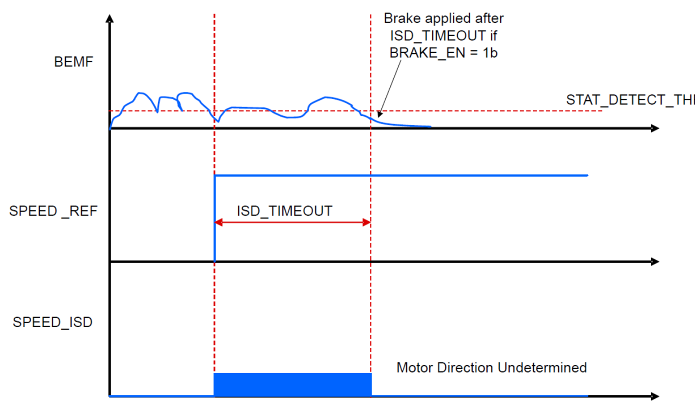

Figure 3-7. ISD_TIMEOUT: Brake Applied as Motor Direction and Speed not Detected Reliably Before ISD_TIMEOUT

3.1.3 Stationary Detect Threshold

The effect of Stationary Detect Threshold (STAT_DETECT_THR) is shown in Figure 3-8 and Figure 3-9.

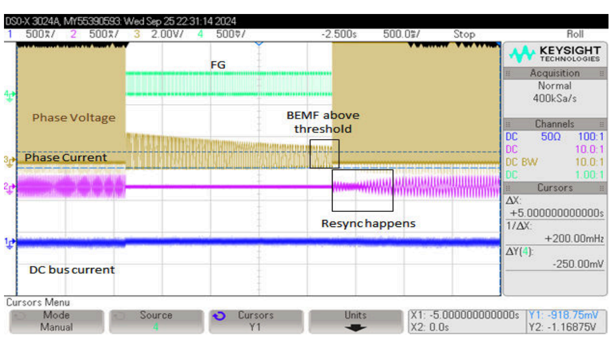

Figure 3-8. BEMF > STAT_DETECT_THR(1000mV) - Resync and Start

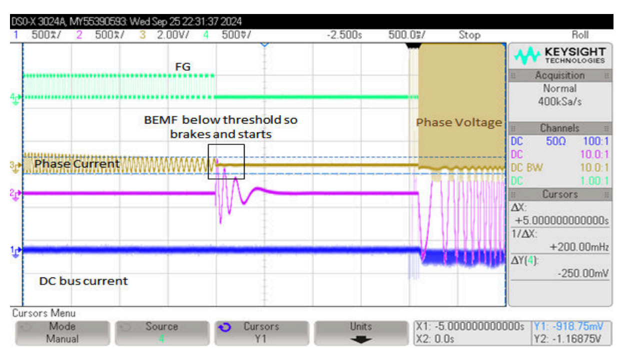

Figure 3-9. BEMF < STAT_DETECT_THR(1000mV) - Brake and Start From Stationary

3.2 Resynchronization

If the motor is already spinning in the commanded direction, resynchronization feature enables us to sync the motor to the drive and ramp to commanded speed. The available configurations are described in Table 3-2.

Table 3-2. Resync Related Configurations

Configuration	Sub-Feature Description	Tuning Considerations
RESYNC_EN	If the motor is spinning forward (same direction as the commanded direction) with sufficient speed (BEMF), this feature resynchronizes with the spinning motor.	Enable for applications that use high inertia motors like Fans.
FWD_DRV_RESYN_THR	If motor speed > FWD_DRV_RESYN_THR, then device can go to resynchronize directly to closed loop otherwise the device can go for open loop drive before closed loop operation.	FWD_DRV_RESYN_THR needs to be the same as OPN_CL_HANDOFF_THR as this is expected to be the minimum speed where BEMF is reliable enough to transition to closed loop. If set too low, device can have reliability issues as closed loop can fail due to unreliable BEMF. If set too high, device forces open loop drive even though BEMF is reliable and closed loop drive is possible. **Note**: BEMF generated = BEMF constant of the motor * motor speed. Make sure speed is sufficient to generate few 100mV at FWD_DRV_RESYN_THR as per motor BEMF constant.

3.2.1 Forward Drive Resync Threshold

The effect of Forward Drive Resync Threshold (FWD_DRV_RESYN_THR) is shown in Figure 3-10 and Figure 3-11.

