Application Report

How to Reduce Motor Noise with Code-Free, Sensorless BLDC Motor Drivers

ABSTRACT

Open-concept floor plans for home and offices have increased demand for quieter appliances, even a little difference in acoustics can make a big difference in audible noise. With advanced real-time control techniques, engineers can achieve better acoustic performance with BLDC motor drivers in applications such as air purifiers, refrigerators, blowers, laptop fans, microwaves, washer & dryer etc. This application note explains how TI's latest code-free sensorless control integrated BLDC motor drivers can achieve industry-leading acoustic performance. MCF8316A device leverages the patented precise automatic dead-time compensation and PWM modulation schemes along with Field oriented control (FOC) commutation to deliver best acoustic performance. Variable commutation techniques used in MCT8316A device can help reduce acoustic noise associated with traditional sensorless trapezoidal control commutation. In this application report, we use industry's best performing motors to benchmark acoustic performance on the latest portfolio of MCF8316A and MCT8316A devices.

Table of Contents

1 Introduction........2
2 Concept........3
2.1 Optimizing acoustics with sensorless field-oriented control motor driver (MCF8316A)........3
2.2 Optimizing acoustics with sensorless trapezoidal control motor driver (MCT8316A)........6
2.3 Comparing acoustic performance between Sensorless FOC motor driver (MCF8316A) and 180° sinusoidal motor driver (DRV10987)........8
3 Summary........10
4 References........11

List of Figures

Figure 2-1. Continuous and Discontinuous PWM Modulation Phase Voltages........3
Figure 2-2. Phase current waveform and FFT - Discontinuous PWM modulation........4
Figure 2-3. Phase current waveform and FFT - Continuous PWM modulation........4
Figure 2-4. Phase current waveform and FFT - Dead time compensation disabled........5
Figure 2-5. Phase current waveform and FFT - Dead time compensation enabled........5
Figure 2-6. Audible Noise Comparison with MCF8316A........6
Figure 2-7. Phase current waveform and FFT - 120° Trapezoidal commutation........7
Figure 2-8. Phase current waveform and FFT - 150° Trapezoidal commutation........8
Figure 2-9. Audible noise comparison between 120° commutation and 150° commutation........8
Figure 2-10. Audible noise comparison between MCF8316A and DRV10987........9

List of Tables

Trademarks

All trademarks are the property of their respective owners.

1 Introduction

Acoustics is audible noise contributed by motor commutation and harmonic frequencies in motor drives applications. Any distortion in motor phase current can translate to audible noise. Stator excitation in motor can generate mechanical resonance at audible frequency ranges leading to audible noise. Acoustics due to motor commutation is clearly heard in motors running at lower speeds. At higher motor speeds, air or liquid flow noise masks the commutation noise. Improving acoustic performance is important for home applications such as washer, dryer, air purifier, vacuum cleaners and laptop fans. Audible noise can be minimized by blocking the noise, shaping the noise or avoiding the noise through control techniques. With MCF8316A and MCT8316A devices, system designers can minimize the audible noise through control techniques such as continuous PWM modulation, dead time compensation and variable commutation mode.

2 Concept

2.1 Optimizing acoustics with sensorless field-oriented control motor driver (MCF8316A)

Acoustics performance with MCF8316A can be optimized by configuring PWM modulation schemes and enabling dead time compensation. In this application note, we used an air purifier motor to optimize acoustics performance with MCF8316A.

2.1.1 PWM Modulation Schemes

The MCF8316 device supports continuous and discontinuous space vector PWM modulation schemes. In continuous PWM modulation, all the three phases are pulse width modulated at the same 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. Figure 2-1 shows the modulated average phase voltages for different modulation schemes.

