RX62T

Three-Shunt Sensorless Vector Control of Permanent Magnet Synchronous Motors (PMSM) with Internal Programmable Gain Amplifier (PGA)

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Introduction

This document presents the RX62T three-shunt sensorless vector control solution using the internal PGA, which has been implemented on the RX62T evaluation kit with three-shunt current measurements. It describes the evaluation kit hardware setup for the internal PGA, the RX62T PGA, the PGA related sample circuit design, the gain calculation, and software implementation. For the three-shunt sensorless vector control, please refer to the application note of “Three-Shunt Sensorless Vector Control of PMSM”.

Target Device

RX62T

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1. Overview

The sensorless vector control requires the current measurement for three-shunt or single-shunt. Traditionally, the current is sampled and amplified by an external amplifier before inputting it to the ADC channels of the microcontroller. It is not complex to design the linear amplifier circuit, but the extra circuits add to the hardware cost and increase the board size.

For the Renesas RX62T microcontroller, the PGA adds additional functionality, and it is integrated in the 12-bit ADC modules. 6 ADC channels for the AN000 to AN002 and AN100 to AN102 can be selected for amplification. The PGA gain value is programmable to 13.3/10.0/6.7/5.7/5.0/4.4/4.0/3.6/3.1/2.5/2.0/1.0. The outputs go into the analog multiplexer of the ADC converter, allowing the amplified signal to be converted by the ADC.

The PGA does not require feedback and input resistance, therefore, it can significantly reduce costs and save board space. Since the gains can be configured through software control, it makes the controls have high adaptability and flexibility. The PGA with the RX62T reduces the amount of components from the original design, and it can greatly simplify the previously complex circuit design and improve work efficiency.

The software described in this application note is applicable to the following devices and platforms:

- MCU: RX62T and RX62N
- Motor: Three-Phase Brushless DC (BLDC) and PMSM
- Platform: Renesas Evaluation Kit
- Control algorithm: Three-Shunt Sensorless Vector Control Using Internal PGA

2. Specifications and Performance Data

The implementation of the three-shunt sensorless vector control solution using an internal PGA is based on the Renesas evaluation kit and the RX62T MCU. The main specifications are described as following:

- Input Voltage: 24VDC
- Rated Bus Voltage: 24V
- Output Voltage: 24VAC
- Rated Output Power: 120W
- PWM Switch Frequency: 20KHz
- Control Loop Frequency: 10KHz
- Current Measurement: 3 Shunt Resistors
- Implementation: FPU
- CPU Bandwidth: 20%
- Used Flash Memory: 33.824Kbytes
- Used RAM: 4.397Kbytes
- Used Stack : 336bytes

3. Hardware Platform and Setup for PGA

The RX62T evaluation board is a single board with an integrated power inverter with the controller. The hardware includes a low-voltage MOSFET power stage, a communication stage, and a RX62T microcontroller based controller as shown in Figure 1.

The board has the following features:

- A complete 3-phase inverter with a low-voltage motor
- 24V external power supply to provide DC bus voltage, 15V and 5V power supply
- Power devices use Renesas low-voltage MOSFETs
- Power rating up to 120 watts
- Supports three-shunt and single-shunt current measurements
- Easily change jumpers from the external amplifiers to the internal PGA
- USB communication with the PC via a H8S2212 MCU
- Graphical User Interface (GUI) used to both modify the motor and control parameters and tune the speed and position control
- Connectors for Hall sensors and encoder connections
- LCD to monitor the operation status
- Supports the standalone mode set by potentiometer and push-buttons
- Supports the second motor drive, signals, and connector for another motor control power stage

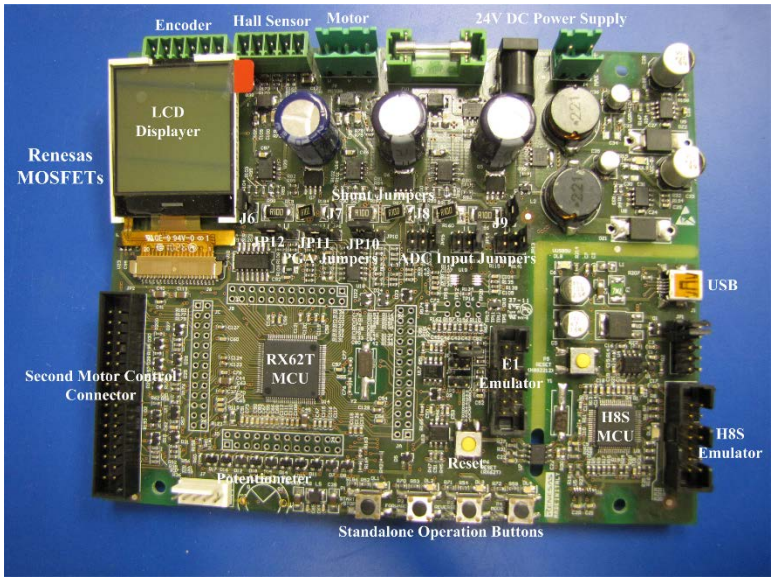


Figure 1 Evaluation Board

Figure 2 shows the evaluation kit hardware circuit for the three-shunt current measurements. Jumpers J6 and J9 are shorted, while J7 and J8 are open. The composite currents of all three MOSFET inverter low side legs can be measured with a single shunt resistor of 0.1Ω, or that the current in each individual leg can be determined with three shunt resistors. Table 1 lists the jumper setting for the three-shunt current measurements.

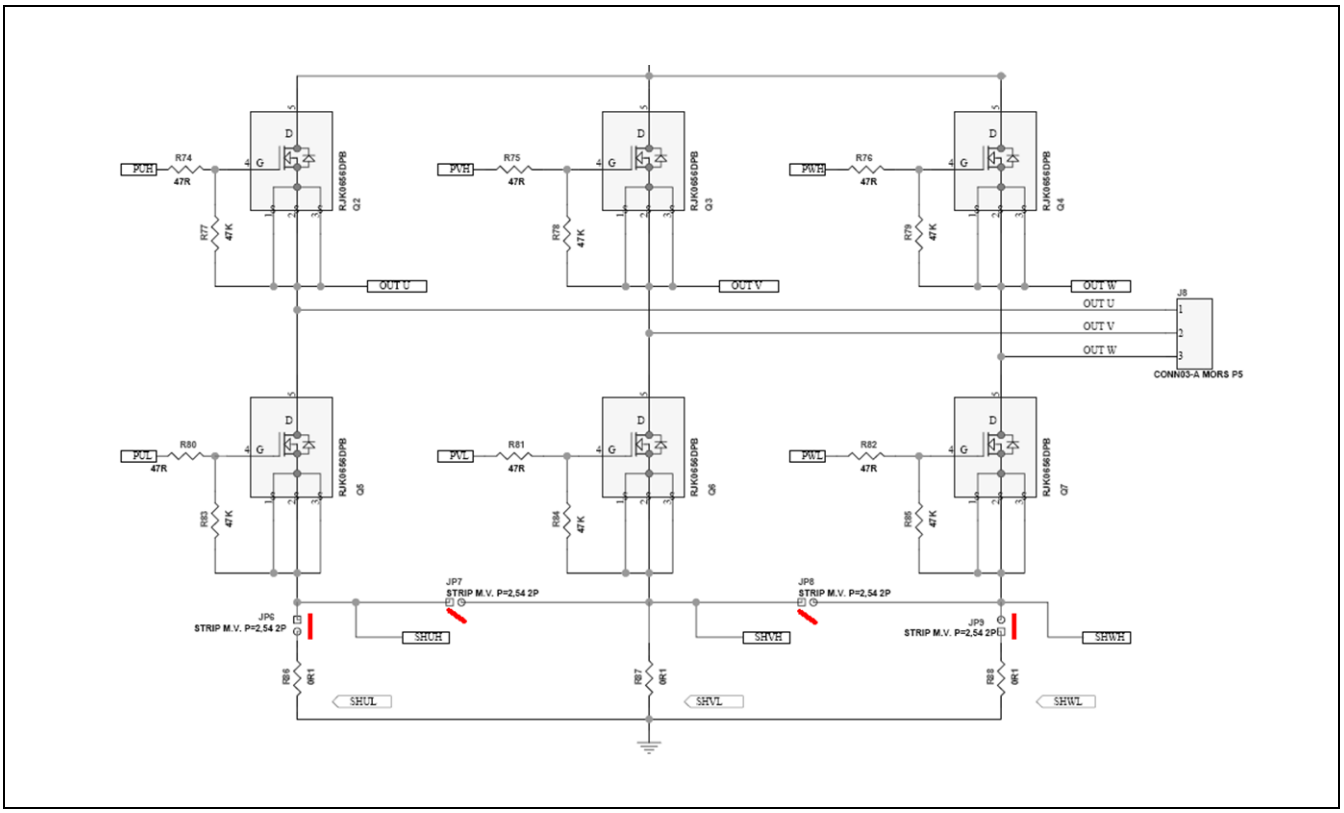


Figure 2 Three-Shunt Current Measurements in the Low Side Inverter Legs

Table 1 Jumper Settings for Three-Shunt Current Measurements

Jumper	J6	J7	J8	J9
State	ON	OFF	OFF	ON

The motor currents of i_u, i_v, i_w are measured by three shunt resistors. The shunt currents (i_u, i_v, i_w) are measured by a 12-bit ADC unit 0 of channel AN002, AN001and AN000. All three ADC channels have PGA support. Figure 3 shows the three-shunt current sample amplifier circuit with the 2.5V DC offset. If using the internal PGA, the external amplifiers in the red frame can be removed. The jumpers of JP10, JP11 and JP12 are set to 2-3. The outputs from the three shunt resistors directly input to the microcontroller after the 5V limit and the small capacitor filter. Table 2 lists the jumper settings for the internal PGA selection.

