MR2 Hardware-in-the-loop Operations Manual

Ver 3.0.1 Mar.2021

Contents

1 MR2 Hardware-in-the-loop Introduction

The MR2 is a hardware-in-the-loop system, independently developed by Gathertech Intelligent Automation CO., LTD. It is specially designed for the motor drive controller, and to help researchers or R&D engineers carry out controller development, validation and troubleshooting in a safe and efficient real-time simulation environment.

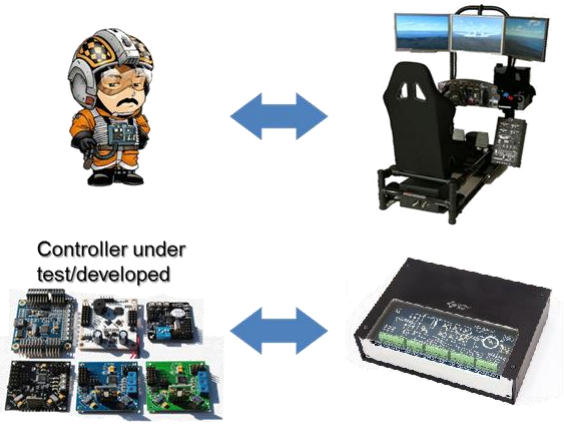


Fig. 1. The basic concept of the hardware-in-a-loop system is similar to the flight simulator used for pilot training. It can be used to conduct practical exercises in low-risk environments through real-time simulation. A flight simulator (real-time simulation) for the pilot (trial subject) is equivalent to a hardware-in-a loop system (real-time simulation) for the controller (trial subject).

The MR2 hardware-in-the-loop system has very high-speed output/input access channels and precise electric motor dynamics emulation capability. After connecting the motor drive controller's output/input terminals, the power switches driving signals, generally pulse width modulation (PWM) signals, can be received by MR2 and, in a very short period of time, the computational results of the motor dynamic model can be sent back to the controller. These results include three-phase electric currents, DC bus voltage, motor position sensor (encoder) signal and so on, so that the motor controller *seems to* be connected to real equipment such as power stage (rear-end), motor, and mechanical system. This enables a large and demanding motor drive controller (algorithms) verification and testing to be done in a safe and flexible real-time simulation environment. This is a high-tech development platform which is the re-evolution of the common software simulation and the achievement of Mixed Reality (combining Virtual Reality with the application of Augmented Reality), which is, also, the origin of the MR2 name. For detailed interface specifications, please refer to the hardware specifications.

In order to fulfill the various applications, MR2 hardware-in-the-loop provides customers with a flexible module collocation. It can be composed by application-specific functions (such as product R&D, employee training, product display box, curriculum and instruction, etc.) according to the demand. There is no need to buy a huge system with unused devices or functions. For detailed modules and instructions, kindly refer to the Standard and Optional Modules.

In addition to accurate and real-time system emulation, a clear and ready-to-go hardware interface, a rich, simple and intuitive operating software, MR2 hardware-in-the-loop is the most acclaimed design by the majority of users. The MR2 hardware-in-the-loop is as practical and easy as the oscilloscope or an In-Circuit Emulator (ICE) used in embedded system development. All R&D staff can easily get started without a long period of learning and complex adjustments, enabling the hardware-in-the-loop to provide the most direct help in the research and development of motor drive controller. Please refer to the User Guide for the quick connection procedures.