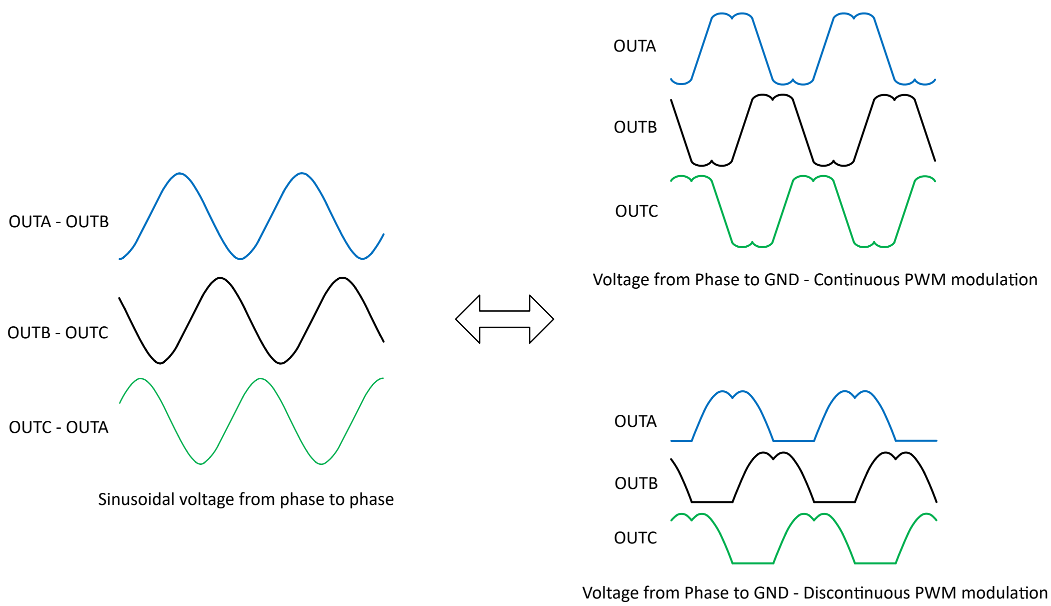

Figure 2-1. Continuous and Discontinuous PWM Modulation Phase Voltages

In continuous space vector modulation, phase current waveform shaping will be sinusoidal with no distortions. In discontinuous space vector modulation, we can expect phase current distortion for low inductance motors because only two phases are pulse width modulated. Figure 2-2 shows phase current waveform in discontinuous PWM modulation mode and the Fast Fourier Transform (FFT) of phase current. Figure 2-3 shows phase current waveform in continuous PWM modulation mode and the FFT of phase current. Phase current waveform in continuous modulation mode is cleaner and more sinusoidal compared to phase current waveform in discontinuous modulation mode.

