AN205353

FM3 Microcontroller with Electrical Brake Application on BLDC Washer

This application note introduces the electrical brake solution on direct drive or belt drive washers.

Contents

1 Introduction

This document introduces the electrical brake solution on direct drive or belt drive washers.

1.1 Purpose

In a great many systems, motors are stopped simply by natural deceleration, but the stop time may be long for the spin cycle of washers. The time often needs to be cut down and electrical braking is a simple and efficient solution. Compared to mechanical and hydraulic braking systems, it has the advantage of steadiness and does not require any wear parts.

1.2 Definitions, Acronyms and Abbreviations

PMSM - Permanent Magnet Synchronous Motor

BLDC - Brush Less DC Motor

DD - Direct drive washer

V_{DC} - DC bus voltage

Vsq - Voltage on q axis of d/q coordinate in FOC algorithm

Vsd - Voltage on d axis of d/q coordinate in FOC algorithm

Isq - Current on q axis of d/q coordinate in FOC algorithm

Isd - Current on d axis of d/q coordinate in FOC algorithm

n - Rotor rotation speed

i_{dref} - d-axis reference current

i_{qref} - q-axis reference current

I_{sMAX} - Max limit of current scalar

V_{sMAX} - Max limit of voltage scalar

λ_f - Flux link-age

ω_r - Rotor electrical angular velocity

1.3 Document Overview

The rest of document is organized as the following:

Chapter 2 explains the principles of electrical braking.

Chapter 3 explains the implementation of electrical braking.

2 Principles of Electrical Braking

The stop time of spin cycle on washer may be above 1 minute If the motor is stopped by the electrical drives, which may be result introducing more the system mechanical noise. The electrical braking solution must be needed in washers due to the cost and system requirement.

There are several solutions for electrical braking such as plug braking, regenerative braking and dynamic braking.

- Dynamic braking
- The back-EMF is consumed on the resistor which is between the DC bus.
- Regenerative braking

  If the back-EMF of the motor is higher than the DC voltage inputted, Regenerative braking sends the regenerated energy from the motor back through the DC-silicon-controlled rectifier (SCR) converter.
- Plugging braking

  Switch on all of the lower bridge directly, this method has the best braking effect and the shortest stop time. But the braking current is the biggest in this solution. No braking resistor is required in this case and the hardware design of the power circuit can be significantly simplified.

The plug braking is adopted on the washer solution of Cypress. And the back-EMF energy can be dissipated in the motor windings. How to reduce the current overshoot at the start of electrical brake has been focused and solved.

2.1 SVPWM Principle

The space vector modulation is used to generate the voltages applied to the stator phases. It uses a special scheme to switch the power transistors to generate sinusoidal currents in the stator phases.

Figure 1 shows the simplified structure of driving hardware which is used to generate the SVPWM signal.

Figure 1. Simplified Structure of Driving Hardware

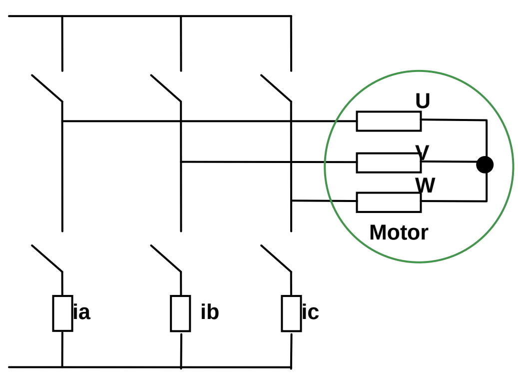
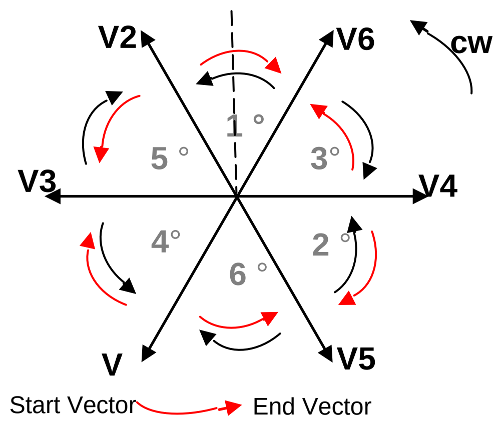