1.1 MR2 HIL Product and Warranty Information

Table.1. MR2 product content

Items	Product Contents	Qty	Remarks
MR2 Host	MR core – Hardware-in-the-loop (HIL)	1	The actual functions vary according to the module
MR2 Expansion Box	MR2 Add-ons – Extension Modules	1	Not available if this option is not selected
Power Cord	Power cord (110V power supply)	1	-
Software Installation	Operation software of the MR Series	1	The software can be downloaded online and the license will be sent by e-mail
Operation Instructions	E-book	1	Sent by e-mail

- The above hardware has a warranty of one year and also includes two years of free product usage technical consultancy and functional maintenance[1]

1.2 Hardware Specifications

1.2.1 MR2 Hardware-in-the-loop Specifications

Size: 24cm(L) x 20cm(W)x 5cm(H)

Operating Temperature: -40 °C to 70 °C

Analog output	Analog input	Digital output	Digital input
6 channels (SE) & 2 channels (Diff.)	1 channel (Diff.) & 1 channel (SE)	6 channels (Diff.)	7 channels
-10V ~ 10V	-10V ~ 10V	5V	3.3 V ~24V
16 bits	16 bits	10 MHz	10 MHz
1 M Samples/s	500 k Samples/s		

1.3 MR2 HIL Modules

1.3.1 Descriptions and list of MR2 Hardware-in-the-loop

The MR2 hardware-in-the-loop can be composed by different functional modules according to the user's needs. The modules are mainly divided into two categories: core module and add-ons (extension) module; the core module is enabled by software authorization (License) and the add-ons module is a box connected with MR2 by a cable. Among the above modules, there are three

[1]Additional and modified functions are quoted separately depending on complexity

standard modules: MR2 main station (with Operation software), Extra low-latency power stage and Sync. & Async. motors (IM & SPMSM). With the three standard modules, you can use the basic real-time simulation functions of MR2. There are also a variety of optional modules including different types of motor models, position/velocity feedback signal modules, physical model extension modules and communication extension modules etc... which can be selected according to the needs for use.

Table. 3. Core modules of MR2 Hardware-in-the-loop system

MR Series Core		
	MR2 main station	>Main station, used to connect control board signals to real-time simulation environments >DIO: 10 MHz; AO: 1 MHz; AI: 500 kHz >Quick-connect terminals: power switch driving signal inputs, phase current analog signal outputs. DC Bus voltage analog signal output, common encoder signal outputs, etc…
	Operation software	>Manage and set all modules (including extension modules) >Concise interface and easy to use >Low PC resource requirements
	Extra low-latency power stage	>High-speed digital signal processing (10MHz), does not miss PWM signal details >Stable signal capture and fast conversation >Phenomenon simulation of free wheeling diode >DC voltage can be set arbitrarily (if Grid and rectifier module used, the DC voltage will be computed by the module)
	Grid and rectifier module	>The power capacity is changeable >The parameters of the passive rectifier (DC link capacitor and DC choke) is adjustable >Can work with brake unit (braking resistor) >Make simulation much close to the real condition
	AC source conditions	>Simulate imperfections of the power system, including voltage sag, swell, interruption, harmonics, notching, noise, frequency changes and other phenomena.
	DC Curve	>Stimulate the voltage changes of BMS >Play recorded voltage changes of battery
	Sync. & Async. motors(IM & SPMSM)	>Some most practical types of motor can be selected and the parameters are adjustable. >Motor reactions varying according to different motor drive control algorithms (e.g.

	Sync. Motor(PM) 1.(PMSM) 2.Advanced Sync. Motor (IPMSM) 3.Advanced Sync. Motor (SynRM)	motor rotational speed, currents, output torques, and so on.) >MR2(2016)add SynRM and BLDCM >MR2(2017)add PMa-SynRM
	Sync. Motor(PMa-SynRM)	
	Sync. Motor(BLDCM)	
	USER Table	> User could get saturate inductance simulation via Ld(id,iq)/Lq(id,iq)/Fm(id,iq) chart. >With linear-3 insert >Rated current ±500%。
	ECE Table	> Users conduct motor finite element via Maxwell and output ECE module chart to complete analysis motor simulation .
	Velocity sensor module 1 (ABZEn coder)	>The rotational speed (or position) of motor can be output in the form of common encoder digital signals. >The update rate of pulse output is up to 10MHz, used to verify high-speed feedback signal and main system.
	Velocity sensor module 2 (ABZ/UVW Encoder)	
	Velocity sensor module 3 (Resolver)	>The rotational speed (or position) of motor can be output in the form of Resolver signals. > The update rate of Resolver output is up to 1MHz, used to verify high-speed feedback signal and main system.

