

3-Phase BLDC Sensorless Motor Control on Kinetis User's Guide

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1.1 Introduction

This application demonstrates a low-power 3-phase brushless DC (BLDC) motor drive software. It is focused on a simple and easy to understand control approach to BLDC using MQX™ in a time-critical application. The control concept of the application is a speed closed-loop BLDC drive using back electromotive force (BEMF) sensing for position recognition. It serves as an example of a BLDC motor control system for low-voltage motor applications. The power stage is designed for an input voltage of +24V DC. The hardware is built on the Freescale Tower rapid prototyping system and contains the following modules:

- TWR elevator
- TWR K60N512
- TWR MC-LV-3PH
- TWR serial

There are two versions of the application software:

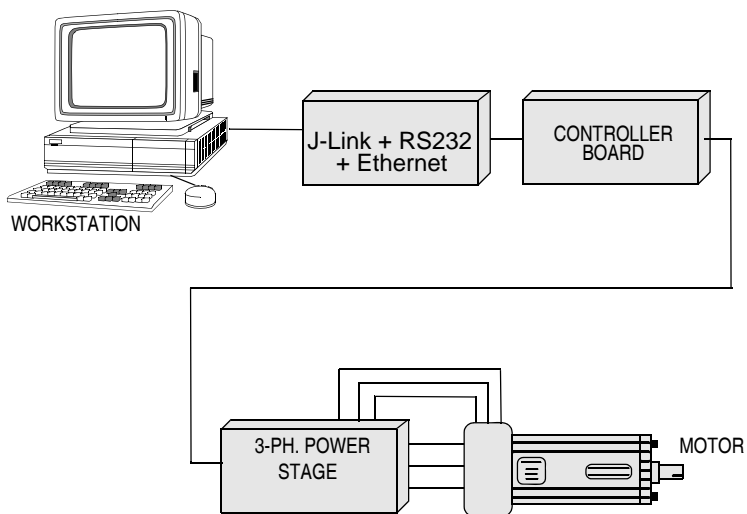
- BLDC under the MQX RTOS and web server
- BLDC on bare metal

Both use the same source code for motor control. The MQX version contains a web server to demonstrate the benefits of the MQX-based solution. Both applications can also be controlled by the FreeMASTER software. This FreeMASTER PC application allows real-time monitoring or modification of all required variables through an easy and user-friendly graphical user interface. Selected variables can also be monitored in a time domain scope representation. The MQX version can be controlled from any web browser on a PC via the Ethernet communication interface, because in this version the web server is implemented.

1.2 About this manual

Key items can be found in the following sections of this manual:

- Introduction to the demo: [Section 1.1, “Introduction”](#)
- Information about safety in using the demo: [Section 1.3, “Warnings”](#)
- Setup instructions: [Section 1.4, “Setup guide”](#)
- USB-to-serial installation: [Section 1.5, “USB-to-serial cable driver installation”](#)
- FreeMASTER installation: [Section 1.6, “FreeMASTER software installation”](#)
- Control via FreeMASTER: [Section 1.7, “FreeMASTER control”](#)
- Ethernet controller setup: [Section 1.8, “Ethernet setup”](#)
- Control of the application via Ethernet: [Section 1.9, “Web control”](#)
- Control from another application: [Section 1.10, “Integration of the motor control driver with other applications”](#)



