AN205351

FM3 MB9AF112L Series PMSM Protection Technology

Associated Part Family: MB9AF112L Series

This application note describes the operation of motor driver protection technology based on the Cypress FM3 32 bits in MB9AF112L Series.

Contents

1 Introduction....1
1.1 Purpose....1
1.2 Document Overview....1
2 Principle of Motor Protection Technology....2
2.1 AD Offset Detection....2
2.2 Open Phase Detection....3
2.3 Motor Locked Detection....4
2.4 Over-Low DC Voltage Detection....5
2.5 IPM Protection Detection....6
2.6 PFC Hardware Over Current Protection Detection....7
2.7 PFC Software Over Current Protection Detection....7
2.8 PFC Software Over Voltage Protection Detection....7
3 Flow Chart and Fault Code Definition of Protection Function....8
3.1 Flow Chart of Protection Function....8
3.2 Definition of Fault Code....9
4 Additional Information....10
Document History....11

1 Introduction

1.1 Purpose

This application note describes the operation of motor driver protection technology based on the Cypress FM3 32 bits in MB9AF112L Series.

This application note describes Cypress protection solution for permanent magnet DC motor driver, which includes motor-lock detection, open-phase detection, start-up detection, over-current detection, over voltage detection, low voltage, IPM protection and so on.

1.2 Document Overview

The rest of document is organized as the following:

Section 2 explains the Principle of Motor Protection Technology.

Section 3 explains Flow Chart and Fault Code Definition of Protection Function.

Section 4 explains Additional Information.

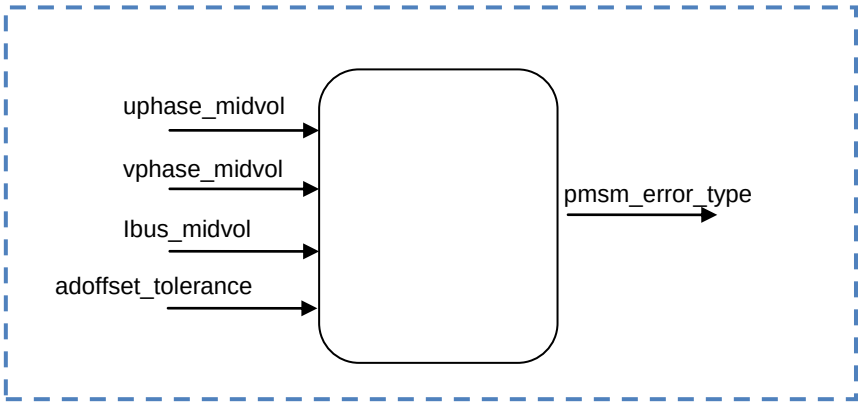
2 Principle of Motor Protection Technology

This section describes the item and implementation of motor protection method in details.

2.1 AD Offset Detection

In Cypress motor sampling current solution, It has a steady middle level voltage (2.5 V), which needs to detect before motor start-up each time. And in the program, the real-time sampling middle voltage has been described as “uphase_midvol”, “vphase_midvol” in dual resistance sampling system, or “Ibus_midvol” in single shunt sampling system. Set the range of tolerance AD offset value (+adoffset_tolerance). The current AD sampling value of the OP-Amplifier is detected at the power on stage. If the detected middle voltage is lower than “2.5-adoffset_tolerance”, or larger than “2.5+adoffset_tolerance”, the program would deal with it as an error, the error flag ‘pmsm_error_type’ for AD offset would be set to ‘1’and motor is stopped. Otherwise, the program would take the real-time sampling value as steady middle voltage to operation, and set “pmsm_error_type ==0” and start up motor. The figure of implementation of AD offset detection is as follows:

Figure 1. AD Offset Detection of Current Sample



2.2 Open Phase Detection

Based on the difference situation, open phase fault can be appeared before motor start-up or motor running.