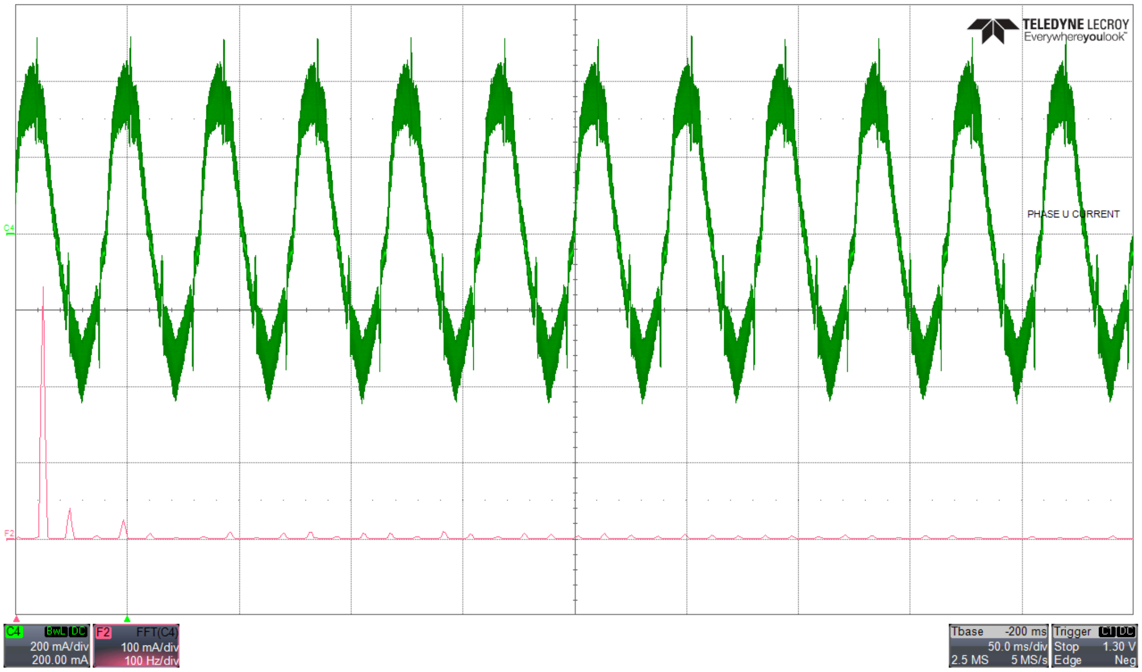

Figure 2-2. Phase current waveform and FFT - Discontinuous PWM modulation

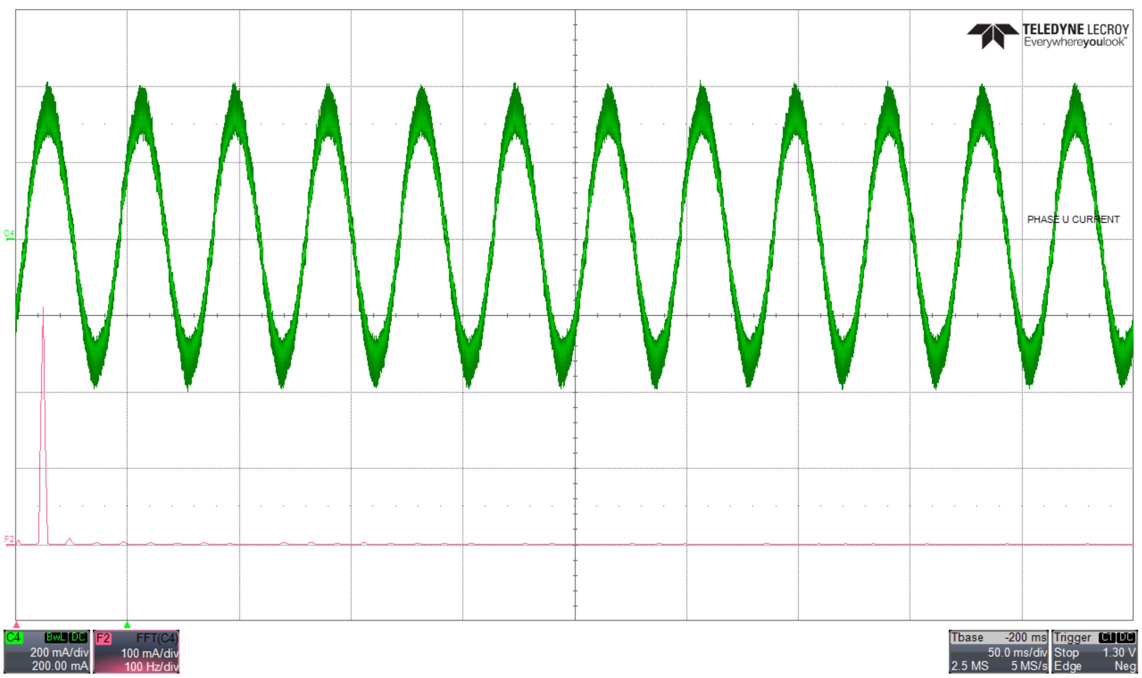

Figure 2-3. Phase current waveform and FFT - Continuous PWM modulation

2.1.2 Dead time compensation

In a half bridge leg, dead time is applied between the switching instants of high side and low side MOSFET to avoid current 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. The MCF8316 device integrates a proprietary dead time compensation using a resonant controller to control the harmonic component in phase current to zero, ensuring that the current distortion due to dead time is alleviated. The resonant controller is employed in both Iq and Id control paths. Figure 2-4 shows phase current waveform when dead time compensation is disabled and the FFT of phase current. Figure 2-5 shows phase current waveform when dead time compensation is enabled and the FFT of phase current. In below graphs, PWM output frequency is set to 60 kHz and dead time is set to 500 ns. Motor electrical speed is 12 Hz. As seen in the FFT on current waveforms in the graphs (Signal in PINK), phase current is much cleaner after enabling dead time compensation.