a) K60N512 MICROCONTROLLER

Figure 1. System configurations

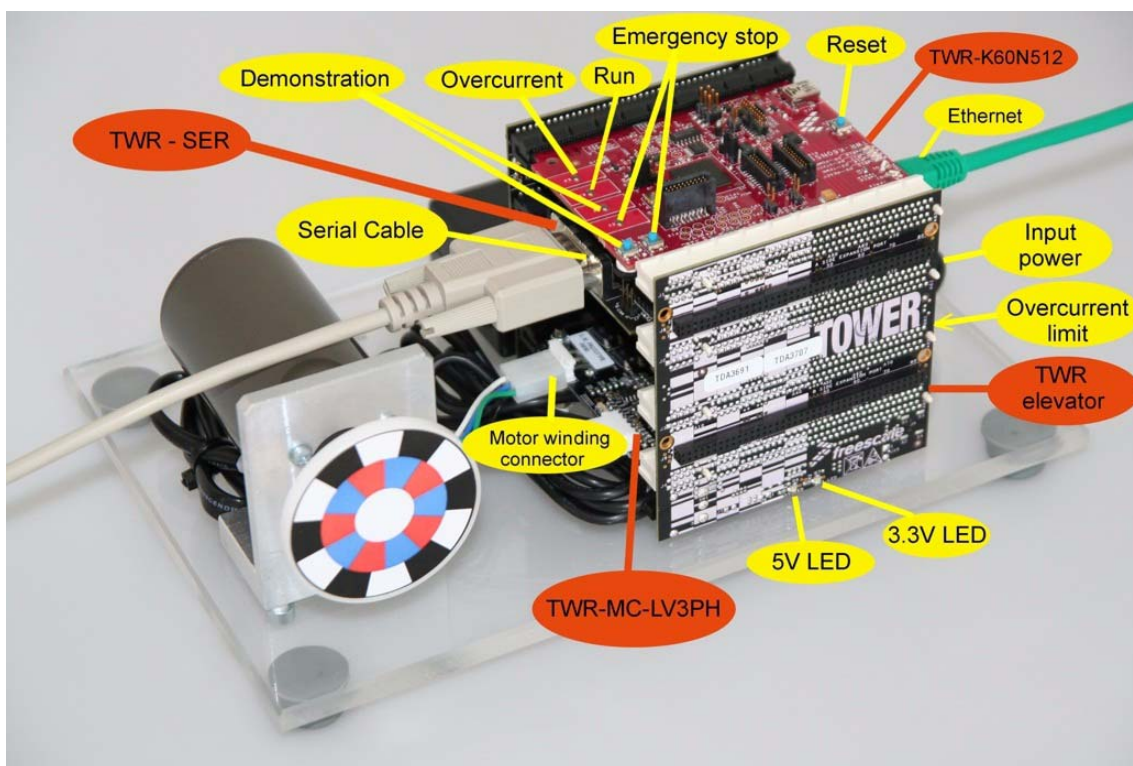


Figure 2. 3-phase BLDC motor control on Kinetis

1.3 Warnings

The power stage includes power components that can reach temperatures hot enough to cause burns. To facilitate safe operation, 24V input power should come from a DC power supply that is current limited to no more than 4 amps.

Keep the following points in mind while following the instructions in this guide:

- Before moving scope probes, making connections, and so on, it is generally advisable to power down the 24-volt supply.
- Wearing safety glasses, avoiding ties and jewelry, using shields, and operation by personnel trained in power electronics lab techniques are also advisable.
- Do not plug any other cables into the demo system except for the power supply cable, Ethernet cable, and serial communication cable. The demo can be powered only via the Tower low-voltage power stage power jack.
- Do not connect any USB cable to the demo while the power is applied to the power stage module. Connecting a USB cable to the Tower elevator module will cause damage to the Kinetis K60 MCU and other systems!
- Only a J-Link can be used for firmware upload.

1.4 Setup guide

The demo should be already configured, if not, configure it as is described below.

1. Jumper settings (board TWR-K60N512 REV C) (see [Figure 3](#)):
 - Jumper J6 to position 2-3—processor clock taken from the TWR-SER board (doesn't work without the TWR-SER)
2. Jumper settings (board TWR-SER REV E) (see [Figure 3](#)):
 - J2—CLK_SEL 3-4
 - J3—CLKIN-SEL 2-3 (processor clock is taken from the PHY)
 - J12—ETH-CONFIG 9-10 to select the RMI communication mode
3. Jumper settings (board TWR-MC-LV-3PH REV B) (see [Figure 3](#)):
 - J2, J3: 1-2—Internal analogue power supply
 - J10, J11, J12: 2-3—Phase A,B,C BEMF sense
 - J13: 2-3—DC bus current sense

NOTE

Both the processor and serial board (TWR-SER) have to be plugged into the Tower. The processor is using an external clock from the Ethernet PHY on these serial card.

All jumpers and other hardware switches not specifically described are expected to be in factory-default positions. Please refer to the board user's guide for the default settings.