Figure 2. SVPWM Sector Rotation for CW



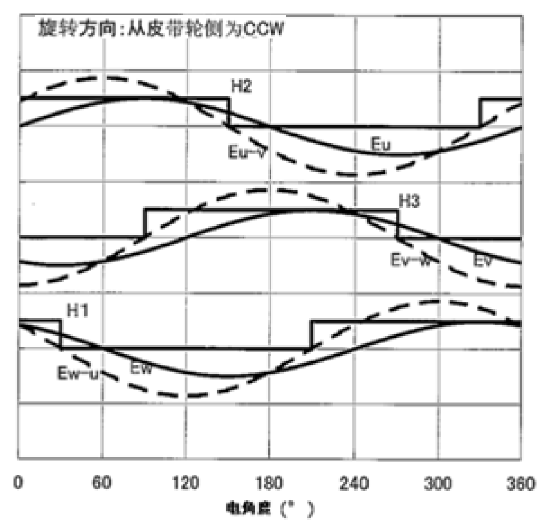
The SVPWM sector and how to generate the SVPWM are shown as Figure 2 and Figure 4 Take the 'sector 4' for example, the vector should be '001'→ '011' and '011' →'001'.

2.2 Electrical Braking Principle

The Plugging braking will generate the phase current overshoot at the start of the brake. But this phase current over charge can be decreased by making use of the back-EMF feature of the BLDC.

The back-EMF of the BLDC motor for CCW rotation is shown as Figure 3. The current overshoot is always caused by the back-EMF, if the back-EMF is not dissipated naturally in the motor windings; the electrical braking current might be overshoot above 17A.

Figure 3. Relationship between Hall and back-EMF



Relationship between SVPWM sector and hall sector is shown as Table 1 and Figure 4.

Table 1. Hall Correction Theta

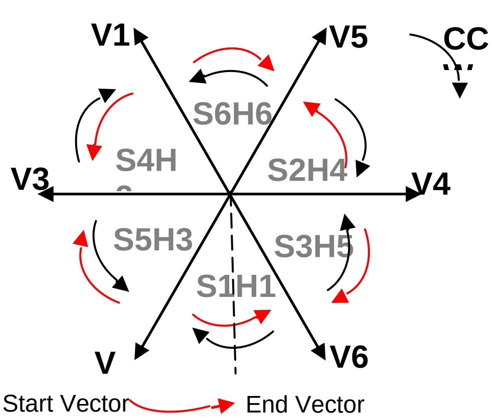
Hall sector	Electrical theta(deg) CW	Electrical theta(deg) CCW
1	210	330
2	90	90
3	150	30
4	330	210
5	270	270
6	30	150

The hall correction sequence for Motor CW(drumb CCW) is 6 →2 →3 →1 → 5 → 4, and on the other hand, The hall correction sequence for Motor CCW(drumb CW) is 3 →2 →6 →4→ 5 →1.

Table 2. Table for SVPWM Switch Rule

Sector	CW UH:VH:WH	CCW WH:VH:UH
V4	**100**	**001**
V6	**110**	**011**
V2	**010**	**010**
V3	**011**	**110**
V1	**001**	**100**
V5	**101**	**101**

Figure 4. Relationship between Hall and SVPWM Sector for Motor CCW



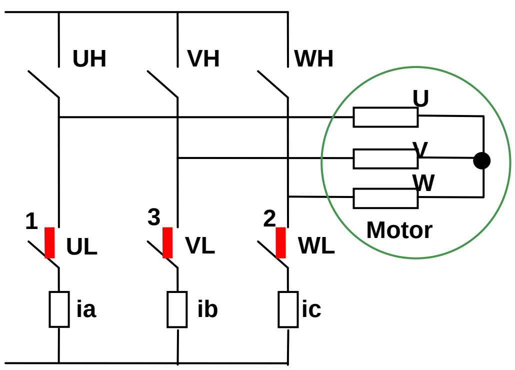
When the BLDC belt drive washer is working on the spin stage, the motor rotates for CCW. And the introduction for electrical braking solution is basic on this motor rotation.