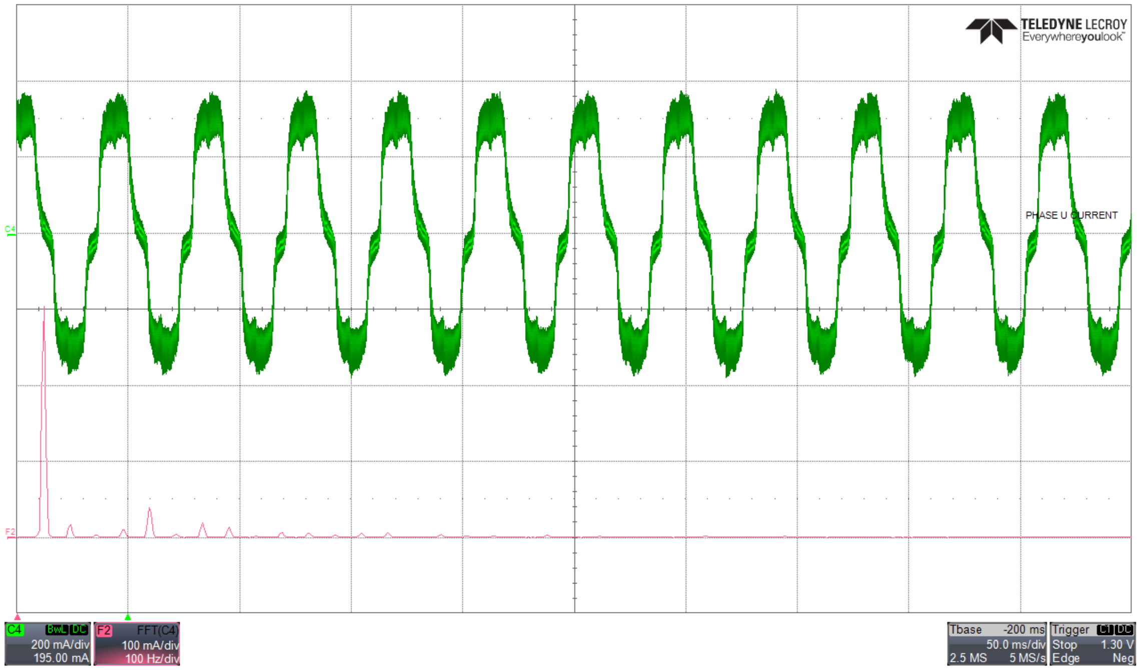

Figure 2-4. Phase current waveform and FFT - Dead time compensation disabled

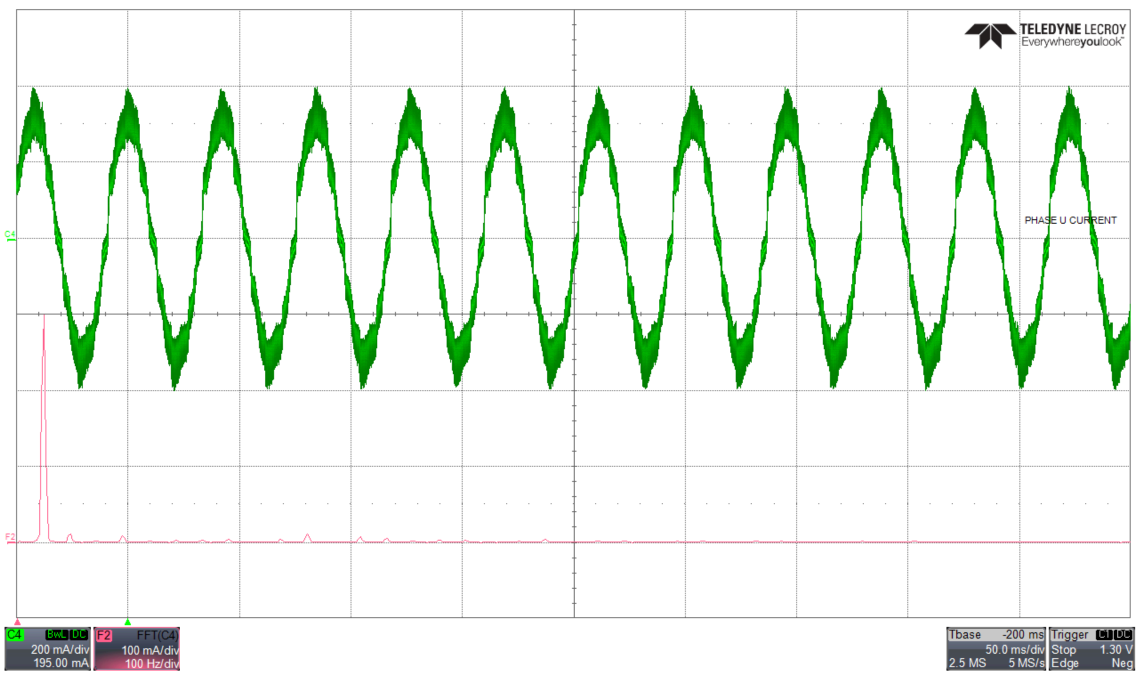

Figure 2-5. Phase current waveform and FFT - Dead time compensation enabled

2.1.3 Comparing audible noise before and after optimizing acoustics with MCF8316A

In below experiment, acoustics performance is measured in dBA using a handheld sound level meter. Figure 2-6 shows the noise level comparison at different motor electrical speeds for an air-purifier motor. Audible noise is reduced by 3.3 dBA at 33 Hz motor electrical frequency with dead time compensation and continuous PWM modulation schemes.