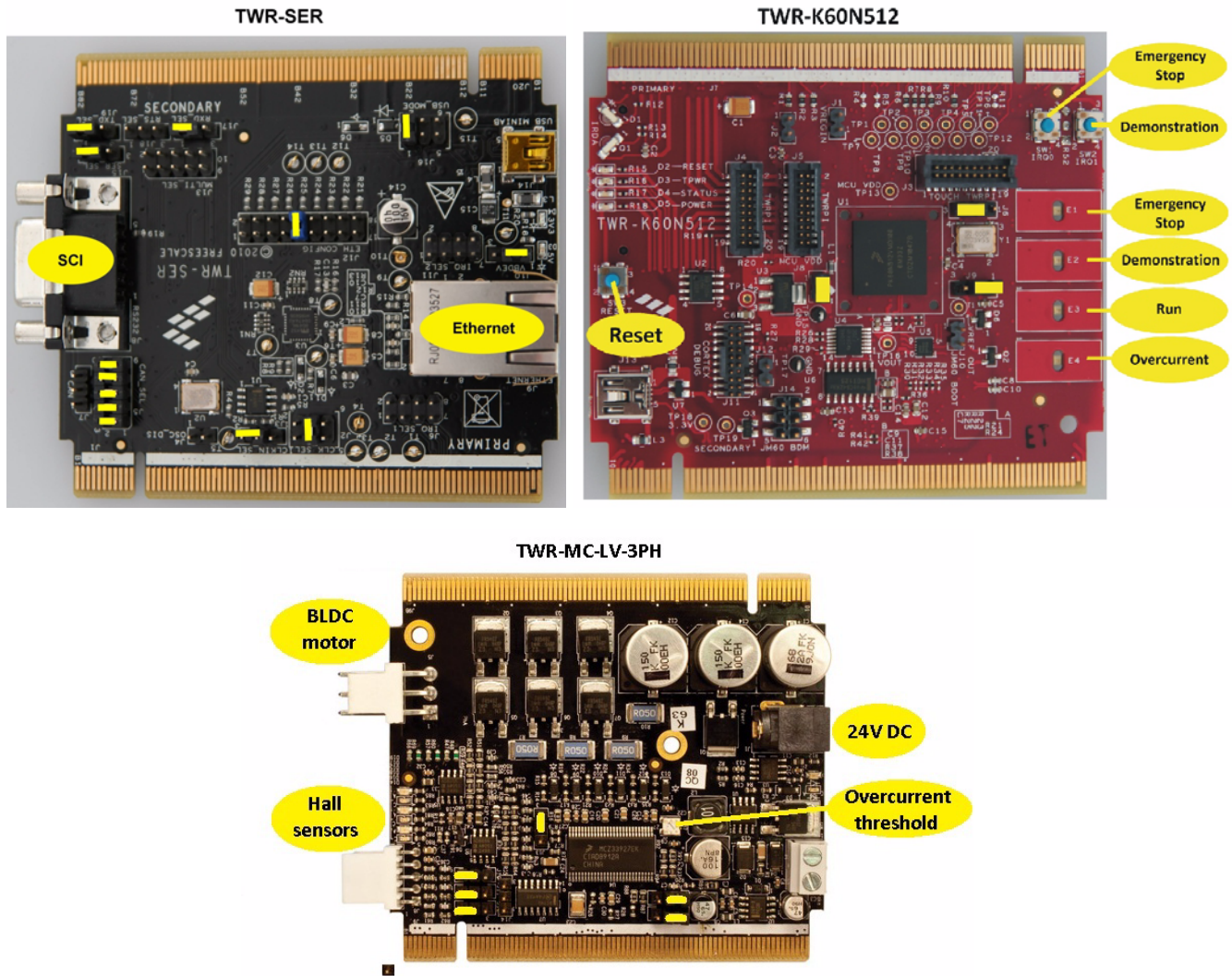


Figure 3. Jumper configuration

4. If your demo is disassembled, you must connect all three boards to the Tower elevator. **Be careful, it is very important to connect the side of the board marked with the white stripe to the white connector of the elevator.** The recommended board order is:
 - a) TRW-K60N512
 - b) TWR-SER
 - c) Empty
 - d) TWR-MC-LV-3PH
5. If you want to operate the demo via FreeMASTER, connect a serial cable between the serial board and the COM port of your computer.
6. Install FreeMASTER. (see [Section 1.6, “FreeMASTER software installation”](#)).
7. Extract the BLDC_KINETIS.exe archive into your computer.

8. Open the FreeMASTER project in `...\SW\FMSTR\TWR_BLDC_BM.pmp` for bare metal, or `...\SW\FMSTR\TWR_BLDC_MQX.pmp` for the MQX version, from the project directory.
9. Set up the COM port number in the FreeMASTER project options. The speed of the port should be 19200. (See [Figure 4.](#))