The motor CCW rotation direction is corresponding to the CW rotation direction of belt drive BLDC washer. When the rotor position is between the hall sensor sector 6, the back-EMF of W phase is crossing zero as Figure 3. And the SVPWM is 6 this time which is shown as 'S6H6' in Table 1 and Figure 4, so the SVPWM vector is "001" →"101".

As shown in Table 2, the bridge ‘UH’ would not be changed and always ‘1’ in each SVPWM cycle, and bridge ‘VH’ may be changed in each SVPWM cycle which will lead the back-EMF changing on this phase. If the lower bridge of ‘UL’ is switch on, the chaining back-EMF of phase ‘W’ will disturb to other phases and the phase current may over shoot over 15A; so the lower bridge of ‘UL’ must be switched off and the chaining back-EMF of phase W can be dissipated naturally in the motor, the phase current may over shoot a little which may be smaller than 13A due to the phase W is crossing zero in this sector, that will ensure the reality of the inverter and motor.

Figure 5 shows the switch sequence at the motor brake. Firstly, the UL switch on and the other bridge are switched off at the hall sector ‘6’ and ‘4’; secondly, The UL and WL switch on and the other bridge are switched off at the hall sector ‘5’ ; and the last is all of the three bridges switch on.

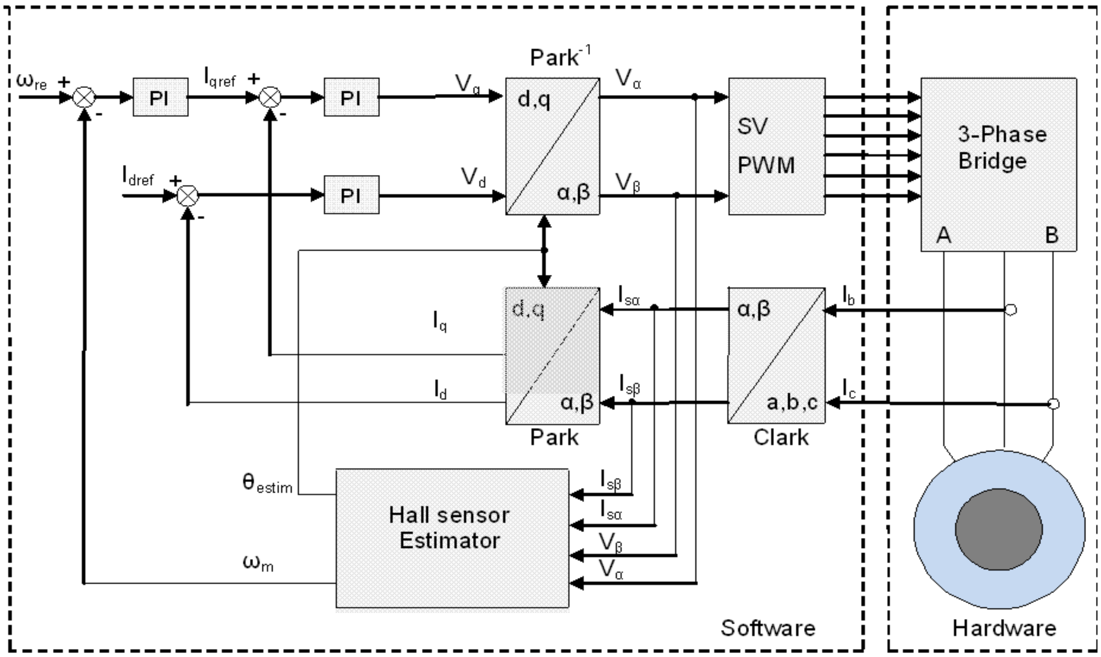
Figure 5. Lower Bridge Switching Sequence at Motor Brake



3 Implementation of Electrical Braking

The implementation of the electrical braking is introduced in the chapter, and the control block of the hall sensor washer solution is shown as Figure 6.

