BLDC motor practice

NEXTY Electronics

April 17th, 2020
Ver1.0

This document summarizes the following.
1. What's BLDC control.
2. Introduction of Infineon iMOTION products
3. Motor control by Infineon iMOTION
4. Motor drive experiment

Advantages of BLDC motor

"BLDC = Brush Less DC motor"
Since there is no electrode brush, electrode wear is eliminated, and the mechanical life of the motor is greatly extended.
Furthermore, it is possible to increase power efficiency and run the motor with low noise.

BLDC features Comparison with other motors	Power efficiency	○ 90% or more high efficiency
	noise	○ small
	Variable speed range	○ wide
	response	× T.B.D.
	life	○ Long life
	price	× Fair to expensive
	Application examples	Air conditioner Dishwasher Washing machine Refrigerator Ventilation fan Small home appliances

Advantages of BLDC
Explains how to achieve high efficiency and low noise

Disadvantages of BLDC
And how to improve responsiveness

In order to realize it,
・ Control circuit (hardware)
・ Algorithm (Software)
should be optimized

BLDC motor control

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To run BLDC motor smoothly

1) It is necessary to synchronize with **the rotor rotation position** and

2) To supply **current to the coil** with good timing.

1) How to know the rotor rotation position

1. Measure the position using a magnetic sensor, etc., and identify the rotor position
2. Measure motor current and estimate rotor position (sensorless) **←Trend**

2) Drive method for passing current to coil

1. Apply rectangular wave current (120 degree conduction)
2. Apply sinusoidal current (180 degree current) **←Trend**

For cost reduction, and low noise and vibration
- **Sensorless without magnetic sensor**
- **Sine-wave drive (180 degree conduction)**

are the trend.

Introduction of Infineon iMOTION

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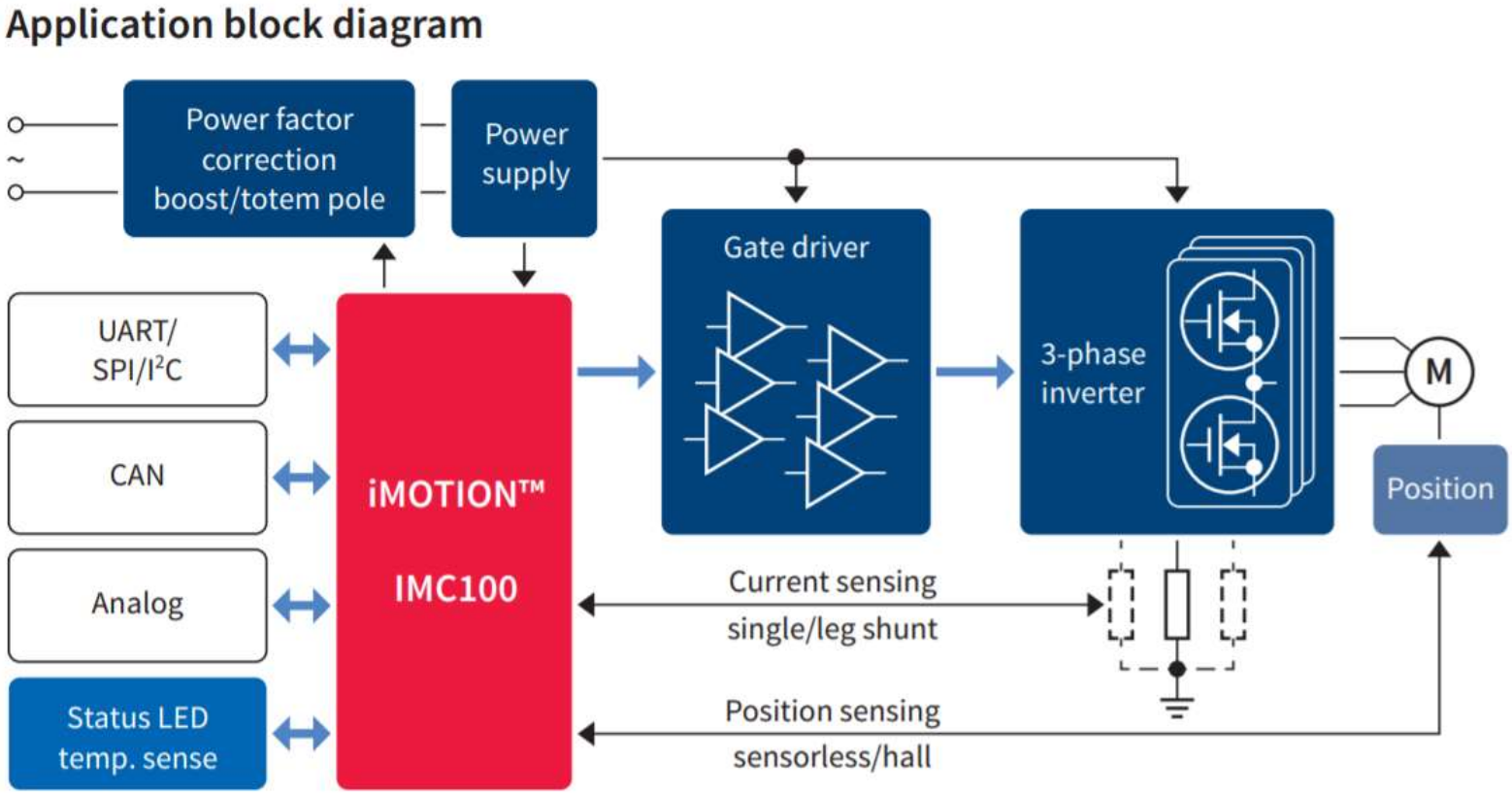
At Infineon,
We release IC for BLDC motor control.
That is the **iMOTION series**.
By using iMOTION IC, BLDC control by sine wave drive with sensorless is possible.

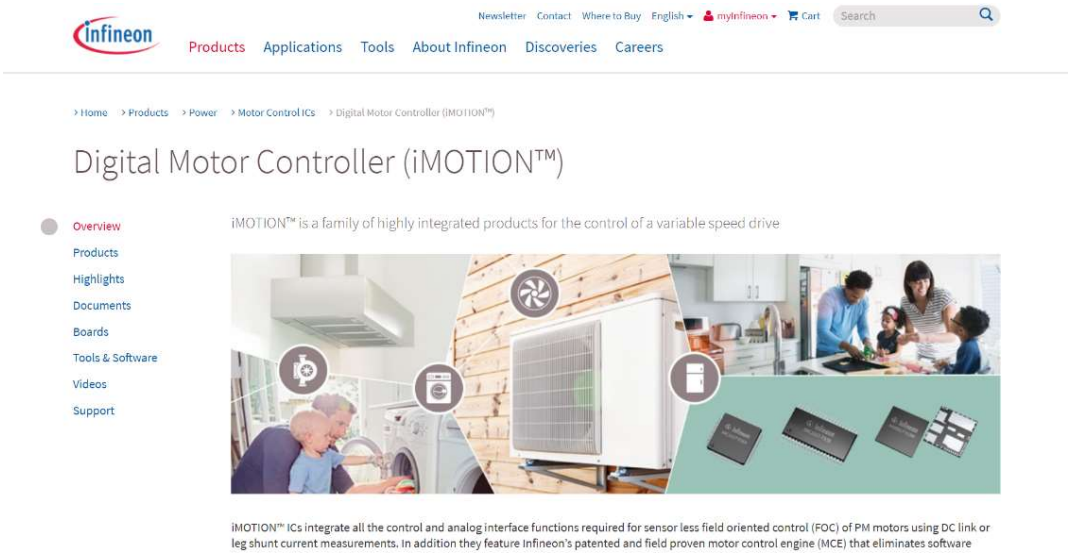


iMOTION IMC100 High performance motor control IC series
Infineon-IMC100_iMOTION-ProductBrief-v01_00-EN.pdf
https://www.infineon.com/dgdl/Infineon-IMC100_iMOTION-ProductBrief-v01_00-EN.pdf?fileId=5546d4626176435901619 8ba6329153f

Introduction of Infineon iMOTION

The advantage of iMOTION is
"Various speed drive solution ready for use"
(As shown on the right)
No programming like a microcomputer is required,
and since the ADC and comparator required for motor control are embedded, the control board can be realized with a minimum number of components.

Infineon's Website
https://www.infineon.com/cms/en/product/power/motor-control-ics/digital-motor-controller-imotion/
provides technical information such as evaluation boards and power element selection guides in addition to iMOTION product information.



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https://www.infineon.com/dgdl/Infineon-IMC100_iMOTION-ProductBrief-v01_00-EN.pdf?fileId=5546d46261764359016198ba6329153f

Key benefits

Ready-to-use solution for variable speed drives based on Field Oriented Control (FOC) of Permanent Magnet Synchronous Motors (PMSM).

Outstanding customer benefits

- Fastest time to market
  - No programming required
  - Easy motor parametrization and tuning
- Lowest BOM cost
  - Integrated ADC and comparators
  - Sensorless FOC algorithm (hall sensors optional)
  - Internal oscillator
- Integrated protection features
- Next generation of field proven Motion Control Engine (MCE 2.0)
  - Single or leg shunt
  - Optional hall/encoder support
  - Boost or totem pole PFC
  - Flexible host interface options
  - Support for IEC 60335 ('Class B')
- Multiple package options

BLDC control by iMOTION

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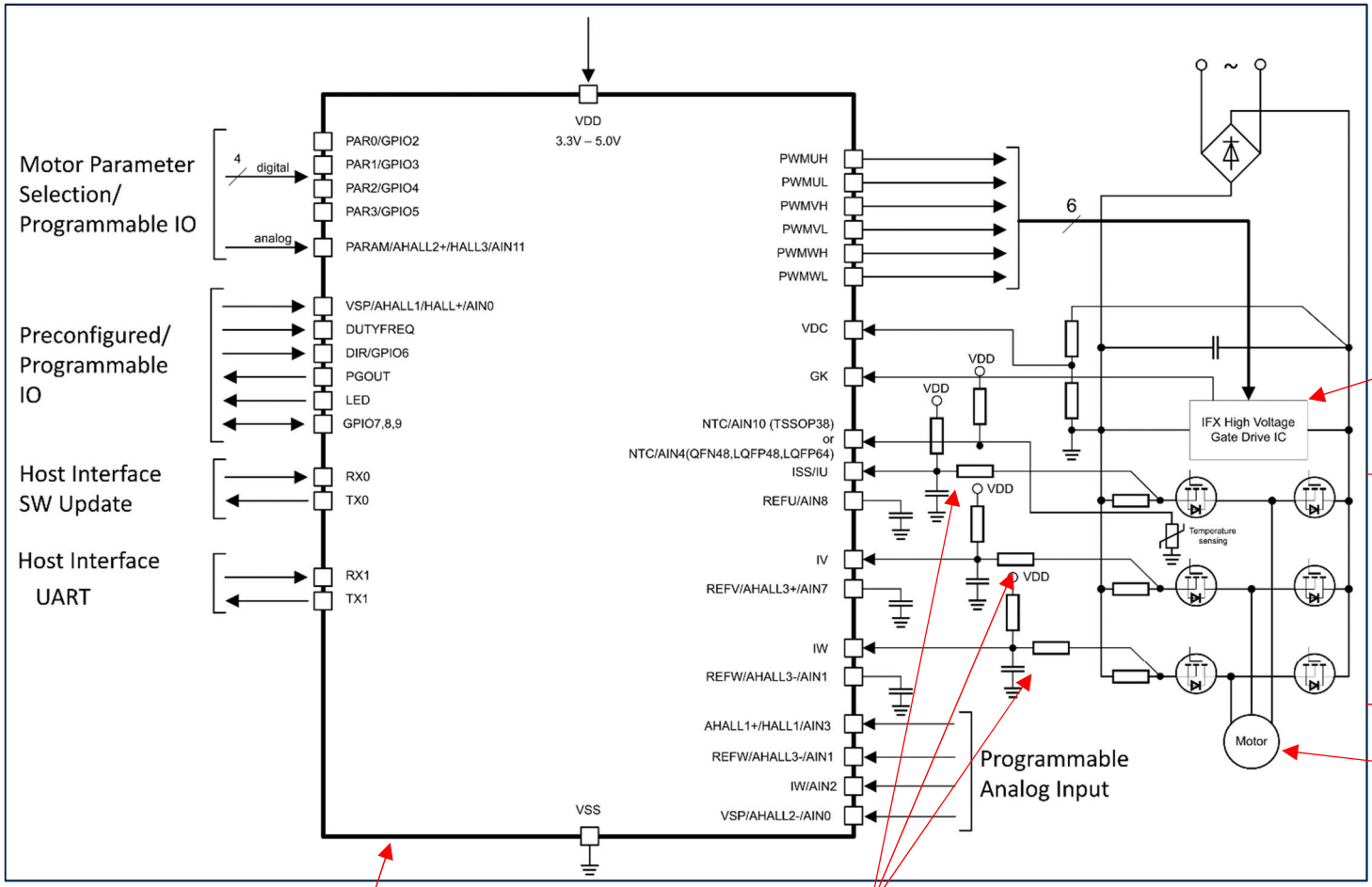
This page introduces how to rotate BLDC without sensor using iMOTION.
The circuit image is as shown in the schematic diagram below.

Sensorless motor drive block diagram

iMOTION IMC100データシート v1.3 2019-02-14
Infineon-IMC100-DS-v01_03-EN.pdf



iMOTION Introduction Guide

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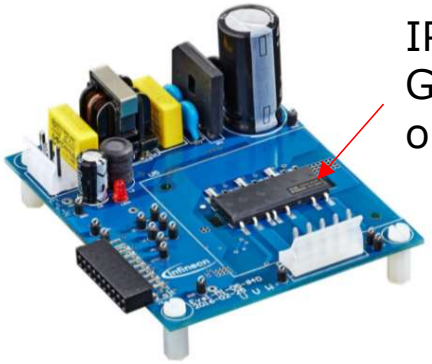
【Purpose】
Use Infineon's evaluation board to run the motor.
Travel time is about 1 hour.

【procedure】
1. Install iMOTION software tools
2. Hardware connection: Use the following two evaluation boards
3. Set the system and motor configuration with “MCEWizard”
4. IC parameter setting and motor rotation with "MCEDesigner"
5. Repeat 3.⇔4. for motor control parameter tuning

There is a brief explanation on the next page

■ Controller IC IMC101T-T03
Eval-M1-101T (2018-01-23)
Equipped with USB debugging function



IPM (Intelligent Power Module)
Gate driver and MOSFET in one package

■ Power board
EVAL-M1-05-84D
IRSM505-084
Input: AC 90-140V / DC 45-200V
20-150W sensorless 3-phase motor

iMOTION Motor Tuning Tool

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iMOTION has released two softwares as motor tuning tools.

1. Enter the parameters required for MCEWizard motor control
   Motor characteristics
   Control board constants (RC parameters)
   Motor rotation specification
   Fail safe setting
   Script function settings

2. MCEDesigner Motor driving experiment and state observation
   Use the debugger (iMOTION LINK)
   Writing parameter/firmware/script files to IC
   Writing and reading of detailed register values of IC
   Understanding motor drive status
   FOC control loop status recording and graph display

If you have not yet installed the software tools,
please follow the instructions on the next page.

