Application Note

MCT8316A - Design Challenges and Solution

Vishnu Balaraj

ABSTRACT

The MCT8316A provides a single-chip, code-free sensorless trapezoidal solution for customers driving BLDC motors for applications such as pedestal fans, vacuum suction motors, leaf blowers, fuel pumps, blowers, and so forth. With more than 50 parameters to tune, it can feel overwhelming and time consuming for customers to tune their motor and meet all system requirements. This application note provides an in-depth discussion of three of the most common design challenges with the MCT8316A and step-by-step guidance on how to address these challenges.

Table of Contents

List of Figures

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

Some of the common challenges in tuning a Sensorless Trapezoidal Control-based Motor driver are minimizing motor startup time, acceleration and deceleration slew rate and improving system efficiency. Motor startup time is very critical in applications such as fuel pumps. With the MCT8316A, system designers can minimize the motor start-up time by configuring the motor start-up parameters. Acceleration and deceleration slew rate is critical in applications such as medical CPAP blowers. For integrated control motor drivers, temperature is often a critical design specification that cannot be violated. With the MCT8316A, system designers can minimize power losses by configuring PWM output frequency, PWM mode, ASR and AAR.

2 Design Challenges and Solutions

2.1 Minimizing Motor Startup Time

In this application note, startup time is defined as the time taken for the motor to spin from 0% to 100% input speed duty cycle. The MCT8316A provides four different motor startup methods as listed below:

- Align
- Double align
- Initial Position Detection (IPD)
- Slow first cycle

For applications that require quick startup time, it is recommended choosing either Align or Initial Position Detection (IPD) as the startup method.

2.1.1 Align

Below are the steps to tune the motor to achieve faster startup time using Align as the motor startup method:

1. Select align as the motor startup method in [MTR_STARTUP].
2. Configure align time [ALIGN_TIME] to 5 ms.

> **Note**
> Ensure the rotor settles to a position and does not oscillate. If the rotor oscillates before spinning in open loop, increase the align time [ALIGN_TIME].

3. Select Open loop current limit [OL_ILIMIT] to be the same as cycle by cycle current limit [ILIMIT].

> **Note**
> If the device triggers cycle by cycle current limit [CBC_ILIMIT], it is recommended to increase [ILIMIT] up to the stall current of the motor. Configuring this to a value higher than motor stall current might overheat or damage the motor.

4. Increase Open loop acceleration coefficient A1 [OL_ACC_A1] and Open loop acceleration coefficient A2 [OL_ACC_A2].

> **Note**
> A1 and A2 can be increased until open loop current reaches Lock detection current threshold [LOCK_ILIMIT]. Open loop current can be measured using oscilloscope.
>
> Increasing Open loop acceleration coefficient A1 [OL_ACC_A1] and Open loop acceleration coefficient A2 [OL_ACC_A2] might trigger LOCK_LIMIT or CBC_ILIMIT. If this happens, reduce A1 and A2 until LOCK_LIMIT no longer triggers.

For ultra-fast startup time (less than 100 ms) it is recommended to follow below steps:

1. Disable auto-handoff [AUTO_HANDOFF].
2. Configure Open loop handoff cycles [OL_HANDOFF_CYCLES] to 3.
3. Configure INTEG_ZC_METHOD to Integration.
4. Enable Dynamic degauss [DYN_DEGAUSS_EN].
5. Configure open to closed loop handoff threshold [OPN_CL_HANDOFF_THR] to a value lesser than or equal to 20 Hz.

For startup times above 100 ms, it is recommended to follow below steps:

1. Enable auto-handoff [AUTO_HANDOFF].
2. Configure Open loop handoff cycles [OL_HANDOFF_CYCLES] to 6.
3. Enable Dynamic degauss [DYN_DEGAUSS_EN].

Note

If Abnormal speed fault [ABN_SPEED] gets triggered, it is recommended to decrease open loop acceleration constants [OL_ACC_A1] and [OL_ACC_A2] and also retune IPD by increasing the IPD current threshold [IPD_CURR_THR] and IPD repeat times [IPD_REPEAT].