Figure 6. PMSM Control Block with Hall Sensor Solution

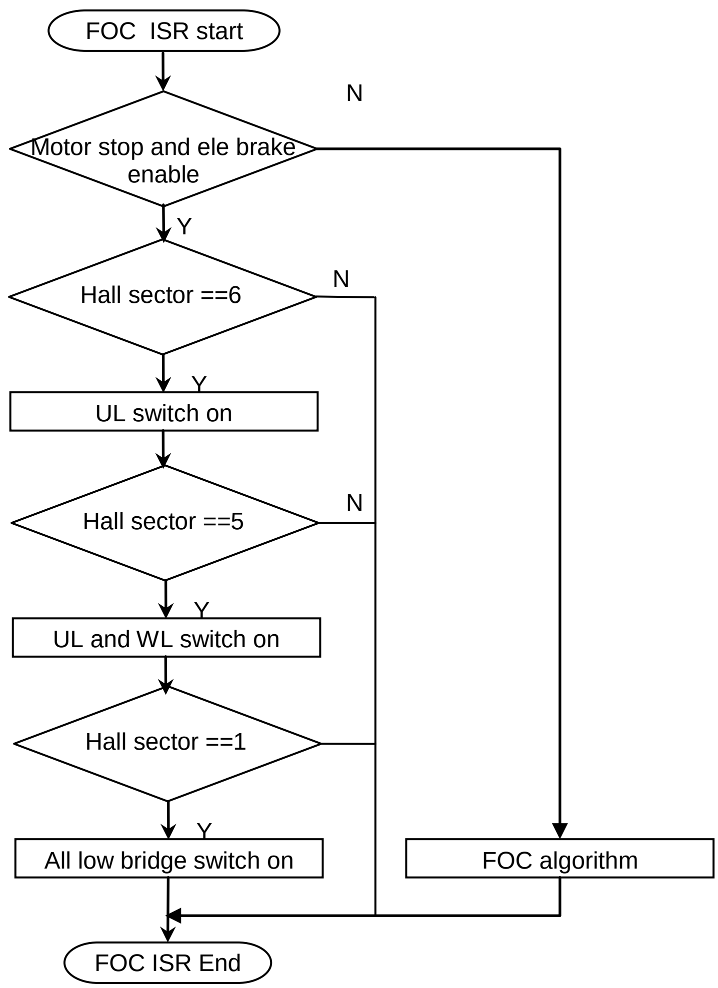


3.1 Feature

- Phase current overshoot about 25% of the motor saturation current at the start of the electrical brake.
- No hardware cost with the electrical braking.
- The stop time decrease greatly by this electrical braking, and low resource occupancy for the FOC control.