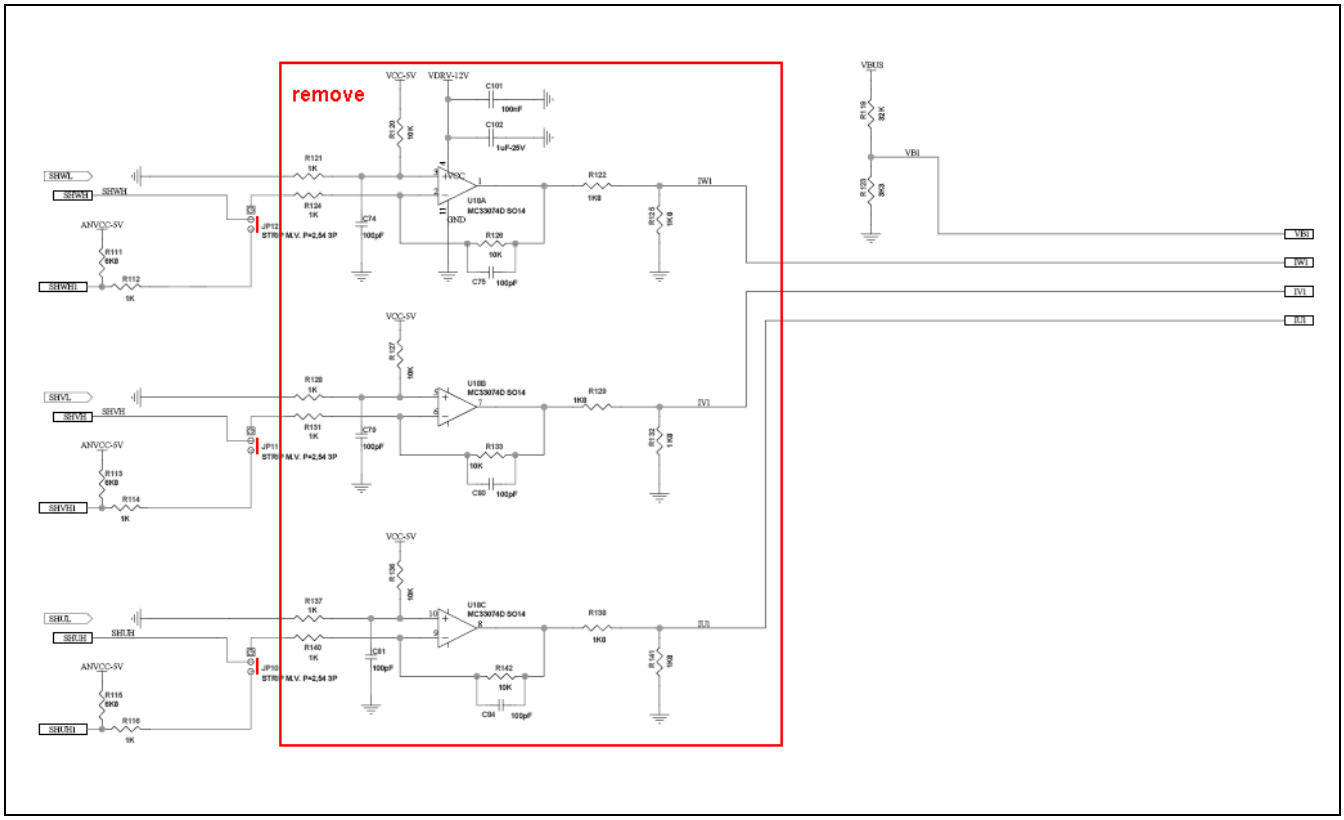


Figure 3 Three-Shunt Current Sampling with External Amplifier

Table 2 Jumper Settings for Internal PGA

Jumper	JP10	JP11	JP12	JP13	JP14	JP15
Pins	2-3	2-3	2-3	3-4	3-4	3-4

4. RX62T PGA

RX62T 12-bit ADC converters include a PGA for additional functionality. The two units of ADC: unit0 (S12ADA0) and unit1 (S12ADA1), can be operated separately. PGA and comparators are provided for AN000 to AN002 and AN100 to AN102. Figure 4 shows the structure of the ADC converter unit0 3 channels with the PGA. It can be seen that each of the ADC channels (AN000, AN001, and AN002) have a separate PGA. It is the same configuration for the ADC unit1. Each PGA should be enabled and defined to be used by the ADC channel selection register. The default is to by-pass the internal PGA.

All three channels have separate sample and hold circuits, which allows the three-shunt currents to be simultaneously sampled.

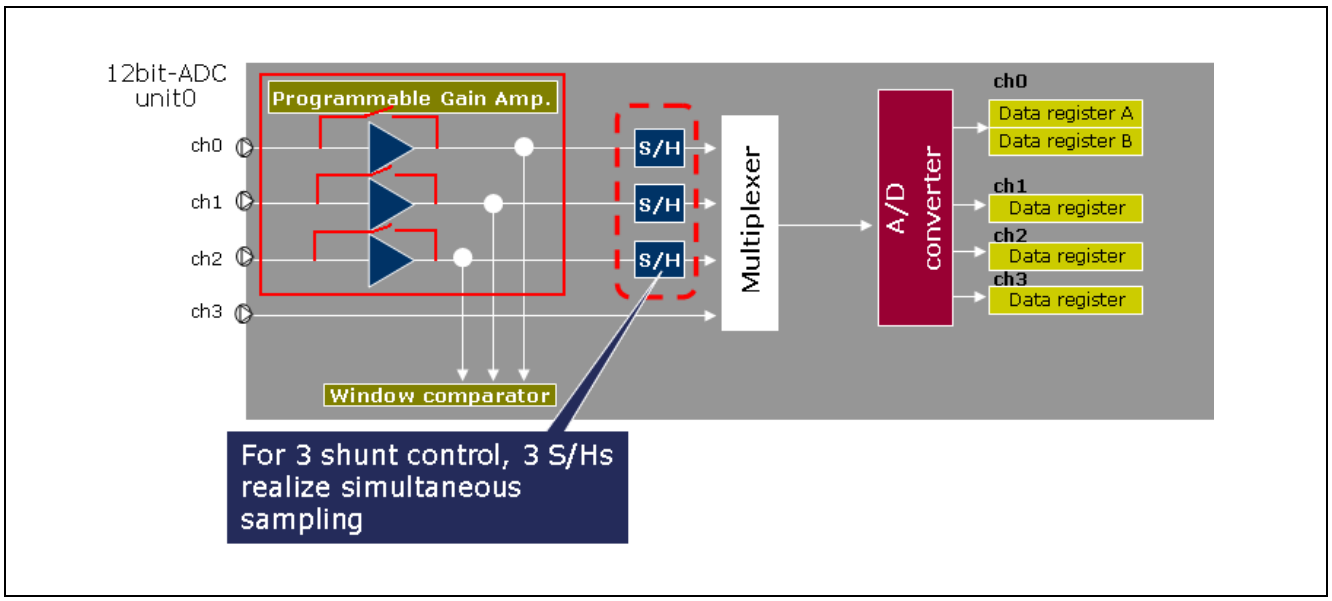


Figure 4 Structure of the RX62T ADC unit0 AN000, AN001, AN002 with PGA

The amplification rate includes 2.0, 2.5, 3.077, 3.636, 4.0, 4.444, 5.0, 5.714, 6.667, 10.0, or 13.333 times amplification, a total of 11 steps as listed in Table 3. The gain can be selected through the ADPG.PGnGAIN[3:0] bits (n = 000 to 002 or 100 to 102), and the operational amplifier can be selected through the ADANS.PGnEN and ADANS.PGnSEL bits.

Table 3 PGA Gain Steps

Amp Gain		
x 2.000	x 4.444	x 13.333
x 2.500	x 5.000	
x 3.077	x 5.714	
x 3.636	x 6.667	
x 4.000	x 10.000	

Table 4 shows characteristics of the PGA. The items for which test conditions are not specifically stated in the table below have the same values under conditions 1 to 3.

- Condition 1: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
  AVCC0 = AVCC = 3.0 to 3.6 V, VREFH0 = 3.0 V to AVCC0, VREF = 3.0 V to AVCC
- Condition 2: VCC = PLLVCC = 2.7 to 3.6 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
  AVCC0 = AVCC = 4.0 to 5.5 V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC
- Condition 3: VCC = PLLVCC = 4.0 to 5.5 V, VSS = PLLVSS = AVSS0 = AVSS = VREFL0 = 0 V
  AVCC0 = AVCC = 4.0 to 5.5V, VREFH0 = 4.0 V to AVCC0, VREF = 4.0 V to AVCC

Ta = −40 to +85° C. Ta is the same under conditions 1 to 3.

Table 4: Characteristics of the PGA

Item		Symbol	Min.	Typ.	Max.	Unit	Test Conditions
Analog input capacitance		Cin	-	-	6	pF	
Input offset voltage		Voff	-	-	8	mV	
Input voltage range (Vin)	Gain × 2.000	Vin	0.050 x AVcc	-	0.38 x AVcc	V	
	Gain × 2.500		0.047 x AVcc		0.30 x AVcc		
	Gain × 3.077		0.045 x AVcc		0.24 x AVcc		
	Gain × 3.636		0.042 x AVcc		0.21 x AVcc		
	Gain × 4.000		0.040 x AVcc		0.19 x AVcc		
	Gain × 4.444		0.036 x AVcc		0.17 x AVcc		
	Gain × 5.000		0.033 x AVcc		0.15 x AVcc		
	Gain × 5.714		0.031 x AVcc		0.13 x AVcc		
	Gain × 6.667		0.029 x AVcc		0.11 x AVcc		
	Gain × 10.000		0.025 x AVcc		0.08 x AVcc		
	Gain × 13.333		0.023 x AVcc	-	0.06 x AVcc		
Slew rate		SR	10	-	-	V/µs	
Gain error	Gain × 2.000	-	-	-	1	%	
	Gain × 2.500		-	-	1		
	Gain × 3.077		-	-	1		
	Gain × 3.636		-	-	1.5		
	Gain × 4.000		-	-	1.5		
	Gain × 4.444		-	-	2		
	Gain × 5.000		-	-	2		
	Gain × 5.714		-	-	2		
	Gain × 6.667		-	-	3		
	Gain × 10.000		-	-	4		
	Gain × 13.333		-	-	4		

5. PGA Related Sample Circuit Design and Gain Calculation

5.1 Difference Between External Amplifier and PGA

Figure 5 just shows one of the shunt current sample and external amplifier circuits. Because of the current polarity, the offset should be added to shift the maximum negative current to 0 volts. R1and Rs have been set in order to get Vin = 2.5V at Is = 0. The output of the amplifier is:

$$Vout = gain \times Vin + V_{offset}$$

Set Rd and Re for the amplifier gain to make Vout = 5V or less.

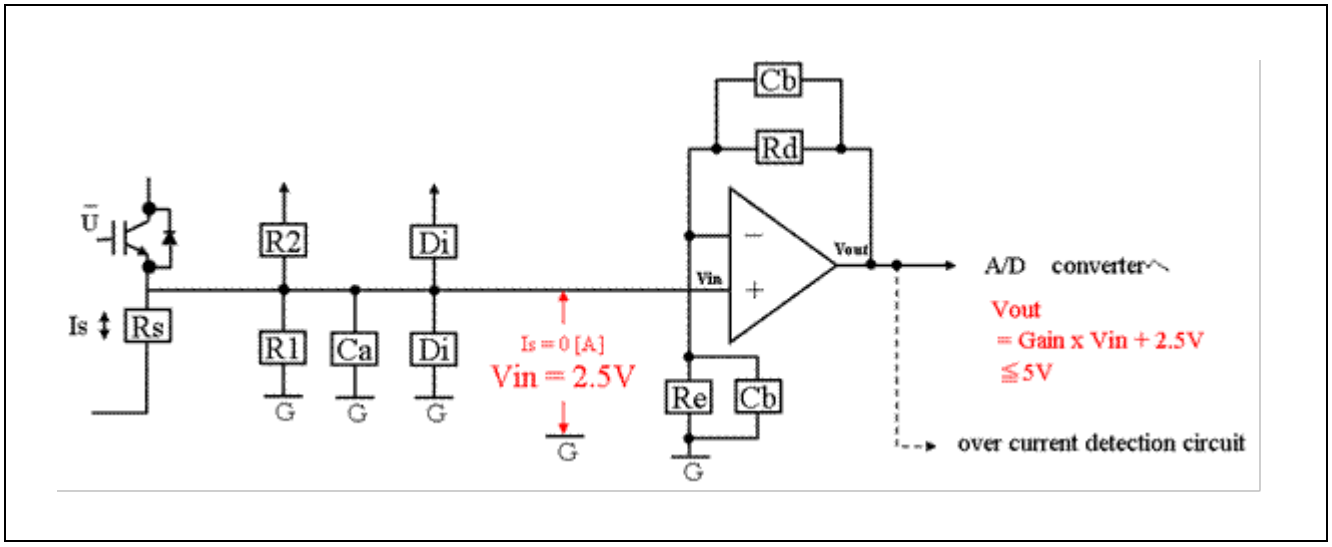


Figure 5 Motor Current Measurement with External Amplifier

Figure 6 depicts one of the shunt current samples with the internal PGA. Actually, there is no amplifier circuit required, because it is integrated with the RX62T microcontroller 12-bit ADC. The outside circuit only needs two resistors.

