

PMSM Vector Control with Encoder on Kinetis

Setup Guide for Demo Kits without a Tablet PC

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1 Introduction

The application demonstrates an advanced design of a 3-phase permanent-magnet (PM) synchronous motor drive. Vector control allows highly dynamic control of the motor, but it can be achieved only when the motor excitation is precisely synchronized with the instantaneous rotor position. There is a critical need to have the shaft position information to successfully perform the vector control algorithm. As a position sensor, an incremental encoder is used in this application.

This document contains several note and caution statements to guide you in the use of this demo. Please pay particular attention to these directions, as departing from them could damage the MCU and associated systems.

The demo application runs on Freescale Semiconductor's 32-bit Kinetis K40 ARM® Cortex M4™ MCU. The hardware is built on Freescale's Tower rapid prototyping system. All boards in the system are assembled together and mounted on the plexiglass.

Contents

1	Introduction	1
2	Hardware setup	3
3	Software setup	4
3.1	USB-to-Serial cable driver installation	4
3.2	FreeMASTER software installation and setup	5
4	Demo operation	6
4.1	Manual operation	6
4.2	FreeMASTER control	7
4.3	Faults	9
5	Revision history	11



Introduction

The demo consists of several components:

- The Tower system
 - Kinetis K40 tower board
 - Tower low-voltage power stage
 - Tower serial module
 - Tower elevators
- 3-Phase permanent magnet synchronous motor
- USB-to-Serial cable
- Power supply with cables

It is possible to operate the demo using the buttons on the Kinetis K40 tower board, or via the FreeMASTER software installed either on a notebook or tablet PC connected to the demo by serial cable or Bluetooth interface.

The demo concept is shown in [Figure 1](#). The Tablet PC shown in the picture is not included in this demo system.



Figure 1. Demo concept

2 Hardware setup

The demo is transported in a plastic case. Follow the steps below to successfully perform the hardware setup:

1. Open the case. To unpack the demo from the case, lift up by the motor or plexiglass. Do not pull on the Tower system. Also remove the power supply and all cables.
2. Connect the power supply to an electrical outlet and the low-voltage jack to the supply connector on the low-voltage power stage on the Tower system. The position of the power supply connector is shown in [Figure 2](#).

