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S12ZVML-MINIBRD User Manual: MC9S12ZVML128 Small Footprint Board for Sensorless Motor Control

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About This Book

This document describes the S12ZVML-MINIBRD, the MC9S12ZVML128 small footprint board design, which is targeted at BLDC and PMSM sensorless motor control applications.

To locate any published updates for this document, refer to [freescale.com](http://www.freescale.com).

Revision History

Table i. Revision History

Date	Revision level	Description	Page number(s)
April 2014	1.0	Initial release	34

Documentation

The MC9S12ZVML128 documentation is available at the web site, <http://www.freescale.com/MagniV> as follows:

- Reference manuals — MC9S12ZVML128 modules in detail
- Data sheets — information mainly on the device's AC, DC, thermal characteristics and package pin-outs
- Product briefs — device overview
- Application notes — address specific design issues

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Chapter 8 S12ZVML-MINIBRD Schematic

Chapter 1 Introduction

This user manual introduces the S12ZVML-MINIBRD board, which represents the MC9S12ZVML128 small footprint board design.

The MC9S12ZVML128 [3.] integrates a 16-bit microcontroller, an automotive voltage regulator, a LIN interface and a gate driver unit, in order to drive six external MOSFETs.

The S12ZVML-MINIBRD board is designed for a 3-phase BLDC and PMSM sensorless motor control application. The board can be used for other applications requiring load switching and load current monitoring as well. An application can be controlled using LIN and FreeMASTER [4.].

For more information on BLDC sensorless applications, see AN4704 [7.].

1.1 Board Features

The board was designed to demonstrate the minimal hardware configuration needed for a 3-phase BLDC and PMSM sensorless motor control application to achieve minimum board size. The board features are as follows, see [Figure 1-1](#) and [Figure 1-2](#):

- MC9S12ZVML128 MCU
- power supply voltage in the range of -25 V to +25 V, nominal +12 V
- reverse battery protection
- load current in range of -10 A to +10 A
- load current monitoring
- boost circuitry designed to allow driving $V_{gs} = 10$ V MOSFETs from a +3.5 V power supply
- on-board charge pumps to allow driving the high side MOSFETs
- analog and digital inputs for target application control and monitoring
- FreeMASTER enabled
- LIN enabled
- BDM enabled
- OSBDM enabled:
 - download and debug MCU code
 - virtual serial line (USB to SCI)
- board size of 5 cm x 9 cm:
 - MC9S12ZVML128 related part size of 5 cm x 5 cm
 - OSBDM related part size of 5 cm x 4 cm

The on-board OSBDM module allows the user to download and debug code using the CW10.5 tool [5.] without the need of a P&E Micro USB Multilink.

The FreeMASTER tool allows the user to control the on-board application via the PC USB line.

