

FR Family FR60 Lite  
32-BIT MICROCONTROLLER  
MB91F267N

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**bits pot red**  
**CAN-Motor board**

**User's Manual**

### Revision History

Date	Revision
August 01, 2008	Revision 1.0: Initial release
September 17, 2008	Revision 1.1 On p.12, type corrected. Correct: NL565050T-103J, Incorrect: L565050T-103J
October 22, 2008	Revision 1.2 On p.13, a download web page is changed. On p.20, "1.1.1 Downloading the software" is added. On p.25, p.30, p.36 and p.43, Description is corrected about the extracting file. The file path is added.
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## Introduction

Thank you very much for purchasing the bits pot red (referred to as this starter kit or the starter kit hereafter).

This starter kit is a beginner's kit intended for those who wish to start learning microcontrollers and on-board network processors. The kit is designed so that the beginners who ask "What is a microcontroller?", "How does it work?" and "How does it control a network?" can easily learn what it is.

The kit includes flash microcontroller development tools, so if you have slight understanding about the C language, you can rewrite a program to let the microcontroller perform in various ways. Even if you do not know of programming, you may be able to enjoy learning a microcontroller with a study-aid book about the C language.

This starter kit can also serve as an introductory training tool for electronic circuit practice or future embedded software development in a class of a college or high school of technology or training for freshman engineers of a manufacturer.

## Contact

For inquiries about this starter kit, contact the following address.



Zip code: 105-8420 2-5-3 Nishi-Shinbashi, Minatoku, Tokyo

E-mail: [pd-bitspot@tsuzuki-densan.co.jp](mailto:pd-bitspot@tsuzuki-densan.co.jp)

bits pot URL: <http://www.tsuzuki-densan.co.jp/bitspot/>

## Suppliers of the parts/materials



Capacitors	22 pF	: GCM1552C1H220JZ02
	0.1 $\mu$ F	: GCM188R11E104KA42
	1 $\mu$ F	: GCM21BR11E105KA42
	10 $\mu$ F	: GCM32ER71E106KA42
Ceramic oscillator		: CSTCR4M00G15C



NTC Thermistors		: NTCG164BH103JT1
Ferrite Beads		: MPZ2012S300AT
Common Mode Filters		: ZJYS81R5-2P24T-G01
Inductors		: NL565050T-103J

## 1 Setting up the starter kit

Before using this starter kit, be sure to check the components listed in Table 1-1 are fully supplied.

Before connecting the bits pot red CAN-Motor board (referred to as the board hereafter), you need to install software in your PC. You can download the software required for the starter kit from the following web site.

bits pot URL: <http://www.tsuzuki-densan.co.jp/bitspot/>

**Table 1-1 Component list**

No.	Article	Qty.	Specifications	Remarks
1	bits pot red CAN motor board 	1	Microcontroller made by Fujitsu FR Family FR60 Lite, MB91F267N mounted	See Figure 1-1
2	USB cable 	1	USB (A to miniB)	Accessory
3	BLDC Motor 	1	Tsukasa Electronic TG-22D-F539, 12 V	Accessory
4	AC adapter 	1	12 V, 1 A	Accessory Be sure to use the adapter included in the kit
5	Motor cable 	1	8-pin cable	Accessory
6	CAN cable 	1	3-pin cable	Accessory
7	PC	1	On which Windows XP normally runs and USB2.0 ports are supported	Prepare the PC by yourself.

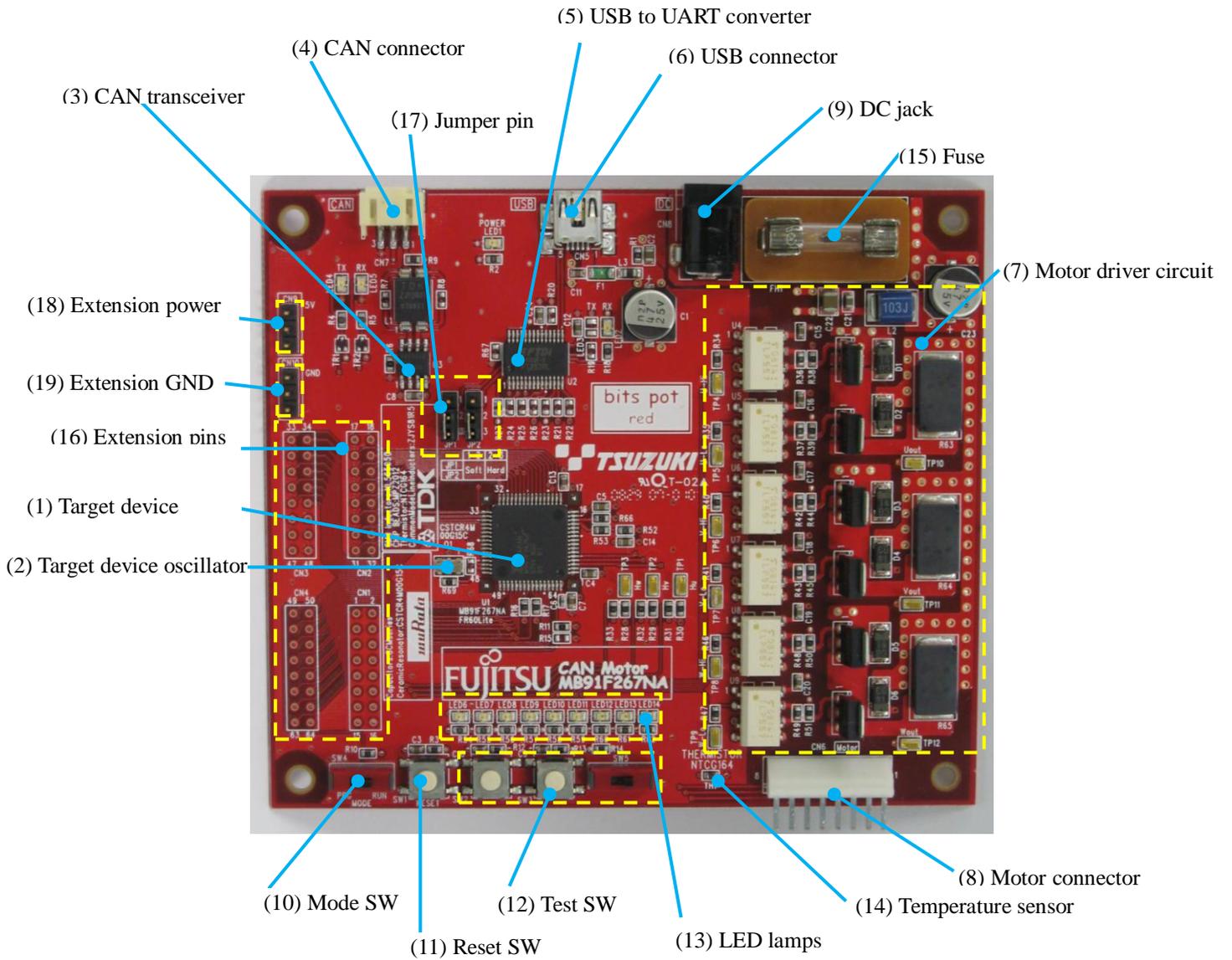


Figure 1-1 External board view

“Table 1-2 Description of the respective board parts” provides descriptions of the respective board parts.

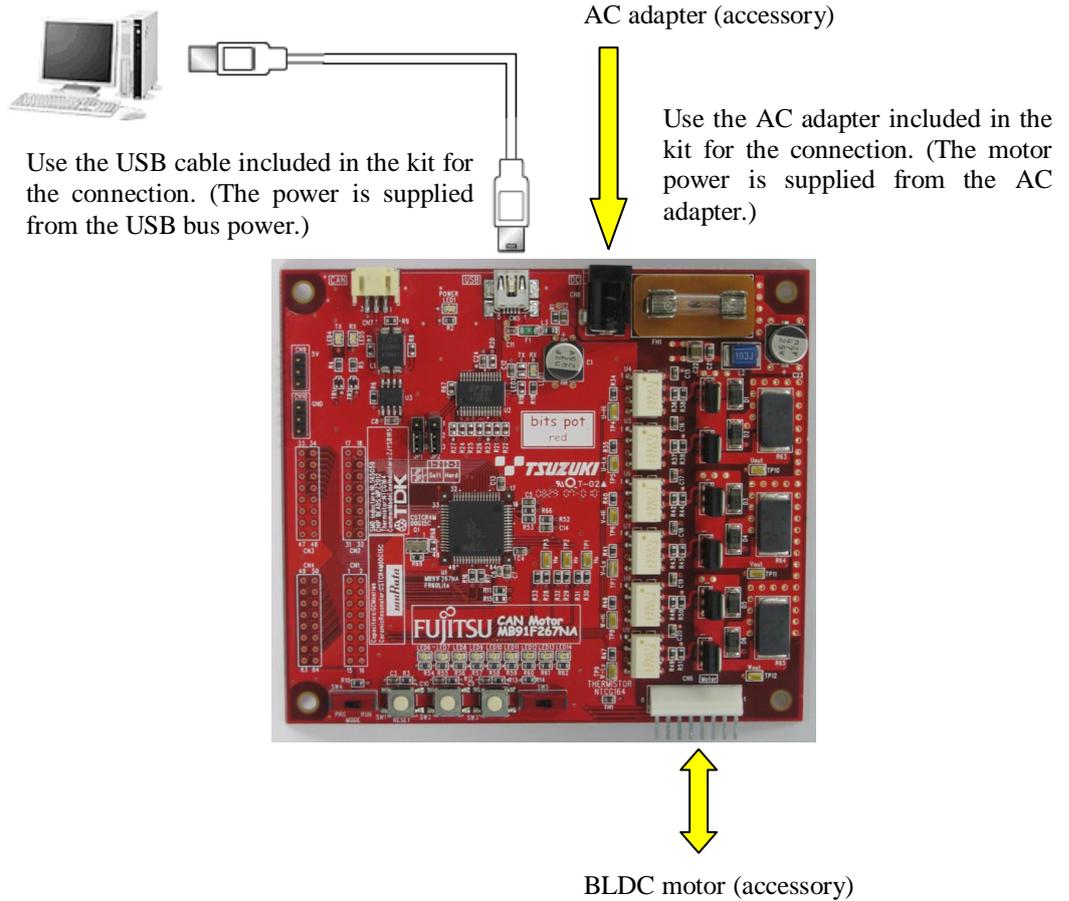
**Table 1-2 Description of the respective board parts**

No.	Name	Function	Description
(1)	Target device	MB91F267N	Main microcontroller (MB91F267N).
(2)	Target device oscillator	CSTCR4M00G15C	Ceralock made by Murata Manufacturing Oscillator for the main microcontroller.
(3)	CAN transceiver	MAX3058ASA+	Transceiver IC for CAN communication.
(4)	CAN connector	3-pin connector	Connector for CAN communication. Connect this connector to the CAN connector on the bits pot white.
(5)	USB to UART converter	FT232RL	IC for conversion between UART and USB.
(6)	USB connector	miniB	USB connector for connection with the PC to write/debug a program.
(7)	Motor driver circuit	3-phase motor driver circuit	Driver circuit for 3-phase motor operation by the main microcontroller.
(8)	Motor connector	8 pins	Connector for connection with the 3-phase motor included in the kit.
(9)	DC jack	-	Power connector for the operation of the motor.
(10)	Mode SW	Slide switch	Switch for selection of operation mode of the board.
(11)	Reset SW	Push switch	Switch to reset the board.
(12)	Test switches	Push switch x 2 Slide switch x 1	Connected to the general-purpose I/O port. The sample program uses this switch for motor rotation.
(13)	LED lamps	LED (green) x 6 LED (red) x 3	General-purpose LED lamps.
(14)	Temperature sensor	NTCG164BH103	NTC thermistor made by TDK Temperature sensor connected to the A/D converter.
(15)	Fuse	0217001P	Fuse for the 12-V power supply.
(16)	Extension pins	-	Extension pins of the main microcontroller. For details, see the circuit diagram.
(17)	Jumper pins (JP1, JP2)	-	Jumper pins for USB-UART conversion setting. UART communication handshake setting. 1-2: Handshake by software. 2-3: Handshake by hardware. The default setting is 2-3 (common to JP1/JP2).

(18)	Extension power (5V)	-	Extension 5-V power terminal.
(19)	Extension GND	-	Extension GND terminal.

“Figure 1-2 System connection diagram” shows the connection of the system.

\* Prepare the PC by yourself.



**Figure 1-2 System connection diagram**

Connect the PC with the board by using the USB cable included in the kit.

The power is supplied to the board from the USB bus power.

Directly connect the USB port to that on the PC. Do not make the connection via a USB hub.

“Table 1-3 MB91F267N pin assignment” shows the pin assignment of the main microcontroller MB91F267N.

**Table 1-3 MB91F267N pin assignment**

Pin No.	Description	Connected to:	Remarks
1	AVss	GND	
2	ACC	GND	
3	AN0/P50	Motor driver circuit	
4	AN1/P51	Motor driver circuit	
5	AN2/P52	Motor driver circuit	
6	AN3/P53	-	
7	AN4/P54	LED6	L output = On
8	AN5/P55	LED7	L output = On
9	AN6/P56	LED8	L output = On
10	AN7/P57	LED9	L output = On
11	AN8/P44	LED10	L output = On
12	AN9/P45	LED11	L output = On
13	AN10/P46	Thermistor	
14	NMI	5 V	
15	C	GND	
16	Vss	GND	
17	Vcc	5 V	
18	INT4/PPG1/P00	LED12	
19	PPG2/P01	LED13	
20	INT5/PPG3/P02	LED14	
21	TIN0/P03	-	
22	TIN1/P04	-	
23	TIN2/P05	-	
24	TOT1/P06	-	
25	TOT2/P07	-	
26	SOT0/P10	USB-UART conversion	
27	SIN0/P11	USB-UART conversion	
28	SCK0/P12	-	
29	SOT1/P13	-	
30	SIN1/P14	-	
31	SCK1/P15	-	

32	INT6/PPG5/RX0/P16	CAN TRANSCEIVER	
33	PPG6/TX0/P17	CAN TRANSCEIVER	
34	ADTG1/IC2/P20	Motor driver circuit	Hall W-phase
35	ADTG2/IC3/P21	-	
36	PWI0/P22	-	
37	DTTI/P23	-	
38	CKI/P24	-	
39	IC0/P25	Motor driver circuit	Hall U-phase
40	IC1/P26	Motor driver circuit	Hall V-phase
41	P27	SW5	
42	PPG0/PG1	-	
43	MD2	SW4	
44	MD1	GND	
45	MD0	GND	
46	X0	Q1	4-MHz oscillator
47	X1	Q1	4-MHz oscillator
48	V <sub>ss</sub>	GND	
49	PPG4/P37	-	
50	INT7/PPG7/P36	-	
51	$\overline{\text{INIT}}$	RESET(SW1)	
52	RTO5/P35	Motor driver circuit	W-phase Low
53	RTO4/P34	Motor driver circuit	W-phase High
54	RTO3/P33	Motor driver circuit	V-phase Low
55	RTO2/P32	Motor driver circuit	V-phase High
56	RTO1/P31	Motor driver circuit	U-phase Low
57	RTO0/P30	Motor driver circuit	U-phase High
58	INT0/P40	SW2	SW pressed = L
59	INT1/P41	SW3	SW pressed = L
60	INT2/P42	USB-UART conversion	
61	INT3/P43	USB-UART conversion	
62	AVRH1	5 V	
63	AVRH2	5 V	
64	AV <sub>cc</sub>	5 V	

## 1.1 Setting up the PC

Install the software required to operate this starter kit into the PC.

To set up the PC, take the following procedures.

- (1) Downloading the software
- (2) Installing a USB driver
- (3) Installing the integrated development environment SOFTUNE (function-limited version)
- (4) Installing PC Writer FUJITSU FLASH MCU Programmer (bits pot red dedicated version)
- (5) Configuring the evaluation board and connecting it to the PC

### 1.1.1 Downloading the software

Download the file from the following web site, and extract the file.

bits pot URL : <http://www.tsuzuki-densan.co.jp/bitspot/>

### 1.1.2 Installing a USB driver

Install a USB driver.

From the FTDI web page shown below, download the Windows driver as directed in “Figure 1-3 Downloading the USB driver”.

<http://www.ftdichip.com/Drivers/D2XX.htm>

Future Technology Devices International Ltd.  
USB Device Solutions ASIC Design Product Design

Home  
Products  
Drivers  
VCP  
D2XX  
3rd Party Drivers  
Documents  
Resources  
Projects  
Support  
Knowledgebase  
Sales Network  
Web Shop  
Design Services  
Corporate  
Press  
FTDI Newsletter  
Contact

**D2XX Direct Drivers**  
This page contains the D2XX drivers currently available for FTDI devices.  
For Virtual COM Port (VCP) drivers, please click [here](#).  
Installation guides are available from the [Installation Guides](#) page of the [Documents](#) section of this site for selected operating systems.

**D2XX Drivers**  
D2XX drivers allow direct access to the USB device through a DLL. Application software can access the USB device through a series of DLL functions available are listed in the [D2XX Programmer's Guide](#) document which is available from the [Documents](#) section of this site.  
Programming examples using the D2XX drivers and DLL can be found in the [Projects](#) section of this site.

Operating System	Devices Supported	Driver Version	Release Date	Comments
Windows Server 2008 Windows Server 2008 x64 Windows Vista Windows Vista x64 Windows XP Windows XP x64 Windows 2000 Windows Server 2003 Windows Server 2003 x64	FT232R, FT245R, FT2232, FT232B, FT245B, FT8U232AM, FT8U245AM	<a href="#">2.04.06</a>	5th March 2008	Microsoft WHQL certified. Also available as a <a href="#">setup executable</a> for default VID and PID values. For custom VID and PID combinations see <a href="#">AN232R-03</a> . Combined driver model (D2XX and VCP). Devices programmed as VCP will expose a COM port, as will AM and BM devices. <a href="#">Release Notes</a>
Windows 98 Windows ME	FT232R, FT245R, FT2232, FT232B, FT245B, FT8U232AM, FT8U245AM	<a href="#">3.01.04</a>	21st December 2005	No longer actively supported. Not Microsoft WHQL certified.
Mac OS X (Intel)	FT232R, FT245R, FT2232, FT232B, FT245B, FT8U232AM, FT8U245AM	<a href="#">0.1.4</a>	6th August 2008	<b>Requires Mac OS X 10.4 (Tiger) or later.</b> Customers who wish to use their own VID and PID with this driver should contact <a href="#">FTDI Support</a> with their requirement.
Mac OS X	FT232R, FT245R, FT2232, FT232B, FT245B, FT8U232AM, FT8U245AM	<a href="#">0.1.4</a>	6th August 2008	<b>Requires Mac OS X 10.3 (Panther) or later.</b> Customers who wish to use their own VID and PID with this driver should contact <a href="#">FTDI Support</a> with their requirement.
Linux	FT232R, FT245R, FT2232, FT232B, FT245B, FT8U232AM, FT8U245AM	<a href="#">0.4.13</a>	11th January 2007	Instructions in <a href="#">ReadMe</a> file.
Windows CE 5.0	FT232R, FT245R, FT2232, FT232B			Windows CE 5.0 required. Please note that FTDI devices will not

**Figure 1-3 Downloading the USB driver**

After downloading the driver, decompress it, and then connect the board to the PC by using the USB cable included in the kit. As shown in “Figure 1-4 Installing FT232R USB UART”, the dialog for “FT232R USB UART” installation is displayed; select “Install from a list or specific location”, and then click the “Next” button.



**Figure 1-4 Installing FT232R USB UART**

As shown in “Figure 1-5 Selecting the search locations”, to search for the installation file, check “Search for the best driver in these locations” and “Include this location in the search” only, select the location at which the driver was decompressed, and then click the “Next” button; installation of the driver starts.



**Figure 1-5 Selecting the search locations**

When the driver installation ends, the dialog shown in “Figure 1-6 Completing the USB Serial Converter ” is displayed; click the “Finish” button.



**Figure 1-6 Completing the USB Serial Converter installation**

After that, as shown in “Figure 1-7 Installing USB Serial Port”, installation of “USB Serial Port” is indicated; select “Install from a list or specific location” and then click the “Next” button.



Figure 1-7 Installing USB Serial Port

As shown in “Figure 1-8 Selecting the search locations”, to search for the installation file, check “Search for the best driver in these locations” and “Include this location in the search” only, select the location at which the driver was decompressed, and then click the “Next” button; installation of the driver starts.

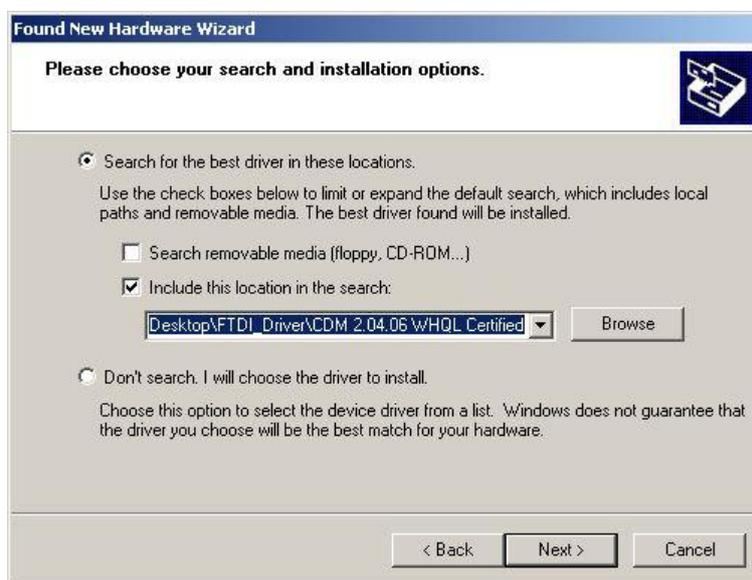


Figure 1-8 Selecting the search locations

When the driver installation ends, the dialog shown in “Figure 1-9 Completing the USB Serial Port installation” is displayed; Click the “Finish” button.



**Figure 1-9 Completing the USB Serial Port installation**

1.1.3 Installing the integrated development environment SOFTUNE (bits pot dedicated version)

**Note**

**If SOFTUNE V6 of the product version has been installed, first uninstall it, and then install the bits pot dedicated version.**

Start installing the integrated development environment SOFTUNE. Extract the following file from the inside of the folder extracted by “1.1.1 Downloading the software”.

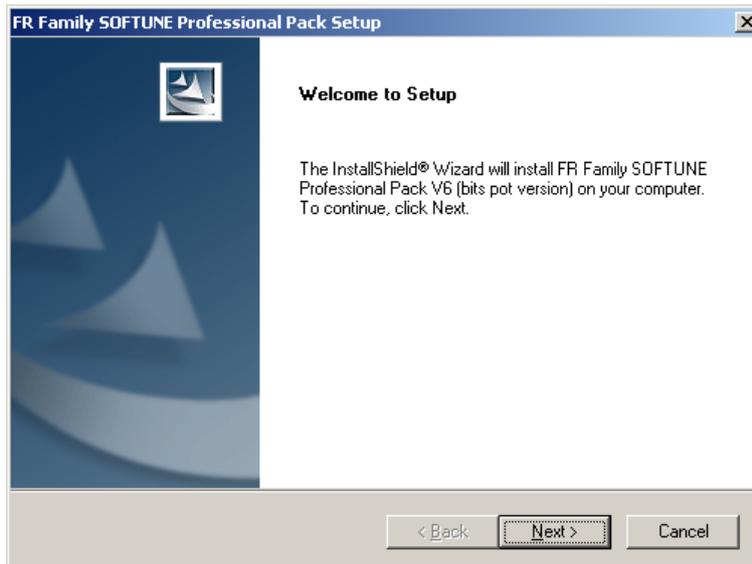
¥softwares¥softune¥REV600010-BV.zip

Double-click “Setup.exe” in the decompressed folder; the dialog shown in “Figure 1-10 SOFTUNE setup confirmation” is displayed. Click the “OK” button.



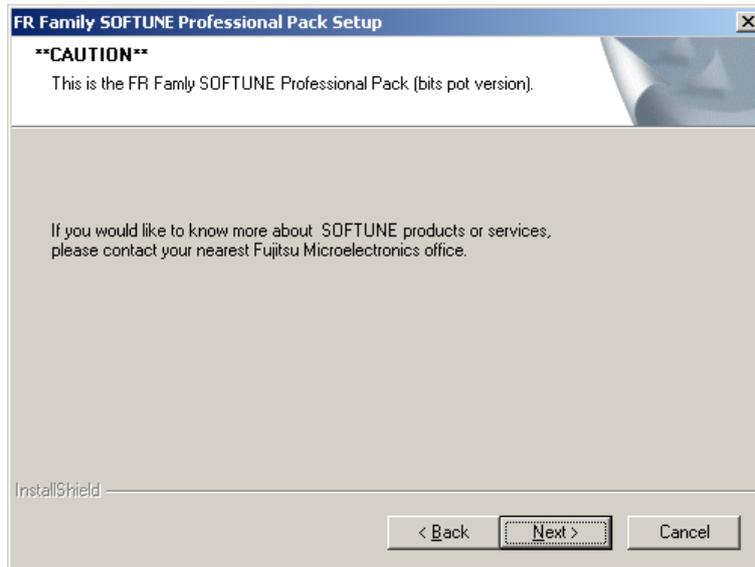
**Figure 1-10 SOFTUNE setup confirmation**

The setup wizard shown in “Figure 1-11 Starting SOFTUNE setup” is displayed; click the “Next” button.