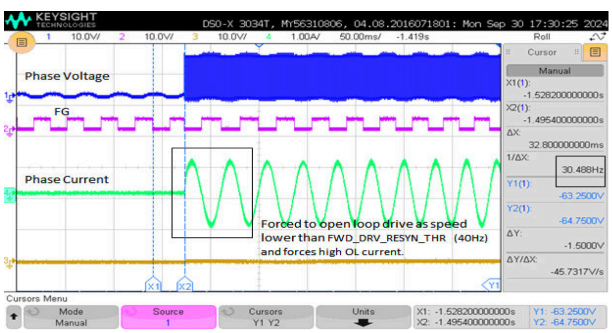

Figure 3-10. Sensed Speed Lesser Than FWD_DRV_RESYN_THR so Resync to Open Loop Leading to Fixed Force Current as Seen

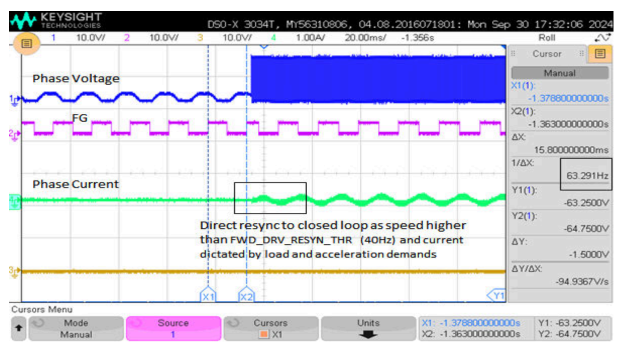

Figure 3-11. Sensed Speed Greater Than FWD_DRV_RESYN_THR so Resync to Closed Loop

3.2.2 Reverse Drive

If motor is already spinning in the opposite direction, reverse drive feature enables us to sync the motor to the drive, slow the motor down in controlled manner and change the direction of rotation. The available configurations are described in Table 3-3.

Table 3-3. Reverse Drive Related Configurations

Configuration	Sub-Feature Description	Tuning Considerations
RVS_DR_EN	If the motor is spinning reverse (opposite direction as the commanded direction) with sufficient speed (BEMF), this feature resynchronizes with the spinning motor and slows the motor down to zero speed and then drives the motor in commanded direction.	Enable for applications that use high inertia motors like Fans. If fan motor like pedestal fans are exposed to external factors like wind, enable reverse drive for smooth motor startup.

Table 3-3. Reverse Drive Related Configurations (continued)

Configuration	Sub-Feature Description	Tuning Considerations
REV_DRV_CONFIG	Decides between reverse drive specific parameters and the startup open loop parameters to be used for reverse drive. The parameters decided are the open to closed loop handoff threshold, open loop acceleration (and deceleration) rates and open loop current limit in reverse drive.	If not reliable with startup OL parameters used for startup from standstill (OL_ILIMIT, OL_ACC_A1, OL_ACC_A2 etc), try tuning independent parameters (described below) by setting REV_DRV_CONFIG as 1b.
REV_DRV_HANDOFF_THR	Threshold to handoff from reverse closed loop to reverse open loop.	REV_DRV_HANDOFF_THR is kept to be same as OPN_CL_HANDOFF_THR. If REV_DRV_HANDOFF_THR kept too low, then motor can lose sync while decelerating due to unreliable BEMF. If too high, then forced to spin in open loop with reliable BEMF. If OL current limit is not sufficient, the motor can lose sync
REV_DRV_OPEN_LOOP_ACCEL_A1	The acceleration rate for reverse drive open loop. The deceleration rate is also decided as REV_DRV_OPEN_LOOP _DEC times REV_DRV_OPEN_LOOP_ACCEL_A1 / REV_DRV_OPEN_LOOP_ACCEL_A2.	Start from OL A1, A2 settings. Reduce the A1, A2 settings to make the deceleration and reverse acceleration gentler. If set too low, jerky motion can be observed sometimes with extended open loop duration. If set too high, motor can lose sync due to high acceleration demand if current limit is not sufficient.
REV_DRV_OPEN_LOOP_ACCEL_A2		
REV_DRV_OPEN_LOOP_CURRENT	The reverse drive open loop current limit.	Start at OL current limit but in case some external factor like wind affecting the reverse rotation, change the current limit to be able to decelerate the motor in a controlled manner without any vibrations. If set too high, can result in jerky motion at low speeds. If set too low, then can lose sync in open loop due to high acceleration demand.
REV_DRV_OPEN_LOOP _DEC	Factor between deceleration rate and acceleration rates in reverse drive open loop.	Start with acceleration and deceleration parameters being same i.e. 100% setting. Based on the times taken to decelerate and accelerate, tune REV_DRV_OPEN_LOOP _DEC to get a more symmetric profile. Decrease if deceleration is not reliable. Increase to reduce open loop deceleration time.