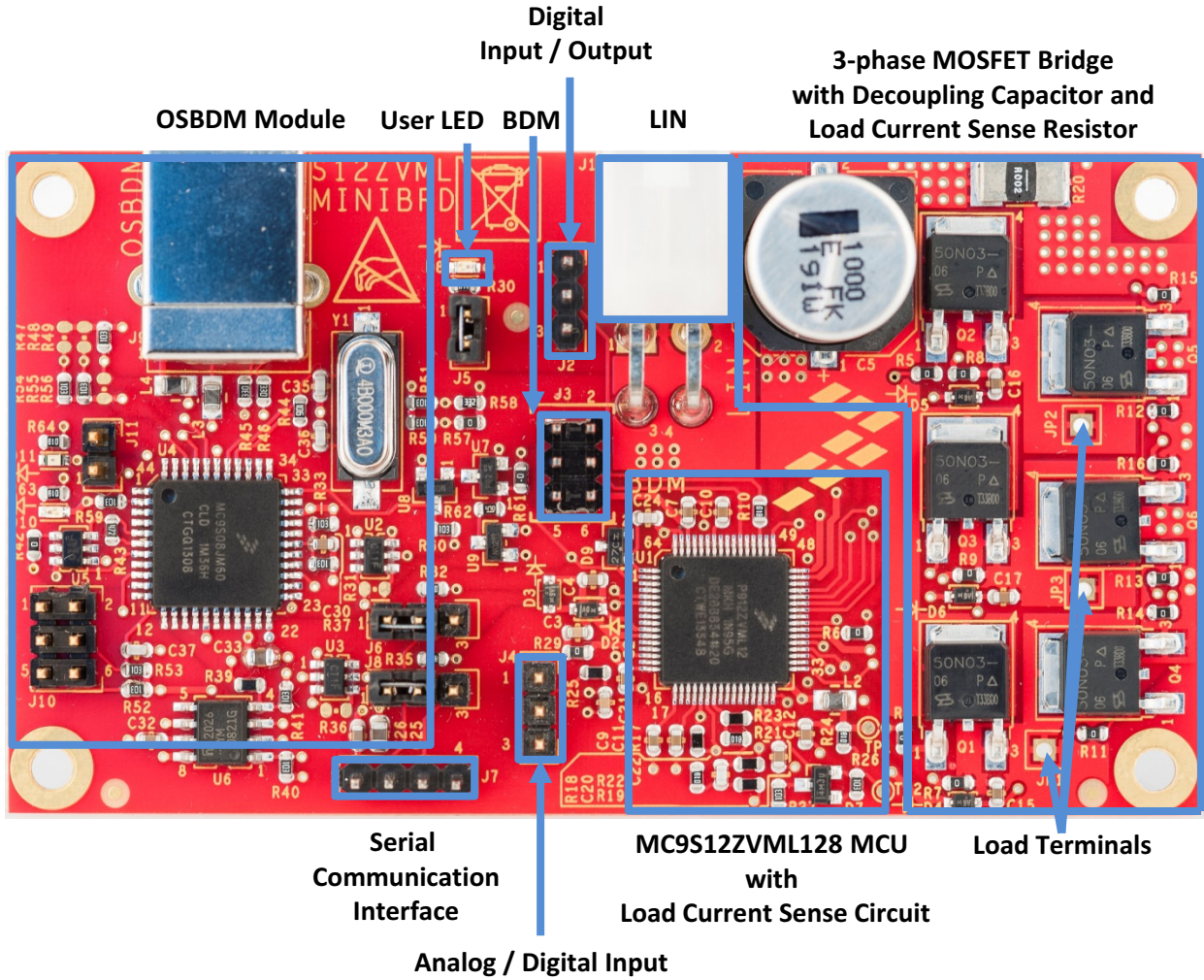


Figure 1-1. The S12ZVML-MINIBRD board top side view

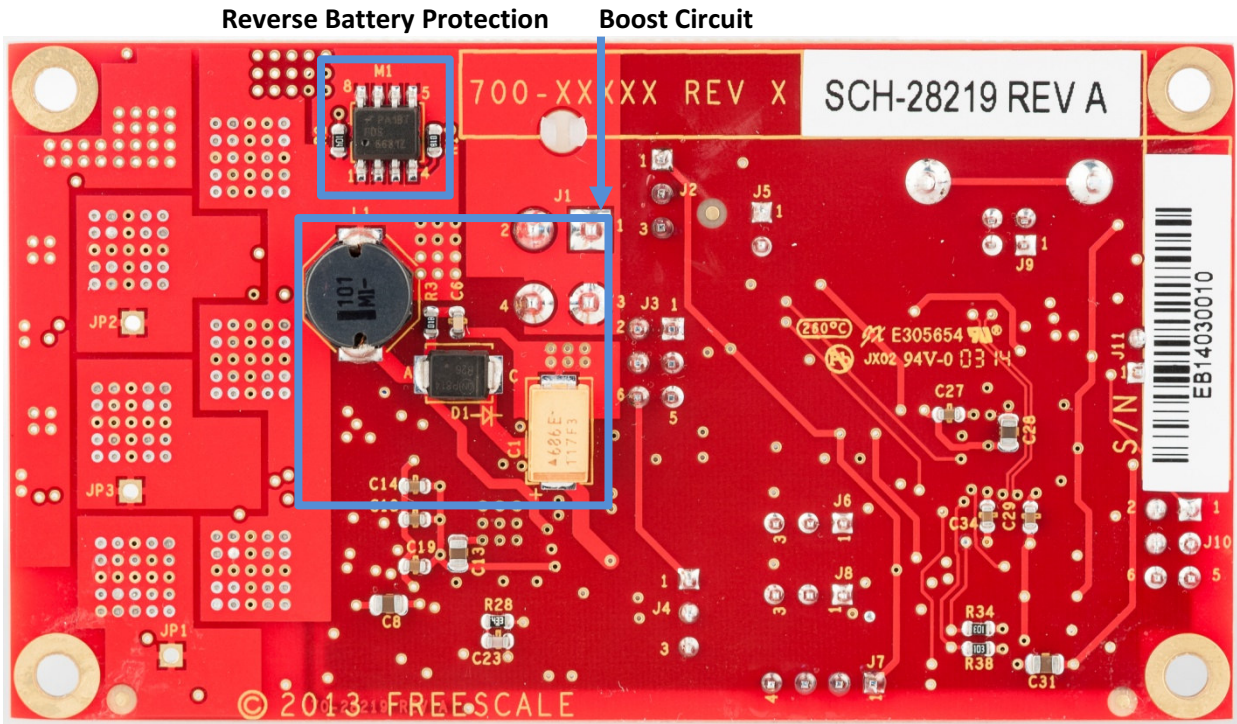


Figure 1-2. The S12ZVML-MINIBRD board bottom side view

1.2 Board Jumper Configuration

See [Table 1-1](#) and [Figure 1-3](#) for proper jumper configuration.

Table 1-1. S12ZVML-MINIBRD Board Configuration

Jumper	MCU pin	Function	Default placement
J5	PP0 EVDD1 ECLK	MCU PP0 output: - ECLK, not placed - EVDD1, placed	Placed
