DRV8711 Decay Mode Setting Optimization

Wilson Zuo, Axel Gao

ABSTRACT

This document is provided as a guide to the decay parameters adjustment for the DRV8711 at high-degree micro stepping to achieve the best sinusoidal current. It analyzes 6 typical abnormal winding current waveforms of stepper and offers a respectively simple method to fix the problem by modifying only 1 parameter. All the analysis and experiments are tested with the DRV8711 EVM. But the conclusions are valid to the other stepper driver. Almost all the abnormal winding current waveforms are seen as the combination of the 6 typical abnormal waveforms and the solution could be also the combination of the introduced methods.

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1 Introduction

High resolution micro stepping is widely used in security cameras, CNC systems, stage lighting, and other applications requiring smooth movement. The DRV8711, which is a stepper motor controller with an integrated indexer, achieves step modes from full step to 1/256-step and is adequate to these high resolution applications. Figure 1 illustrates to 1/256-step, the ideal waveform of winding current is sinusoidal.

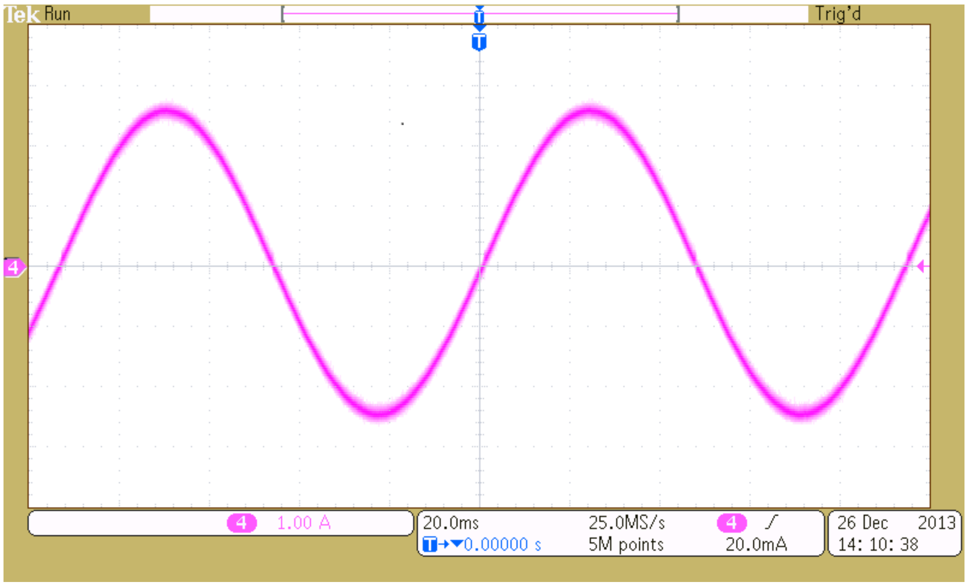


Figure 1. Ideal Winding Current Waveform of 1/256 Micro Stepping

The ideal sinusoidal winding current could match the magnetic natural characteristic of a stepper and assure the stepper to have a smooth and uniform movement in high degree micro-stepping. However, due to the different electrical parameters and different motors, there are always some difficulties in realizing a perfect sinusoidal wave. The current profile is actually the result of the detailed decay settings. Since the DRV8711 gives the most flexibilty of decay mode configuration including slow, fast, mixed, slow+mixed, slow+auto mixed, and auto mixed 6 modes and related detail tunings, we chose the DRV8711 EVM to demonstrate the adjustment methods.

This application note analyzes the decay adjustment methods to fix the typical abnormal waveforms of winding current. All the following adjustments attempt to just change one parameter at a time, such as off-time, blanking time, decay time, and decay mode, in order to give the clear trend of each parameter‘s change. In real applications, there could be a combination of parameters tunings to get the most optimized result with the least side effects.

The following experiments are all completed in a laboratory enviroment with 2 different motors, respectively, as listed in the following table:

Motor	Phase Resistance	Phase Inductance	Description
Motor 1	0.8 Ohm	3.5 mH @ 1 kHz	Normal inductive
Motor 2	1.1 Ohm	7 mH @ 1 kHz	Large inductive