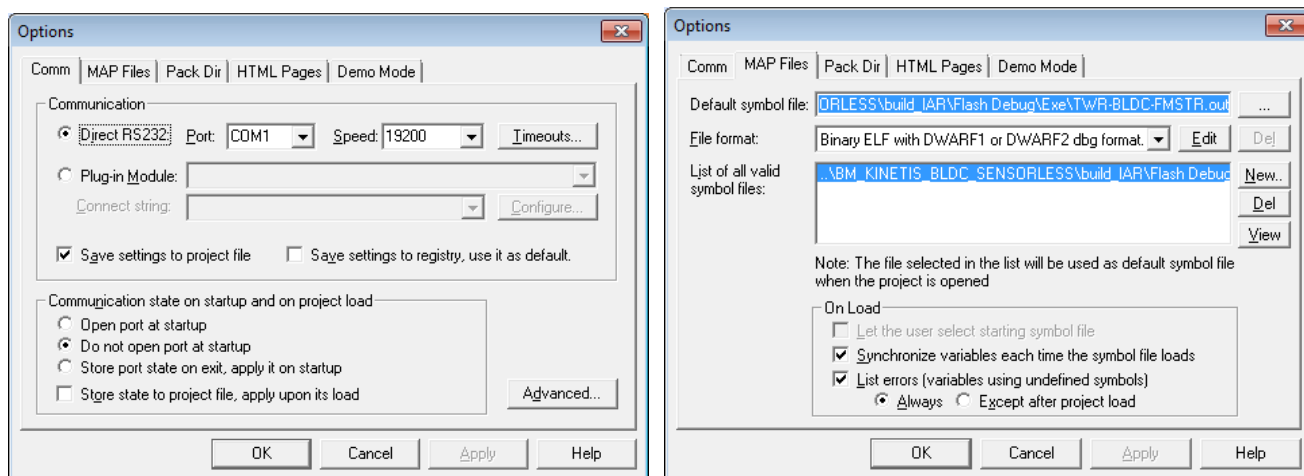


Figure 4. FreeMASTER configuration

10. 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. If you use the USB-to-serial cable, follow [Section 1.5](#), “[USB-to-serial cable driver installation.](#)”
11. Install the IAR Embedded Workbench.
12. The project directory contains its own BSP, PSP and library files, already configured as necessary. (you don’t need to install MQX on your computer).
13. Connect a J-Link to the TWR-K60N512 board.
14. Open the IAR project `..\SW\BM_KINETIS_BLDC_SENSORLESS\build_IAR\BLDC_example.eww` for the bare metal version, or `..\SW\MQX_KINETIS_BLDC_SENSORLESS\BLDC_WEB_SERVER.eww` for the MQX version, from the project directory.
15. Connect a 24V supply voltage to the power stage (the green LED [D7] near the power supply connector should be lit). **DO NOT CONNECT ANY OTHER SUPPLY VOLTAGE OR USB CABLE.** If any other voltage is applied, the hardware can be damaged. The power stage generates 3.3V and 5V for other modules in the tower system. The presence of 3.3V is indicated by LEDs D1 and D7, and the presence of 5V is indicated by D2 and D6 on the Tower elevator.
16. Load firmware via the J-Link and then run the application.
17. Start communication in FreeMASTER.
18. Connect the motor connector to the power stage.
19. Push the demonstration button or type a speed from 400 to 4000, or –400 to –4000 rpm, into the Speed Required field. The motor should run.

20. If the motor doesn't run, check the status of the application in FreeMASTER. If the overcurrent fault has occurred, set up the overcurrent limit by turning trimmer R37 on the MC-LV-3PH power stage.

NOTE

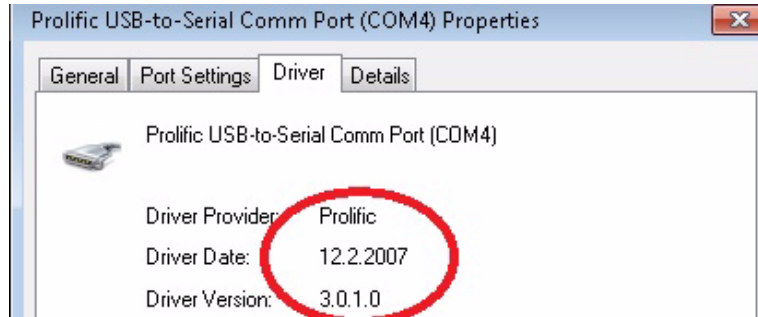
Resetting of any fault status can be done only using the RESET button on the K60 board.

1.5 USB-to-serial cable driver installation

1. Don't plug the USB-to-serial cable into your computer.
2. Insert the CD that is part of the demo kit into your CD-ROM drive.
3. **For Windows XP** Run the following file: [your CD ROM Drive]:
 \USB_to_RS232\Windows\Win_98_XP\Win98~XP_V2.0.21 Driver Installer.exe.
For Windows 7 Run the following file: [your CD ROM Drive]:
 \USB_to_RS232\Windows\Win7_Vista\PL-2303 Vista Driver Installer.exe
4. Follow the onscreen instructions to complete the installation.
5. Plug the USB-to-serial adaptor into your computer's USB port.
6. 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. The following is one possible way to open 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.
7. Now the USB-to-serial Cable is ready to use.

Under Windows 7 the driver software sometimes causes FreeMASTER to stop working. This can be fixed by downgrading the driver to an older version.