3.2.3 Reverse Acceleration Parameters

These parameters tune a smooth, reliable direction reversal; improper settings can result in motor stall or faults during direction reversal.

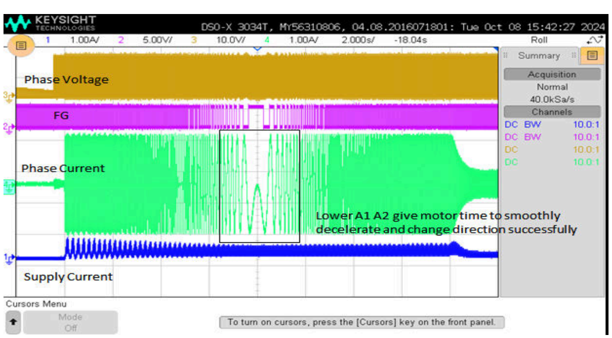

Figure 3-12. Proper Acceleration Parameters as per Motor Characteristics and Current Limits. Successful Direction Change

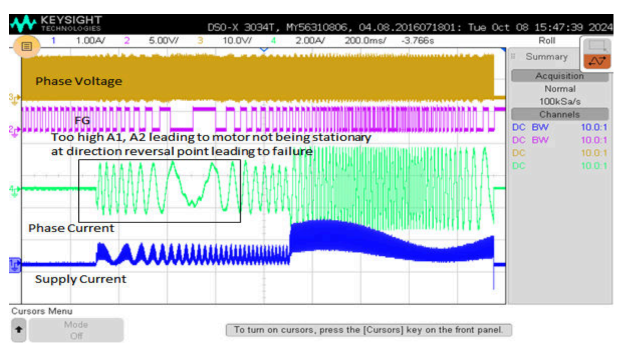

Figure 3-13. Too High Acceleration Parameters Leading to Lose of Sync

3.2.4 Reverse Drive Current Limits

This current limit controls the motor torque during direction reversal.

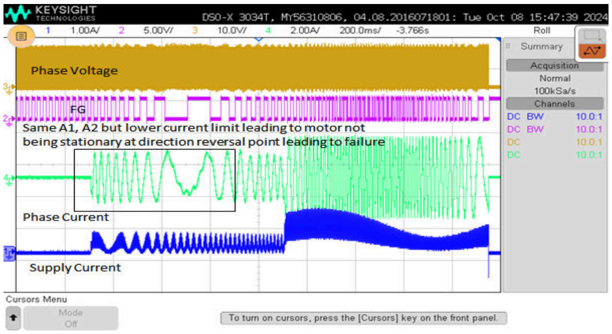

Figure 3-14. High A1 (100Hz/s) at REV_DRV_OPEN_LOOP_CURRENT = 1.5A Leading to Fault as Motor is not Stationary at Direction Change

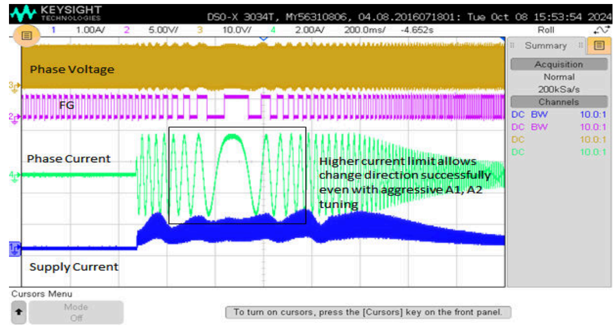

Figure 3-15. Increasing REV_DRV_OPEN_LOOP_CURRENT = 2.5A Works as Expected

3.2.5 Reverse Drive Handoff Threshold

This parameter sets the speed threshold in reverse direction at which the device transitions from closed loop to open loop.