Because of the current polarity, the offset should be added to shift the maximum negative current above 0 volts. R1, R2, and Rs have been set in order to get:

Vin = 0V + x

x is a small, positive value above 0.1 volts to less than 2 volts, which depends on the PGA gain.

Define the PGA register for the gain to get Vout = 5V or less:

$$Vout = gain \times Vin$$

Figure 7 clearly shows the difference between these two amplifiers. The external amplifier shifts the output voltage from the shunt resistor to the positive value. The offset makes 0 to 2.5V. When the gain equals 2.5:

$$V_{out_max} = 2.5 + 1 \times 2.5 = 5V$$

$$V_{out_min} = 2.5 - 1 \times 2.5 = 0V$$

The input voltage to the ADC channels is 0 to 5 volts.

On the other hand, for the internal PGA, there is no offset circuit for the internal amplifier. It just amplifies the voltage to the maximum 5 volts. Therefore, the input voltage to the ADC should be a small positive value for the maximum polarity current. As described above, R1 and R2 can be set to make the input voltage as:

$$Vin = 0V + x$$

For example, in Figure 7, x equals 0.235 to 1.5V. If the PGA gain is set as 2.5, the ADC sample voltage would be 0.5875V for the maximum -5 Amps current, and 3.75V for the maximum 5 Amps current for the evaluation board.

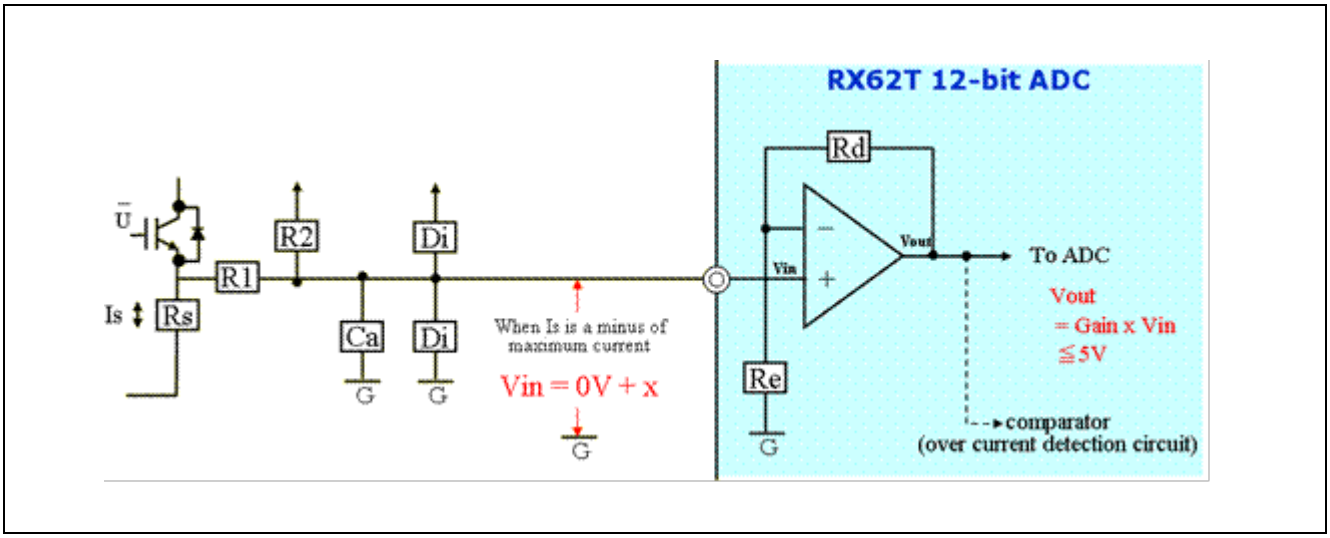


Figure 6 Motor Current Measurement with PGA

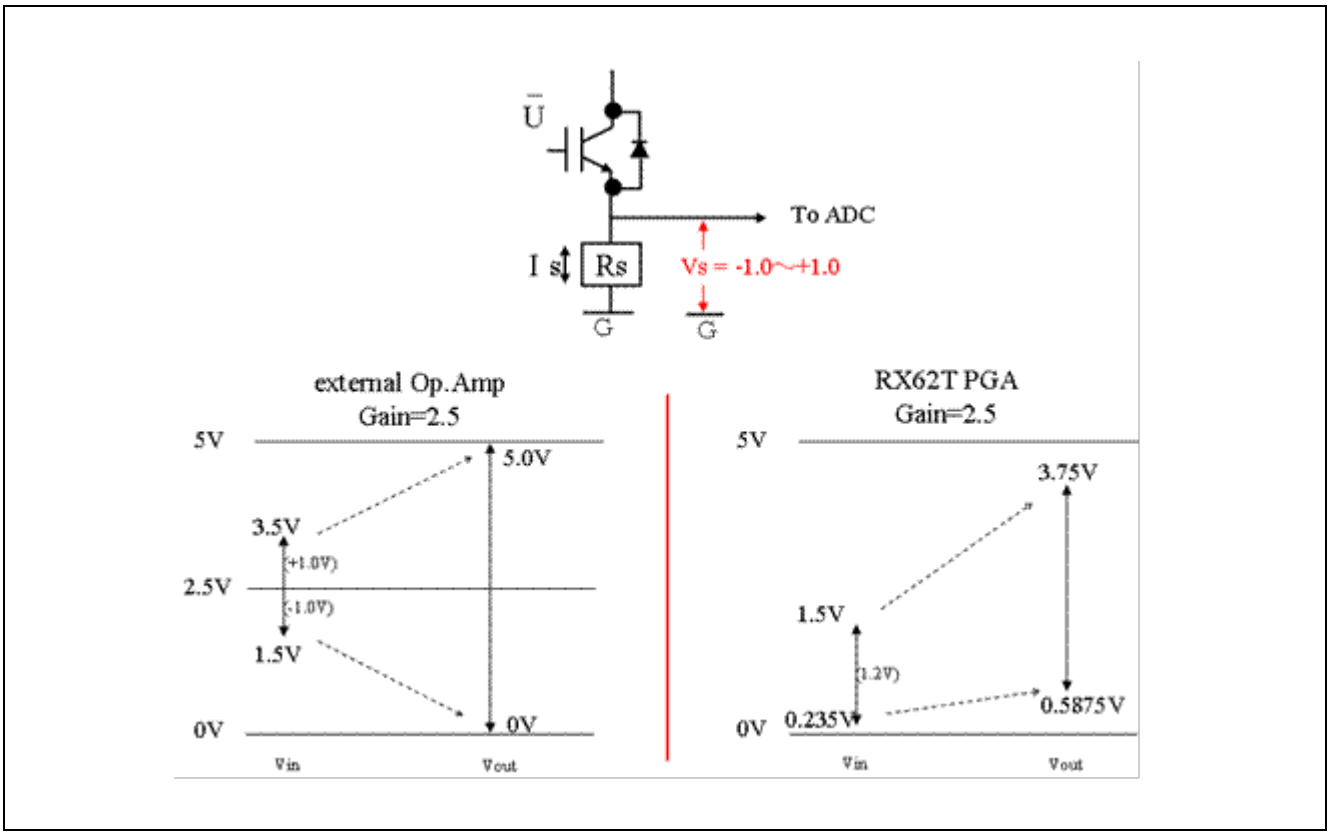


Figure 7 Motor Current Sensing Comparison Between External Amplifier and PGA

5.2 PGA Gain Calculation

Figure 8 shows the shunt current measurement with the PGA. The shunt resistor used in this application is 0.1Ω. The measured current range is from -5A to 5A. The voltage of the shunt resistance is from -0.5V to 0.5V. R1 and R2 resistors are selected to make this voltage to the some positive value.

The value of Vs, Vin and Vout can be estimated as below:

$$Vs[V] = 0[V] \pm Rs \times Is$$

$$\mathrm{Vin[V]} = \frac{\mathrm{Vref} \times \mathrm{R1}}{\mathrm{R1} + \mathrm{R2}} \pm \frac{\mathrm{Rs} \times \mathrm{Is} \times \mathrm{R2}}{\mathrm{R1} + \mathrm{R2}}$$

$$\mathrm{Vout[V]} = \frac{\mathrm{G} \times \mathrm{Vref} \times \mathrm{R1}}{\mathrm{R1} + \mathrm{R2}} \pm \frac{\mathrm{G} \times \mathrm{Rs} \times \mathrm{Is} \times \mathrm{R2}}{\mathrm{R1} + \mathrm{R2}}$$

Vout includes two parts: one is for the offset part voltage and the other is for the gain voltage.

The offset voltage and gain voltage of the RX62T are under:

$$\frac{\mathrm{G} \times \mathrm{V_{ref}} \times \mathrm{R1}}{\mathrm{R1} + \mathrm{R2}} = 2.5$$

$$\frac{\mathrm{G} \times \mathrm{Rs} \times \mathrm{Is} \times \mathrm{R2}}{\mathrm{R1} + \mathrm{R2}} \leqq 2.5$$

Circuit condition is with Vref = 5V, Is = 5A, R2 = kR1

$$\frac{5 \times \mathrm{G} \times \mathrm{R1}}{\mathrm{R1} + \mathrm{kR1}} = 2.5,$$

$$\frac{\mathrm{Rs} \times 5\mathrm{G} \times \mathrm{kR1}}{\mathrm{R1} + \mathrm{kR1}} \leqq 2.5$$

Therefore,

$2G = 1 + k$

$2 \text{ x } kG \text{ x } Rs \leqq 1 + k$

Gain k = 4 and Rs = 0.1Ω set to the equations above:

R1 = 1KΩ

R2 = 6.8kΩ

They are selected by the evaluation kit. Therefore the voltages are:

iu = 0A, the voltage to the ADC of Vu = 0.6V

iu = -5A, Vu = 0.16V

iu = 5A, Vu = 1.04V.

And the internal amplifier gain is set as 4.