J6	PS2 RxD1	Select MCU RxD1 pin connection: - USB OSBDM, placed, pins 1-2 - J7 SCI PORT, placed, pins 2-3	Placed, pins 1-2
J8	PS3 TxD1	Select MCU TxD1 pin connection: - USB OSBDM, placed, pins 1-2 - J7 SCI PORT, placed, pins 2-3	Placed, pins 1-2

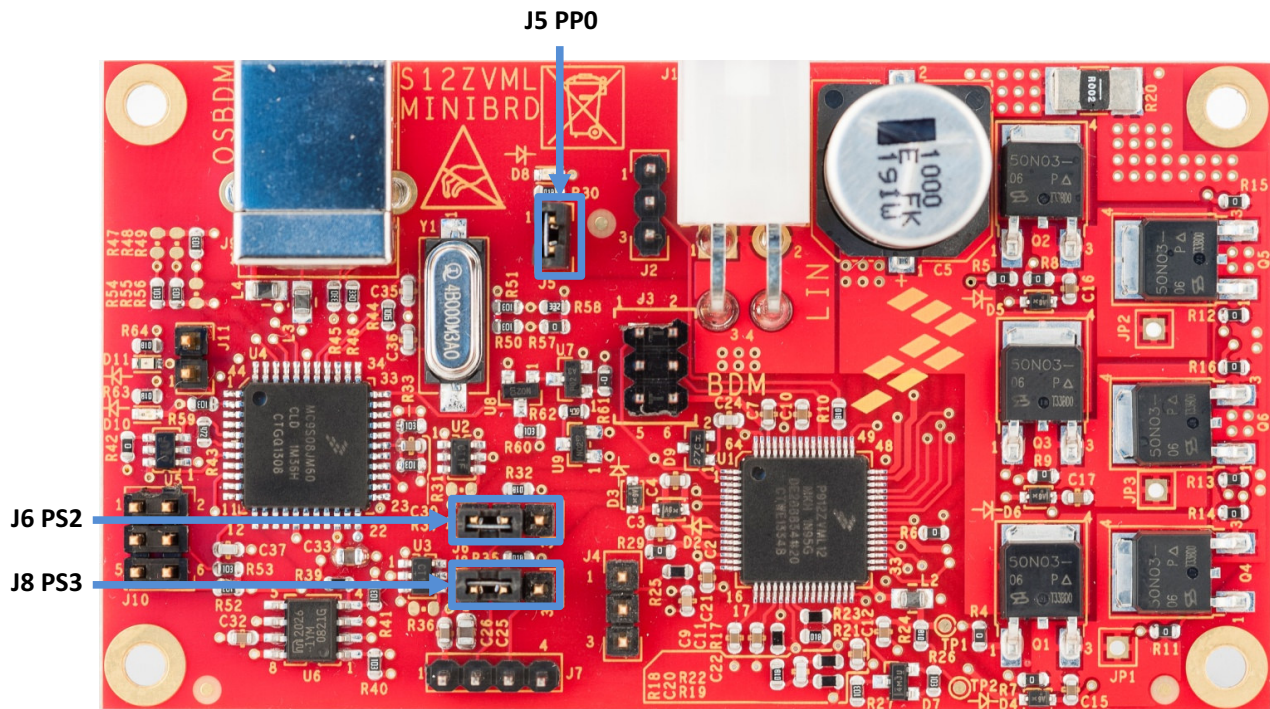


Figure 1-3. S12ZVML-MINIBRD board jumper position and setting

Chapter 2 Board Interface Description

This chapter summarizes the on-board connectors and header pin-outs, signal meanings, and MCU pins assignments.

