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1. Introduction

Scope of This Document

This application note describes the below products:

<table>
<thead>
<tr>
<th>Series</th>
<th>Product Number (Not Including Package Suffix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB9AF110K Series</td>
<td>All products</td>
</tr>
</tbody>
</table>

1.1 Overview

The FM3 washing machine board is intended to aid the user in the rapid evaluation and development of washing machine motor control applications using FM3 Series MCUs which are embedded with ARM Cortex-M3 core. This Board is targeted to control Permanent Magnet Synchronous Motors or BLDC that are widely employed in washing machine.

Hardware version: schematic v0.3.1, board v0.3.1

Figure 1 provides the block diagram of the board.

Figure 1. Block Diagram
1.2 Features

This board is composed of many elements. The key features of the solution board are listed as below:

**AC power stage:**
- 220VAC ± 15% input compatible
- On-board EMI filter and in-rush limiter
- 15A/800V rectifier module

**Inverter stage:**
- Three-phase Intelligent Power Module (IPM) with a power rating of 600V/15A
- Phase current sense resistor for dual shunt vector control
- Over-current protection

**Input / Output:**
- One hall sensor input connector (J5)
- Two UART connectors (J2 and J9), share the same UART module
- Programming and debug interface:
  - JTAG via 6-pin connector (J8)
2. Getting Started

2.1 Board Elements

The Washing Machine Board comprises four main parts:

- **EMI filter and In-rush Limiter**
  In order to suppress the common mode noise and in-rush current, the board employs EMI filter and in-rush limiter before rectifier module.

- **Rectifier Module and Power Module Stage**
  The rectifier module converts the AC voltage to full wave voltage. Then, it goes through the DC capacitor and provides DC power to the inverter power module.

- **SMPS**
  This board adopts the transformer-less SMPS to provide 5V power to the control unit and 15V power to the driver unit of power module.

- **MCU and User Interface**
  This solution supports MB9AF110K series MCUs. The board provides some dedicated interfaces for washing machine application, for example: UART for data communication between drive board and top board, and hall sensor input interface. The board can be used to drive the washing machine directly.

Figure 2. Top View of the Board
2.2 User Interface

This board uses the following components to interact with user. Figure 3 shows the position of the related components.

- **LED**
  One LED(DT3) is used to indicate 5V.

- **Isolated UART port**
  There are two isolated UART connectors, sharing only one UART port.

- **Debugging port**
  The 6-pin connector(J8) is for JTAG connecting.

- **Hall sensor input port**
  The board provides a hall sensor input connector(J5). This board supports three-phase hall sensor.

- **Motor Connectors**

---

**Figure 3. User Interfaces**
**Table 1** collects the connectors.

<table>
<thead>
<tr>
<th>Number</th>
<th>Component Designator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>J9</td>
<td>UART connector</td>
</tr>
<tr>
<td>2</td>
<td>J2</td>
<td>Isolated UART connector</td>
</tr>
<tr>
<td>3</td>
<td>J5</td>
<td>Hall sensor connector</td>
</tr>
<tr>
<td>4</td>
<td>J8</td>
<td>JTAG connector</td>
</tr>
<tr>
<td>5</td>
<td>D3</td>
<td>Power supply indicator</td>
</tr>
<tr>
<td>6</td>
<td>J1</td>
<td>AC mains connector</td>
</tr>
</tbody>
</table>

### 2.3 Connection Sequence

The recommended connection sequence is listed below. The user should ensure that the following sequence is met before connecting the system to the AC mains and a motor.

1. Connect J1 to the AC mains with a 10A cable.
2. Connect J5 to the hall sensor connector of the motor.
3. Connect J2 to the motor phases respectively.
4. Connect the J-Link to the JTAG port (J8) on board and connect J-Link to host computer via USB cable.

**Note:**

Please make sure the AC mains power is isolated power if trying to debug with computer!

### 2.4 System Connection

*Figure 4* shows the system connection for debugging.

![Figure 4. System Connection](image-url)
2.5 Pin Assignment of Connector

2.5.1 UART0 Connector J9

Table 2 lists pins of J9.