Software installation

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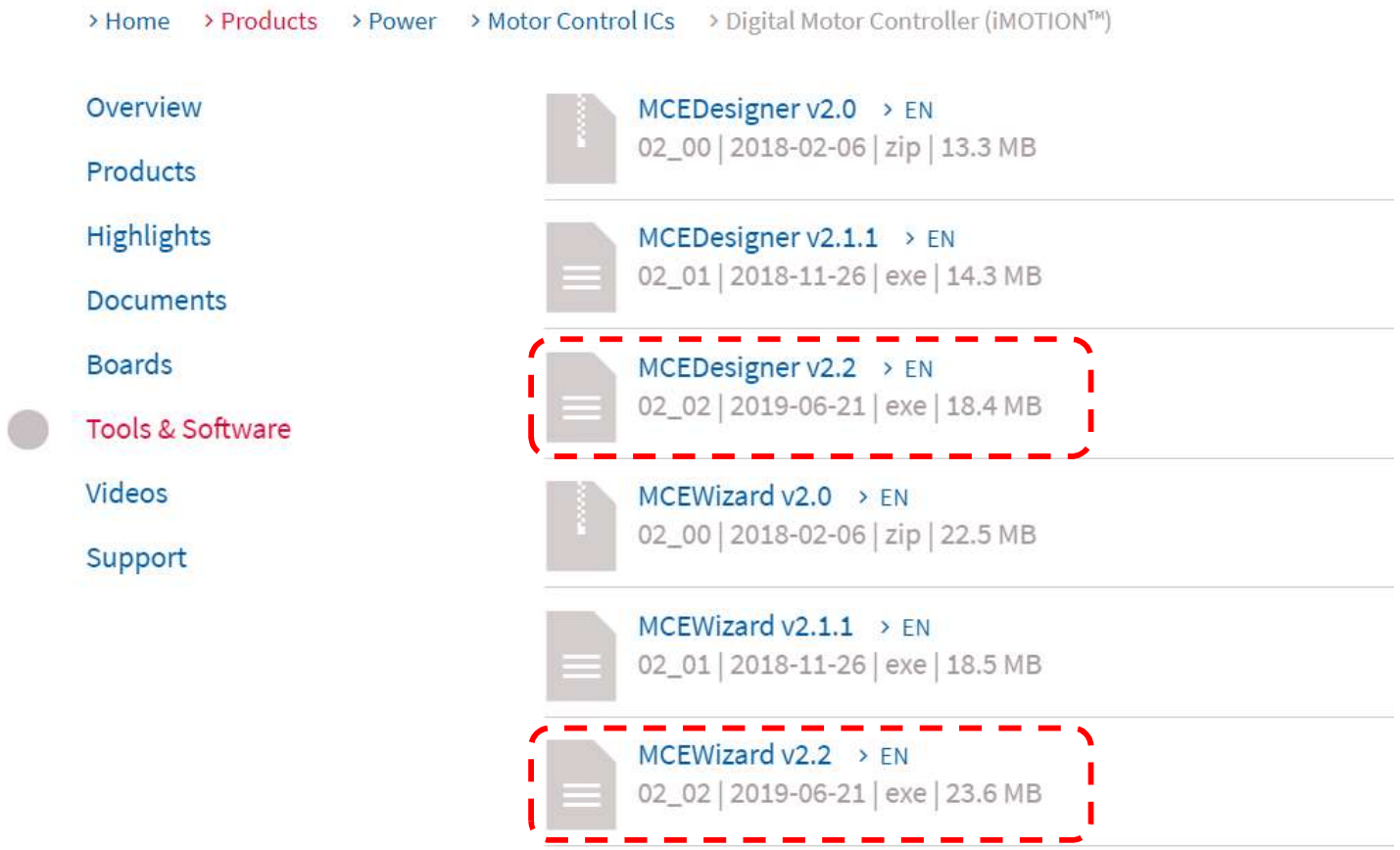
Install the iMOTION software tools.

<<https://www.infineon.com/cms/en/product/power/motor-control-ics/digital-motor-controller-imotion/>>
Click "MCEDesigner v2.2" and "MCEWizard v2.2" to download.
If you have the latest version, please install it.

The latest version is v2.2. (February 3, 2020)

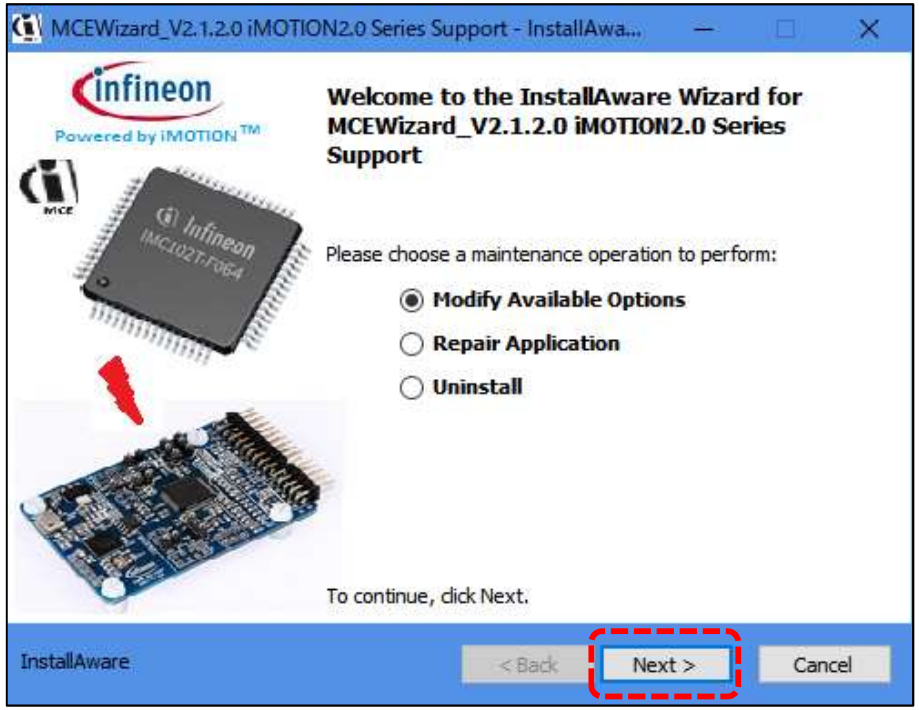


Software installation

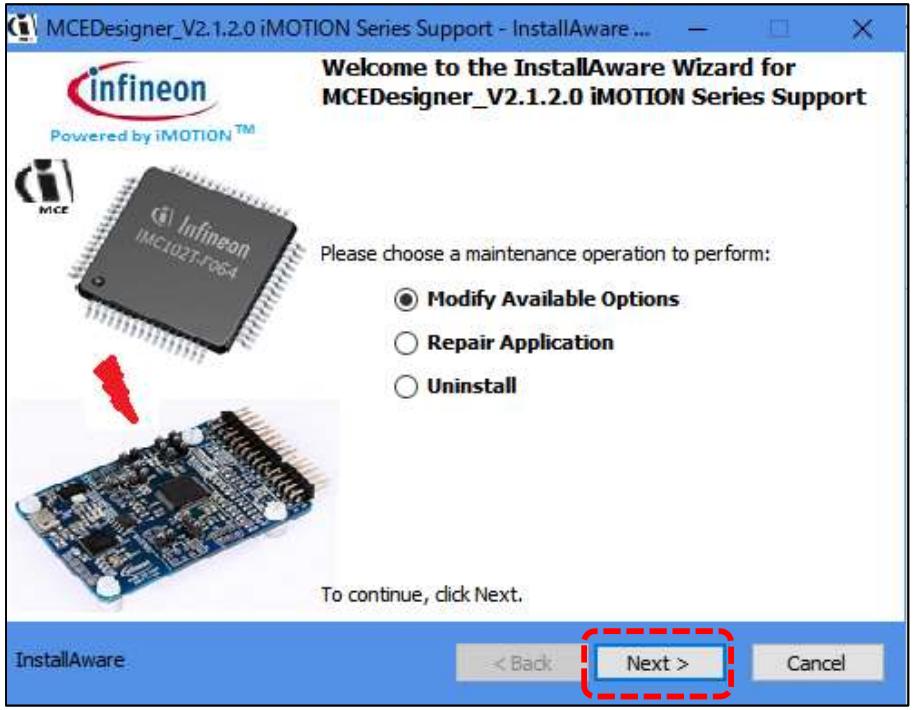
After downloading, check the file size of the executable file
(confirm whether the download was successful), and then execute the installation.

名前	日付時刻	種類	サイズ
Infineon-MCEWizard-Software-v02_02-EN.exe	2020/02/03 16:48	アプリケーション	24,137 KB
Infineon-MCE_Designer-Software-v02_02-EN.exe	2020/02/03 16:48	アプリケーション	18,795 KB

MCEWizard installation screen

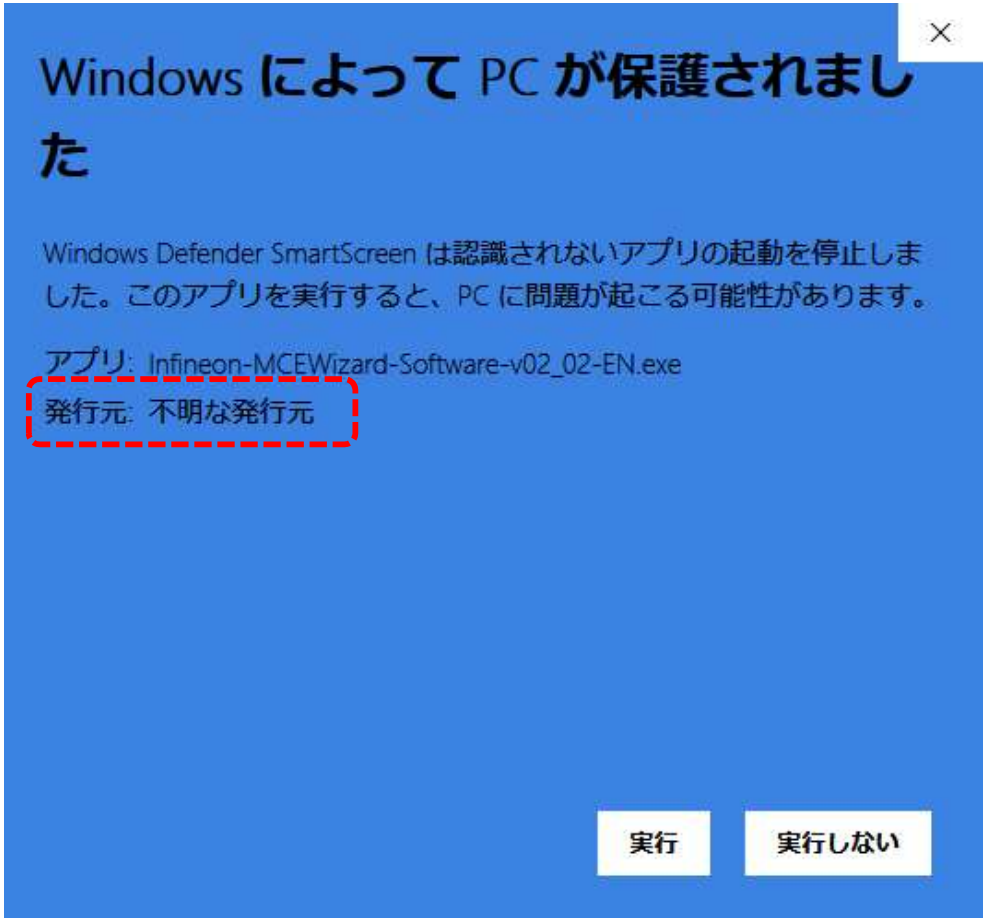


MCEDesigner installation screen



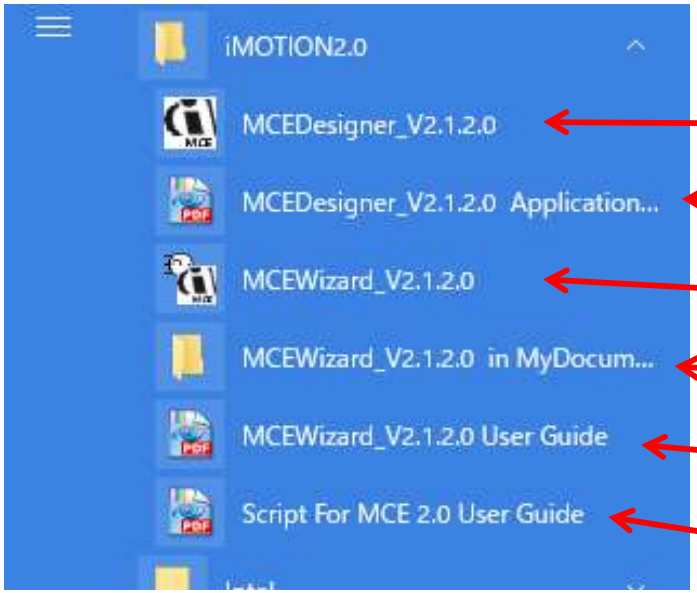
Software installation

During the installation, security software may be checked.
It may be due to "unknown publisher".
At this time, files are downloaded from the official Infineon website,
so assuming there is no problem and installation is continued.



Software installation

After the installation is completed,
an “iMotion2.0” folder is created in the Windows Start menu.



Run MCEDesigner

How to use MCEDesigner

Run MCEWizard

Script sample collection

How to use MCEWizard

Script Function Manual

This completes the software tool installation

Hardware preparation

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■Main power supply

Both AC and DC power supply can be used. The connection of the J1 connector is as shown in Table 5 below.
(This time, experiment is done with AC100V)

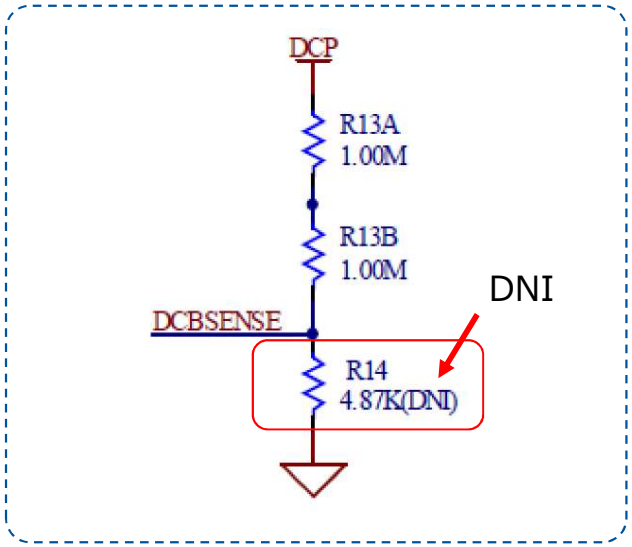
Table 5 J1- AC Line connector

S. No.	Pin	Details
1	E	Earth ground
2	L	AC line input (120 V – 240 V) or DC+ connector
3	N	AC neutral input or DC- connector

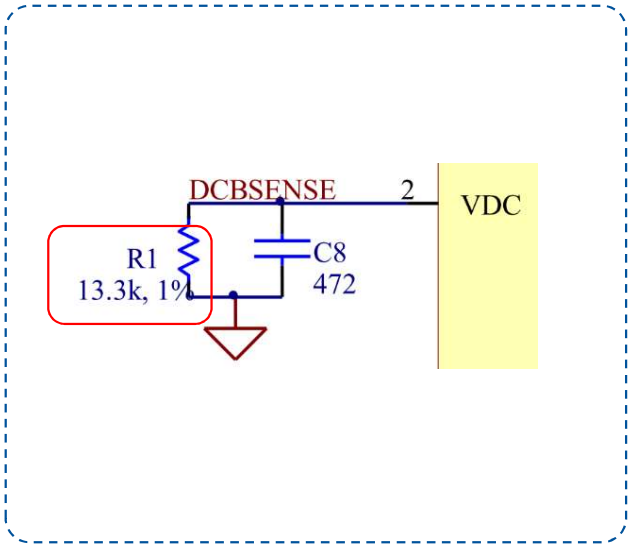
■Low side resistance of DC-BUS voltage sensing

At power board initial setting, DC Sense low side resistor R14 is not mounted (DNI).
Instead, R1 = 13.3kΩ is mounted on the controller board.

