

**SIM2602M: Motor Driver with Built-in Hall Amplifier**

# **A Guide to Demo Board Evaluation and Phase Advance Angle Tuning**

## Precautions for High Voltage



Dangerously high voltages exist inside the demonstration board.

Mishandling the demonstration board may cause the death or serious injury of a person.

Before using the demonstration board, read the following cautions carefully, and then use the demonstration board correctly.

### **DO NOT touch the demonstration board being energized.**

Dangerously high voltages that can cause death or serious injury exist inside the demonstration board being energized.

### **Electrical shock may be caused even by accidental short-time contact or by putting hands close to the demonstration board.**

Electrical shock can result in death or serious injury.

Before touching the demonstration board, make sure that the capacitors have been discharged.

### **For safety purpose, an operator familiar with electrical knowledge must handle the demonstration board.**

The demonstration board is for evaluation of all the features of the SIM2602M.

The demonstration board shall not be included or used in your mass-produced products.

Before using the demonstration board, see this document and refer to the SIM2602M data sheet.

Be sure to use the demonstration board within the ranges of the ratings for input voltage, frequency, output voltage, and output current.

Be sure to strictly maintain the specified ambient environmental conditions, such as ambient temperature and humidity.

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**Introduction**

The SIM2602M is high voltage 3-phase motor driver driven by a sinusoidal control, which can support Hall element and Hall IC inputs, thus offering high-efficient yet low-noise motor control. Supplied in a package, where a controller, a gate driver, the output transistors of three phases, and bootstrap diodes are highly integrated, the SIM2602M requires only a few external components for building a motor driver. This also allows a motor driver to be highly reliable in performance and design-friendly with its compactness. These products can optimally control the inverter systems of low- to medium-capacity motors that require universal input standards.

This application note describes how to evaluate a demo board equipped with an SIM2602M device and how to tune the phase advance angle with the GUI. For more details, refer to the SIM2602M data sheet.

**Features**

- Pb-free (RoHS Compliant)
- Isolation Voltage: 1500 V (for 1 min) (UL Recognition Pending)
- Low Noise, High Efficiency (Sinusoidal Current Waveform)
- Reduced Number of Parts Achieved by Built-in Bootstrap Diodes
- Hall Element and Hall IC Inputs
- Application-specific Optimal Settings with External Signals:
  - Motor Speed
  - Phase Advance Angle
  - Motor Direction
  - User-settable Motor Lock Detection (Enabled or Disabled)
- 5V Reference Voltage Output (Used for Driving Hall Elements etc.)
- Fault Signal Output at Protection Activation (FO Pin)
- Protection Functions
  - VREG Pin Undervoltage Lockout (UVLO\_REG)
  - Undervoltage Lockout for Power Supplies
    - VBx Pin (UVLO\_VB)
    - VCC Pin (UVLO\_VCC)
  - Overcurrent Limit (OCL)
  - Overcurrent Protection (OCP)
  - Thermal Shutdown (TSD)
  - Motor Lock Protection (MLP)
  - Reverse Rotation Detection
  - Hall Signal Abnormality Detection

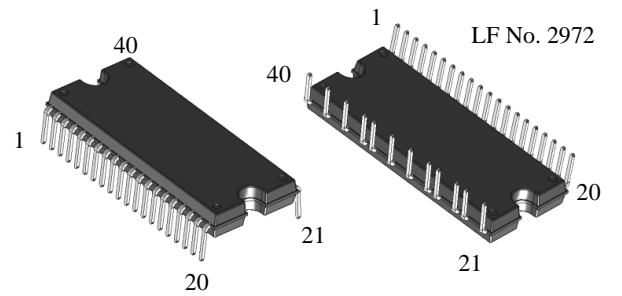
**Applications**

- Fan Motor and Pump Motor for Washer and Dryer
- Fan Motor for Air Conditioner
- Fan Motor for Air Purifier and Electric Fan

**Package**

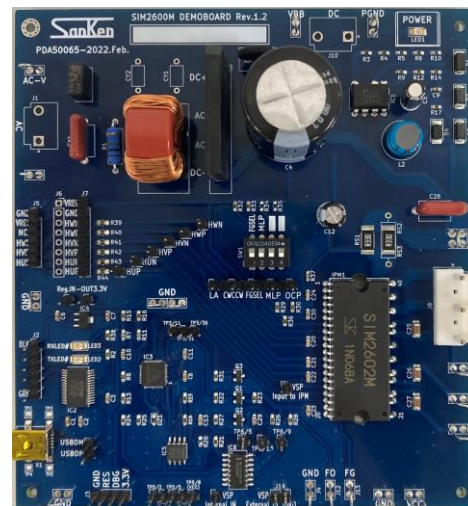
DIP40

(Mold Dimensions: 36.0 mm × 14.8 mm × 4.0 mm)

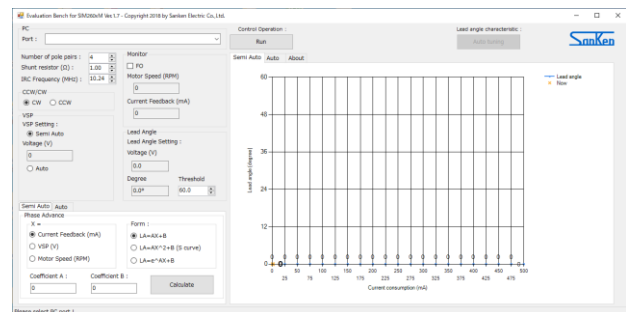


Not to scale

**Demo Board**



**GUI**



**1. Demo Board Overview**

Table 1-1 provides the specifications of the demo board for evaluating the SIM2602M device. Select a demo board based on your applications and power supply specifications. The demo board is available from the URL below.

URL: Under preparation

Table 1-1. Demo Board Specifications

No.	On-board IC (V <sub>DSS</sub> , I <sub>O</sub> )	Motor Type	Input Supply Voltage	Rectified Voltage	VCC Pin Voltage <sup>(1)</sup>	VSP Pin Voltage <sup>(2)</sup>
Demo Board 1	SIM2602M (600 V, 5.0 A)	100 V system/ 240 V system	AC100 V/ AC240 V	141 VDC/ 339 VDC	15 V	2.1 V to 5.4 V

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<sup>(1)</sup>This is the power supply pin for the SIM2602M.

<sup>(2)</sup>This is the motor speed control signal input pin for the SIM2602M.

Figure 1-1, Figure 1-2, and Figure 1-3 are the circuit diagrams of a demo board populated with an SIM2602M device.

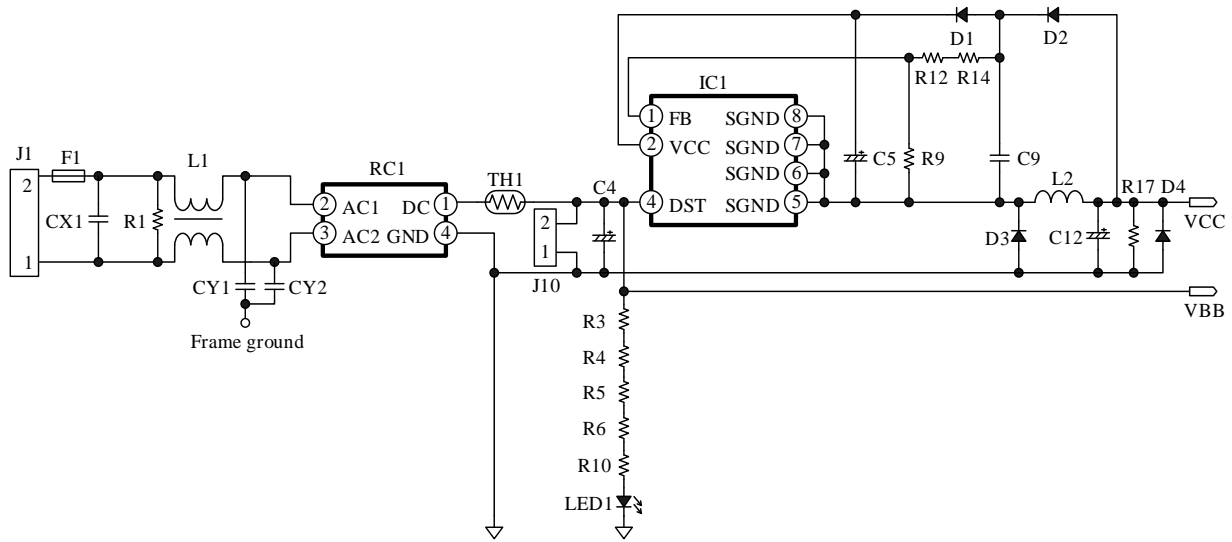


Figure 1-1. Circuit Diagram of Demo Board 1 (Power Supply Circuit)