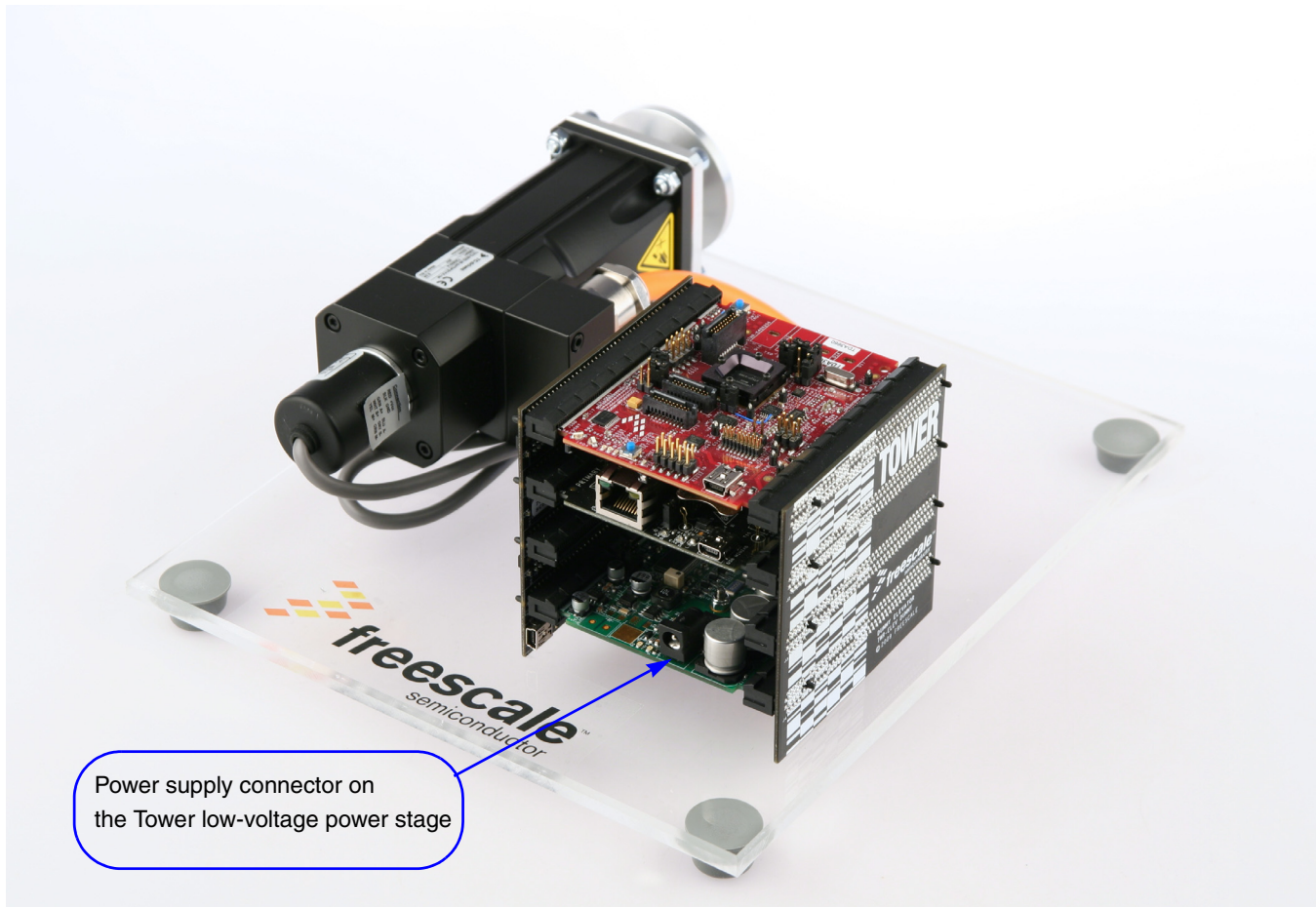


Figure 2. Power supply connector

CAUTION

Connecting a USB cable to the Tower Elevator Module will cause damage to the Kinetis K40 MCU and other systems! Do not plug any other cables into the demo system except for the power supply cable and serial communication cable. Do not connect any USB cable to the demo while the power is applied to the power stage module.

The demo system can be powered only via the Tower low-voltage power stage.

3. Immediately after applying voltage, you will observe a short movement of the rotor shaft (so-called “alignment”). This is done in order to put the rotor into a known position. After successful alignment, the blue LED on the Kinetis K40 tower board is lit and the demo is ready for operation. If you wish to operate the demo only using the buttons on the Kinetis K40 tower board, proceed now to [Section 4.1, “Manual operation.”](#)
4. If you want to operate the demo via FreeMASTER software installed on the PC or notebook, you will have to establish a serial connection between the demo and the PC. Even though newer models of notebooks are not equipped with a serial communication port, its use on the MCU is beneficial because it doesn’t load the CPU too much.
5. Use your own serial cable if you have a serial connector on the notebook or on the port replicator.
6. You can also use the USB-to-Serial cable (USB virtual serial port) that is part of the demo kit if your notebook or PC has only a USB port.

NOTE

If you want to use the USB-to-Serial cable that is part of the demo kit, *don’t plug* the USB-to-Serial cable into your computer prior to installing the drivers.