The first situation, when in start-up motor, at the orientation stage, it would sample the phase current ('pmsm_isalpha'), at the same time, based on the Q-axis reference current ('pmsm_isqref') and the rotor angle ('pmsm_theta'), the α-axis current ('lose_isalpha') can be calculated. If the sampling current value ('pmsm_isalpha') is nearly less than ¾ 'lose_isalpha', or 'pmsm_isalpha' is larger than 5/4 'lose_isalpha' in continuous 50 ms, the error flag 'pmsm_error_type' for open phase would be set to '1' and motor is stopped, otherwise, startup motor as normal.

The second, when in running motor, when the given Q-axis reference current is larger than 1 A, If the average of current sample value is nearly less than 0.5 A in continuous 200 ms, motor is stopped right now, and the error flag 'pmsm_error_type' for open phase would be set to '1'. Otherwise, run motor as normal. (**Attention:** 1 A and 0.5 A are manual given, which should be changed in different driver system for getting the best effect.)

Figure 2. Sequence Diagram of Motor Open Phase Detection

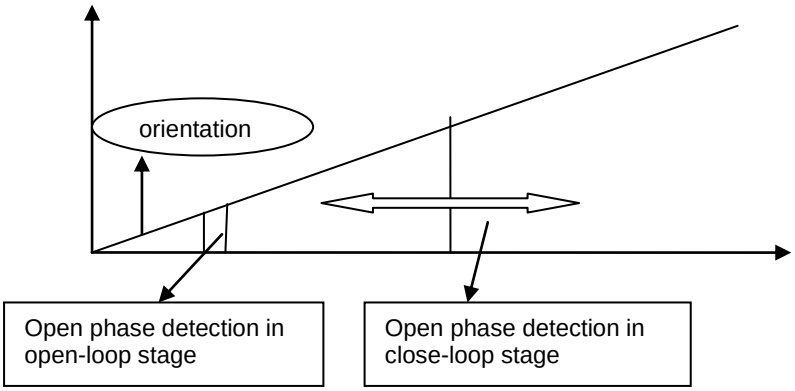
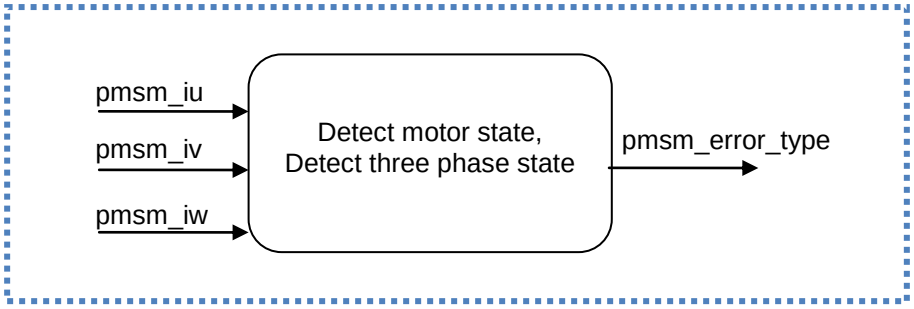


Figure 3. Motor Open Phase Detection Module Frame



2.3 Motor Locked Detection

Start-up motor, if the motor runs in the open loop stage, and the given PI target speed is no more less than 800 rpm. When the running time is over 1s, but the estimated speed (‘omegaMr_avr’) in program is also less than 500 rpm, motor is stopped right now, and the error flag ‘pmsm_error_type’ for the locked rotor would be set to ‘1’. Otherwise, run motor as normal.

The other situation, if the motor runs in the close loop stage, and the given PI target speed is larger than 3000 rpm. the estimated speed (‘omegaMr_avr’) in program is less than 1200 rpm lasting out more than 500 ms, or the given PI target speed is larger than 2400 rpm. the estimated speed (‘omegaMr_avr’) in program is less than 600 rpm lasting out more than 500 ms, motor is stopped right now, and the error flag ‘pmsm_error_type’ for the locked rotor would be set to ‘1’. Otherwise, run motor as normal.