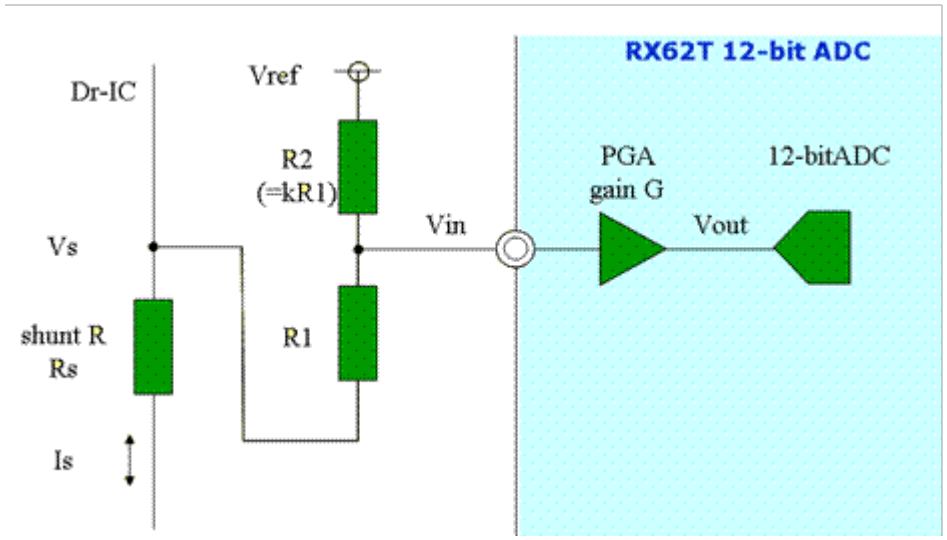


Figure 8 Shunt Current Sensing with PGA

6. Software Implementation

The three-shunt sensorless vector control software is the same as the one in the Application Note of “Three-Shunt Sensorless Vector Control of PMSM”. This section just explains how to set up the registers and modify the gain for the internal PGA in the software.

If the internal PGA is used, the changes of the software are only for the ADC registers and the gain of the three-shunt current measurement. Two ADC registers should be defined for the PGA usage.

6.1 ADC Channel Select Register (ADANS)

Figure 9 defines the bit definition of the ADC channel select register for three-shunt current measurements. If the bits 0 to 2 are set to 1, the PGAs for AN000, AN001, and AN002 are enabled. These channels are used to sample the three-shunt currents. The bits 8 to 10 need to set to 1 in order to select AN000, AN001 and AN002 PGAs. Therefore, this register is set as 0707 for this application.

Address: 0008 9004h

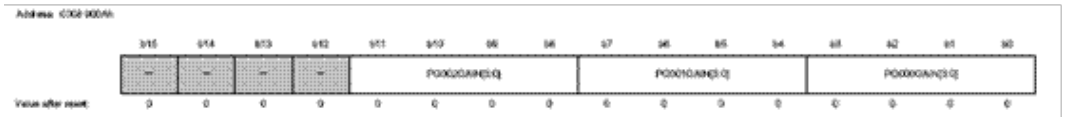
	b15	b14	b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0
	—	—	CH[1:0]		—	PG002 SEL	PG001 SEL	PG000 SEL	—	—	—	—	—	PG002 EN	PG001 EN	PG000 EN
Value after reset:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	Symbol	Bit Name	Description	R/W
b0	PG000EN	AN000 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b1	PG001EN	AN001 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b2	PG002EN	AN002 Programmable Gain Amplifier Enable	0: Programmable gain amplifier disabled 1: Programmable gain amplifier enabled	R/W
b7 to b3	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W
b8	PG000SEL	AN000 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b9	PG001SEL	AN001 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b10	PG002SEL	AN002 Programmable Gain Amplifier Select	0: Programmable gain amplifier not used (bypassed) 1: Programmable gain amplifier used	R/W
b11	—	Reserved	This bit is always read as 0. The write value should always be 0.	R/W
b13, b12	CH[1:0]	Channel Set	These bits select the analog input channels to be A/D-converted in S12ADA0. For details, see table 27.6	R/W
b15, b14	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Figure 9 Bit Definition of the ADC Channel Select Register for Three-Shunt Current Measurements

6.2 ADC Programmable Gain Amplifier Register (ADPG)

Figure 10 defines the bit definition of the ADC PGA register for the three-shunt current measurements. It defines the gain of the PGA for each ADC channel. The bits 0 to 3 are set for AN000; the bits 4 to 7 for AN001, and the bits 8 to 11 for AN002. Typically, the same gain is used for three-shunt currents. As calculated above in section 5.2 “PGA Gain Calculation”, the gain is set as 4 for this application. Therefore, the bits need to set as 0111 for each channel.



Bit	Symbol	Bit Name	Description	R/W
b3 to b0	PG000GAIN[3:0]	Gain Select for AN000 Programmable Gain Amplifier	b3 b0 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting proh bited 0 0 1 1: Setting proh bited 0 1 0 0: ×3.077 0 1 0 1: Setting proh bited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting proh bited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting proh bited	R/W
b7 to b4	PG001GAIN[3:0]	Gain Select for AN001 Programmable Gain Amplifier	b7 b4 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting proh bited 0 0 1 1: Setting proh bited 0 1 0 0: ×3.077 0 1 0 1: Setting proh bited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting proh bited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting proh bited	R/W
b11 to b8	PG002GAIN[3:0]	Gain Select for AN002 Programmable Gain Amplifier	b11 b8 0 0 0 0: ×2.0 0 0 0 1: ×2.5 0 0 1 0: Setting proh bited 0 0 1 1: Setting proh bited 0 1 0 0: ×3.077 0 1 0 1: Setting proh bited 0 1 1 0: ×3.636 0 1 1 1: ×4.0 1 0 0 0: ×4.444 1 0 0 1: ×5.0 1 0 1 0: ×5.714 1 0 1 1: ×6.667 1 1 0 0: Setting proh bited 1 1 0 1: ×10.0 1 1 1 0: ×13.333 1 1 1 1: Setting proh bited	R/W
b15 to b12	—	Reserved	These bits are always read as 0. The write value should always be 0.	R/W

Figure 10 Bit Definition of the ADC PGA Register for the Three-Shunt Current Measurements

6.3 Current Gain Setting

The shunt resistor 0.1Ω senses the maximum ±5Amps of current to convert the current to the ±0.5 voltage. R1 and R2 are 1KΩ and 6.8KΩ, respectively. When the shunt current iu = 0A, the voltage to the ADC of Vu = 0.6V; iu = -5A, Vu = 0.16V; iu = 5A, Vu = 1.04V. The internal amplifier gain is 4. The three-phase motor currents are measured as:

$$i_u = KADI * (AN002 - i_{u_offset})$$

$$i_v = KADI * (AN001 - i_{v_offset})$$

$$i_w = KADI * (AN000 - i_{w_offset})$$

$$KADI = 5/(4096 * Rshunt * Kamp)$$

Where,

i_u, i_v, and i_w are three-phase motor currents;

i_{u_offset}, i_{v_offset}, and i_{w_offset} are u, v and w phase current offsets, respectively;

$AN002$, $AN001$, and $AN000$ are the 12-bit ADC reading values of u, v and w phase shunt currents;

$KADI$ is the motor phase current scaling;

$Rshunt$ is the value of the shunt resistor;

$Kamp$ is the gain of the internal PGA.

7. Demonstration Guide

7.1 Introduction to the Demonstration Guide

The purpose of this Demonstration Guide is to help users get up and running quickly with the RX62T motor control kit (YMCRPRX62T). The RX62T Microcontroller is pre-programmed to run "Three-Shunt Sensorless Vector Control with External Amplifier". Therefore, the user will need to reprogram the board using the E1 programmer/debugger to demonstrate the Three-Shunt Sensorless Vector Control of PMSM with Internal PGA, and later sections will explain how to (1) setup the demo board, (2) build and debug the demo project with e^{2}studio, and (3) run the GUI application. The user needs to connect the motor and the power supply to experience the efficient motor control capabilities of the Renesas RX62T microcontroller.

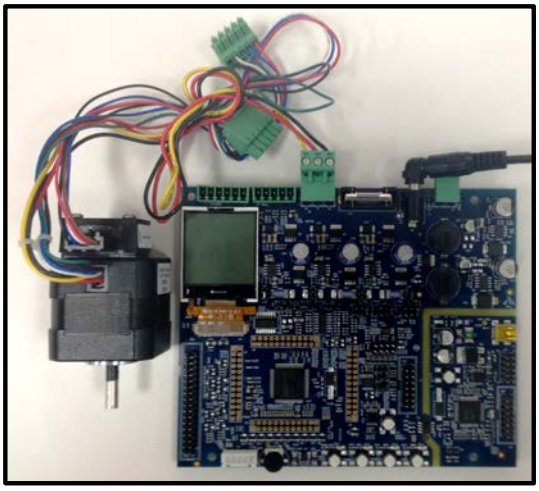
Caution: Do not connect power to the board until all instructions are followed.

The Demo contains the following items:

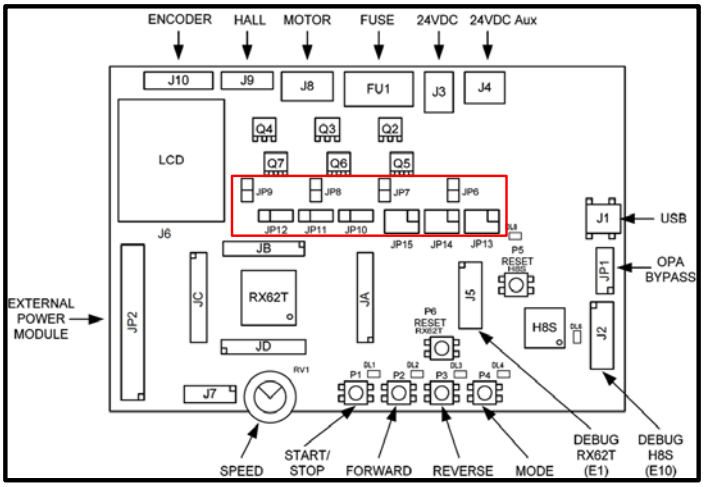
- RX62T Motor Control Evaluation Board (YMCRPRX62T)
- One BLDC Motors with a 3-way Molex connector and encoder cable
- 24V DC power supply
- E1 debugger
- Mini-USB cable
- CD ROM for motor firmware and application GUI

7.2 Demo Board Setup

Figure 11 (a) shows the board with the motor connected to **J8** and the power supply to **J3**. There are four push-buttons, a thumb-wheel potentiometer, a graphic LCD, and a few simple steps to quickly operate the motor out of the box. For debugging or programming, the user needs to connect **J5** with E1. Use the Mini-USB connector, **J1**, in the evaluation board for communication to the GUI.



(a) Board Layout



(b) Functional Layout

Figure 11 Board Layout

Before starting the demo, reconfigure the jumpers (**JP6** – **JP15**) as highlighted with red in Table 5. The jumper's location is shown in Figure 11 (b). The board can be operated in standalone mode or in GUI mode.

Table 5 Configuration Jumper Settings

Operation		JP6	JP7	JP8	JP9	JP10	JP11	JP12	JP13	JP14	JP15
External OPA	3 - Shunt	1 - 2	–	–	1 - 2	1 - 2	1 - 2	1 - 2	1 - 2	1 - 2	1 - 2
	1 - Shunt	–	1 - 2	1 - 2	–						
Internal PGA	3 - Shunt	**1 - 2**	**–**	**–**	**1 - 2**	**2 – 3**	**2 - 3**	**2 - 3**	**3 - 4**	**3 - 4**	**3 - 4**
	1 - Shunt	–	1 - 2	1 - 2	–						

For standalone mode, press and hold **P4** (mode) button during power cycle or **P6** (reset). Then, release the **P4** button. Now the board is in standalone mode. Press **P1** (start/stop) to start or stop motor. Set **RV1** for motor speed and change motor rotation direction by pressing **P2** (forward) or **P3** (reverse) button. **P4** toggles different modes on the LCD.