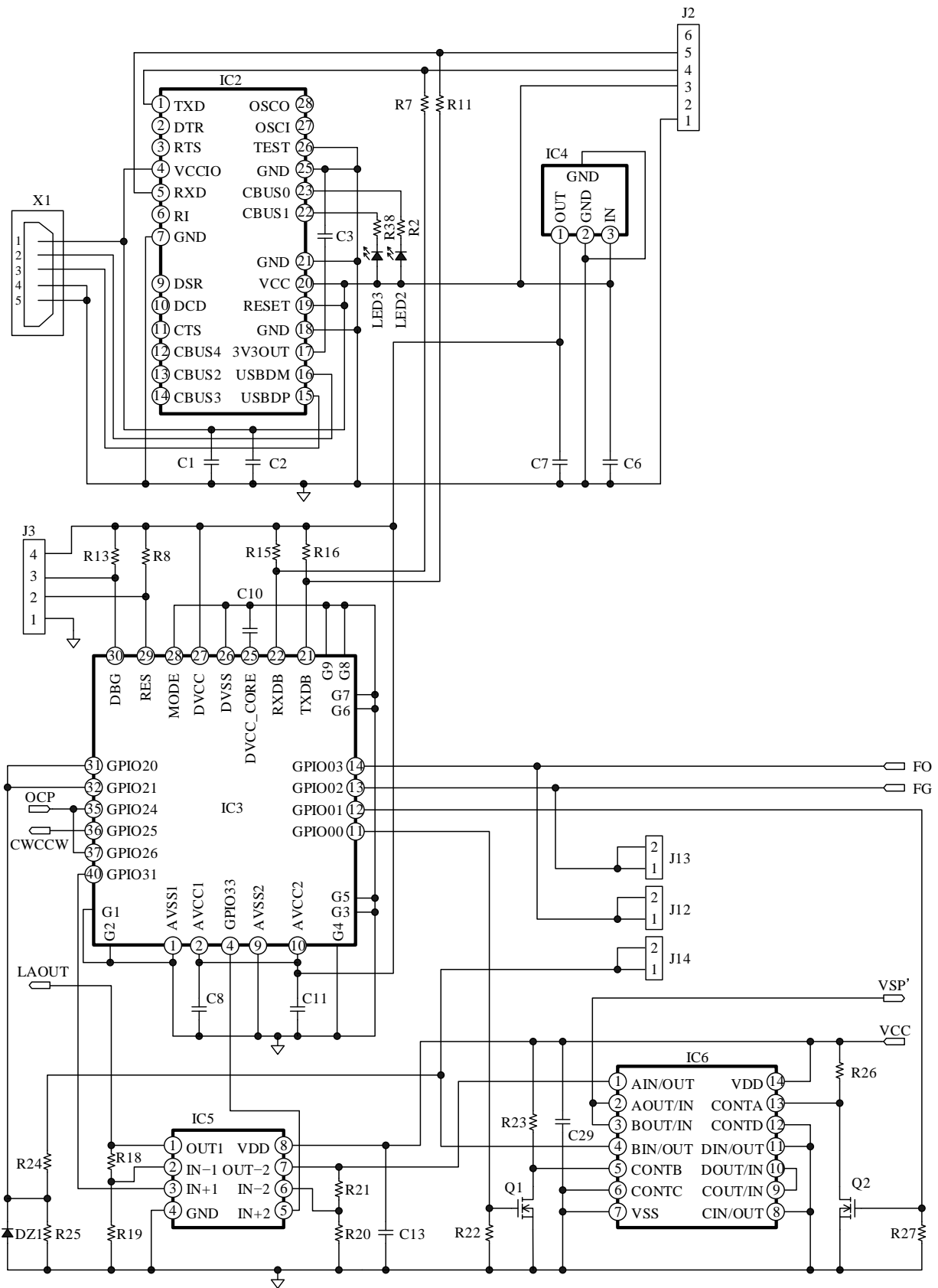


Figure 1-2. Circuit Diagram of Demo Board 2 (I<sup>2</sup>C Communication Circuit)

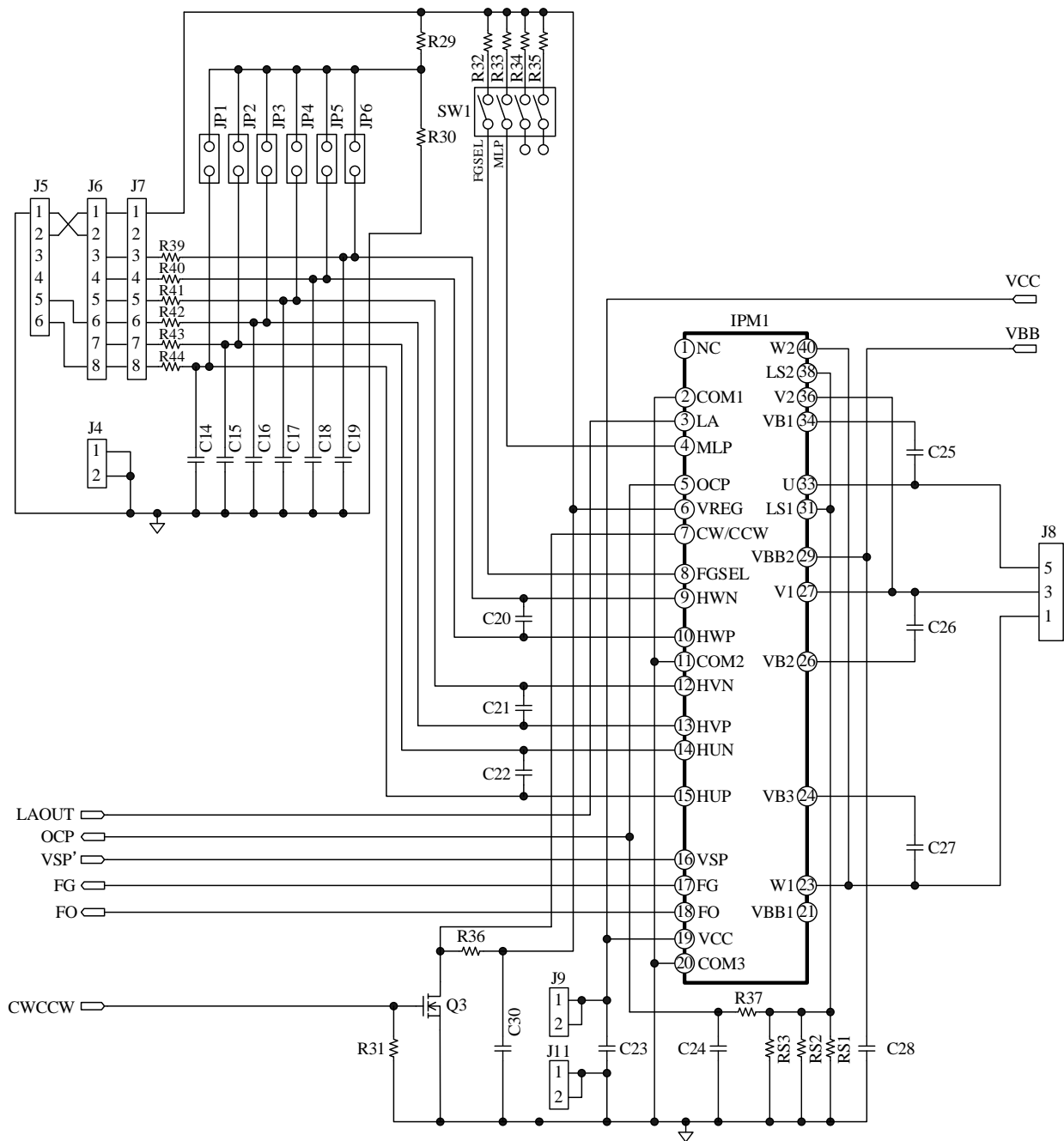


Figure 1-3. Circuit Diagram of Demo Board 3 (IPM Circuit)