	Velocity sensor module 6 (Absolute Encoder with PWM Output)	>The rotational speed (or position) of motor can be output in the form of PWM encoder digital signals. > The update rate of pulse output is up to 10MHz, used to verify high-speed feedback signal and main system. >The resolution of a revolution (PWM signal) is adjustable from 7bits to 16bits.
	Customized analog output module(AO1/AO2)	>Specific signal can be output by analog terminals module.

Table. 4. Add-ons (extension) modules of MR2 Hardware-in-the-loop system

MR Series Add-ons

MR Series Add-ons		
	Battery power source module	>Support three popular batteries: LiIon battery、NiMH battery、LeadAcid battery >Measure the function of battery level, charging, voltage and current.
	Velocity sensor module 4 (Serial interface encoder - TAMAGAWA)	>MODEL: TS5668N20 >Function name: SI 35 >17 bits / LPS 5V >Support other types , ex: 23bits (Please contact us)
	(Selected) "Velocity sensor module 5 (Analog Encoder, 1 Vpp sinusoidal signals)	>Output Signal :A/B/R/C/D >Electrical Specification: 1-Vpp output >Resolution Specification: 16bits 1Mhz sample rate
	Velocity sensor module 7	>Output Signa l:SG+SG- > Electrical Specification: 5-Vpp output > Resolution Specification: (Pepperl+Fuchs encoder、ASM58N-F2AK1R0GN-1213)
	Velocity sensor module 8	> Output Signal :Sin/Cos > Electrical Specification : adjustable line drive/one-port output > Resolution Specification : 16bits 100Khz Sample rate
	Load torque module	>Support for a variety forms of load torque generation. >Support for analog input signal controlled by load torque. >Support for raw data(recorded from real system) to generate the load torque of simulated motor.

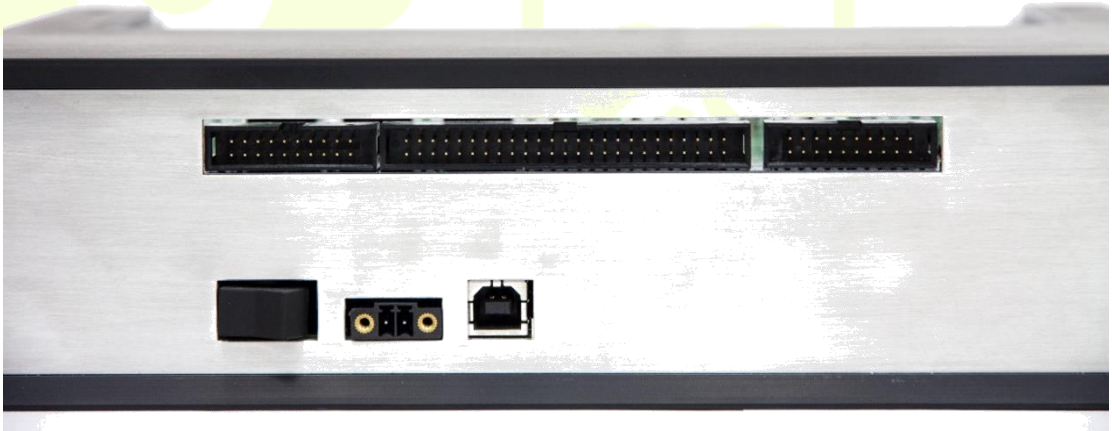
	NI RT Connector with USB	>Support popular simulation software (ex: Simulink) to modeling by motor load torque physical system , and interact with MR2 on this system. >Enable to connect any types of module and present completely synchronic simulation.
	Communication module	>Support RS485 communication(115200 bps) >Support to read all MR2 parameters via communication. >Support to give instructions to high speed communication via load torque.
	RT Connector with CAN Bus	>Support standard CAN BUS > Support to read all MR2 parameters via CAN BUS . >Support to give instructions to high speed load torque via CAN BUS.