1. Insert the CD that is part of the demo kit into your CD-ROM drive.
2. Plug the USB-to-serial adapter into your computer's USB port.
3. By right-clicking on Computer, go to the Device Manager. Right-click to **Prolific USB-to-Serial Comm Port (ComXX)**.
4. Choose **Update Driver Software** from the menu.
5. Click **Browse my computer for driver software**.
6. Click **Let me pick from a list of device drivers on my computer**.
7. Click **Have Disk...**
8. Navigate to ...\\USB_to_RS232\Windows\Win7_Vista\ser2pl.sys.
9. Choose **Prolific USB-to-Serial Comm Port**.
10. Click Next.
11. Check the version of the driver. It should be:



12. Now the USB-to-serial cable is ready to use.

1.6 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 for PC\FMMASTERSW.exe`, or check the most recent version on the Freescale FreeMASTER web page. In case of any problem with the installation process or with using the software, download the documentation from the Freescale web page.

1.7 FreeMASTER control

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

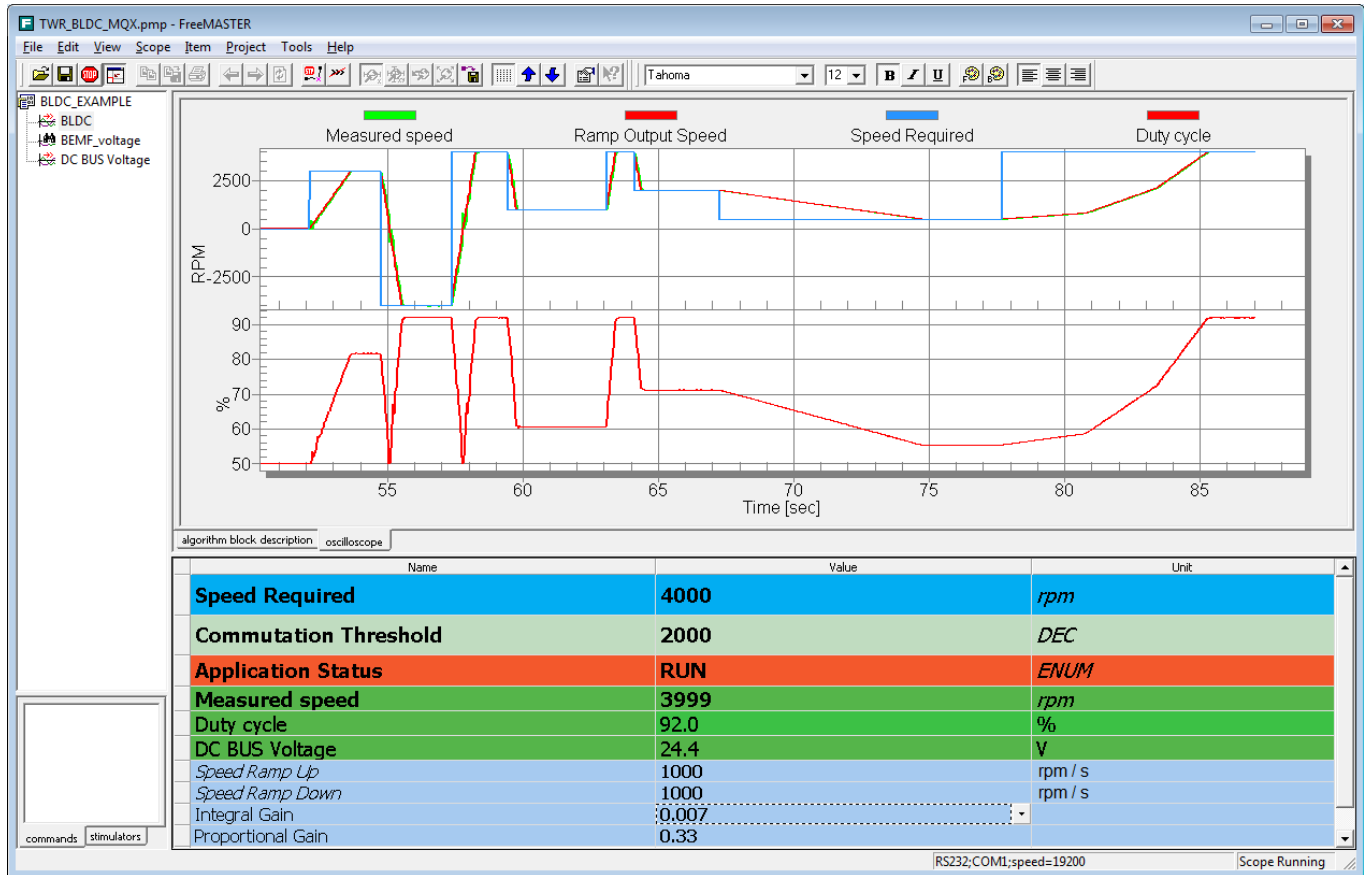


Figure 5. FreeMASTER user interface

Description of variables:

Speed required: This variable serves for entering the required speed of the motor and the direction of motion. If the number is negative, the motor runs in a counter-clockwise direction; if it is positive, the motor runs clockwise. You can modify this variable from -400 to -4000 , and from 400 to 4000 . Any other numbers will be ignored.