Note: The user needs to set speed to 2000 rpm or more to run the motor in this demo. GUI mode will be explained in section 7.4.

7.3 Build Project and Debug Operation with e²studio

To generate the firmware program for demonstration, the provided zip file must be imported to project workspace using e²studio IDE (Integrated Development Environment) revision 3.0 or higher. The following steps will explain the procedure for importing the project and setting up the debugger in the e²studio IDE.

7.3.1 Build Project Procedure in e²studio

Before importing the project, the user needs to install e²studio version 3.0 or higher and Renesas complier CCRX revision v1.02.01. *Note: This demo will only use Renesas complier CCRX revision v1.02.01.* The user will need to create a new file folder in Windows Explorer. Open the e²studio IDE as shown in Figure 12 and proceed with the following steps:

Step 1. Browse or type the newly created file folder path in the "Workspace Launcher" window and click the <OK> button.

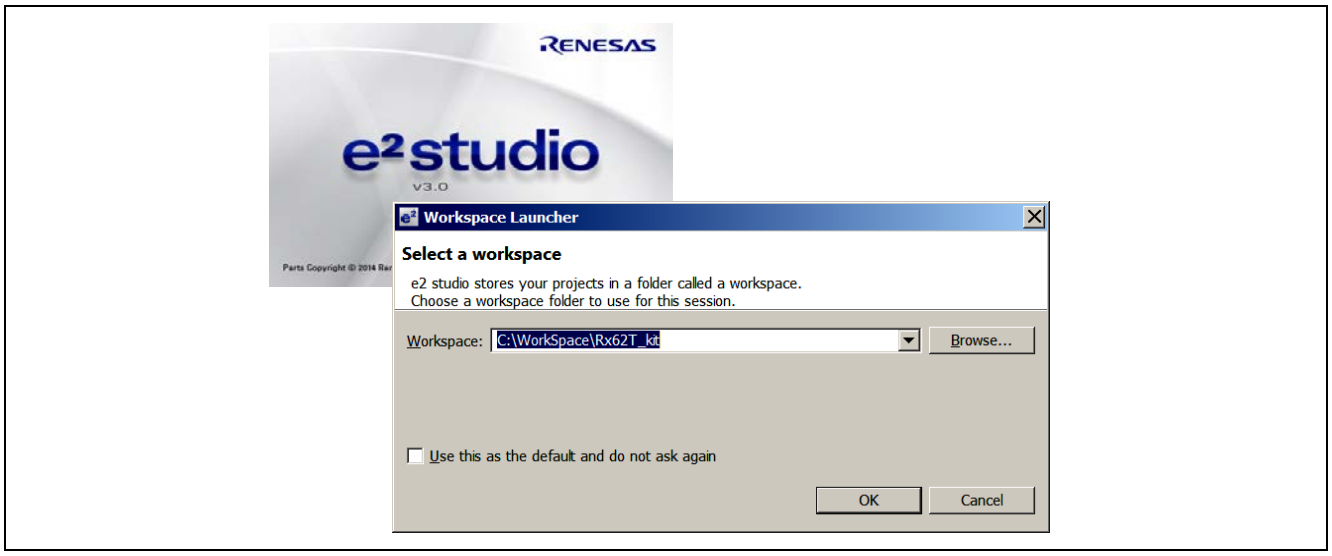


Figure 12 e²studio IDE Start-up Windows and Workspace Launcher

Step 2. Select "Import" from the "File" pull-down menu.

After selecting "Import", Figure 13 shows a *Select* dialog box that prompts the user to "Create new projects from an archive file or directory."

Step 3. Select "Existing Projects into Workspace" from the *Select* pop-up dialog box and click the <Next> button.

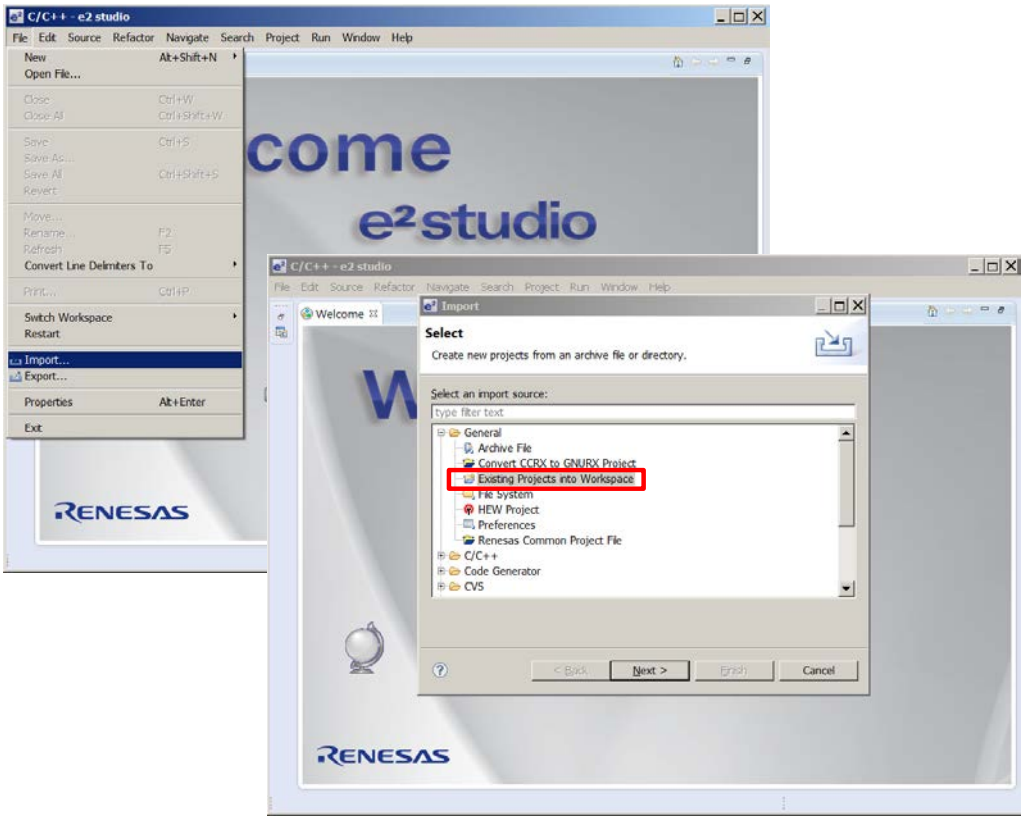


Figure 13 Importing Projects into the Workspace 1 of 2

After clicking the <Next> Button, the *Import Projects* dialog box in Figure 14 prompts the user to "Select a directory to search for existing Eclipse projects."

Step 4. Select the Radio Button "Select archive file" and click <Browse> to locate the Three-Shunt Sensorless Vector Control with Internal PGA zip file to import into the workspace.

The selected project will then appear with a checked box in the *Projects* message box as seen in Figure 14.

Step 5. Check the "Add project to working sets" check box, and then click the <Finish> button to complete the project import.

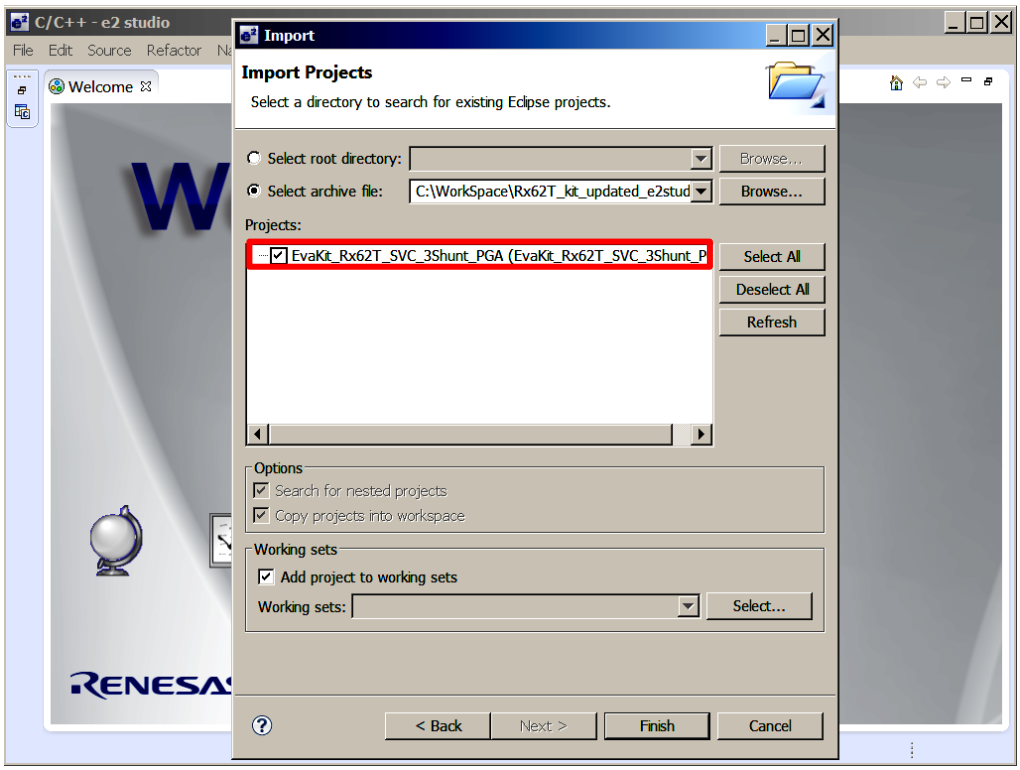


Figure 14 Importing Projects into the Workspace 2 of 2

If the file does not appear with a check box in the *Projects* message box, the selected zip file is the wrong zip file type, or it was not properly exported. If the file already exists in the workspace, then the user will see a message that states, "Some projects cannot be imported because they already exist in the workspace."

After clicking <Finish>, the imported project is now in the e^{2}studio workspace shown in Figure 15, and the project should be in Debug mode by default.

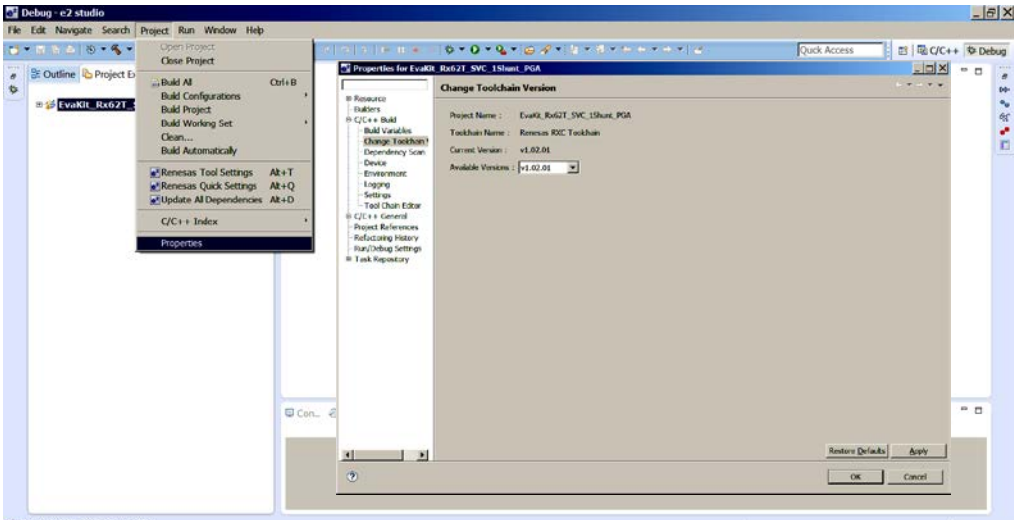


Figure 15 Setting the Toolchain Version in the e^{2}studio Workspace

Step 6. Select "Properties" from the "Project" pull-down menu and expand "C/C++ Build" section. Select the "Change Toolchain Version" option and set the "Available Versions" to v1.02.01.