Power Board



Controller board



Hardware preparation

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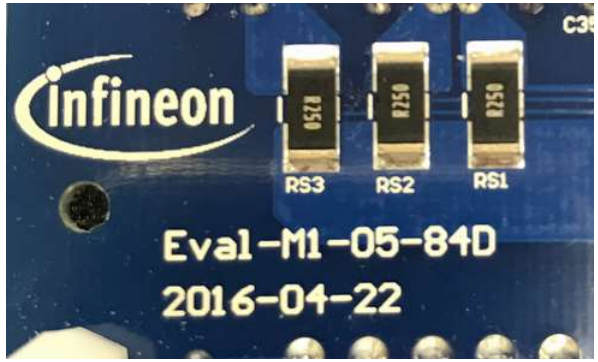
■Shunt configuration and resistance

At the beginning of Power Board, Leg shunt (3 shunts) is mounted.
The resistance value is R250 (250mΩ).

It can be converted to a single shunt.
The remodeling procedure is described in the manual,

1) RS1 and RS3 have to be removed
2) IU+,IV+,IW+ have to be connected
3) R7 has to be changed to 3.48 kΩ



Leg shunt (3 shunts)

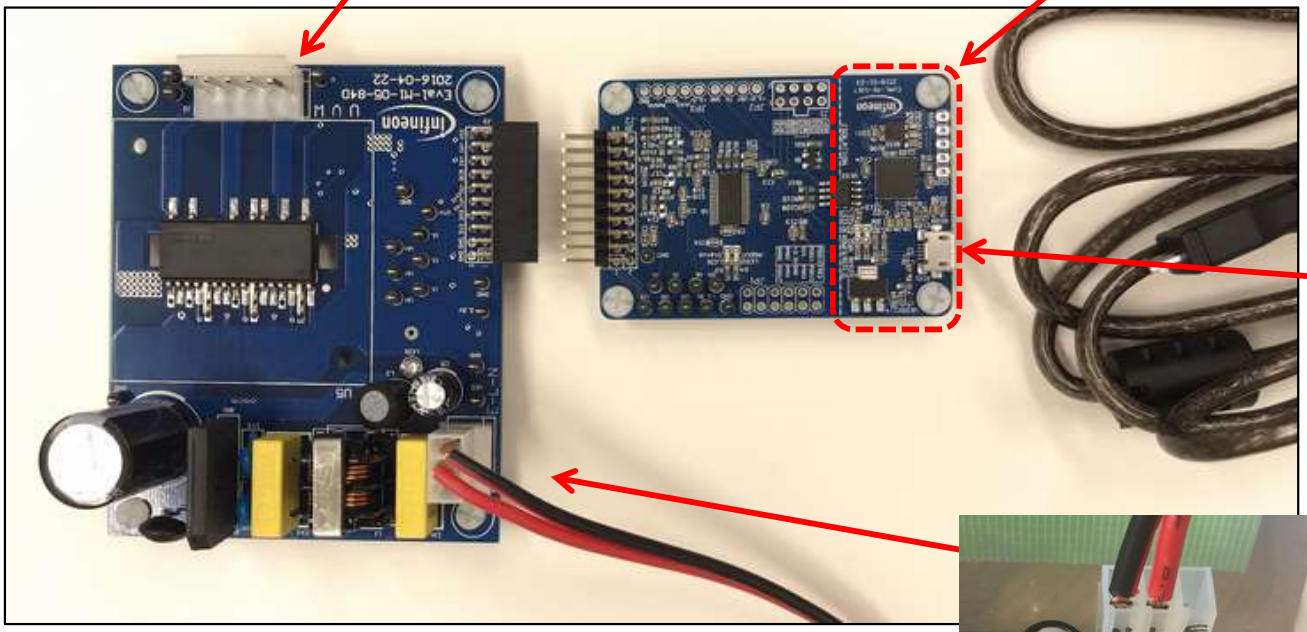
Here, proceed with the Leg shunt without modification.

Hardware preparation

Make hardware connections

3 phase motor connector

Equipped with a debugger function. (The debugger iMOTION LINK is not required)



Connect a PC to the USB connector of Eval-M1-101T. The power supply for the PC and the motor are insulated.

Power connector

Motor drive tuning

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[Software setting procedure]

1. Start "MCEWizard" on your PC
2. Set the parameters of the power board and motor with "MCEWizard" and generate .txt (parameter file)
3. Start "MCEDesinger" on your PC
4. Write the firmware (.ldf file) to the controller IC with "MCEDesinger"
5. Write .txt (parameter file)
6. Start the motor with the "Start Motor" command
7. If it does not rotate properly, repeat steps "2, 5, and 6" = Tuning work

Input parameters with MCE Wizard

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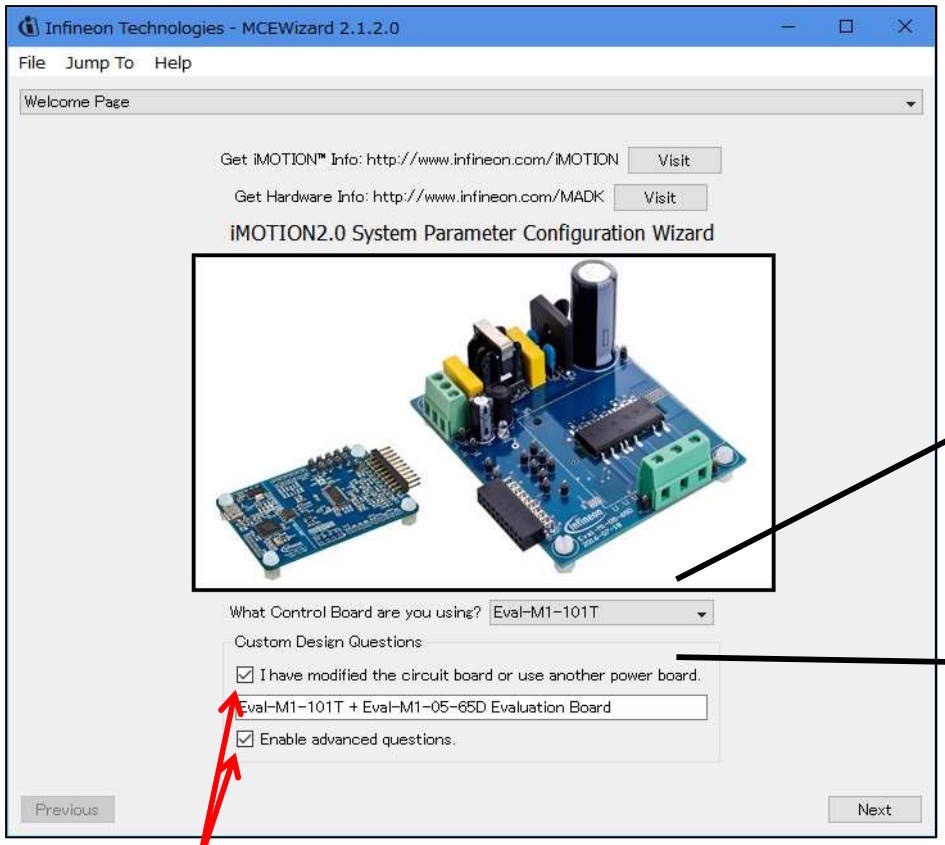
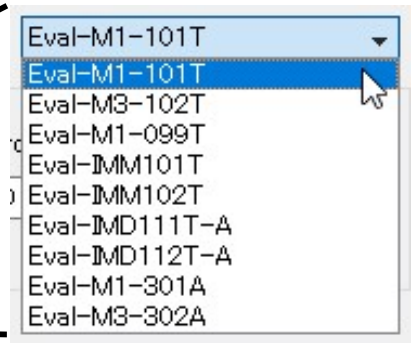
Start "MCEWizard"





Please select Eval-M1-101T

Check here for detailed settings such as shunt resistance value and amplifier forward / reverse setting. The gray item (default setting) can be changed.

Input parameters with MCE Wizard

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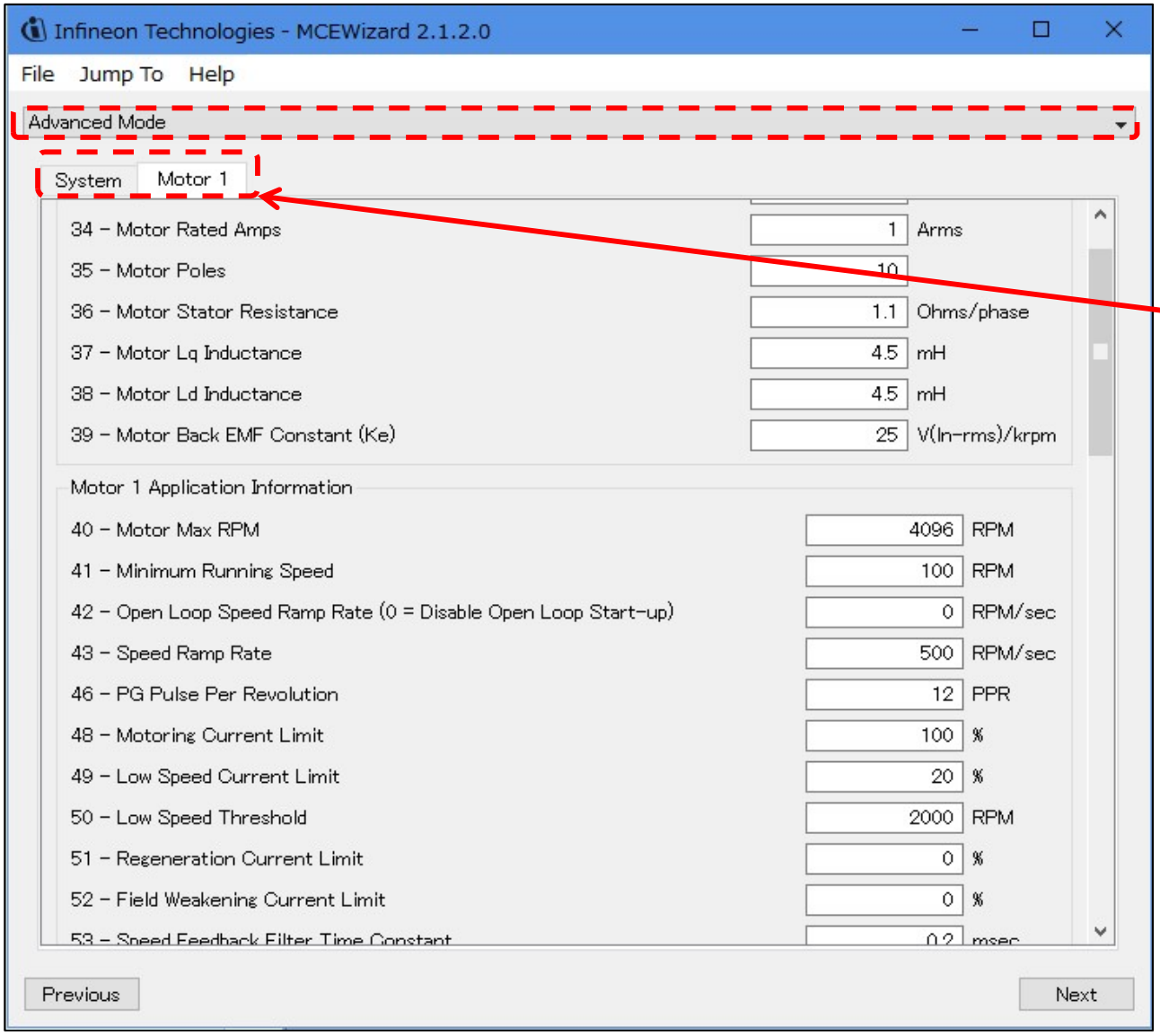
Screen layout of MCE Wizard



Select "Advanced Mode" from the pull-down menu to display the parameter list setting screen.

There are separate categories for “System” and “Motor” settings. Switch by tab operation.

Input parameters with MCE Wizard

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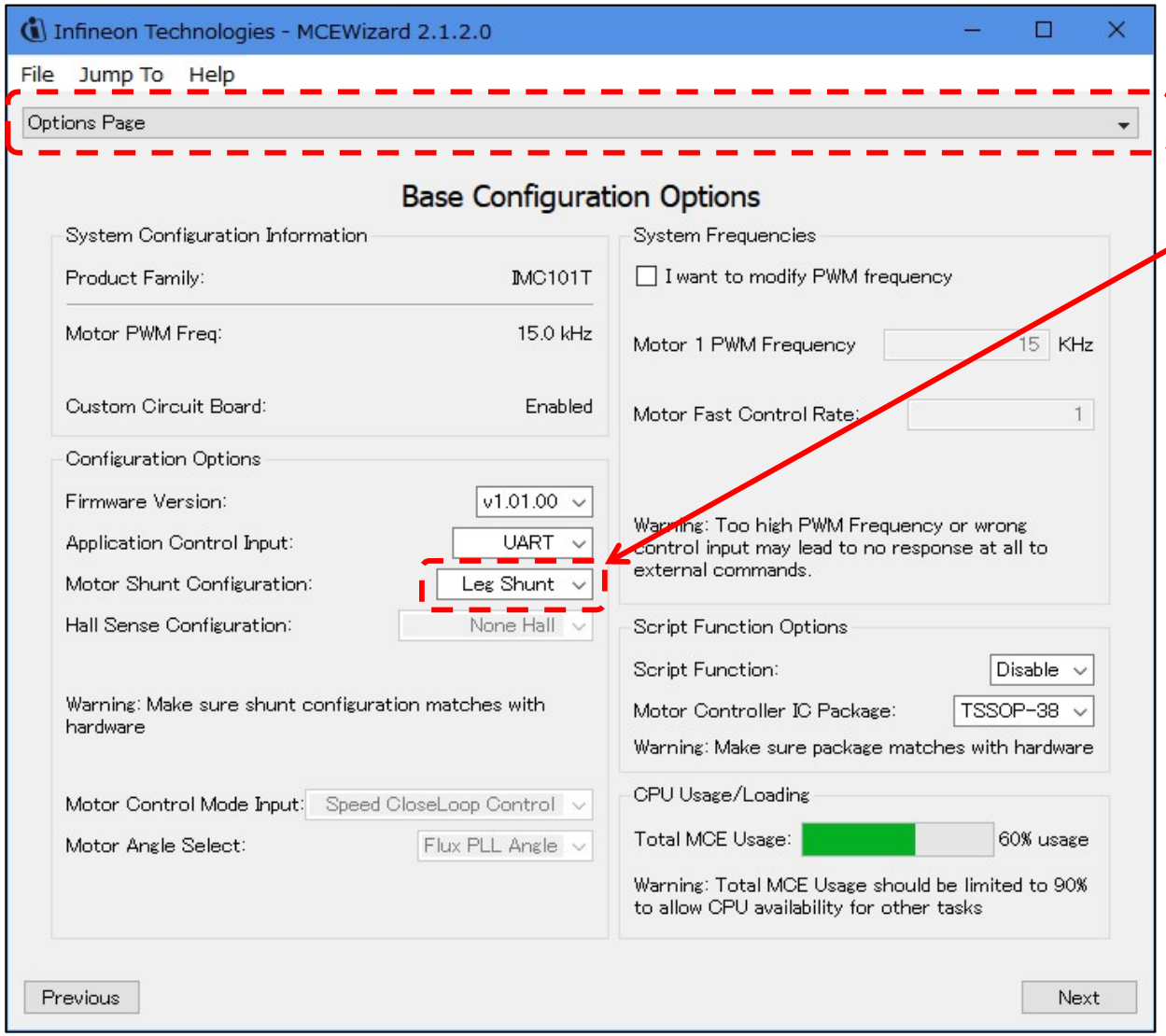
Basic check items in MCE Wizard