4. Increase Closed loop acceleration rate [CL_ACC]

Note

Closed loop acceleration rate [CL_ACC] can be increased until closed loop current reaches Lock detection current threshold [LOCK_ILIMIT]. Closed loop current can be measured using oscilloscope. Increasing closed loop acceleration rate [CL_ACC] might trigger LOCK_LIMIT. If this happens, reduce closed loop acceleration rate [CL_ACC] until no longer triggers.

Figure 2-1 shows the phase current, FG and Speed curve when the motor is started using Align as the startup method. Time taken for the motor to accelerate to 100% duty cycle is around 46 ms.

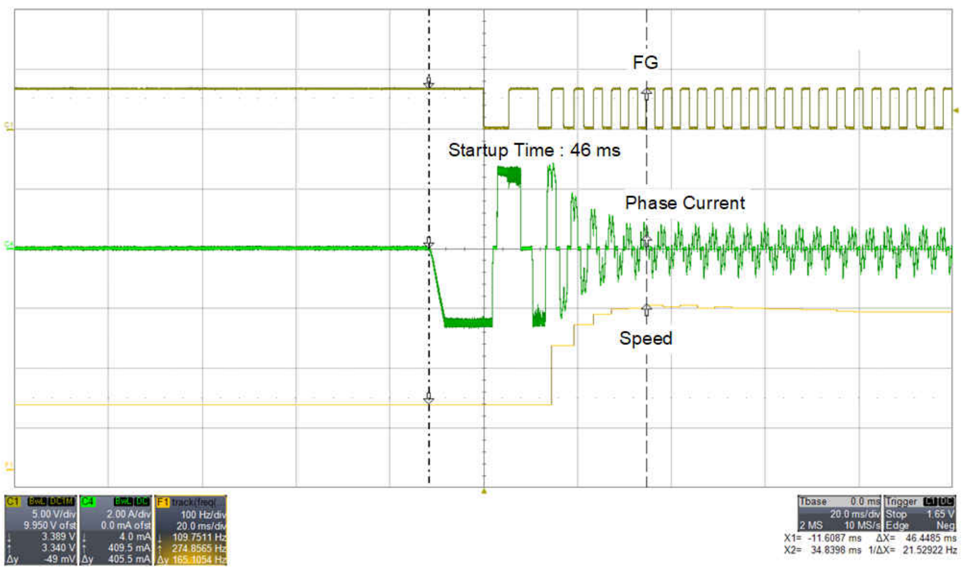

Figure 2-1. Startup Time Using Align as Motor Startup Method

2.1.2 Initial Position Detect (IPD)

Below are the steps to tune the motor to achieve faster startup time using IPD as the motor startup method:

1. Select IPD [MTR_STARTUP] as the motor startup method.
2. Increase IPD current threshold [IPD_CURR_THR] to rated current of the motor. Use equation 4 to choose the correct IPD_CURR_THR.
3. Increase IPD clock value [IPD_CLK_FREQ] to higher frequency up to a value where the device does not trigger IPD frequency fault.
4. Select IPD repeating times [IPD_REPEAT] to 1 time.
5. Configure IPD release mode [IPD_RLS_MODE] to Tri state.
6. Select Open loop current limit [OL_ILIMIT] to be the same as cycle by cycle current limit [ILIMIT].

Note

If the device triggers cycle by cycle current limit [CBC_ILIMIT], it is recommended to increase [ILIMIT] upto the stall current of the motor. Configuring this to a value higher than motor stall current might overheat or damage the motor.

7. Increase Open loop acceleration coefficient A1 [OL_ACC_A1] and Open loop acceleration coefficient A2 [OL_ACC_A2].

Note

A1 and A2 can be increased until open loop current reaches Lock detection current threshold [LOCK_ILIMIT]. Open loop current can be measured using oscilloscope.

Increasing Open loop acceleration coefficient A1 [OL_ACC_A1] and Open loop acceleration coefficient A2 [OL_ACC_A2] might trigger LOCK_LIMIT or CBC_ILIMIT. If this happens, reduce A1 and A2 until LOCK_LIMIT no longer triggers.