2 Current Distortion Pattern 1

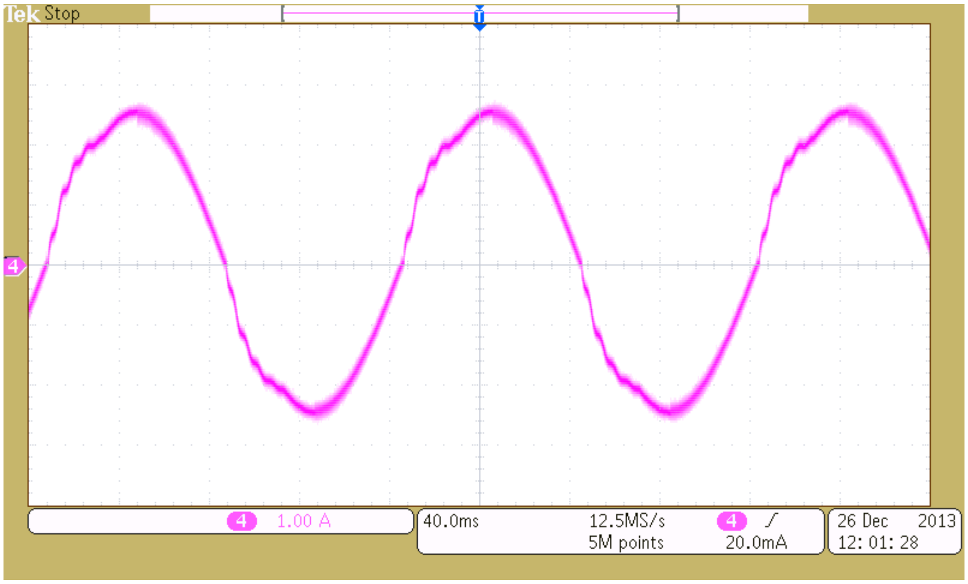
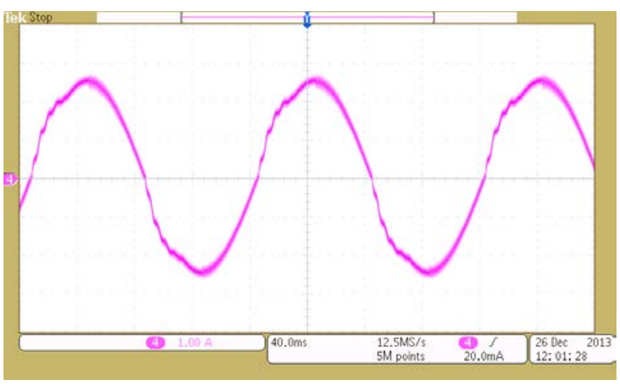
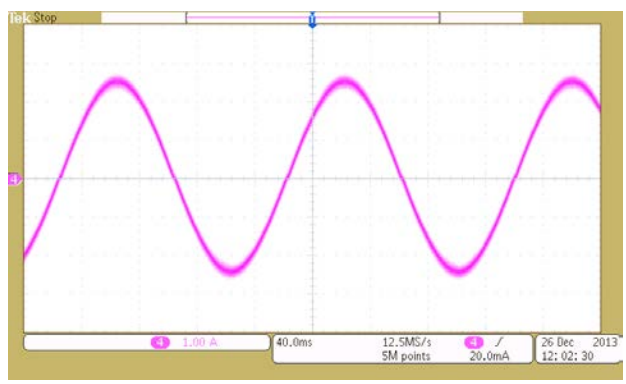


Figure 2. Current Distortion Pattern 1

Test conditions: DRV8711EVM, VM = 24 V, I_{torque} = 2.5 A, Micro-step = 1/256, Motor 1.

2.1 Adjustment Method 1

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 001 Slow+Mixed TBLANK (blanking time): 1 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 5 µs TOFF(PWM off time): 9 µs	**DECMOD (decay mode): 011 All Mixed** TBLANK (blanking time): 1 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 5 µs TOFF(PWM off time): 9 µs

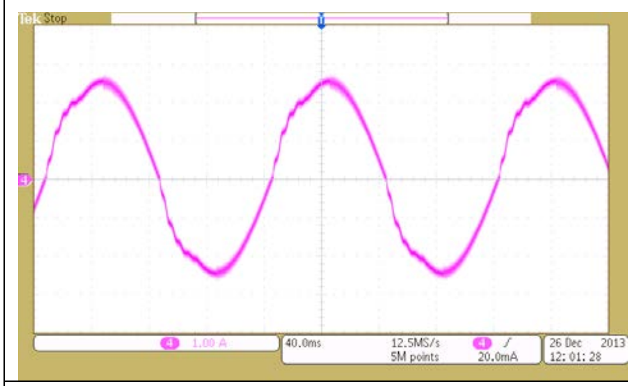
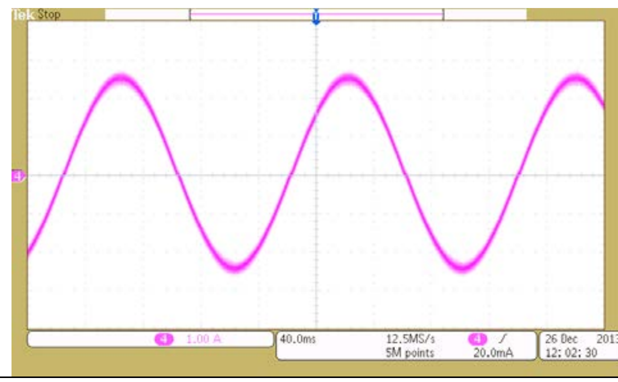
1. Root cause analysis:

Figure 1 shows the winding current stays at a higher level than the ideal waveform during the current increasing stage. This distortion is mainly caused by the current decay rate being too slow and usually happens to a stepper with low phase resistance and inductance.