In the "Option Page" pulldown, make sure it is "Leg Shunt"

Input parameters with MCE Wizard

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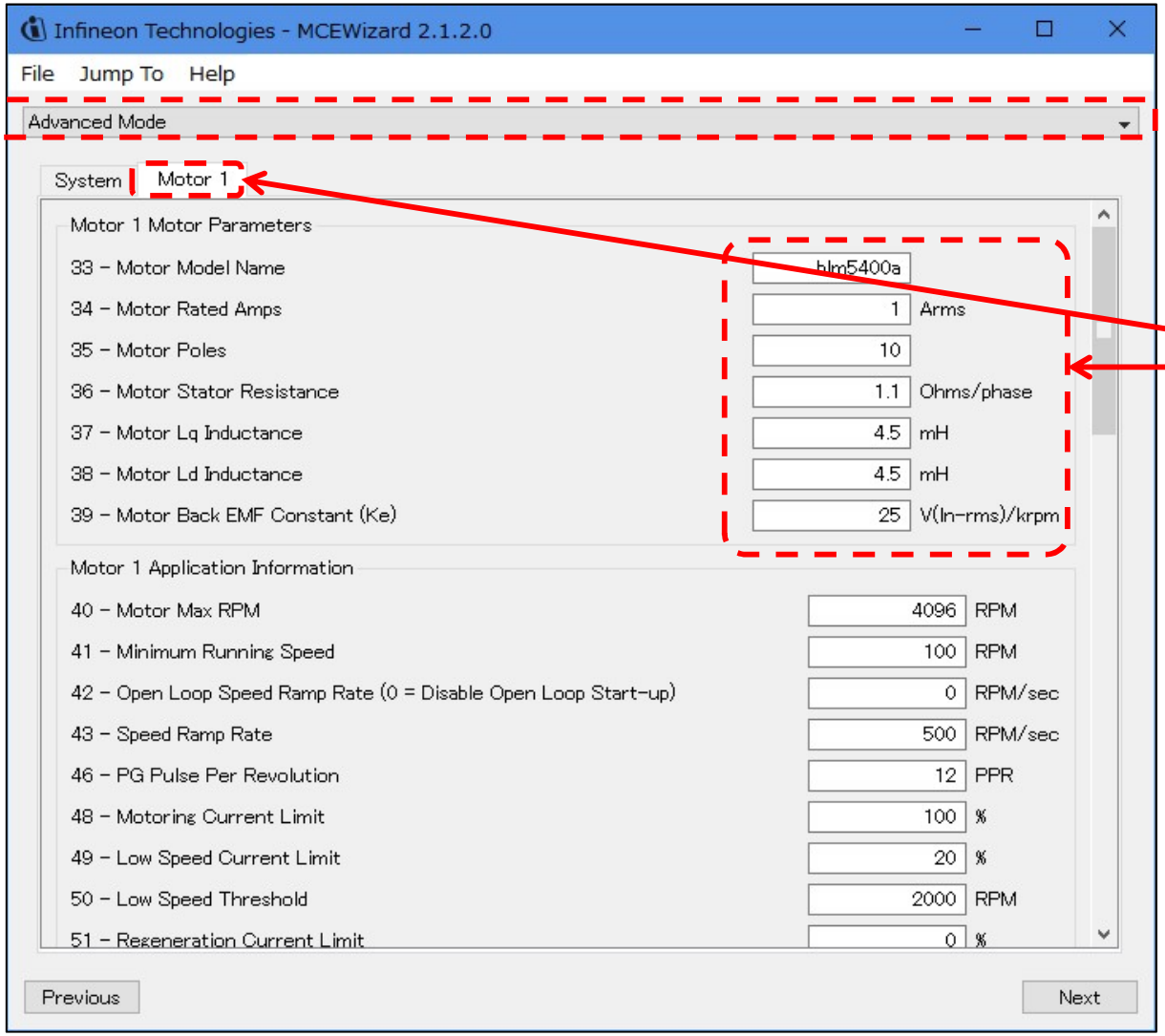
Motor characteristics (current, number of rotor poles, resistance, inductance, maximum / minimum speed) are essential.



Motor basic settings

Input parameters with MCE Wizard

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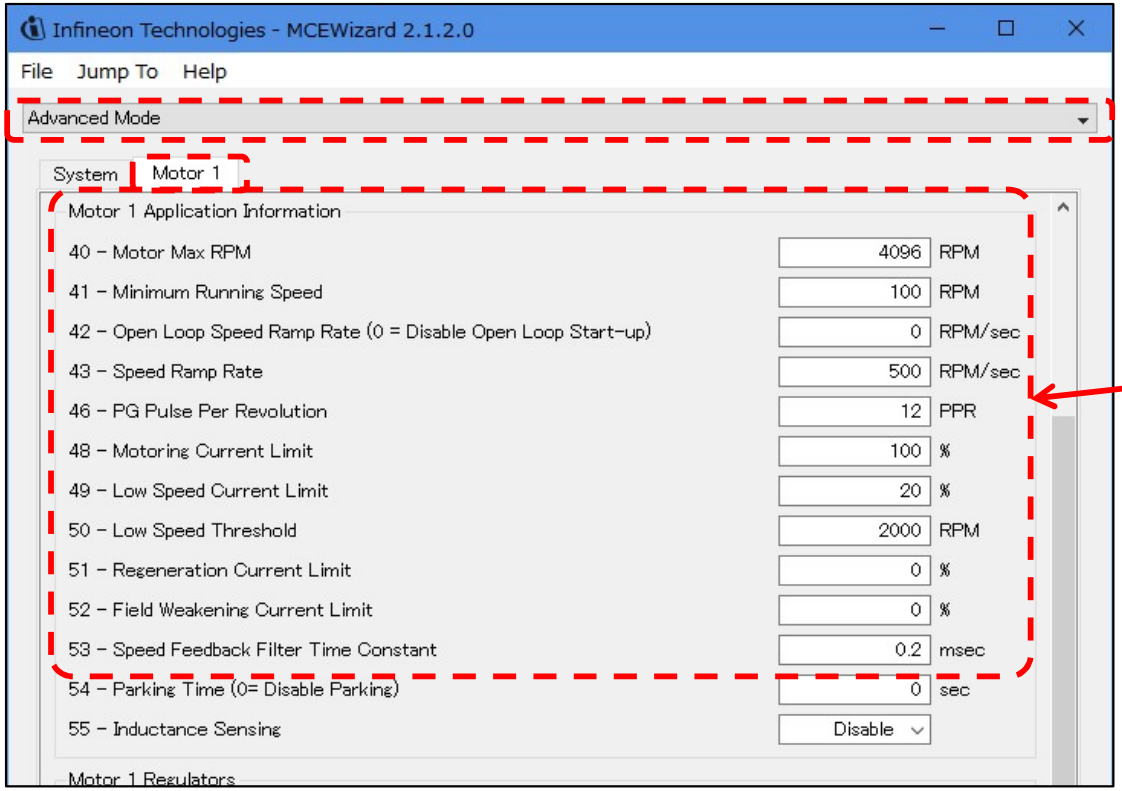
Set the rotation speed related parameters.



Parameters related to rotation speed

Input parameters with MCE Wizard

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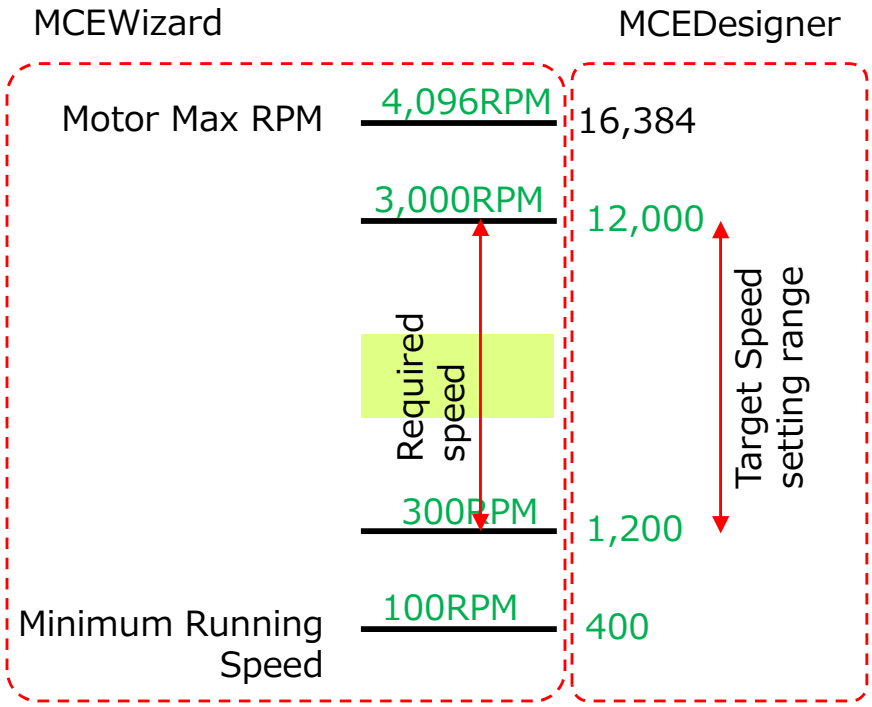
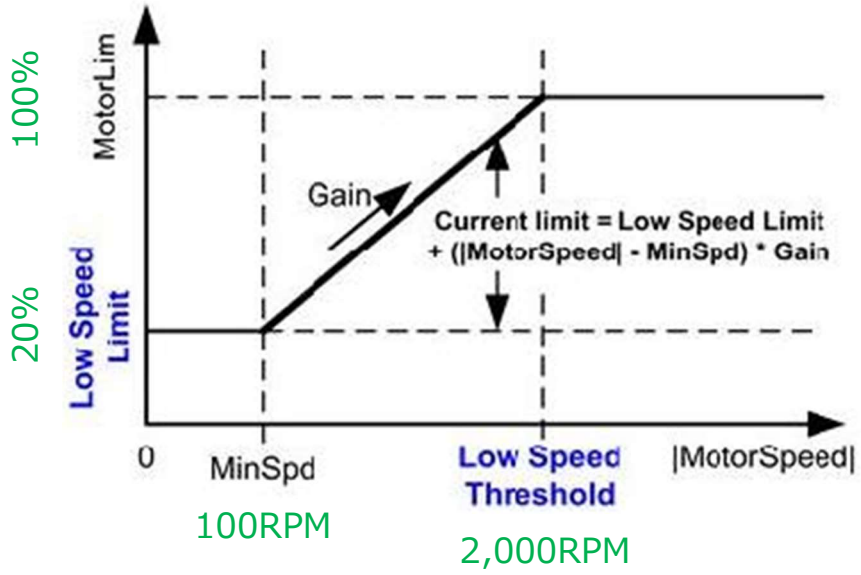
(e.g.) Rotation speed specification setting





Input parameters with MCE Wizard

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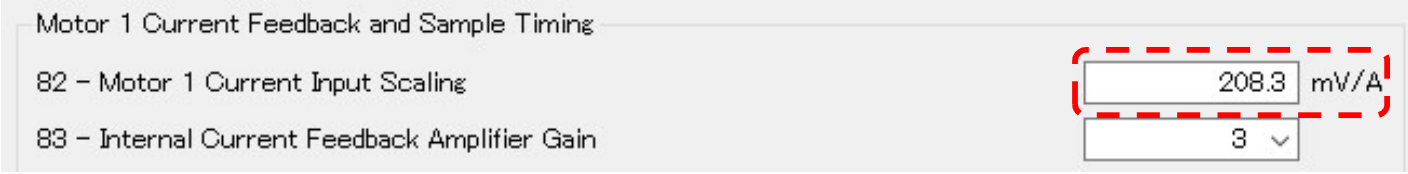
Enter the current scaling value correctly based on the resistance value of the shunt resistor.
Incorrect settings may cause overcurrent and damage the evaluation board. Please check carefully.

【Verification】



The input value is determined by the "shunt resistance" and "amplifier circuit".
The default of EVAL-M1-05-84D is
Leg shunt 250 mΩ
↓
Eval-M1-101T amplifier circuit default setting is
R6 = 10 kΩ
R7 = 2 kΩ
↓
208.3mV / A is the default value.
(250 * 10k/(10k+2k) = 208.3)

Input parameters with MCE Wizard

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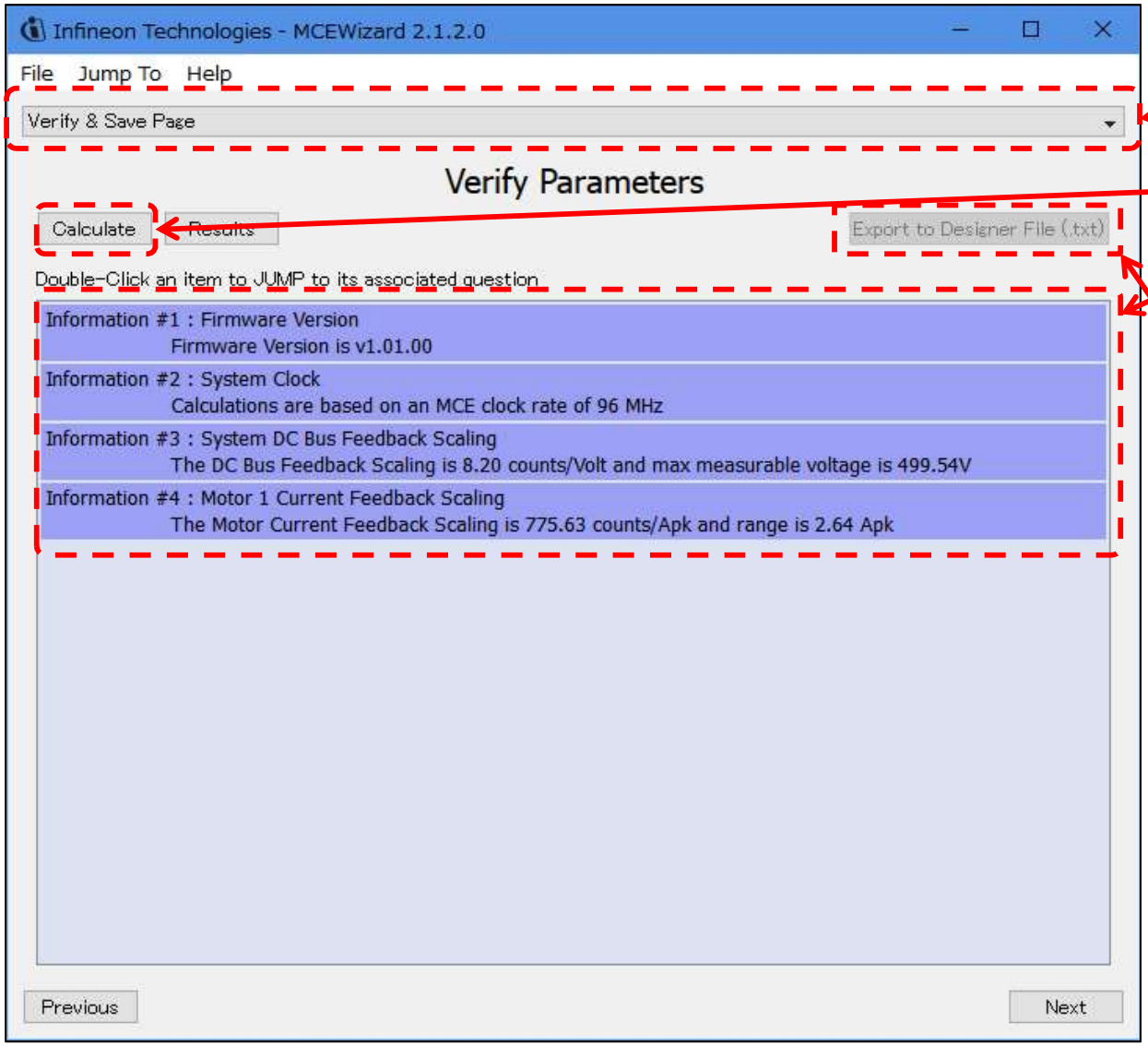
Validate settings input, save to file



After entering the parameters, select “Verify & Save Page”,

Click “Calculate” and check if the setting items are correct.
If all are displayed in blue, there is no error.