2.1 J1 LIN Connector

The board is supplied using the LIN connector J1, see [Table 2-1](#) for the connector pin-outs. The MCU is configured as a LIN Slave node.

Table 2-1. J1 LIN connector

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	GND	-	Ground	-
2	GND	-	Ground	-
3	VSUP	-	Power Supply	-
4	LIN	RXD1/TXD1	LIN bus	Bidirectional

The J1 LIN connector opposite uses MOLEX 39-01-2040 with pins MOLEX 39-00-0039.

2.2 J9 USB Connector

The USB line is used for on-board OSBDM module communication with the PC. The OSBDM module is used for MCU code download and debug using the CW 10.5 tool, as well as a virtual serial port when using the FreeMASTER tool to control the user application.

The interface uses a USB 2.0 B type connector, see [Table 2-2](#).

Table 2-2. J9 USB connector

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	VBUS	-	USB Power Supply	-
2	D-	RXD0/TXD0	Data –	Bidirectional
3	D+	RXD0/TXD0	Data +	Bidirectional
4	GNDB	-	USB Ground	-

2.3 J2 MCU Digital Pin Header

The MCU PT1 digital pin can be used for an application control and monitoring, see [Table 2-3](#).

Table 2-3. 2 MCU PT1 pin header

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	VDDX	-	VDDX output (+5V)	-
2	-	PT1/IOC1	PT1 pin input / output	Bidirectional
3	GND	-	GND	-

2.4 J4 MCU Analog Pin Header

The MCU PAD3 analog pin can be used for an application control and monitoring, see [Table 2-4](#).

Table 2-4. J4 MCU PAD3 pin header

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	VDDX	-	VDDX output (+5V)	-
2	-	PAD3/AN0_3	PAD3 pin input	Input
3	GND	-	GND	-

2.5 J7 MCU SCI Port Header

The J7 allows to connect board external device using the MCU SCI module, see [Table 2-5](#). The MCU SCI port availability depends on the J6 and J8 configuration, see [Table 1-1](#).

Table 2-5. J7 MCU SCI port header

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	VDDX	-	VDDX output (+5V)	-
2	RXD	RXD1	Connection depending on J6 configuration	Input
3	TXD	TXD1	Connection depending on J8 configuration	Output
4	GNDB	-	Ground	-

2.6 JP1, JP2, JP3 Motor Terminal Pins

The JP1, JP2, JP3 are the phases half-bridge outputs. The terminals are used to connect the controlled load, for example BLDC, PMSM motor.

Chapter 3 Design Consideration

The S12ZVML-MINIBRD board schematic can be found in [Chapter 8, “S12ZVML-MINIBRD Schematic”](#).

3.1 Power Supply

The board is supplied using the J1 LIN connector, see [Table 1-1](#) for the connector pin-outs. The board nominal power supply voltage equals +12 V. The board sustains negative voltages up to -25 V due to M1 reverse battery protection.

The power supply line is decoupled by C5. The value of the capacitor is dependent on the required power supply voltage ripple, when board load, for example BLDC / PMSM motor, is PWM driven. The goal is to achieve minimum power supply voltage ripple to reduce board electromagnetic emissions.

An on-board boost circuit, L1, D1, C1, C2 allows controlling the $V_{gs} = 10$ V MOSFETs starting from a +3.5V power supply voltage. The boost circuitry is turned ON and controlled by the MCU GDU boost controller module when the power supply voltage drops below +10 V. The boost circuitry is optimized for operation at 520 kHz with the MCU GDU boost controller duty cycle set to 75% and the L1 inductor current limit at 750 mA. The boost snubber circuitry R3 and C6 is included to dump the oscillations appearing when the boost transistor is switched.

The on-board D7 +2.47 V voltage reference sets the ADC voltage, when the load current equals 0 A, see [Table 3-1](#).