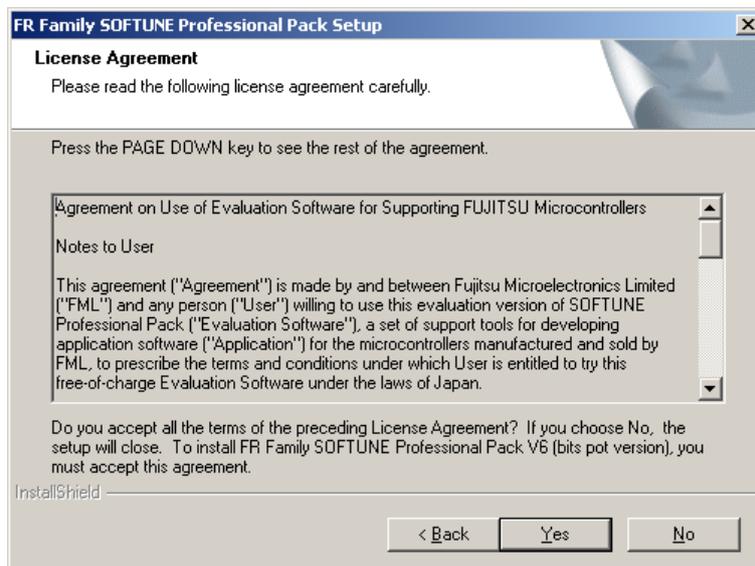
**Figure 1-11 Starting SOFTUNE setup**

The dialog shown in “Figure 1-12 Caution on SOFTUNE setup” is displayed; click the “Next” button.



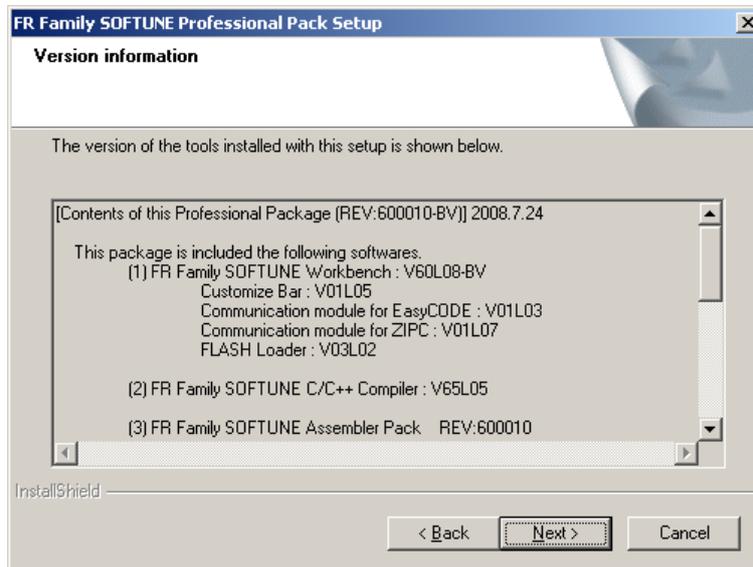
**Figure 1-12 Caution on SOFTUNE setup**

The dialog shown in “Figure 1-13 SOFTUNE setup/License agreement” appears; read through the agreements and then click “Yes” button.



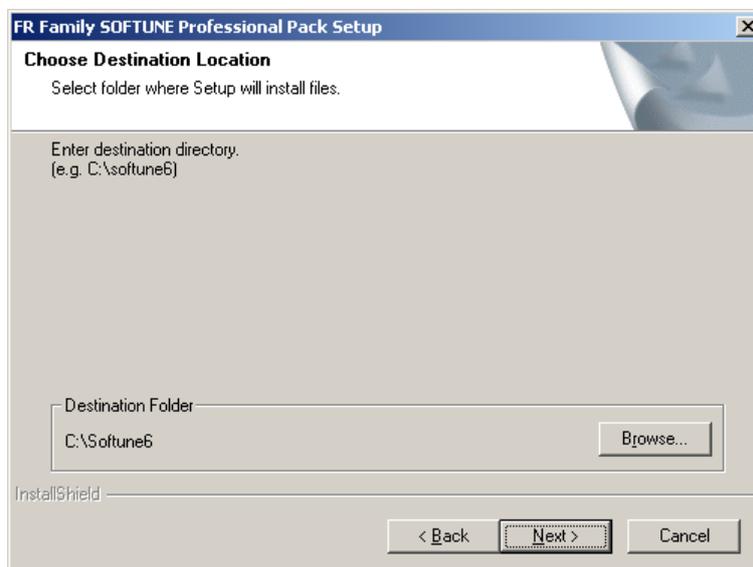
**Figure 1-13 SOFTUNE setup/License agreement**

The version information is displayed as shown in “Figure 1-14 SOFTUNE setup/Version ”; click the “Next” button.



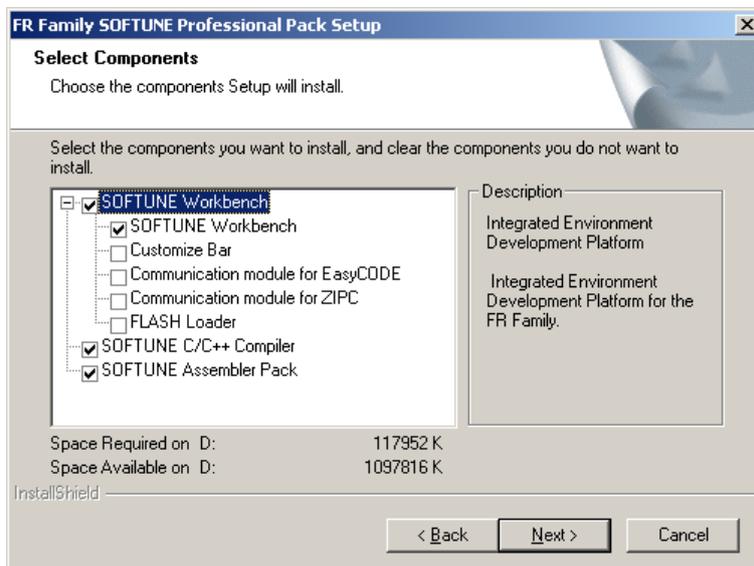
**Figure 1-14 SOFTUNE setup/Version information**

The dialog about the destination of installation shown in “Figure 1-15 SOFTUNE setup/Selecting the destination of installation” appears; select the default folder or desired folder and then click the “Next” button.



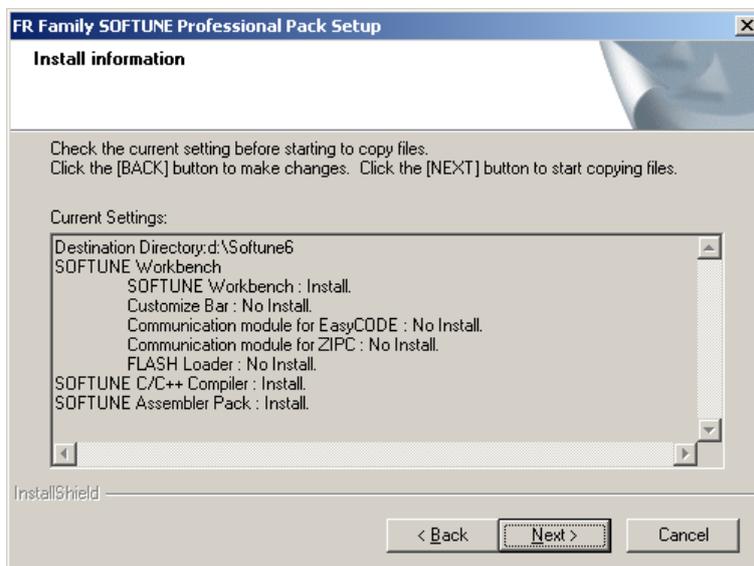
**Figure 1-15 SOFTUNE setup/Selecting the destination of installation**

The dialog for component selection is displayed as shown in “Figure 1-16 SOFTUNE setup/Selecting the components”; keep the default settings and then click the “Next” button.



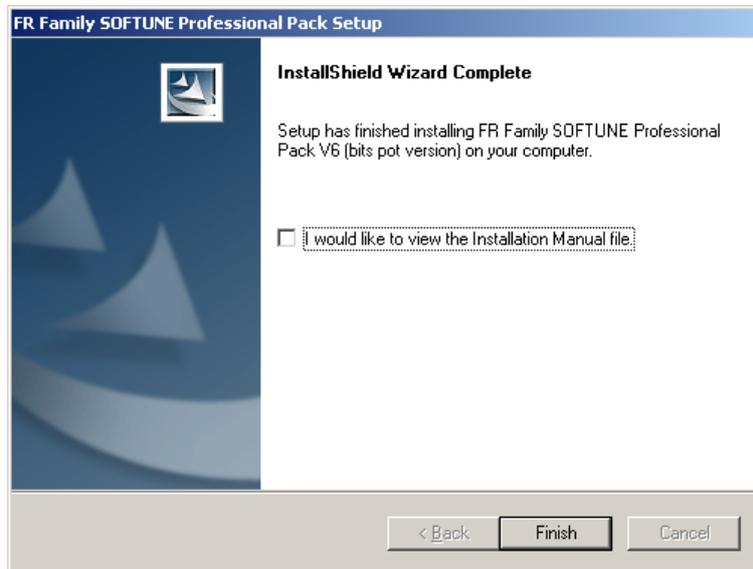
**Figure 1-16 SOFTUNE setup/Selecting the components**

As shown in “Figure 1-17 SOFTUNE setup/Confirming the installation settings”, the dialog for confirmation of the installation settings is displayed. Click the “Next” button; installation begins.



**Figure 1-17 SOFTUNE setup/Confirming the installation settings**

The dialog shown in “Figure 1-18 SOFTUNE setup/Completion” appears to tell the completion of installation; click the “Finish” button.



**Figure 1-18 SOFTUNE setup/Completion**

#### 1.1.4 Installing PC Writer (bits pot red dedicated version)

Start installing PC Writer. Confirm the following file from the inside of the folder extracted by “1.1.1 Downloading the software”.

¥softwares¥pc writer¥MB91F267NA\_setup.exe

Double-click “MB91F267NA\_setup.exe”; the dialog shown in “Figure 1-19 PC Writer/Installation dialog” appears and installation starts; click the “Next” button.

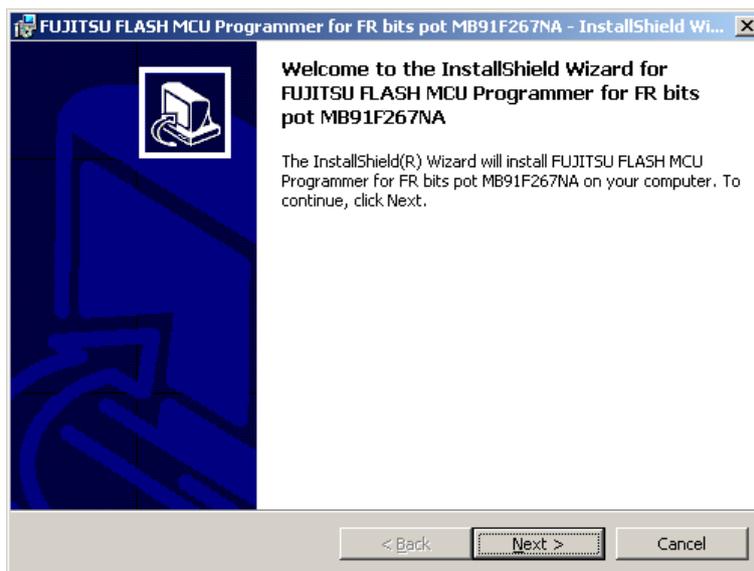
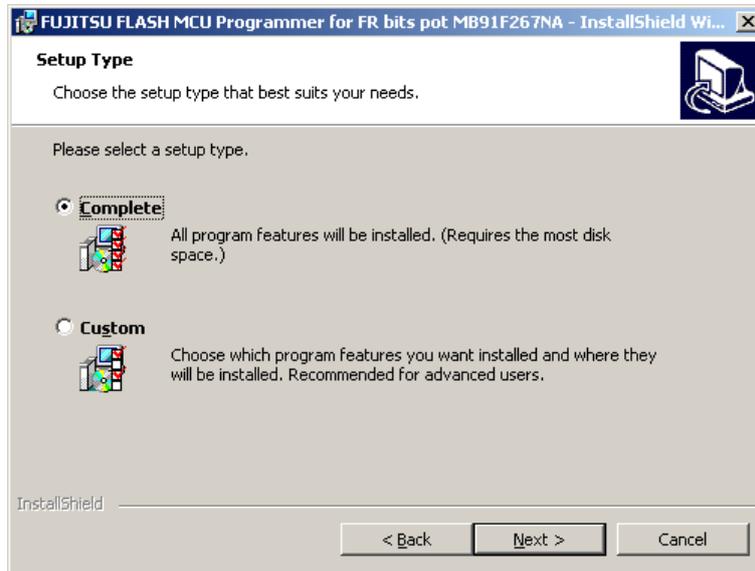


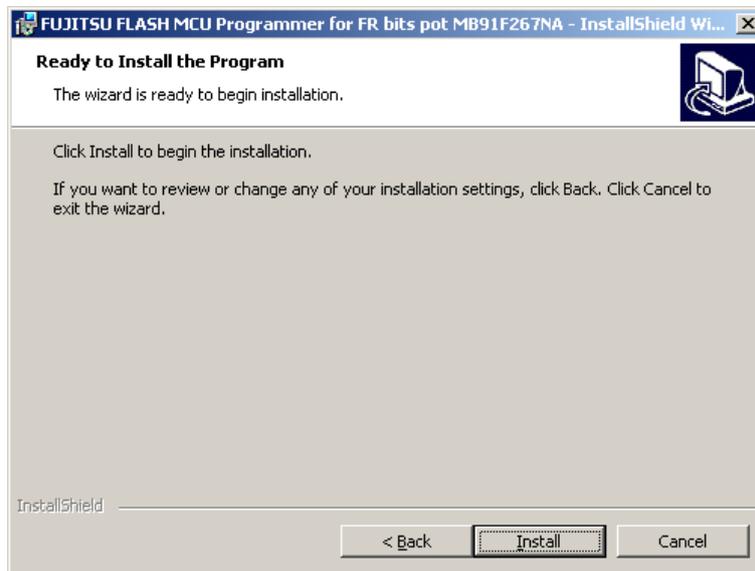
Figure 1-19 PC Writer/Installation dialog

The dialog shown in “Figure 1-20 PC Writer/Setup type” appears; select “All”, and then click the “Next” button.



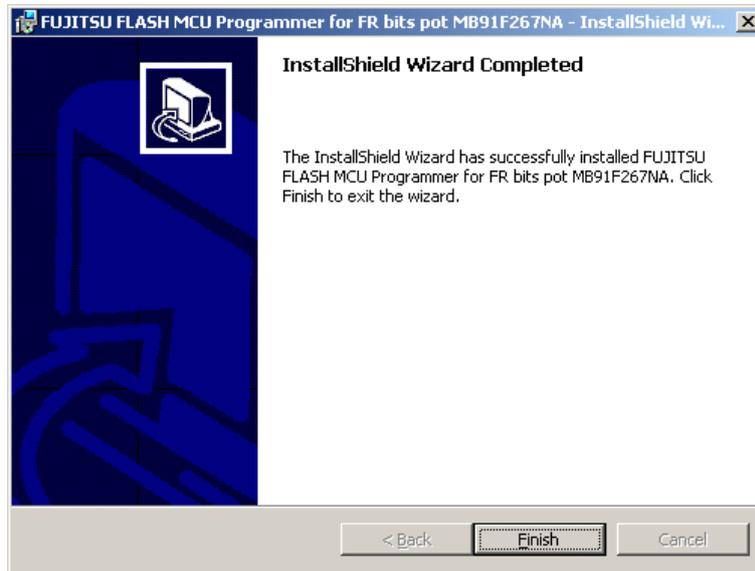
**Figure 1-20 PC Writer/Setup type**

The dialog shown in “Figure 1-21 PC Writer/Ready to install” appears to tell that the setup is ready to install PC Writer; click “Install”.



**Figure 1-21 PC Writer/Ready to install**

After the installation ends, the dialog shown in “Figure 1-22 Completing the PC Writer ” appears to tell the completion of installation; click “Finish”.



**Figure 1-22 Completing the PC Writer installation**

1.1.5 Configuring the evaluation board and connecting it to the PC

After SOFTUNE installation, configure a switch on the board and then connect it to the PC.

Set the “MODE” selector on the board to “PRG”.

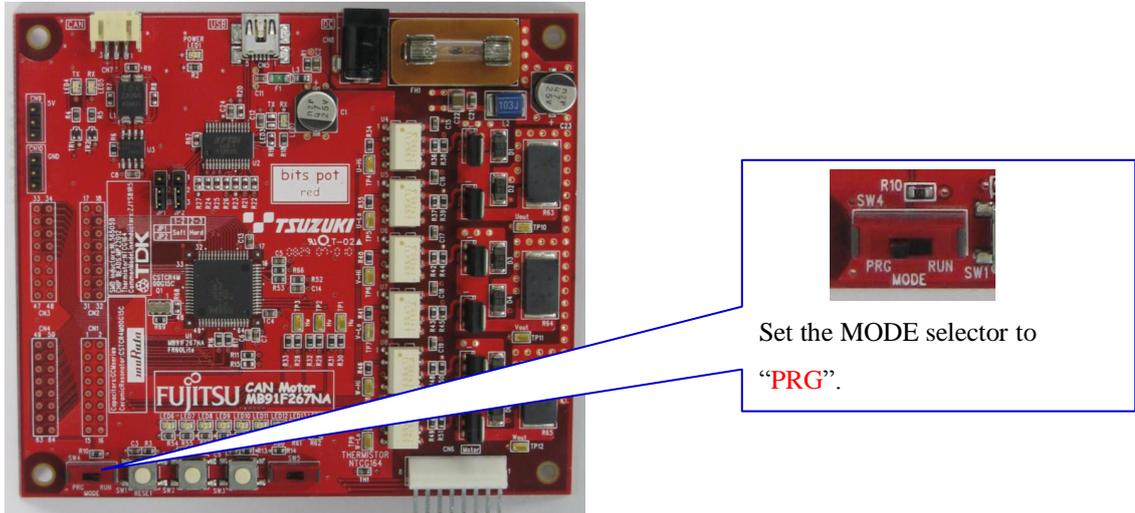


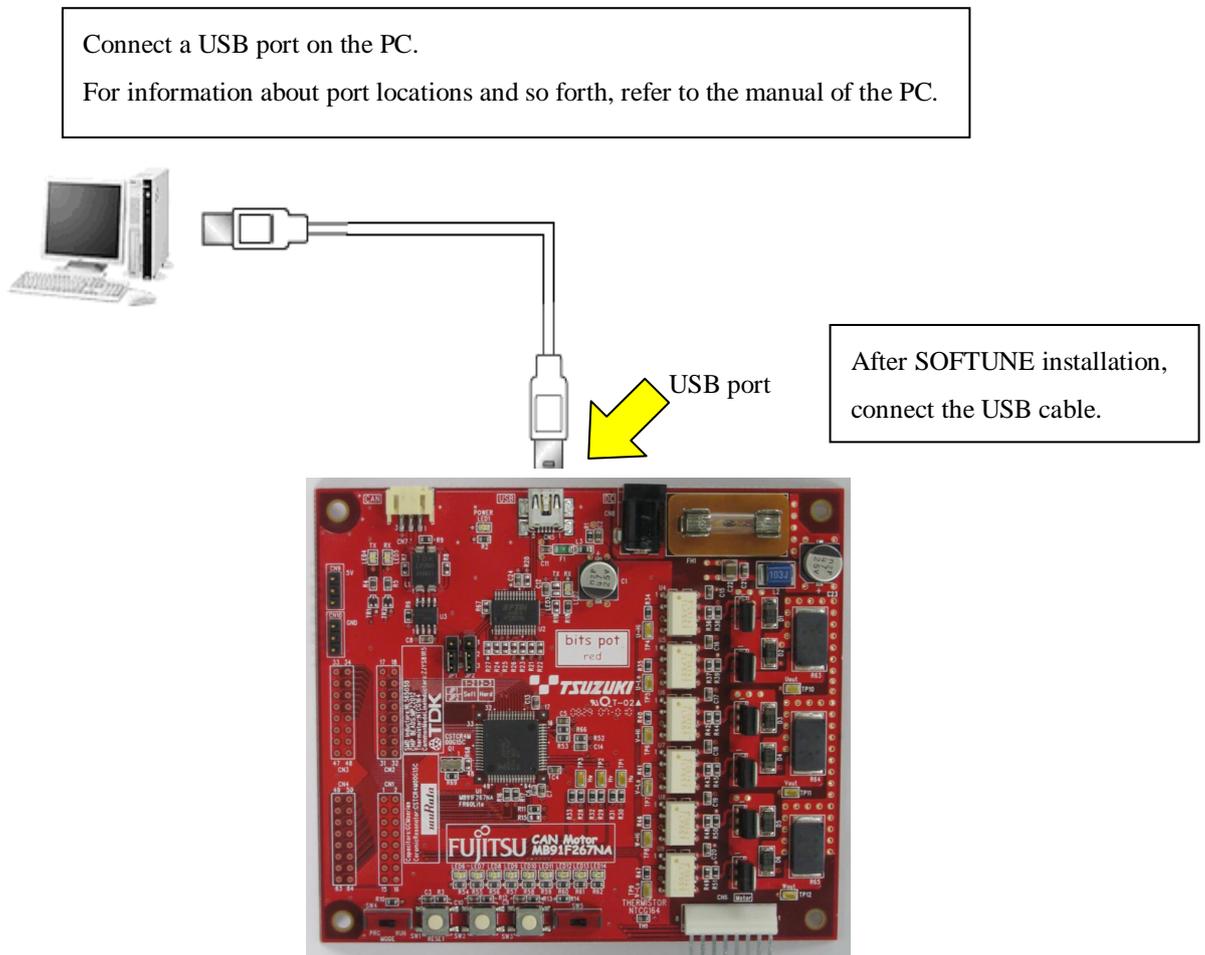
Figure 1-23 MODE selection

MODE selector	Operation
PRG	FLASH memory serial write mode →Used to write a program into the microcontroller.
RUN	Single ship mode →Used to run the program written into it.

Make sure that the MODE selector is set to “PRG”.

Then, connect it to the PC.

Connect the USB cable included in the kit to a USB port on the PC and the USB port on the board. Be sure to directly connect between them without using a USB hub.



**Figure 1-24 Connection between the PC and the board**

The power of the board is supplied via USB (USB bus power).

[Note]

If a driver installation dialog is displayed after connecting the board to the PC, USB drivers may be incorrectly installed.

Install drivers according to the USB driver installation manual.

## 2 Running the program

To run a program with the starter kit, take either of the following procedures.

- (1) Executing in single chip mode                      Go to P.36
- (2) Debugging by using Monitor Debugger              Go to P.43

## 2.1 Executing in single chip mode

In single chip mode, take the following procedures.

- (1) Building a project
- (2) Writing the program into the microcontroller

### 2.1.1 Building a project

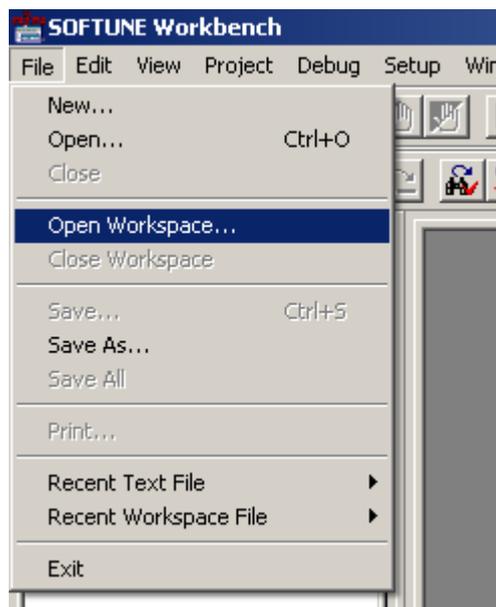
#### Preparation

Extract the following file from the inside of the folder extracted by “1.1.1 Downloading the software”.

¥sample programs¥bitpot\_red\_SampleProgram.zip

Select “Start” → “All Programs” → “Softune V6” → “FR Family Softune Workbench” to activate SOFTUNE.

As shown in “Figure 2-1 Opening a workspace”, select the menu of SOFTUNE, “File” and then “Open Workspace” to open a workspace.



**Figure 2-1 Opening a workspace**

As shown in “Figure 2-2 Selecting a workspace”, the dialog that allows you to select a workspace is displayed. Select the folder containing the sample program, select the workspace of “bitpot\_red\_SampleProgram.wsp”, and then click “Open”.

¥bitpot\_red\_SampleProgram¥bitpot\_red\_SampleProgram.wsp

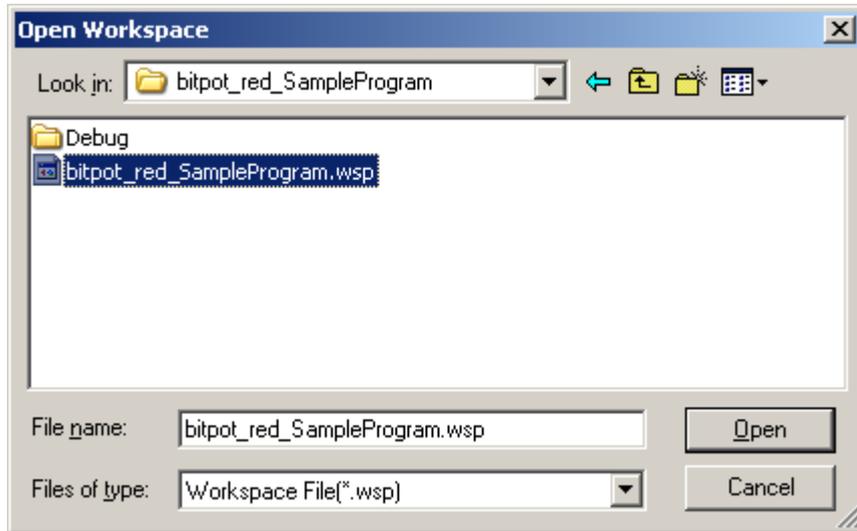


Figure 2-2 Selecting a workspace

The workspace opens; from the “project” menu, click “Build” to build it.