Step 7. Select the “Clean” command from the “Project” pull-down menu for cleaning and rebuilding the project.

Figure 16 shows the “Clean” Windows dialog box.

Step 8. Check the “Start a build immediately” option and select the Radio buttons “Clean all projects” and “Build the entire workspace.” Then click the <OK> button to clean and rebuild all projects in the workspace.

For debugging, the target firmware (.x file) is generated in the “Binaries” workspace folder shown in Figure 17. For release, set the active project to release mode for building projects. The target firmware (.mot file) is generated in the workspace “Release” folder.

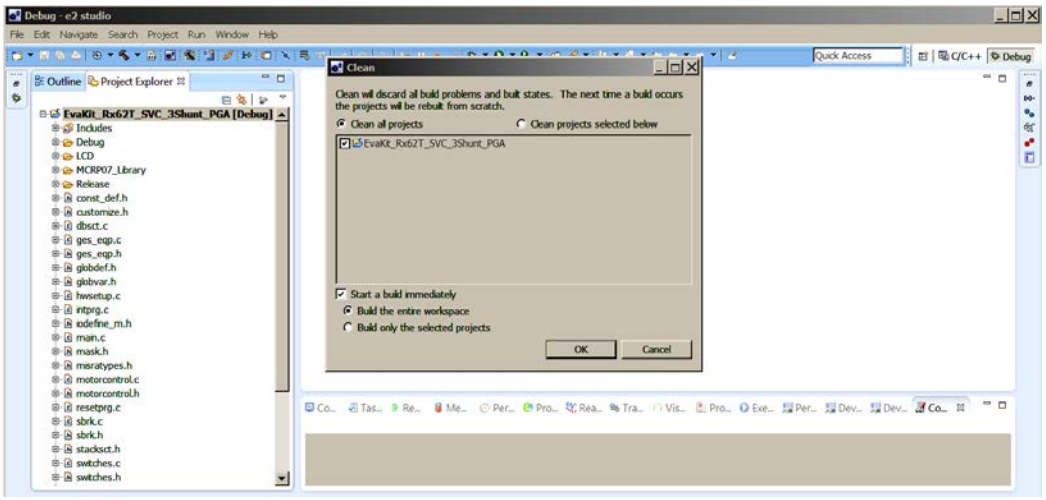


Figure 16 Clean Message Box

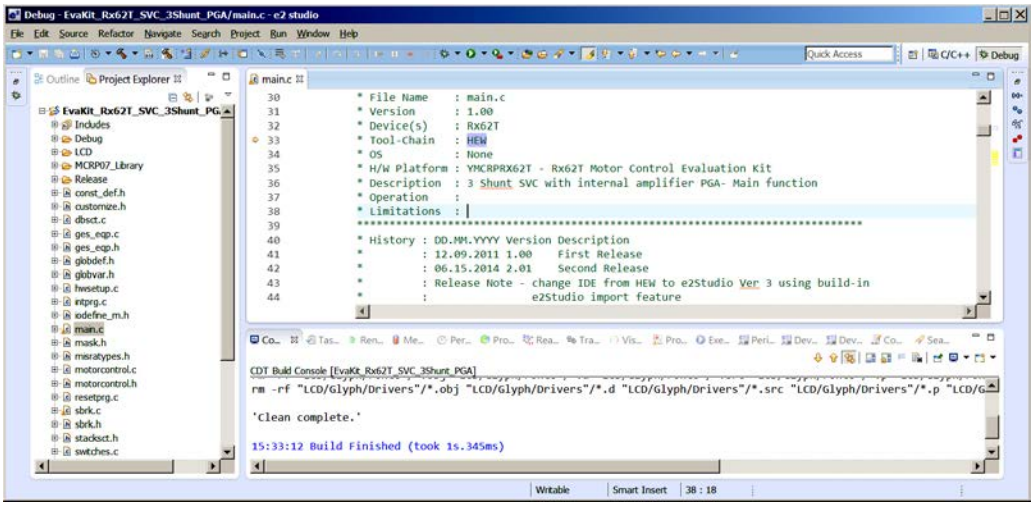


Figure 17 Target Firmware in Workspace

7.3.2 Debug procedure in e²studio IDE

After generating the target firmware, the user is now ready to setup the debug interface through the E1 debugger. The E1 debugger is necessary as an interface from the software to the hardware. Even if there is no need for any "debugging," this procedure is still necessary to reprogram the board using the provided algorithms. Connect the 24V DC power to **J3**, the E1 Debugger to **J5**, and the motor to the **J8** connector. The connections are shown in Figure 18. Check the recommended jumper settings for this demo (refer to section 7.2).

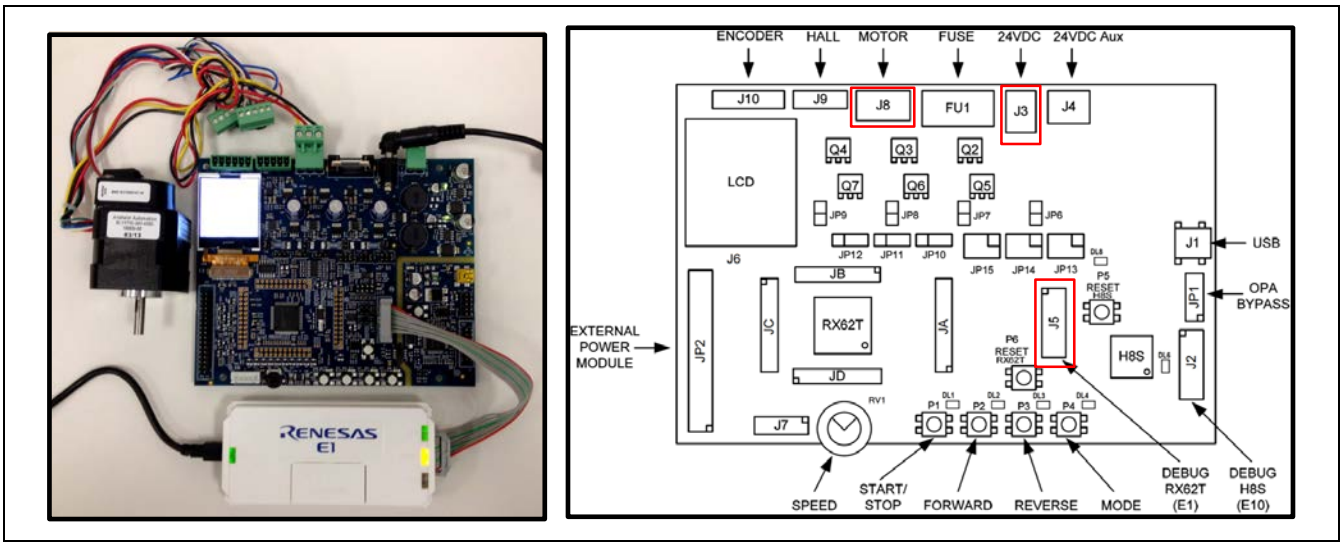


Figure 18 Debug Setup for the Demo Board

Step 1. Select "Debug Configurations" from the "Run" pull-down menu or click the debug icon [ ] and select "Debug Configurations"

Now, the user will view the "Debug Configurations" Windows dialog box, as shown in Figure 19.

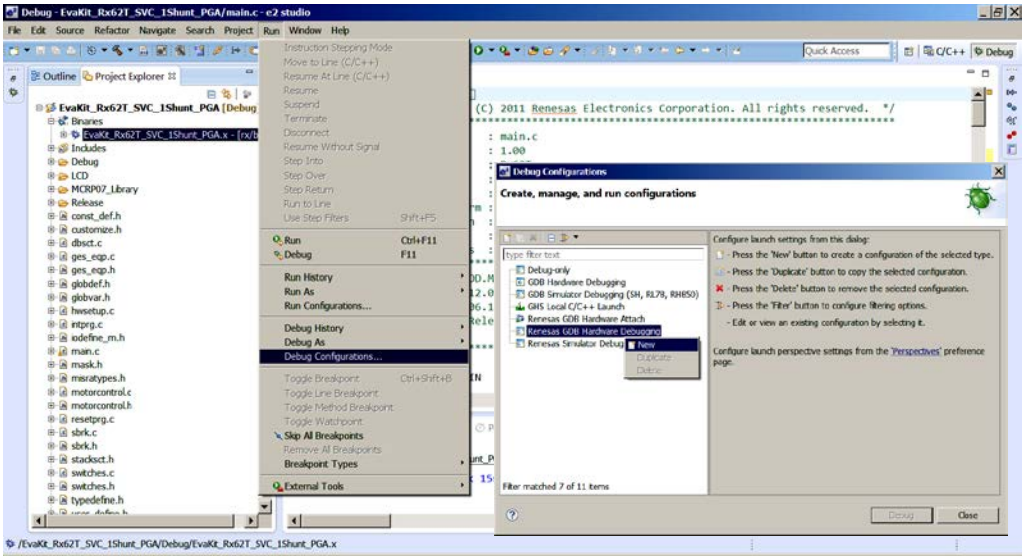


Figure 19 Setup Debug Configuration in Workspace

Step 2. Select "Renesas GDB Hardware Debugging". Using the mouse, right click on "Renesas GDB Hardware Debugging" and select "New" as shown in Figure 19.

Step 3. In Figure 20 under the "Main" tab in Debug Configurations, Select the Three-Shunt Sensorless Vector Control with Internal PGA (EvaKit_Rx62T_SVC_3Shunt_PGA) as the "Project" and verify the "Build Configuration" tab is selected as "Debug" and the "Use workspace settings" is selected.