Commutation threshold: For commutation tuning.

Measured speed: Variable showing the measured speed. A speed under 200 rpm is not measured exactly.

Standstill detection: Detection of a rotor standstill. If a rotor is locked, the software periodically tries to restart it. If the required speed is equal to 0, and motor is stopped for more than 2 seconds, the software turns off the PWM.

Closed-loop: Enables or disables the speed regulator. If it is disabled, the Duty cycle parameter can be changed. [50%...100%]

Integral gain, proportional gain: Speed PI controller setting.

trMyRamp.s32RampDown: Motor deceleration. Can be set in rpm/s.

trMyRamp.s32RampUp: Motor acceleration. Can be set in rpm/s.

1.8 Ethernet setup

To configure the Ethernet communication interface on your PC, follow the steps below:

1. Disconnect all network cables and turn off your WIFI adapter.
2. Use the automatic IP configuration in your wired adapter local area connection setting window as shown in [Figure 6](#).
3. Connect the Ethernet cable between the Tower serial module and your computer.
4. Click OK.
5. Wait for an established connection.
6. Open Internet Explorer.
7. Go to **Tools\Internet options**.
8. Click the **LAN settings** button.
9. Disable the proxy server, unchecking the box, as shown in [Figure 7](#).
10. Click OK.

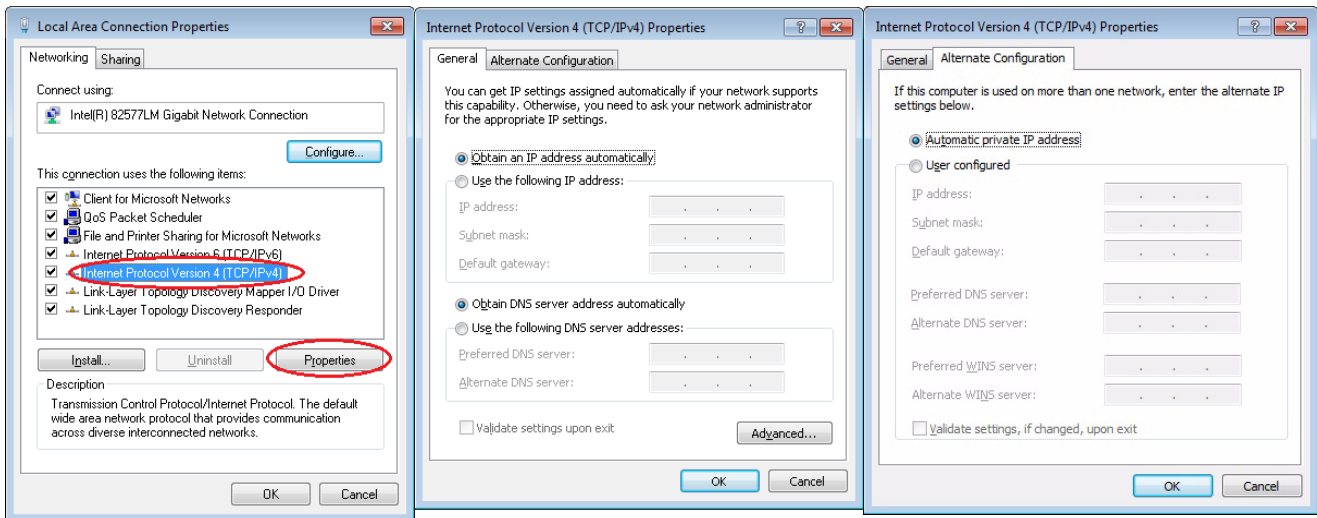


Figure 6. Configuration of Ethernet connection

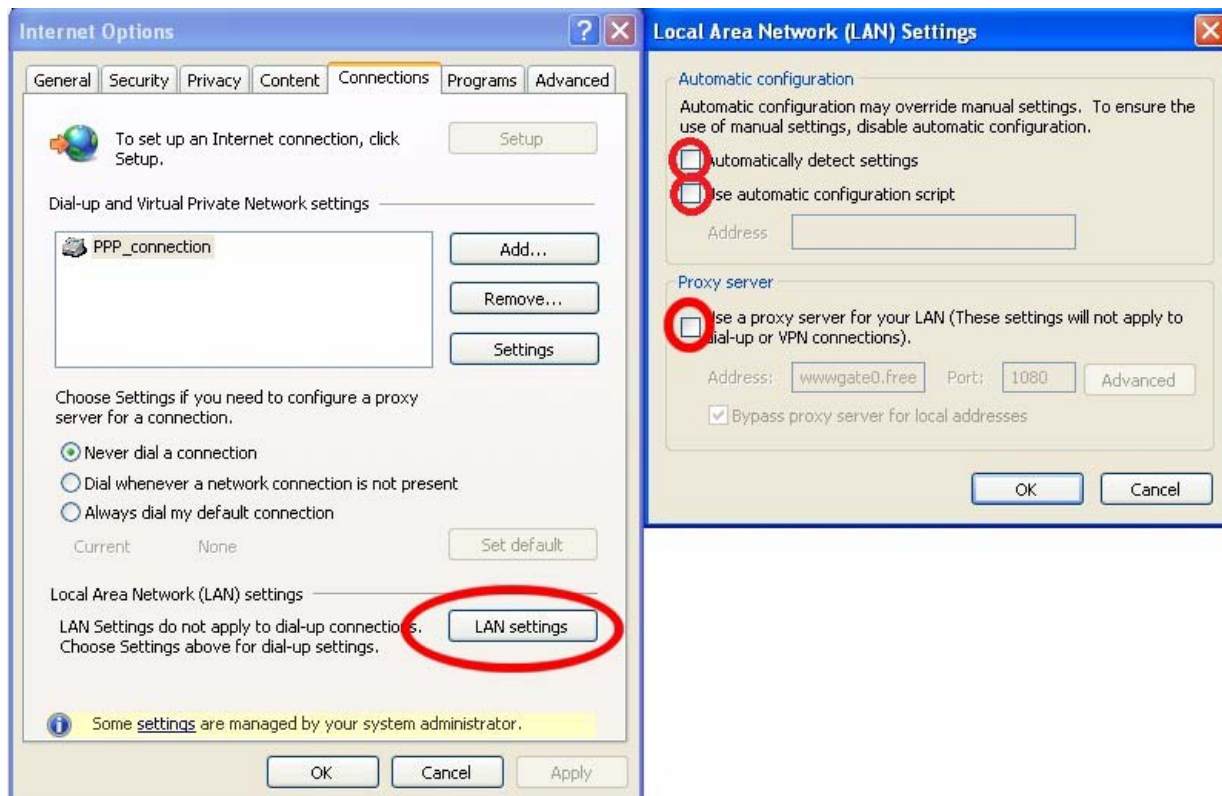


Figure 7. Configuration of MS Internet Explorer for demo control

1.9 Web control

The MQX version of the application can be controlled via a web server, but you must set up your Ethernet interface as described in [Section 1.8, “Ethernet setup.”](#) Then follow the steps below.

1. Open Internet Explorer.
2. Write the IP address of the demo device into Internet Explorer. The default IP address is **169.254.3.3**. Then press enter.
3. You should see a web page with the Freescale logo and the title **Freescale MQX Web Server**.
4. Click the **BLDC Control** on the left side of the web page.
5. You should see the web page as in [Figure 8](#).
6. Click one of the buttons with the required speed.
7. The motor should be set in motion.

NOTE

The web server is optimized only for MS Internet Explorer 8.