Click “Export to Designer File (.txt)” to output .txt.

Save the setting file (extension .mc2) of "MCEWizard" with File-> Save Wizard File.

Input parameters with MCE Wizard

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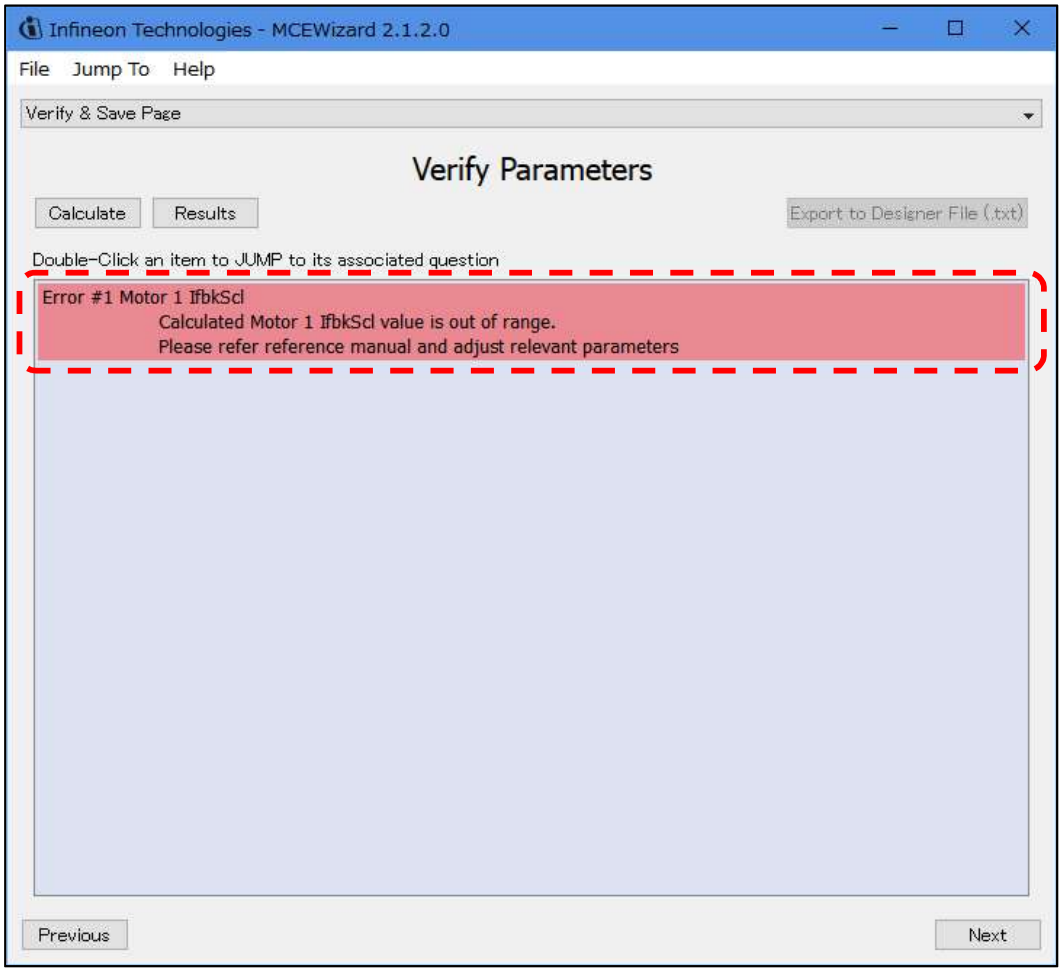
If an error occurs when validating the settings input



If you click “Calculate” and there are incorrect settings, errors will be displayed in red.

Adjust the parameters until the error disappears.

Drive the motor with MCE Designer

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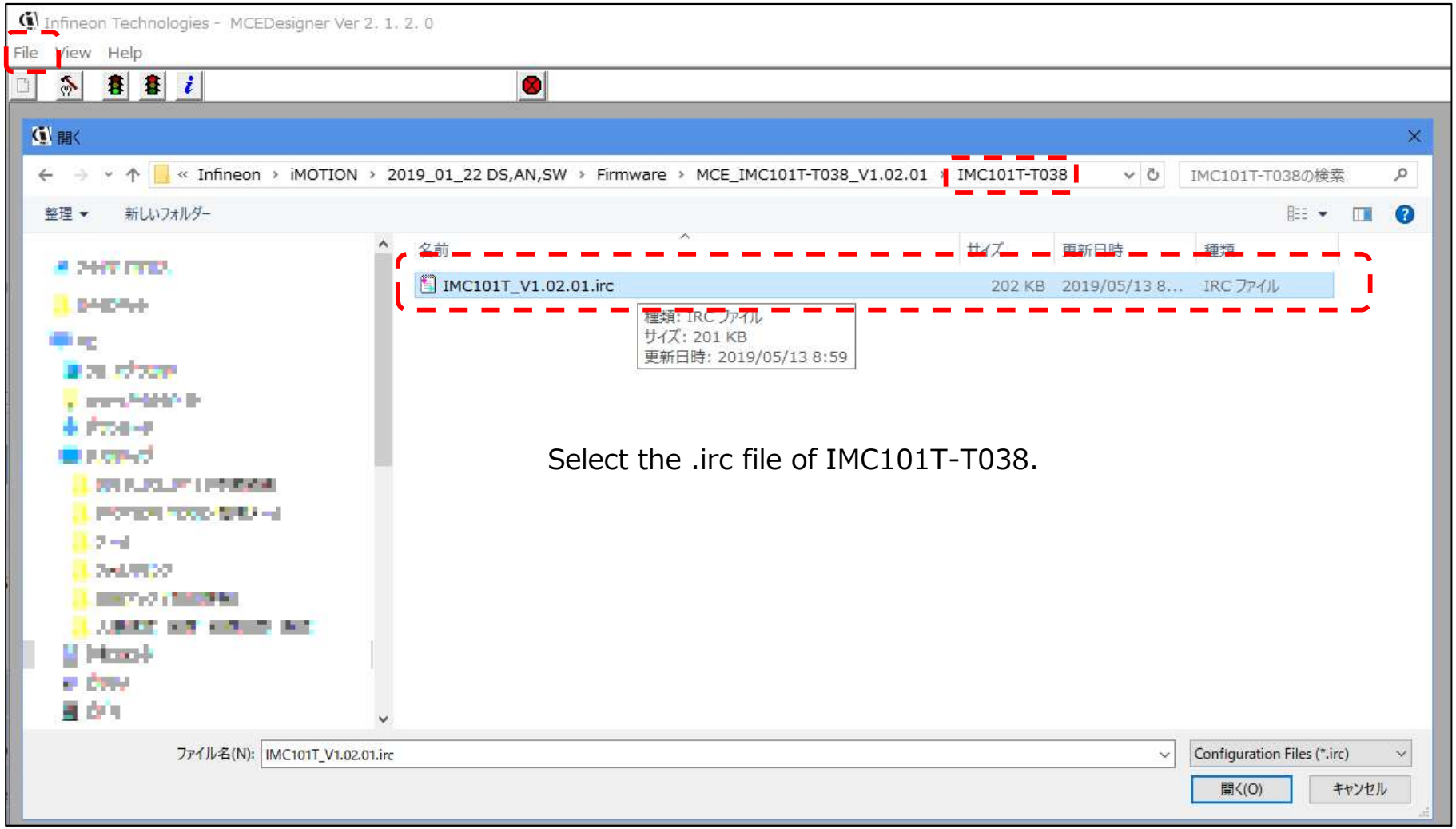
Load .irc (configuration file = MCEDesigner setting file) with File-> Open
The default settings of the device are read.



Select the .irc file of IMC101T-T038.

Drive the motor with MCE Designer

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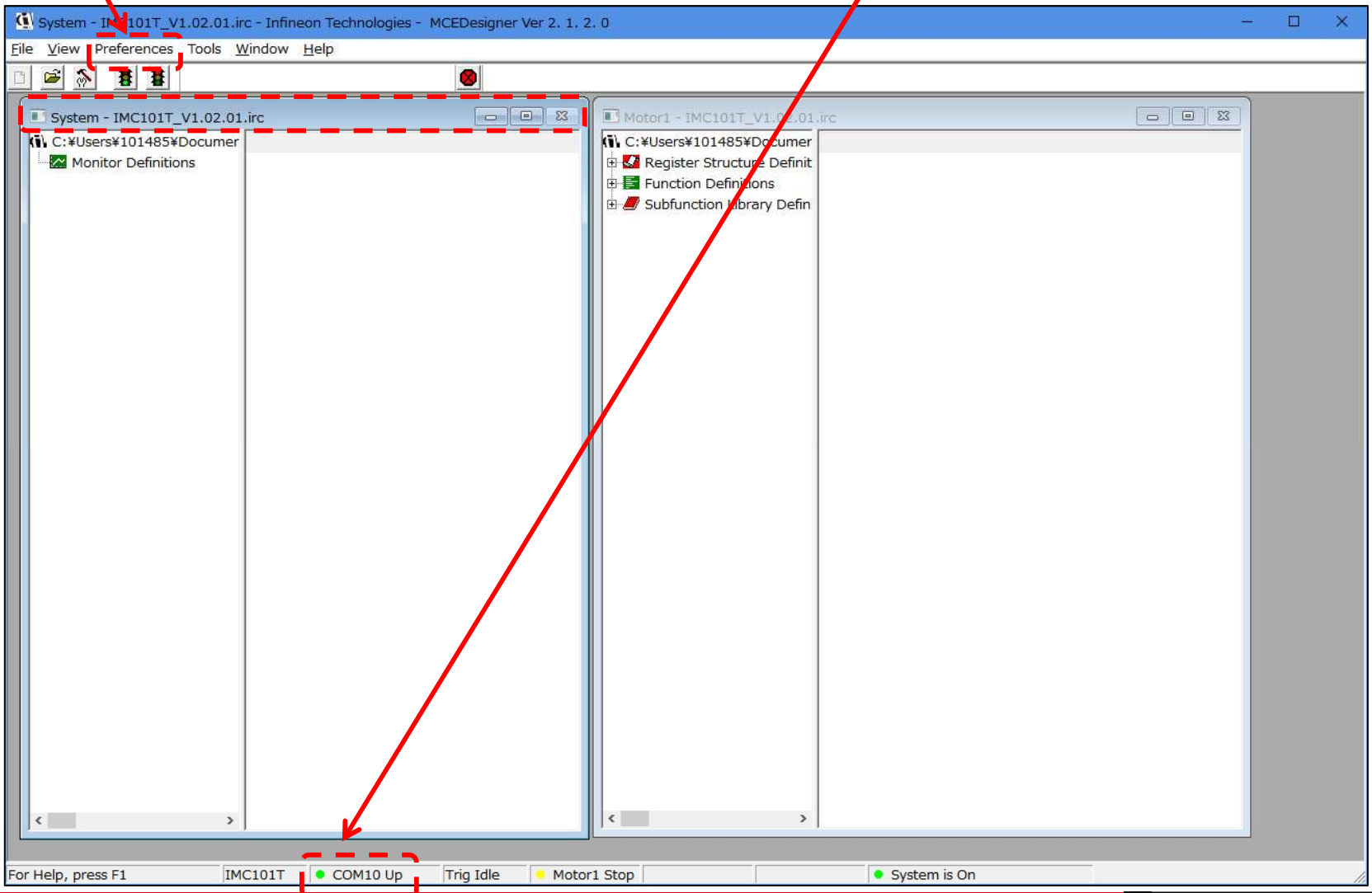
After activating the “System” window (the menu structure will be different if the “Motor1” window is active), select “Preference” from the menu and set the COM port.
When it is possible to communicate with the controller IC, a green circle and COM port are displayed in the status line.



Drive the motor with MCE Designer

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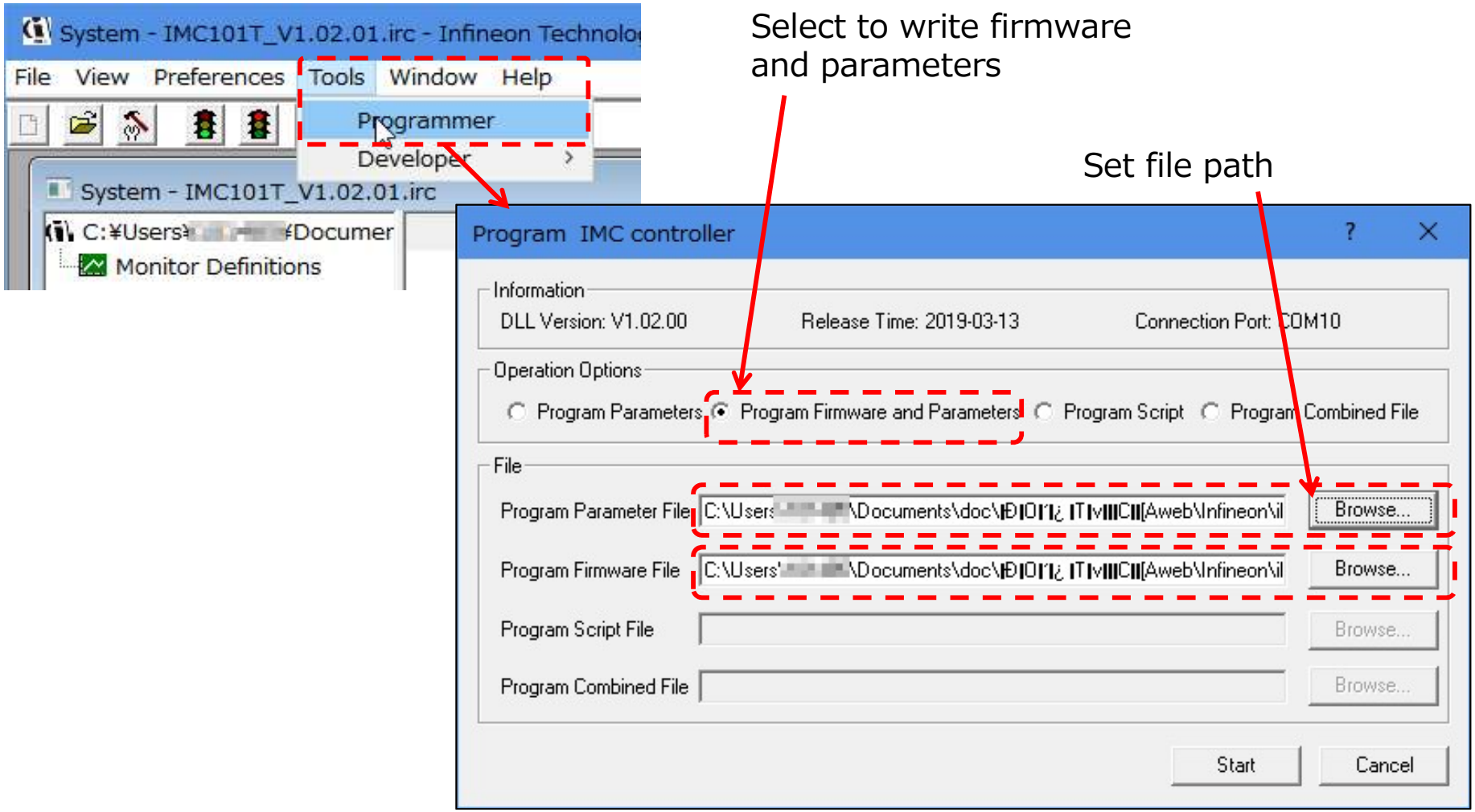
Tools → Programmer
Select to write the firmware and parameters to the device.