3.2 MCU Related Circuitry

The MCU is supplied with VSUP pin. The MCU on-chip +5 V voltage regulator generates the voltage for the MCU digital and analog circuitry. The decoupling capacitors C7, C8, C9 reduce noise on the power supply lines. The MCU analog power supply line noise is reduced using the ferrite bead L2 and capacitor C12.

The GDU drives the Q1, Q2, Q3, Q4, Q5, Q6 MOSFETs configured in a 3-phase bridge unit with phase outputs JP1, JP2, JP3. The GDU is supplied by the on-chip +11 V VLS regulator decoupled by C13, C14, C18 and C19. Whenever the power supply voltage drops below +10 V, the boost circuitry starts to operate and the VSUP voltage is maintained at +10 V. The boost circuitry allows driving the $V_{gs} = 10$ V MOSFETs starting from a +3.5 V power supply voltage.

The J2 digital PT1 pin signal and J4 analog PAD3 signal can be used for an application monitoring and control.

The PP0 pin controls the D8 LED. The PP0 shares the MCU clock output ECLK as well.

The J7 allows to connect board external device using the MCU SCI module. The availability depends on J6 and J8 jumper header settings, see [Table 1-1](#).

3.3 Charge Pumps

There are four charge pumps to supply the GDU HSDs modules.

The D4, C15, D5, C16, D6, C17 charge pumps are driven by the phase voltages. They supply the GDU HSDs when the PWM duty cycle is within minimal and maximal limits.

The D2, D3, C3, C4 charge pump is driven by the MCU VCP pin. This is used to supply the GDU HSDs when the PWM duty cycle is either 0% or 100%.

3.4 Load Current Sense

The load current sense circuitry is designed to measure load current in both directions. This is useful when the attached motor is controlled in dynamo mode as well.

The load current is sensed by R20 and amplified by the on-chip amplifier AMP0. The R19, R22, and C20 reduce the sense line noise. The R28 and C23 shape the AMP0 signal.

The load current conversion slope theoretically equals 0.125 V/ 1 A, see [Table 3-1](#).

Table 3-1. Load current sense

Load current [A]	MCU AN0 pin voltage [V]
10	3.72
0	2.47
-10	1.22

3.5 BDM Interface

The on-board J3 BDM connector allows a download and debug of the code in the MCU using CodeWarrior 10.5 and P&E Micro USB Multilink.

The BDM interface can be used for application control using FreeMASTER as well.

3.6 OSBDM Interface

The on-board OSBDM interface allows a download and debug of the code in the MCU without any additional debugging hardware. The P&E Micro USB Multilink is not needed.

The OSBDM interface can be used as a board virtual serial port for FreeMASTER based application control.

Chapter 4 Board Electrical Characteristics

The electrical characteristics in [Table 4-1](#) apply to operation at 25 °C.

Table 4-1. Electrical Characteristics

Characteristic	Symbol	Min	Typ	Max	Units
Maximal power supply voltage range, J1 pin3	V_{DCMAX}	-25	-	25	V
Operating power supply voltage range, J1 pin3 ⁽¹⁾	V_{DC}	3.5	12	20	V
Power supply current consumption ⁽²⁾	I_{DC}	-	20	-	mA
J2 pin2, J4 pin2, J7 pin2, J7 pin3 voltage range	V_{PER}	0	-	5	V

¹MCU boost option enabled. When MCU boost option disabled, $V_{DC_MIN} = 6V$.

²Measured at 12 V power supply. MCU flash memory erased.



Chapter 5 Board Quick Start Guide

This chapter describes how to set-up the S12ZVML-MINIBRD board to control the BLDC motor, see [Figure 5-1](#).