Figure 4. Flow Chart of Motor Locked Detection

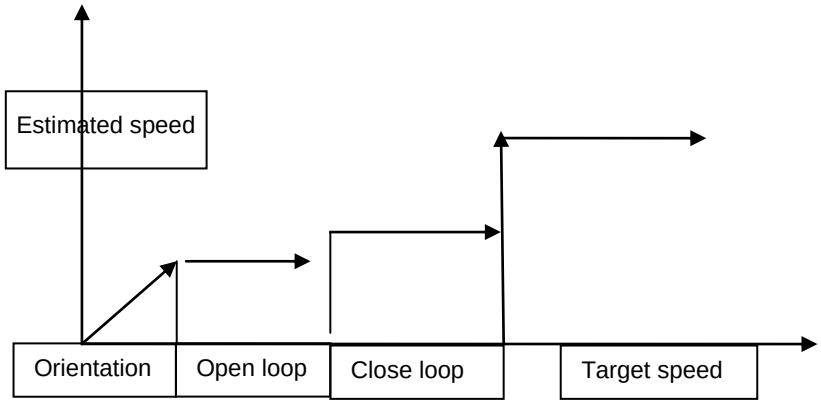
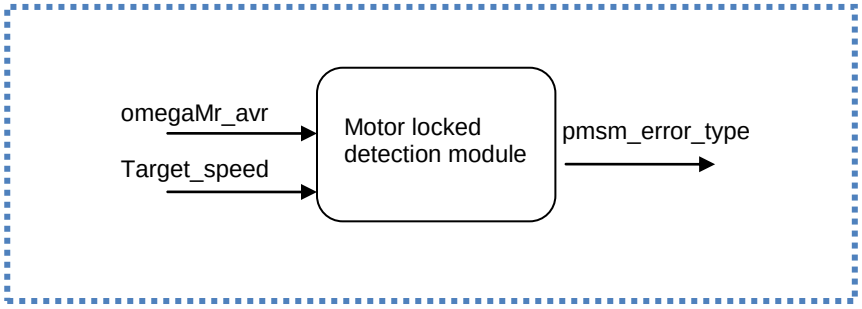


Figure 5. Motor Locked Detection Module Frame



2.4 Over-Low DC Voltage Detection

With the influence of electrical net and PFC module, it would maybe induce the wavy DC voltage. Sample DC voltage, if the sampling DC voltage is larger or less than the given range of the steady DC voltage, it would be deal with as a over or low DC voltage fault. The details are as follows:

Over DC voltage protection: If the real-time sample DC voltage ('direct_voltage') is larger than the given max DC voltage ('max_dcvoltage') lasting out 1 ms, motor is stopped, and the error flag 'pmsm_error_type' for over DC voltage would be set to '1'. Otherwise, run motor as normal.

Low DC voltage protection: If the real-time sample DC voltage ('direct_voltage') is less than the given minimal DC voltage ('min_dcvoltage') lasting out 1 ms, motor is stopped, and the error flag 'pmsm_error_type' for low DC voltage would be set to '1'. Otherwise, run motor as normal.