2. How does the adjustment work?

Fix this problem by replacing slow decay with mixed decay during the current increasing stage because mixed decay has a faster decay rate than slow decay.

2.2 Adjustment Method 2

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 001 Slow+Mixed TBLANK (blanking time): 1 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 5 µs **TOFF(PWM off time): 9 µs**	DECMOD (decay mode): 001 Slow+Mixed TBLANK (blanking time): 1 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 5 µs **TOFF(PWM off time): 32 µs**

1. Root cause analysis:

The same as Section 2.1

2. How does the adjustment work?

To make the winding current decay more, we could also prolong the off-time . Therefore, PWM off-time increases from 9 µs to 32 µs, which has an effective influence on the current waveform.

3 Current Distortion Pattern 2

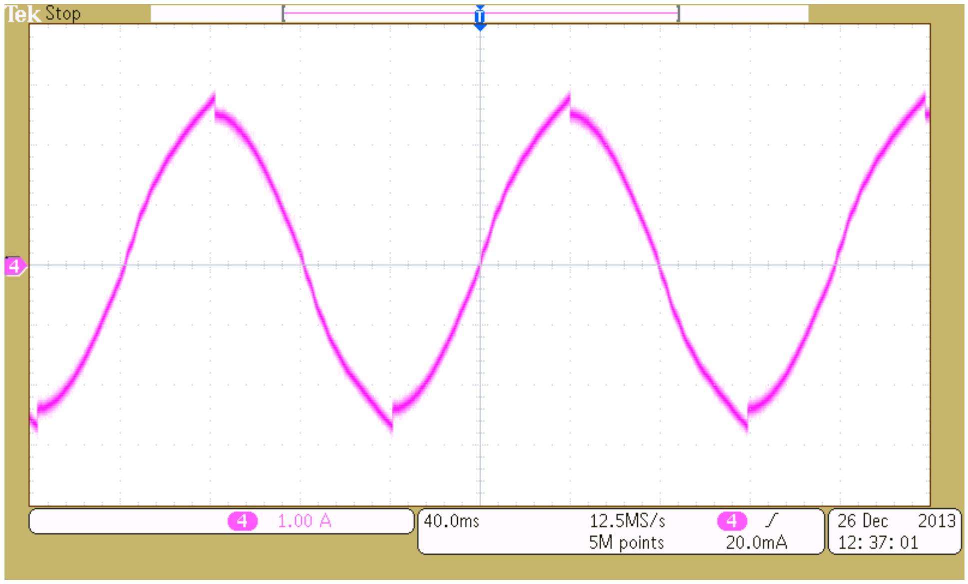
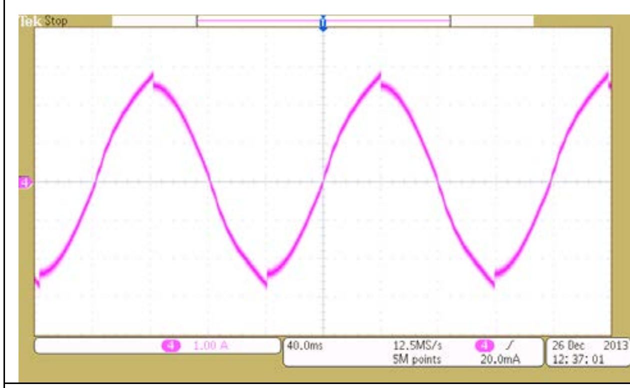
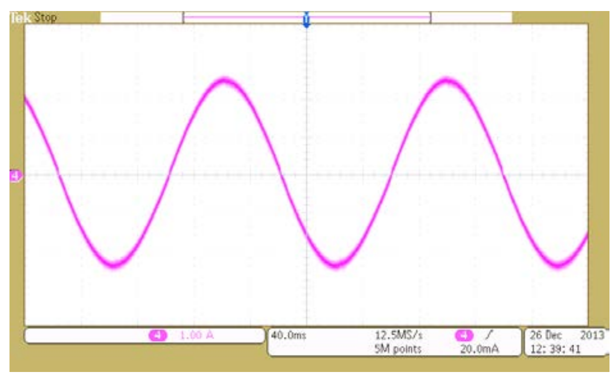


Figure 3. Current Distortion Pattern 2

Test conditions: DRV8711EVM, VM = 24 V, I_{torque} = 2.5 A, Micro-step = 1/256, Motor 2.

