

Optimizing High-Level Micro Stepping of the DRV88xx Driver

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ABSTRACT

This document is provided as a supplement to the DRV8812/DRV8813, DRV8828/DRV8829, and DRV8841/8843 (DRV88xx with separated VREFA and VREFB) datasheets. A simple method on offset shifting is introduced to enhance the smoothness in high-level micro stepping applications.

High-resolution micro stepping such as 1/64, 1/128, and 1/256 is normally achieved by current control through VREFA and VREFB ([SLVA416](#)). This method works well in most applications, while there is a defect which makes it not suitable for applications requiring high smoothness. The root cause is the linearity of VREF to phase current – it gets worse at zero point and causes the short pause on the motor side. This application gives an offset shifting method to measure and compensate the nonlinearity to produce smooth micro stepping. The implementation only needs a simple software change to the DAC control and no external component or hardware change is needed.

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1 Introduction

High-degree micro stepping is widely used in security cameras, CNC systems, stage lighting and other applications which require smooth movement.

DRV88xx stepper drivers such as DRV8812, DRV8813, DRV8828, DRV8829, DRV8841, and DRV8843 can use VREF to control the winding current and achieve high-definition micro stepping ([SLVA416](#)). [Figure 1](#) shows the basic mechanism on one winding loop. High level micro stepping such as 1/64, 1/128, or 1/256 is achieved by setting the two windings current respectively with sine modulated DAC.

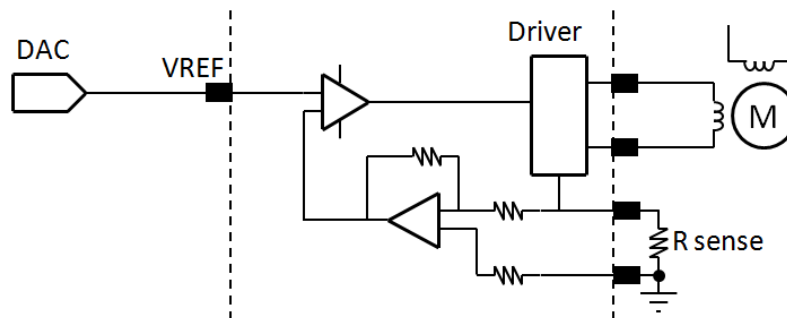


Figure 1. High-Level Micro Stepping with VREF Interface

The accuracy of current control relies on the linearity of VREF-to-current regulation. However, at around zero point of phase current, the linearity is worse because of the decay pattern of the current regulation. When the motor works in high-level micro stepping mode, it has a little pause at the zero current position and degrades the performance of the system. This application note gives a method to optimize micro-stepping performance.

2 Nonlinearity at Zero Point

The following section analyzes the cause of nonlinearity and gives the method to measure the curve of the VREFx voltage-to-phase current.

2.1 Root Cause of Nonlinearity

The root cause of nonlinearity comes when setting the level close to zero, the current decays from the setting value to zero totally during each current chopping cycle. So, the average current is lower than the setting level. [Figure 2](#) shows the difference between the setting level and the real average level.

The nonlinearity could be more serious when the motor's phase resistance and inductance is relative small. The current is more easy to decay to zero when the current setting level is nearing zero.