For ultra-fast startup time (less than 100 ms) it is recommended to follow below steps:

1. Disable auto-handoff [AUTO_HANDOFF].
2. Configure Open loop handoff cycles [OL_HANDOFF_CYCLES] to 3.
3. Configure INTEG_ZC_METHOD to Integration.
4. Enable Dynamic degauss [DYN_DEGAUSS_EN].
5. Configure open to closed loop handoff threshold [OPN_CL_HANDOFF_THR] to a value lesser than or equal to 20 Hz.

For startup times above 100 ms, it is recommended to follow below steps:

1. Enable auto-handoff [AUTO_HANDOFF].
2. Configure Open loop handoff cycles [OL_HANDOFF_CYCLES] to 6.
3. Enable Dynamic degauss [DYN_DEGAUSS_EN].

Note

If Abnormal speed fault [ABN_SPEED] gets triggered, it is recommended to decrease open loop acceleration constants [OL_ACC_A1] and [OL_ACC_A2] and also retune IPD by increasing the IPD current threshold [IPD_CURR_THR] and IPD repeat times [IPD_REPEAT].

4. Increase Closed loop acceleration rate [CL_ACC].

Note

Closed loop acceleration rate [CL_ACC] can be increased until closed loop current reaches Lock detection current threshold [LOCK_ILIMIT]. Closed loop current can be measured using oscilloscope. Increasing closed loop acceleration rate [CL_ACC] might trigger LOCK_LIMIT. If this happens, reduce closed loop acceleration rate [CL_ACC] until no longer triggers.

Figure 2-2 shows the phase current, FG and Speed curve when the motor is started using IPD as the startup method. Time taken for the motor to accelerate to 100% duty cycle is around 35 ms.

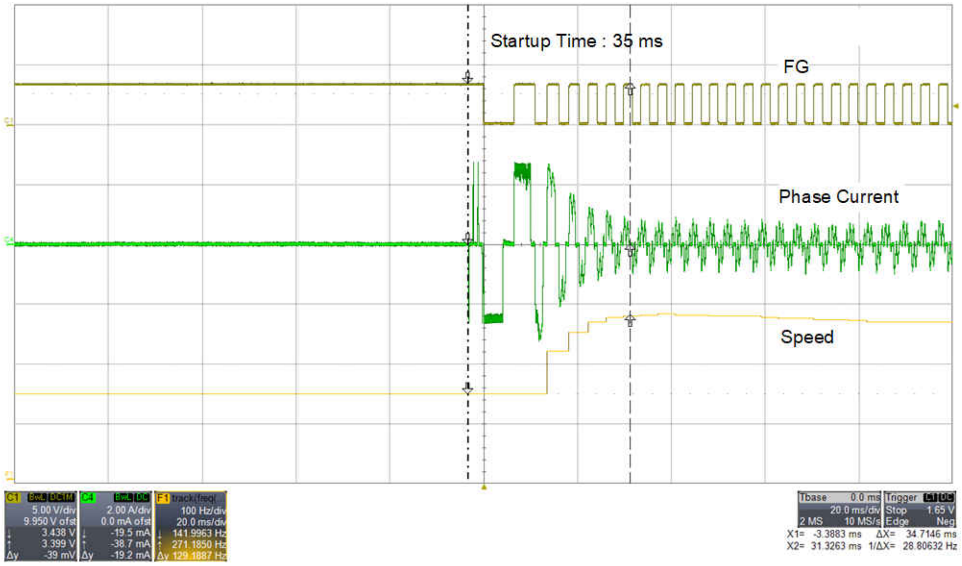

Figure 2-2. Startup Time Using IPD as Motor Startup Method

2.2 Minimizing Acceleration and Deceleration Slew Rate

Below are the steps to tune the motor to achieve fast acceleration in closed loop:

1. Enable Dynamic degauss [DYN_DEGAUSS_EN].
2. Configure Closed loop acceleration rate to 1000V/s.

Figure 2-3 shows phase current, FG and speed curve when the motor accelerates from 10% duty cycle to 100% duty cycle. Time taken for the motor to accelerate from 10% duty cycle to 100% duty cycle is around 170 ms.