Drive the motor with MCE Designer

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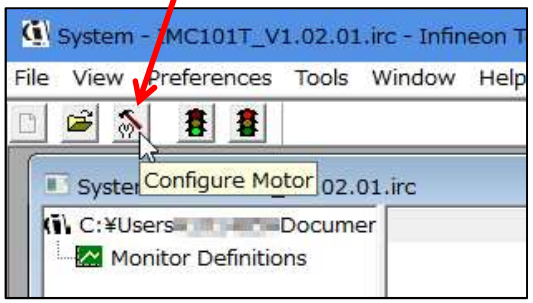
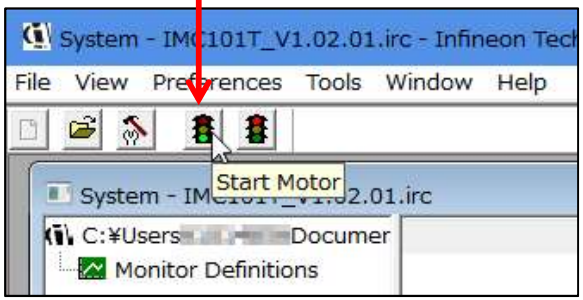
Click the “Configure Motor” icon to initialize the motor.



Click the "Start Motor" icon to rotate the motor.

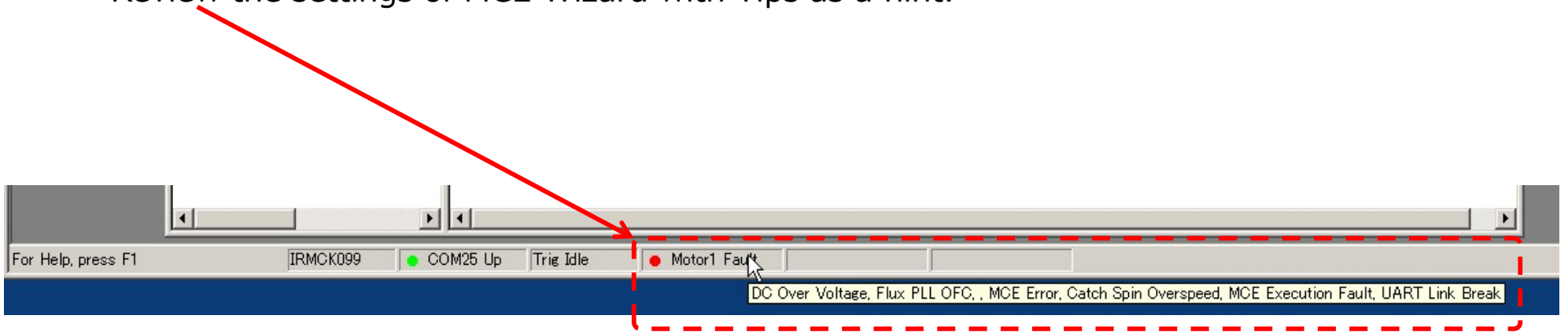


Up to this point, the motor will move for a moment, but it will not rotate.
The cause is insufficient tuning.
Recheck the parameters with MCE Wizard.

Tuning work, check-1

If the motor does not rotate or it stops abnormally,
check the status line of MCE Designer.

(Example) Motor stops at "Motor1 Fault"
Tips are displayed when the mouse cursor is placed.
Review the settings of MCE Wizard with Tips as a hint.



In the above case, the DC voltage overvoltage is detected and
the motor is stopped abnormally.
Review the DC voltage overvoltage setting to see if it is set too low.

Tuning work, check-2

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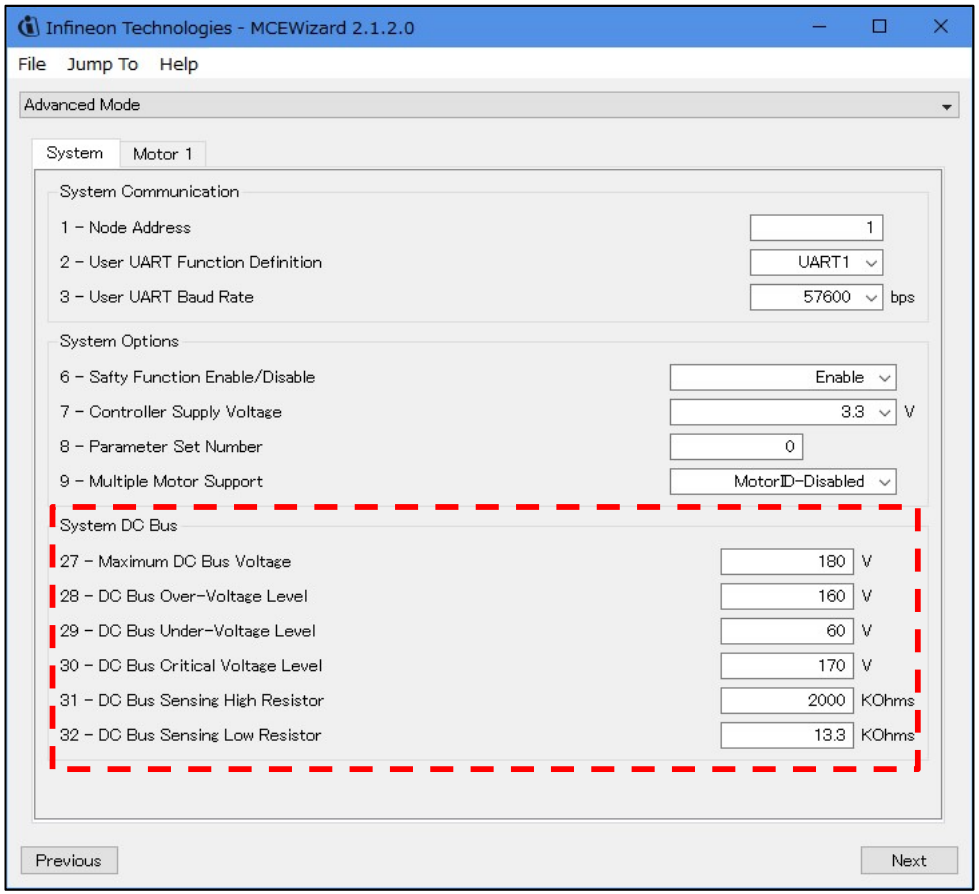
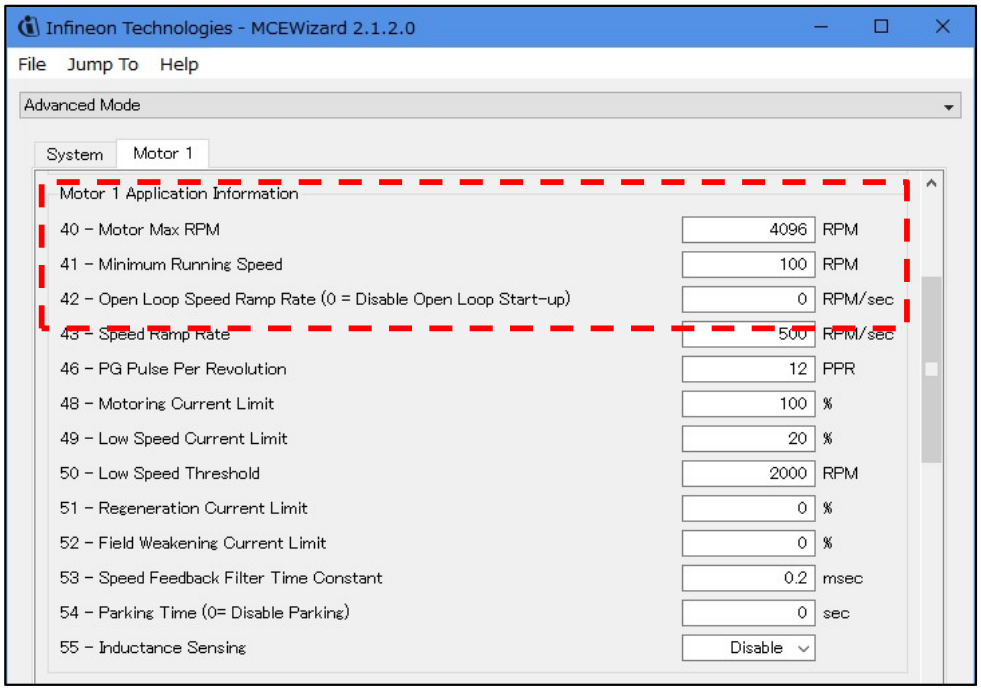
【 Setting review example 1 】

When "GateKill" is displayed on the "Motor1 Fault" Tips display,
the motor drive circuit is forcibly turned off due to current limitation.
Review the settings of "Current limit amount" and "Maximum/Minimum speed".

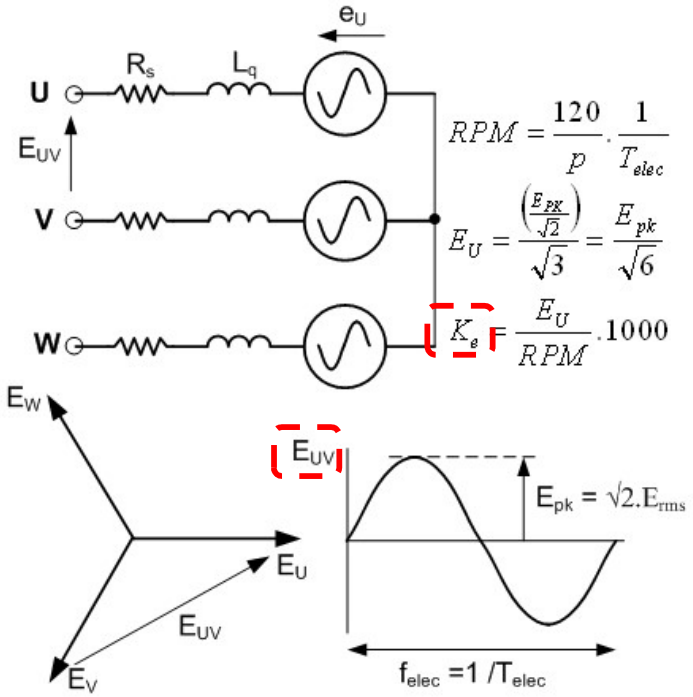


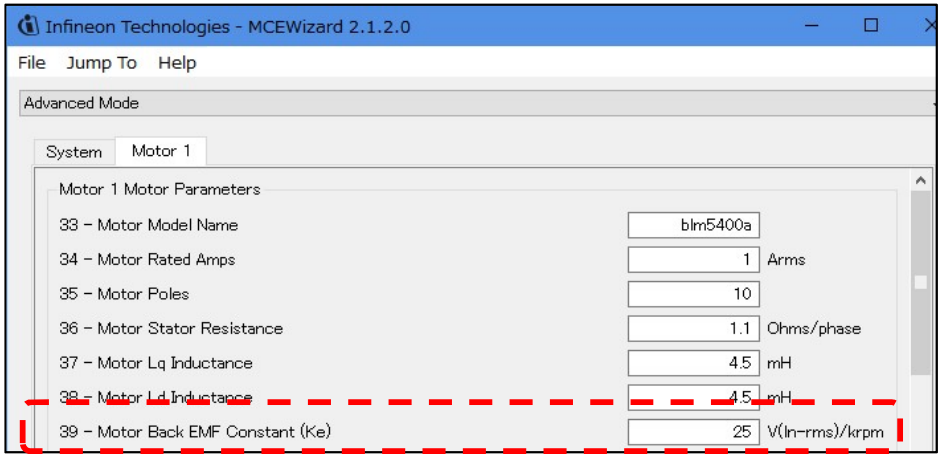


Tuning work, check-3

【Setting review example 2 (Motor Back EMF Constant (Ke))】

You can observe the back electromotive force by probing between UVs with an oscilloscope and turning the motor.
The counter electromotive force Euv when rotated at 1000 rpm is measured, and Epk, Eu, and Ke are calculated.





MCE Designer Features Tips

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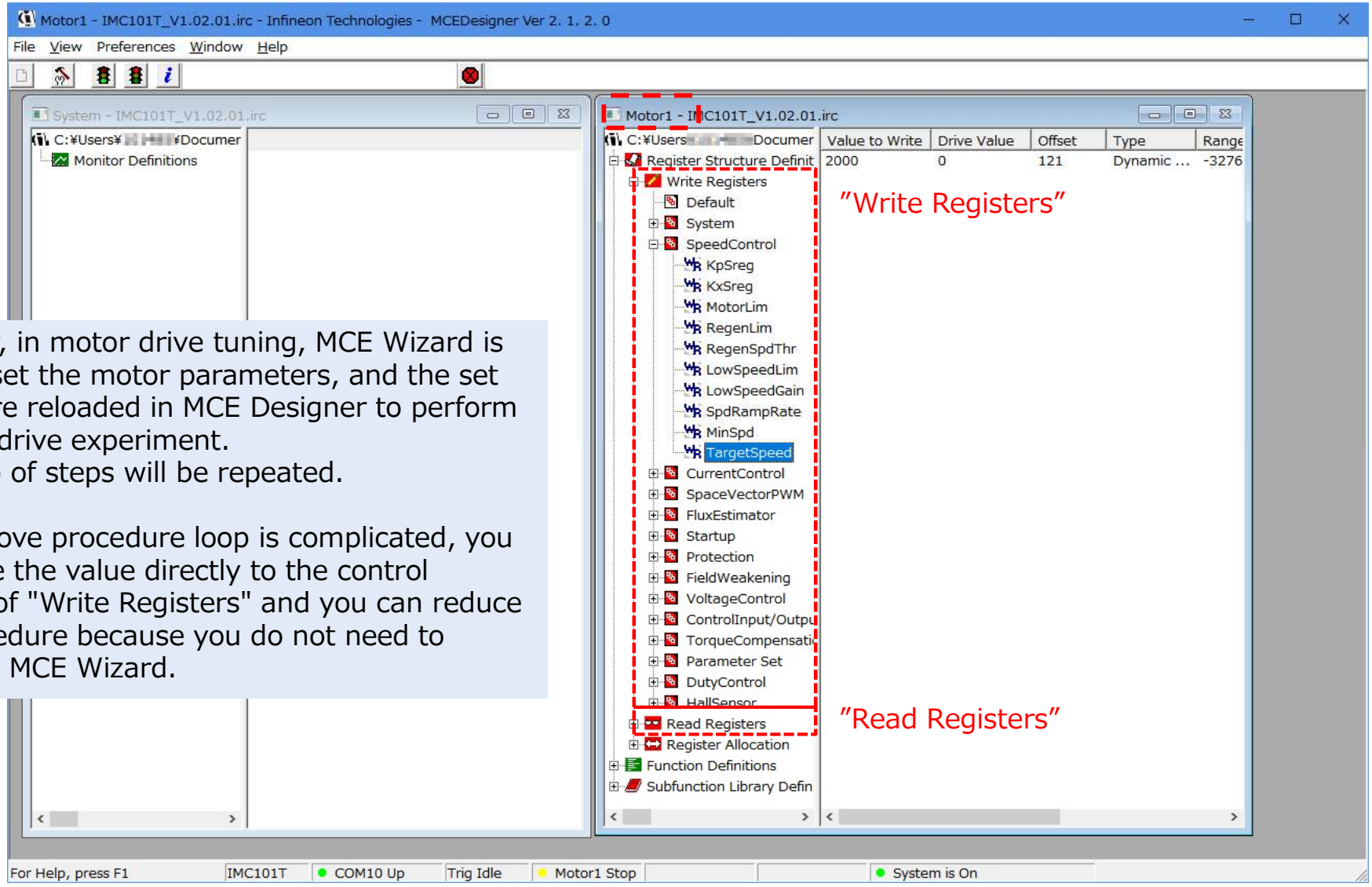
■ Can read control register settings and values
Use "Write Registers" and "Read Registers" in the Motor window.