## ● Bill of Materials

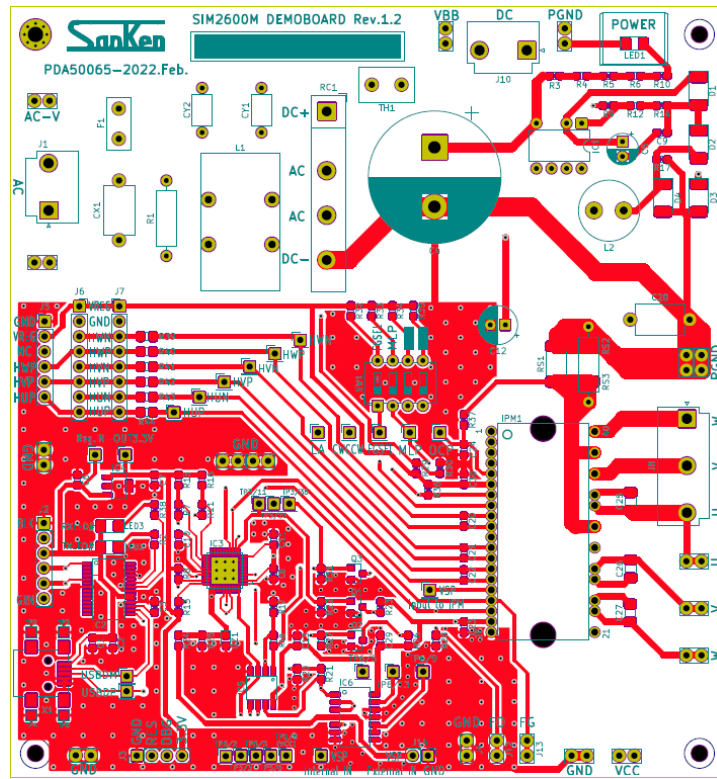
Symbol	Part Type	Rating	Symbol	Part Type	Rating
C1	Ceramic	0.1 $\mu$ F, 50 V	R1	General	1 M $\Omega$ , 1 W
C2	Ceramic	0.1 $\mu$ F, 50 V	R2	General	1 k $\Omega$ , 0.1 W
C3	Ceramic	0.1 $\mu$ F, 50 V	R3	General	33 k $\Omega$ , 0.1 W
C4	Electrolytic	150 $\mu$ F, 450 V	R4	General	33 k $\Omega$ , 0.1 W
C5	Electrolytic	10 $\mu$ F, 50 V	R5	General	33 k $\Omega$ , 0.1 W
C6	Ceramic	0.1 $\mu$ F, 50 V	R6	General	33 k $\Omega$ , 0.1 W
C7	Ceramic	0.1 $\mu$ F, 50 V	R7	General	100 $\Omega$ , 0.1 W
C8	Ceramic	0.1 $\mu$ F, 50 V	R8	General	4.7 k $\Omega$ , 0.25 W
C9	Ceramic	0.22 $\mu$ F, 50 V	R9	General	10 k $\Omega$ , 0.1 W
C10	Ceramic	0.1 $\mu$ F, 50 V	R10	General	33 k $\Omega$ , 0.1 W
C11	Ceramic	0.1 $\mu$ F, 50 V	R11	General	100 $\Omega$ , 0.1 W
C12	Electrolytic	100 $\mu$ F, 25 V	R12	General	47 k $\Omega$ , 0.1 W
C13	Ceramic	0.1 $\mu$ F, 50 V	R13	General	47 k $\Omega$ , 0.25 W
C14	Ceramic	0.1 $\mu$ F, 50 V	R14	General	47 k $\Omega$ , 0.25 W
C15	Ceramic	0.1 $\mu$ F, 50 V	R15	General	47 k $\Omega$ , 0.25 W
C16	Ceramic	0.1 $\mu$ F, 50 V	R16	General	47 k $\Omega$ , 0.25 W
C17	Ceramic	0.1 $\mu$ F, 50 V	R17	General	47 k $\Omega$ , 0.25 W
C18	Ceramic	0.1 $\mu$ F, 50 V	R18	General	18 k $\Omega$ , 0.1 W
C19	Ceramic	0.1 $\mu$ F, 50 V	R19	General	33 k $\Omega$ , 0.1 W
C20	Ceramic	1000 pF, 50 V	R20	General	33 k $\Omega$ , 0.1 W
C21	Ceramic	1000 pF, 50 V	R21	General	22 k $\Omega$ , 0.1 W
C22	Ceramic	1000 pF, 50 V	R22	General	47 k $\Omega$ , 0.1 W
C23	Ceramic	0.1 $\mu$ F, 50 V	R23	General	47 k $\Omega$ , 0.1 W
C24	Ceramic	1000 pF, 50 V	R24	General	22 k $\Omega$ , 0.1 W
C25	Ceramic	1 $\mu$ F, 50 V	R25	General	33 k $\Omega$ , 0.1 W
C26	Ceramic	1 $\mu$ F, 50 V	R26	General	47 k $\Omega$ , 0.1 W
C27	Ceramic	1 $\mu$ F, 50 V	R27	General	47 k $\Omega$ , 0.1 W
C28	Film	0.1 $\mu$ F, 450 V	R28	General	47 k $\Omega$ , 0.1 W
C29	Ceramic	1 $\mu$ F, 50 V	R29	General	47 k $\Omega$ , 0.1 W
C30	Ceramic	1 $\mu$ F, 50 V	R30	General	47 k $\Omega$ , 0.1 W
CX1	Film	0.1 $\mu$ F, 450 V	R31	General	47 k $\Omega$ , 0.1 W
CY1	Film	Not implemented	R32	General	47 k $\Omega$ , 0.1 W
CY2	Film	Not implemented	R33	General	47 k $\Omega$ , 0.1 W
IC1	IC	STR5A464D	R34	General	47 k $\Omega$ , 0.1 W
IC2	IC	FT232RL	R35	General	47 k $\Omega$ , 0.1 W
IC3	IC	MD6602	R36	General	47 k $\Omega$ , 0.1 W
IC4	IC	78L33	R37	General	100 $\Omega$ , 0.1 W
IC5	IC	TLV272CD	R38	General	1 k $\Omega$ , 0.1 W
IC6	IC	CD4066BM96	R39	General	1 k $\Omega$ , 0.1 W
IPM1	IC	SIM2602M	R40	General	1 k $\Omega$ , 0.1 W
RC1	Bridge diode	D10XB60	R41	General	1 k $\Omega$ , 0.1 W
RS1*	Metal plate	0.33 $\Omega$ , 1 W	R42	General	1 k $\Omega$ , 0.1 W
RS2*	Metal plate	0.33 $\Omega$ , 1 W	R43	General	1 k $\Omega$ , 0.1 W
RS3*	Metal plate	Not implemented	R44	General	1 k $\Omega$ , 0.1 W
			TH1	Thermistor	10 $\Omega$ , 3 A

\* Refers to a part that requires adjustment based on operation performance in an actual application.

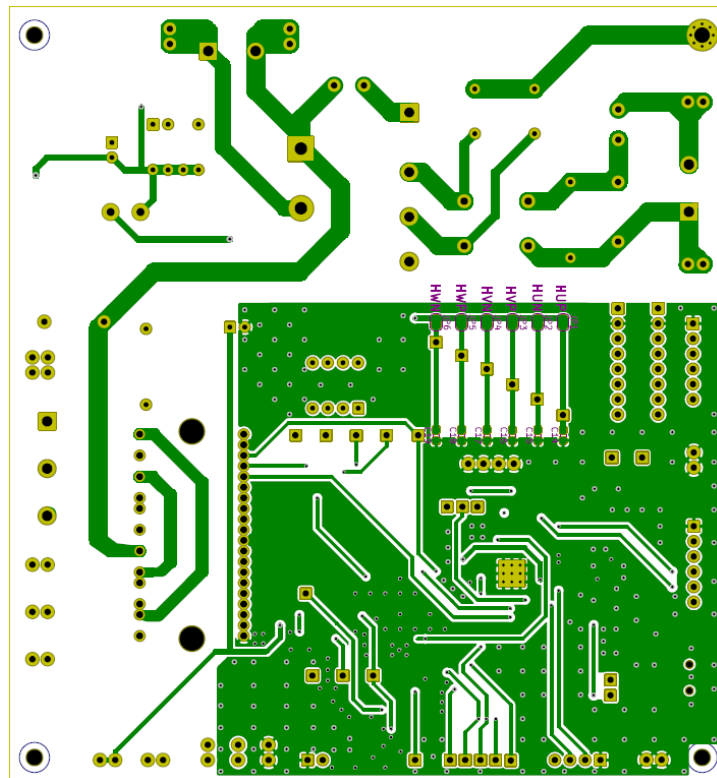
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Symbol	Part Type	Rating	Symbol	Part Type	Rating
D1	Fast recovery	200 V, 1 A	J1	Connector	Equiv. to B2P3-VH
D2	Fast recovery	500 V, 1 A	J2	Pin header	2.54 mm pitch
D3	Fast recovery	500 V, 1 A	J3	Pin header	2.54 mm pitch
D4	Zener diode	1 W, $V_z = 20$ V	J5	Pin header	2.54 mm pitch
DZ1	Zener diode	300 mW, $V_z = 3.9$ V	J6	Pin header	2.54 mm pitch
LED1	LED	5 V, 30 mA	J7	Pin header	2.54 mm pitch
LED2	LED	5 V, 30 mA	J8	Connector	Equiv. to B3P5-VH
LED2	LED	5 V, 30 mA	J10	Connector	Equiv. to B2P3-VH
Q1	Nch MOSFET	60 V, 300 mA	L1	Filter	20 mH, 1.5 A
Q2	Nch MOSFET	60 V, 300 mA	L2	Inductor	1 mH, 250 mA
Q3	Nch MOSFET	60 V, 300 mA	F1	Fuse	250 VAC, 2 A
SW1	Switch	DIP switch 4P 2.54 mm pitch	X1	USB mini-b connector	MUSB-5B-NE-S175

• Pattern Layout



(Top View)



(Bottom View)

## 1.1. Setting Hall Signal Inputs

The demo board supports various Hall signals. As shown in Table 1-2, connect the jumper wire (open or short) based on the Hall signal input. The factory default setting is for P-characteristic Hall IC signal input.

Table 1-2. Setting Hall Signal Inputs

Hall Signal Inputs	Jumper Wire Connection (Connection Pin)					
	JP1 (HUP Pin)	JP2 (HUN Pin)	JP3 (HVP Pin)	JP4 (HVN Pin)	JP5 (HWP Pin)	JP6 (HWN Pin)
P-characteristic Hall IC Signal Input <sup>(1)</sup>	Open	Shorted	Open	Shorted	Open	Shorted
N-characteristic Hall IC Signal Input <sup>(1)</sup>	Shorted	Open	Shorted	Open	Shorted	Open
Hall Element Signal Input <sup>(2)</sup>	Open	Open	Open	Open	Open	Open

<sup>(1)</sup>When the jumper is shorted, the VREG pin output voltage divided by two resistors, R29 and R30, (2.5 V) is applied to the HxP/HxN pins.

<sup>(2)</sup>Connect capacitors for noise suppression, C20, C21, and C22 as needed.

## 2. Evaluating the Demo Board

This section explains the procedure until the motor starts to rotate. For more details on tuning the phase advance angle, see Section 3.

### 2.1. Preparing the Devices and Tools for Evaluations

- **Required Devices**

Make sure that the following devices have been prepared before starting your demo board evaluation.

Table 2-1. Required Devices

Device	Description	Remarks
AC Power Supply	Constant voltage power supply or SLIDAC	Required
USB Cable	USB A – USB mini B cable	Required
USB Isolator	Model name: 114991949 Manufacturer: Seeed Studio URL: <a href="https://www.mouser.jp/ProductDetail/Seeed-Studio/114991949?qs=P1JMDcb91o6Z7ld6yCt%2FVQ==">https://www.mouser.jp/ProductDetail/Seeed-Studio/114991949?qs=P1JMDcb91o6Z7ld6yCt%2FVQ==</a>	Required (The items at left are examples; you can use any USB isolator.)
	Model name: USB Isolator USB-ISO Manufacturer: OLIMEX URL: <a href="https://strawberry-linux.com/catalog/items?code=15043">https://strawberry-linux.com/catalog/items?code=15043</a>	
Motor		Required
Load		Required in tuning
Control PC	OS: Windows 7 or later	Required
Logic Power Supply	Power supply for motor speed control signal input	Used in semi auto tuning

- **Required Measuring Instruments**

Make sure that the following measuring instruments have been prepared before starting your demo board evaluation.

Table 2-2. Required Measuring Instruments

Measuring Instruments	Target Parameter	Remarks
Rotational speed meter	Rotational speed	
Encoder	Mechanical angles	
Torque meter	Torques	
Oscilloscope	Current waves etc.	Required
Power meter	Electric power, losses, etc.	
Thermometer/data logger	Temperatures on and around the IC	Required
Digital multimeter	Voltages etc.	

• GUI Executable File

The GUI for tuning phase advance angles is available.

From the URL below, download the SIM2600M\_demoboard.exe file.

URL: <https://www.semicon.sanken-ele.co.jp/en/support/documentsfordesign/hvmdtools/sim2600m.html#tool>

2.2. Connecting the Devices

The following steps describe how to connect your demo board and control PC. DO NOT connect any AC power supply at this stage.