2 Description of Hardware

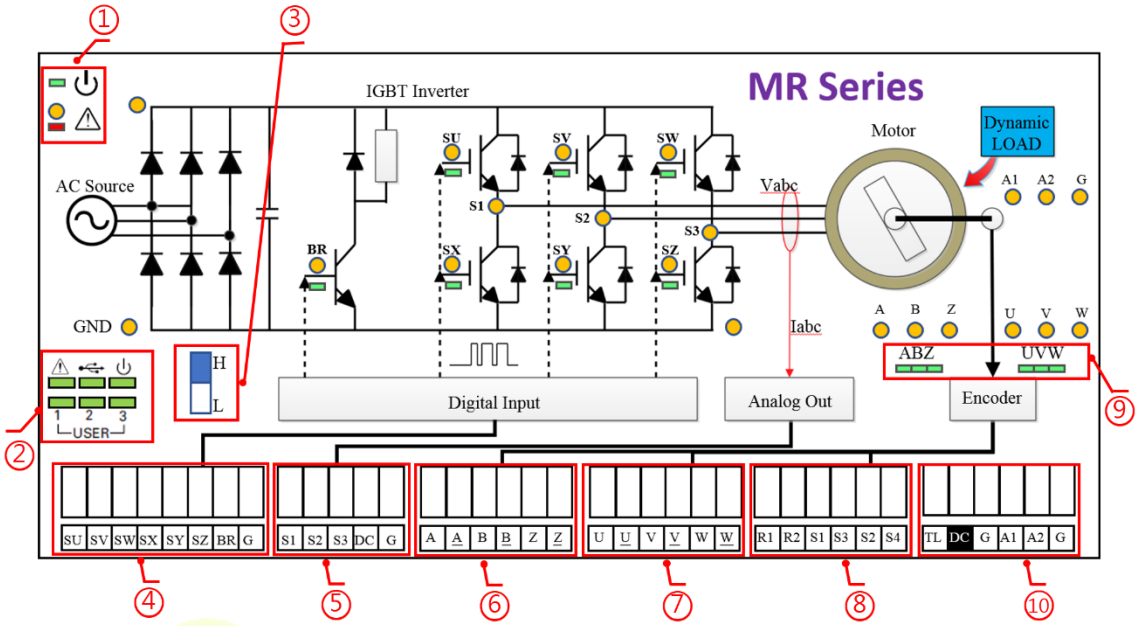
2.1 Product Appearance

- Main station front

- Back of Main station
  (The slots at upper-left and upper-right are for extension module connection.)



2.2 Description of MR2 Front Panel



① System status indicators:

: System power (green light)

: The red light will blink when error occurs.(There is a short circuit between the upper and the lower bridge.)
It is available for user to detect signal by oscilloscope and make sure it can work.

② Motherboard status indicators:

: Motherboard power (green light)

: USB connected indicator
Light on: PC connected.
Light off: device driver is not correctly installed.

: Motherboard hardware error indicator

User1 Blinks when the system state monitoring by operation software is running
: User2 Lights up when the load torque is not 0, and blinks when the Load Torque Module is standby.
User3 Reserved

③ Digital Input High/Low Active Level Reversal:

The active level of gate driving signals (PWM signals) can be reversed by this switch.

Switch **L**: remain its level(keep the status)

Note: The active level of the six digital inputs can be changed individually by parameter setting, please refer to section 3.2.2.1 for details.

Switch **H**: the digital level will be reversed

④ Gate driving signal inputs terminal block:

The gate driving signals (PWM signals) from the control board can be transmitted to MR2 via this terminal block. (3.3V ~ 24V digital signals).