3.2 Flowchart of Electrical Braking

Figure 7. Flowchart for Electrical Braking



3.3 Waveform of Electrical Braking

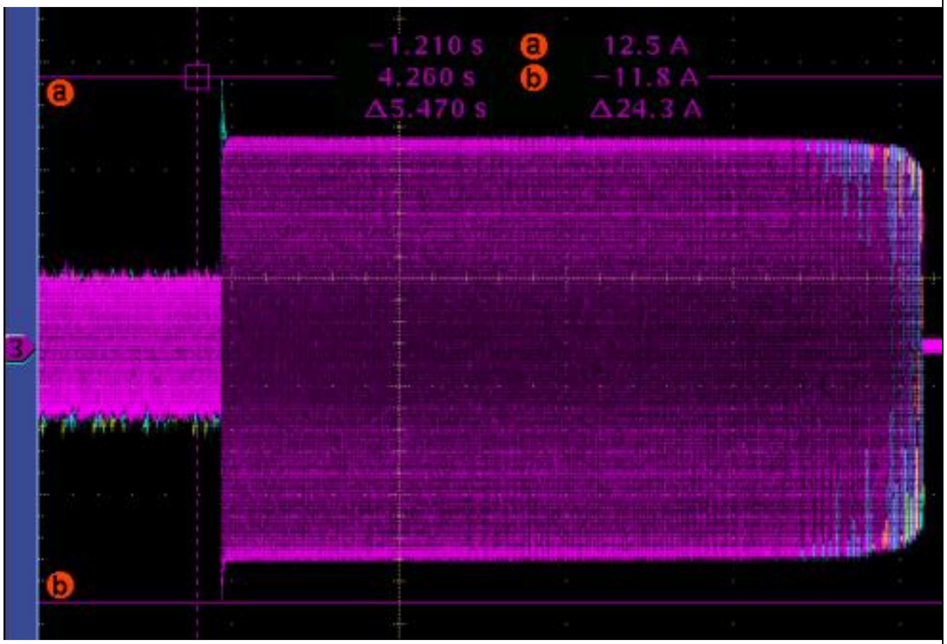
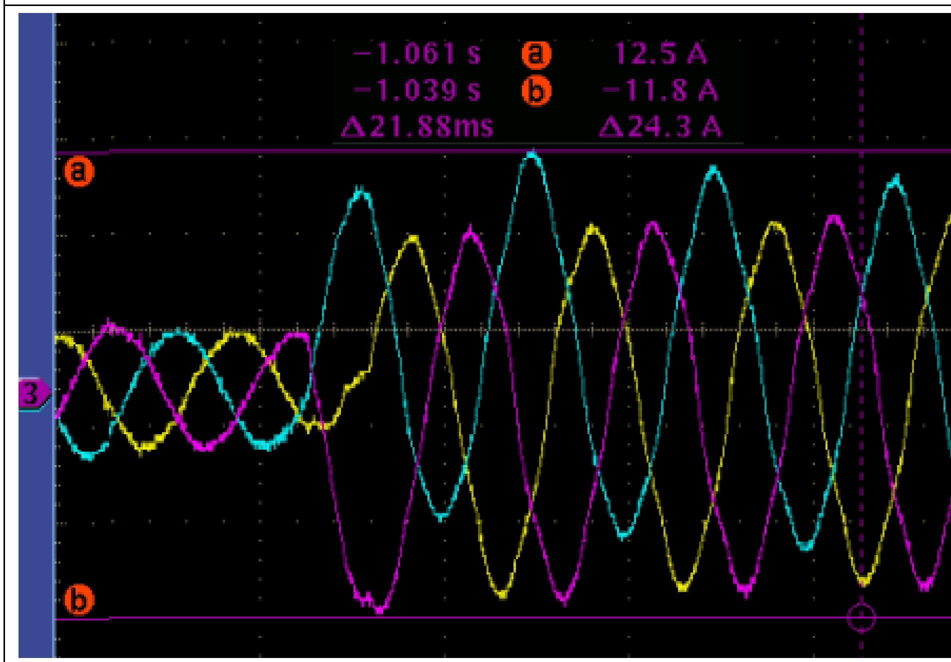
The waveform for the improved electrical braking has been tested, the performance of the braking phase current has been achieve the requirement the inverter and motor.