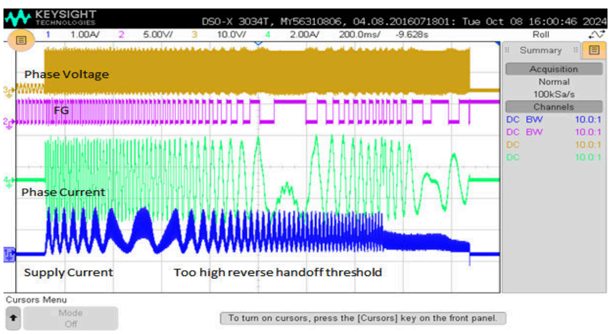

Figure 3-16. Too High REV_DRV_HANDOFF_THR Losing Sync due to Blind Deceleration in Reverse Open Loop

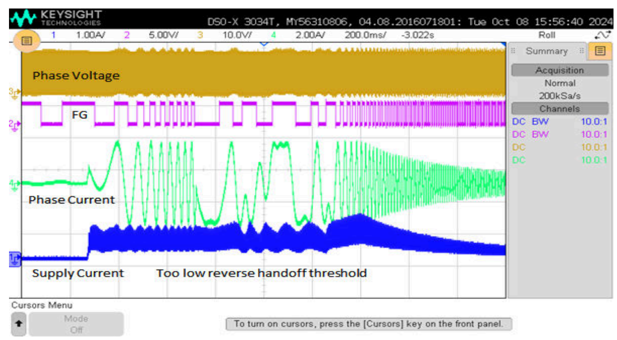

Figure 3-17. Too low REV_DRV_HANDOFF_THR Losing Sync due to Unreliable BEMF in Reverse Closed Loop

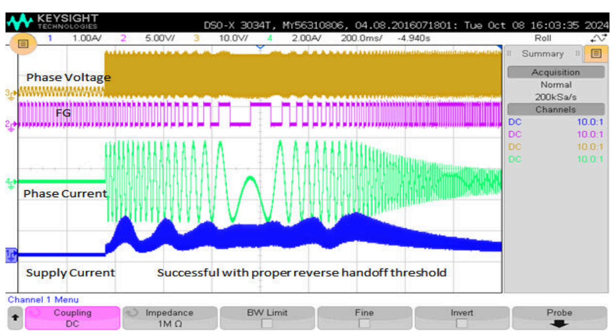

Figure 3-18. Successful Direction Reversal With Proper REV_DRV_HANDOFF_THR

3.2.6 Reverse Drive Open Loop Deceleration (REV_DRV_OPEN_LOOP _DEC)

Decides ratio of acceleration rates to deceleration rates in open loops during direction change.

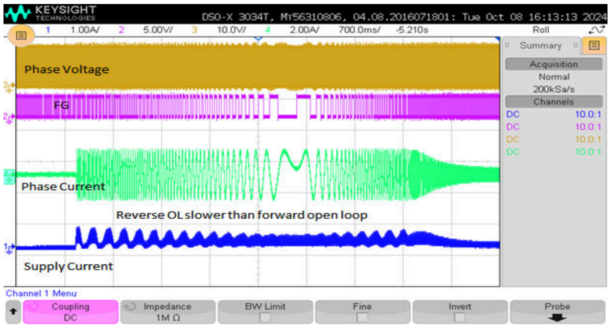

Figure 3-19. Reverse Open Loop Slower Than Forward Open Loop Acceleration

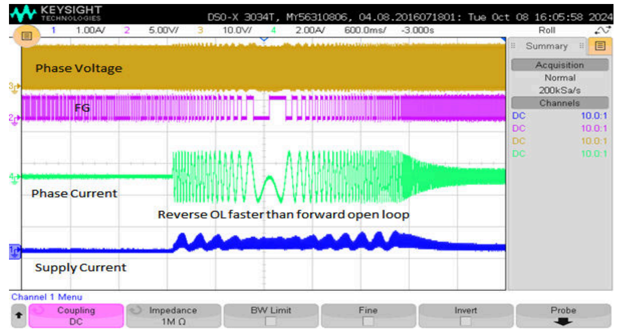

Figure 3-20. Reverse Open Loop Faster Than Forward Open Loop Acceleration

3.3 Coasting (Hi-Z)

Coasting allows motor to lose energy gradually with friction. This is especially useful if ISD is enabled and reverse drive is disabled but motor is spinning in opposite direction with speed that can cause high brake currents. Enabling coasting lets the motor reduce the speed before applying brake to bring the motor to stationary state before driving to set reference.