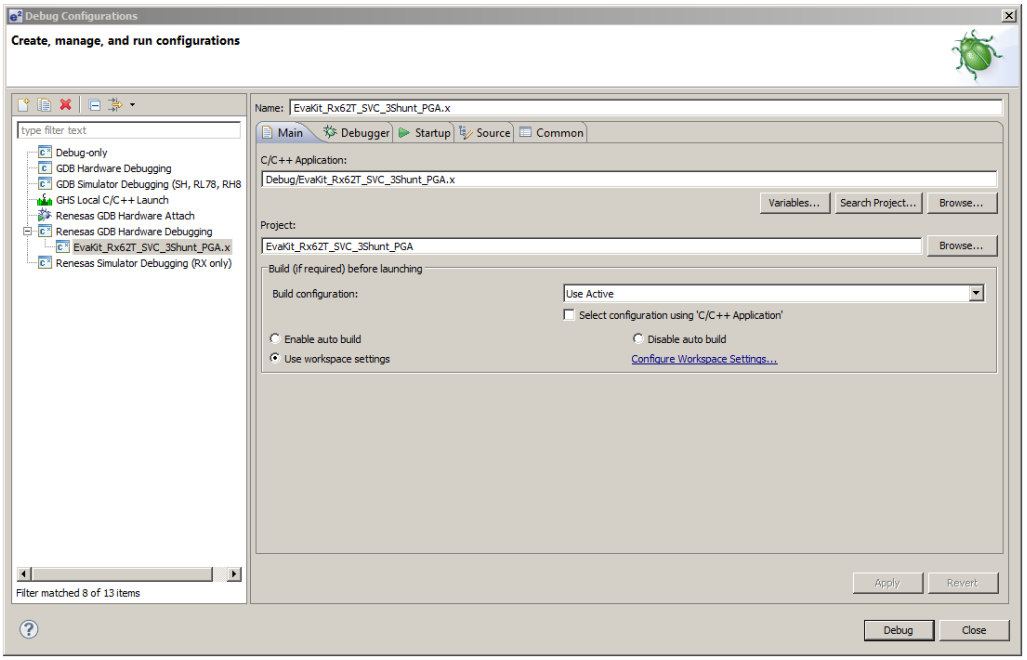


Figure 20 Debug Configuration Main Dialog Box

Step 4. Select the “Debugger” tab as shown in Figure 21.

Step 5. Select the “GDB Settings” sub-tab under the “Debugger” tab and set the “Debugger hardware” to “E1” and “Target Device” to “R5F562TA”.

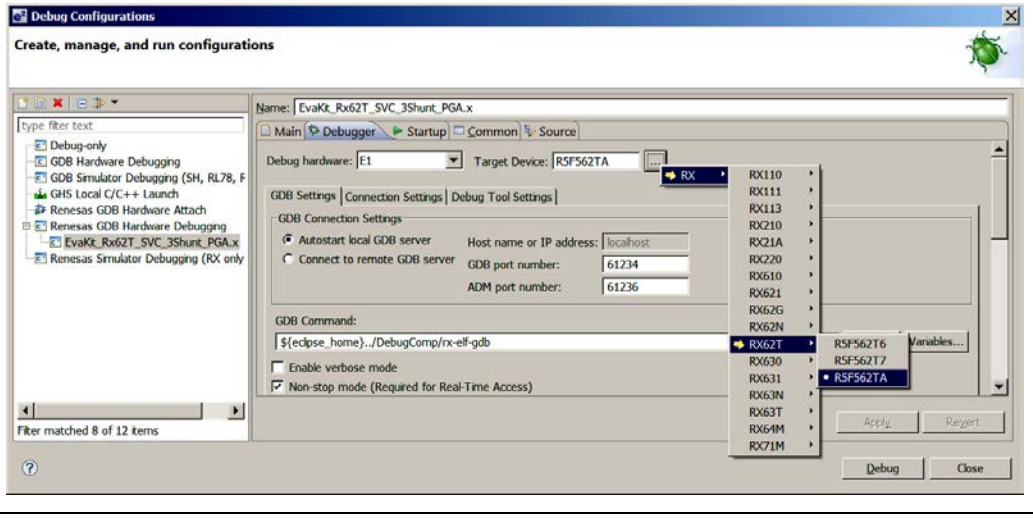


Figure 21 Debug Configuration Debugger Dialog Box

Step 6. Select the “Connection Settings” sub-tab and change the “External Frequency” value to 12.00 MHz and “JTag Clock Frequency” to 12.38 MHz. Set “Power” to “No.”

Step 7. Select the “Debug Tool Settings” sub-tab under the “Debugger” tab and select “Big Endian” in the “Endian” setting under “Memory.” Then click the <Apply> button.

The typical debug settings for this demo are shown with RED boxes in Figure 22 and in Figure 23.

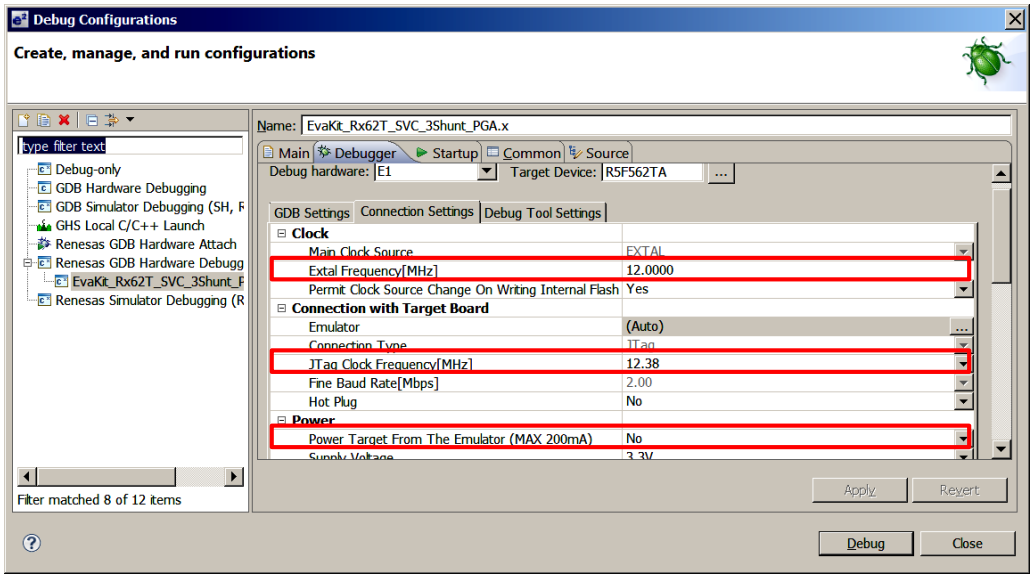


Figure 22 Debug Configuration Dialog Box 1 of 2

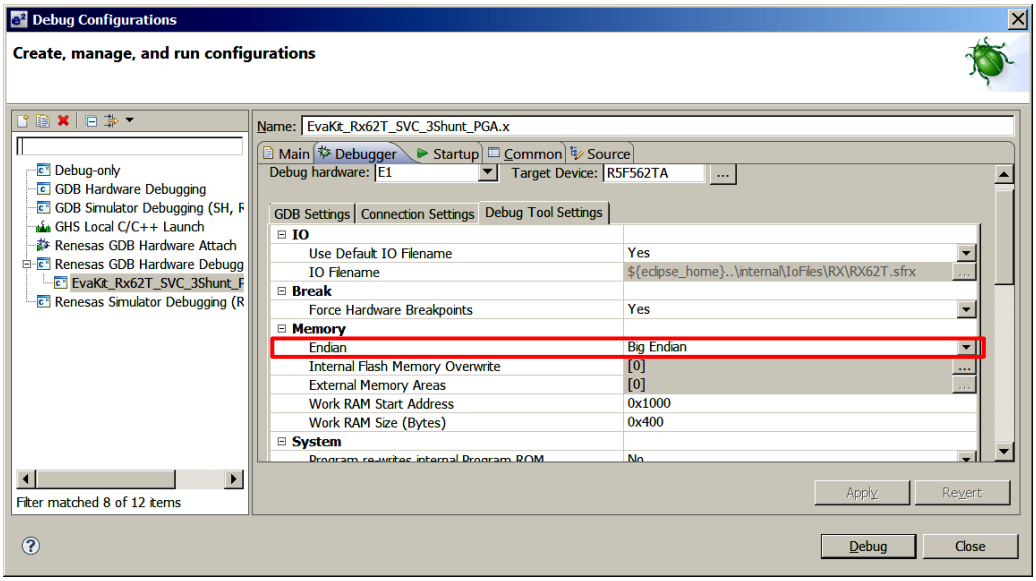


Figure 23 Debug Configuration Dialog Box 2 of 2

Step 8. Check the target board power is ON and verify the connections through the PC, E1 debugger, and the target board.

Clicking the <Debug> button in the “Debug Configurations” dialog box will download the firmware to the target board.

Step 9. Click the “Resume” icon [ ] or press the F8 Key to run the program. This may require the user to press the “Resume” icon or F8 multiple times depending on the delay in the code. The icon should turn gray when the program is running.

The LED **DL1** will blink at about a one second rate continuously while running the target board.

7.4 GUI Operation

This operation requires the demo board to be connected to the PC using the supplied Mini-USB cable.

Step 1. Connect the Mini-USB cable to **J1** from the PC

LED **DL8** is on when the USB bus power is applied to evaluation board. The PC will recognize the new hardware and will launch the driver installation screen. Follow the instruction from the "Message Box" to install respective USB device driver.

Note: Separate instructions for the USB device driver installation are provided in the Quick Start Guide or the driver will install automatically depending on the CD ROM installer. Figure 24 shows the necessary connections and LED designations.

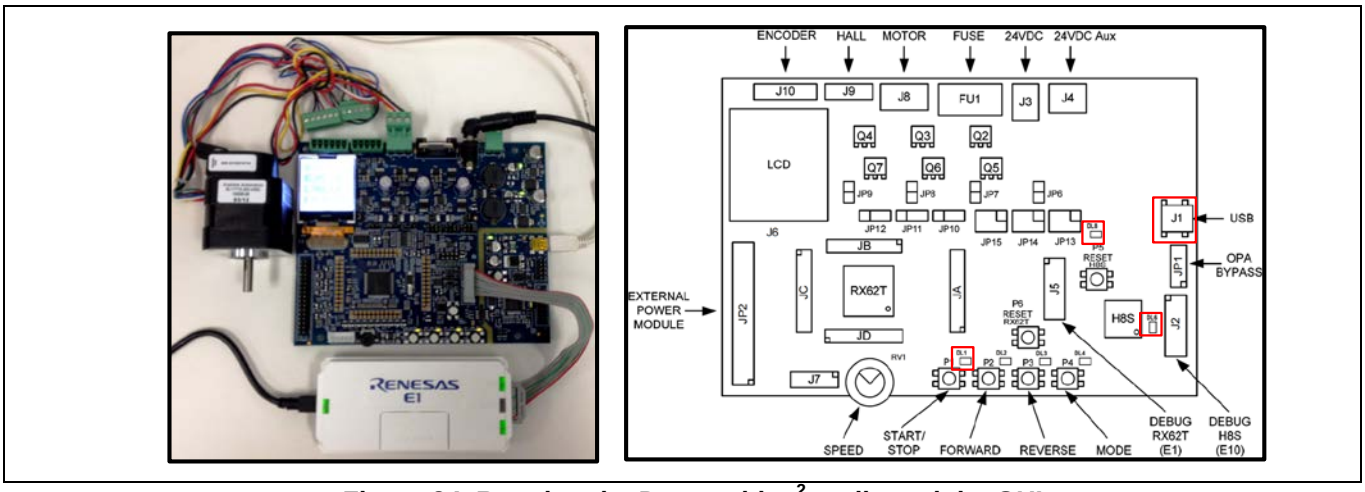


Figure 24 Running the Demo with e^{2}studio and the GUI

Step 2. Start the GUI program by double clicking on the Motor Control Demo icon [ ] or select the "Motor Control Demo" program from the Windows taskbar "Start" in "All Programs" under the "Motor Control Demonstrator" folder.

The GUI program screen will launch and display as shown in Figure 25. For a serial port update, wait for a few seconds to get the "Connect" button highlighted and then proceed to Step 3.