⑤ Currents and DC bus voltage outputs terminal block:

The three phase currents of the motor and DC bus voltage emulated by MR2 can be transmitted back to the control board via this terminal block.

Note: Support to transmit from -10V to 10V analog signals. Special requirements need converting circuit specification. We recommend that you use 2kΩ input impedance.

⑥ Pulse-output incremental rotary encoder (A-B-Z) terminal block:

The rotational angle emulated by MR2 can be transmitted in the form of signal of incremental rotary encoder. The complementary (differential) signals can be sent directly into the encoder card (PG card). If the Wire-Saving mode is enabled, the terminals of ABZ will deliver the UVW status (Hall-effect sensor signals). These terminals will present normal AB phase pulses and Z index when the Wire-Saving mode is disabled by users.

⑦ Hall-effect sensors (U-V-W commutation signals) terminal block:

The commutation signals emulated by MR2 can be transmitted in the form of signal of a set of three digital Hall-effect sensors. The complementary (differential) signals can be sent directly into the encoder card (PG card). If PWM-output mode is selected, the PWM signal associated with absolute rotor angle can be output by U end-point. Please refer to 3.2.2.4 Hall Sensor Type Parameter Description.

⑧ Resolver terminal block:

The rotational angle emulated by MR2 can be transmitted in the form of signal of Resolvers. The complementary (differential) signals for input of Resolver with voltage ranging from -20V to 20V and the complementary (differential) signals for output of Resolver with voltage ranging from -10V to 10V can be transmitted between MR2 and the Resolver card.

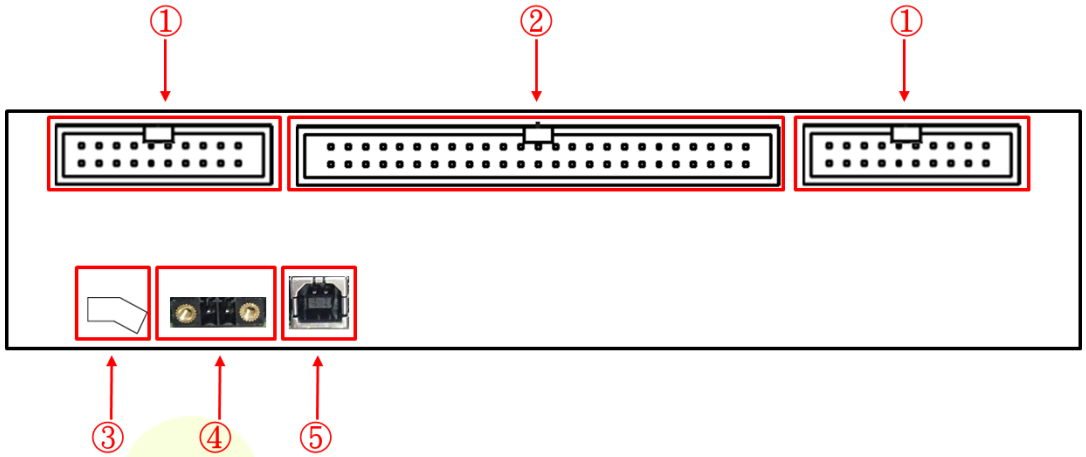
⑨ Incremental rotary encoder and commutation signal indicators:

These lights allow the users to quickly determine whether the motor is rotating or not. The probes above can be used for more precise detection through the oscilloscope.

⑩ Customized analog output and external load torque input terminal block:

This terminal block is for *Customized analog output module*. The output data and its scaling and limit can be set individually, please refer to Section 3.2.2.5 for more details.

2.3 Description of MR2 Backplane



① Bus ports for add-ons modules (2 sets)

The add-ons modules are connected with MR2 by a cable via these ports.