Table 3-4. Coasting Related Configurations

Configuration	Sub-Feature Description	Tuning Considerations
HIZ_EN	Enable coasting to slow down the motor naturally with frictional losses	Enable if braking to stop the motor is part of application use case to slow down the motor before braking to avoid high braking currents. Enable if ISD is enabled but reverse drive is disabled.
HIZ_TIME	Coasting time based on the inertia of the motor to ramp down the motor.	Take the time to coast from maximum speed to acceptable speed to apply brake with acceptable braking current. If motor spinning due to external factors like wind, then coasting can possibly not help.

3.4 Brake

Brake is enabled to bring the motor to a stationary state before motor startup for reliable spin-up.

Table 3-5. Brake Related Configurations

Configuration	Sub-Feature Description	Tuning Considerations
BRAKE_EN	Enables brake to make the motor stationary before going to motor startup. Usually comes into effect when ISD is disabled or when sensed BEMF is less than STAT_DETECT _THR.	Keep enabled to make sure motor startup with stationary rotor
BRK_MODE	Selects between high-side braking and low-side braking.	Can depend on the FETs used and the FET RDSon for thermals. Current sensing for current based brake only available for low side braking.
BRK_CONFIG	Allows user to choose between brake time and brake current threshold to come out of brake state	Current based braking is recommended to apply brake only for the time motor is spinning. Once motor slows down and brake current fall below configured threshold, brake is released. ** Current based brake is only available for low side brake. If current based brake is set with High side braking, then device defaults to time based brake.

Table 3-5. Brake Related Configurations (continued)

Configuration	Sub-Feature Description	Tuning Considerations
BRK_TIME	The maximum amount of time for which the device applies brake.	BRK_TIME is the maximum brake time in current based brake even if current doesn't fall below BRK_CURR_THR. For time-based brake, BRK_TIME defines the fixed time to exit brake state Set this to be the time to stop the motor from maximum safe speed to apply brake.
BRK_CURR_THR	Current threshold till which the motor performs brake	This is used to exit from brake if current based braking is enabled. There is importance to make sure that BRK_CURR_THR is low enough that motor is almost stopped before exiting brake for reliable startup. Too low setting can lead to motor state being stuck in ISD till ISD_TIMEOUT due to noise. Try with lowest setting and increase if unable to exit brake on time.
BRAKE_CURRENT_PERSIST	Persistence time for current below threshold during current based ISD brake	Keep the persistence time high enough to avoid mis-detection due to sinusoidal nature of brake current.

3.4.1 Brake Config (BRK_CONFIG)

This parameter configures the brake exit mode for example, time-based brake or current based brake with brake time as a timeout.

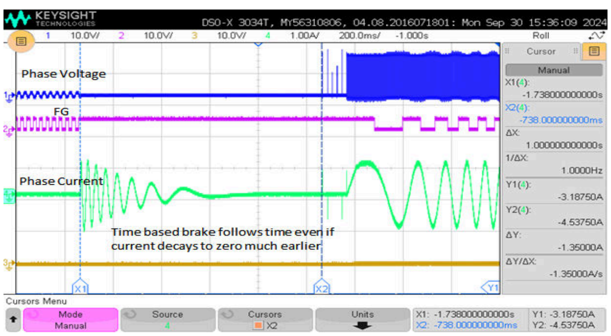

Figure 3-21. Time Based Brake. Exits Brake After Configured 1s Brake Time

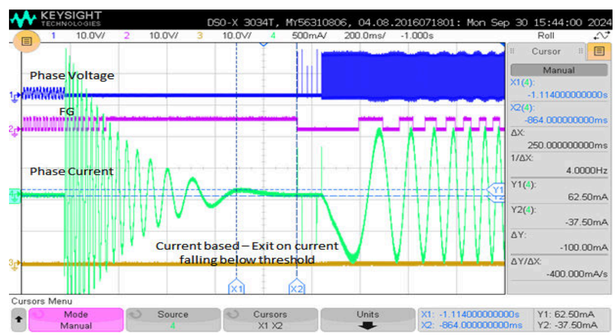

Figure 3-22. Current Based Braking : Brake Exit Based on Current Threshold.