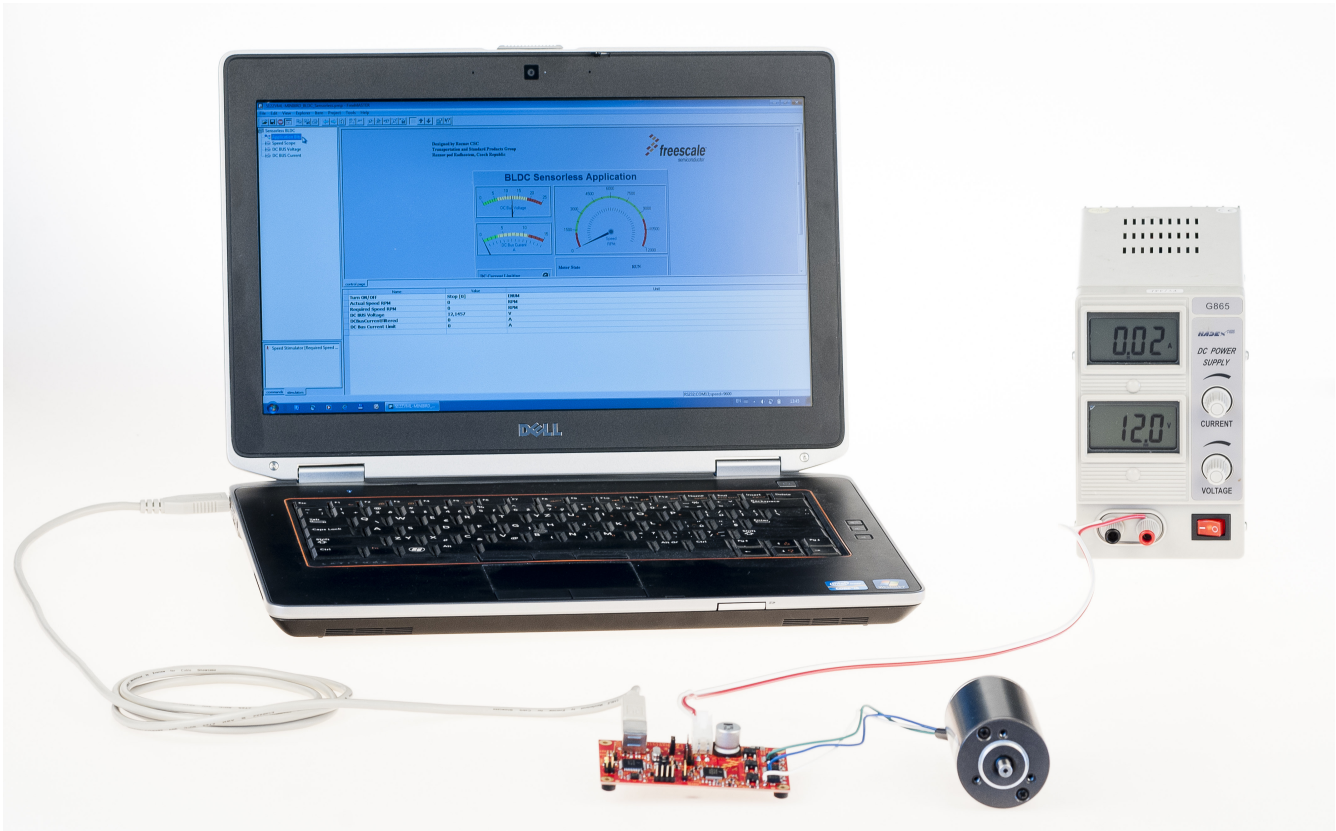


Figure 5-1. S12ZVML-MINIBRD set-up

5.1 Download the S12ZVML-MINIBRD Support Package

Visit the MagniV S12ZVML-MINIBRD related Freescale’s web pages [2.]. Navigate the “Jump Start Your Design” section and download the latest version of documentation and software package.

5.2 Software Tool Chain Set-up

5.2.1 BLDC Motor Control Software Package

Run the “S12ZVML-MINIBRD_BLDC_Sensorless_CW_IDE.exe” file and install and BLDC Motor Control project “S12ZVML-MINIBRD_BLDC_Sensorless_CW_IDE” and the Automotive Math and Motor Control Library Set [6.].

5.2.2 CodeWarrior

The CodeWarrior tool enables development, download and debug code in on-board MCU. Visit the CodeWarrior [5.] web page and install the free trial CW 10.5 version on your PC. Once the CW 10.5 is installed, import the “S12ZVML-MINIBRD_BLDC_Sensorless_CW_IDE” project in CW 10.5:

1. Open CW 10.5
2. Go to the “Help” folder and choose “Search”
3. Type in the search window the key words “Import existing project”
4. Follow the instructions to import the “S12ZVML-MINIBRD_BLDC_Sensorless_CW_IDE” project

For additional information:

1. Go to the “Help” folder and choose “Documentation”
2. Open the “Getting Started” folder
3. Download “Microcontroller V10.x Quick Start”

5.2.3 FreeMASTER

Install the free of charge FreeMASTER tool on your PC available at [4.]