3.1 Adjustment Method 1

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 001 Slow+Mixed **TBLANK (blanking time): 3 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 4 µs TOFF(PWM off time): 18 µs	DECMOD (decay mode): 001 Slow+Mixed **TBLANK (blanking time): 2 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 4 µs TOFF(PWM off time): 18 µs

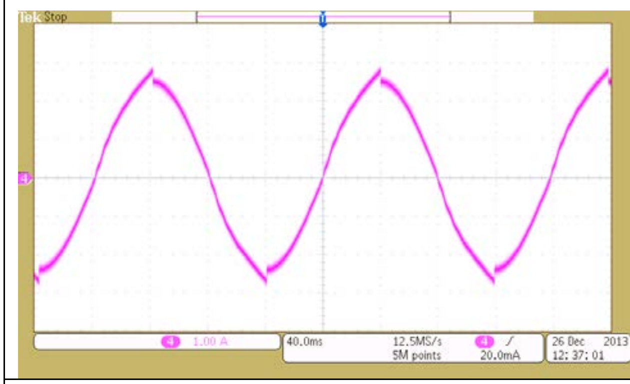
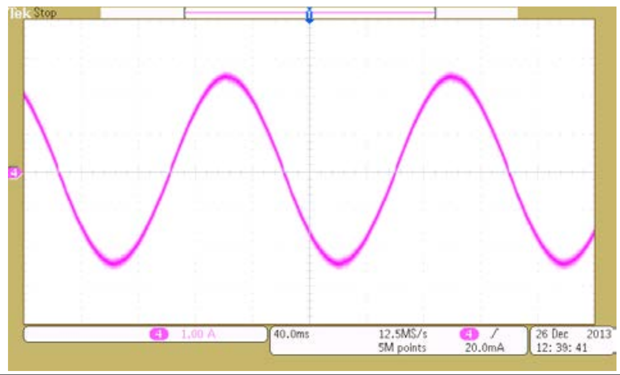
1. Root cause analysis:

As shown in Figure 2, the winding current is overcharged at the end of the current level-up stage. This is mainly due to the long blanking time and the slow decay rate.

2. How does the adjustment work?

To fix this problem, reduce the charged current by cutting down the blanking time. There is an effective influence on the current waveform, as shown in the chart above.

3.2 Adjustment Method 2

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 001 Slow+Mixed TBLANK (blanking time): 3 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 4 µs **TOFF(PWM off time): 18 µs**	DECMOD (decay mode): 001 Slow+Mixed TBLANK (blanking time): 3 µs ABT(adaptive blanking time):0 TDECAY (decay time): 4 µs **TOFF(PWM off time): 26 µs**

1. Root cause analysis:

The same as for section 2.1.

2. How does the adjustment work?

The other method is increasing off-time to reduce more current during the current decay stage. The previous chart shows the effect of increasing off-time from 18 µs to 26 µs.

4 Current Distortion Pattern 3

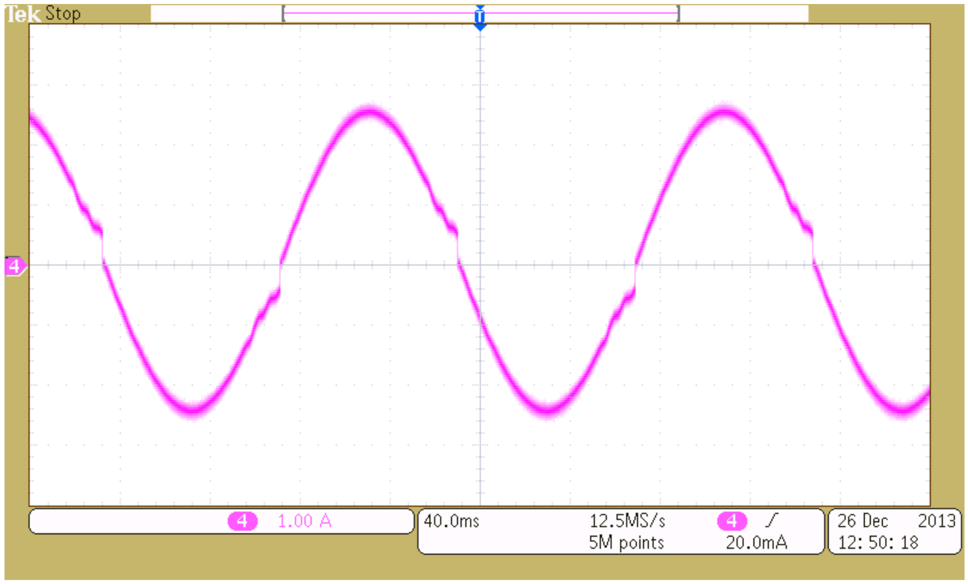
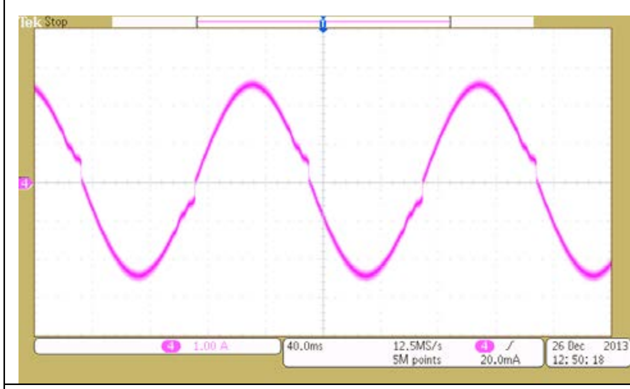
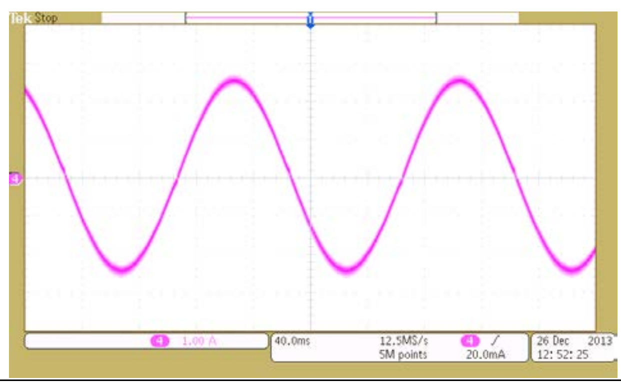