3 Software setup

3.1 USB-to-Serial cable driver installation

1. Ensure that the USB-to-Serial cable *is not* plugged into your computer.
2. Insert the CD from the demo kit into your CD-ROM drive.
 - a) For Windows 2000 /XP/ Server2003, run the following file:
[your CD ROM Drive]:\SW\USB to RS232\Windows\Setup.exe
 - b) For Windows Vista, run the following file:
[your CD ROM Drive]:\SW\USB to RS232\Windows\Vista\Setup.exe
3. Follow the on-screen instructions to complete the installation.
4. Plug the USB-to-Serial adaptor into your computer’s USB port.
5. Open “Device Manager” under System Properties and check for the device you installed under **“Prolific USB-to-Serial Comm Port (ComXX).”** Keep the number of the assigned COM port as it will be needed later during the FreeMASTER software configuration. Below is one possible way of opening the System Properties window in Windows XP:
At the Windows taskbar click **Start** and then select Settings → Control Panel → System. The System Properties window will appear. The “Device Manager” is located at the “Hardware” tab.
6. Now the USB-to-Serial cable is ready to use.

3.2 FreeMASTER software installation and setup

3.2.1 FreeMASTER software installation

If there is no FreeMASTER software installed on the notebook or PC that you intend to use for the demo control, you can find the installation file on the enclosed CD in the folder \SW\FreeMASTER\FreeMASTER for PC installation\, or check the most recent version on the Roznov web page:

http://roznov.ea.freescale.net/unix_www/main.asp?add=5&clanek=244

In case of any problem with the installation process or with using of the software, download the documentation from the above link.

3.2.2 FreeMASTER software setup

The only setting that needs to be entered in the FreeMASTER software is the correct communication port, as mentioned in Section 3.1, “USB-to-Serial cable driver installation.”

1. Run the FreeMASTER application by double clicking on the “Kinetis_FOC_demo.pmp” file located in \SW\FreeMASTER\. This file contains FreeMASTER application environment settings.
2. Click the menu item Project/Option.
3. The “Option” window will appear. On the first tab “Comm,” select the communication port that is assigned to the USB-to-Serial cable, as shown in Figure 3.

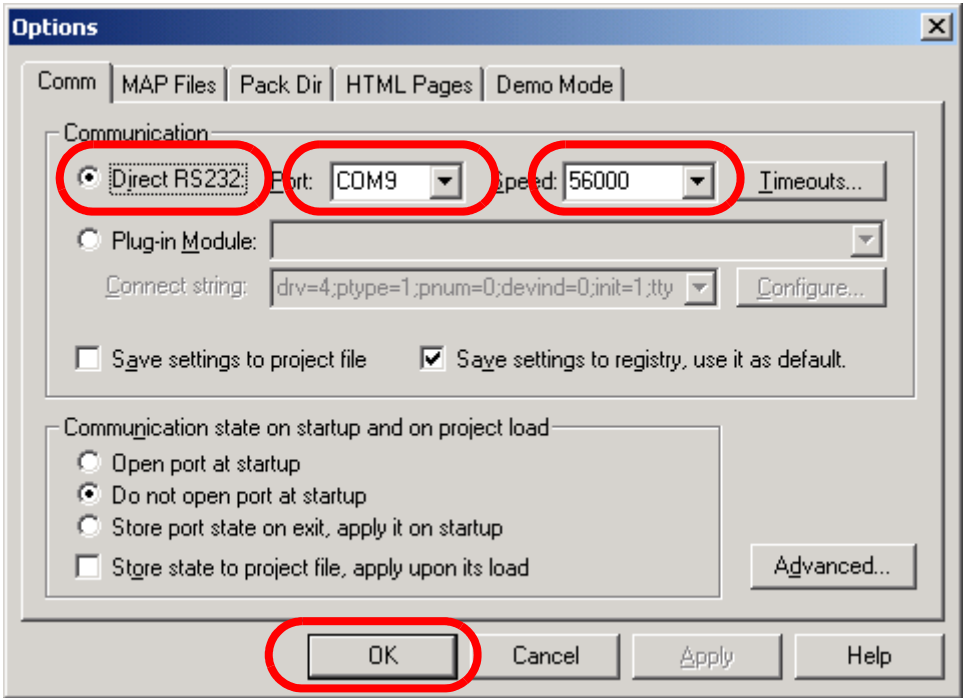


Figure 3. FreeMASTER communication settings

Also check also the communication interface and speed settings, which must be “Direct RS232” and “56000,” respectively.