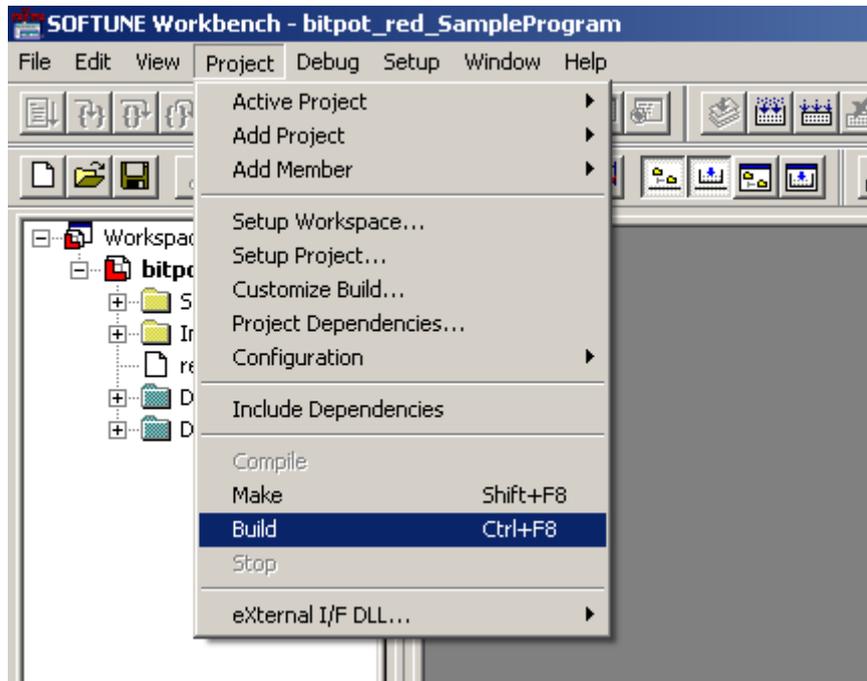


Figure 2-3 Building a project

The message pane at the bottom of the window shows a message that tells no error was found as shown in “Figure 2-4 Completing the build” to inform you of successful build.

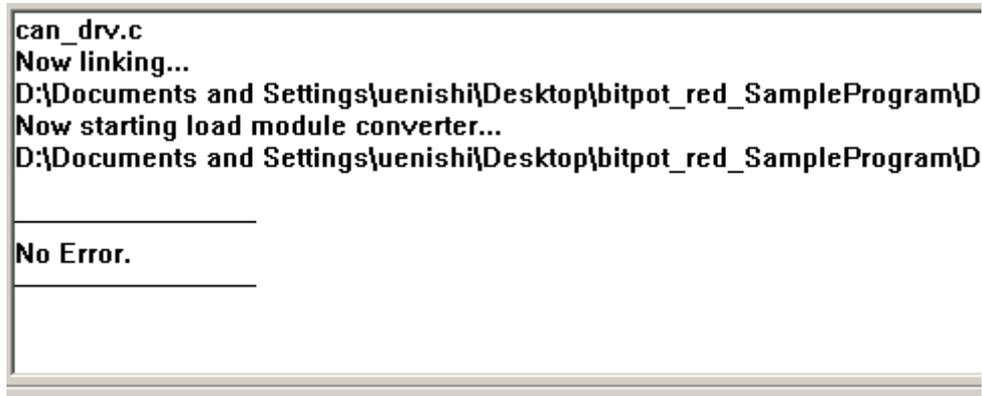


Figure 2-4 Completing the build

### 2.1.2 Writing the program into the microcontroller

#### Preparation

Set MODE on the board to “PRG” in advance.

Select “Start” → “All Programs” → “FUJITSU FLASH MCU Programmer” → “MB91F267NA” to activate PC Writer.

To select a file to be written as shown in “Figure 2-5 Opening the file to write”, click the “Open” button.

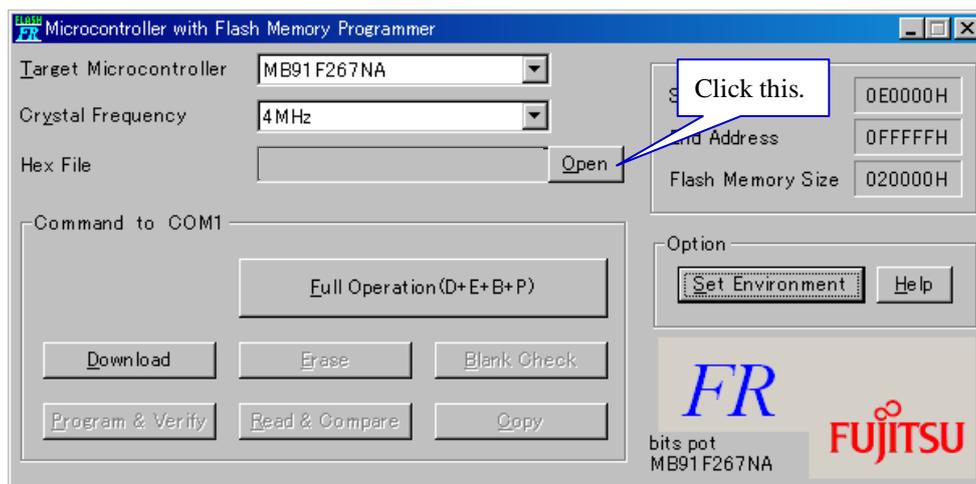
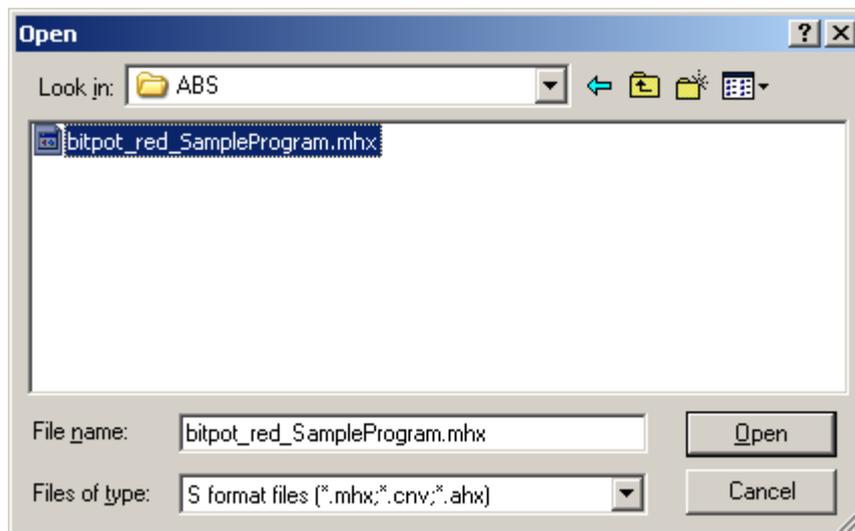


Figure 2-5 Opening the file to write

The dialog that allows you to select the file is displayed as shown in “Figure 2-6 Selecting the file to write”; select the file built in “2.1.1 Building a project” and then click “Open”.

¥bitpot\_red\_SampleProgram¥Debug¥ABS¥bitpot\_red\_SampleProgram.mhx



**Figure 2-6 Selecting the file to write**

Then, select the COM port to be used for the writing. Click the “Set Environment” button; the COM port selection dialog appears. Select the COM port with which the board is connected, and then click the “OK” button.

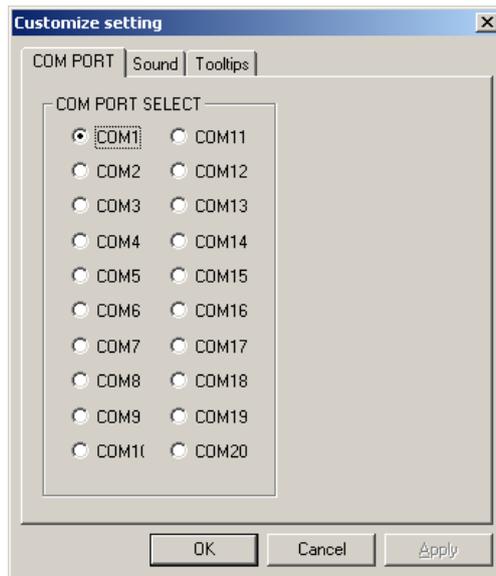
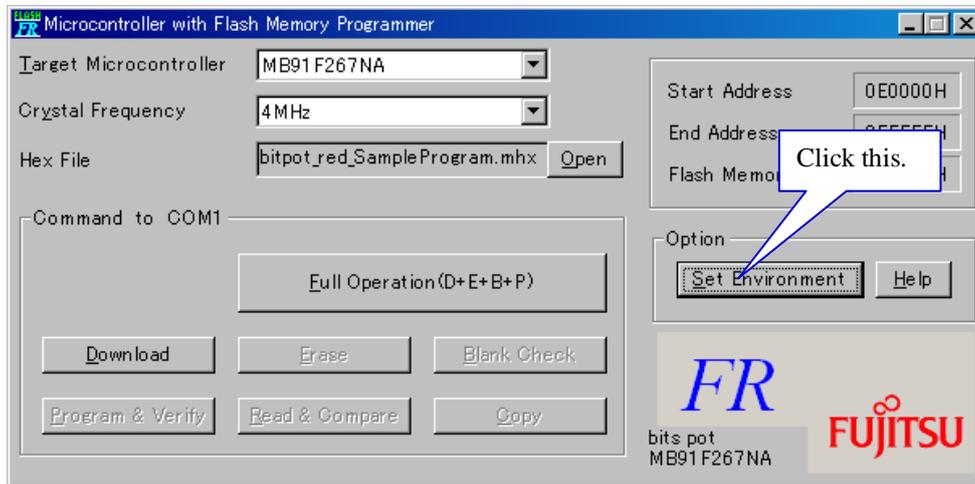


Figure 2-7 Select the COM port to be used for the writing

To check the COM port in use, right-click “My Computer” and then select “Properties”; the system properties are displayed. Select the “Hardware” tab and then click the “Device Manager” button.

After Device Manager activates, check the COM port number in the parentheses of “USB Serial Port (COM n)” under “Port (COM and LPT)” in the tree shown in “Figure 2-8 Checking the COM port”.

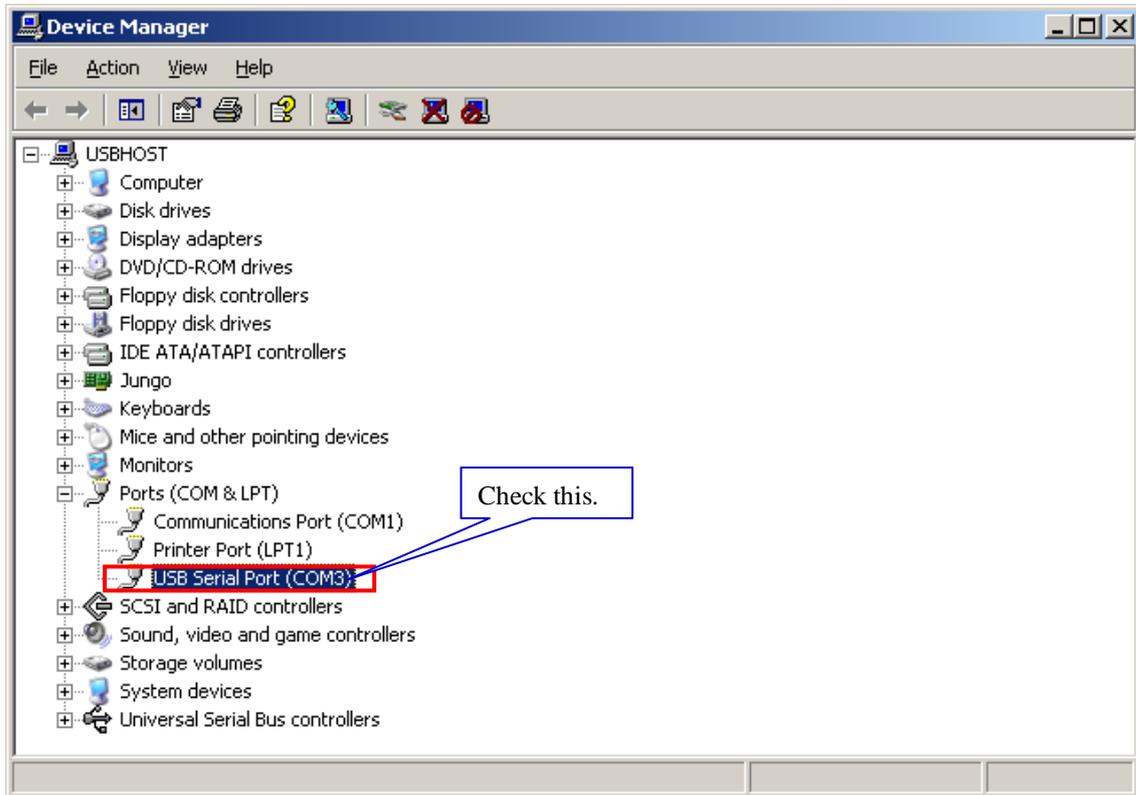
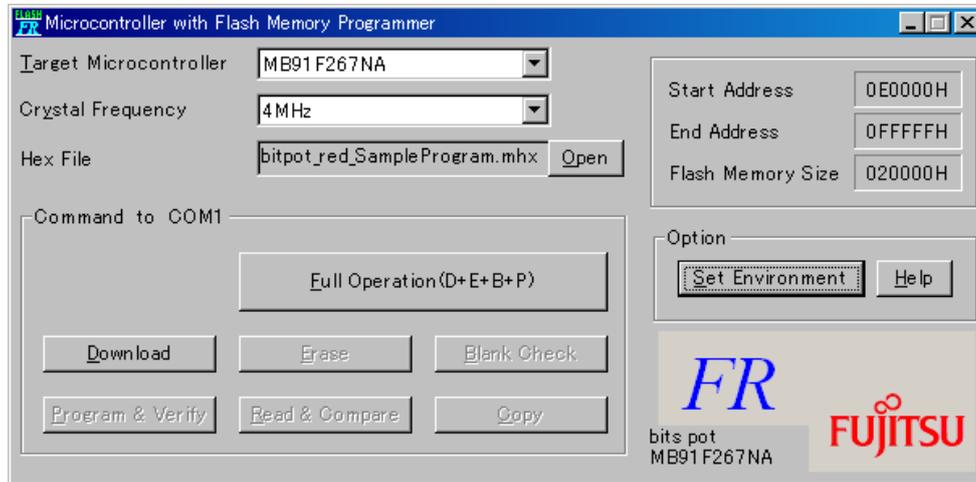


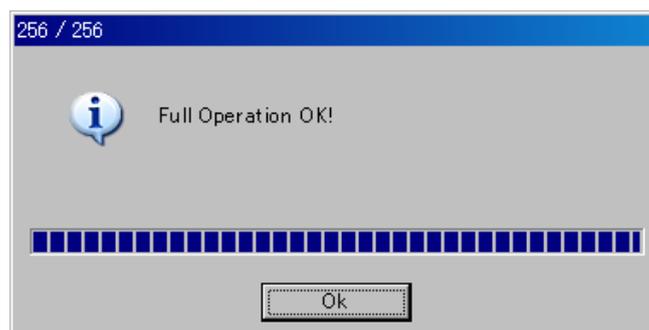
Figure 2-8 Checking the COM port

As shown in “Figure 2-9 Writing the program”, press the “Full Operation” button to start writing the program; the dialog that asks you to press the Reset switch is displayed. Press the Reset SW on the board, and then click the “OK” button on the dialog; the program write sequence starts. For the location of the Reset SW, see “Figure 1-1 External board view”.



**Figure 2-9 Writing the program**

The dialog shown in “Figure 2-10 Completing the program writing” is displayed to notify you of the completion of the program writing; press the “OK” button to quit PC Writer.



**Figure 2-10 Completing the program writing**

Set the MODE switch on the board to “RUN” and then press the Reset button; the program starts running.

## 2.2 Debugging by using Monitor Debugger

To debug by using Monitor Debugger, take the following procedures.

- (1) Writing Monitor Debugger into the microcontroller
- (2) Activating SOFTUNE and configuring the debug settings
- (3) Writing the program into the microcontroller
- (4) Loading the target file
- (5) Running the debugger

### 2.2.1 Writing Monitor Debugger into the microcontroller

#### Preparation

Extract the following file from the inside of the folder extracted by “1.1.1 Downloading the software”.

¥sample programs¥bitpot\_red\_SampleProgram\_md\_set.zip

Select “Start” → “All Programs” → “FUJITSU FLASH MCU Programmer” → “MB91F267NA” to activate PC Writer.

As shown in “Figure 2-11 Opening the file to write”, to select a file to be written, click the “Open” button.

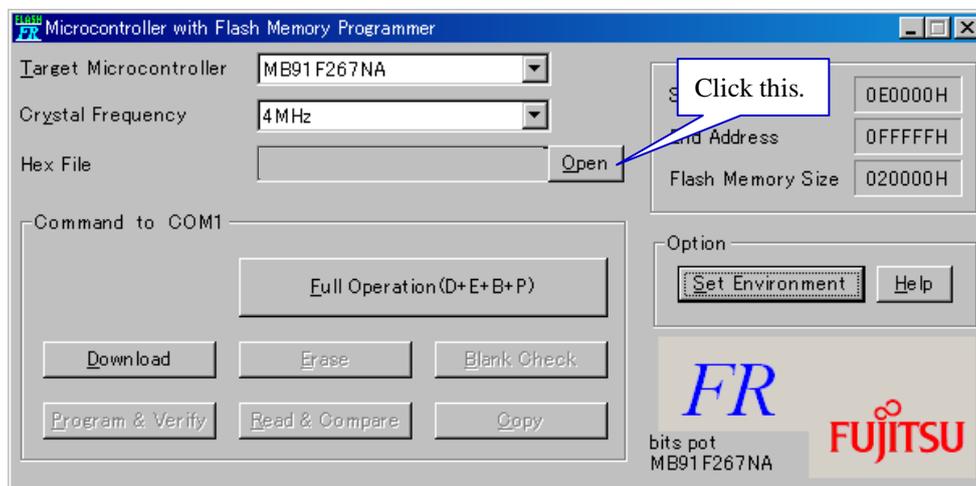
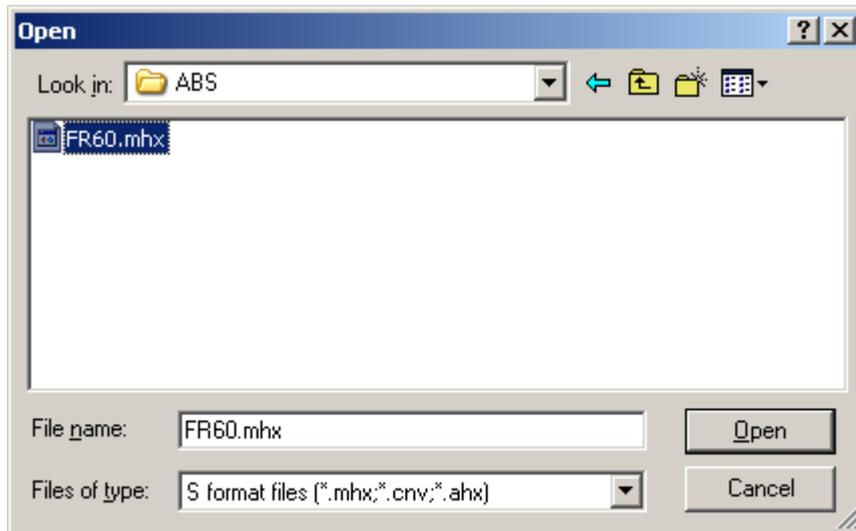


Figure 2-11 Opening the file to write

As shown in “Figure 2-12 Selecting the file to write”, the dialog that allows you to select the file to write appears; select the file as shown below, and then click “Open”.

¥FR60¥Debug¥ABS¥FR60.mhx



**Figure 2-12 Selecting the file to write**

Then, select the COM port to be used for the writing. Click the “Set Environment” button; the COM port selection dialog appears. Select the COM port with which the board is connected, and then click the “OK” button.

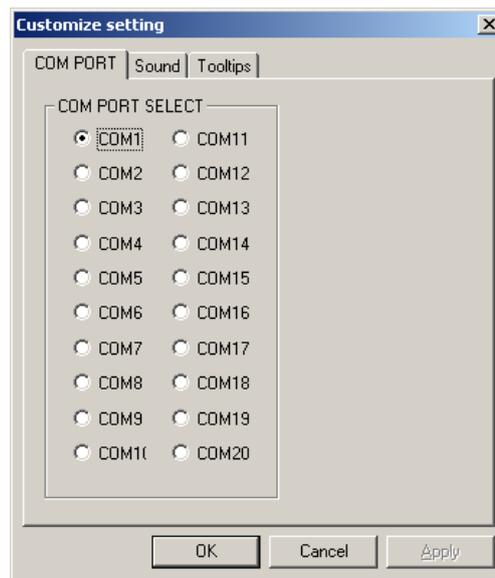
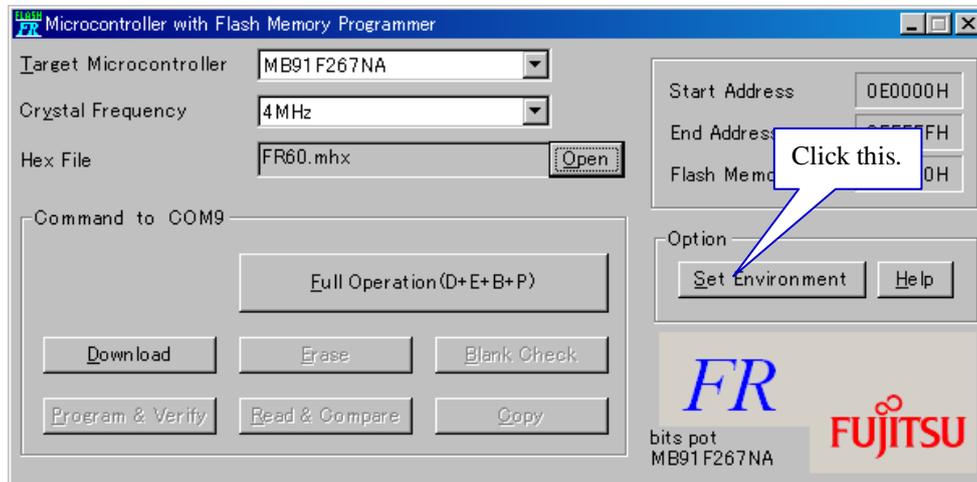


Figure 2-13 Select the COM port to be used for the writing

To check the COM port in use, right-click “My Computer” and then select “Properties”; the system properties are displayed. Select the “Hardware” tab and then click the “Device Manager” button.

After Device Manager activates, check the COM port number in the parentheses of “USB Serial Port (COM n)” under “Port (COM and LPT)” in the tree shown in “Figure 2-14 Checking the COM port”.