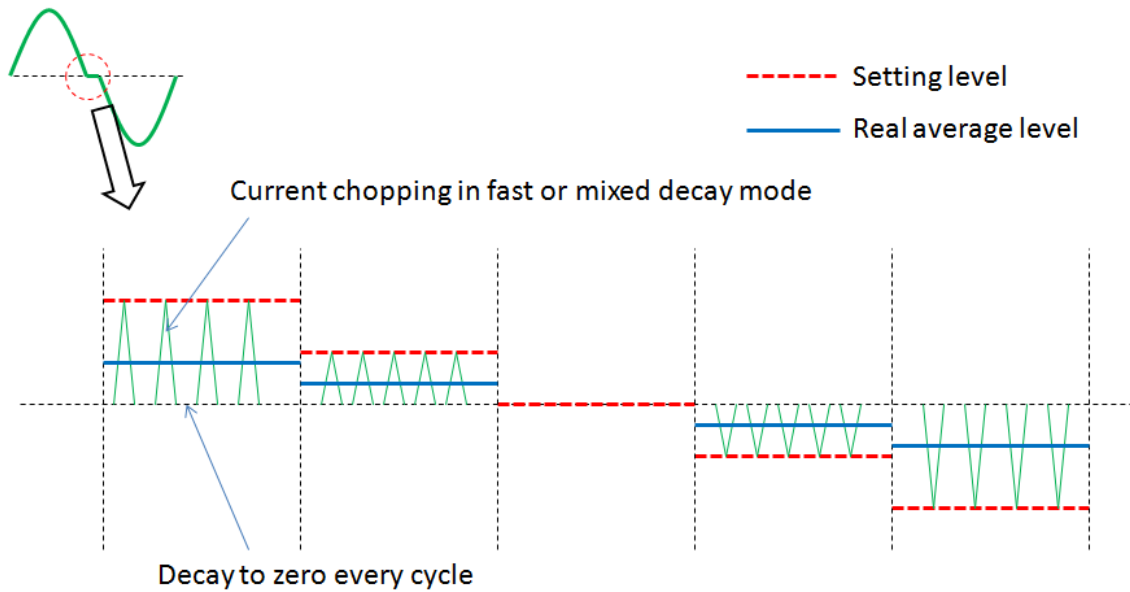


Figure 2. Setting Level and the Real Average Level

2.2 Measure the Nonlinearity

There is no need to set up a special bench to do the measurement. [Figure 3](#) shows the way to test and record the curve in existing application system. A test DAC program is placed on the upper controller side and a multimeter is enough to finish all the measurements.

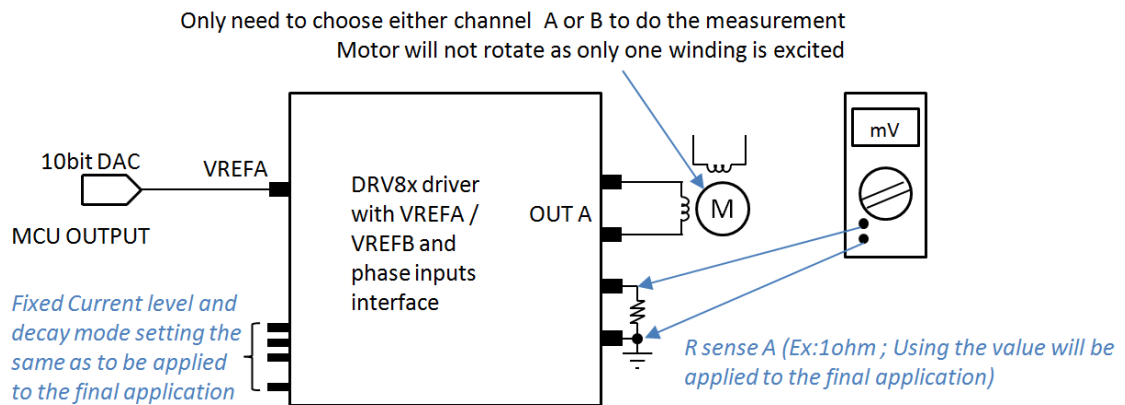


Figure 3. Measure the Current Regulation Curve

As shown in [Figure 4](#), a DAC is used to give voltage to VREFx with minimum resolution. For example, if a 10-bit DAC is used, and maximum value 1024 stands for 2.5 V, the DAC outputs $2.5 \text{ V}/1024 = 2.4 \text{ mV}$ each step. The regulated current in winding is measured by monitoring the voltage of the sense resistor using a multimeter. If a 1- Ω sense resistor is used, 10 mV stands for 10 mA for the regulated current. Record each step of the DAC voltage and the current, the V-I curve is made for further compensation.

Note that the measurement should be taken when all the settings including the current level, decay mode, and sense resistor are the same as those to be used in final application. The curve shape is different if those settings are not the same.