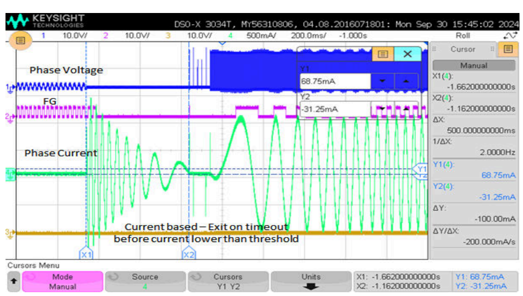

Figure 3-23. Current Based Braking : Brake Exit Based on Current Brake Timeout

In Figure 3-22, brake is released when brake current falls below BRK_CURR_THR as the brake timeout is set to 10s. In Figure 3-23, brake is forced to release after 500ms due to brake timeout even through brake current is higher than BRK_CURR_THR.

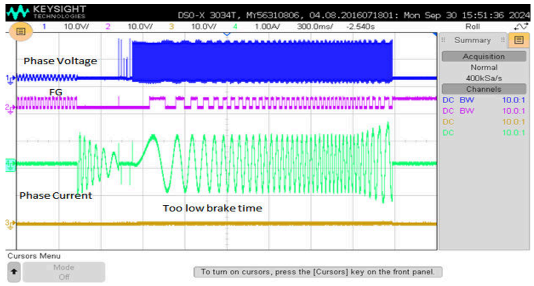

Figure 3-24. Motor not Stationary Before Start Scenarios: Exits Brake too Early While Motor Still Spinning Due to Low Brake Time

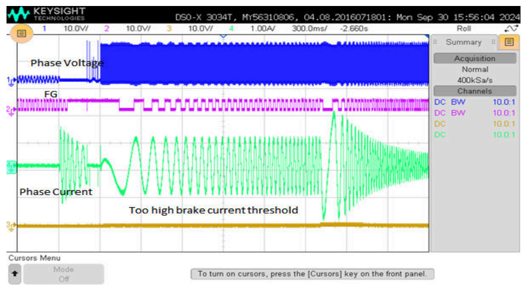

Figure 3-25. Motor not Stationary Before Start Scenarios: Exits Brake too Early While Motor Still Spinning due to High Brake Current Threshold

4 Feature Availability of MCx Devices

A table of devices and availability of features. Unless mentioned, all features are supported.

4.1 FOC Family (MCF83xx devices)

In FOC family (MCF83xx devices), some features are not available in older devices. In MCF8329A, some features are missing as this is a single shunt device while all other are three shunt devices.

Table 4-1. FOC Family

Device	Family	Features not Supported
MCF8316A	FOC	1. ISD_BEMF_FILE_ENABLE 2. BRK_CONFIG 3. BRK_CURR_THR 4. BRAKE_CURRENT_PERSIST
MCF8316C	FOC	1. ISD_BEMF_FILT_ENABLE
MCF8315C-Q1	FOC	1. ISD_BEMF_FILT_ENABLE
MCF8315A	FOC	1. ISD_BEMF_FILT_ENABLE
MCF8315C	FOC	1. ISD_BEMF_FILT_ENABLE
MCF8315C-Q1	FOC	1. ISD_BEMF_FILT_ENABLE
MCF8329A	FOC	1. ISD_BEMF_FILT_ENABLE 2. BRK_MODE 3. BRK_CONFIG as current based brake 4. BRK_CURR_THR 5. BRAKE_CURRENT_PERSIST

4.2 TRAP Family (MCT83xx devices)

TRAP (MCT83xx devices) family of devices have a sub-set of the FOC pre-start-up configurations. The reverse drive uses the open loop parameters instead of having separate configuration parameters.

Table 4-2. Trap Device Feature Availability

Device	Family	Features not Supported
MCT8316A	TRAP	1. FAST_ISD_EN 2. ISD_STOP_TIME 3. ISD_RUN_TIME 4. ISD_TIMEOUT 5. ISD_BEMF_FILT_ENABLE 6. DIR_CHANGE_MODE 7. REV_DRV_CONFIG 8. REV_DRV_HANDOFF_THR 9. REV_DRV_OPEN_LOOP_ACCEL_A1 10. REV_DRV_OPEN_LOOP_ACCEL_A2 11. REV_DRV_OPEN_LOOP_CURRENT 12. REV_DRV_OPEN_LOOP_DEC 13. BRK_CONFIG 14. BRK_CURR_THR 15. BRAKE_CURRENT_PERSIST