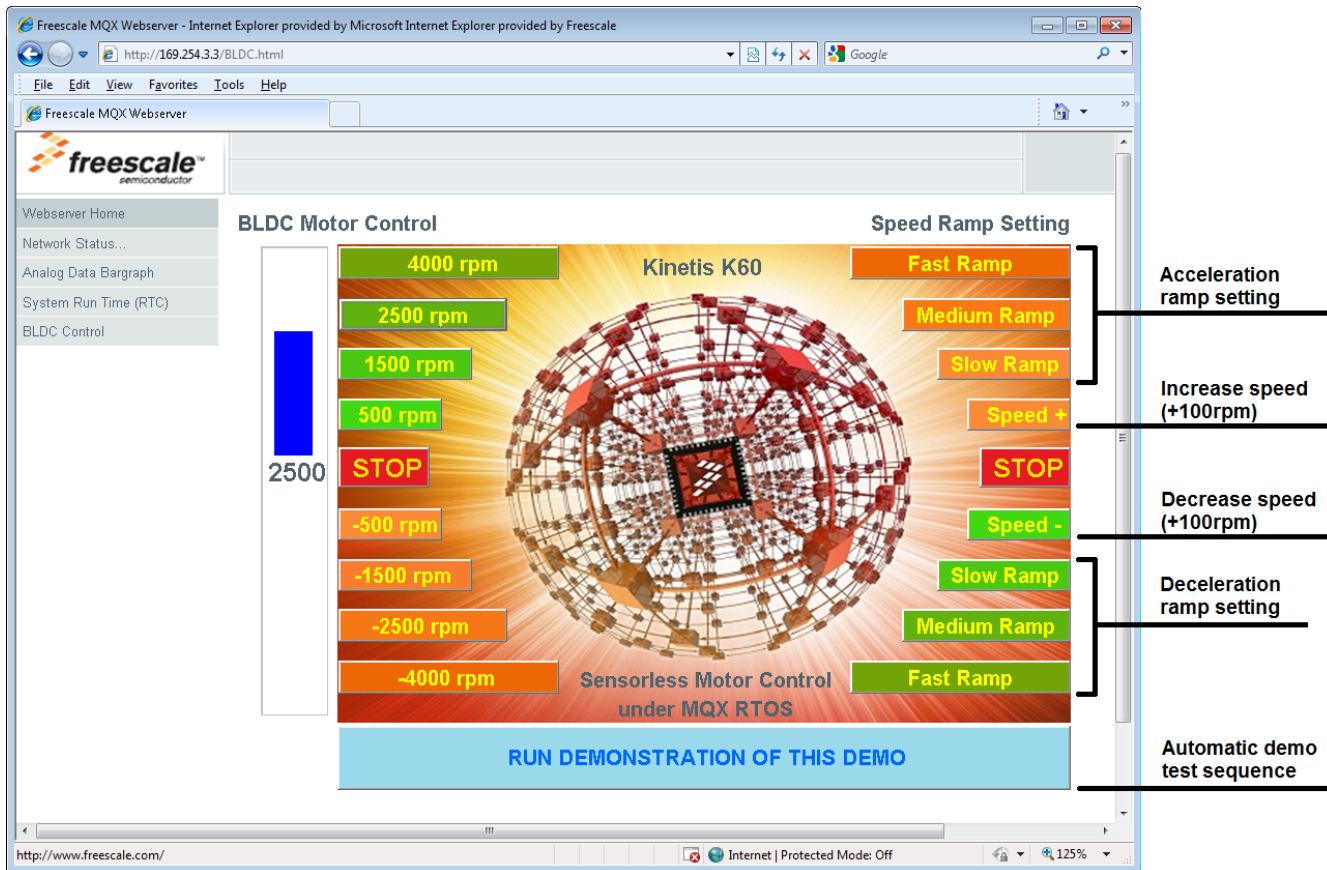


Figure 8. Web page for speed control

1.10 Integration of the motor control driver with other applications

Both versions of the motor control driver can be part of other applications. The API is defined by the following six functions. A detailed description can be found in DRM135, *3-Phase BLDC Sensorless Control with MQX RTOS Using K60N512*.

1. **void** Set speed(**int** motor number, **signed short** speed input)

The first parameter is the number of the motor that receives the command. This demo has only one motor, so enter 1.

The **second parameter** is the input speed in **signed short** format. The input value is in RPM.

Return: void

2. **unsigned char** Get_status(**void**)

Return: Status of the application

0-IDLE, 1-STOP, 2-RUNNING, 3-ALIGNMENT, 6-EMERGENCY_STOP,
7-UNDER_VOLTAGE_FAULT, 8-OVER_VOLTAGE_FAULT,
9-OVER_CURRENT_FAULT

3. **signed short** Get_speed(**int** motor number)

The first parameter is the number of the motor that receives the command. This demo has only one motor, so enter 1.

Return: measured speed in signed short data format. The value is in RPM.

4. **signed short** Get req speed(**int** motor number)

The first parameter is the number of the motor that receives the command.

Return: Required speed in signed short data format. The value is in RPM.

5. **void** Set ramp up(**int** motor number, **int** ramp up)

The first parameter is the number of the motor that receives the command.

Second parameter: Ramp up profile. The value is in RPM per second.

Return: void

6. **void** Set ramp down(**int** motor number, **int** ramp down)

The first parameter is the number of the motor that receives the command.

Second parameter: Ramp down profile. The value is in RPM per second.

Return: void

NOTE

Because the hardware connection between the K60 tower board and the low-voltage power stage doesn't allow performing a reset of the MOSFET driver by a software command, some faults can be cleared only by pressing the reset button on the K60 tower board. Only in this way can the MOSFET driver properly execute the reset procedure.