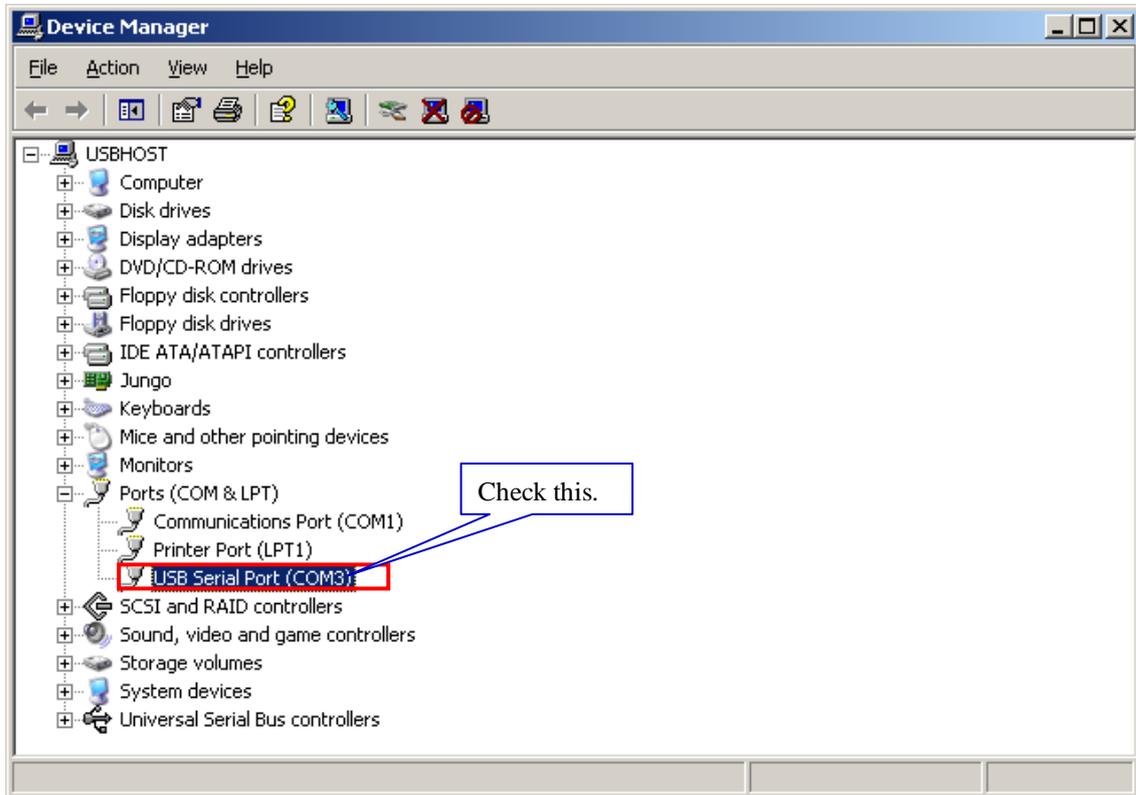
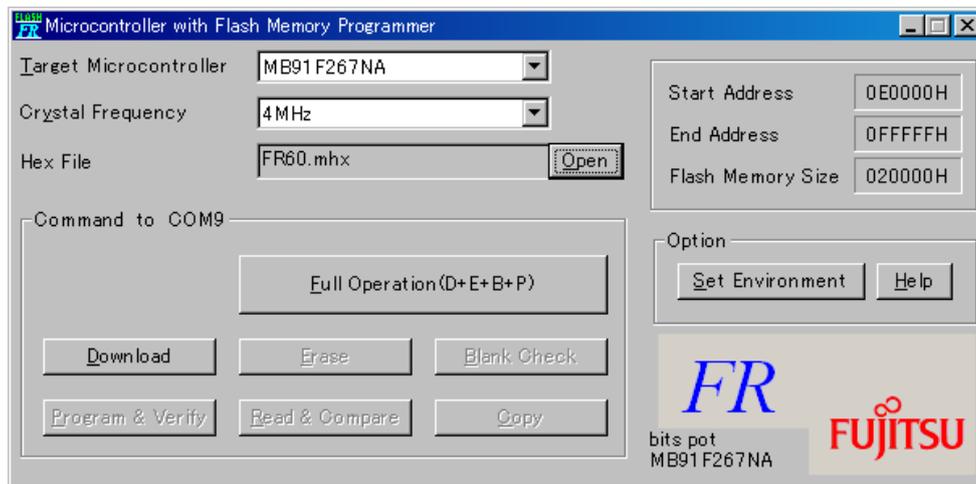


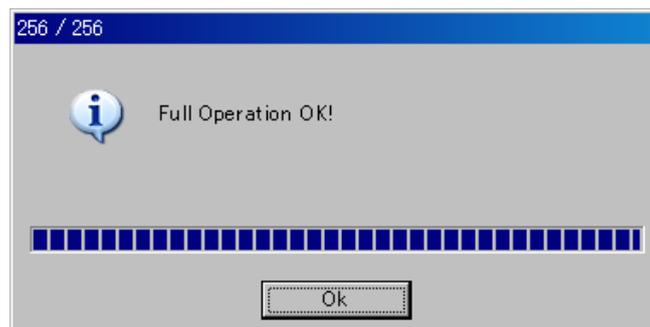
Figure 2-14 Checking the COM port

As shown in “Figure 2-15 Writing the program”, press the “Full Operation” button to start writing the program; the dialog that asks you to press the Reset switch is displayed. Press the Reset SW on the board, and then click the “OK” button on the dialog; the program write sequence starts. For the location of the Reset SW, see “Figure 1-1 External board view”.



**Figure 2-15 Writing the program**

The dialog shown in “Figure 2-16 Completing the program writing” is displayed to notify you of the completion of the program writing; press the “OK” button to quit PC Writer.



**Figure 2-16 Completing the program writing**

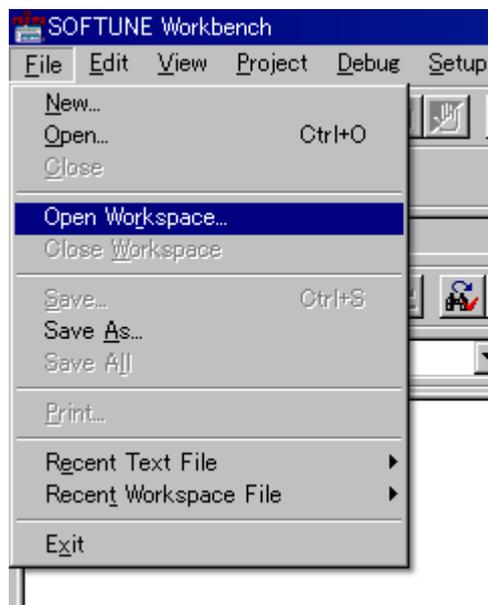
### 2.2.2 Activating SOFTUNE and configuring the debug settings

#### Preparation

Set MODE on the board to “RUN” in advance, and then press the Reset button.

Select “Start” → “All Programs” → “Softune V6” → “FR Family Softune Workbench” to activate SOFTUNE.

As shown in “Figure 2-17 Opening a workspace”, from a menu of SOFTUNE, select “File” → “Open Workspace” to open a workspace.



**Figure 2-17 Opening a workspace**

As shown in “Figure 2-18 Selecting a workspace”, the dialog that allows you to select a workspace is displayed. Select the folder containing the sample program, select the workspace of “bitpot\_red\_SampleProgram\_md.wsp”, and then click “Open”.

¥bitpot\_red\_SampleProgram\_md¥bitpot\_red\_SampleProgram\_md.wsp

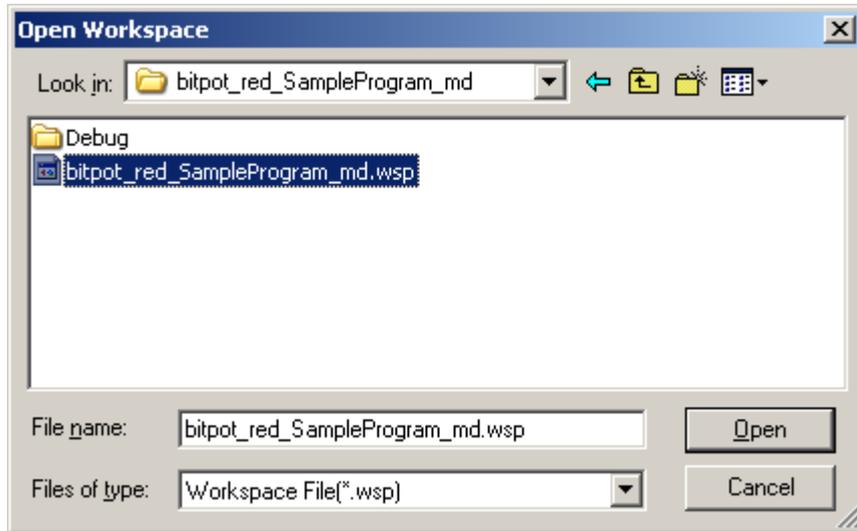


Figure 2-18 Selecting a workspace

The workspace opens; from the “project” menu, click “Build” to build it.

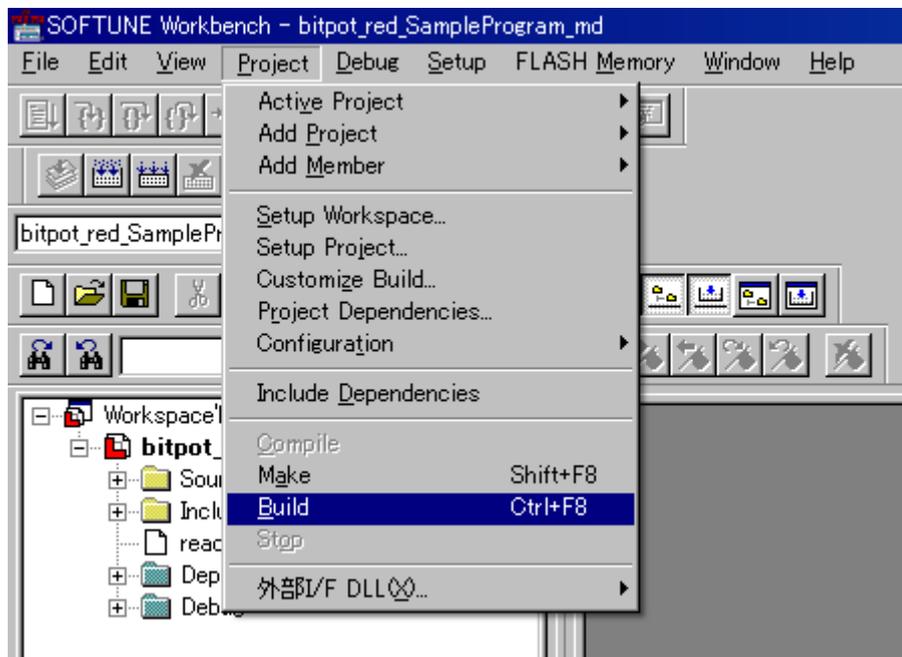


Figure 2-19 Building a project

The message pane at the bottom of the window shows a message as shown in “Figure 2-20 Completing the build”. A warning is displayed but the build has been successfully ended. (The warning indicates no problem.)

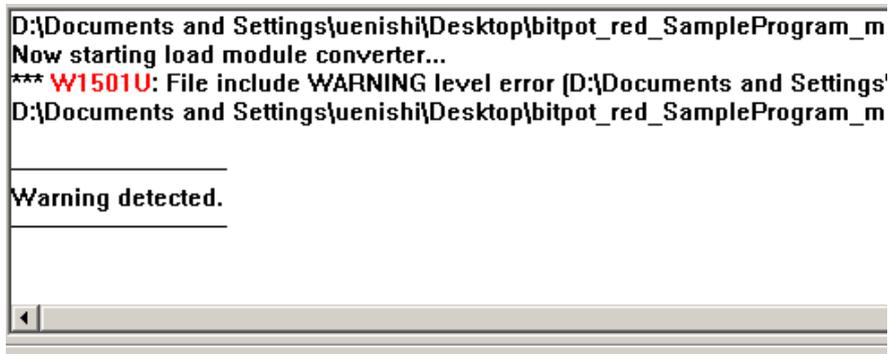


Figure 2-20 Completing the build

Then, configure the debug settings. As shown in “Figure 2-21 Changing the debug settings”, expand “Debug”, select “mon\_38400.sup”, and then right-click on it. A menu appears; click “Change Settings”.

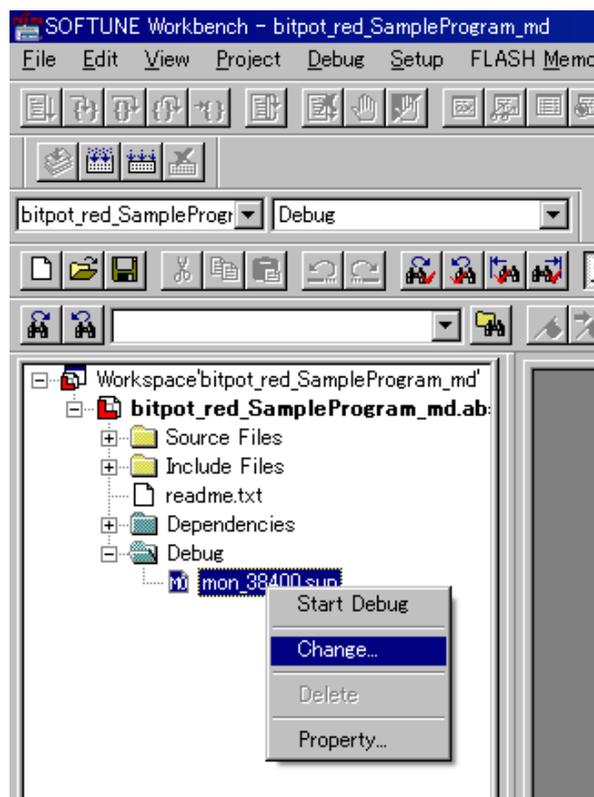
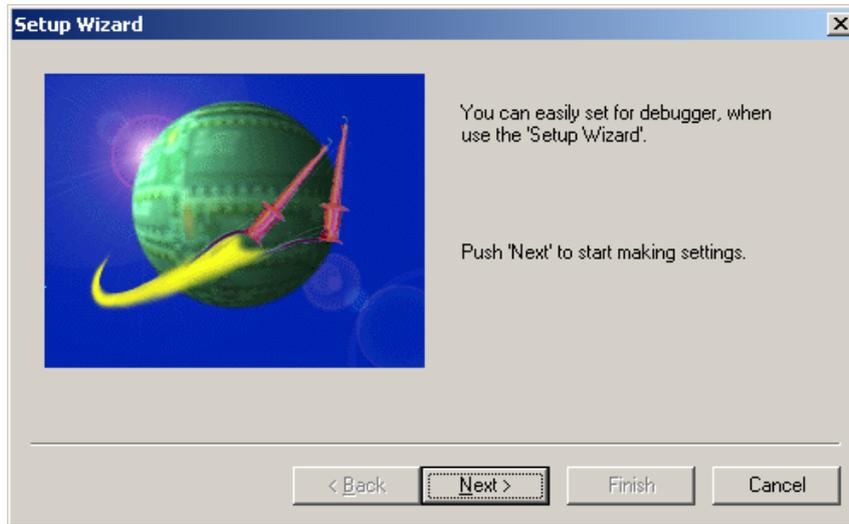


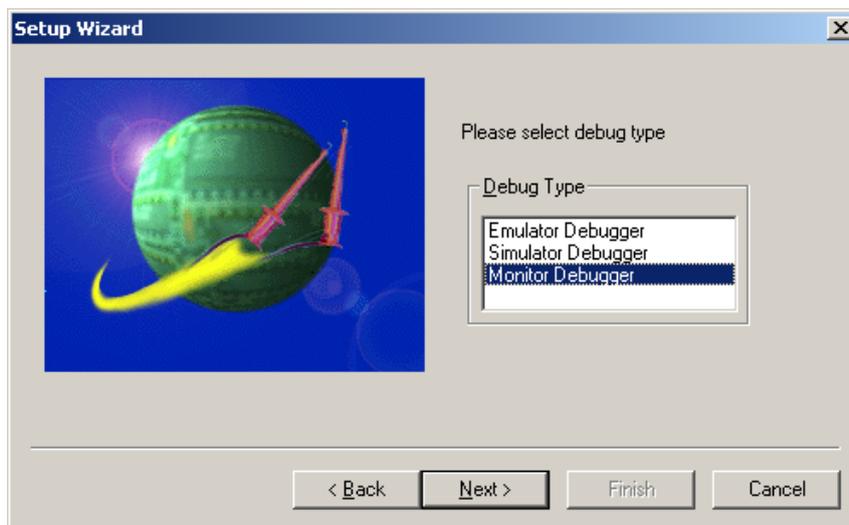
Figure 2-21 Changing the debug settings

As shown in “Figure 2-22 Starting the debug setting ”, the debug setup wizard is displayed; click the “Next” button.



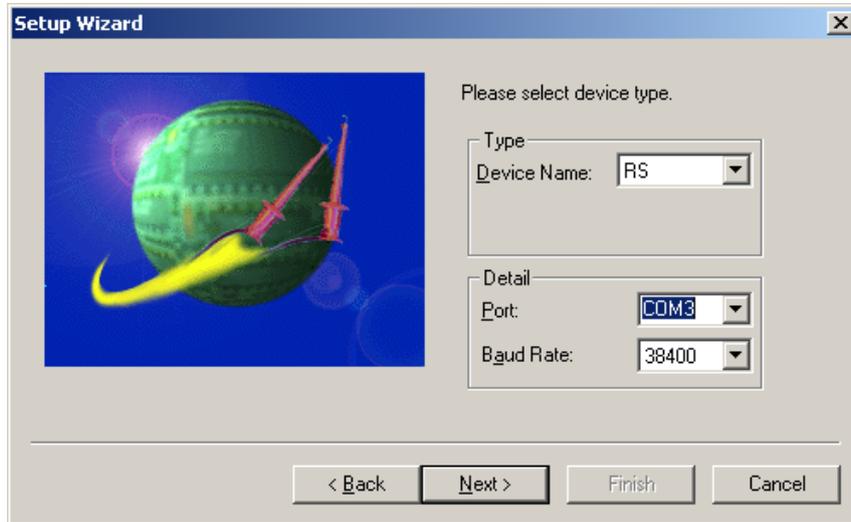
**Figure 2-22 Starting the debug setting wizard**

Select the debugger type as shown in “Figure 2-23 Selecting the debugger type”; select “Monitor Debugger”, and then click the “Next” button.



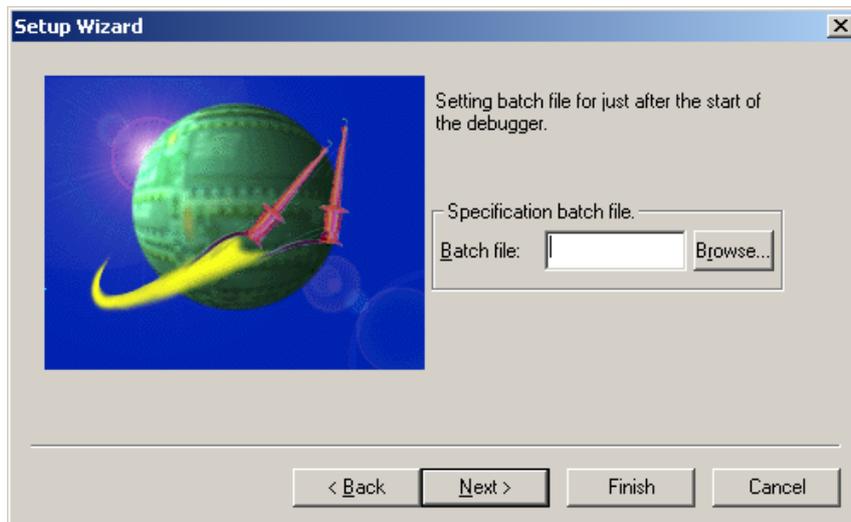
**Figure 2-23 Selecting the debugger type**

Select the device type as shown in “Figure 2-24 Selecting the device type”. Set “RS” to the device name, set the COM port number to which the board is connected to the port name, set “38400” to the baud rate, and then click the “Next” button.



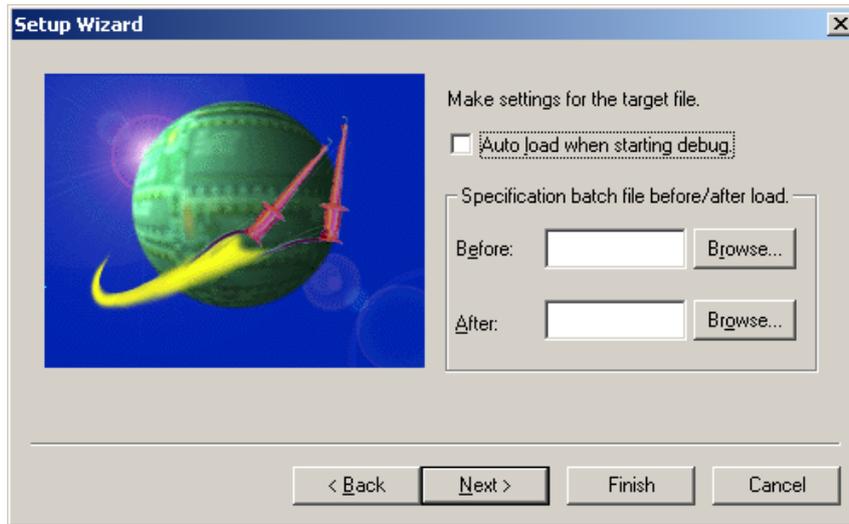
**Figure 2-24 Selecting the device type**

Specify nothing to the batch file field as shown in “Figure 2-25 Specifying a batch file”; keep the field left blank and click the “Next” button.



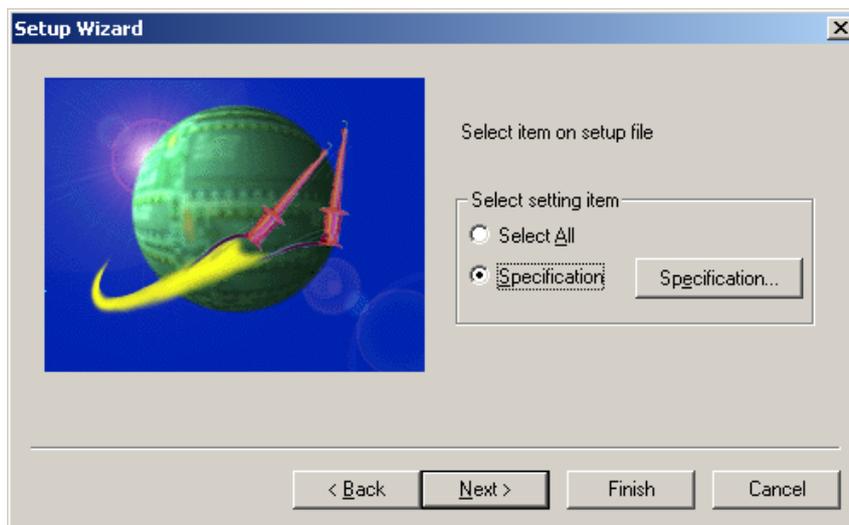
**Figure 2-25 Specifying a batch file**

Just ignore the target file settings as shown in “Figure 2-26 Configuring the target file settings”; click the “Next” button.



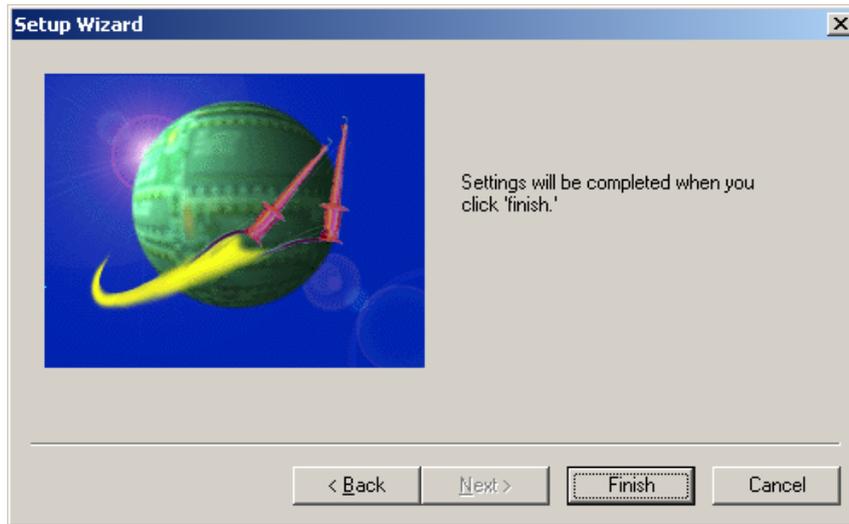
**Figure 2-26 Configuring the target file settings**

As shown in “Figure 2-27 Setting setup file selection”, select “Specify” for setup file selection, and then click the “Next” button.



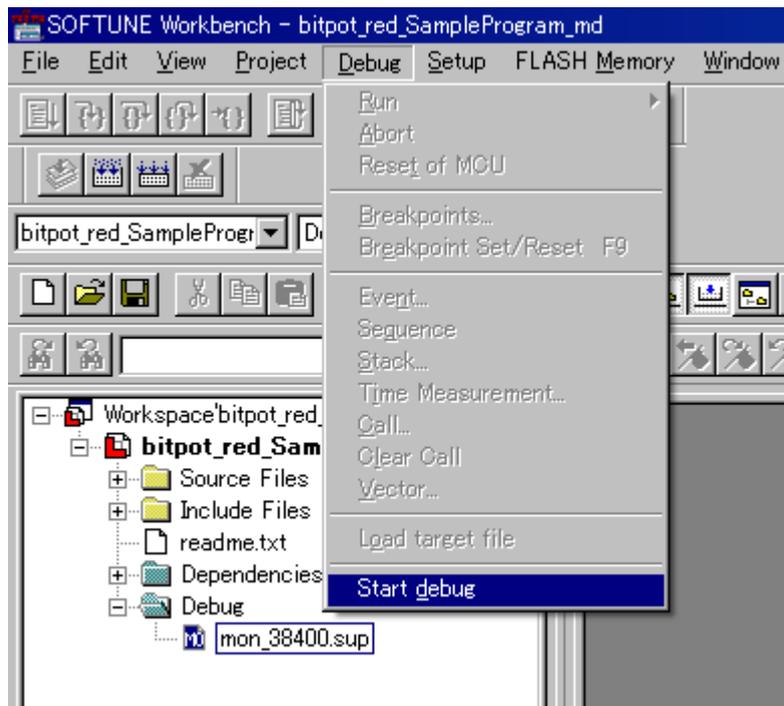
**Figure 2-27 Setting setup file selection**

On the dialog shown in “Figure 2-28 Completing the setup wizard”, click the “Finish” button to finish configuring the settings.



**Figure 2-28 Completing the setup wizard**

Start debugging as shown in “Figure 2-29 Start debugging”.



**Figure 2-29 Start debugging**

### 2.2.3 Writing the program into the microcontroller

As shown in “Figure 2-30 Showing the commands window”, from the “View” menu, select “Commands” to show the program window.