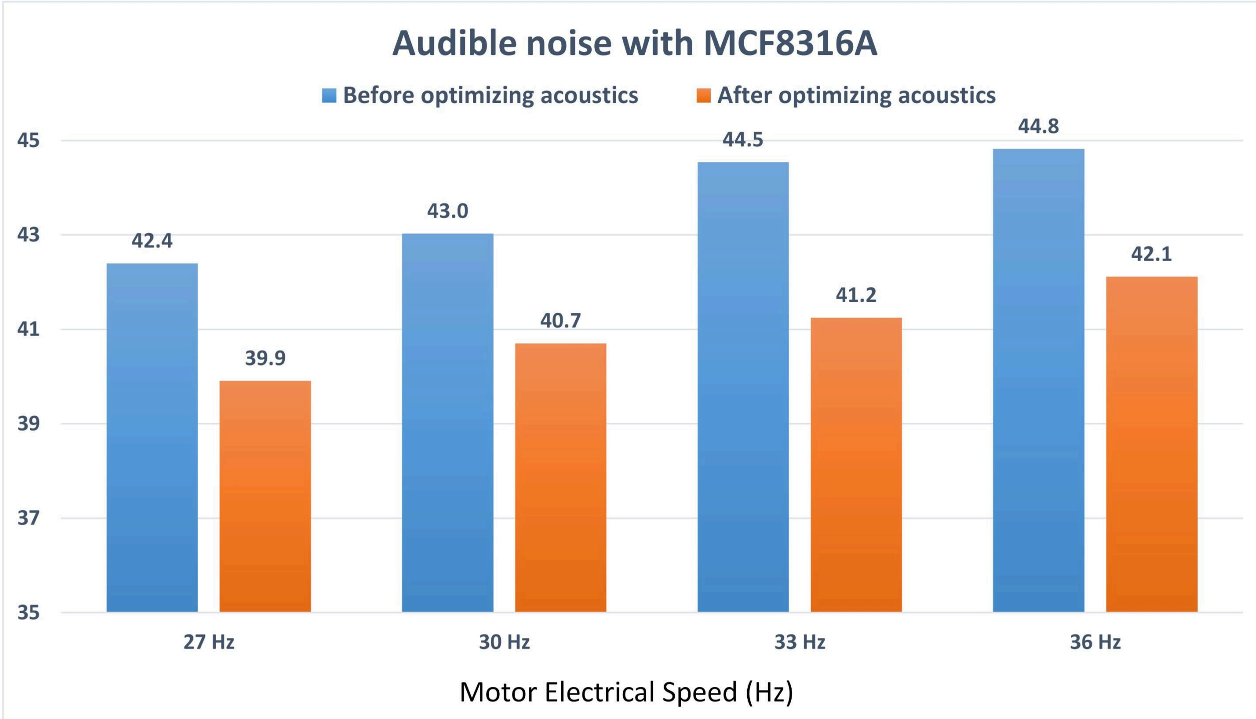

Figure 2-6. Audible Noise Comparison with MCF8316A

2.2 Optimizing acoustics with sensorless trapezoidal control motor driver (MCT8316A)

Acoustics with MCT8316A can be optimized by configuring sensorless trapezoidal commutation modes. In this application note, we used a blower fan motor to compare acoustic performance with different modulation schemes in MCT8316A device.

2.2.1 120° Trapezoidal commutation Scheme

In 120° commutation scheme, each motor phase is driven for 120° and Hi-Z for 60° within each half electrical cycle, resulting in six different commutation states for a motor. Figure 2-7 shows the phase current and current waveform FFT in 120° commutation mode.