Normally, in motor drive tuning, MCE Wizard is used to set the motor parameters, and the set values are reloaded in MCE Designer to perform a motor drive experiment.
This loop of steps will be repeated.

If the above procedure loop is complicated, you can write the value directly to the control register of "Write Registers" and you can reduce the procedure because you do not need to return to MCE Wizard.

MCE Designer Features Tips

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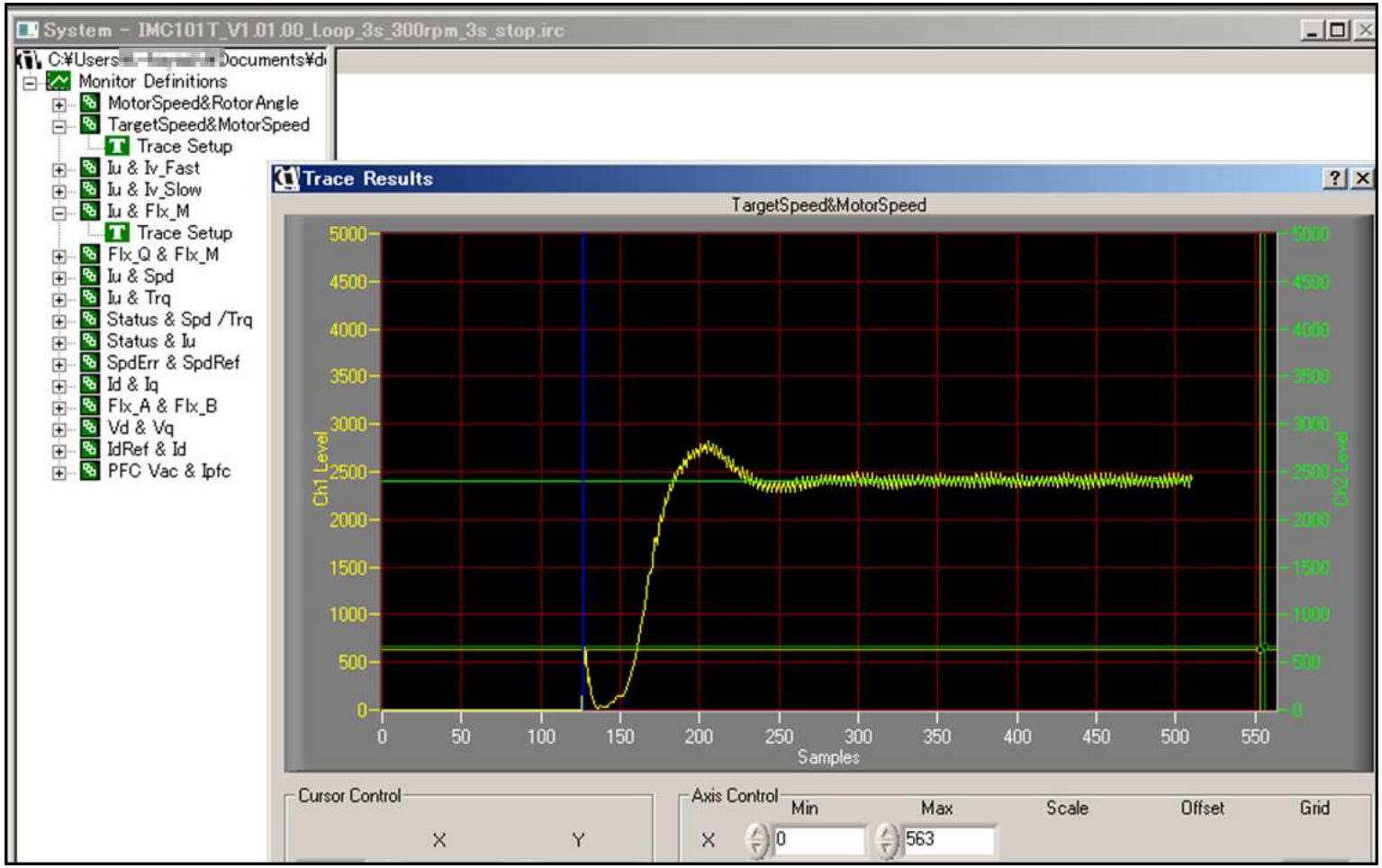
■ Waveform display is possible
The iMOTION internal parameter values are displayed on the waveform screen in real time.

(e.g.) Motor Target Speed (green) and Motor Speed (yellow)



MCE Designer Features Tips

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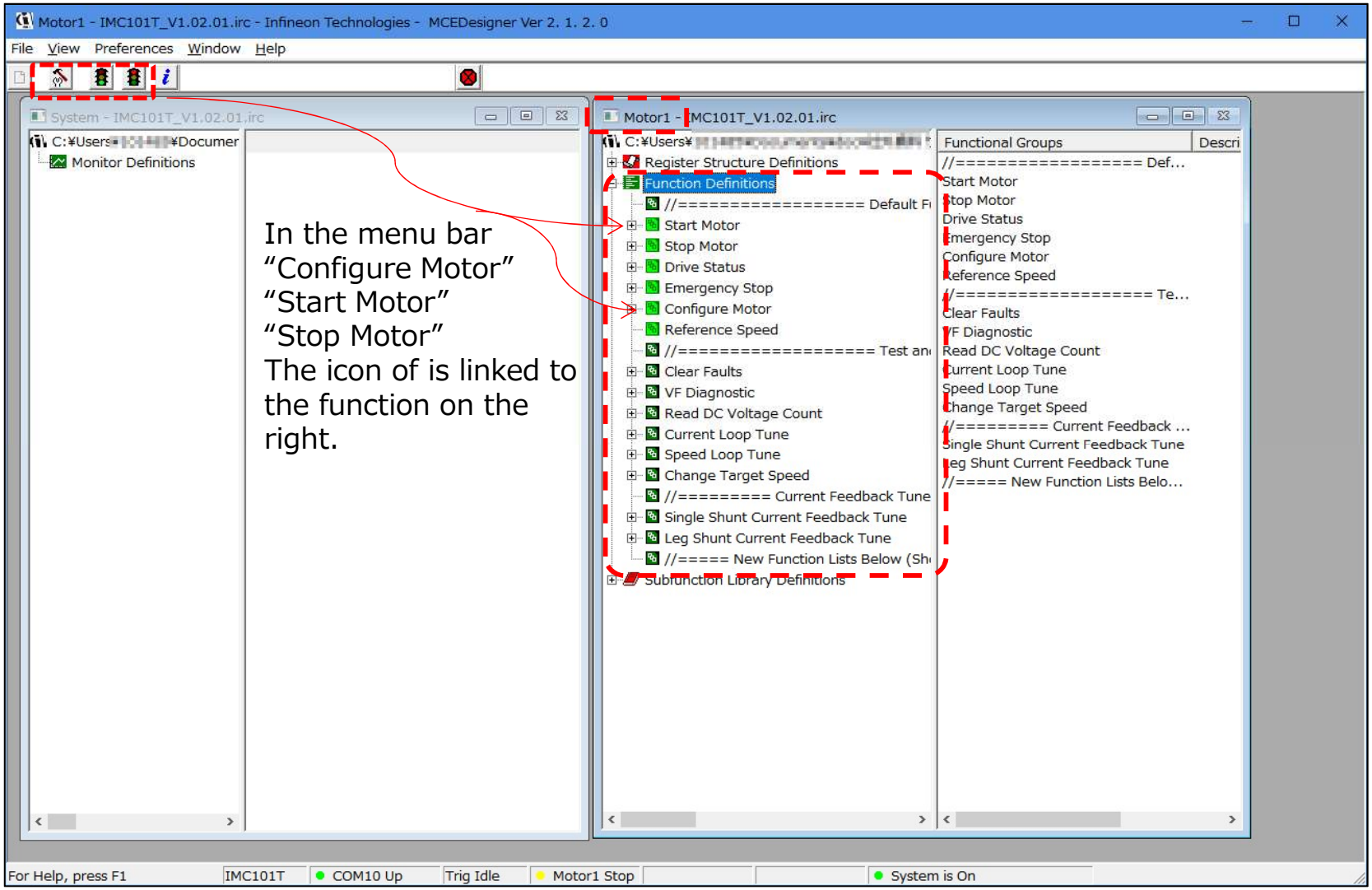
■ User Function

You can register and execute a task process.
It can be used for motor characteristic evaluation and testing.



Reference material

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Reference Manual List

MCE Designer Manual ： MCEDesigner Users Guide.pdf
Script function manual ：Script For MCE 2.0 User Guide.pdf

EVAL-M1-05-84D Application note, schematic
https://www.infineon.com/cms/jp/product/evaluation-boards/EVAL-M1-05-84D/productType.html?productType=5546d46253f6505701544c6f6143172b

EVAL-M1-101T Data sheet
https://www.infineon.com/cms/jp/product/evaluation-boards/eval-m1-101t/

Motor experiment example

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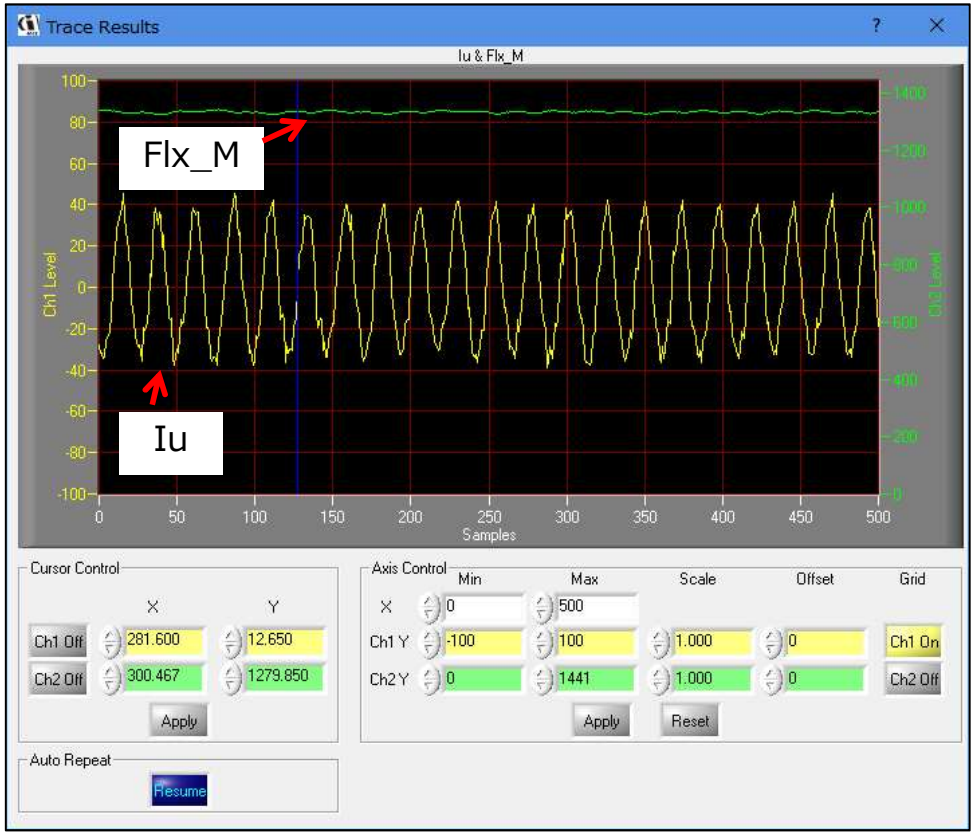
1. Adjustment of motor current waveform
2. Adjustment of rotation rise time
3. Change of rotation speed
4. Speed and power supply current
5. Noise adjustment

[Experiment] Motor current waveform adjustment

■ Adjustment tips

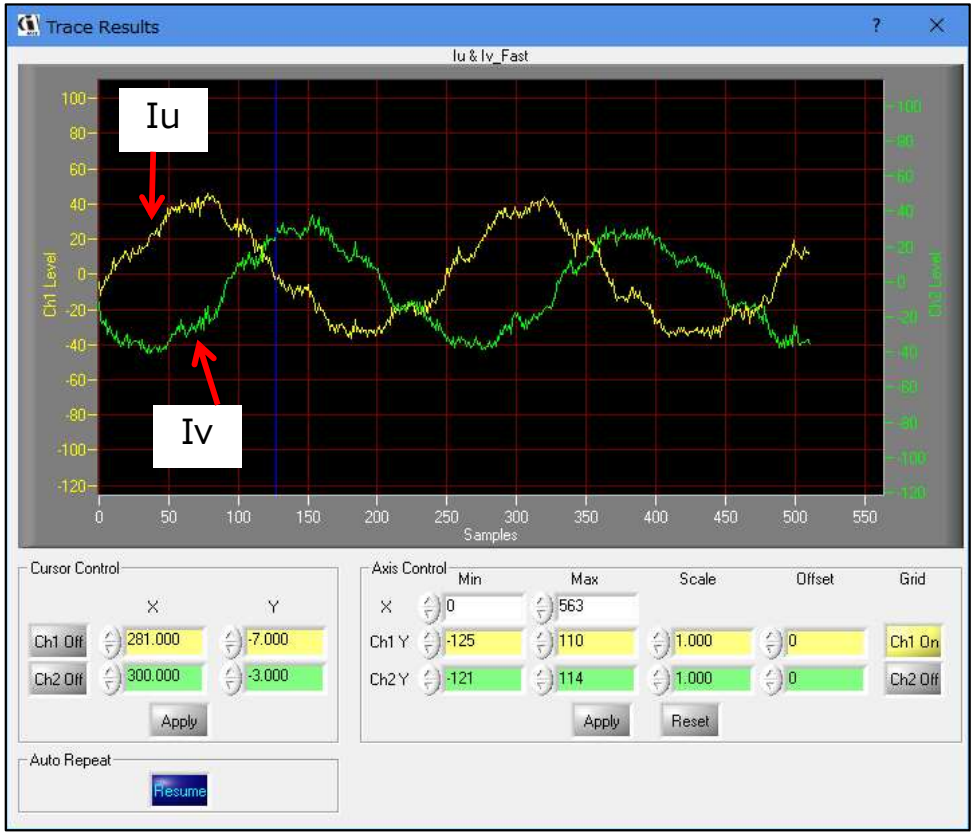
Flx_M is flat and 2,048 is the best value.
In the measurement below, it is flat and around 1,350
While adjusting the **Flux Estimator Time Constant**, find a setting where Flx_M is stable.