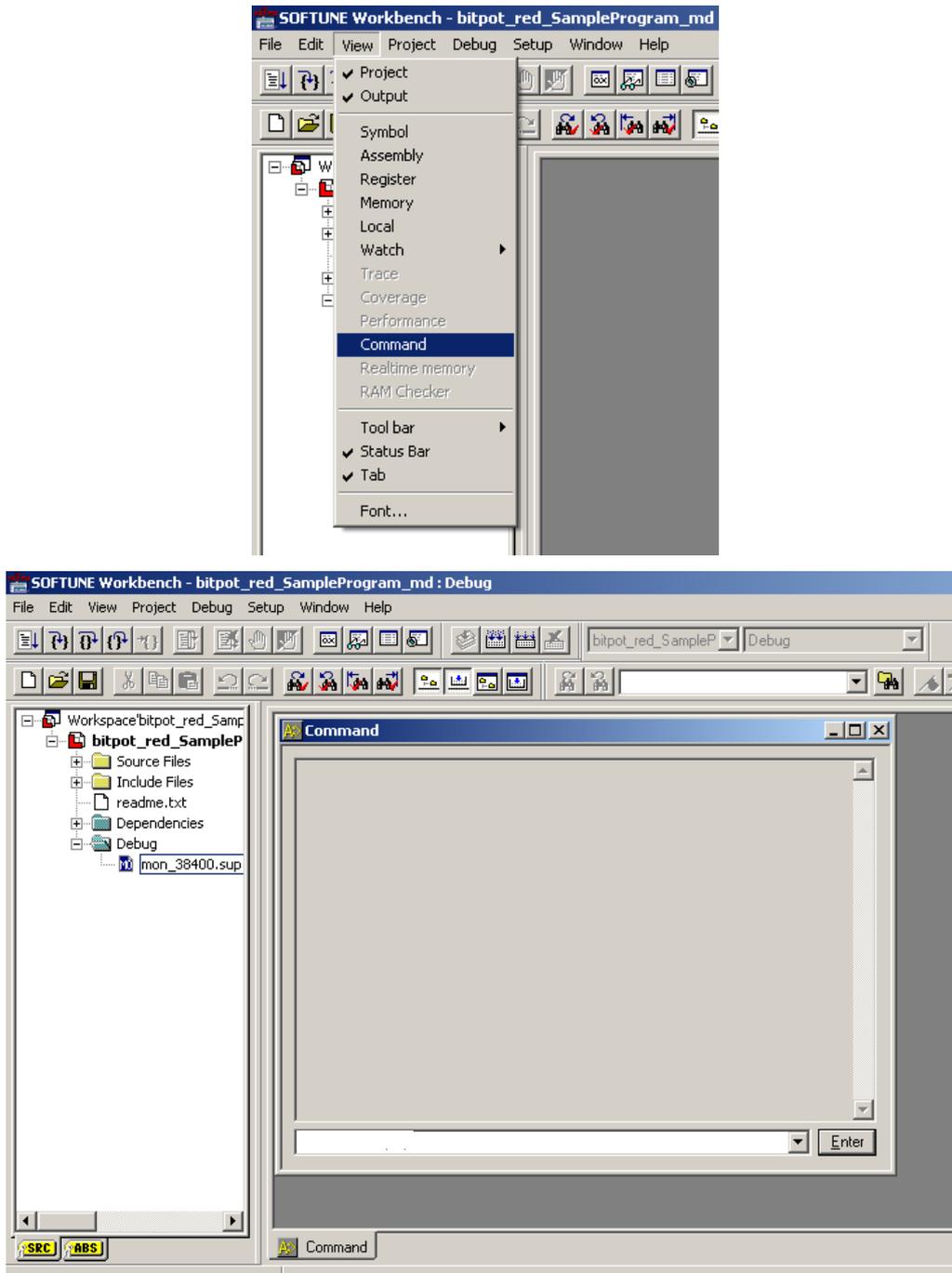
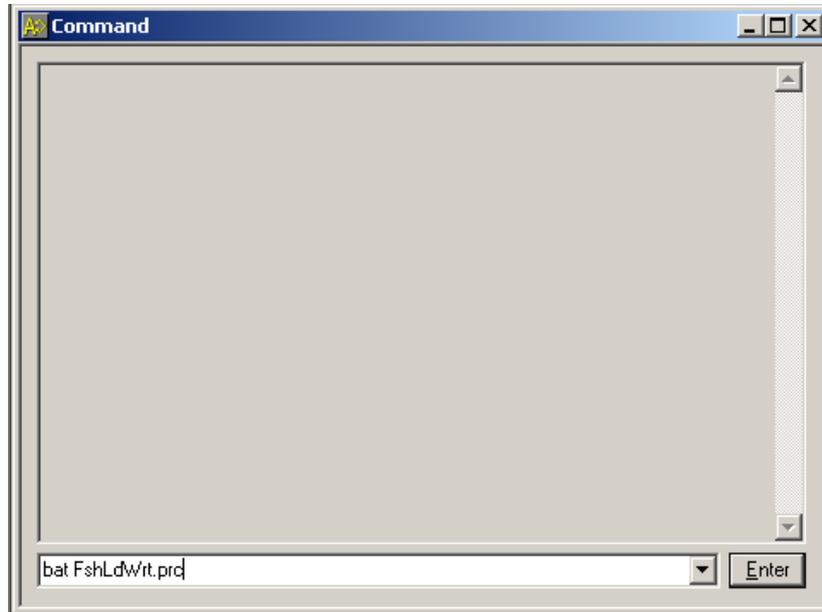


Figure 2-30 Showing the commands window

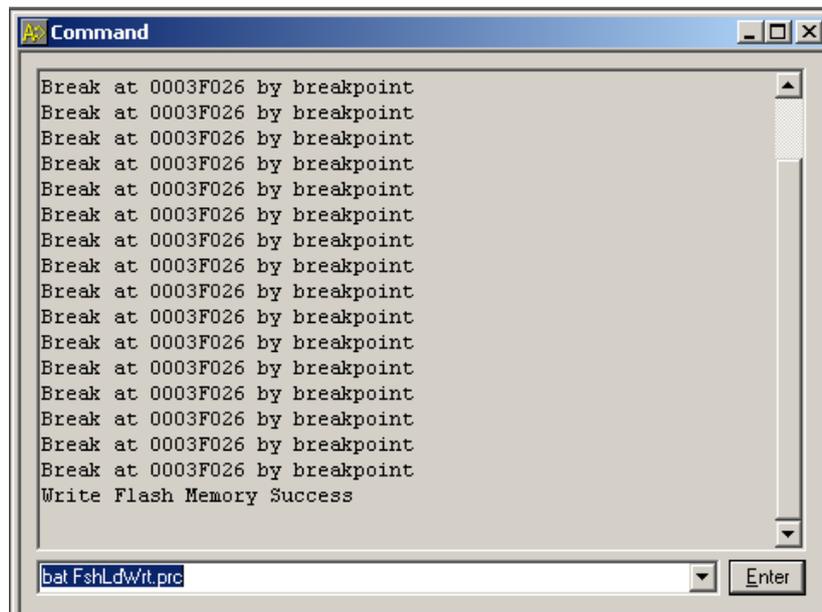
Input the following command into the field as shown in “Figure 2-31 Inputting commands”, and then click the “Enter” button. The program is started to be written.

`bat FshLdWrt.prc`



**Figure 2-31 Inputting commands**

As shown in “Figure 2-32 Completing the program writing”, the command window shows “Write Flash Memory Success” to notify you of successful completion of the program writing into the microcontroller.



**Figure 2-32 Completing the program writing**

### 2.2.4 Loading the target file

As shown in “Figure 2-33 Loading the target file”, from the “Debug” menu, select “Load Target File”. The target file is loaded; you can set break points at desired points.

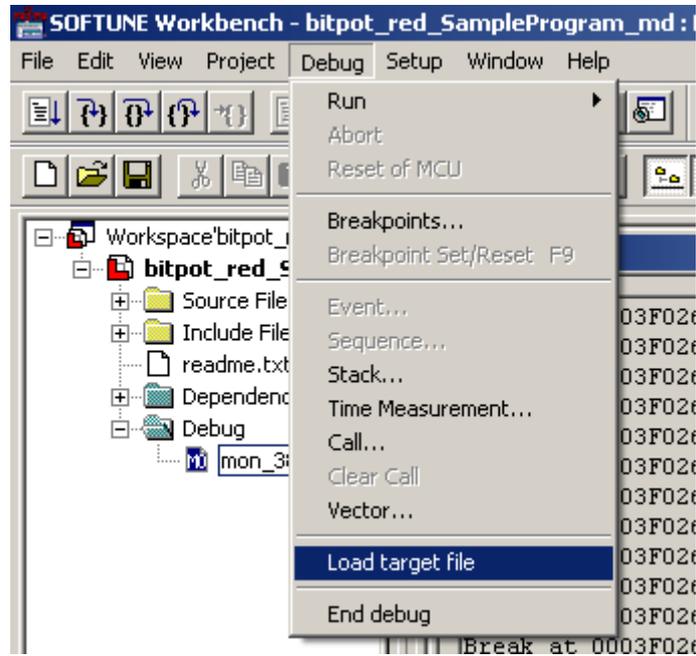


Figure 2-33 Loading the target file

2.2.5 Running the debugger

As shown in “Figure 2-34 Setting break points”, you can set break points to lines with a green round mark on the left side in the source file. Note that you cannot set break points while the program is running.

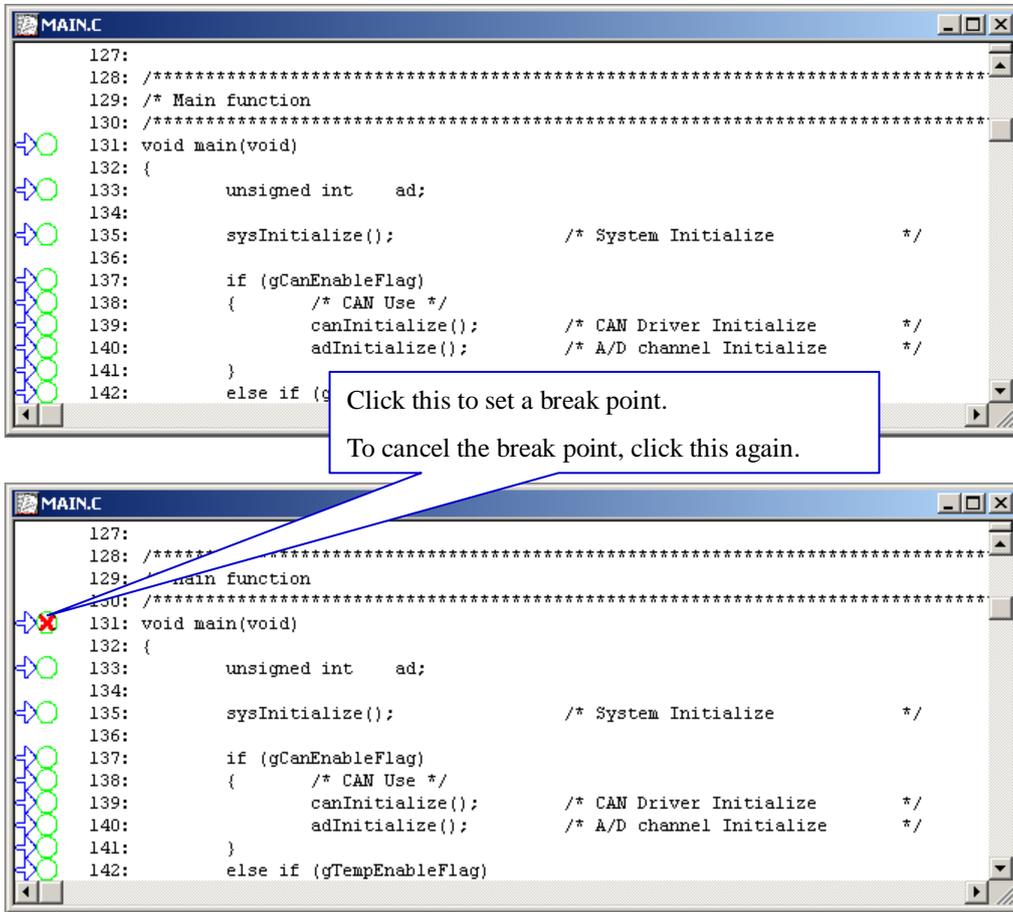


Figure 2-34 Setting break points

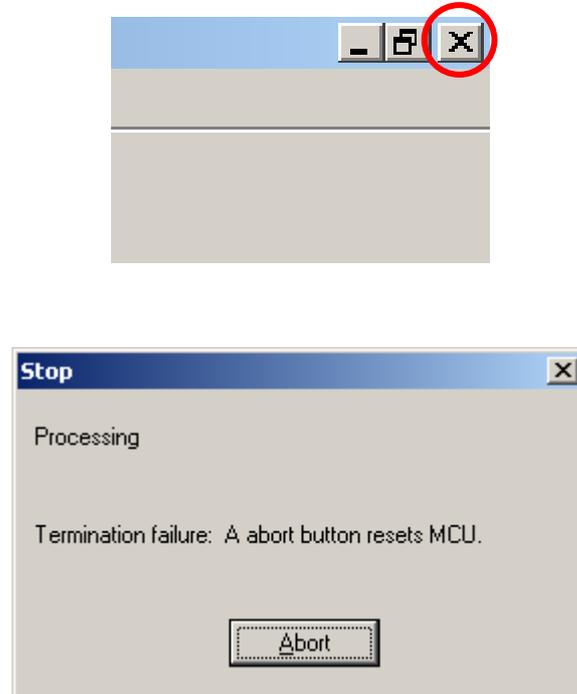
As shown in “Figure 2-35 Running the program”, click the “Run Continuously” icon to run the program.



Figure 2-35 Running the program

As shown in “Figure 2-36 Stopping the program”, click the × button for closing the application on the upper right side of the window to stop running the program.

Although a warning dialog for the stop is displayed, click the “Abort” button in any case.



**Figure 2-36 Stopping the program**

#### 2.2.6 Notes on Monitor Debugger

Note that Monitor Debugger has the following restrictions.

- Only up to 16 break points can be set. No more break point can be set, so to set other break points, cancel some of those already set and set new break point.
- While Monitor Debugger is running (after Monitor Debugger is activated in 2.2.2 Activating SOFTUNE and configuring the debug settings), it is prohibited to press the Reset SW on the board; it causes Monitor Debugger to stop.
- For the operation of Monitor Debugger, UART0 is used. If you modify the sample program or apply it to some other purpose, remind this.

### 3 Operation of the sample program

This section describes the operation of the sample program. The operation of the sample is classified into the following two categories.

- (1) bits pot red single-unit operation
- (2) CAN communication operation (CAN communication operation with the bits pot white)

3.1 bits pot red single-unit operation

“Figure 3-1 Single-unit operation/Controls and mechanicals” shows the controls and mechanicals, and “Table 3-1 Single-unit operation/Descriptions of the controls and mechanicals” provides descriptions about them.

SW2, SW3, SW5, and temperature sensor on the board control the operations of the green and red LEDs and BLDC motor.

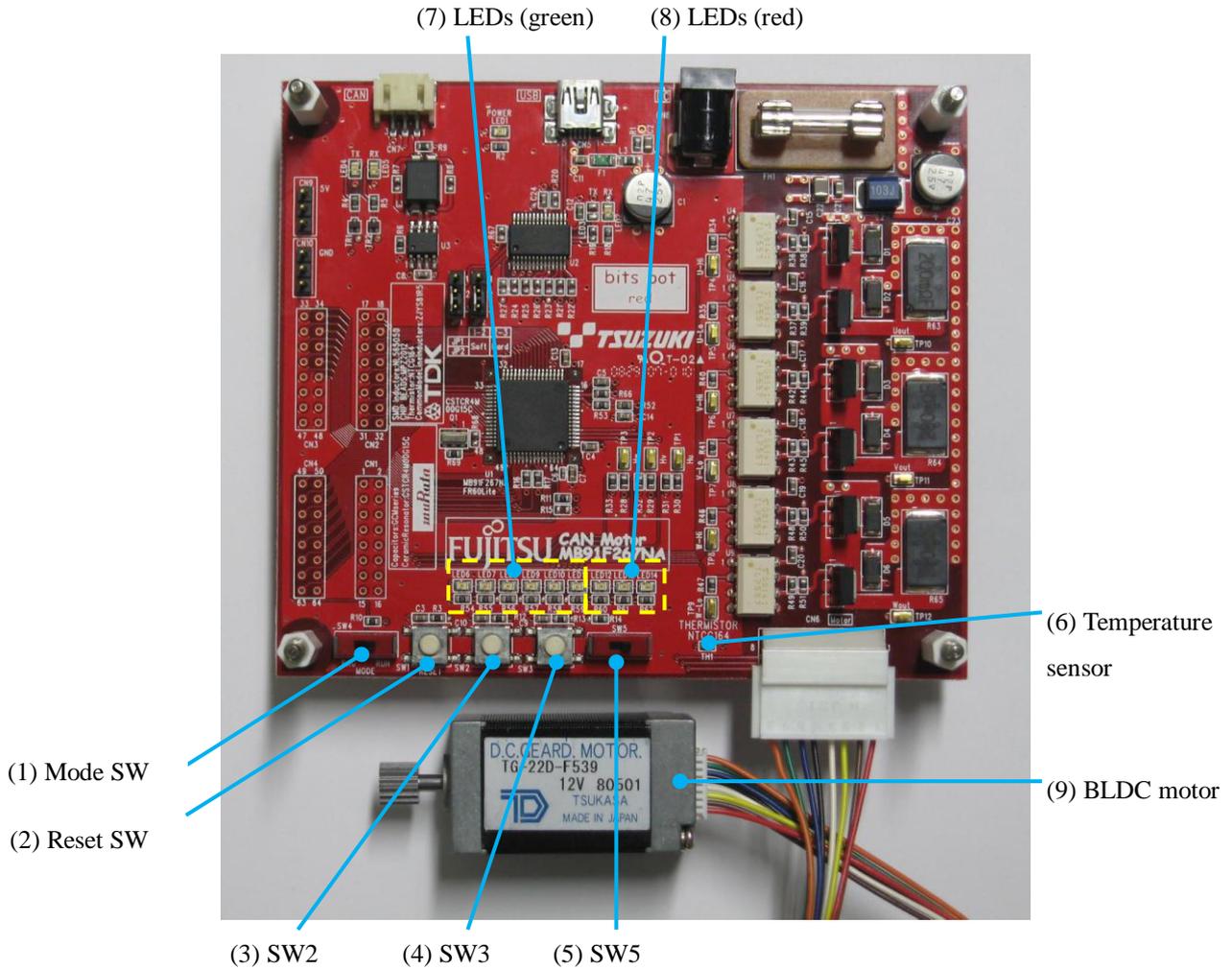


Figure 3-1 Single-unit operation/Controls and mechanicals

**Table 3-1 Single-unit operation/Descriptions of the controls and mechanicals**

No.	Name	Function	Description
(1)	Mode SW	Control	Switches between RPG mode and RUN mode. PRG: Write a program RUN: Run the program
(2)	Reset SW	Control	Rests the MCU when pressed.
(3)	SW2	Control	Rotates/stops the motor in turn when pressed. The motor rotates if it is stopped and stops if it is rotating when this switch is pressed.
(4)	SW3	Control	Brakes the (stops) motor if it is rotating when pressed. The brake is applied while the switch is pressed. Releasing the switch turns off the brake and the motor starts rotating.
(5)	SW5	Control	Selects the direction of the motor rotation. Right side: The motor rotates clockwise. Left side: The motor rotates counterclockwise.
(6)	Temperature sensor	Control	Changes the rotation speed according to information from the temperature sensor. When the temperature rises, the rotation speed increases. When the temperature falls, the rotation speed decreases.
(7)	LEDs (green)	Mechanical	Indicate the status of whether the motor driver circuit is ON/OFF.
(8)	LEDs (red)	Mechanical	Indicate the status of whether the hall elements are ON/OFF.
(9)	BLDC motor	Mechanical	Operates according to rotation/stop by the SW2. The brake, rotation direction, and rotation speed respectively depend on the SW3, SW5, and temperature sensor.

3.2 CAN communication operation (CAN communication operation with the bits pot white)

“Figure 3-2 CAN communication operation/Controls and mechanicals” shows the controls and mechanicals, and “Table 3-2 CAN communication operation/Descriptions of the controls and mechanicals” provides descriptions about them.

The bits pot white performs CAN communication, and on execution of a motor operation command, the green and red LEDs and BLDC motor work. On execution of a temperature measurement command, the temperature is returned from the temperature sensor.

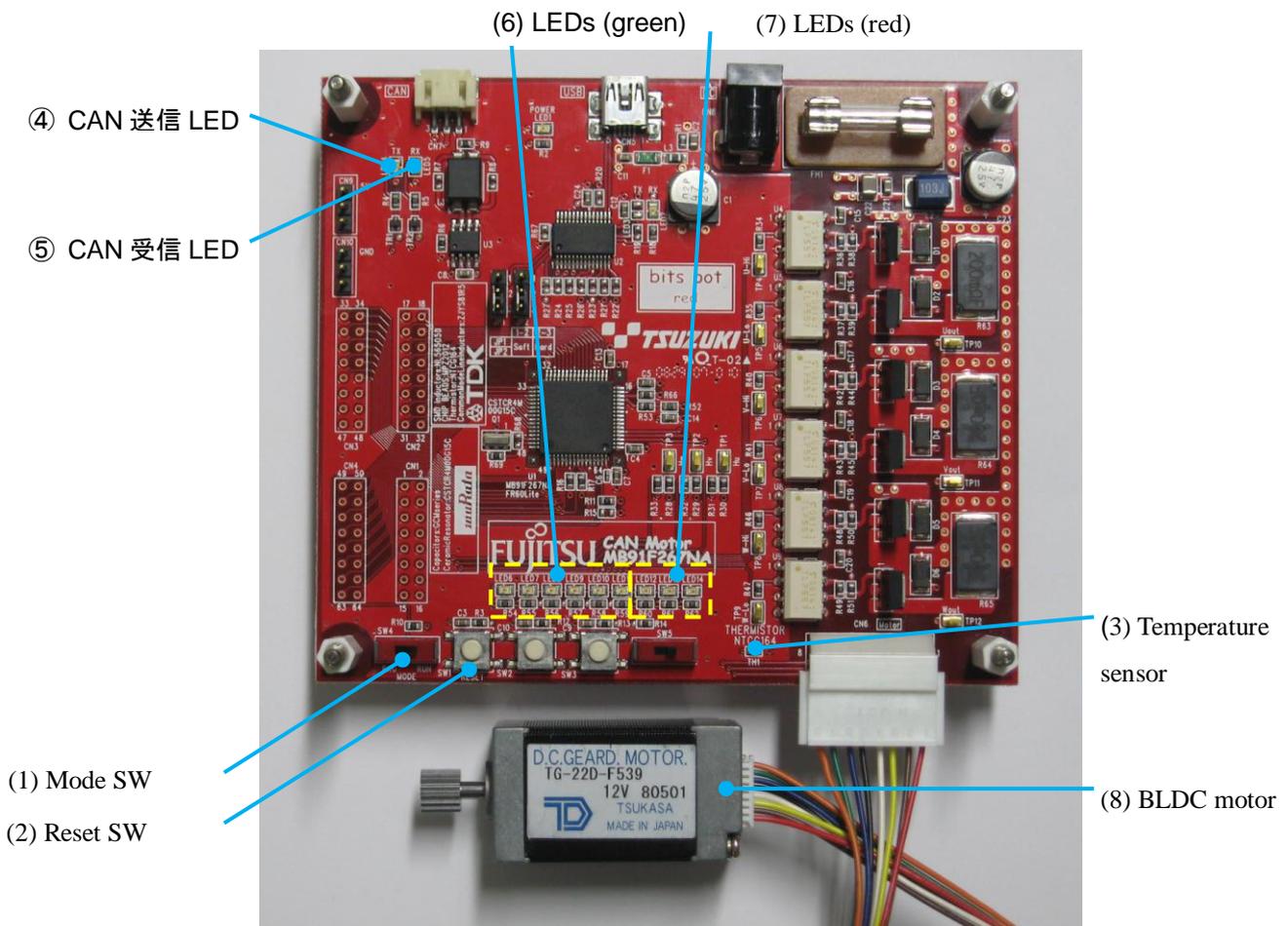


Figure 3-2 CAN communication operation/Controls and mechanicals

**Table 3-2 CAN communication operation/Descriptions of the controls and mechanicals**

No.	Name	Function	Description
(1)	Mode SW	Control	Switches between RPG mode and RUN mode. PRG: Write a program RUN: Run the program
(2)	Reset SW	Control	Rests the MCU when pressed.
(3)	Temperature sensor	Control	Returns the temperature measured by this temperature sensor on a temperature measurement command in CAN communication.
(4)	CAN transmit LED	Mechanical	Lights when a CAN transmit is performed.
(5)	CAN receive LED	Mechanical	Lights when a CAN receive is performed.
(6)	LEDs (green)	Mechanical	Indicate the status of whether the motor driver circuit is ON/OFF.
(7)	LEDs (red)	Mechanical	Indicate the status of whether the hall elements are ON/OFF.
(8)	BLDC motor	Mechanical	Operates according to rotation/stop by motor operation commands. The brake, rotation direction, and rotation speed respectively depend on motor operation commands.

## 4 Try to rotate the BLDC motor

In these days, motors are indispensable in our daily life. Motors are now used in various places, for example, air conditioners, compressors of refrigerators, turn tables of CD and DVD drives, and wipers and door mirrors of vehicles.

This chapter provides descriptions about how to rotate the BLDC motor by using a microcontroller macro.

### 4.1 What is the BLDC motor?

The BLDC motor is a DC brushless motor that is a type of motors. In distinction from generally known DC motors, the DC brushless motor has no brush, longer life, and low electric noise, so it tends to be suitable for miniaturization. Uses of the DC brushless motor are still increasing.

Rotation of both the DC motor and BLDC motor is controlled by the currents from a DC power supply. The DC motor switches the direction of the rotor coil current by using brushes (commutator) to change the magnetic flux for rotation control. On the other hand, the BLDC motor has no brush. As shown in “Figure 4-1 DC motor/BLDC motor configuration examples”, it switches the directions of the stator coil currents by using switches to change the magnetic fluxes for rotation control. To do this switching, the microcontroller is used. For detection of the rotor position, hall elements are used.