[Figure 4](#) shows the ideal and actual current regulation curve. The distortion zone is easily found by comparing with the ideal curve:

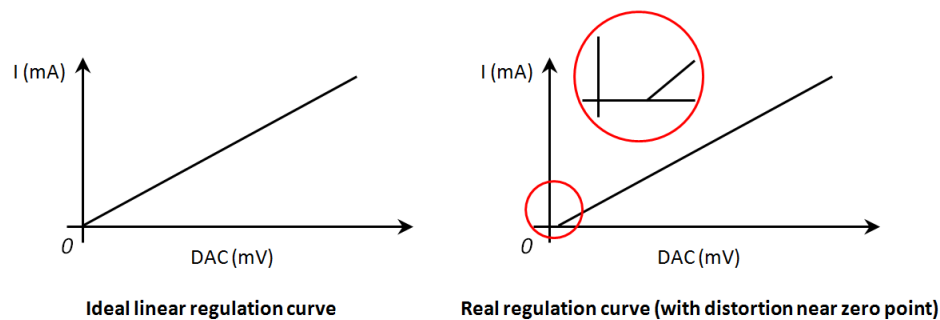


Figure 4. Current Regulation Curve

2.3 Consequence of Nonlinearity

The distortion of the V-I causes the nonlinearity of phase current at zero point. As shown in [Figure 5](#), the real current waveform of phase A and B will have a flat section around the zero crossing point. When one phase current reaches zero point, the other one has the maximum value. During this flat section, the two currents are both nearly unchanged, causing a pause on the motor side. Take an example calculating, if nonlinear distortion offset is 70 mV, maximum VREF is 2 V and DAC is 8 bit for 1/256 micro stepping, there are $70/(2000/256) \approx 8$ steps nearly paused for every 256 steps.

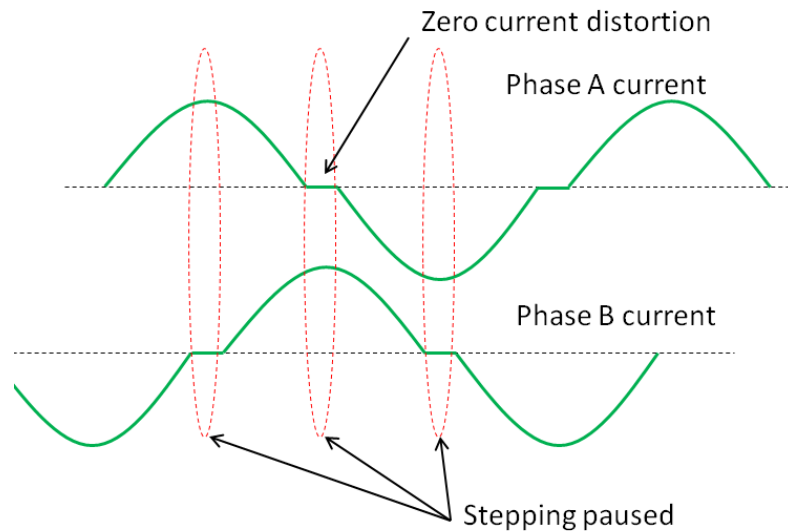


Figure 5. Phase A and B Current with Zero Distortion

3 Offset Compensation Method

An easy method called offset compensation is introduced in this part. This method is simple to apply for most MCU (DAC) + DRV88xx systems. Usually fast or mixed decay mode setting is needed for high level micro stepping setting.

The offset compensation is to add the offset value as a constant shifting on the VREF DAC table (Sine table, usually) and this helps make the curve shift to the origin point.

Take an example DAC value table as follows. Normally, a sine and a cosine table is used (Using MSP430F1612 MCU).

```
DAC12_0DAT = sin_table [step_counter]; // for VREFA
```

```
DAC12_1DAT = cos_table [step_counter]; // for VREFB
```

The compensation will process with a simple OFFSET value adding to the DAC output. The OFFSET value added should be the same as the offset voltage measured.

```
DAC12_0DAT = sin_table [step_counter] + OFFSET; //for VREFA
```

```
DAC12_1DAT = cos_table [step_counter] + OFFSET; //for VREFB
```

Note that the maximum DAC value should not exceed the DAC limit after adding the OFFSET.