Figure 4. Current Distortion Pattern 3

Test conditions: DRV8711EVM, VM = 24 V, I_{torque} = 2.5 A, Micro-step = 1/256. Motor 1.

4.1 Adjustment Method 1

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 011 All Mixed **TBLANK (blanking time): 2.6 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 1 µs TOFF(PWM off time): 28 µs	DECMOD (decay mode): 011 All Mixed **TBLANK (blanking time): 1.5 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 1 µs TOFF(PWM off time): 28 µs

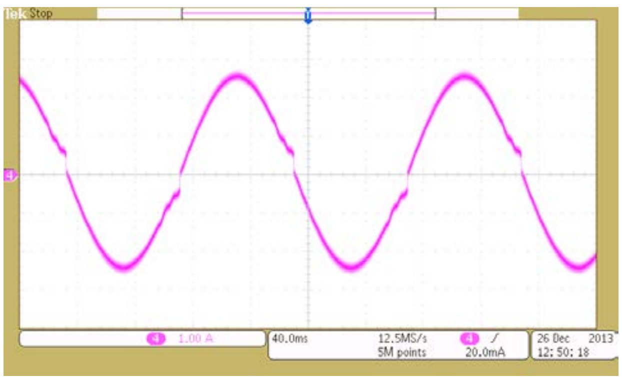
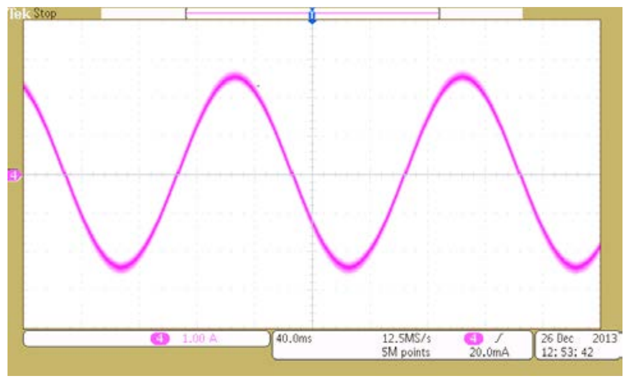
1. Root cause analysis:

As shown in Figure 3, the winding current is overcharged at the end of the current level-down stage, especially around the 0 point. This is mainly due to the long blanking time resulting in too much charged current above the command level.

2. How does the adjustment work?

To avoid charging too much current, cut down the blanking time. The chart above shows the effect of reducing blanking time from 2.6 µs to 1.5 µs.

4.2 Adjustment Method 2

Before Adjustment	**After Adjustment**
	
DECMOD (decay mode): 011 All Mixed TBLANK (blanking time): 2.6 µs ABT(adaptive blanking time): 0 **TDECAY (decay time): 1 µs** TOFF(PWM off time): 18 µs	DECMOD (decay mode): 011 All Mixed TBLANK (blanking time): 2.6 µs ABT(adaptive blanking time):0 **TDECAY (decay time): 3 µs** TOFF(PWM off time): 26 µs

1. Root cause analysis:

The same as section 3.1.

2.How does the adjustment work?

The other method is to increase the decay time, because the more fast decay, the more current is eliminated. The chart above shows the effect.