5.3 Hardware Set-up

The S12ZVML-MINIBRD kit contains:

1. S12ZVML-MINIBRD board
2. J1 power supply cable, length 1 m
3. USB A male to B male cable, length 2 m

Follow instructions for board hardware set-up:

1. Check the S12ZVM-MINIBRD jumper settings, see [Table 1-1](#), [Figure 1-3](#).
1. Connect BLDC motor, type LINUX 45ZWN24-90-B, with the S12ZVML-MINIBRD, pins JP1, JP2, JP3, see [Figure 1-1](#) and [Figure 5-1](#)
2. Connect the power supply cable with the S12ZVML-MINIBRD, J1 LIN connector
3. Connect the power supply cable with the 12 V / 4 A power supply. The red wire goes to the positive terminal, the black wire (white wire) goes to the negative terminal
4. Turn ON the power supply
5. Connect the PC and S12ZVML-MINIBRD terminal J9 with a USB2.0 cable, type A to B

5.4 MCU Code Download and Debug

Create an OSBDM download profile, see the CW 10.5 project “Run” tab “Debug configuration”. Go to the “Run” tab, choose “Debug” and download code to the S12ZVML MCU using the on-board OSBDM module. Once the code is downloaded, go to “Run” and select “Resume” to run the code in MCU.

5.5 Run and Stop Motor Using External Interface

The motor can be controlled using the J2 header. Run motor by placing the jumper short bar to J2, pin 1-2.

5.6 Control Motor Using FreeMASTER tool

The motor can be controlled using the FreeMASTER tool, see [Figure 5-2](#):

1. Go to CodeWarrior 10.5 “Run” folder and select “Disconnect” to release the board USB channel. The USB communication channel will be used by FreeMASTER tool now
2. Place jumper short bar J2, pins 2-3
3. Search for the USB virtual port in the PC Device Manager
4. Open the FreeMASTER control page “S12ZVML-MINIBRD_BLDC_Sensorless.pmp” located in the “S12ZVML-MINIBRD_BLDC_Sensorless_CW_IDE” folder
5. Go to the Project/Options comm tab and set the USB virtual port number, and the communication speed 9600 kBd, see [Figure 5-3](#)
6. Run the communication by pressing CTRL+K
7. Enter the required BLDC motor rotation speed in the “Required Speed RPM” variable, range from 1500 rpm to 8000 rpm at 12 V power supply
8. Run / Stop motor by variable “Turn ON/OFF”
9. Analyze motor behavior in the “Speed Scope” window
10. Monitor the DC BUS Voltage (module power supply voltage) and DC BUS Current (motor current)

For more information on BLDC sensorless applications, see AN4704 [7.].