1) Connect the USB isolator to the control PC.

To protect the control PC from any damage, be sure to use the USB isolator you have chosen.

2) Connect the USB isolator and the demo board by using a USB cable.

When the USB cable is connected, the LED blinks several times.

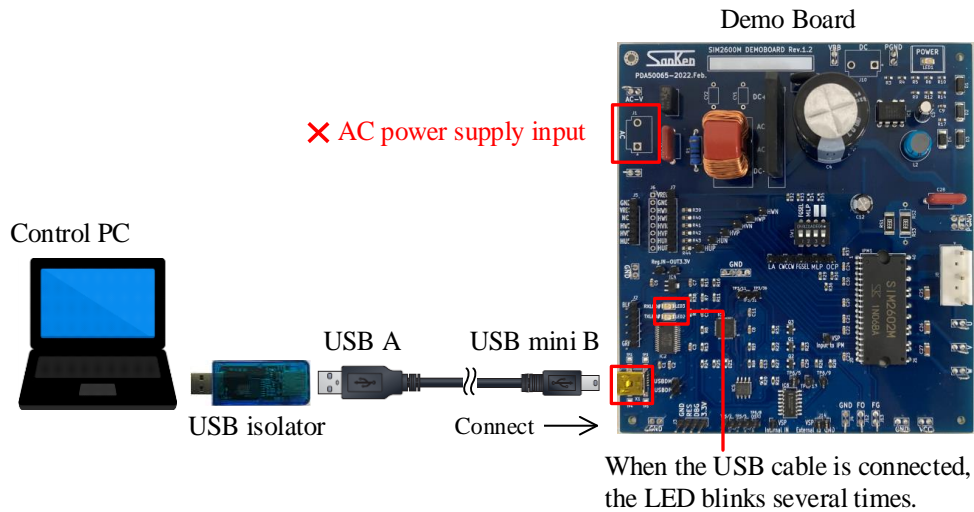
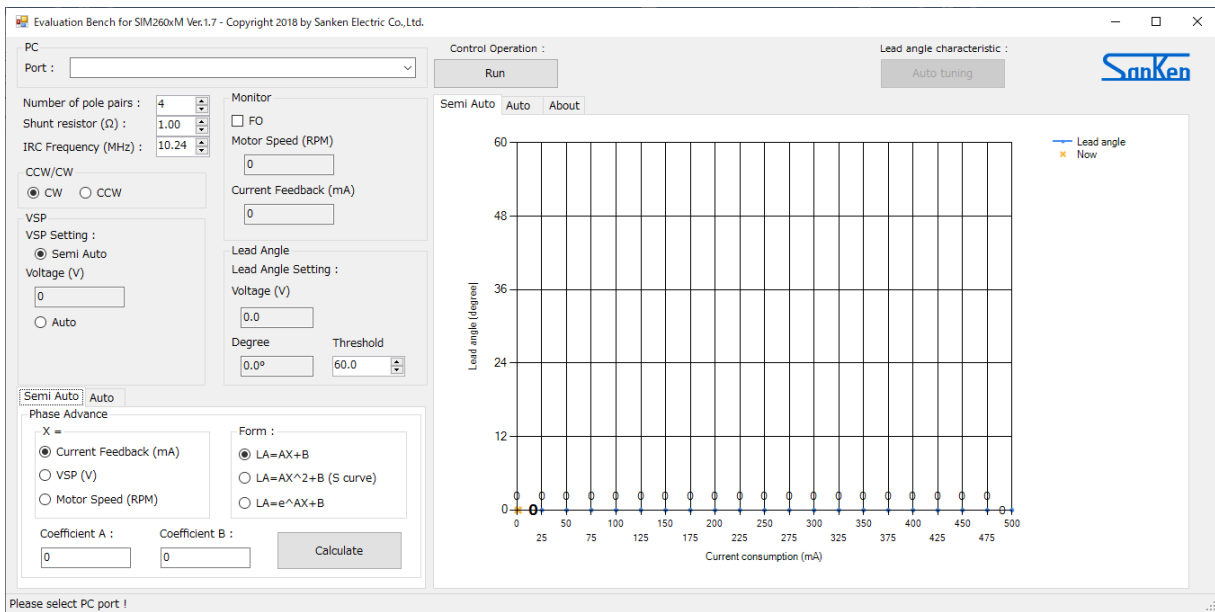


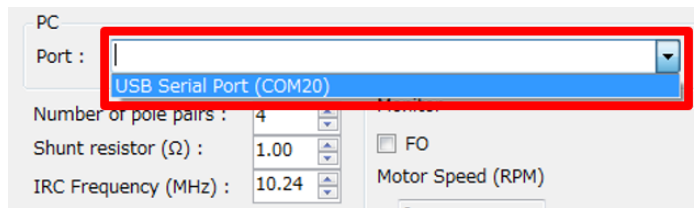
Figure 2-1. Connection by USB Cable

3) To launch the GUI, double-click the SIM2600M\_demoboard.exe file.

Section 4 gives detailed descriptions on the GUI.

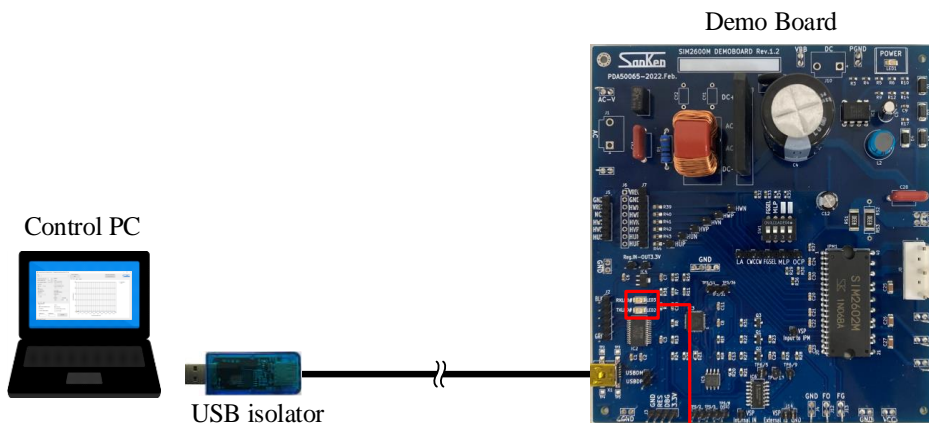


4) Select the USB port of the control PC



If you connect your demo board to the control PC after the startup of the GUI, the USB port is not displayed. In this case, restart the GUI after connecting your demo board and the control PC.

Once the communications between the control PC and the IC become available, the LED blinks. The LED keeps blinking during communication. The communication is disconnected after a certain period of time of GUI inactivity and the LED turns off. To establish communication again, turn off the AC power supply and logic power supply, and connect the device again starting with step 1).



Once the communications between the control PC and IC become available, the LED blinks.

### 2.3. Checking the Motor Operation

The following steps explain how to connect the devices, to initialize the GUI settings, and to check the motor operation. The following must be taken into account in checking the motor operation:

- At AC power-on, apply a low voltage (about 50 VAC) and gradually increase the voltage.
- Rotate the motor while checking IC case temperatures, which should be < 100 °C.
- Rotate the motor while checking operational waveforms.
- Turn off the AC power supply when switching the rotation direction.

Be sure to switch the rotation direction after turning off the AC power supply. Note that the setting is not changed if the rotation direction is switched during the AC power supply on-state.

- Check the motor operation after turning off the FGSEL of SW1.

Be sure to turn off the FGSEL of SW1 after turning off the AC power supply. Note that the setting is not changed if the FGSEL of SW1 is switched during the AC power supply on-state. When the FGSEL of SW1 is turned off, the rotation pulse signal output from the FG pin is generated three times per 360° electric angle. For details on the FGSEL pin, refer to the SIM2602M data sheet.

In case of contingency events, click the **Stop** button on the GUI to stop the motor operation or turn off the AC power supply.

The following steps describe how to rotate the motor.

- 1) **Connect the motor to the connector J8.**
- 2) **Connect a connector below according to the Hall signal input.**

Adjust the jumper wire connection of the demo board according to the Hall signal input (see Section 1.1).

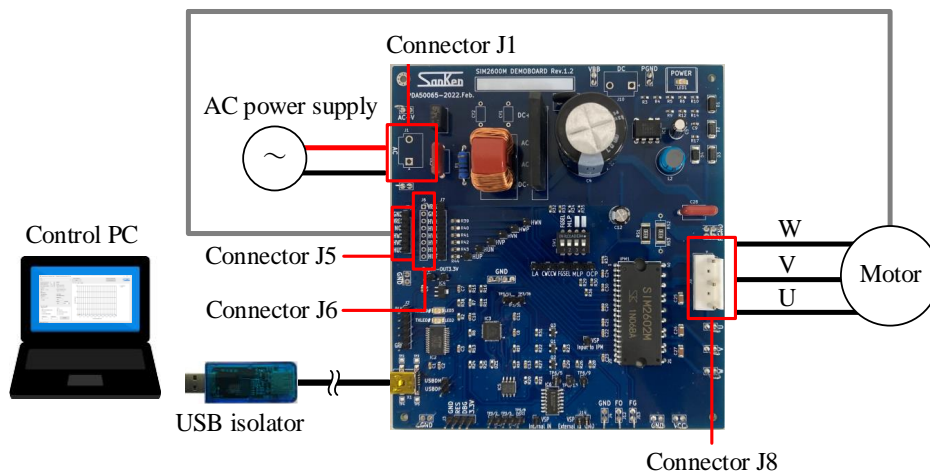
**Application using signals input from Hall ICs:**

Connect the connector J5 and the Hall ICs (the Hall signal input pins, VREG pin, and COMx pin of the SIM2602M).

**Application using signals input from Hall elements:**

Connect the connector J6 and Hall elements (the Hall signal input pins, VREG pin, and COMx pin of the SIM2602M).