5 Current Distortion Pattern 4

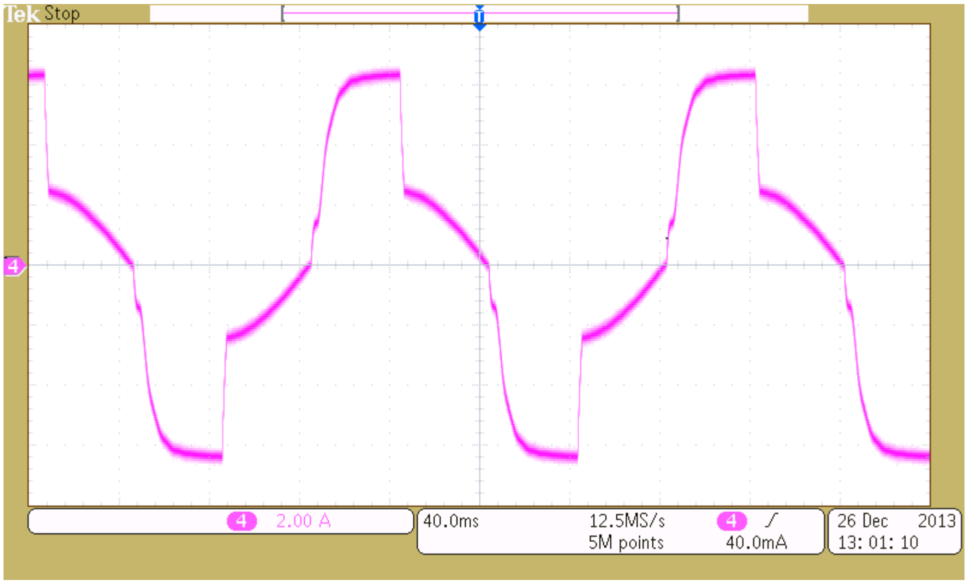
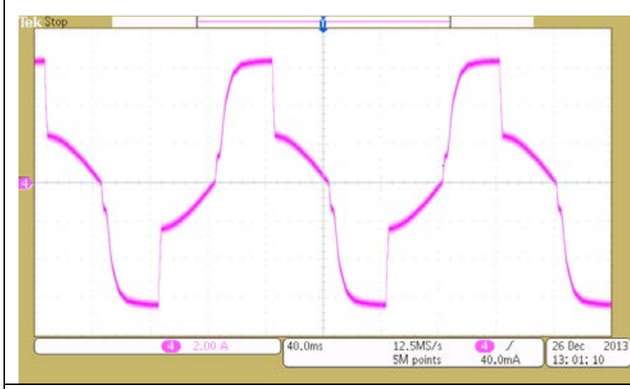
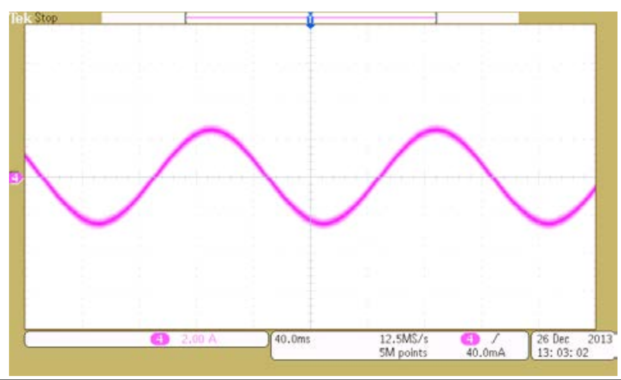


Figure 5. Current Distortion Pattern 4

Test conditions: DRV8711EVM, VM = 24 V, I_{torque} = 2.5 A, Micro-step = 1/256. Motor 1.

5.1 Adjustment Method 1

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 001 Slow+Mixed TBLANK (blanking time): 3 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 3 µs TOFF(PWM off time): 6 µs	**DECMOD (decay mode): 011 All Mixed** TBLANK (blanking time): 3 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 3 µs TOFF(PWM off time): 6 µs

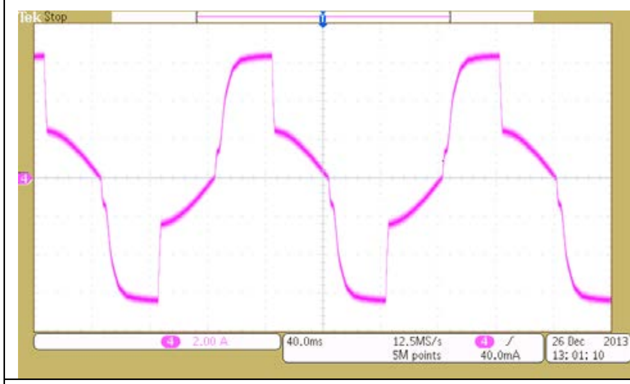
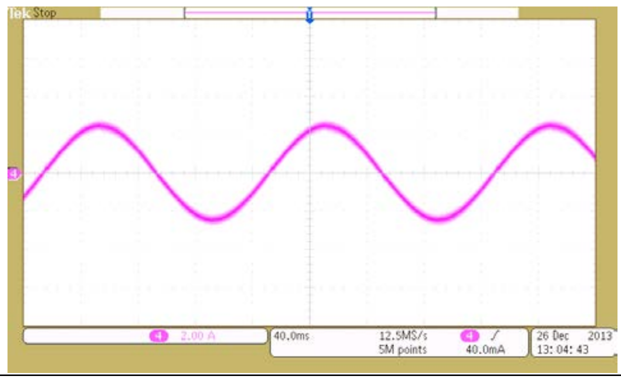
1. Root cause analysis:

This abnormal waveform is an extreme situation of distortion pattern 1 and pattern 2. It is extremely overcharged due to the slow rate of slow decay in current level-up stage.

2. How does the adjustment work?

To avoid charging too much current, replacing slow decay with mixed decay is effective. The chart above shows the effect of modifying the decay mode to all mixed decay.

5.2 Adjustment Method 2

Before Adjustment	**After Adjustment**
	
DECMOD (decay mode): 001 Slow+Mixed **TBLANK (blanking time): 3 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 3 µs **TOFF(PWM off time): 6 µs**	DECMOD (decay mode): 001 Slow+Mixed **TBLANK (blanking time): 0.5 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 3 µs **TOFF(PWM off time): 20 µs**

1. Root cause analysis:

The same as for section 4.1.