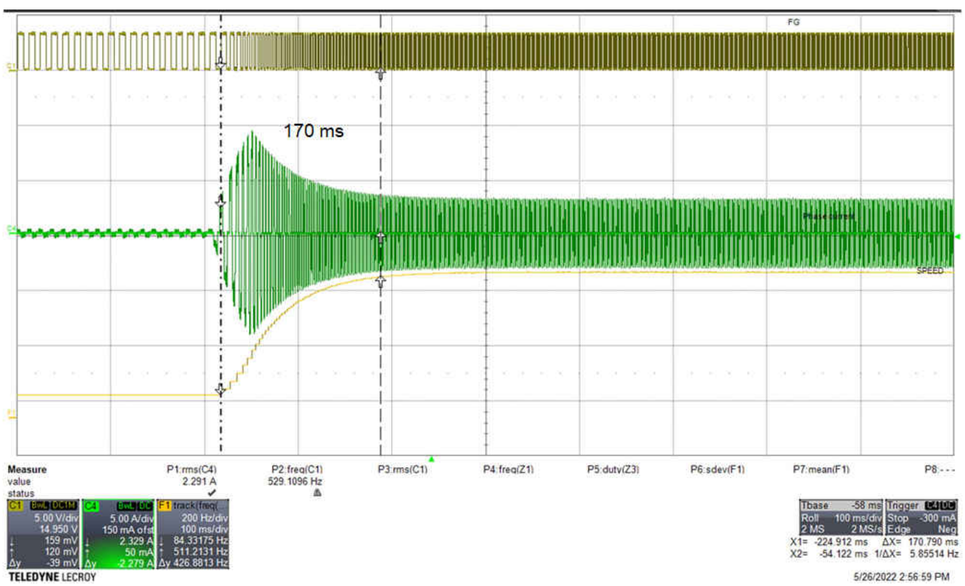

Figure 2-3. Fast Acceleration

Below are the steps to tune the motor to achieve fast deceleration:

1. Configure closed loop deceleration [CL_DEC] to a value that is same as closed loop acceleration [CL_ACC].
2. Enable Fast deceleration [FAST_DECEL_EN].
3. Configure Fast deceleration current limit [FAST_DECEL_CURR_LIM]. Fast deceleration current limit will be higher for motors with higher inertia.

4. Enable AVS [AVS_EN] to protect the power supply from voltage overshoots during motor deceleration. If AVS is enabled, the time taken to decelerate the motor will increase. Disable AVS, if the power supply can withstand voltage overshoots.
5. Configure Fast Decel Brake Threshold [FAST_BRK_DELTA] if the fast deceleration should be disabled before the actual motor speed reaches the target speed. For example, if the Fast Decel Brake Threshold [FAST_BRK_DELTA] is configured to 0.5% and target duty cycle is configured to 5%, device will stop decelerating the motor at 5.5%. This can be helpful in applications where the motor is decelerated to critically low speeds. While the motor decelerates quickly to critically low speeds, there are possibilities that the motor might stop. In such applications, it is required to stop decelerating the motor at slightly higher speeds to avoid the device from completely stopping the motor.

Figure 2-4 shows phase current, FG and speed curve when the motor decelerates from 100% duty cycle to 10% duty cycle. Time taken for the motor to decelerate from 100% duty cycle to 10% duty cycle when fast delegation is disabled is around 126 ms.

Note

When fast deceleration is enabled and anti-voltage surge (AVS) is disabled, there might be voltage spikes seen in supply voltage. Enable AVS to protect the power supply from voltage overshoots during motor deceleration.