Table 4-2. Trap Device Feature Availability (continued)

Device	Family	Features not Supported
MCT8315A	TRAP	1. FAST_ISD_EN 2. ISD_STOP_TIME 3. ISD_RUN_TIME 4. ISD_TIMEOUT 5. ISD_BEMF_FILT_ENABLE 6. DIR_CHANGE_MODE 7. REV_DRV_CONFIG 8. REV_DRV_HANDOFF_THR 9. REV_DRV_OPEN_LOOP_ACCEL_A1 10. REV_DRV_OPEN_LOOP_ACCEL_A2 11. REV_DRV_OPEN_LOOP_CURRENT 12. REV_DRV_OPEN_LOOP_DEC 13. BRAKE_CURRENT_PERSIST
MCT8329A	TRAP	1. FAST_ISD_EN 2. ISD_STOP_TIME 3. ISD_RUN_TIME 4. ISD_TIMEOUT 5. ISD_BEMF_FILT_ENABLE 6. DIR_CHANGE_MODE 7. REV_DRV_CONFIG 8. REV_DRV_HANDOFF_THR 9. REV_DRV_OPEN_LOOP_ACCEL_A1 10. REV_DRV_OPEN_LOOP_ACCEL_A2 11. REV_DRV_OPEN_LOOP_CURRENT 12. REV_DRV_OPEN_LOOP_DEC 13. BRK_CONFIG 14. BRK_CURR_THR 15. BRAKE_CURRENT_PERSIST

Table 4-3 shows dependency of configuration on other configurations and impact of the configuration on motor operation

Table 4-3. Configuration With Dependency and Tradeoffs

Configuration	Impact on Motor Operation	Dependency
ISD_EN	Reliable and fast motor startup based on the initial condition of the motor speed.	None
FAST_ISD_EN	TRADEOFF: • Initial current spikes possible due to inaccuracy in BEMF measured. • Possibility of reverse spinning observed in some cases.	• ISD_EN = 1b
ISD_STOP_TIME ISD_RUN_TIME	TRADEOFF: • If persistence time is too high, the resyncing time increases. • If kept too low, the ISD robustness decreases.	• ISD_EN = 1b

Table 4-3. Configuration With Dependency and Tradeoffs (continued)

Configuration	Impact on Motor Operation	Dependency
ISD_TIMEOUT	TRADEOFF: • If timeout is too high, the ISD time increases • If kept too low, the ISD robustness decreases.	• ISD_EN = 1b
ISD_BEMF_FILT_ENABLE	Smoothens the sensed BEMF to maintain reliable speed and direction determination	• ISD_EN = 1b
STAT_DETECT_THR	TRADEOFF: • If set too high, device can be forced to go through brake at higher speed leading to higher brake currents. • If set too low, device can attempt to resync without sufficient BEMF leading to faults or ISD timeout	• ISD_EN = 1b
RESYNC_EN = 1b	Fastest possible start-up time if motor spinning in commanded direction.	• ISD_EN = 1b
FW_DRV_RESYN_THR	TRADEOFF: • If set too low, then device can try to enter closed loop with insufficient BEMF leading to faults. • If set too high, the device can try to drive motor in open loop instead of handing off to closed loop even when sufficient speed is available leading to reliability issues.	• ISD_EN = 1b • RESYNC_EN = 1b
DIR_CHANGE_MODE	If set to 1b, direction is changed through reverse drive by slowing down the motor to zero speed and reversing direction. Else, direction is changes through ISD state machine and if ISD is disabled, motor is stopped through brake before starting in commanded direction.	None
RVS_DRV_EN	Fastest possible start-up time in a controlled manner if motor spinning in opposite to commanded direction. Considered as a more controlled way to reduce the speed and reverse the motor.	• ISD_EN = 1b
REV_DRV_CONFIG	If REV_DRV_CONFIG = 1b, the motor changes the direction using reverse drive specific open loop parameters. Open loop parameters can be tuned to handle different dynamics from normal OL startup.	• ISD_EN = 1b • RVS_DRV_EN = 1b
REV_DRV_HANDOFF_THR	TRADEOFF: • If set too low, then device can fail to handover to open loop even with insufficient BEMF leading to faults. • If set too high, the device hands over to open loop instead of decelerating in closed loop even when sufficient BEMF is available. This results in longer open loop time and inefficient drive.	• ISD_EN = 1b • RVS_DRV_EN = 1b • REV_DRV_CONFIG = 1b