- 3) **Connect the AC power supply to the connector J1.**



- 4) **Connect the current and voltage probes of your oscilloscope according to the waveforms.**



5) Set the number of magnetic pole pairs in the motor.

Number of pole pairs :	4
Shunt resistor ( $\Omega$ ) :	0.56
IRC Frequency (MHz) :	10.24

6) Set the value of the shunt resistor of the demo board.

Number of pole pairs :	4
Shunt resistor ( $\Omega$ ) :	0.17
IRC Frequency (MHz) :	10.24

No need to change the value of **IRC Frequency (MHz)**.

7) Select the motor direction.

CCW/CW

CW  CCW

**CW**: Clockwise

**CCW**: Counterclockwise

8) Select the Auto.

VSP

VSP Setting :

Semi Auto

Auto

Voltage (V)

2.50

The **Auto** is the mode where the VSP voltage is output from the MCU mounted on the demo board.

9) Set the Voltage (V) to 2.8 V.

VSP

VSP Setting :

Semi Auto

Auto

Voltage (V)

2.80

The VSP pin input voltage is set to 2.8 V.

This pin operates as the motor speed control signal input. See Section 3.2 for the motor speed control.

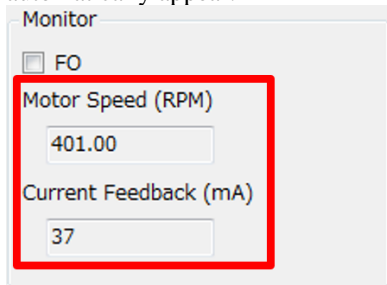
### 10) Turn on the AC power supply.

First, apply a low voltage (about 50 VAC) and check the motor operation.

### 11) To start the motor rotation, click the Run button.

Once you click the **Run** button, the button label switches to “Stop”.

Once the motor rotates, the motor rotation speed and the feedback current flowing through the shunt resistor automatically appear.



After checking the motor operation under low voltage (about 50 VAC) conditions, gradually raise the AC power supply to the values on actual operating conditions (100 VAC to 240 VAC) and check the motor operation. High voltages are then applied to the demo board. Therefore, extreme care must be taken during the work.

### 12) To stop the motor rotation, click the Stop button.

Once you click the **Stop** button, the button label switches to “Run”.

### 13) Turn off the AC power supply.

### 3. Phase Advance Angle Tuning

Power consumption can be reduced by setting the phase advance angle so that there is no phase difference between the phase current and the phase voltage.

This section provides the guide for phase advance angle tuning using the dedicated GUI. There are two tuning methods: auto tuning (see Section 3.1) and semi auto tuning (see Section 3.2).

For proper tuning, use the devices, tools, and measuring instruments listed in Table 2-1 and Table 2-2. The following must be taken into account in tuning the phase advance angle:

- Tune the phase advance angle after AC power-on with the AC power supply set to the value on actual operating condition (100 VAC to 240 ACV).  
Be sure to perform tuning after checking the motor operation under actual operating conditions (100 VAC to 240 VAC). Section 2.2 and Section 2.3 show how to check the motor operation on actual operating conditions.
- Tune the phase advance angle while measuring IC case temperatures, which should be < 100 °C.
- Tune the phase advance angle while measuring and checking operational waveforms.
- Turn off the AC power supply when switching the direction of rotation.  
Be sure to switch the rotation direction after turning off the AC power supply. Note that the setting is not changed if the rotation direction is switched during the AC power supply on-state.
- Tune the phase advance angle after turning off the FGSEL of SW1.  
Be sure to turn off the FGSEL of SW1 after turning off the AC power supply. Note that the setting is not changed if the FGSEL of SW1 is switched during the AC power supply on-state. When the FGSEL of SW1 is turned off, the rotation pulse signal output from the FG pin is generated three times per 360° electric angle. For details on the FGSEL pin, refer to the SIM2602M data sheet.
- Check the motor operation after turning on the MLP of SW1.  
Be sure to turn on the MLP of SW1 after turning off the AC power supply. Note that the setting is not changed if the MLP of SW1 is switched during the AC power supply on-state. To disable the MLP (Motor Lock Protection), turn on the MLP of SW1. For details on the MLP, refer to the SIM2602M data sheet.

In case of contingency events, click the **Stop** button on the GUI to stop the motor operation or turn off the AC power supply.

#### 3.1. Auto Tuning of the Phase Advance Angle

The auto tuning automatically tunes the optimal phase advance angle according to the rotation speed. In addition, the phase advance characteristics are automatically calculated from the auto tuning results. As a result, the tuning time is significantly reduced compared to the manual tuning.

For auto tuning, the speed control signal (VSP) and the phase advance control signal (LA) are automatically output from the MCU mounted on the demo board.

To tune the phase advance angle, follow the steps below.

- 1) **Connect the devices according to the procedure as shown in Section 2.2.**
- 2) **Connect the motor to the connector J8.**
- 3) **Connect a connector below according to the Hall signal input.**

Adjust the jumper wire connection of the demo board according to the Hall signal input (see Section 1.1).

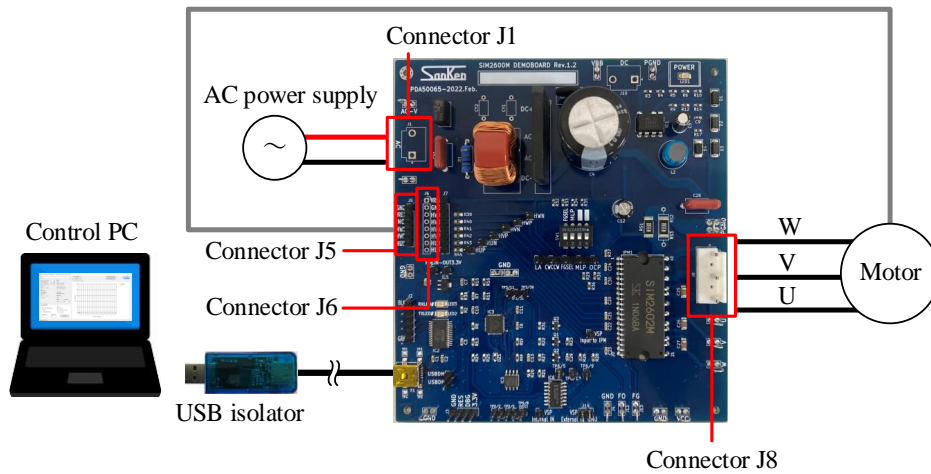
##### **Application using signals input from Hall ICs:**

Connect the connector J5 and the Hall ICs (the Hall signal input pins, VREG pin, and COMx pin of the SIM2602M)

##### **Application using signals input from Hall elements:**

Connect the connector J6 and Hall elements (the Hall signal input pins, VREG pin, and COMx pin of the SIM2602M)

4) Connect the AC power supply to the connector J1.



5) Connect the current and voltage probes of your oscilloscope according to the waveforms.

6) Set the number of magnetic pole pairs in the motor.

Number of pole pairs :	<input type="text" value="4"/>
Shunt resistor ( $\Omega$ ) :	<input type="text" value="0.56"/>
IRC Frequency (MHz) :	<input type="text" value="10.24"/>

7) Set the value of the shunt resistor of the demo board.

Number of pole pairs :	<input type="text" value="4"/>
Shunt resistor ( $\Omega$ ) :	<input type="text" value="0.17"/>
IRC Frequency (MHz) :	<input type="text" value="10.24"/>

No need to change the value of IRC Frequency (MHz).

8) Select the motor direction.

CCW/CW

CW  CCW

CW: Clockwise

CCW: Counterclockwise

9) Select the Auto.

VSP

VSP Setting :

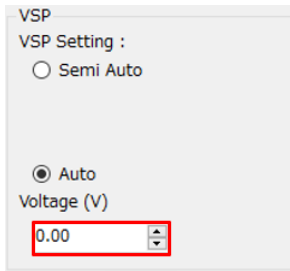
Semi Auto

Auto

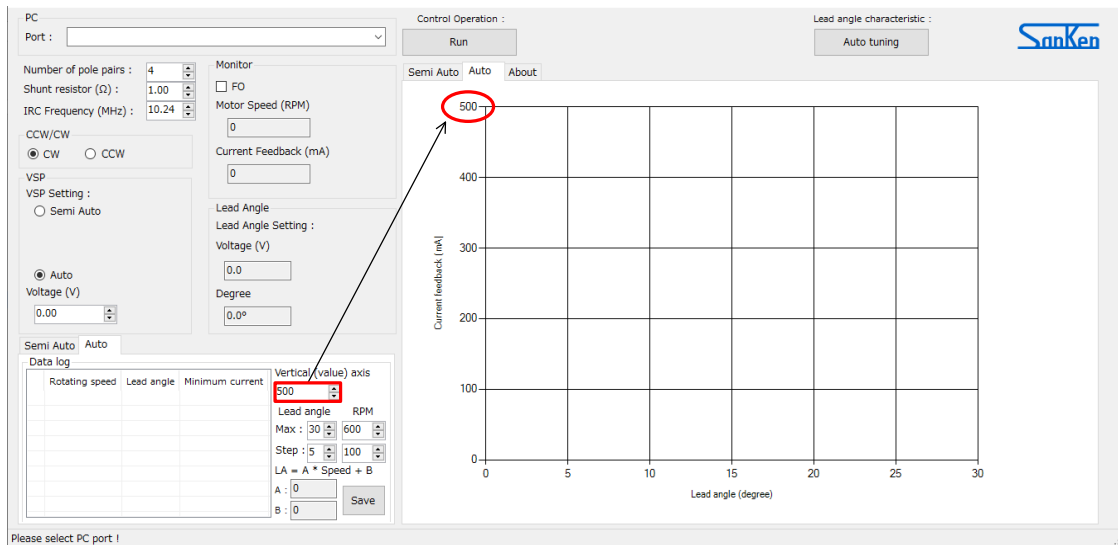
Voltage (V)

The **Auto** is the mode where the VSP voltage is output from the MCU mounted on the demo board.