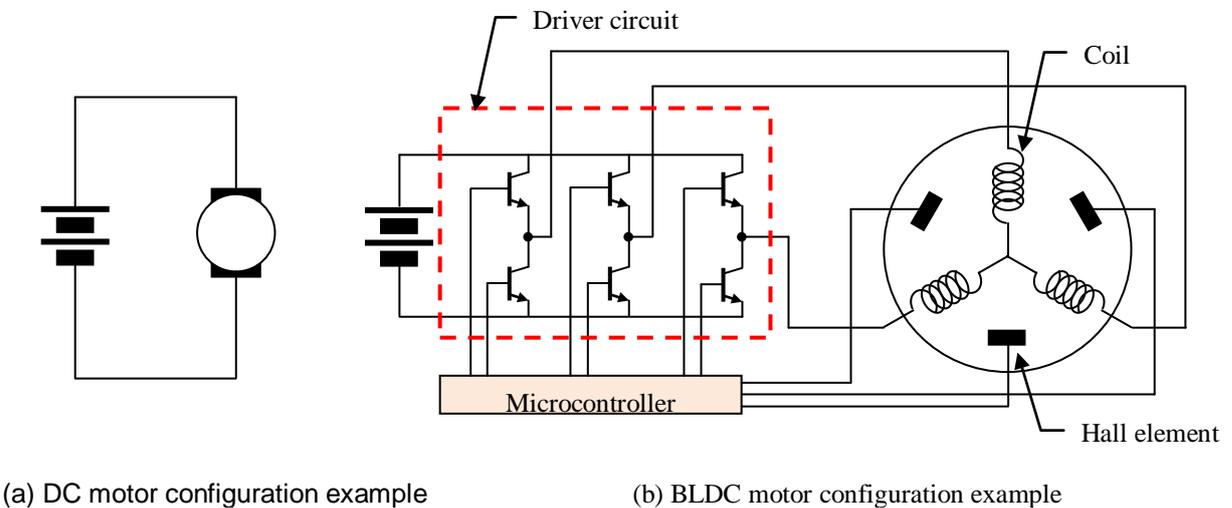


Figure 4-1 DC motor/BLDC motor configuration examples

This board has a driver circuit, so you can start rotating the BLDC motor immediately.

4.2 How does the BLDC motor rotate?

The BLDC motor has three phases different by 120°. As shown in “Figure 4-2 Names of the respective elements”, the phases are called the U-phase, V-phase, and W-phase respectively.

The switches on the driver circuit are respectively called U-High, U-Low, V-High, V-Low, W-High, and W-Low and connected as outputs from the microcontroller. The hall elements for detection of the rotor position are respectively called Hall-U, Hall-V, and Hall-W and connected as inputs to the microcontroller.

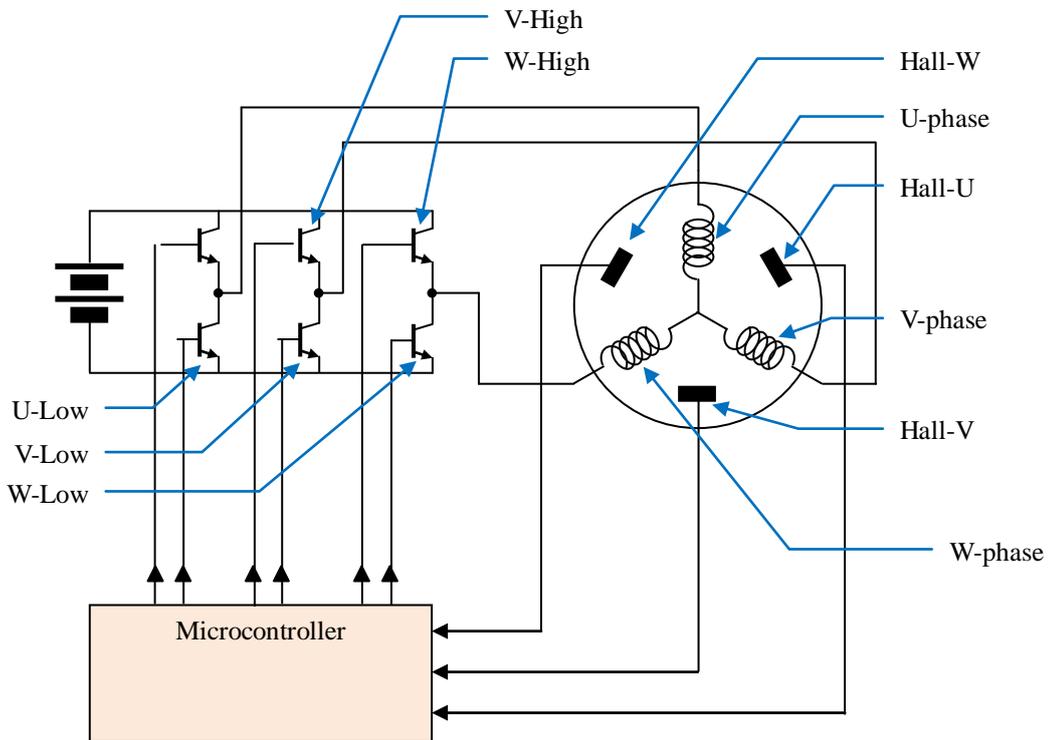


Figure 4-2 Names of the respective elements

By turning on/off the switches, the directions of the currents conducted to the motor are controlled. Two of the three coils are set to positive or negative to generate a magnetic field for motor rotation.

The hall elements are used to detect the position of the rotor by 60° and the detection is represented with 1 or 0. According to their values, the switches are turned on/off. On detection of the hall elements, the High side of the phase corresponding to it is turned ON, and on no detection, the Low side is turned ON. “Figure 4-3 120° conduction method time chart” shows their relationship.

This way of driving control is called the 120° conduction method (square-weave control).

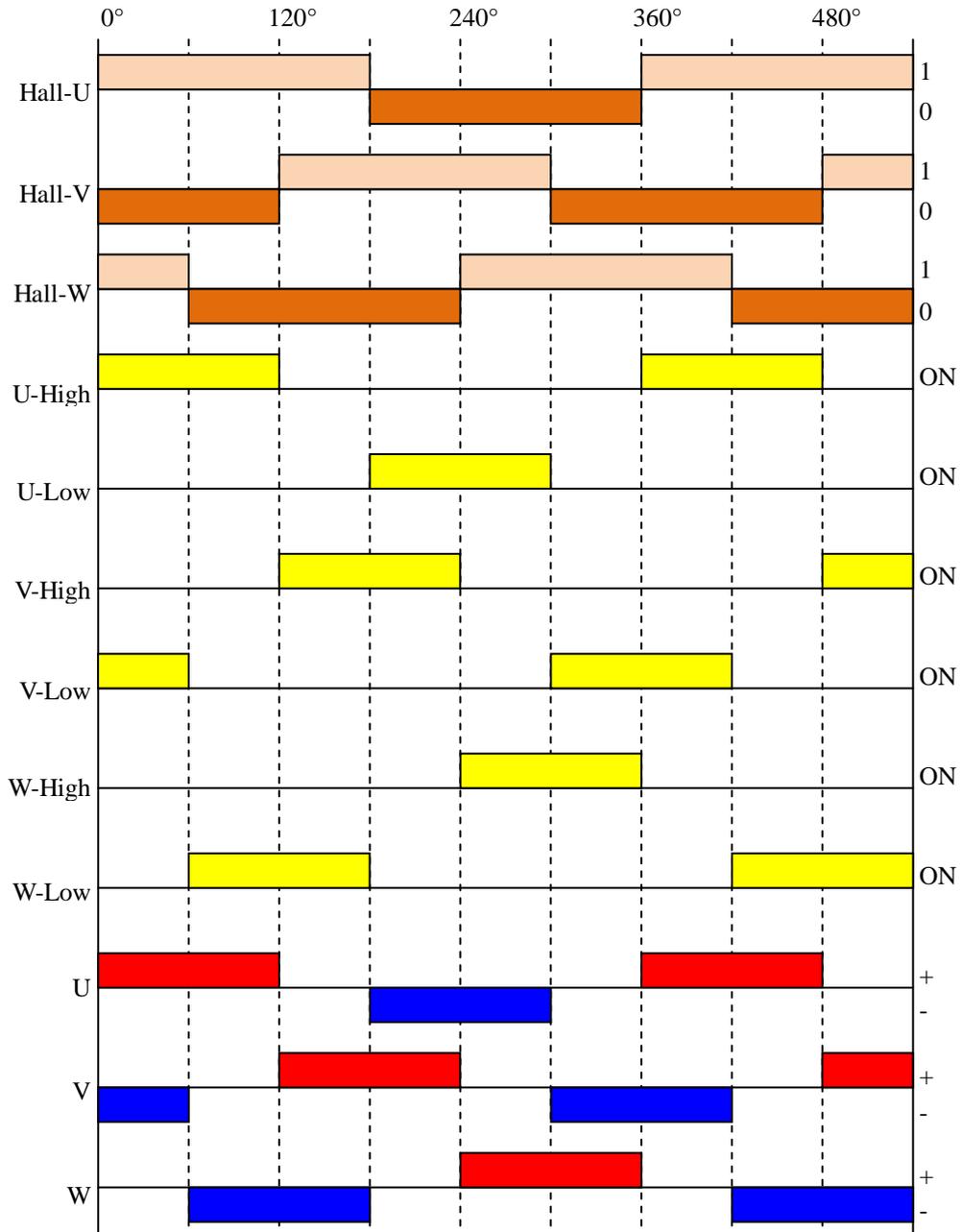


Figure 4-3 120° conduction method time chart

4.3 BLDC motor rotation control by the microcontroller

This section describes how the BLDC motor is practically controlled with the 120° conduction method by the microcontroller.

On the board, as shown in “Figure 4-4 Motor driver circuit”, the microcontroller is connected with the motor driver circuit. The relationship of the connections with the semiconductor elements described in “4.2 How does the BLDC motor rotate?” is as shown in “Table 4-1 Microcontroller pin/Motor driver circuit connections”. By turning RTO0 to 5 on/off according to the positions of the hall elements as shown in “Figure 4-3 120° conduction method time chart”, the motor can be rotated.

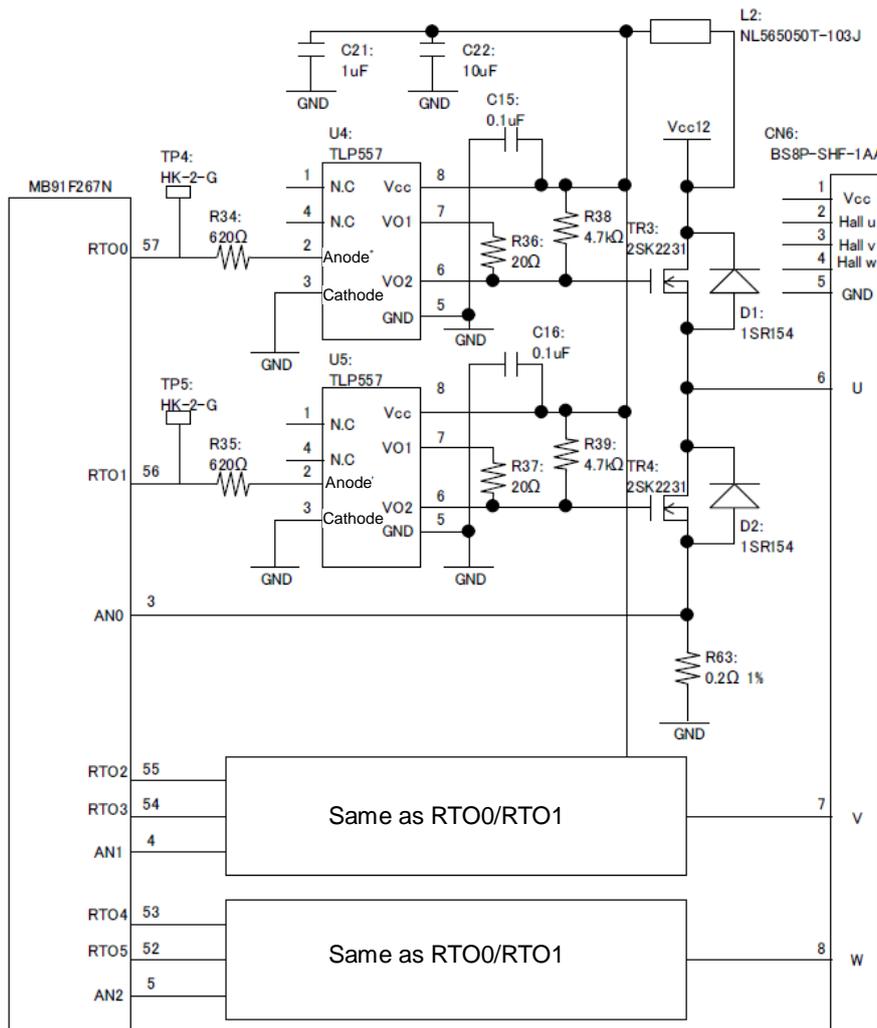


Figure 4-4 Motor driver circuit

**Table 4-1 Microcontroller pin/Motor driver circuit connections**

Microcontroller pin number	Pin name	Name of the semiconductor element connected
Pin57	RTO0	U-High
Pin56	RTO1	U-Low
Pin55	RTO2	V-High
Pin54	RTO3	V-Low
Pin53	RTO4	W-High
Pin52	RTO5	W-Low

RTO0 to 5 ON/OFF control is practically taken by the macro in the microprocessor mounted on the board. So, it is necessary to configure registers for functions employed by the macro. “Table 4-2 Functions employed by the motor driving macro” shows the functions employed.

**Table 4-2 Functions employed by the motor driving macro**

Function name	Description
16-bit free-run timer	Timer in which an up/down counter is used. This counter is used to configure the output compare function.
16-bit output compare	Used to make comparisons with the value of the free-run timer, and the resulting values are used to turn on/off RTO0 to 5.

The registers used for the 16-bit free-run timer are as shown in “Figure 4-5 Timer control registers”. A description of the registers and their setting values in the sample program are as described in “Table 4-3 Description of the timer control registers and setting values”. For more information of the registers, refer to the microcontroller hardware manual.

Timer control high-order bits

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
TCCSH0	ECKE	IRQZF	IRQZE	MSI2	MSI1	MSI0	ICLR	ICRE

Timer control low-order bits

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
TCCSL0	BFE	STOP	MODE	SCLR	CLK3	CLK2	CLK1	CLK0

**Figure 4-5 Timer control registers**

**Table 4-3 Description of the timer control registers and setting values**

Register name	Setting value [function]	Description
TCCSH0_ECKE	0 [internal clock]	Clock select bit
TCCSH0_IRQZF	0 [bit clear]	0 detection interrupt flag bit
TCCSH0_IRQZE	0 [interrupt request disable]	0 detection interrupt request enable bit
TCCSH0_MS12	-	Interrupt mask select bits Not used
TCCSH0_MS11	-	
TCCSH0_MS10	-	
TCCSH0_ICLR	0 [bit clear]	Compare clear interrupt flag bit
TCCSH0_ICRE	1 [interrupt request enable]	Compare clear interrupt request enable bit
TCCSL0_BFE	1 [compare clear buffer enable]	Compare clear buffer enable bit
TCCSL0_STOP	1 [counter stop]	Timer enable bit
TCCSL0_MODE	1 [up/down count mode]	Timer counter mode bit
TCCSL0_SCLR	1 [counter initialization to 0000]	Timer clear bit
TCCSL0_CLK3	0 [62.5 ns]	Clock frequency select bits
TCCSL0_CLK2	0 [↑]	
TCCSL0_CLK1	0 [↑]	
TCCSL0_CLK0	0 [↑]	

The registers used for the 16-bit output compare function are as shown in “Figure 4-6 Output compare registers”. A description of the registers and their setting values in the sample program are as described in “Table 4-4 Description of the output compare registers and setting values”. For more information of the registers, refer to the microcontroller hardware manual.

Compare clear buffer register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
CPCLRBO	CL15	CL14	CL13	CL12	CL11	CL10	CL9	CL8
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	CL7	CL6	CL5	CL4	CL3	CL2	CL1	CL0

Output compare buffer register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
OCCPB0 to	OP15	OP14	OP13	OP12	OP11	OP10	OP9	OP8
OCCPB 5	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	OP7	OP6	OP5	OP4	OP3	OP2	OP1	OP0

Compare mode control register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
OCMOD	-	-	MOD15	MOD14	MOD13	MOD12	MOD11	MOD10

Compare control register high-order bit/s

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
OCSH1,3,5	-	BTS1	BTS0	CMOD	OTE1	OTE0	OTD1	OTD0

Compare control register low-order bit/s

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
OCSL0,2,4	IOP1	IOP0	IOE1	IOE0	BUF1	BUF0	CST1	CST0

**Figure 4-6 Output compare registers**

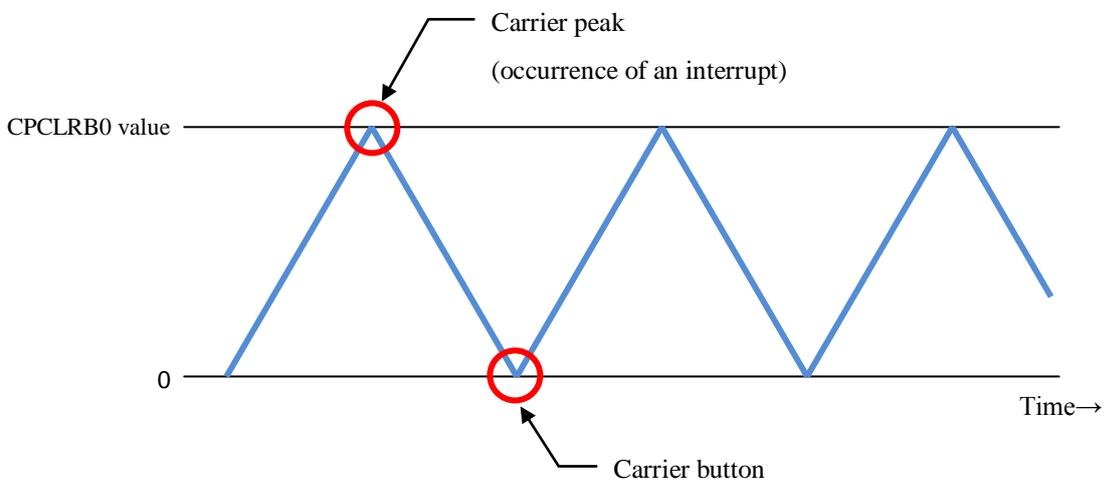
**Table 4-4 Description of the output compare registers and setting values**

Register name	Setting value [function]	Description
CPCLRB0	1599	Compare value setting
OCCPB0	1598	Output compare value settings
OCCPB1	1000	
OCCPB2	1598	
OCCPB3	1000	
OCCPB4	1598	
OCCPB5	1000	
OCMOD	0xFF [1 output on a match]	
OCSH1,3,5_BTS1	1 [transfer on a compare clear match]	Buffer transfer select bit (ch 1,3,5)
OCSH1,3,5_BTS0	1 [transfer on a compare clear match]	buffer transfer select bit (ch 0,2,4)
OCSH1,3,5_CMOD	1 [inversion mode]	Output level inversion mode bit
OCSH1,3,5_OTE1	0 [general-purpose output port]	Output enable bit (ch 1,3,5)
OCSH1,3,5_OTE0	0 [general-purpose output port]	Output enable bit (ch 0,2,4)
OCSH1,3,5_OTD1	0 [1 output]	Output level bit (ch 1,3,5)
OCSH1,3,5_OTD0	0 [1 output]	Output level bit (ch 0,2,4)
OCSL0,2,4_IOP1	0 [bit clear]	Compare match interrupt flag bit (ch 1,3,5)
OCSL0,2,4_IOP0	0 [bit clear]	Compare match interrupt flag bit (ch 0,2,4)
OCSL0,2,4_IOE1	0 [compare match interrupt disable]	Compare match interrupt enable bit (ch 1,3,5)
OCSL0,2,4_IOE0	0 [compare match interrupt disable]	Compare match interrupt enable bit (ch 0,2,4)
OCSL0,2,4_BUF1	0 [compare buffer enable]	Compare buffer disable bit (ch 1,3,5)
OCSL0,2,4_BUF0	0 [compare buffer enable]	Compare buffer disable bit (ch 0,2,4)
OCSL0,2,4_CST1	0 [compare operation disable]	Compare operation enable bit (ch 1,3,5)
OCSL0,2,4_CST0	1 [compare operation enable]	Compare operation enable bit (ch 0,2,4)

Initialize the 16-bit free-run timer and 16-bit output compare functions as shown in “Table 4-3 Description of the timer control registers and setting values”, “Table 4-4 Description of the output compare registers and setting values”.

After the initialization, running the 16-bit free-run timer starts a count up using the value configured to CPCLRB0 as the carrier peak as shown in “Figure 4-7 Operation of the free-run timer”. When the carrier peak is reached, an interrupt takes place, and according to information about the hall elements on that occasion, the outputs are switched on/off through comparisons with the output compare values.

After that, a countdown to the carrier bottom (0) is performed. When the count reaches 0, a count up starts again, and this sequence is repeated.



**Figure 4-7 Operation of the free-run timer**

The output compare values are respectively configured by OCCPB0-5. According to the values, the outputs of U-High, U-Low, V-High, V-Low, W-High, and W-Low are turned on/off by the macro. “ Table 4-5 Correspondence between the output compare values and the switchings” shows their association. In addition to that, “Figure 4-8 U-High output to output comparisons” shows an example of the U-High output.

**Table 4-5 Correspondence between the output compare values and the switchings**

Register name	Switching
OCCPB0	U-High
OCCPB1	U-Low
OCCPB2	V-High
OCCPB3	V-Low
OCCPB4	W-High
OCCPB5	W-Low

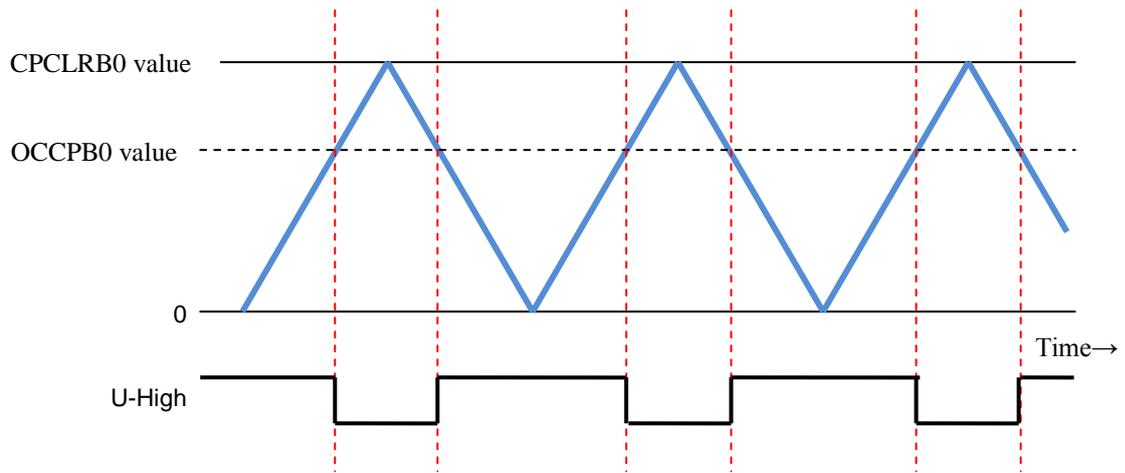


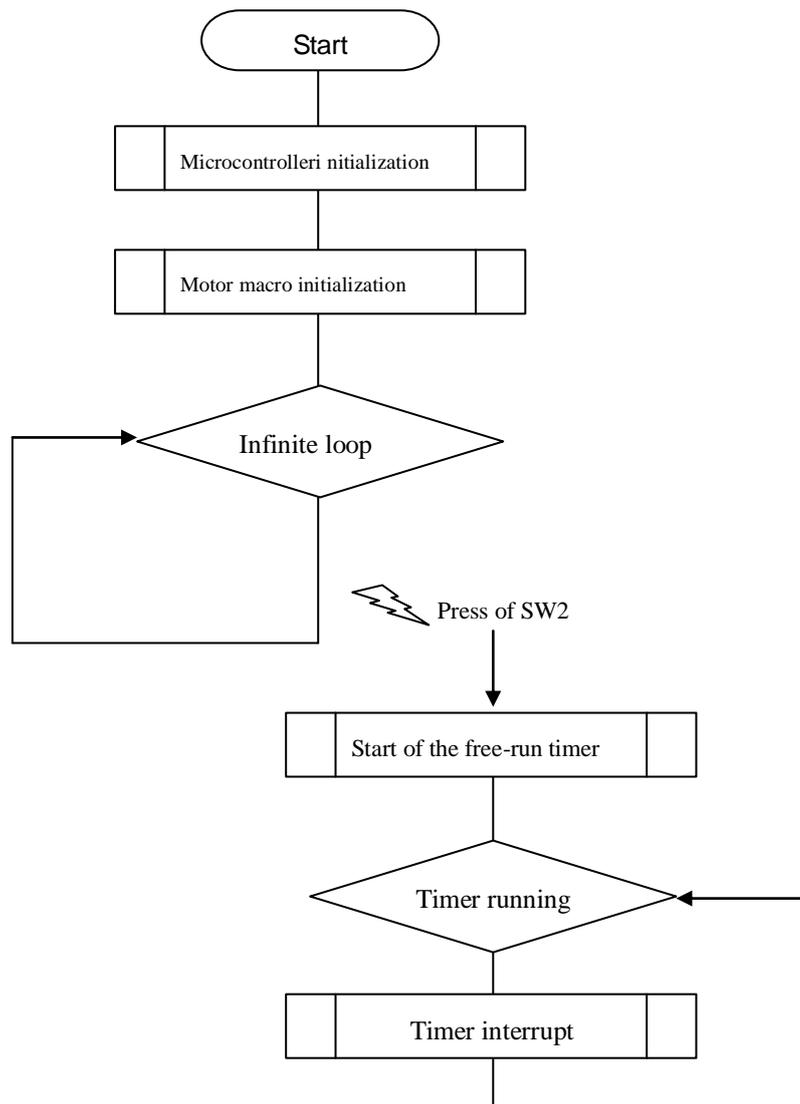
Figure 4-8 U-High output to output comparisons

#### 4.4 Understanding and running the program for the BLDC motor operation

This section provides descriptions of the sample program that can really serve to operate the BLDC motor.