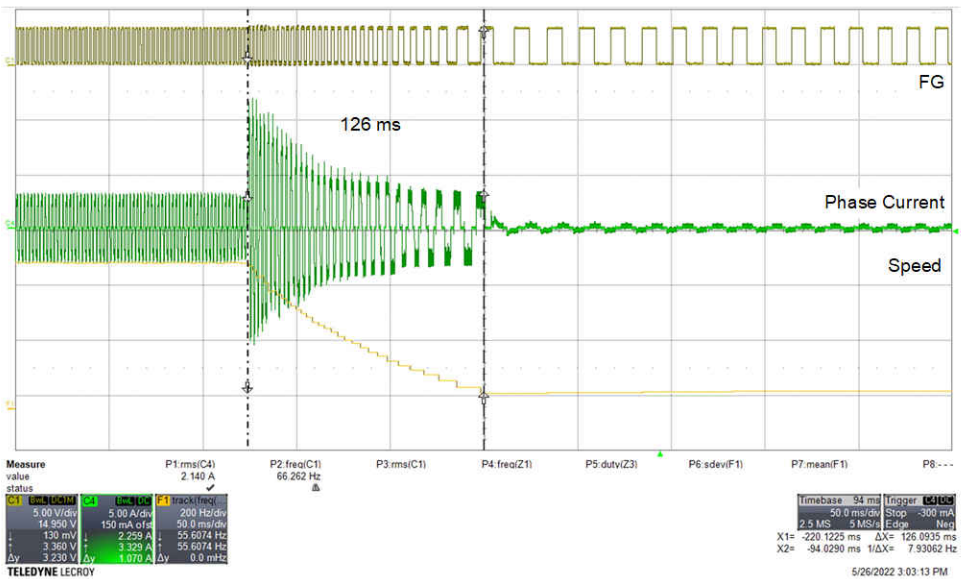

Figure 2-4. Fast Deceleration

MCT8316A provides a dynamic current limit option during fast deceleration to improve the stability of fast deceleration when braking to very low speeds. Using this feature, the current limit during fast deceleration can be reduced as the motor speed decreases.

If motor stalls at lower speeds, it is recommended to follow below steps:

1. Enable dynamic decrease in current limit [DYNAMIC_BRK_CURR].
2. Configure FAST_DEC_DUTY_THR. This sets the speed below which fast deceleration will be implemented. For example, if FAST_DEC_DUTY_THR is set to 70%, any deceleration from speeds above 70% will not use fast deceleration until the speed goes below 70%. If AVS is enabled, AVS will be active when motor decelerates from 100% to 70% duty cycle.
3. Configure DYN_BRK_CURR_LOW_LIM. This sets the current limit at zero speed.
4. Configure FAST_DEC_DUTY_WIN. This is used to set the minimum deceleration window (initial speed - target speed) below which fast deceleration will not be implemented. For example, if FAST_DEC_DUTY_WIN is set to 7.5%, FAST_DEC_DUTY_THR is set to 75% and 75% to 50% deceleration command is received, fast deceleration will be active below 67.5%. If FAST_DEC_DUTY_WIN is set to 15% and 50%->40% deceleration command is received, fast deceleration is not used to reduce the speed from 50% to 40% since the deceleration window (10%) is smaller than FAST_DEC_DUTY_WIN.

Note

Disable WCOMP_BLANK_EN if voltage spikes are seen on supply voltage.

2.3 Improving System Efficiency by Minimizing Power Losses

Power dissipation in MCT8316A can be from various sources such as R_{dsOn} of the MOSFETs, MOSFET switching losses, MOSFET slew rate, operating supply current dissipation, and so forth. MCT8316A provides configurable options to minimize power losses and maximize thermal efficiency.

Power losses in MCT8316A can be minimized by configuring PWM output frequency, PWM mode, ASR and AAR.

Device case temperature drops by 8°C (from 72.3°C to 64.3°C) by configuring the following parameters:

- Enable ASR [EN_ASR] and AAR [EN_AAR]
- Decreased PWM output frequency [PWM_FREQ_OUT] from 50 kHz to 30 kHz.
- Changed PWM mode [PWM_MODE] from Complimentary to Single ended mode.

Figure 2-5 shows the thermal image of MCT8316A at 50 kHz PWM output frequency, ASR and AAR disabled and PWM mode configured to Complimentary mode.