Note: If the "Connect" button is not highlighted, the GUI couldn't find the correct USB device driver for COM port setting.

Step 3. Click the "Communication Settings" tab on the top left of the GUI seen in Figure 25 and select "Auto detect" under the serial port drop-down tab.

Step 4. Click <Connect>.

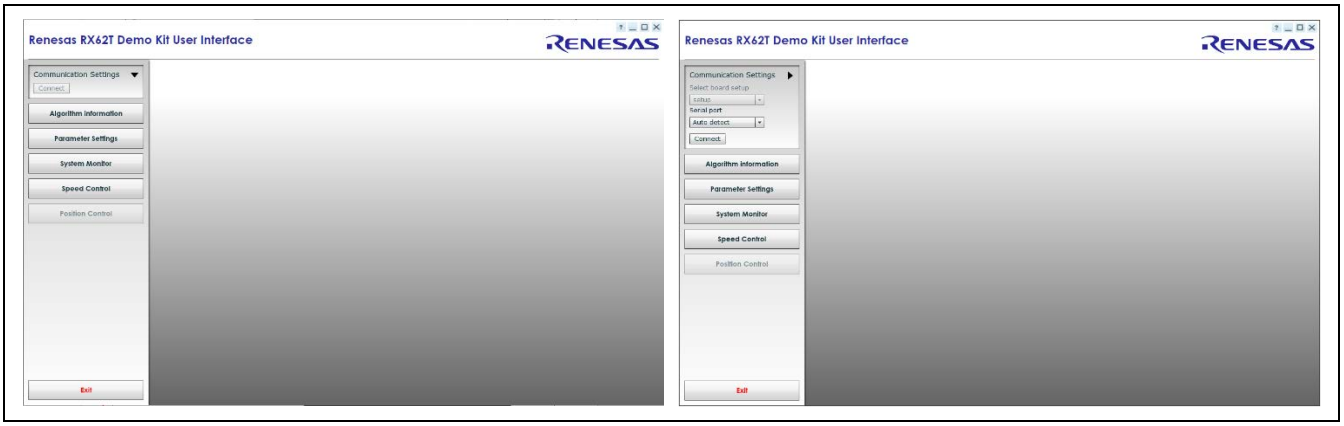


Figure 25 Connecting to the Motor Control Demo GUI 1 of 2

After successfully connecting with the target board, the "Communication Settings" area will change to a green color and the "Connect" button will change to "Disconnect." The LED **DL6** will blink while communicating between the target board and GUI.

Figure 26 shows the GUI after a successful connection.

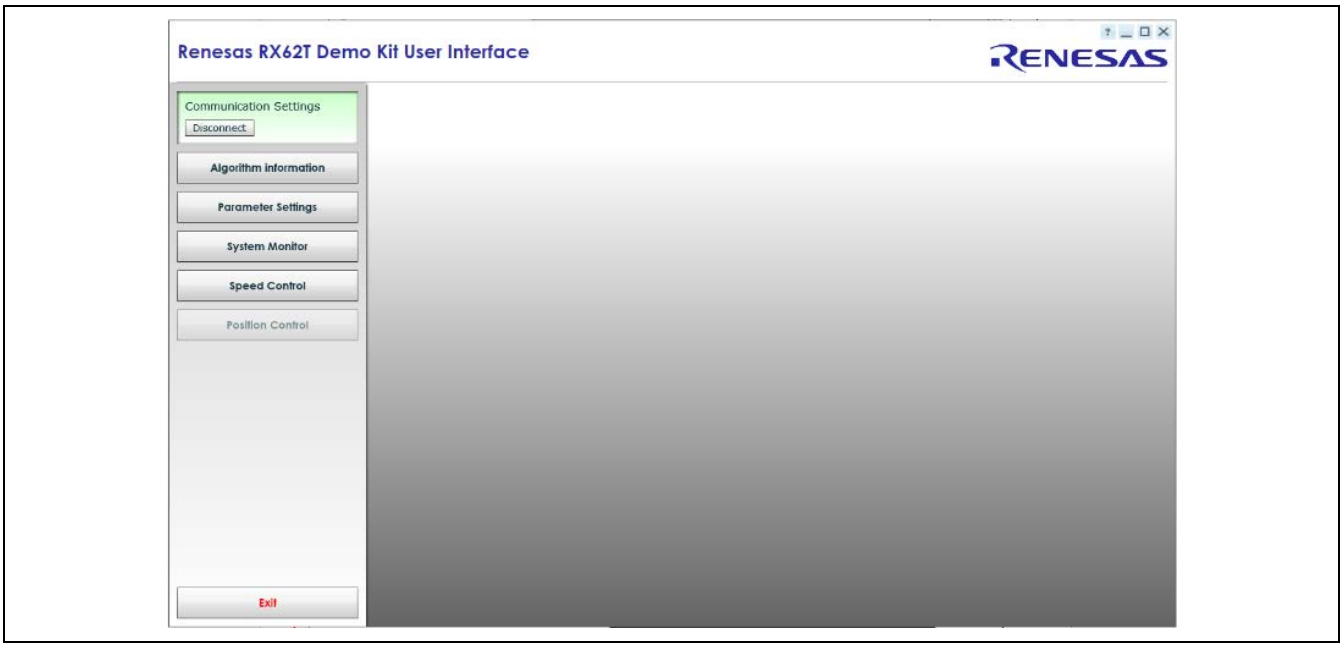


Figure 26 Connecting to the Motor Control Demo GUI 2 of 2

The GUI will detect the programmed algorithm. In this case the "3 Shunt Sensorless Vector Control with Internal Amplifier" will be used. After connection, the "Speed Control" button is active while the "Position Control" button is grayed out. The user can check with the "Algorithm Information" message box which shows a valid algorithm. Clicking the "Verify Jumper Settings" button shows Table 5 in the GUI. Figure 27 shows the "Algorithm Information" dialog box. Follow the below procedure for using the GUI.

The LED **DL1** will be blinking continuously while running demo with no fault occurrence. If a fault occurs, the LED **DL2** will flash and **DL1** will remain illuminated without flashing. If a fault occurs, press **P6** (reset) and check if **DL1** begins to blink. If pressing **P6** does not fix the fault, disconnect and reconnect the E1 debugger and the Mini-USB and reprogram the board using the steps discussed in section 7.3.2.

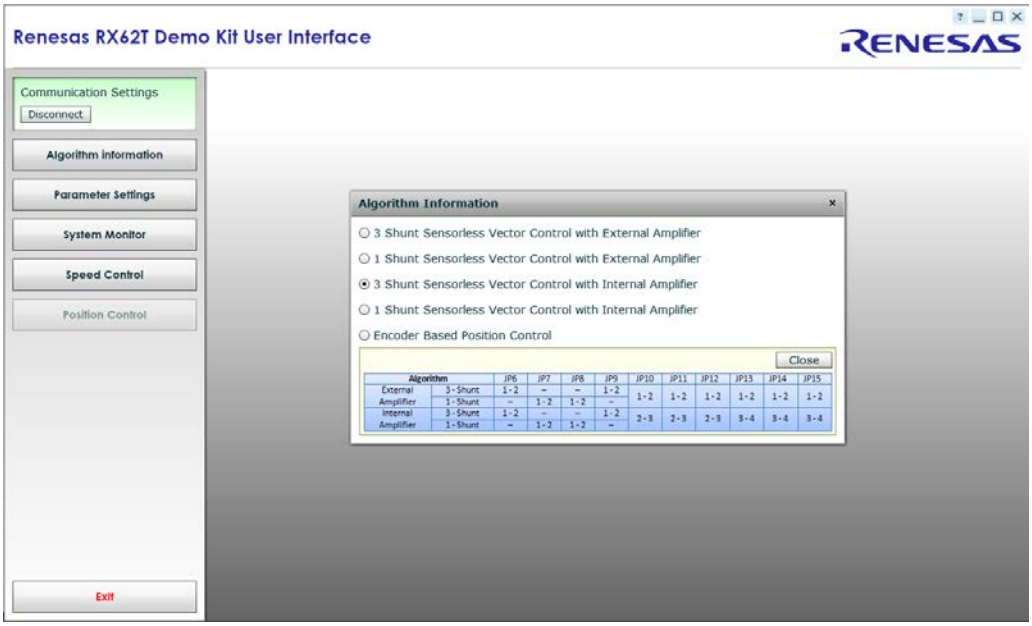


Figure 27 Algorithm Information in the GUI Application

Step 5. Click the <Speed Control> button.

Step 6. Set the speed arbitrarily by dragging the indicator needle to the right or left as shown in Figure 28. The speed can also be manually typed into the dialog box below the needle shown in Figure 28.

Note: The user needs to set the directional speed value from 2000 to 4000 rpm to run this demo.

The motor shaft should rotate with the setting speed. Returning the control needle to zero position stops the motor. By default, the demo sets parameter values for speed.

- Minimum speed 2000 rpm
- Maximum speed 4000 rpm
- Acceleration 5000 rpm/s
- Deceleration 5000 rpm/s
- Startup time 1000 ms

Figure 28 Setting the Speed to Turn the Motor in the GUI Application

Step 7. Click the "Parameter Settings" button

The "Parameter Settings" feature can be used to manually adjust the preset variables using the GUI. Figure 29 shows the "Parameter Settings" dialog box.

Figure 29 Changing the Parameter Settings in the GUI Application

If standalone mode is used the target board will "Disconnect" and no longer be communicating with the GUI. The LED **DL6** will be on, but it will no longer be blinking. In order to reconnect from standalone mode, press **P6** (reset) and "Connect" to the GUI using the User Interface.

To terminate the GUI application, return the control needle to zero position, press the "Disconnect" button and then press the "Exit" button to close the application.

Appendix A - References

1. RX62T Group User's Manual: Hardware, R01UH0034EJ0110, April 20, 2011
2. DevCon 2010 Courses:
   - ID-620C, Complete Motor Control Integration with RX62T.
   - ID-623C, Understanding Sensorless Vector Control with Floating Point Unit (FPU) Implementation.
3. Application Note of Sensorless Vector Control of Three-Phase PMSM Motors, REU05B0103-0100/Rev.1.00, March, 2009
4. Application Note of Mcrp05: Brushless AC Motor Reference Platform, REU05B0051-0100, Feb, 2009
5. Huangsheng Xu, Rohan Hubin, and Dave Cocca, "Sensorless Vector Control of PMSM Motor Using One Shunt Current Detection", IEEE-IAS 2008, Oct. 5-9, Edmonton, Alberta, Canada.
6. Huangsheng Xu, and Yashvant Jani, "Understanding Sensorless Vector Control for Brushless DC Motors", ESC-2008, Embedded System Silicon Valley Conference, April 15-17, San Jose, California, USA.

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Revision Record

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Nov. 18, 2011.	—	First edition issued
2.00	Jan. 31, 2014.	—	Second edition issued
2.01	Jul. 30, 2014.	16	Demonstration Guide added

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   Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.
   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on
   The state of the product is undefined at the moment when power is supplied.
   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.
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   Access to reserved addresses is prohibited.
   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals
   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.
   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.
5. Differences between Products
   Before changing from one product to another, i.e. to one with a different type number, confirm that the change will not lead to problems.
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