Then click “OK” to accept changes.

4. By clicking the “OK” button, the settings are applied and the FreeMASTER software on the PC (notebook) side is ready for controlling the demo.
5. You may also copy the FreeMASTER directory to your hard drive. Then you are able to save the changes that were made. Go to the menu item File → Save Project, or press Ctrl + S.
6. If the demo system is powered, press Ctrl + K to start the communication with the target.

CAUTION

Do not enable the communication until the demo system is powered. The FreeMASTER communication will not work, and the embedded application will not initialize properly if the power to the demo system is applied after enabling communication on the PC side. In such a case, disable the communication first and then press the reset button on the K40 tower board (see [Figure 4](#)).

7. If any error message appears after the communication is enabled, the possible problems are:
 - The demo system has no power.
 - The wrong communication port is selected.
 - FreeMASTER application has been started from the Windows Start menu and the *.pmp file with all settings has not been opened afterwards.
 - There is no serial connection between the demo and the notebook (a damaged USB-to-Serial cable or an unplugged cable).

4 Demo operation

4.1 Manual operation

There are two user buttons and four user LEDs available on the Tower K40 board. In the demo application, the functionality of the buttons is “Run/Increase Speed” and “Stop/Decrease Speed.” It is not possible to change the direction of the motor rotation. This can be done only from the FreeMASTER software.

[Figure 4](#) shows position of the buttons and LEDs on the K40 Tower board.