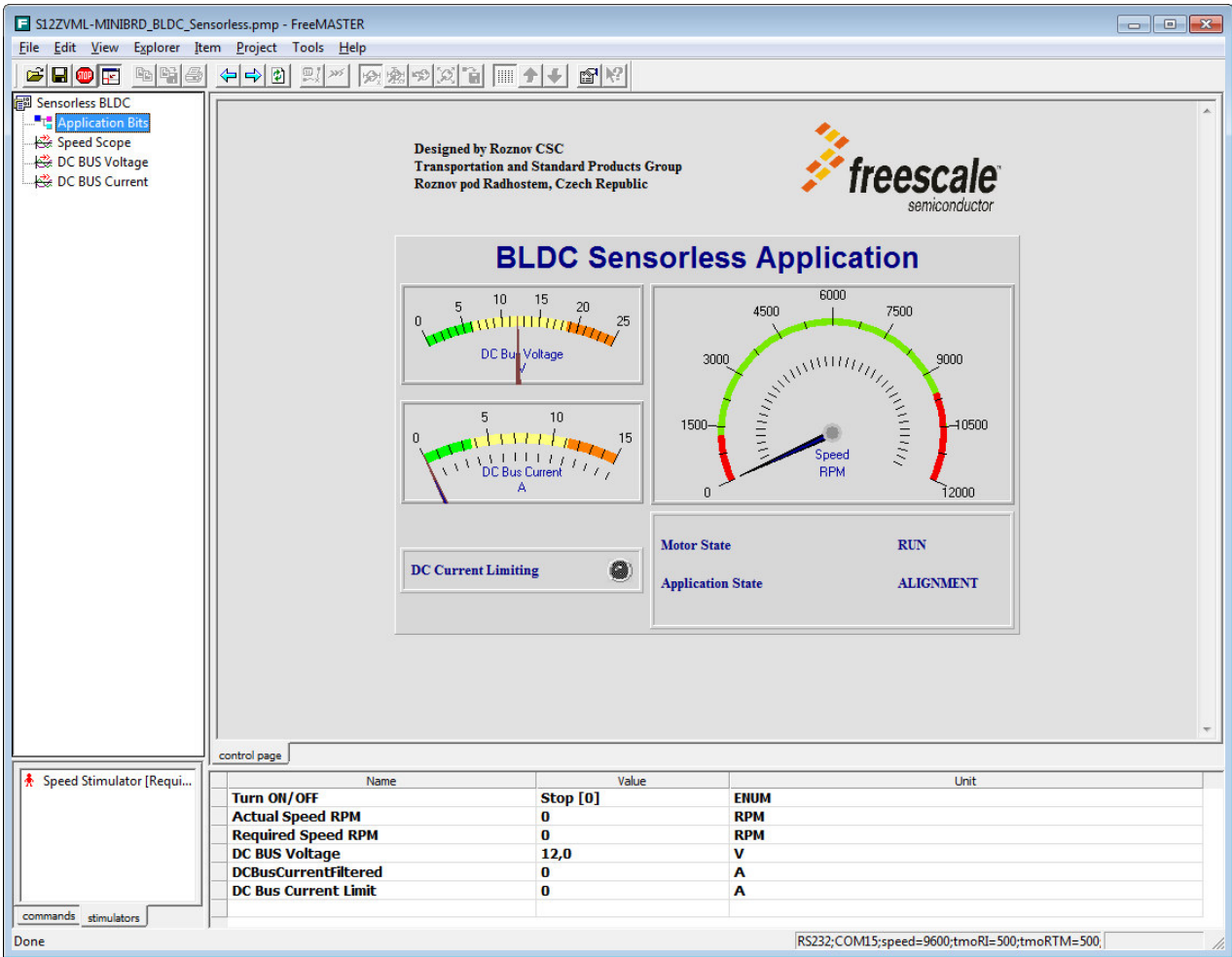


Figure 5-2. FreeMASTER control page

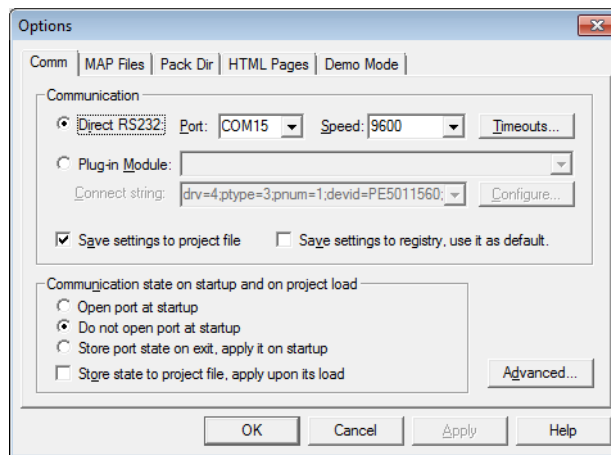


Figure 5-3. FreeMASTER options communication tab

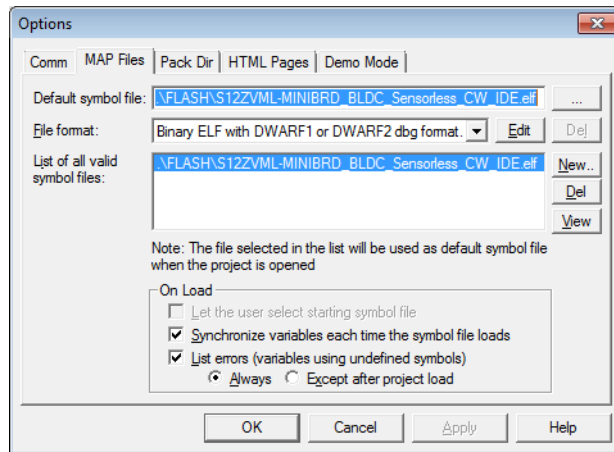


Figure 5-4. FreeMASTER options map file tab



Chapter 6 References

1. MagniV family web page, www.freescale.com/MagniV
2. S12ZVML-MINIBRD web page, www.freescale.com/S12ZVML-MINIBRD
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