Table 2. Pin Assignment of J9

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>RX</td>
<td>Data input</td>
</tr>
<tr>
<td>3</td>
<td>TX</td>
<td>Data output</td>
</tr>
<tr>
<td>4</td>
<td>5V</td>
<td>Power supply</td>
</tr>
</tbody>
</table>

2.5.2 UART1 connector J2

Table 3 lists pins of J2

Table 3. Pins of J2

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HOST_TXD</td>
<td>Isolated data output</td>
</tr>
<tr>
<td>2</td>
<td>HOST_VCC</td>
<td>Isolated VCC</td>
</tr>
<tr>
<td>3</td>
<td>NC</td>
<td>Not connected</td>
</tr>
<tr>
<td>4</td>
<td>HOST_GND</td>
<td>Isolated Ground</td>
</tr>
<tr>
<td>5</td>
<td>HOST_RXD</td>
<td>Isolated data input</td>
</tr>
</tbody>
</table>

2.5.3 Hall Sensor Connector J5

Table 4 lists pins of J5

Table 4. Pins of J5

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>5V</td>
</tr>
<tr>
<td>2</td>
<td>HA</td>
<td>Phase A of Hall sensor</td>
</tr>
<tr>
<td>3</td>
<td>HB</td>
<td>Phase B of Hall sensor</td>
</tr>
<tr>
<td>4</td>
<td>HC</td>
<td>Phase C of Hall sensor</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>Ground</td>
</tr>
</tbody>
</table>
2.5.4 JTAG Connector J8

Table 5 lists pins of J8

Table 5. Pins of J8

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>5V</td>
</tr>
<tr>
<td>2</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>TDI</td>
<td>JTAG data input of target CPU</td>
</tr>
<tr>
<td>4</td>
<td>TMS</td>
<td>JTAG mode set input of target CPU</td>
</tr>
<tr>
<td>5</td>
<td>TCK</td>
<td>JTAG clock to target CPU</td>
</tr>
<tr>
<td>6</td>
<td>TDO</td>
<td>JTAG data from target MCU</td>
</tr>
</tbody>
</table>
3. Hardware

3.1 Amplifier Circuit for Phase Current

This solution employs two shunt resistors to measure the phase current of a motor. Accordingly, two channel of amplifier are needed to extend the range of current waveform and lift the middle point of current waveform from ground to 2.5V.

Figure 5 shows the detail of amplifier circuit.

![Amplifier Circuit](image)

Figure 5. Amplifier Circuit

Compute the voltage of current waveform as follow:

\[
U_{out} = 2.5 + \left( \frac{R_{142}}{R_{129}} \right) \cdot U_{in}
\]

Where:

- \( U_{out} = \) amplified voltage
- \( U_{in} = \) voltage between shunt resistor
3.2 Over-current Protection Circuit

To prevent the damage to the IPM caused by the unexpected huge current. The system needs over-current protection circuit Figure 6 to detect the current surge.

Figure 6. Over-Current Projection Circuit

\[
U_{out} = \frac{1}{3} \times \left( \frac{R_{148}}{R_{147} + R_{148}} \right) \times \left( \frac{R_{146}}{R_{145}} + 1 \right) \times U_{nu} (U_{nv} or U_{nw})
\]

Where:

- \( U_{out} \) = voltage to fault pin of IPM
- \( U_{nu}, U_{nv}, U_{nw} \) = voltage between shunt resisters

As mentioned in the specification of IPM, the self-protection function will be trigged if the voltage on the fault pin is higher than 0.5V. Then, it is easy to calculate and adjust the threshold value that trigs the over-current protection.
4. Additional Information

For more Information on Cypress semiconductor products, visit the following websites:

English version address:
http://www.cypress.com/cypress-microcontrollers

Chinese version address:
http://www.cypress.com/cypress-microcontrollers-cn

Please contact your local support team for any technical question

America: http://www.cypress.com/cypress-solutionsnetwork

Other: http://www.cypress.com/spansionsupport
## 5. Revision History

### Document Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Issue Date</th>
<th>Origin of Change</th>
<th>Description of Change</th>
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<tr>
<td>**</td>
<td>02/01/2015</td>
<td>BOZH</td>
<td>Initial Release</td>
</tr>
<tr>
<td>*A</td>
<td>06/14/2016</td>
<td>BOZH</td>
<td>Migrated Spansion guide “MB9AF111K_AN706-00097-E” to Cypress format</td>
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