Figure 6. Sequence Diagram of Motor Over-Low Voltage Detection

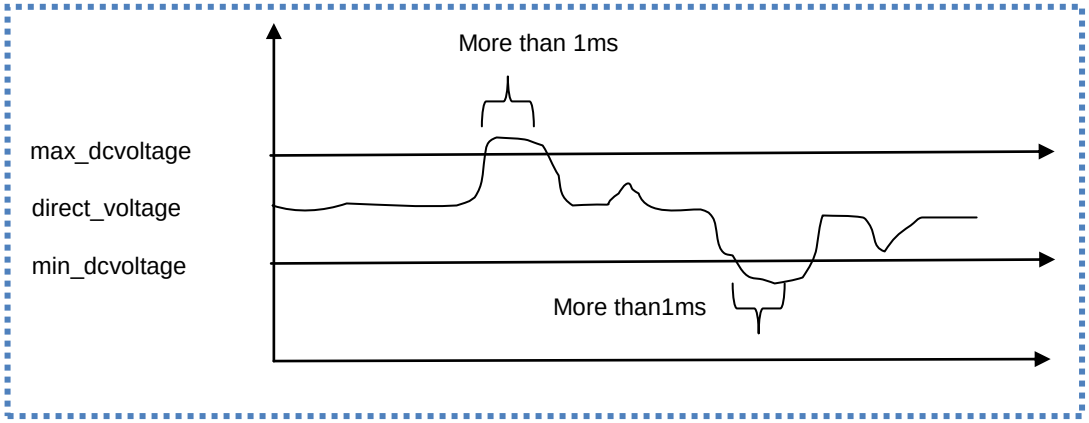
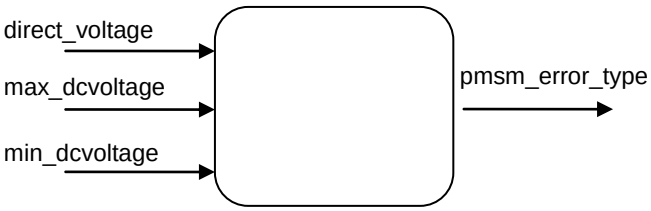


Figure 7. Motor Over-Low Voltage Detection Module Frame



2.5 IPM Protection Detection

When running the motor, if the hardware IPM is over hot, over current or low power(+15 V), the pin (FO) of the IPM would put out a low level signal. Then, motor is stopped right now, and set ‘pmsm_status ==3’.

Attention:

When the IPM is over hot, only the pin (FO) would put out a low level signal just lies on the IPM module has the temperature detection function.

The manual given value of the max current for protection lies on the parameter of the current protection circuit, IPM current trigger value and the ability of the anti-jamming.

Figure 8. Sequence Diagram of IPM Hardware Over Current Detection

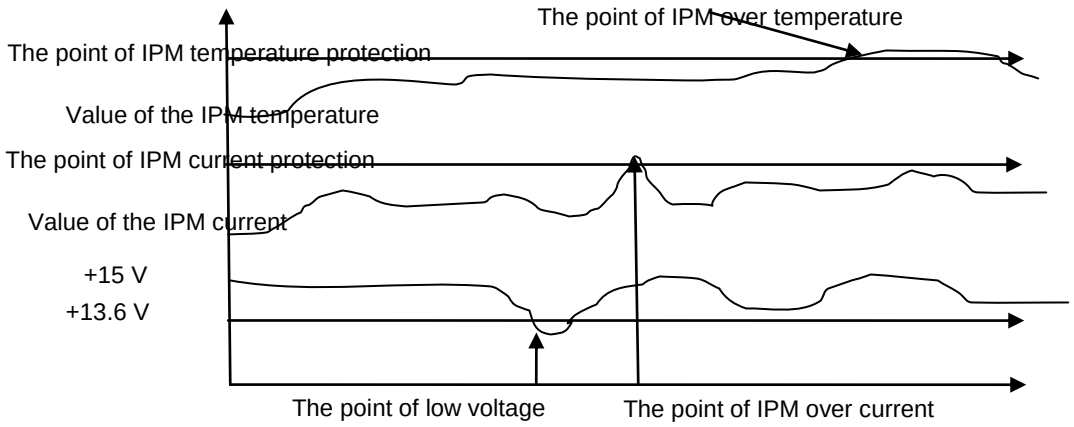
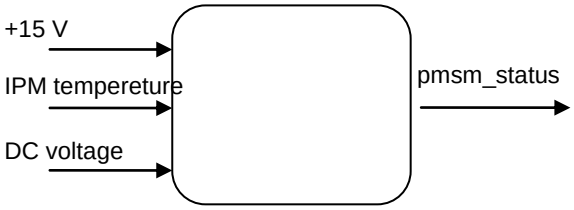


Figure 9. IPM Hardware Over Current Detection Module Frame



2.6 PFC Hardware Over Current Protection Detection

When running the PFC module, if the current of the PFC circuit is larger than the max permitted current, the PFC hardware circuit would put out a low pulse signal and trigger an interrupt to close the PFC operation. The error flag 'PFC_stop_Flag' for PFC module would be set to '1'. Otherwise, run PFC module as normal.