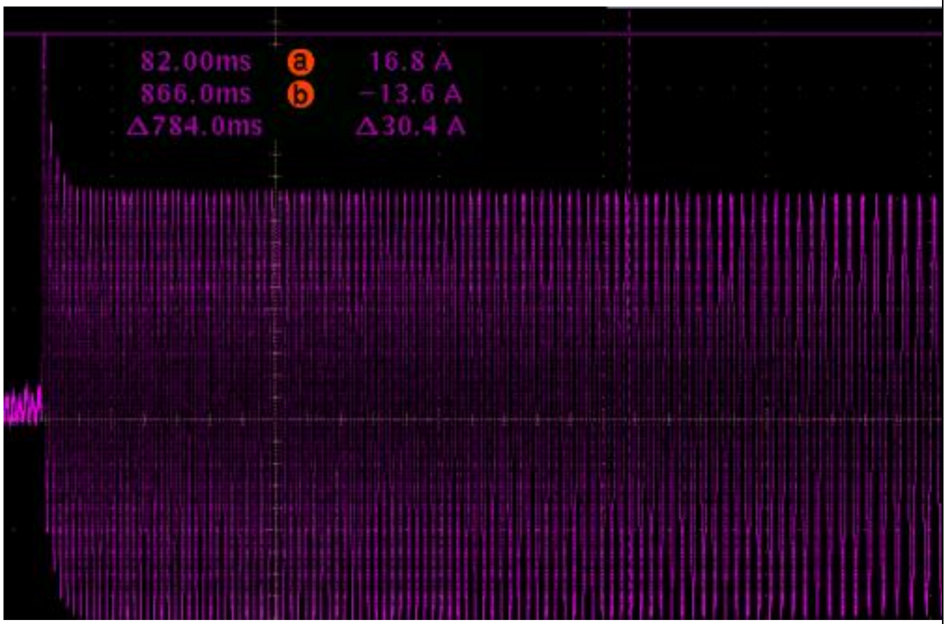
1 -- current for W on inverter board

2 -- current for U on inverter board

3 -- current for V on inverter board

The braking waveform on BLDC washers.

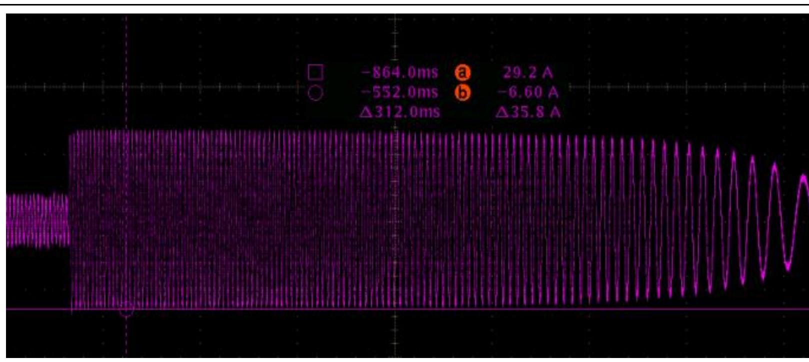
	The max phase current at the start of the electrical braking is 12.5A, and the stable value is 9.8A.
	The expansion waveform of electrical braking. The phase sequence of U V W is not changed, and the back-EMF is not overcharge much on the phase current.



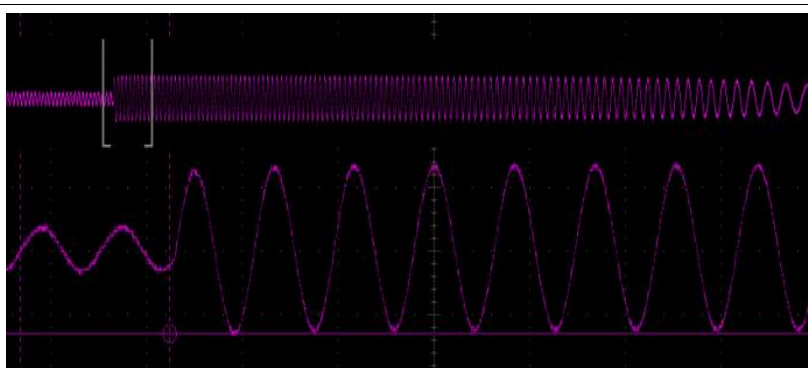
Waveform with no optimized electrical braking

the max phase current at the start of the electrical braking is 16.8A, it will destroy the IPM for long time running.

The braking waveform on DD washers.



The max phase current at the start of the electrical braking is 7A, and the stable value is 6.6A.



The expansion waveform of electrical braking. The back-EMF is not overcharge much on the phase current.

3.4 Conclusion

The plug braking is realized on the washer solution of Cypress. And the back-EMF energy can be dissipated in the motor windings. The current overshoot at the start of electrical brake has been reduced to safe level by the special solution.

4 Document History

Document Title: AN205353 - FM3 Microcontroller with Electrical Brake Application on BLDC Washer

Document Number: 002-05353

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	-	BOZH	02/29/2012	Initial Release
*A	5045479	BOZH	12/10/2015	Migrated from Spansion Application Note from MCU-AN-510113-E-10 to Cypress format
*B	5843006	AESATMP9	08/03/2017	Updated logo and copyright.

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