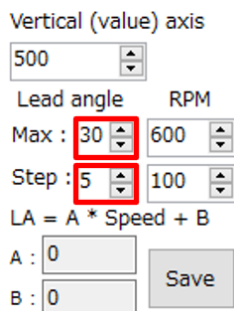
10) Set the Voltage (V) to 0.00 V.



11) Set the vertical axis of the graph (the maximum value of the feedback current).



12) Set the phase advance angle.



**Lead angle Max:** Set the maximum value of the phase advance angle.

**Lead angle Step:** Set the step of the phase advance angle.

Finer steps to improve tuning accuracy increases the tuning time.

**13) Set the motor rotation speed.**

Vertical (value) axis  
 500

Lead angle      RPM  
 Max : 30      600  
 Step : 5      100

LA = A \* Speed + B  
 A : 0  
 B : 0

Save

**RPM Max:** Set the maximum value of the motor rotation speed.  
**RPM Step:** Set the step of the motor rotation speed.  
 Finer steps to improve tuning accuracy increases the tuning time.

The motor rotation speed at the start of auto tuning is 200 rpm. For example, the following steps describe the auto tuning when RPM Max = 600, RPM Step = 100, Lead angle Max = 30, and Lead angle Step = 5.

	Motor Rotation Speed (rpm)	Phase Advance Angle (°)
1	200	0 → 5 → 10 → 15 → 20 → 25 → 30
2	300	0 → 5 → 10 → 15 → 20 → 25 → 30
3	400	0 → 5 → 10 → 15 → 20 → 25 → 30
4	500	0 → 5 → 10 → 15 → 20 → 25 → 30
5	600	0 → 5 → 10 → 15 → 20 → 25 → 30

**14) Turn on the AC power supply.**

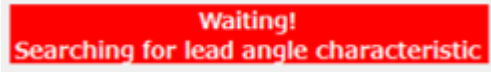
Apply a voltage on actual operating conditions (100 VAC to 240 VAC).

**15) Click the Run button.**

At this point, the motor does not rotate yet.

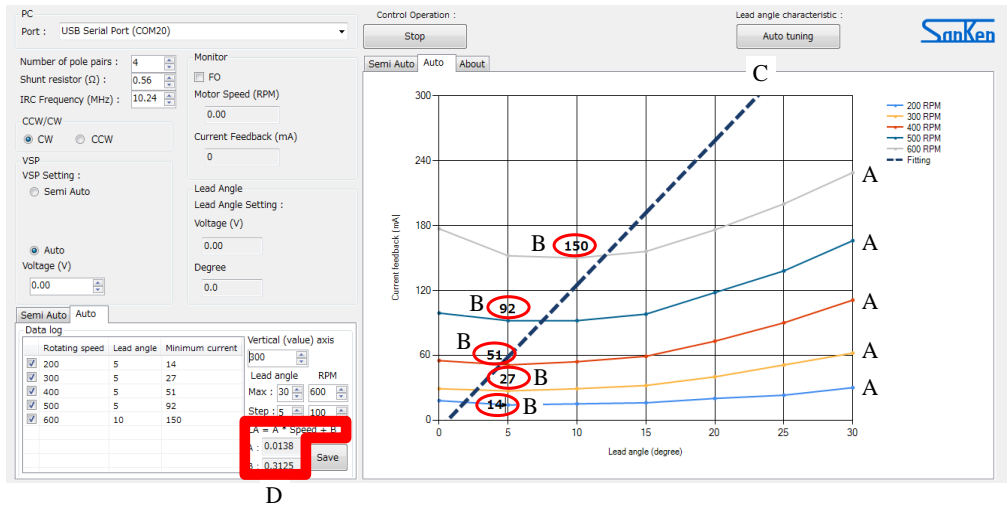
16) Click the Auto tuning button.

Auto tuning starts and the motor rotates. Note that an error message appears because the auto tuning does not start unless you click the **Run** button in step 15). The following message appears during auto tuning.



Auto tuning result

The result of auto tuning is displayed on the graph each time. When auto tuning is completed, the motor stops and the message disappears.



- A: The tuning results of the feedback current and phase advance angle (for each motor rotation speed)
- B: The lowest feedback current value among the tuned phase advance angles (for each motor rotation speed)
- C: Approximate line calculated from the auto tuning result
- D: Equation of the approximate line (C)

From the approximate expression (D), the phase advance angle (LA) based on the rotation speed can be calculated. For example, when A = 0.0138, B = 0.3125, and Speed (rotation speed) = 250 rpm, LA = 0.0138 × 250 + 0.3125 = 3.7625°.

17) Click the Stop button.

Be sure to click the **Stop** button. In fact, the motor automatically stops when the tuning completes, but this is required for your safety.

18) Turn off the AC power supply.

### 3.2. Semi Auto Tuning of the Phase Advance Angle

The purposes of using semi auto tuning are as follows.

- **To check the auto tuning result again**

Manually set the phase advance angle for each motor rotation speed. Record the feedback current that flows at this point and compare it with the auto tuning result.

- **To obtain the optimal phase advance angle in finer steps than auto tuning**

The optimal phase advance angle is obtained by setting the phase advance angle in finer steps than auto tuning. Tuning accuracy is improved resulting in reducing the power consumption.

- **To check the specified phase advance characteristics in actual operation**

By displaying the specified phase advance characteristics on the GUI, check the motor rotation speed (RPM), feedback current (mA), phase advance angle (V), phase advance angle (°), and VSP voltage (V) in actual operation.

For semi auto tuning, the speed control signal (VSP) is input from the external control power supply. Manually obtain the phase advance characteristics while adjusting VSP.

The IC controls the speed of motor rotation with an analog voltage applied to the VSP pin. In the range of  $2.1\text{ V} \leq V_{SP} \leq 5.4\text{ V}$ , the IC controls the duty cycles of the PWM output according to the VSP pin voltage,  $V_{SP}$ . Figure 3-1 shows the relationship between VSP pin voltage and the duty cycle.

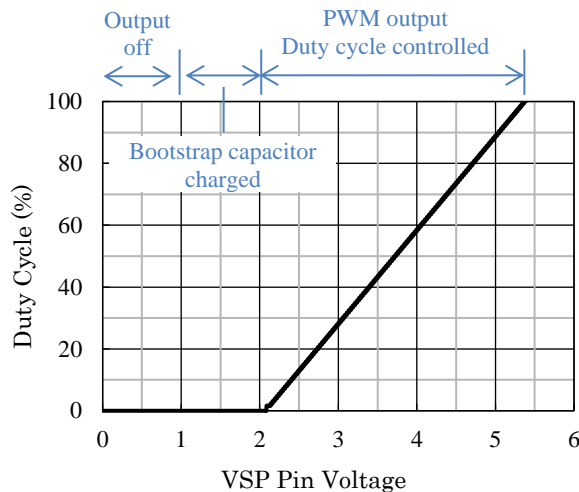


Figure 3-1. VSP Pin Voltage vs. Duty Cycle

When using both an AC power supply and a logic power supply in these procedures, make sure that the logic power supply has a floating connection to the demo board. In case both supplies are connected to the same ground, your demo board may have an overcurrent and thus permanent damage.



To tune the phase advance angle, follow the steps below.

- 1) **Connect the devices according to the procedure as shown in Section 2.2.**
- 2) **Connect the motor to the connector J8.**
- 3) **Connect a connector below according to the Hall signal input.**

Adjust the jumper wire connection of the demo board according to the Hall signal input (see Section 1.1).

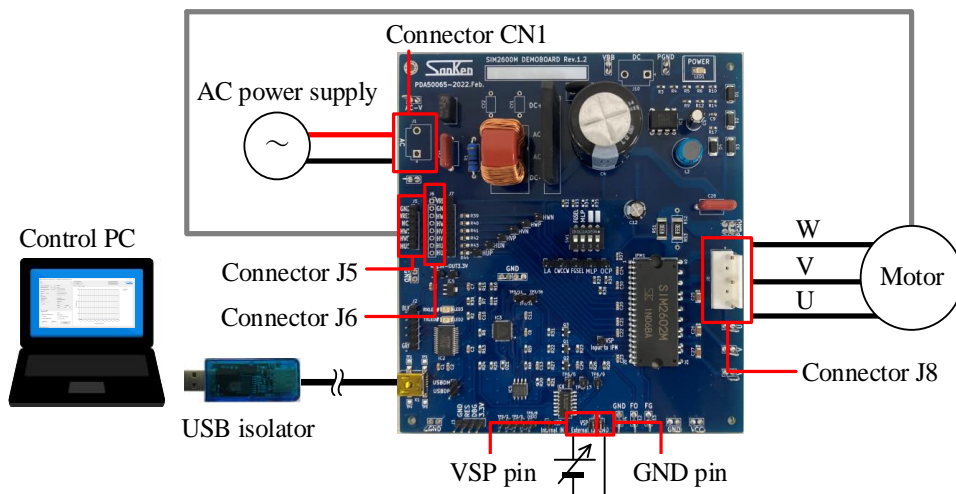
**Application using signals input from Hall ICs:**

Connect the connector J5 and the Hall ICs (the Hall signal input pins, VREG pin, and COMx pin of the SIM2602M)

**Application using signals input from Hall elements:**

Connect the connector J6 and Hall elements (the Hall signal input pins, VREG pin, and COMx pin of the SIM2602M)

- 4) **Connect the AC power supply to the connector J1.**



- 5) **Connect the current and voltage probes of your oscilloscope according to the waveforms.**
- 6) **Connect the logic power supply between VSP and GND pins.**  
Make sure that the logic power supply has a floating connection to the demo board.
- 7) **Set the number of magnetic pole pairs in the motor.**

Number of pole pairs :	<input type="text" value="4"/>
Shunt resistor ( $\Omega$ ) :	<input type="text" value="0.56"/>
IRC Frequency (MHz) :	<input type="text" value="10.24"/>

No need to change the value of **IRC Frequency (MHz)**.