Figure 10. PFC Over Current Detection Module Frame

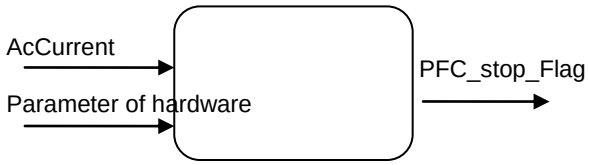
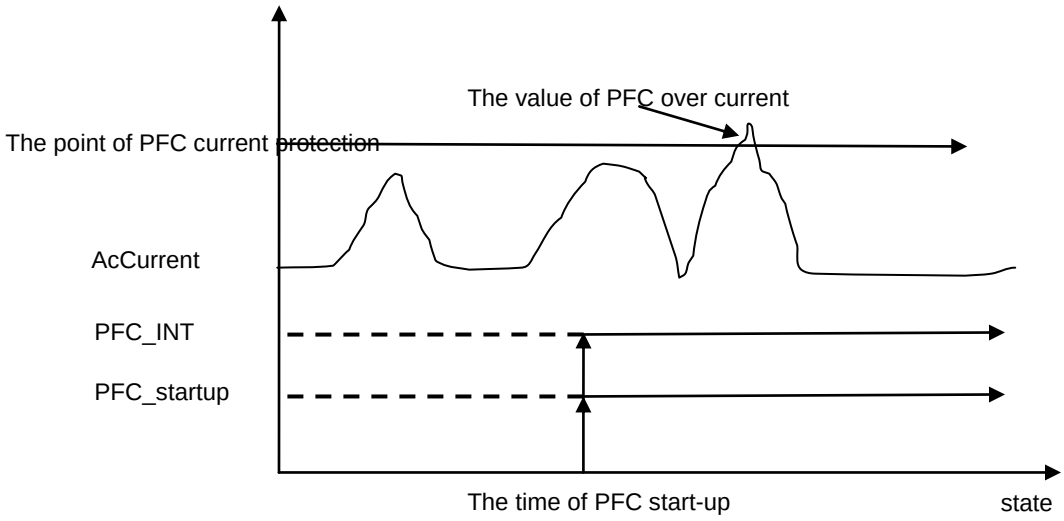


Figure 11. Sequence Diagram of PFC Over Current Detection



2.7 PFC Software Over Current Protection Detection

When running the PFC module, if the current of the AC side is larger than the given max current in program, it should stop the PFC operation and set the error flag "PFC_stop_Flag ==6". Otherwise, run the PFC module as normal.

Attention: The sequence diagram of PFC software over current protection detection is similar as the motor over current detection.

2.8 PFC Software Over Voltage Protection Detection

When running the PFC module, if the DC voltage is larger than the given max voltage in program, it should stop the PFC operation and set the error flag "PFC_stop_Flag ==5". Otherwise, run the PFC module as normal.