2. How does the adjustment work?

To deal with this extreme overcharge situation, not only blanking time needs reduction but also increasing off-time. From the chart above, the effect of reducing blanking time from 3 µs to 0.5 µs and increasing off-time from 6 µs to 20 µs is illustrated.

6 Current Distortion Pattern 5

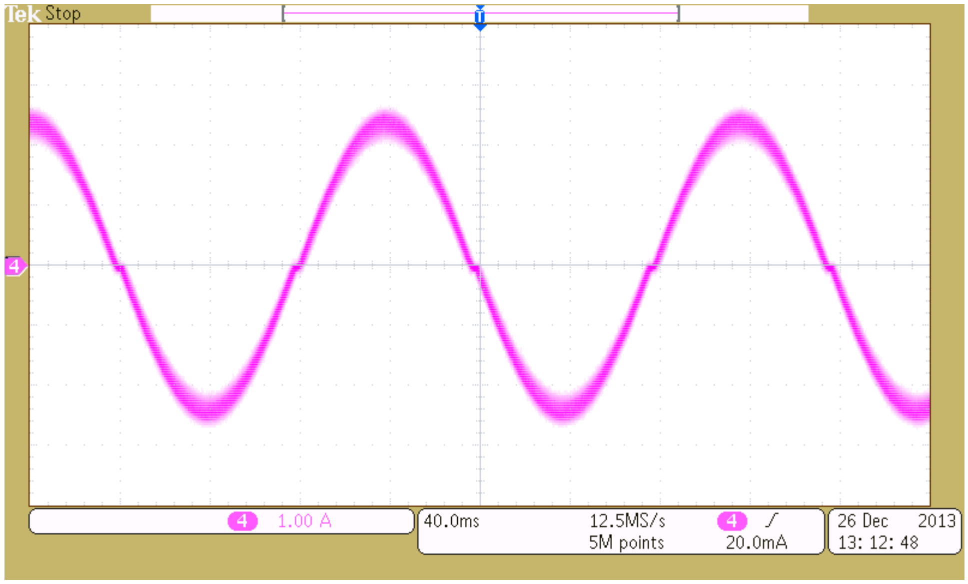
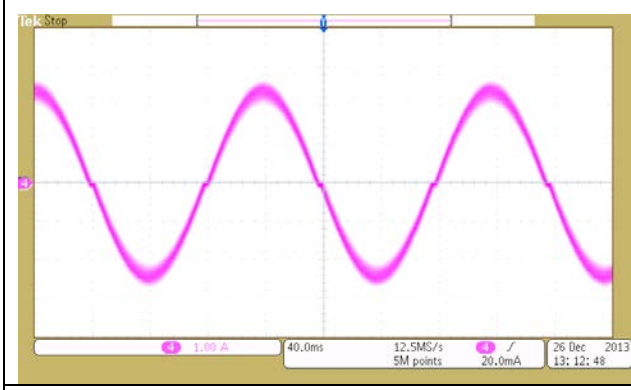
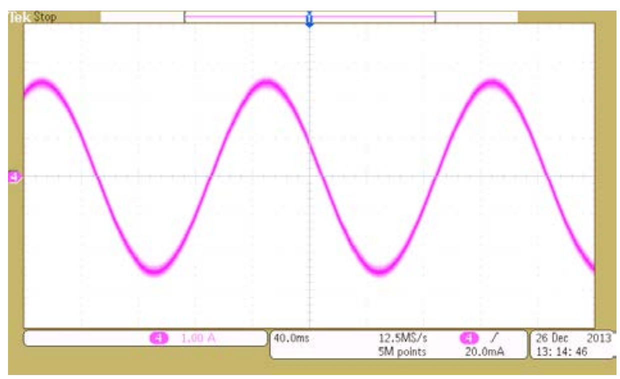


Figure 6. Current Distortion Pattern 5

Test conditions: DRV8711EVM, VM = 24 V, I_{torque} = 2.5 A, Micro-step = 1/256. Motor 1.

6.1 Adjustment Method

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 010 All Fast TBLANK (blanking time): 1.5 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 4 µs **TOFF(PWM off time): 30 µs**	DECMOD (decay mode): 010 All Fast TBLANK (blanking time): 1.5 µs ABT(adaptive blanking time): 0 TDECAY (decay time): 4 µs **TOFF(PWM off time): 4 µs**

1. Root cause analysis:

This abnormal waveform has a large ripple and an obvious plateau around zero current point. It's mainly due to too much current eliminated by fast decay in the off time and the lowered average current causing a flat zero distortion.

2. How does the adjustment work?

To avoid consuming too much current and keep fast decay, reduce off-time. From the chart above, the plateau around the 0 point disappears and the current ripple gets smaller by decreasing off-time from 30 µs to 4 µs.

Also, the current ripple is cured by lowering the off time which increases the total PWM frequency.