- 8) **Set the value of the shunt resistor of the demo board.**

Number of pole pairs :	<input type="text" value="4"/>
Shunt resistor ( $\Omega$ ) :	<input type="text" value="0.17"/>
IRC Frequency (MHz) :	<input type="text" value="10.24"/>

9) Select the motor direction.

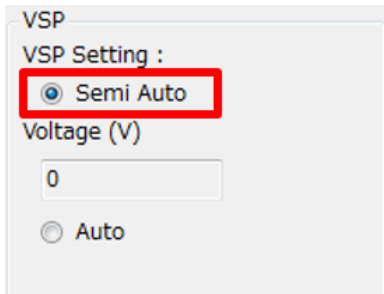


CCW/CW  
 CCW  CW

CW: Clockwise

CCW: Counterclockwise

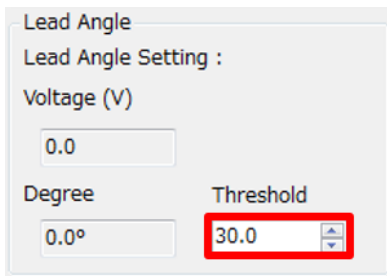
10) Select the Semi Auto.



VSP  
VSP Setting :  
 Semi Auto  
Voltage (V)  
0  
 Auto

The **Semi Auto** is the mode where the VSP voltage is manually set from the external logic power supply.

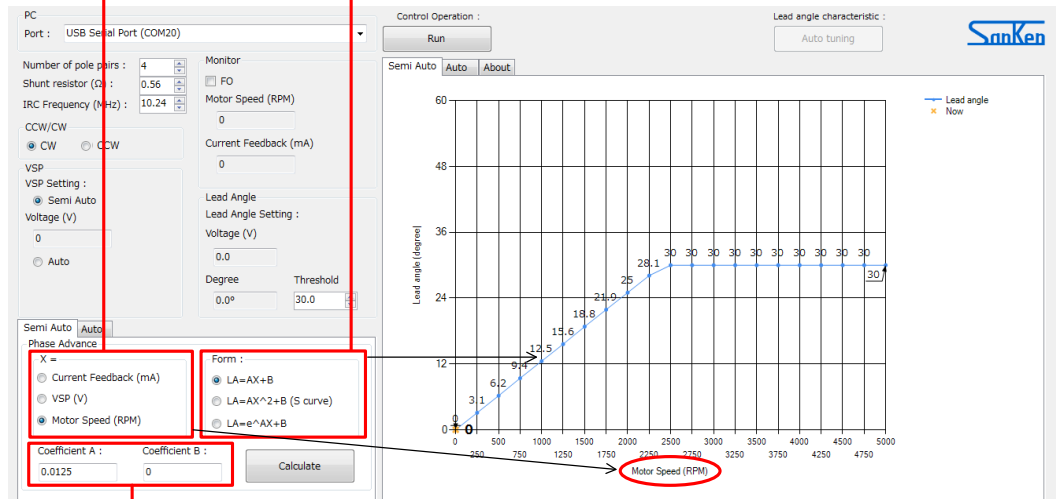
11) Set the maximum phase advance angle.



Lead Angle  
Lead Angle Setting :  
Voltage (V)  
0.0  
Degree      Threshold  
0.0°      30.0

12) Set the parameters of the phase advance characteristics.

- 1. Select the X axis of the phase advance characteristics
- 2. Select the formula of the phase advance characteristics



- 3. Set the coefficient A and B of the formula selected in 2.

Parameter	Checking the auto tuning result again	Obtaining the optimal phase advance angle in finer steps than auto tuning	Checking the specified phase advance characteristics in actual operation
X=	Motor Speed (RPM)	Motor Speed (RPM)	Arbitrary
Form	LA=AX+B	LA=AX+B	Arbitrary
Coefficient A	0*	0*	Arbitrary
Coefficient B	Arbitrary*	Arbitrary*	Arbitrary

\* The value entered in Coefficient B will be the phase advance angle (°) to be tuned (LA = B).

13) Click the Calculate button.

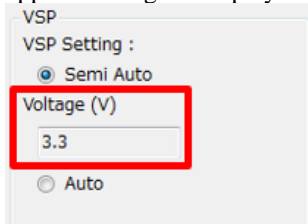
14) Click the Run button.

15) Turn on the AC power supply.

Apply a voltage on actual operating conditions (100 VAC to 240 VAC).

16) Turn on the VSP power supply.

Make sure that the logic power supply has a floating connection to the demo board before applying the voltage. The applied voltage is displayed in Voltage (V).

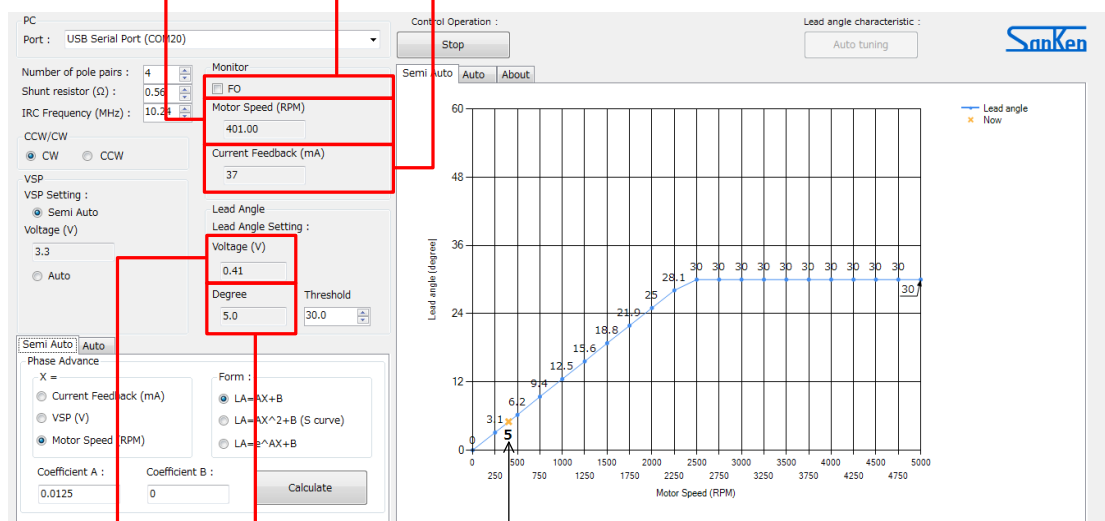


When the motor rotates, the following information is displayed.

Monitoring fault signals from the SIM2600M

Motor rotation speed (rpm)

Feedback current (mA)



Phase advance angle (°)

Motor rotation speed is also displayed in the graph

The voltage applied to the LA pin in setting the phase advance angle (°) for the SIM2600M

17) Check and obtain the data

**Checking the auto tuning result again:**

**Obtaining the optimal phase advance angle in finer steps than auto tuning:**

Repeat the procedures below to obtain the optimal phase advance angle.

- 17) – 1 Enter the phase advance angle to be tuned in the **Coefficient B**.
- 17) – 2 Click the **Calculate** button.
- 17) – 3 Adjust the VSP power supply to match the rotation speed to be tuned.
- 17) – 4 Record the value of the feedback current.

**Checking the specified phase advance characteristics in actual operation:**

Adjust the X axis (X =) value of the phase advance characteristics set in the step 12) and check the actual operation.

18) Turn off the VSP power supply.

19) Turn off the AC power supply.

20) Click the Stop button.

### 3.3. Operational Waveforms Confirmation

Check with an oscilloscope if the signal is output according to the set phase advance angle. The phase difference between the Hall signal (FG pin voltage) and the output pin voltage is the phase advance angle. This section describes the operational waveforms when the phase advance angle is set to 0° and when set to 15° as examples.

Figure 3-2 shows the operational waveform with the 0° phase advance angle; Figure 3-3 shows the operational waveform with the 15° phase advance angle.

Conditions: 50 VAC (VBB = 70 V)

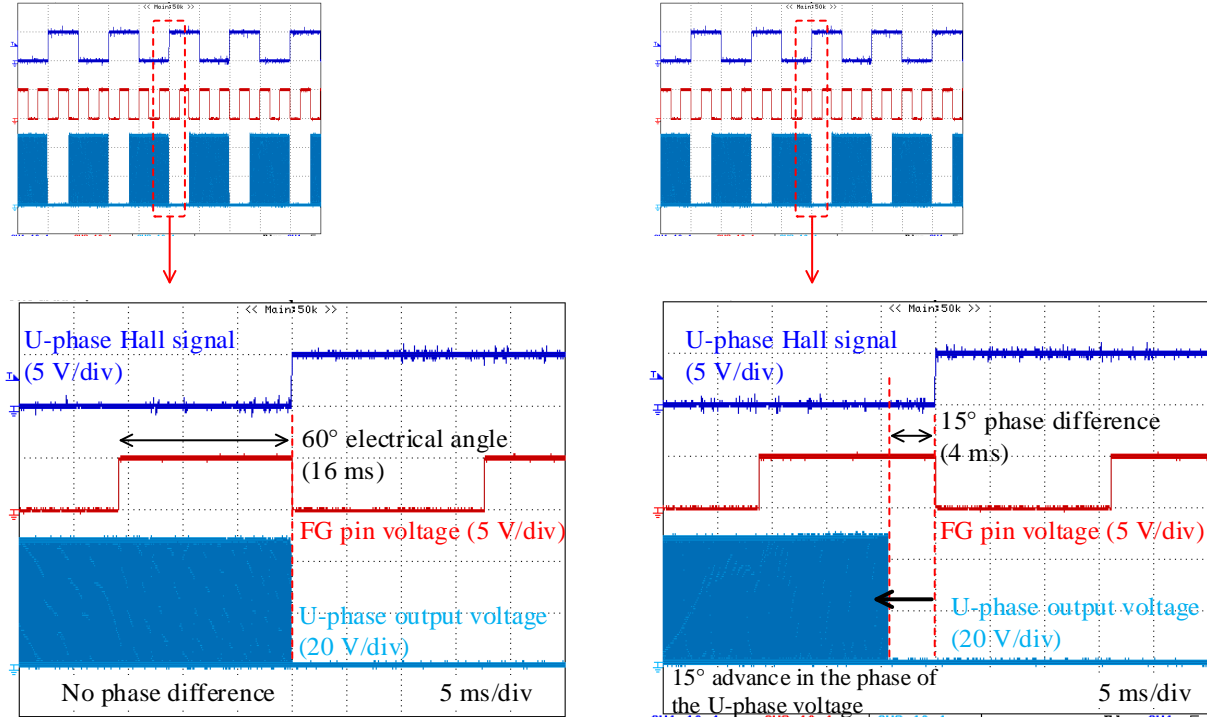


Figure 3-2. Operational Waveform with the 0° Phase Advance Angle

Figure 3-3. Operational Waveform with the 15° Phase Advance Angle

When the phase advance angle is 0°, there is no phase difference between the Hall signal (the FG pin voltage) waveform and the output voltage waveform. When the phase advance angle is 15°, you can see that the phase difference between the Hall signal (the FG pin voltage) waveform and the output voltage waveform is 15°.