“Figure 4-9 Motor operation flowchart” shows the sequence of the sample program flow. First, the microcontroller is initialized, and then the motor macro is initialized. After that, the program goes into a loop. In the loop, pressing SW2 starts the free-run timer and the motor macro starts operating.

When SW2 is pressed again, the free-run timer stops.



**Figure 4-9 Motor operation flowchart**

Now, take a look at the details of the program.

Look into the following folder of the sample program. There are some files stored in it. At first, open MAIN.C first.

```
¥bitpot_red_SampleProgram¥Debug¥SRC
```

Look at around Line 40 that looks “Figure 4-10 Operation mode settings” for operation mode selection. There are #define settings that enable (1) or disable (0) CAN and temperature sensor.

In this program, CAN is not to be used and the temperature sensor is to be used.

```
/* CAN communication use (1), or unused (0) */
#define CAN_PERMIT          (0)    ←CAN
/* Temperature sensor use (1), or unused (0) */
#define TEMP_SENSOR_USE    (1)    ←Temperature sensor
```

**Figure 4-10 Operation mode settings**

As shown in “Figure 4-11 Main function”, there is the main function around Line 131. In it, there are “microcontroller initialization”, “motor macro initialization”, and “infinite loop”.

```
void main(void)
{
    (omitted);

    sysInitialize();    ←Microcontroller initialization
    (omitted)

    mtInitialize();    ←Motor macro initialization
    (omitted)

    /* main loop */
    while (1)          ←Infinite loop
    {
        (omitted)
    }
}
```

**Figure 4-11 Main function**

When SW2 is pressed, an interrupt takes place. Around Line 763 in MAIN.C, the interrupt function IRQ\_ext\_0 is invoked as shown in “Figure 4-12 SW2 interrupt”. In it, the register value of TCCSL0\_STOP, which is used to start/top the free-run timer, is changed.

```
__interrupt void IRQ_ext_0(void)
{
    (omitted)

    if(gMtStatus == MTST_STOP){
        (omitted)
        TCCSL0_STOP = 0;      ←Start of the free-run timer
    }else{
        (omitted)
        TCCSL0_STOP = 1;      ←Stop of the free-run timer
    }

    (omitted)
}
```

**Figure 4-12 SW2 interrupt**

Once the free-run timer starts running, the timer interrupt function IRQ\_FreeRunComp of motor\_drv.c is invoked on every carrier peak as shown in “Figure 4-13 Free-run timer interrupt”. In it, the status of the hall elements is checked and configured into the macro.

```
__interrupt void IRQ_FreeRunComp(void)
{
    if(TCCSH0_ICLR == 1)      /* if OCU interrupt */
    {
        mtPWMController();    ←Macro configuration
        (omitted)
    }
}
```

**Figure 4-13 Free-run timer interrupt**

### 4.5 Handling controls of the BLDC motor

You were able to rotate the BLDC motor by using the microcontroller macro. Then, try to control the rotation speed, brake, and rotation direction now.

In the sample program, the controls are handled in the infinite loop inside the main function shown in “Figure 4-11 Main function”.

The rotation speed is determined according to the temperature sensor or input from programmed variables, and the brake is applied whether SW3 is pressed. The direction of motor rotation is determined according to the position of SW5. “Figure 4-14 Motor controls flowchart” illustrates how the controls are handled.

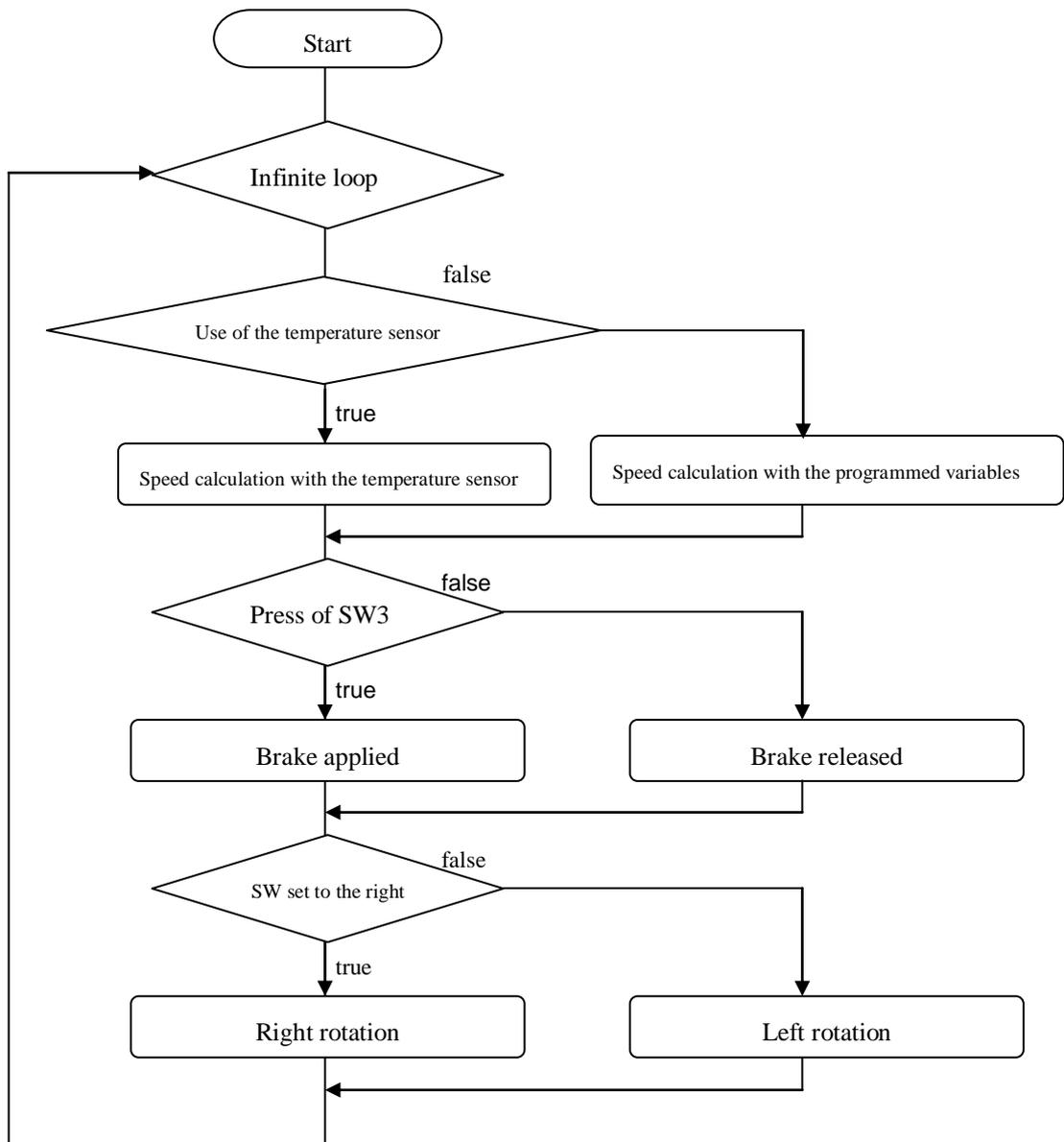


Figure 4-14 Motor controls flowchart

The rotation speed routine is written around Line 166 in the MAIN.C main function as shown in “Figure 4-15 Rotation speed control”.

When the temperature sensor is used, the rotation speed is determined in the range of 0 to 100% by a conversion according to the A/D value obtained from the temperature sensor and the upper limit. When the programmed variables are used, the rotation speed is determined in the range of 0 to 100% by a conversion according to the specified current and upper limit values.

```

void main(void)
{
  (omitted)
  /* main loop */
  while (1)
  {
    if (!gCanEnableFlag)
    {
      /* Set motor turn speed */
      if (gTempEnableFlag)
      {
        /* get an A/D channel */
        ad = adGetValue();
        ad = ad > TEMP_AD_VALUE_00 ? TEMP_AD_VALUE_00 : ad;
        ad = ad < TEMP_AD_VALUE_09 ? TEMP_AD_VALUE_09 : ad;

        /* calc motor turn speed */
        gMtSpeedMax = TEMP_AD_VALUE_00 - TEMP_AD_VALUE_09;
        gMtRevSpeed = gMtSpeedMax - (ad - TEMP_AD_VALUE_09);

        (omitted)

      }
      else
      {
        gMtRevSpeed = 512;
        gMtSpeedMax = 1024;
      }

      (omitted)

      mtSetDuty(gMtRevSpeed,gMtSpeedMax);

    }
    (omitted)
  }
}

```

← Calculation of the rotation speed according to the

← Calculation of the rotation speed according to the programmed variables

← Speed setting

**Figure 4-15 Rotation speed control**

The brake control routine is written around Line 192 in the MAIN.C main function as shown in “Figure 4-16 Brake control”.

While SW3 is pressed, the outputs to all the semiconductor elements are set to off and the brake is applied to the motor.

```

void main(void)
{
  (omitted)
  /* main loop */
  while (1)
  {
    if (!gCanEnableFlag)
    {
      (omitted)

      /* Set motor break */
      if(gMtStatus == MTST_MOVE)
      {
        /* Set the Motor Start Flag */
        if (PDR4_P41)
        {
          OCSH1_OTE0 = 1;
          OCSH1_OTE1 = 1;
          OCSH3_OTE0 = 1;
          OCSH3_OTE1 = 1;
          OCSH5_OTE0 = 1;
          OCSH5_OTE1 = 1;

          TCCSL0_STOP = 0;
        }
        else
        {
          OCSH1_OTE0 = 0;
          OCSH1_OTE1 = 0;
          OCSH3_OTE0 = 0;
          OCSH3_OTE1 = 0;
          OCSH5_OTE0 = 0;
          OCSH5_OTE1 = 0;
          PDR3 = 0x00;

          TCCSL0_STOP = 1;
        }
      }
      (omitted)
    }
    (omitted)
  }
}

```

The code block for setting OCSH1\_OTE0, OCSH1\_OTE1, OCSH3\_OTE0, OCSH3\_OTE1, OCSH5\_OTE0, and OCSH5\_OTE1 to 1 is annotated with a red bracket and the text "← Brake released".

The code block for setting OCSH1\_OTE0, OCSH1\_OTE1, OCSH3\_OTE0, OCSH3\_OTE1, OCSH5\_OTE0, and OCSH5\_OTE1 to 0, and setting PDR3 = 0x00, is annotated with a red bracket and the text "← Brake applied".

Figure 4-16 Brake control

The rotation direction routine is written around Line 221 in the MAIN.C main function as shown in “Figure 4-17 Rotation direction control”.

When SW5 is set to the right side, the motor rotates to the right, and when it is set to the left side, the motor rotates to the left.

```
void main(void)
{
  (omitted)
  /* main loop */
  while (1)
  {
    if (!gCanEnableFlag)
    {
      (omitted)

      /* Motor Rev Direction */
      gMtRevDir = PDR2_P27; ←Acquisition of the rotation direction

      /* Set Value */
      gDirection = gMtRevDir; ←Configuration of the rotation direction
      (omitted)
    }
    (omitted)
  }
}
```

**Figure 4-17 Rotation direction control**

## 5 Try to use CAN communication

Communication is to send/receive information. There are various types of communication such as utterance/hearing of spoken words, writing/reading of written letters, and electrical transmission of information.

Among them, there are various standards for communication based on electrical transmission. This chapter describes a communication standard called CAN.

CAN is a global standard of the ISO (International Organization for Standardization).

### 5.1 What is CAN?

CAN stands for Controller Area Network, which is an on-board LAN specification proposed by Bosch in Germany. It is the most popular on-board control LAN and used in various parts of a vehicle as shown in “Figure 5-1 Example of on-board CAN application”.

It is now also used not only in vehicles but also in many industries.

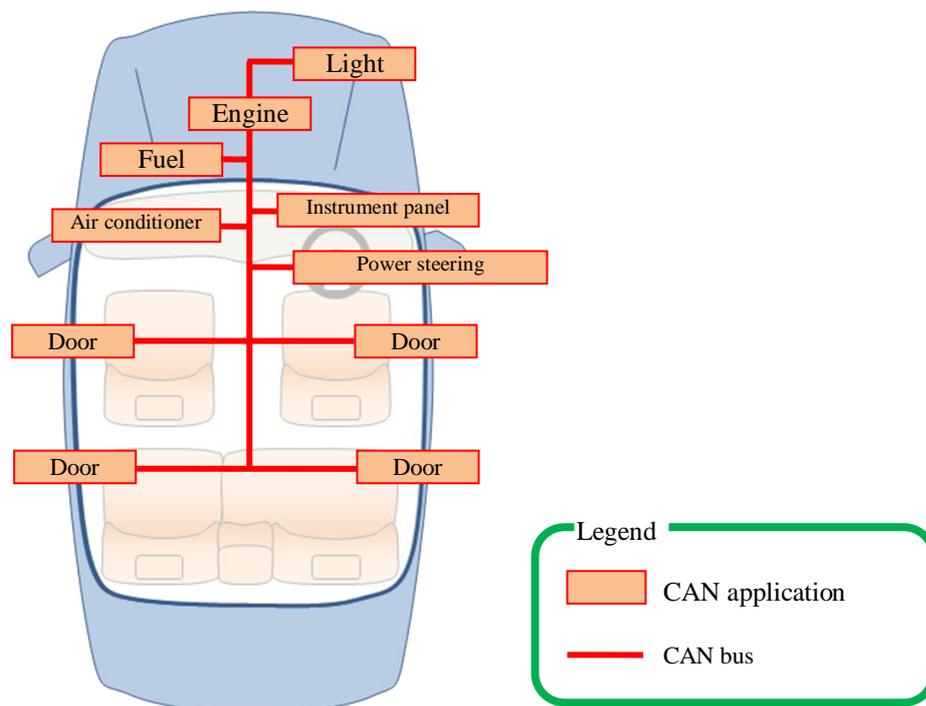


Figure 5-1 Example of on-board CAN application

The features of CAN can be classified into the following five points.

1. Multi-master communication

CAN employs the multi-master system in which each node is allowed to start communication as desired. The timing of a start of communication is occurrence of an event. The word “event” mentioned here indicates an occasion at which a node needs to start communication.

CAN avoid conflicts in communication through mediation with node signals if more than one event occurs on nodes simultaneously. This mediation is called arbitration.

2. Bus-type topology

The CAN topology is the bus type. The maximum number of nodes depends on the communication speed; in the case of 1M bits/sec, up to 30 nodes are allowed. This is specified as a regulation.

3. Differential transmission system

Taking account of influence from noise on the transmission paths, CAN employs the differential transmission system in which the voltage difference between two signal lines is used to determine “0”/”1”. The signal lines are respectively called CANH and CANL and the voltage difference between them is used to determine the bus level. The differential is used to determine logical “0”/”1”. As shown in “Figure 5-2 CAN bus signal levels”, the bus status of logical “0” is called dominant and the bus status of logical “1” is called recessive. The communicable distance depends on the communication speed; in the case of 1M bits/sec, up to 40 m is allowed. This is also specified by a regulation.

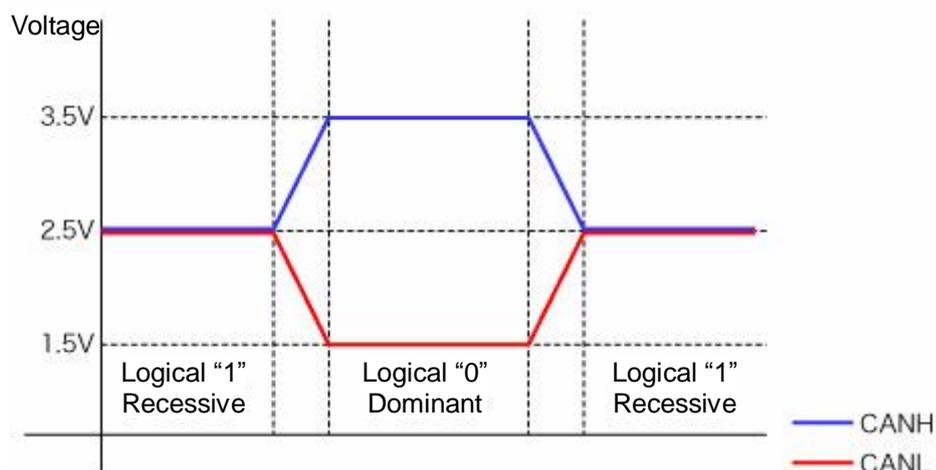


Figure 5-2 CAN bus signal levels

#### 4. High-speed version and low-speed version

There are two CAN specifications with different communication speeds. One of them is High-speed-CAN. High-speed-CAN is standardized as ISO11898 and its maximum and minimum communication speeds are 1 Mbits/sec and 125 kbits/sec. The other is Low-speed-CAN. Low-speed-CAN is standardized as ISO11519 and its maximum communication rate is 125 kbits/sec. The communication speeds currently popular are, in order of rates, 500 kbits/sec, 250 kbits/sec, 125 kbits/sec, 83.3 kbits/sec, 33.3 kbits/sec and so forth.

#### 5. Node control with error counters against errors

CAN supports five types of error detection. Each node has error counters. If an error occurs, either counter is increased by a specified count. On the contrary, when communication is successful, the counter is decreased by a specified constant. The communication status of each node is determined by the values of the error counters. This mechanism serves to limit communication by node.

## 5.2 CAN specifications

This section provides brief descriptions of the CAN specifications.

For more information about the specifications, access the web site of the CAN promoting organization CiA (CAN in Automation) (<http://www.can-cia.org/>) and make a registration; you can get the specifications.

### 5.2.1 CAN frame configurations

This section describes frames that are the fundamental communication unit of CAN.

CAN provides four types of frames, which are respectively named the data frame, remote frame, error frame, and overload frame as shown in “Figure 5-3 CAN frame configurations”.

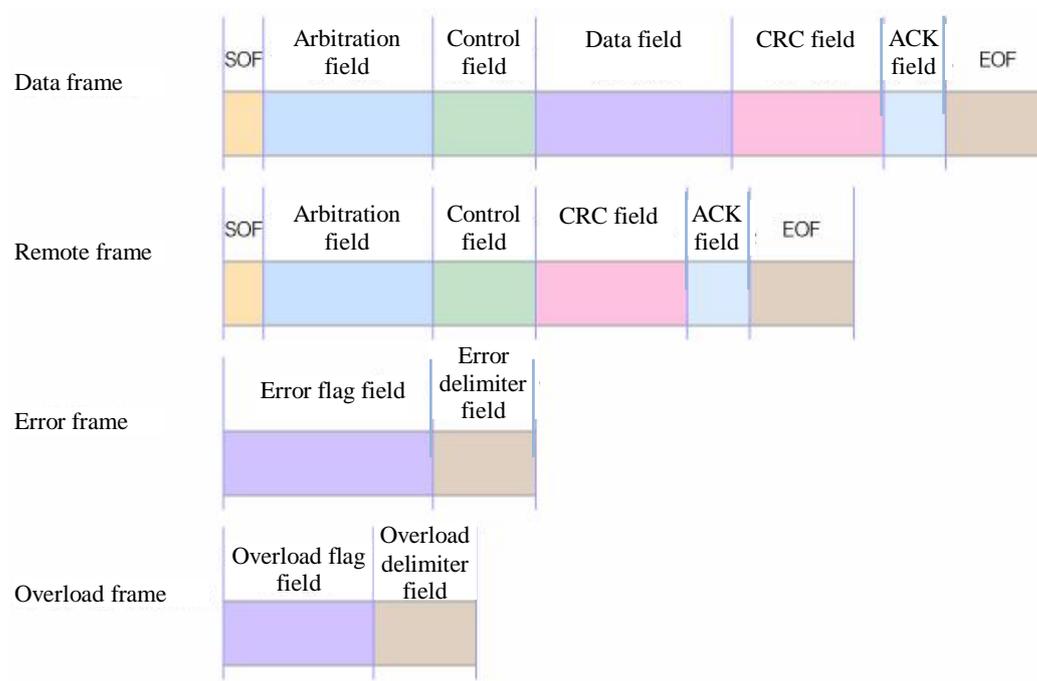


Figure 5-3 CAN frame configurations

### 1. Data frame

Transfer format for data transmit. It consists of seven fields.

Field name	Description
Start of frame (SOF)	1-bit field containing “0” that indicates the start of a data frame
Arbitration field	Field that determines the priority of the data. This field is also called the ID field and there are two types of format; standard format and extended format. The standard format is 12 bits and extended format is 32 bits.
Control field	6-bit field that indicates the length of the data field.
Data field	0-byte to 8-byte field that stores real data.
CRC field	16-bit field that serves to allow a check of the transmitted frame validity.
ACK field	2-bit field that is used to notify of successful reception.
End of frame (EOF)	7-bit field containing “1” that indicates the end of the data frame.

### 2. Remote frame

Usually, in CAN, a form of transmit of communication information to a node is generally used, but it is also allowed to request a specific node to transmit specific data. For this purpose, the remote frame is available.

The remote frame has almost the same configuration with the data frame; it consists of six fields except the data field. The control field of the remote frame indicates the length of the data field for the requested data.

### 3. Error frame

Transfer format immediately sent on error detection on a node. The error frame consists of two fields.

Field name	Description
Error flag	6-bit to 12-bit field that indicates the error type.
Error delimiter	8-bit field containing “1” that indicates the end of the error frame.

## 4. Overload frame

Transfer format sent to indicate that the node is in unreceivable status

Field name	Description
Overload flag	6-bit to 12-bit field that indicates the type of overload.
Overload delimiter	8-bit field containing “1” that indicates the end of the error frame.

5.2.2 Arbitration

CAN employs the multi-master communication system, so any node can start communication. But, the number of communication sessions actually allowed on one bus is only one. Each node is cyclically checking whether the bus is the status of transmission. When there is no transmission on the bus, communication is started, but if more than one node starts transmission, they conflict. Against this, CAN performs arbitration to give priority to one with a lower ID for transmission. This section describes the arbitration.

The arbitration is carried out by comparison between the ID and the bus level by bit as shown in “Figure 5-4 Operation of the arbitration”. Bit 10 to 7 of Node 1 and Node 2 are the same as the bus level. This indicates that both Node 1 and Node 2 are transmitting signals. But, Bit 6 of Node 1 is set to “0” and that of Node 2 is set to “1”. The bus level is “0”, so Node 2 recognizes that the frame is not of its own communication and stops the transmission immediately. Node 1 keeps on transmitting. After Node 1 ends communication and stops the transmission immediately. Node 2 resumes transmission.

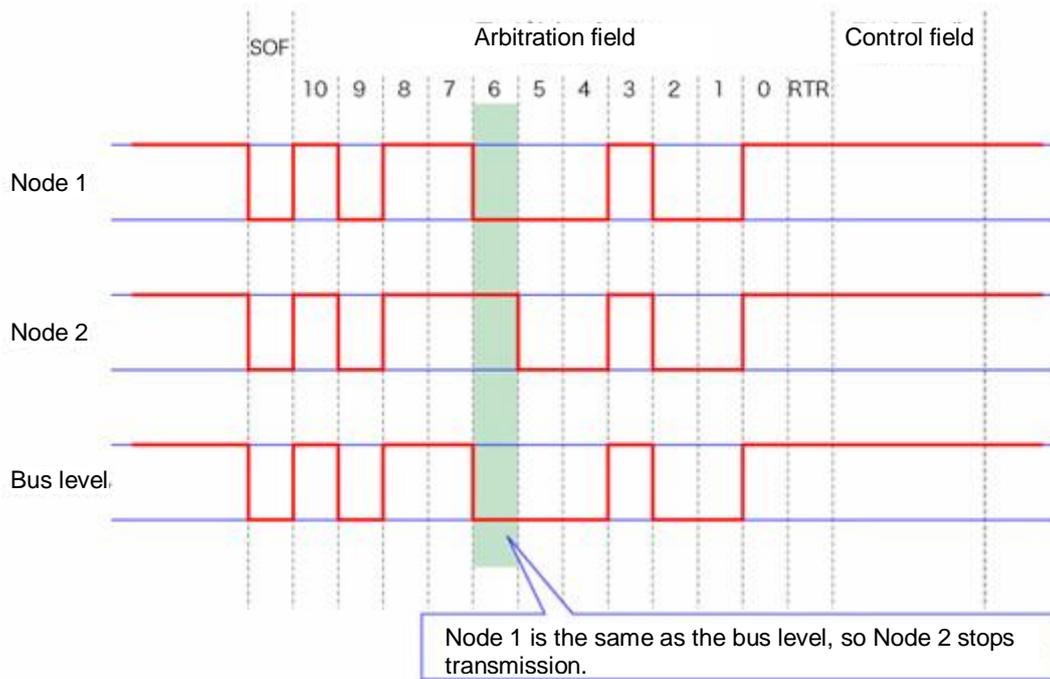


Figure 5-4 Operation of the arbitration

The bus status is determined according to the logical product of IDs, so “0” is prior to “1”. This means that a lower ID takes priority.

A practical communication flow shown in “Figure 5-5 Example of arbitration among nodes” is as described below. First, Node 1 and Node 2 starts transmission simultaneously. The arbitration results in

giving priority to the Node 1 transmission with a lower ID. After Node 1 ends its transmission, Node 2 resumes transmission.

After that, Node 1 and Node 3 starts transmission simultaneously. The arbitration is also performed and results in giving priority to the Node 3 transmission. After that, Node 4 starts transmission as soon as Node 3 ends its transmission. On this occasion, arbitration between Node 1 retransmission and Node 4 transmission is performed. This results in transmission in order of Node 4 to Node 1. That is, setting a lower ID to those of preference allows priorities to be settled for communication.