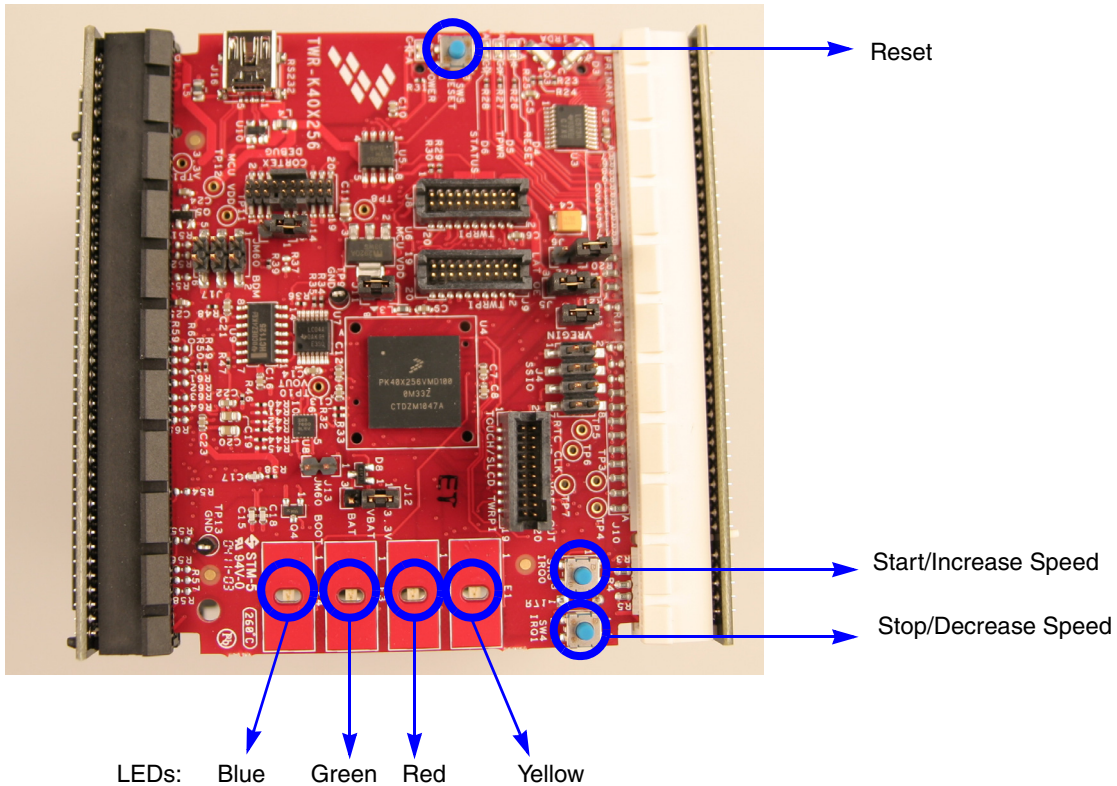


Figure 4. K40 Tower board overview

Connecting the demo to the power supply automatically starts application initialization. This also includes the analog-to-digital converter calibration and the rotor alignment (a small movement of the rotor shaft to a known position). After performing a successful initialization procedure, the blue LED is lit.

To start the motor, press the “Start” button. Now the voltage is applied to the motor winding but the speed is kept at zero. The blue LED is turned off and the green LED starts to light. By repeatedly pressing the “Start” button, the motor speed will be increased in 10% steps of the nominal speed up to 100% of the nominal speed, which is 3000 rpm.

To decrease the speed at any time, press the “Stop” button. Similarly, the speed is decreased in 10% steps of the nominal speed.

4.2 FreeMASTER control

After launching the application and performing all settings described above, click the “Speed scope” item in the project tree structure of the FreeMASTER application window, as shown in [Figure 5](#). In this view, only variables used for the application state and speed settings are visible. For the demonstration purposes, this is sufficient and clear.

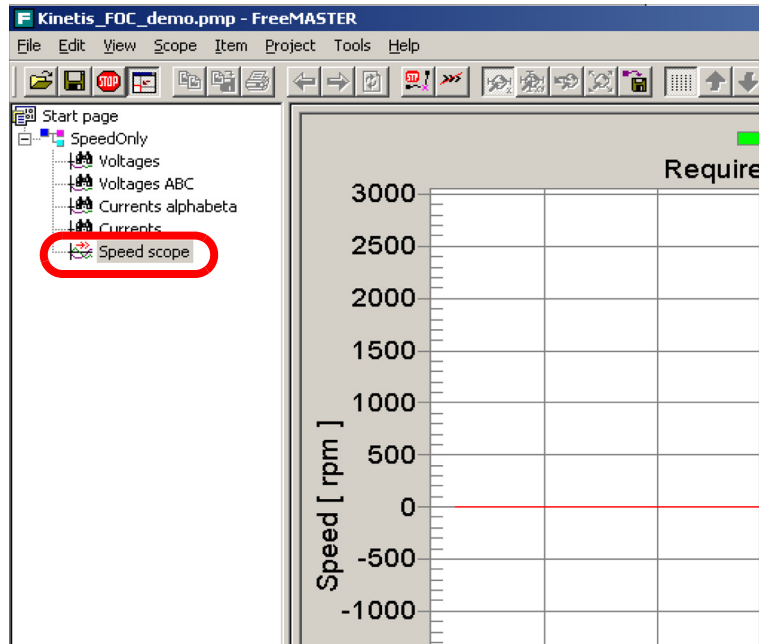


Figure 5. Entering the Speed Scope window

The motor is started by setting the “App Control>” variable to the “Run” value. Click on the “Select>>” cell and choose “Run”.

Then, by setting one of the predefined speed values in the value box of the “Required Speed>” variable as shown in Figure 6, the motor will be set in motion.