Table 4-3. Configuration With Dependency and Tradeoffs (continued)

Configuration	Impact on Motor Operation	Dependency
REV_DRV_OPEN_LOOP_ACCEL_A1 REV_DRV_OPEN_LOOP_ACCEL_A2	TRADEOFF: • If set too high, the device can try to decelerate the motor too fast and unable to spin up and loose sync. • If set too low, the drive can look jerky as the motor speed reduces.	• ISD_EN = 1b, • RVS_DRV_EN = 1b • REV_DRV_CONFIG = 1b
REV_DRV_OPEN_LOOP_CURRENT	TRADEOFF: • If set too high, heats up the motor and reduces the efficiency of the drive as more than required current is pushed into the motor. • If set too low, the drive cannot decelerate the motor and accelerate the motor in the opposite direction in a controlled manner, which can lead to vibrations or faults.	• ISD_EN = 1b • RVS_DRV_EN = 1b • REV_DRV_CONFIG = 1b
REV_DRV_OPEN_LOOP _DEC	If some external factor is affecting the drive then the rate of deceleration and acceleration needs to be different from the corresponding values at open loop startup.	• ISD_EN = 1b • RVS_DRV_EN = 1b
HIZ_EN	Gives the motor time to coast and slow down before applying brake and proceeding to motor startup.	• ISD_EN = 1b • (RVS_DRV_EN = 1b or RESYNC_EN = 1b)
HIZ_TIME	As energy is lost only through friction, speed falls slowly and a higher setting for high inertia motor is recommended.	• ISD_EN = 1b • (RVS_DRV_EN = 1b or RESYNC_EN = 1b) • HIZ_EN = 1b
BRAKE_EN	Makes sure motor is stationary before motor startup by braking before motor startup.	None
BRK_MODE	This method involves turning ON all low-side/high-side FETs at once to allow current to recirculate through the low-side/high-side MOSFETs. Doing this effectively shorts the back emf, quickly lowering the motor speed and dissipating the motor mechanical energy. Braking adds to thermal stress on the FETs and care to be taken to avoid frequent braking that can result in thermal shutdown	• BRAKE_EN = 1b
BRK_CONFIG	Time based brake applies brake for a fixed time irrespective of the motor speed. Current based brake allows brake to be applied only till motor BEMF falls indicated by current falling below BRK_CURR_THR.	• BRAKE_EN = 1b • BRK_TIME • BRK_CURR_THR
BRK_TIME	If BRK_CONFIG = 0b, then device applies brake for BRK_TIME. If BRK_CONFIG = 1b, device applies brake till current falls below BRK_CURR_THR and BRK_TIME acts as a timeout incase current fails to fall below BRK_CURR_THR before BRK_TIME.	• BRAKE_EN = 1b
BRK_CURR_THR	If BRK_CONFIG = 1b, device applies brake till brake current falls below the BRK_CURR_THR.	• BRAKE_EN = 1b • BRK_CONFIG = 1b • BRK_MODE = 1b

Table 4-3. Configuration With Dependency and Tradeoffs (continued)

Configuration	Impact on Motor Operation	Dependency
BRAKE_CURRENT_PERSIST	TRADEOFF: • If set too low, drive can give false positive for current falling below threshold as brake current is sinusoidal. • If set too high, increases the brake exit time.	• BRAKE_EN = 1b • BRK_CONFIG = 1b • BRK_CURR_THR • BRK_MODE = 1b

5 Summary

Reliable spin-up irrespective of motor initial state is critical and depends on settings of the pre-startup parameters. Pre-startup tuning allows users to use features like resynchronization and reverse drive to motor to commanded velocity irrespective of initial speed and direction. Based on end application and motor parameters, this is crucial to tune the pre-startup to extract best performance. This application note provides an approachable guide to help tune BLDC motor pre-startup.

6 References

- Texas Instruments, *MCF8316C-Q1 Sensorless Field Oriented Control (FOC) Integrated FET BLDC Driver*, data sheet.
- Texas Instruments, *MCT831A High Speed Sensorless Trapezoidal Control Integrated FET BLDC Driver*, data sheet.
- Texas Instruments, *MCF8316A Tuning Guide*, user's guide.