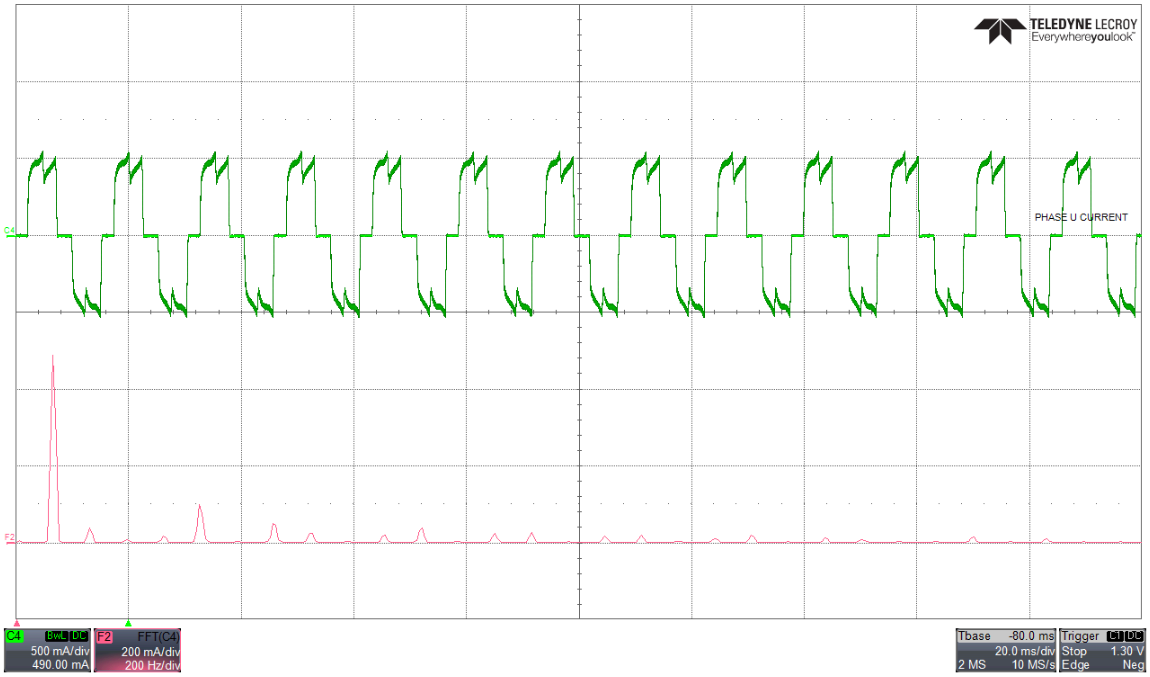

Figure 2-7. Phase current waveform and FFT - 120° Trapezoidal commutation

2.2.2 Variable commutation Scheme

In variable commutation scheme, MCT8316A device switches dynamically between 120° and 150° trapezoidal commutation depending on motor speed. The device operates in 150° mode at lower speeds and moves to 120 mode at higher speeds. In 120° commutation, when motor phase is Hi-Z due to stored inductive current, there is torque ripple in phase current which leads to acoustic noise. In order to reduce the effect of torque ripple and improve acoustic noise, in a variable commutation mode MCT8316A device reduces the phase current by extending 120° driving time and gradually decreasing duty cycle prior to entering Hi-Z state. In this mode, phase is Hi-Z between 30° and 60° and this window size is dynamically adjusted based on speed, smaller window size gives best acoustic performance. Figure 2-8 shows the phase current and current waveform FFT in 150° commutation. Phase current shape is more sinusoidal waveform in 150° commutation mode.