■ Adjustment tips

Gating Propagation Delay
Phase Shift Window Size

While adjusting (current sampling timing), search for a setting that improves the motor current waveform.



[Experiment] Adjusting the rotation rise time

■ Adjustment tips

Adjust the

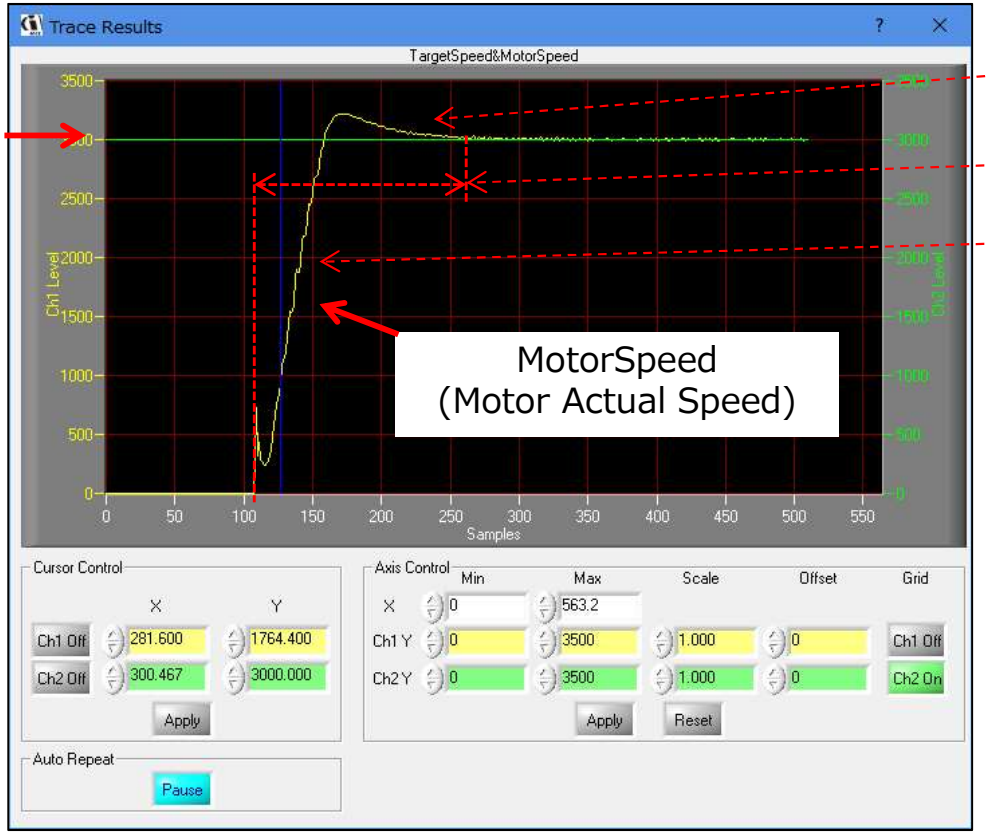
Speed Regulator Proportional Gain

Speed Regulator Integral Gain

Speed Ramp Rate

so that the target speed is reached in the expected time while reducing overshoot.

TargetSpeed
Desired motor speed



Overshoot

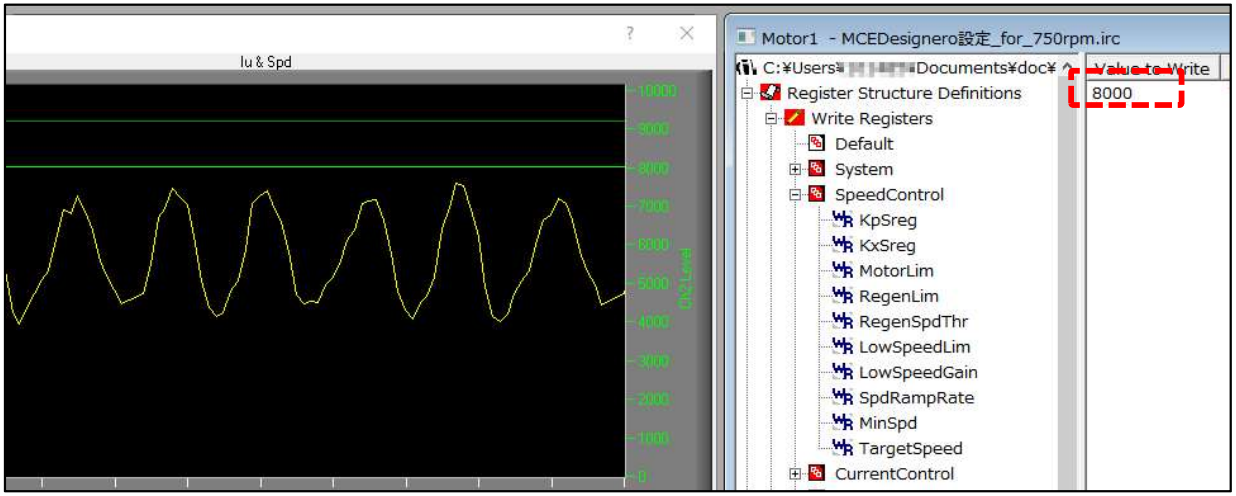
Rise time

Rise speed
(RPM / s,
acceleration)

[Experiment] Change of rotation speed

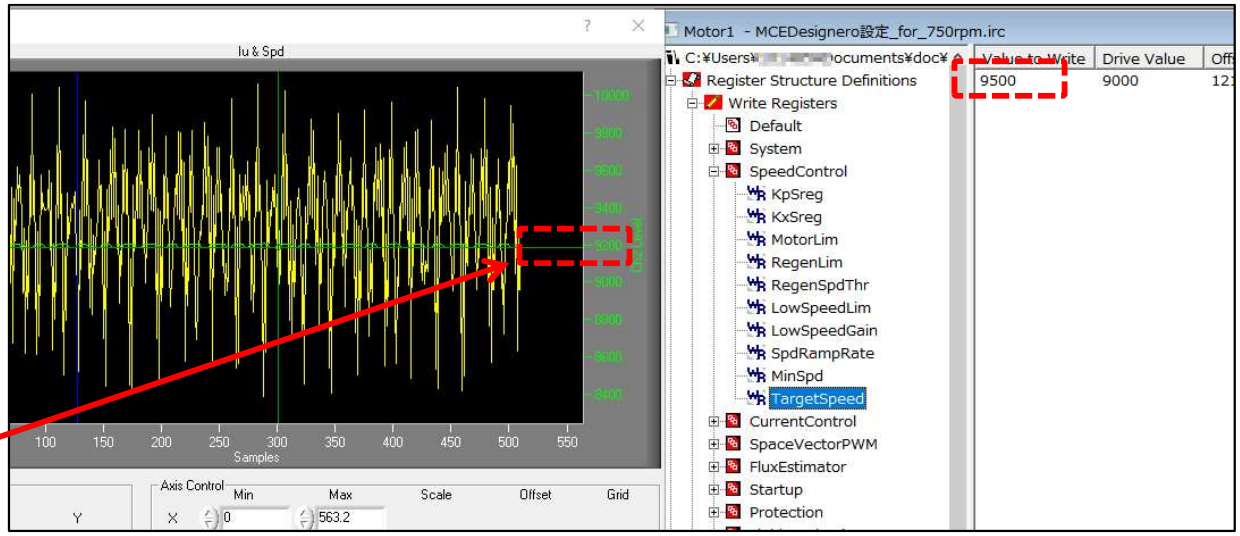
TargetSpeed = 8,000
Then, rotation is stable.

The parameter settings were adjusted to be stable at TargetSpeed = 3,600.



The current waveform began to be disturbed from around TargetSeed = 8,500,
and synchronous control became impossible at TargetSpeed = 9,500.
It seems that the parameter setting at TargetSpeed = 9,500 is necessary.
Multiple parameters are possible by using the Script function.

Does not rise from 9,300



[Experiment] Speed and power supply current

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Observe rotation speed and current value by changing DC voltage (experiment without motor load)

DC voltage 140.5V

750rpm

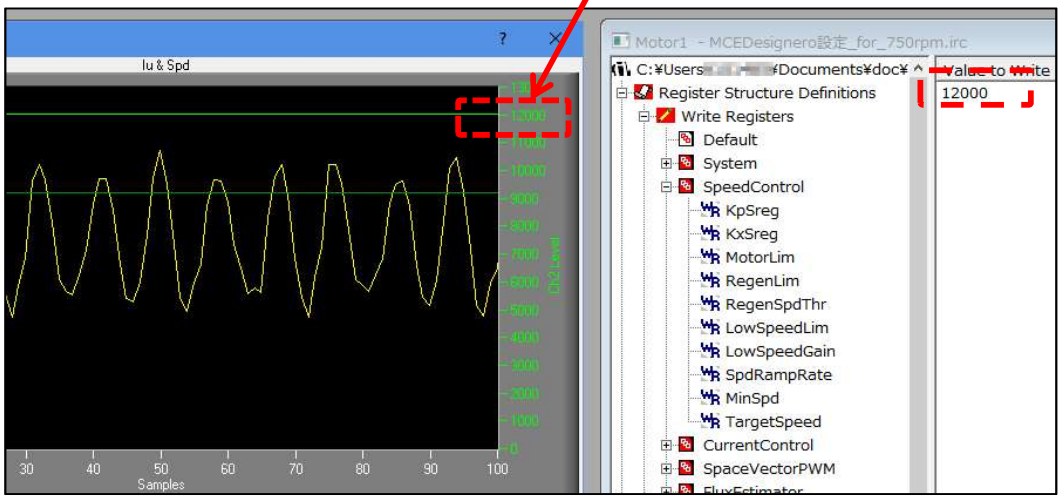
1,500rpm

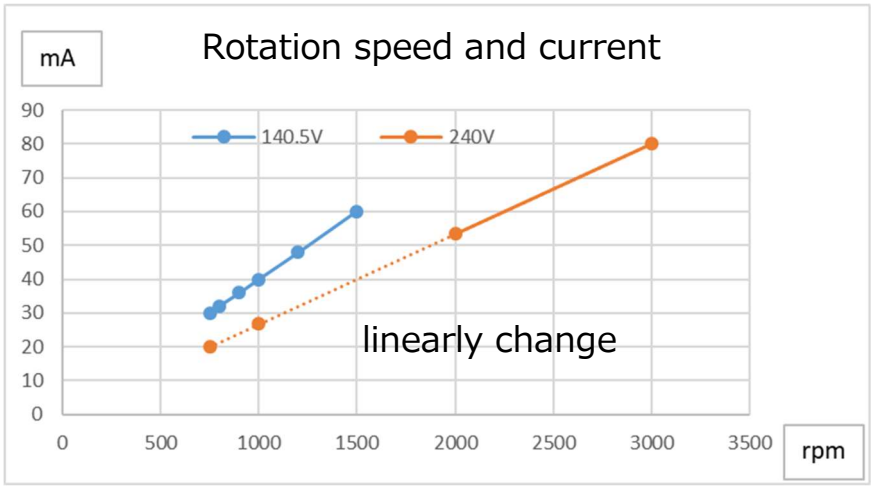
Increase DC voltage

DC setting 240V

3,000rpm

Reached 3,000 rpm
TargetSpeed = 12,000





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[Experiment] Noise adjustment

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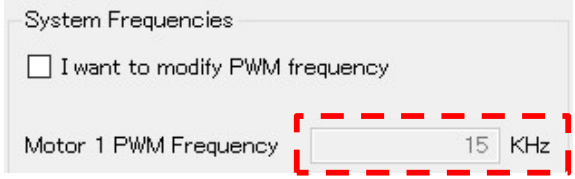
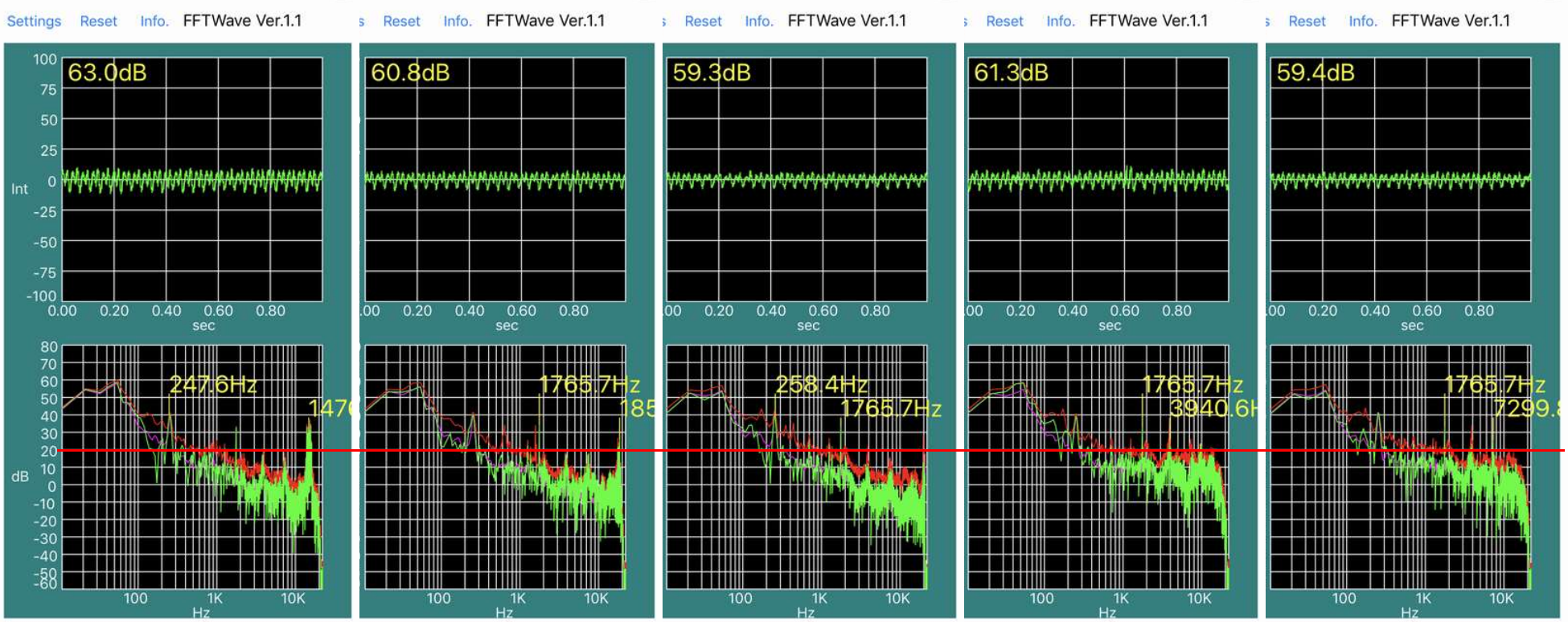
Experiment without motor load fixed at 1,500 rpm
Only the PWM carrier frequency is changed, other parameters are fixed.
PWM carrier frequency 15kHz → 18kHz → 20kHz → 22kHz → 24kHz



(For noise measurement, the iPhone7 FFT Wave application is used simply)



■Findings

① Approximately 3dB improvement at PWM carrier frequency 15kHz vs. 24kHz (63.0dB → 59.4dB)
② When the PWM carrier frequency was raised above 20kHz, the peak noise could be shifted out of the audible range.
③ There are natural frequencies at 250Hz and 1.7kHz. This is independent of the PWM carrier frequency (presumed to be rotation speed and mechanical factors).

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