The ID is assigned by the command, information, and type of transmit data. The ID settings can be configured as desired.

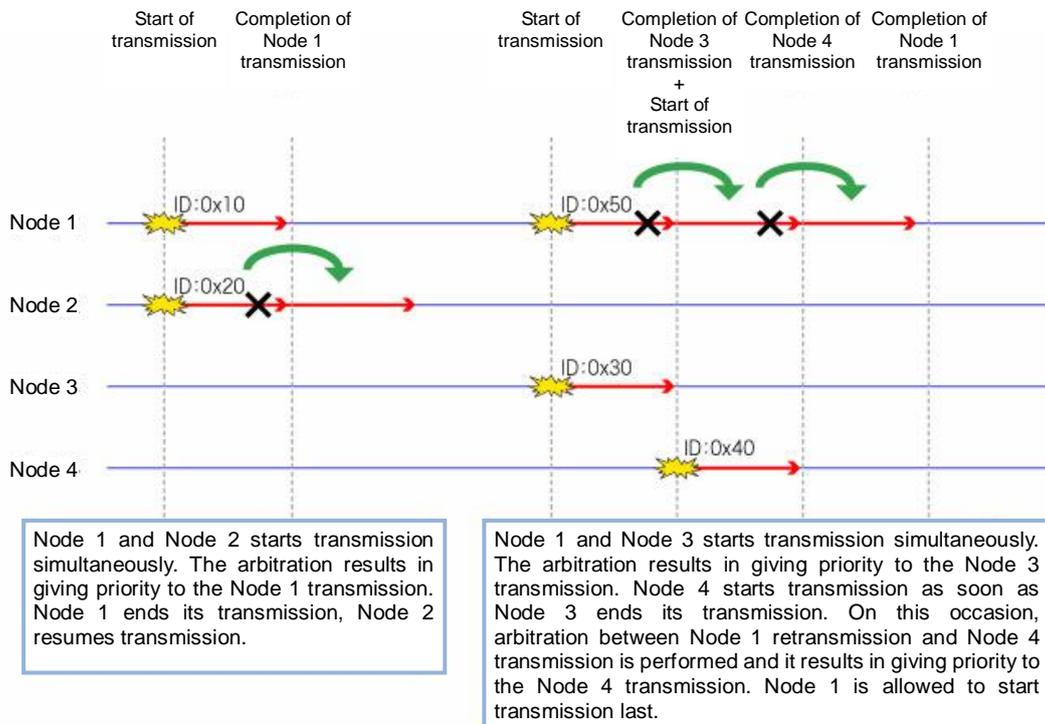


Figure 5-5 Example of arbitration among nodes

### 5.2.3 Error management

CAN error management is defined in its protocol. Five types of error detection and three types of status are used.

#### 1. Error detection

As shown in “Table 5-1 Description of the error types”, errors that can be detected depends on whether the node is transmitting or receiving.

**Table 5-1 Description of the error types**

Error type	Transmitting node	Receiving node	Description
Bit error	○	-	Detected if there is a difference between the transmitted data and the bus level.
ACK error	○	-	Detected if an acknowledgement to transmission cannot be obtained.
Stuff error	-	○	Detected if bit stuffing is not applied. Bit stuffing is to set an inverted bit by 5 bits if the number of successive bits with the same level is 5 or more. This prevents bits with the same level from being successive over 6 bits.
CRC error	-	○	Detected if CRC (cyclic redundancy check) fails on the received data.
Format error	-	○	Detected if the received data does not confirm to any of the frame formats.

#### 2. Statuses

Each node has error counters whose value depends on the status. The error counters of the nodes are named TEC (transmit error count) and REC (receive error count) intending transmission and reception. The three statuses are as described below.

Status	Description
Error active	The node is normally joining in the bus.
Error passive	The node has frequent errors so it is influencing the bus.
Bus off	The node is disconnected from the bus. To restore to the bus, the bus needs to satisfy the restoration condition.

Transition between the statuses is described below along the example shown in “Figure 5-6 CAN status transition”. The initial status of a node is error active. In this status, occurrence of errors increases the TEC/REC counters.

If either of the TEC/REC counters comes to 127 or higher, the status of the node changes to error passive. In this status, the node remains communicable and the values of the counters decrease whenever a communication session is normally carried out.

When both the TEC/REC counters decrease to 127 or less, the status of the node returns to error active.

If the TEC counter increases after the node comes to error passive and the count comes to 255 or higher, the status of the node changes to bus off.

If the status of the node becomes bus off, the node cannot be restored to error active unless the restoration condition that successive 11-bit recessive is received 128 times is satisfied.

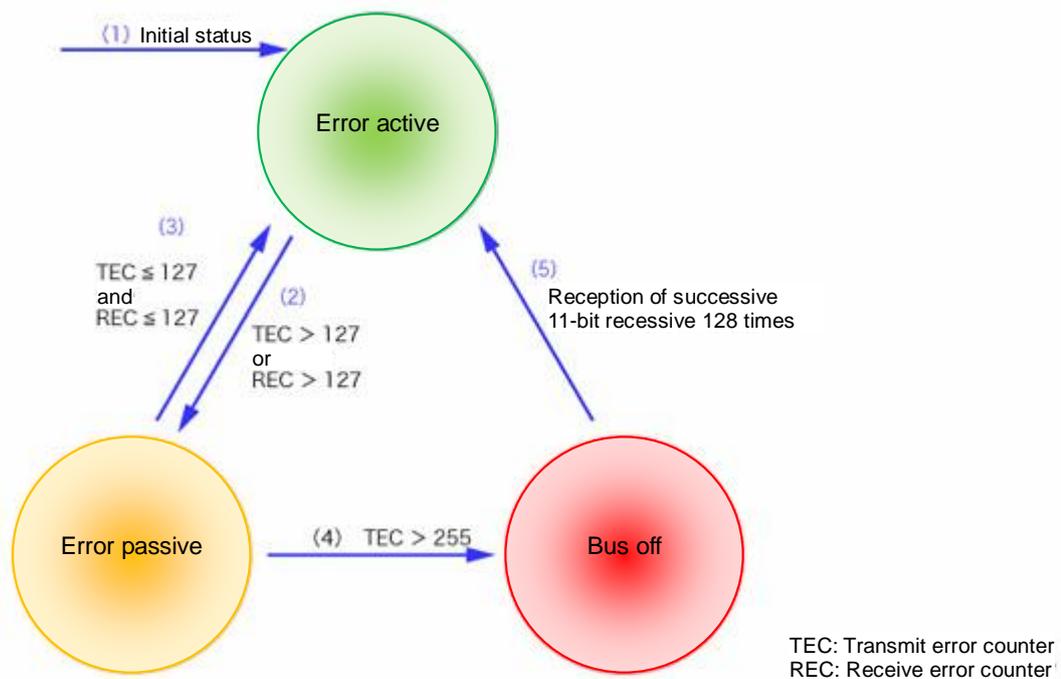


Figure 5-6 CAN status transition

### 5.3 CAN communication by using the microcontroller

This section describes how to perform practical CAN communication with the microcontroller.

On the board, as shown in “Figure 5-7 CAN circuit”, the microcontroller is connected with the CAN transceiver (MAX3058). TX0 on the microcontroller is used for transmission and RX0 is used for reception. Signals transmitted/received are transferred to CAN-High and CAN-Low as the differential signals on the bus through the CAN transceiver. Signals transmitted/received are transferred to CAN-High and CAN-Low as the differential signals on the bus through the CAN transceiver.

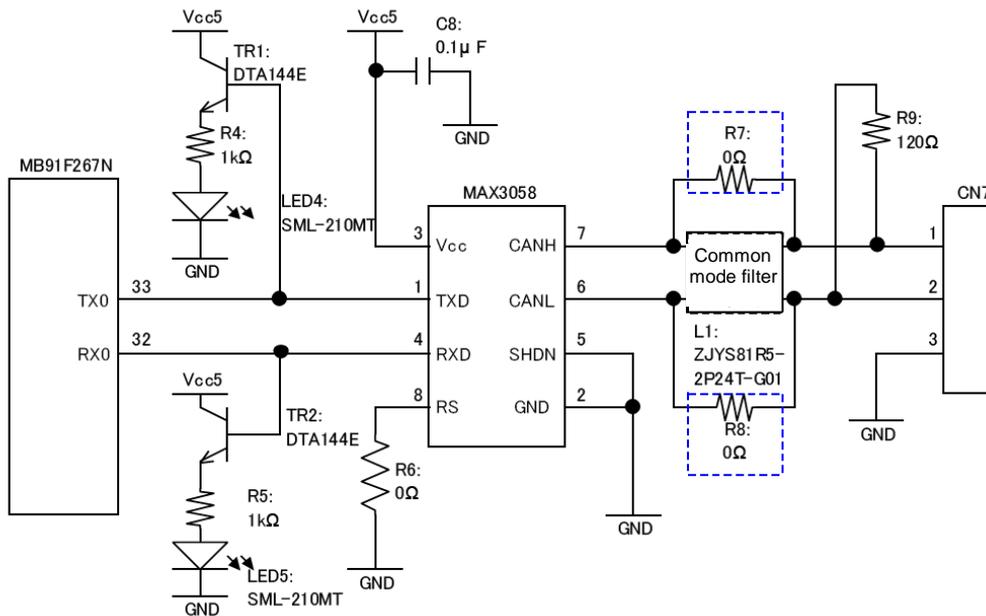


Figure 5-7 CAN circuit

The registers used for entire CAN communication control on the microcontroller are as shown in “Figure 5-8 Entire CAN communication control register”. The register bits whose name is “res” are reserved and not used.

A description of the registers and their setting values in the sample program are as described in “Table 5-2 Description of the entire CAN communication control registers and setting values”. For more information of the registers, refer to the microcontroller hardware manual.

CAN control register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
CTRLR0	res	res	res	res	res	res	res	res
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	Test	CCE	DAR	res	EIE	SIE	IE	Init

CAN bit timing register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
BTR0	res	TSeg2			TSeg1			
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	SJW		BRP					

CAN test register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
TESTR0	res	res	res	res	res	res	res	res
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	Rx	Tx1	Tx0	LBack	Silent	Basic	res	res

CAN prescaler extension register

	bit15	bit14	bit13	bit12	bit11	bit10	bit9	bit8
BRPER0	res	res	res	res	res	res	res	res
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
	res	res	res	res	BRPE			

**Figure 5-8 Entire CAN communication control register**

**Table 5-2 Description of the entire CAN communication control registers and setting values**

Register name	Setting value [function]	Description
CTRLR0_Test	0 [normal operation]	Test mode enable bit
CTRLR0_CCE	1 [write enable]	Bit timing register write enable bit
CTRLR0_DAR	0 [automatic retransmit enable]	Automatic retransmit prohibit bit
CTRLR0_EIE	0 [code setting disable]	Error interrupt code enable bit
CTRLR0_SIE	0 [code setting disable]	Status interrupt code enable bit
CTRLR0_IE	0 [interrupt disable]	Interrupt enable bit
CTRLR0_Init	1 [initialization]	Initialization bit
BTR0	0x2B43 [250 Kbps]	CAN communication speed
TESTR0_Rx	0 [dominant]	RXO pin monitor bit
TESTR0_Tx1	0 [normal operation]	TXO pin control bits
TESTR0_Tx0	0 ↑	
TESTR0_LBack	0 [loopback mode disable]	Loopback mode
TESTR0_Silent	0 [silent mode disable]	Silent mode
TESTR0_Basic	0 [basic mode disable]	Basic mode
BRPER0_BRPE	0 [value added to BTR0]	Baud rate prescaler extension bit

The registers used for CAN communication message handling on the microcontroller are APIs of the CAN driver in the sample software, so descriptions of the following registers are omitted. For more information of the registers, refer to the microcontroller hardware manual.

■Message interface registers

- IFx command request register (IFxCREQ)
- IFx command mask register (IFxCMSK)
- IFx mask register 1, 2 (IFxMSK1, IFxMSK2)
- IFx arbitration register 1, 2 (IFxARB1, IFxARB2)
- IFx message control register (IFxMCTR)
- IFx data register A1, A2, B1, B2 (IFxDTA1, IFxDTA2, IFxDTB1, IFxDTB2)

■Message handler registers

- CAN transmit request register 1, 2 (TREQR1, TREQR2)
- CAN data update register 1, 2 (NEWDT1, NEWDT2)
- CAN interrupt pending register 1, 2 (INTPND1, INTPND2)
- CAN message enable register 1, 2 (MSGVAL1, MSGVAL2)

## 5.4 Understanding and running the program for CAN communication

This section provides descriptions of the sample program that can serve for practical CAN communication.

### 5.4.1 CAN communication configuration

“Table 5-3 CAN communication conditions of the sample program” shows the CAN communication conditions of the sample program.

**Table 5-3 CAN communication conditions of the sample program**

Condition	Setting value
Communication speed	250 Kbps
CAN clock frequency	16 MHz
Bit time (NBT)	16
Sample point	81.3%
Sync. Jump width (SJW)	2
Sample count (SAM)	1
Data length	8 bytes

“Table 5-4 CAN message IDs in the sample program” provides a description of the message IDs used for CAN communication.

**Table 5-4 CAN message IDs in the sample program**

ID	Description	Communication direction
0x101	Motor operation start/stop command	receive
0x102	Motor operation rotation speed/Rotation direction/Brake command	receive
0x103	Temperature sensor measurement command	receive
0x201	Motor rotation information	transmit
0x202	Temperature sensor information	transmit

Details of the IDs are as shown below.

1. ID: 0x101

byte 0	Motor operation
byte 1	Motor rotation direction
byte 2	Motor rotation speed
byte 3	
byte 4	A/D maximum value
byte 5	
byte 6	Reserved
byte 7	Reserved

Field name	Setting value	Remarks
Motor operation command	0: Stop 1: Start	-
Motor rotation direction	0: Clockwise 1: Counterclockwise	-
Motor rotation speed	0 to 65535	The motor rotation speed and A/D maximum value are used for conversion of the speed to a percentage of 0% to 100%.
A/D maximum value	0 to 65535	

2. ID: 0x102

byte 0	Motor rotation direction
byte 1	Brake application
byte 2	Motor rotation speed
byte 3	
byte 4	A/D maximum value
byte 5	
byte 6	Reserved
byte 7	Reserved

Field name	Setting value	Remarks
Motor rotation direction	0: Clockwise 1: Counterclockwise	-
Brake application	0: Brake released 1: Brake applied	-
Motor rotation speed	0 to 65535	The motor rotation speed and A/D maximum value are used for conversion of the speed to a percentage of 0% to 100%.
A/D maximum value	0 to 65535	

## 3. ID: 0x103

byte 0	Temperature measurement command
byte 1	Reserved
byte 2	Reserved
byte 3	Reserved
byte 4	Reserved
byte 5	Reserved
byte 6	Reserved
byte 7	Reserved

Field name	Setting value	Remarks
Temperature measurement command	0: Start 1: Stop	-

## 4. ID: 0x201

byte 0	Motor rotation direction information
byte 1	Brake application information
byte 2	Motor rotation speed information
byte 3	
byte 4	A/D maximum value information
byte 5	
byte 6	Reserved
byte 7	Reserved

Field name	Setting value	Remarks
Motor rotation direction information	0: Clockwise 1: Counterclockwise	-
Brake application information	0: Brake released 1: Brake applied	-
Motor rotation speed information	0 to 65535	The motor rotation speed and A/D maximum value are used for conversion of the speed to a percentage of 0% to 100%.
A/D maximum value information	0 to 65535	

## 5. ID: 0x202

byte 0	Temperature information
byte 1	Reserved
byte 2	Reserved
byte 3	Reserved
byte 4	Reserved
byte 5	Reserved
byte 6	Reserved
byte 7	Reserved

Field name	Setting value	Remarks
Temperature information	0 to 50	-

5.4.2 Sample program sequence

“Figure 5-9 CAN communication flowchart” shows the CAN communication sequence of the sample program flow. First, the microcontroller is initialized. On the microcontroller initialization, the CAN operation timer starts operating.

After that, the CAN driver is initialized. Then, the motor driving macro is initialized and then the program goes into a loop.

Subsequently, motor rotation information transmit, temperature sensor information transmit, receive processing are handled in the timer routine.

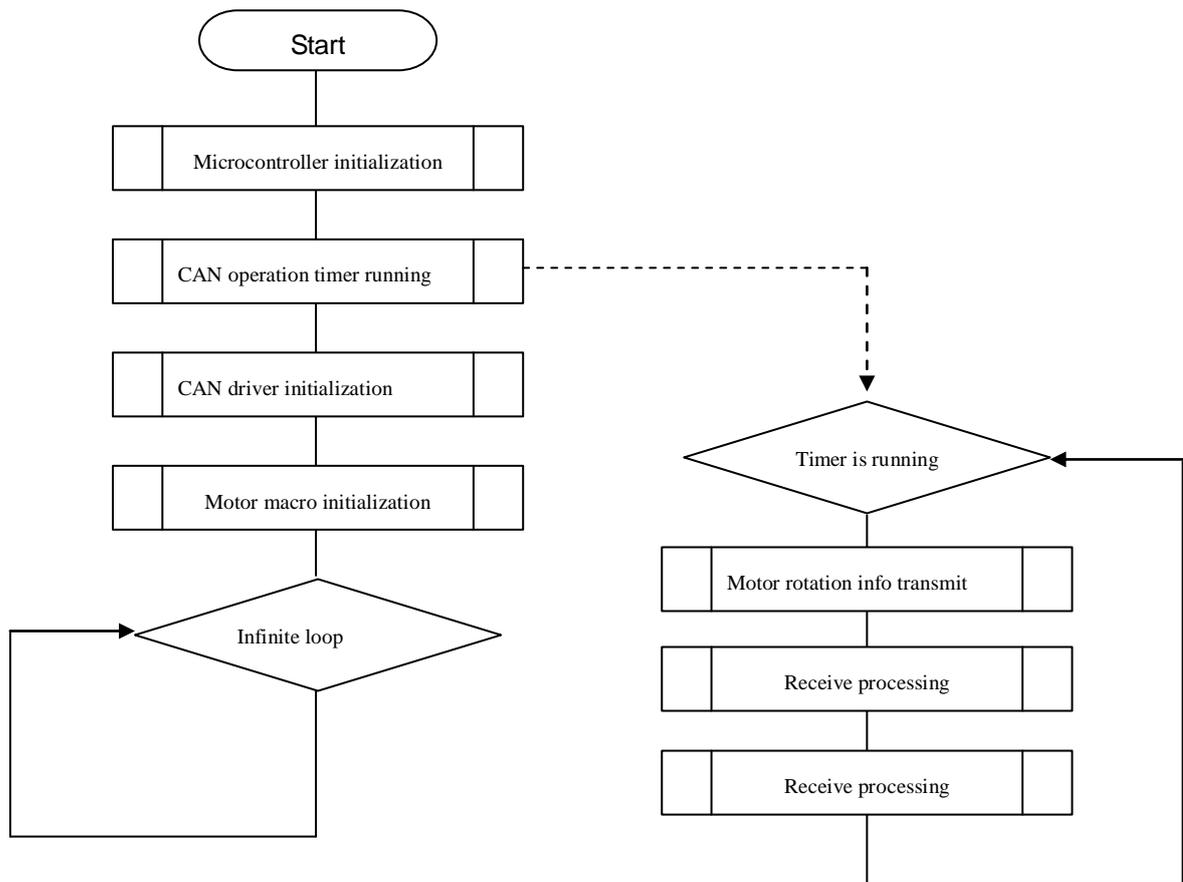


Figure 5-9 CAN communication flowchart

Now, take a look at the details of the program.

Look into the following folder of the sample program. There are some files stored in it. At first, open MAIN.C.

¥bitpot\_red\_SampleProgram¥Debug¥SRC

Look at around Line 40 that looks “Figure 5-10 Operation mode settings” for operation mode selection. There are #define settings that enable (1) or disable (0) CAN and temperature sensor.

In this program, both CAN and temperature sensor are to be used.

```

/* CAN communication use (1), or unused (0) */
#define CAN_PERMIT          (1)    ←CAN
/* Temperature sensor use (1), or unused (0) */
#define TEMP_SENSOR_USE    (1)    ←Temperature sensor
    
```

**Figure 5-10 Operation mode settings**

As shown in “Figure 5-11 Main function”, there is the main function around Line 131. In it, there are “microcontroller initialization”, “CAN driver initialization”, “motor macro initialization”, and “infinite loop”.

```

void main(void)
{
    (omitted);

    sysInitialize();          ←Microcontroller initialization

    if (gCanEnableFlag)
    {
        /* CAN Use */
        canInitialize();     ←CAN driver initialization
        adInitialize();
    }
    (omitted)

    mtInitialize();         ←Motor macro initialization

    (omitted)

    /* main loop */
    while (1)
    {
        (omitted)          ←Infinite loop
    }
}
    
```

**Figure 5-11 Main function**

As shown in “Figure 5-12 CAN timer interrupt control”, around Line 817 in MAIN.C, there is the timer interrupt function IRQ\_reload1. In it, motor rotation information transmit, temperature sensor information transmit, and receive processing are handled.

```
__interrupt void IRQ_reload1(void)
{
    (omitted)

    for (i = 0; i < 3; i++)
    {
        (omitted)

        /* Cycle check */
        if (counter[i] >= val)
        {
            switch (i)
            {
                case 0:
                    canSendTask01(); ←Motor rotation information transmit
                    break;
                case 1:
                    canSendTask02(); ←Temperature sensor information transmit
                    break;
                case 2:
                    canRecvTask(); ←Receive processing
                    break;
                default:
                    break;
            }
        }
    }
    (omitted)
}
```

**Figure 5-12 CAN timer interrupt control**

Details of motor rotation information transmit, temperature sensor information transmit, and receive processing are as described below.

First, concerning motor rotation information transmit, as shown in “Figure 5-13 Motor rotation information transmit”, there is the canSendTask01 function around Line 577 in MAIN.C. Only when the motor is rotating, a message sent with CAN is created and the transmit function canSendData, which is a CAN driver API, is invoked.

```
void canSendTask01(void)
{
    if (gMotorStartFlag == MOTOR_START)
    {
        /* Calc Send Data */
        calcCanSendData(CAN_MT_STATUS_ID, gCanSendBuf01);           ←Creation of a transmit
        /* Send Data */
        canSendData(CAN_MT_STATUS_MSG_NO, 8, gCanSendBuf01);       ←CAN transmit API
    }
}
```

**Figure 5-13 Motor rotation information transmit**

Concerning temperature sensor information transmit, as shown in “Figure 5-14 Temperature sensor information transmit”, there is the canSendTask02 function around Line 601 in MAIN.C. Only when a request for temperature sensor information is made, a message sent with CAN is created and the transmit function canSendData, which is a CAN driver API, is invoked.

```
void canSendTask02(void)
{
    if (gTempMeasureFlag == TEMP_MEASURE_ON) /* Measure Enable */
    {
        /* Calc Send Data */
        calcCanSendData(CAN_TEMP_INFO_ID, gCanSendBuf02);           ←Creation of a transmit
        /* Send Data */
        canSendData(CAN_TEMP_INFO_MSG_NO, 8, gCanSendBuf02);       ←CAN transmit API
    }
}
```

**Figure 5-14 Temperature sensor information transmit**

Concerning receive processing, as shown in “Figure 5-15 CAN receive processing”, there is the `canRecvTask` function around Line 625 in MAIN.C. First, the receive function `canRecvData`, which is a CAN driver API, is invoked by received ID, and then only those with `recvData` are processed.

```
void canRecvTask(void)
{
    (omitted)

    /* CAN Receive Data */
    ret = canRecvData(1, &canID, &dlc, recvData);    ←ID:0x0101 receive check

    (omitted)                                       ←ID:0x0101 receive processing

    /* CAN Receive Data */
    ret = canRecvData(2, &canID, &dlc, recvData);    ←ID:0x0102 receive check

    (omitted)                                       ←ID:0x0102 receive processing

    /* CAN Receive Data */
    ret = canRecvData(3, &canID, &dlc, recvData);    ←ID:0x0103 receive check

    (omitted)                                       ←ID:0x0103 receive processing
}
```

**Figure 5-15 CAN receive processing**

## 6 Appendix

### 6.1 Sample program folder/file configuration

“Table 6-1 Sample program folder/file configuration” shows the folder/file configuration of the sample program.

**Table 6-1 Sample program folder/file configuration**

File/folder name	Provision of the file		Description
	Single	Monitor	
bitpot_red_SampleProgram/bitpot_red_SampleProgram_md			
bitpot_red_SampleProgram.prj	○	-	Softune project file
bitpot_red_SampleProgram.wsp	○	-	Softune work space file
bitpot_red_SampleProgram_md.prj	-	○	Softune project file
bitpot_red_SampleProgram_md.wsp	-	○	Softune work space file
flash_erase_sec.bin	-	○	Flash erase program
flash_write.bin	-	○	Flash write program
FshLdWrt.prc	-	○	Flash execution program
template.dat	○	○	Softune configuration file
Debug			
mon_38400.sup	-	○	Monitor Debugger file
ABS			
bitpot_red_SampleProgram.mhx	○	○	Sample program hex file
bitpot_red_SampleProgram_md.mhx	○	○	Sample program hex file
LST			
OBJ			
OPT			
SRC			
can_drv.c	○	○	CAN driver source file
can_drv.h	○	○	CAN driver header file
MAIN.C	○	○	Main source file
MB91265.h	○	○	Microcontroller header file
motor_drv.c	○	○	Motor driver source file
motor_drv.h	○	○	Motor driver header file
Start91265.asm	○	○	Microcontroller start assembler file
UART0.c	○	○	UART source file
usr_def.h	○	○	Common define header file
vectors.c	○	○	Vector table source file
FR60			
Debug			
ABS			
FR60.mhx	-	○	Monitor Debugger hex file