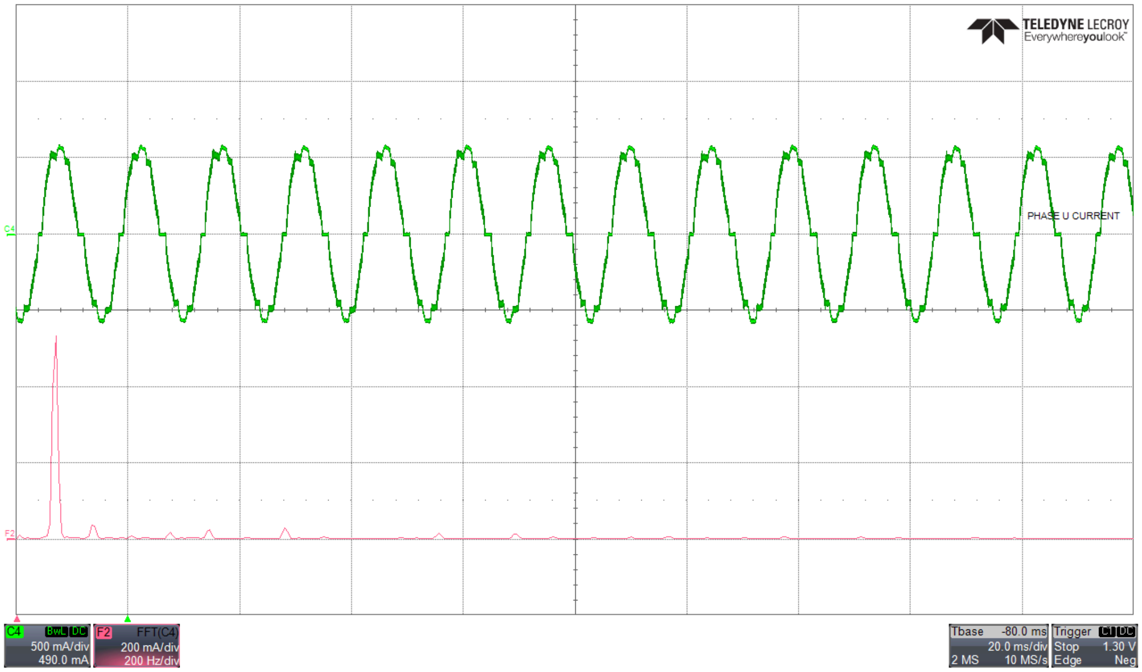

Figure 2-8. Phase current waveform and FFT - 150° Trapezoidal commutation

2.2.3 Comparing audible noise between 120° commutation and Variable commutation with MCT8316A

Similar to MCF8316A results, acoustics performance is measured in dBA using a handheld sound level meter. Figure 2-9 shows the noise level comparison between 120° commutation and 150° commutation at different motor speeds. Audible noise is lesser in 150° commutation by 3.3 dBA at lower motor speed operation of 15 Hz and 16.5 Hz.

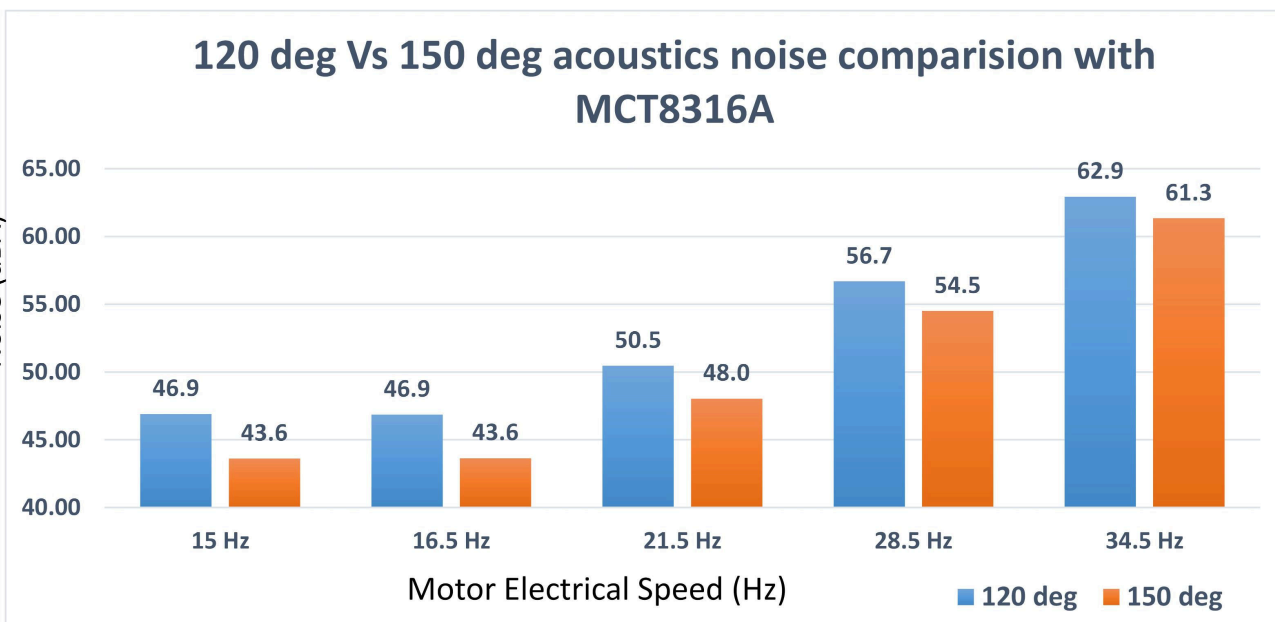

Figure 2-9. Audible noise comparison between 120° commutation and 150° commutation