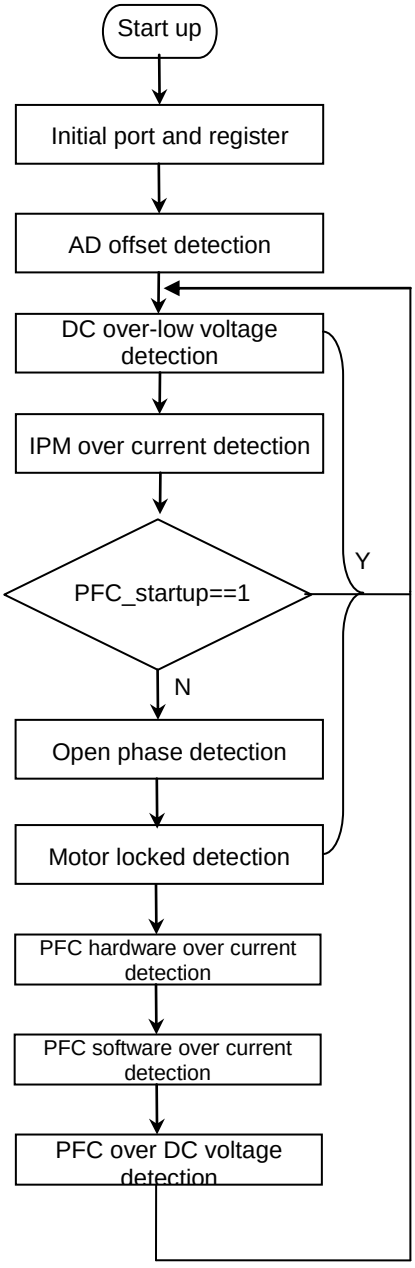
Attention: The sequence diagram of PFC software over DC voltage protection detection is similar as the motor over voltage detection.

3 Flow Chart and Fault Code Definition of Protection Function

This section describes the flow chart and fault code definition of protection function.

3.1 Flow Chart of Protection Function

Figure 12. Flow Chart of Protection Function



3.2 Definition of Fault Code

In Cypress motor driver system, the definitions of fault code can be described as Table 1, it also can be found in the relevant head files.

```
pmsm_error_type    = 0x00,    //Motor initial or normal state
pmsm_error_type    = 0x01,    //Motor over DC voltage state
pmsm_error_type    = 0x02,    //Motor low DC voltage state
pmsm_error_type    = 0x04,    //Motor software over current state
pmsm_error_type    = 0x08,    //Motor failed start-up
pmsm_error_type    = 0x10,    //Motor open phase state
pmsm_error_type    = 0x20,    //No Motor
pmsm_error_type    = 0x40,    //Motor AD offset fault state
pmsm_error_type    = 0x80     //Motor locked state

PFC_stop_Flag   = 0;          //PFC initial or normal state
PFC_stop_Flag   = 1;          //PFC hardware over current state
PFC_stop_Flag   = 5;          //PFC software over voltage state
PFC_stop_Flag   = 6;          //PFC software over current state
```

Table 1. Fault Code of Protection Function

Fault Code	Type of Fault	Reason
0x0000	Motor initial or normal state	Motor stop or normal run
0x0001	Motor over DC voltage state	High AC input, DC sample circuit fault, PFC abnormity
0x0002	Motor low DC voltage state	Low AC input, DC sample circuit fault
0x0004	Motor software over current state	Motor run abnormity, current sample fault
0x0008	Motor failed start-up	Improper parameter, hardware driver fault
0x0010	Motor open phase state	Motor connected abnormity
0x0020	No Motor	Motor connected abnormity
0x0040	Motor AD offset fault state	AD current sample abnormity
0x0080	Motor locked state	Motor fault, Improper parameter, hardware circuit fault
0	PFC initial or normal state	PFC no work or normal work
1	PFC hardware over current state	PFC run abnormity or sample fault or hardware fault
5	PFC software over voltage state	PFC run abnormity or sample fault or hardware fault
6	PFC software over current state	PFC run abnormity or sample fault or hardware fault

4 Additional Information

For more information on Cypress products, visit the following website:

http://www.cypress.com/cypress-microcontrollers

Document History

Document Title: AN205351 – FM3 MB9AF112L Series PMSM Protection Technology

Document Number: 002-05351

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	-	FCZH	01/17/2012	Initial release
*A	5264232	FCZH	05/09/2016	Migrated Spansion Application Note MCU-AN-510112-E-10 to Cypress format.
*B	5843103	AESATMP9	08/03/2017	Updated logo and copyright.

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