7 Current Distortion Pattern 6

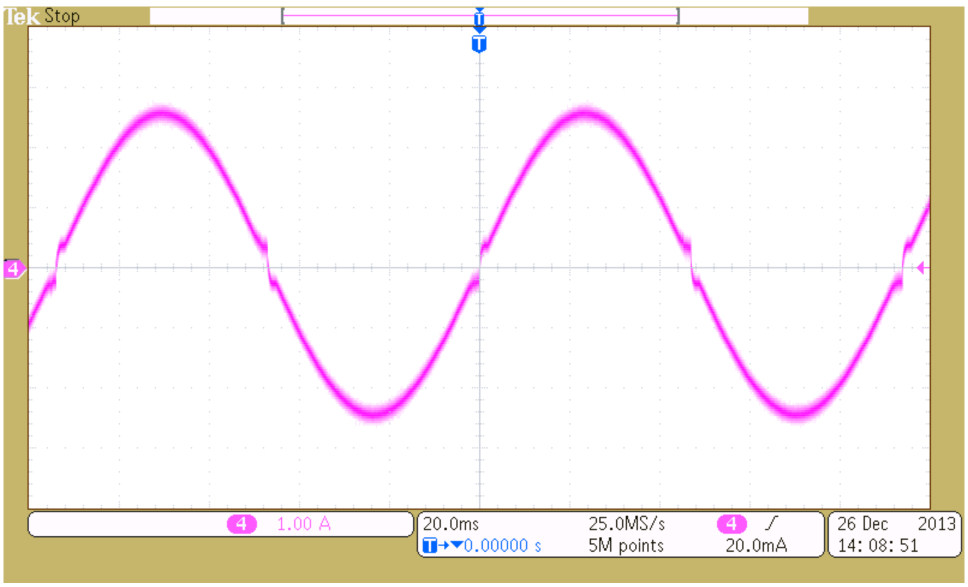
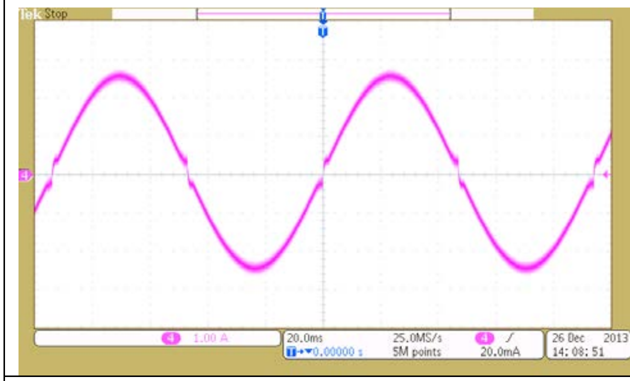
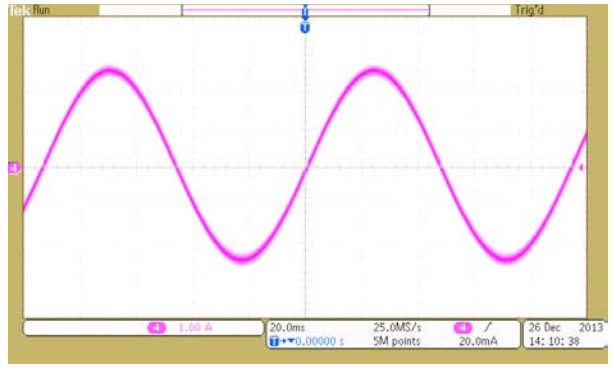


Figure 7. Current Distortion Pattern 6

Test conditions: DRV8711EVM, VM = 24 V, I_{torque} = 2.5 A, Micro-step = 1/256. Motor 1.

7.1 Adjustment Method

Before Adjustment	After Adjustment
	
DECMOD (decay mode): 101 All AutoMixed **TBLANK (blanking time): 0.5 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 3 µs TOFF(PWM off time): 7.5 µs	DECMOD (decay mode): 101 All AutoMixed **TBLANK (blanking time): 2.5 µs** ABT(adaptive blanking time): 0 TDECAY (decay time): 3 µs TOFF(PWM off time): 7.5 µs

1. Root cause analysis:

Auto-mixed decay is a peculiar decay mode of the DRV8711, refer to the datasheet (SLVSC40) for the detailed function. For this motor, here the distortion is because of too small a blanking time which causes the total decay effect in auto mixed decay to be too low for the current command level change.

2. How does the adjustment work?

By increasing the blanking time, the auto mixed decay is able to decay the current to the index command level.

8 Summary

In real practice, the combination of adjustment methods shown in this application report efficiently leads to the best sinusoidal current waveform of different applications. The adjustment trends are also valid to other micro stepping levels, current level settings, motor types, and other DRV8x stepper drivers with related adjustable parameters. The adjustment practice should be done at low speed in which the back electromotive force (BEMF) effect could be ignored. When motor speed increases, meaning the current index commands change faster, and including the BEMF effect, there is a speed point that the the sinusoidal current waveform can no longer maintain. Proper decay parameters increase the speed threshold of maintaining the sinusoidal current waveform.