In real practice, if it is not convenient to measurement the OFFSET value using the method shown in section 2.2, the following steps show how to get the offset tuned by trial and error method.

Step 1. Add an initial offset voltage to your DAC table. The initial offset should be within the range of 20–200 mV.

Step 2. Monitor the phase current when the motor is running at very low speed with highest micro stepping. Monitoring the phase current, if the initial value is not proper, search and repeat trying the offset value in the 20–200 mV range. Note that if the offset added is not enough, the pause while running still occurs (as shown in [Figure 6](#)). If the offset added exceeds needed, the motor will have jumper at zero current point (as shown in [Figure 7](#)).

Step 3. Record the offset value which gives the best performance during the trial and error process. Use this value as the final compensation to the application.

4 Example of Compensation Results

Figures 6–8 show the results before and after the compensation. The upper curves stand for the voltages on VREFA and VREFB. The lower green curve shows one of the real phase currents. [Figure 6](#) shows the current waveform with no or not-enough compensation and [Figure 7](#) shows the result with overcompensation. If overcompensation is applied, the current distortion pattern is shown as [Figure 7](#), the motor will jump a little at the overcompensation condition. [Figure 8](#) shows the proper compensation, the current wave is continuous with no distortion at zero point. The motor runs smoothly.

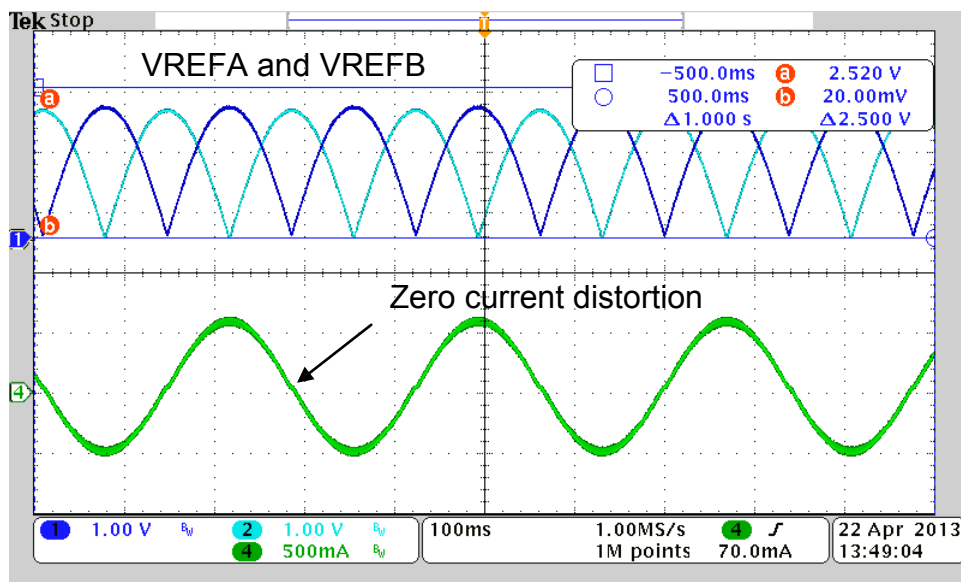


Figure 6. Current Waveform Before Compensation

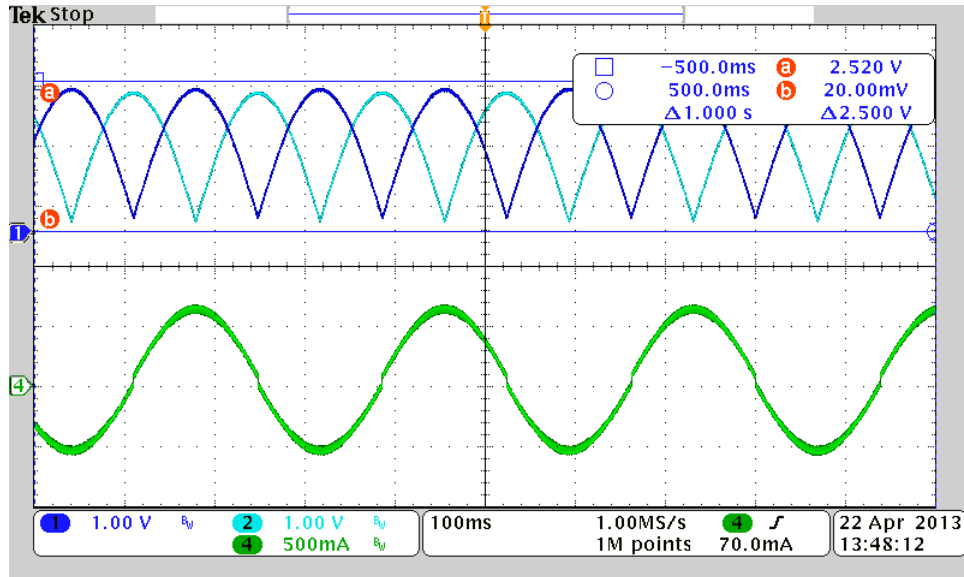


Figure 7. Current Waveform with Overcompensation

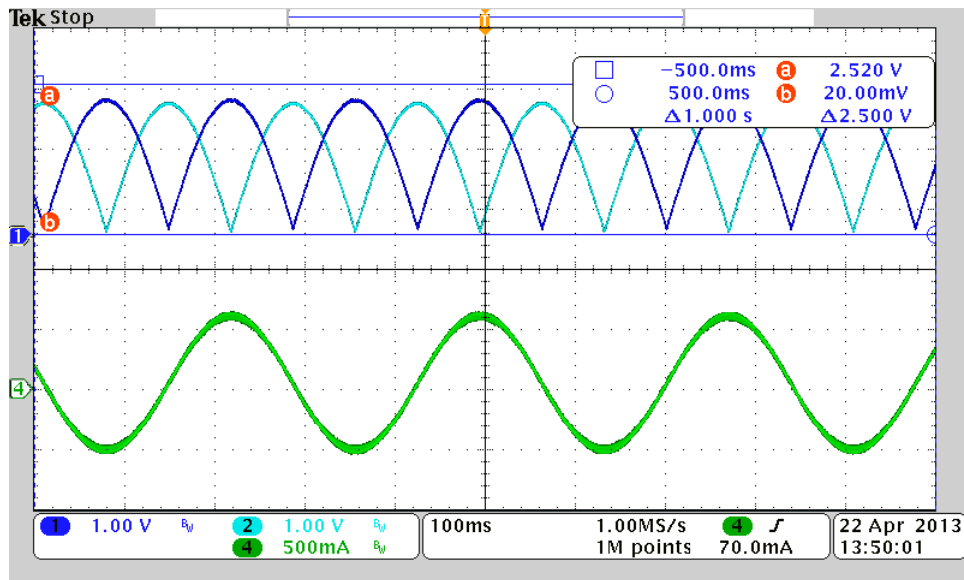


Figure 8. Current Waveform with Proper Compensation

This example is tested on DRV8812 at conditions with a 1-Ω sense resistor, a 5-Ω phase resistor stepper, fast decay, VM 12 V and about 500-mA current level setting (100% xIN inputs setting).

5 Summary

The offset compensation method given in this application note can reduce or eliminate the zero crossing current distortion and produce an optimized smooth regulation curve. The vibration of the stepper motor will be greatly improved in low speed and high level resolution application such as security, stage lighting, CNC, robot, and video systems.

The method is adapted for all DRV88xx stepper driving devices with separated VREFA/VREFB and phase inputs control interface. Typical models include: DRV8812, DRV8813, DRV8828, DRV8829, DRV8841, and DRV8843.

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