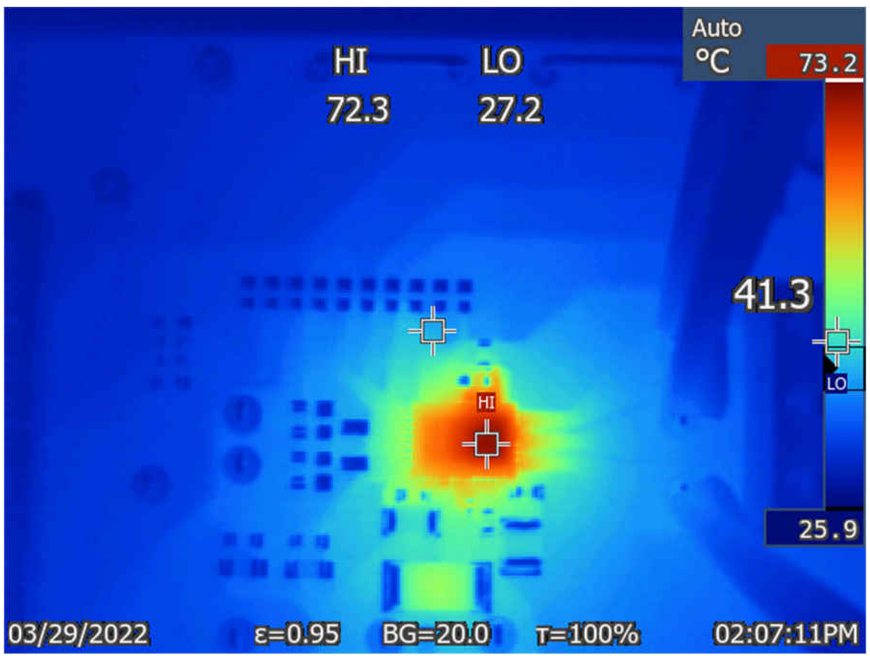

Figure 2-5. Thermal Image of MCT8316A – Higher Case Temperature

Figure 2-6 shows the thermal image of MCT8316A at 30 kHz PWM output frequency, ASR and AAR enabled and PWM mode configured to single ended mode.

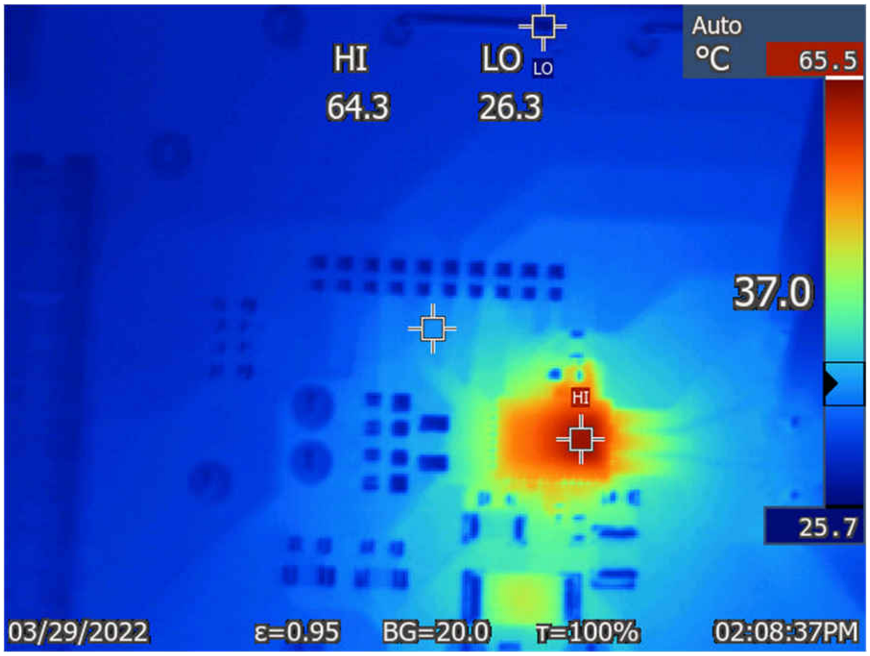

Figure 2-6. Thermal Image of MCT8316A - Lower Case Temperature

3 References

- Texas Instruments, *MCT8316A High Speed Sensorless Trapezoidal Control Integrated FET BLDC Driver Data Sheet*
- Texas Instruments, *MCT8316A Tunign Guide*
- Texas Instruments, Thermal calculator