2.3 Comparing acoustic performance between Sensorless FOC motor driver (MCF8316A) and 180° sinusoidal motor driver (DRV10987)

As shown in Figure 2-10, acoustics noise is compared between MCF8316A and DRV10987 by measuring the audible noise in dBA at different motor electrical speeds with laptop fan motor. MCF8316A device delivers quieter motor operation by 2.71 dBA at 115 Hz compared to DRV10987 device. MCF8316A optimizes acoustic noise at lower speed with PWM modulation and dead time compensation techniques.

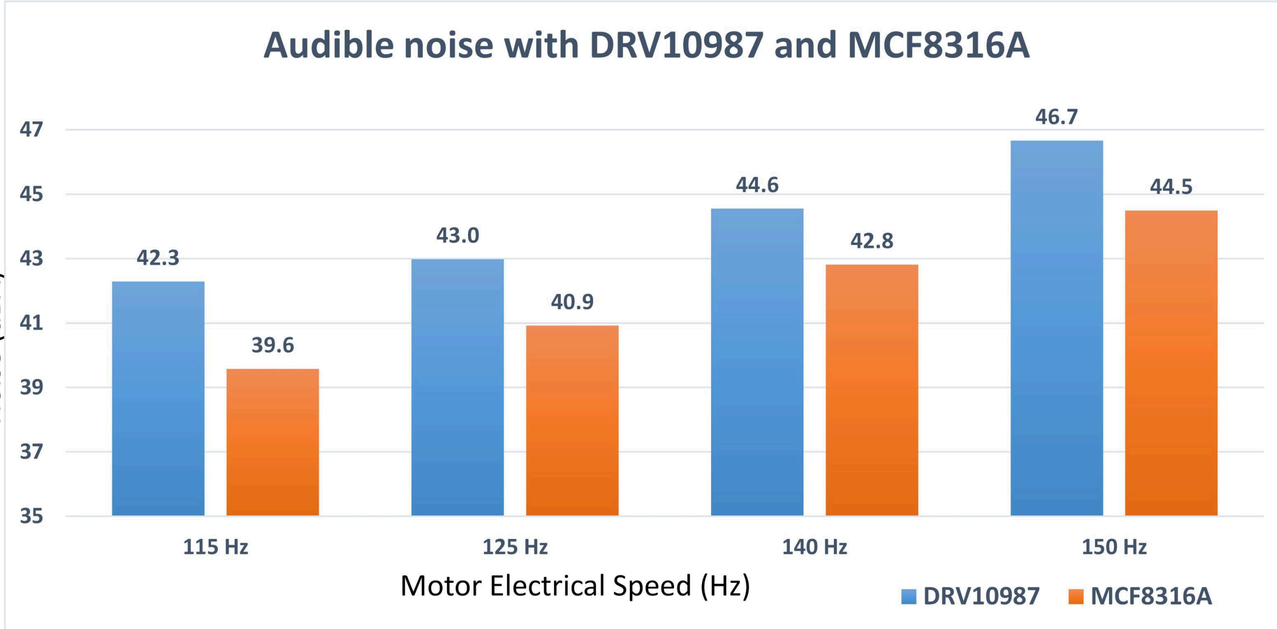

Figure 2-10. Audible noise comparison between MCF8316A and DRV10987

3 Summary

Phase current waveforms, FFT of phase current waveforms and audible noise results show how TI's latest code-free sensorless control integrated BLDC motor drivers can reduce motor noise and achieve industry-leading acoustic performance. For more details, please check below links.

MCF8316A - www.ti.com/product/MCF8316A

MCT8316A - www.ti.com/product/MCT8316A

4 References

For additional reference, refer to the following:

- Texas Instruments, MCF8316A Datasheet
- Texas Instruments, MCT8316A Datasheet
- Texas Instruments, MCF8316A Tuning Guide
- Texas Instruments, MCT8316A Tuning Guide
- Texas Instruments, DRV10987 Datasheet