## 4. GUI

### 4.1. GUI Display Screen

Figure 4-1 shows the GUI (Graphic User Interface) display screen for semi auto tuning of the phase advance angle. Select the **Semi Auto** for semi auto tuning (see 7 in Figure 4-1).

Figure 4-2 shows the GUI display screen for auto tuning of the phase advance angle. Select the **Auto** for auto tuning (see 9 in Figure 4-2).

Table 4-1 provides the functional descriptions of the individual GUI elements such as parameters and indications.

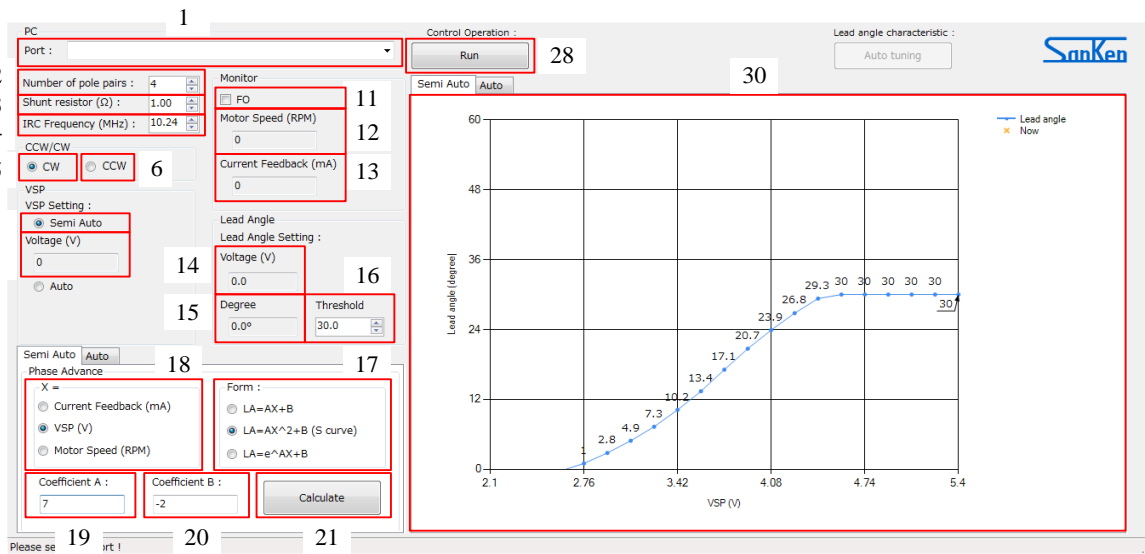


Figure 4-1. Semi Auto Tuning Screen (when the Semi Auto is selected)

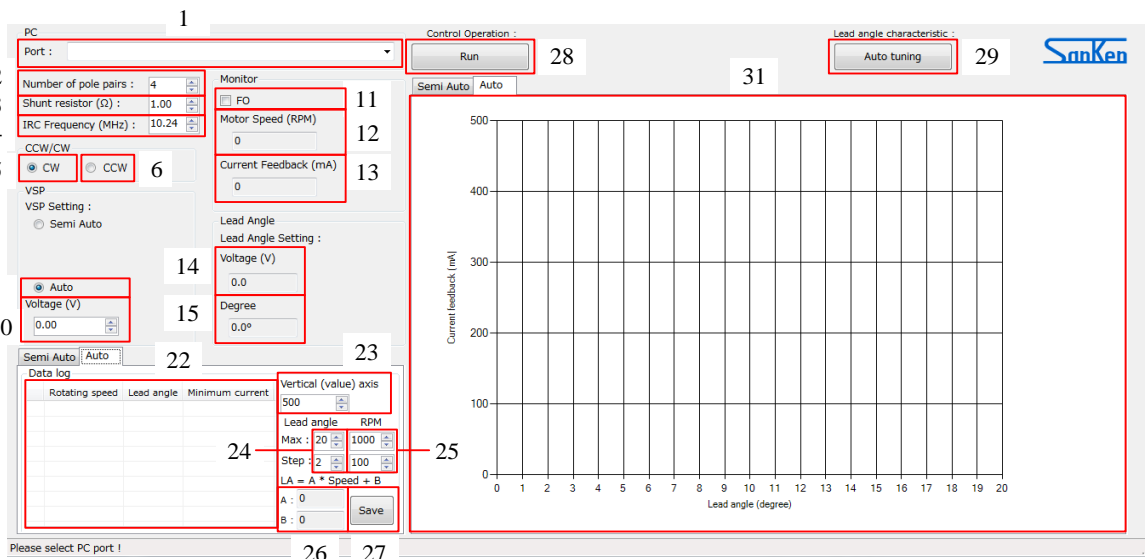


Figure 4-2. Auto Tuning Screen (when the Auto is selected)

Table 4-1. Individual GUI Elements and Functions

No.	Group Box/ GUI Parameter	Description	Remarks
<b>PC</b>			
1	Port	Select the port for control PC.	
<b>Motor Specification</b>			
2	Number of pole pairs	Enter the number of pole pairs in the test motor.	Used in calculating the motor rotation speed.
3	Shunt resistor ( $\Omega$ )	Enter the shunt resistance value.	Used in calculating the feedback current.
4	IRC Frequency (MHz)	Set the MCU internal oscillator frequency.	Adjusted when the motor rotation speed does not match the actual operation.
<b>CCW/CW</b>			
5	CW	Set the direction of motor rotation to clockwise.	Be sure to switch CCW/CW after turning off the AC power supply. The setting is not changed if the rotation direction is switched during the AC power supply on-state.
6	CCW	Set the direction of motor rotation to counterclockwise.	
<b>VSP</b>			
7	Semi Auto	Selected when the phase advance angle is tuned in semi auto tuning.	The VSP pin voltage is applied from the logic power supply. The LA voltage is output from the MCU according to the setting in the <b>Phase Advance</b> group box.
8	Voltage (V)	VSP pin voltage is displayed.	Only when the Semi Auto selected
9	Auto	Selected when the phase advance angle is tuned in automatic tuning.	The VSP voltage and the LA voltage are output from the MCU.
10	Voltage (V)	Set the VSP pin voltage.	Only when the Auto selected
<b>Monitor</b>			
11	FO	To monitor the FO (fault signal output) of the SIM2602M. When a fault signal is detected, a check mark is displayed and the motor rotation stops.	
12	Motor Speed (RPM)	The motor rotation speed is displayed.	
13	Current Feedback (mA)	The feedback current is displayed.	
<b>Lead Angle</b>			
14	Voltage (V)	The voltage applied to the LA pin in setting the phase advance angle ( $^{\circ}$ ) for the SIM2602M	The LA voltage is output from the MCU according to the setting in the <b>Phase Advance</b> group box.
15	Degree	The phase advance angle ( $^{\circ}$ ) is displayed.	The LA voltage is output from the MCU according to the setting in the <b>Phase Advance</b> group box.
16	Threshold	Set the maximum value of the phase advance angle to be tuned	Only when the Semi Auto selected

Phase Advance			
17	Form	Select the formula for the phase advance characteristics.	Only when the Semi Auto selected
18	X=	Select the formula X.	Only when the Semi Auto selected
19	Coefficient A	Set the value for the formula A.	Only when the Semi Auto selected
20	Coefficient B	Set the value for the formula B.	Only when the Semi Auto selected
21	Calculate	After setting the Form, X =, Coefficient A, and Coefficient B, click to display the advance characteristics.	Only when the Semi Auto selected
Data log			
22	Rotating speed / Lead angle / Minimum Current	The auto tuning result is displayed for each rotation speed.	Only when the Auto selected
23	Vertical (value) axis	Set the maximum value on the vertical axis of the graph	Only when the Auto selected
24	Lead angle	<ul style="list-style-type: none"> <li>● <b>Max:</b> Set the maximum value of the phase advance angle to be tuned</li> <li>● <b>Step:</b> Set the step of the phase advance angle to be tuned</li> </ul>	Only when the Auto selected The phase advance angle to be tuned is set to 0° by default.
25	RPM	<ul style="list-style-type: none"> <li>● <b>Max:</b> Set the maximum rotation speed of the phase advance angle to be tuned</li> <li>● <b>Step:</b> Set the step for the rotation speed of the phase advance angle to be tuned</li> </ul>	Only when the Auto selected The rotation speed to be tuned is set to 200 rpm by default.
26	$LA = A * Speed + B$	The optimal value of the auto tuning result is displayed in a linear function.	Only when the Auto selected
27	Save	Save the auto tuning result.	Only when the Auto selected
Other			
28	Run / Stop	<ul style="list-style-type: none"> <li>● <b>Run:</b> Start the motor.</li> <li>● <b>Stop:</b> Stop the motor.</li> </ul>	
29	Auto tuning	Start the auto tuning.	Only when the Auto selected
30	Semi Auto	Displayed during the semi auto tuning	Only when the Semi Auto selected
31	Auto	Displaying the auto tuning result	Only when the Auto selected

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