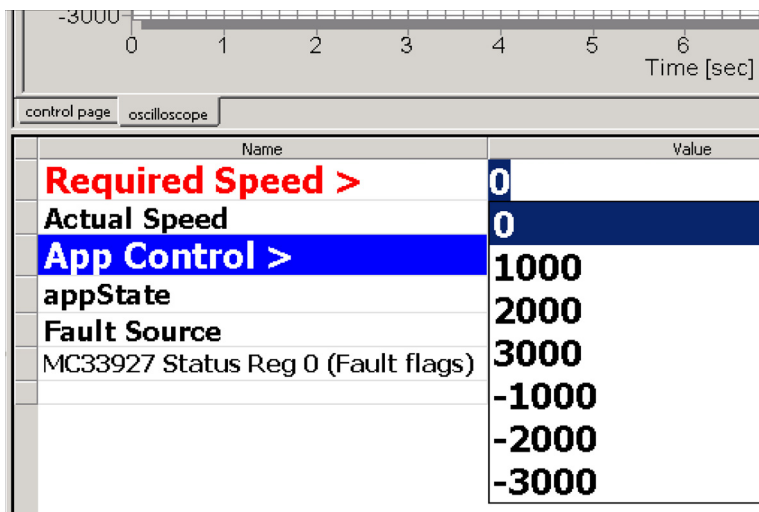


Figure 6. Setting the predefined speed

It is possible to enable a predefined demo sequence. The motor will run at different speeds and in different rotation directions without need of any intervention. To enable demo mode, right-click in the “stimulators” area of the FreeMASTER window on the “Demo [Required Speed>]” row, and select “Run!” as listed in Figure 7. The “stimulators” area is in the bottom left corner of the FreeMASTER application window.

There are a couple of recorders available that display physical quantities in real time (application currents and voltages). To enable a recorder, click on one of the fields shown in [Figure 8](#).

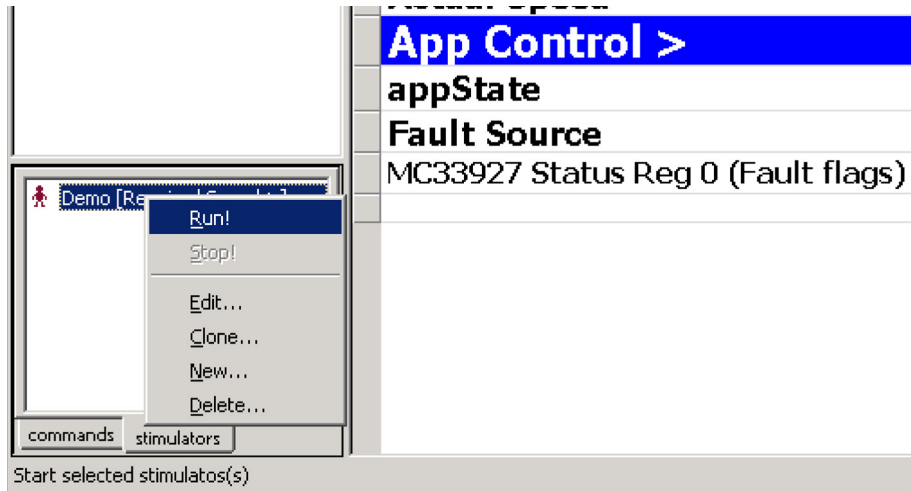


Figure 7. Enabling the demo mode

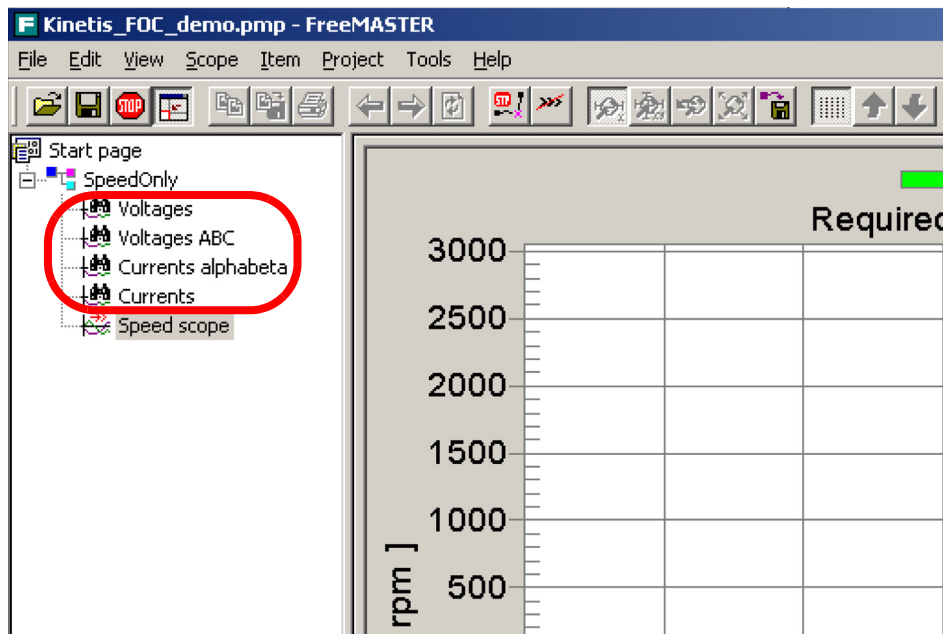


Figure 8. Recorders

4.3 Faults

There are several fault sources that are detected by the application:

- Software overcurrent
- Software overvoltage
- Faults latched by MOSFET driver MC33937

Demo operation

- Disconnection of one motor phase

Detected faults can be viewed in the FreeMASTER window next to the “Faults” variable in the “Speed scope” view.

4.3.1 Software overcurrent detection

To demonstrate the overcurrent detection, the rotor of the motor can be carefully braked by hand. The regulator will increase the current in order to maintain a constant speed. When the current limit is reached, the motor will be disconnected from the voltage, and the red LED will start to light. The application enters the fault state. To enable the motor rotation, it is necessary to press the “Stop” button. If the fault is removed, alignment of the rotor is performed and the blue LED starts to light. Even there is possibility of hardware protection, the limitation of the Tower system doesn’t allow to connect interrupt output of the MOSFET driver with the FlexTimer hardware fault input on the Kinetis K40. The threshold value is set to 2 A.

NOTE

The software overcurrent detection is relatively slow (compared to hardware detection that could not be implemented). Therefore, it may happen that after the software overcurrent event the internal power supply reversible fuse acts. In such a case, unplug the power supply from the line and wait until the green LED on the power supply is switched off.

4.3.2 Software overvoltage detection

The DC-bus voltage level is sampled by ADC at the same rate as motor phase current. The evaluation of the overvoltage fault is performed in the same ISR. The threshold value is set to 24 V.

4.3.3 Faults latched by MOSFET driver MC33937

The MOSFET driver MC33937 can also latch faults. Status bits can be seen in the FreeMASTER control page. The status of each fault is shown as one bit of the driver’s status register. The application checks the status register of the MC33937 over the SPI interface every 1 ms. [Table 1](#) summarizes for quick reference the significance of individual bits.

Table 1. Explanation of the MC33937 Status Register bits

Bits	7	6	5	4	3	2	1	0
Bit Meaning	Reset	Write Error	Framing Error	Phase Error	Overcurrent	Low supply voltage	Desaturation	Overtemp.

More information on the faults and the device itself can be found in the MC33937 Data Sheet included in the \Doc\Datasheets\ folder on the enclosed CD.

In the case where the fault is triggered by the MOSFET driver, follow the same procedure as listed in the previous paragraph to exit the fault state after the fault has been removed.

NOTE

Because the hardware connection between the K40 Tower board and the low-voltage power stage doesn't allow a reset of the MOSFET driver by software command, some faults can be cleared only by pressing the reset button on the K40 tower board. Only in this way can the MOSFET driver properly execute the reset procedure. As mentioned earlier in this document, the FreeMASTER communication has to be disabled before the reset button is pressed!

4.3.4 Motor phase disconnection

There is also a check for disconnected motor phase that can be caused by bad connector contact or a wire break. Because the motor supply cable is firm, the motor cable can become partially unplugged from the connector on the Tower low-voltage power stage. To remove the fault state, push the motor cable wires into the connector housing.

5 Revision history

The following revision history table summarizes changes contained in this document.

Table 2. Revision History

Date	Revision	Description
10/2011	0	Initial version.

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