② Alternative Terminal Block

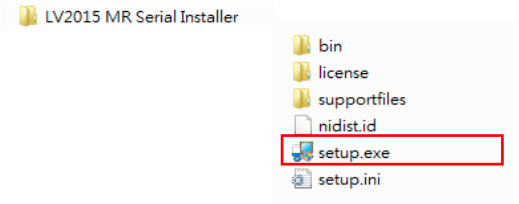
Alternative Terminal Block, like conversion board (ABZ/UVW signals of 3.3V), please contact us by service@gathertech.net.

③ Power switch
④ Power input
⑤ USB port for connection with operation software on PC

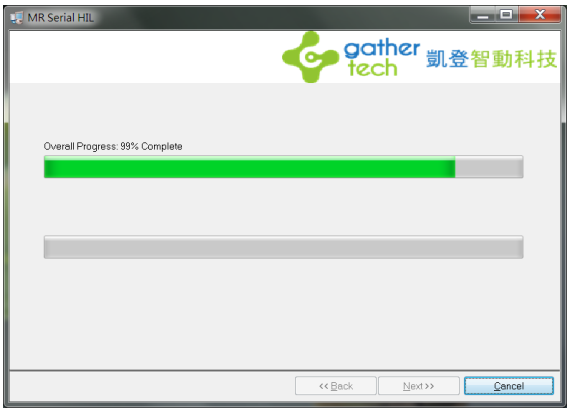
3 Software Operation

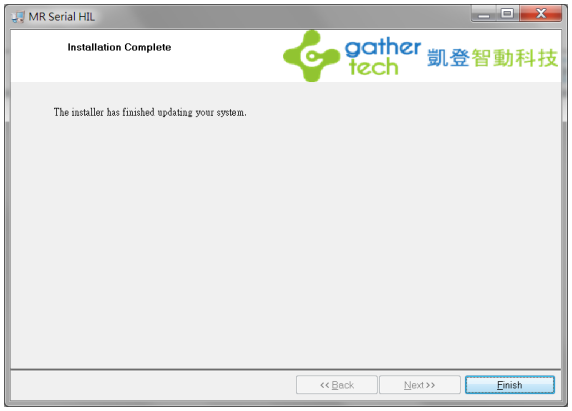
3.1 Software Installation

1. **Installation**



Double click “setup.exe” file to start the installation and follow the instruction until complete. Please make sure to reboot your PC after installation.



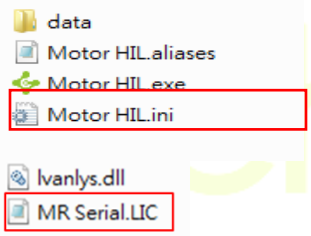


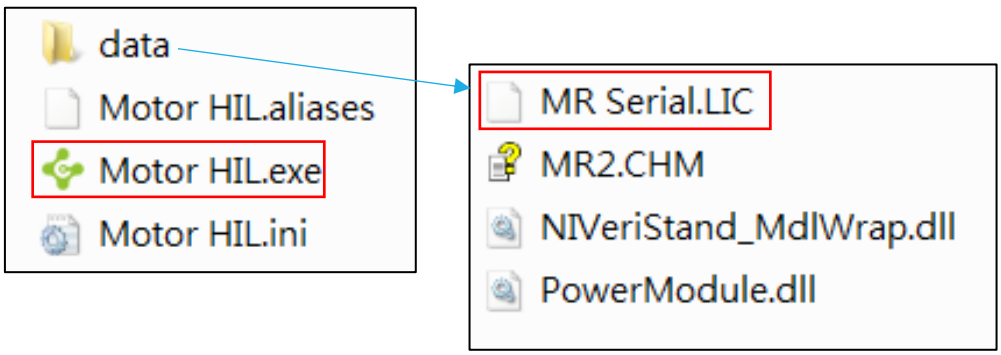
1.2 Execute the operation software

Before executing “Motor HIL.exe”, please make sure the “MR Serial.LIC” file has been copied and pasted to the folder named “data.”

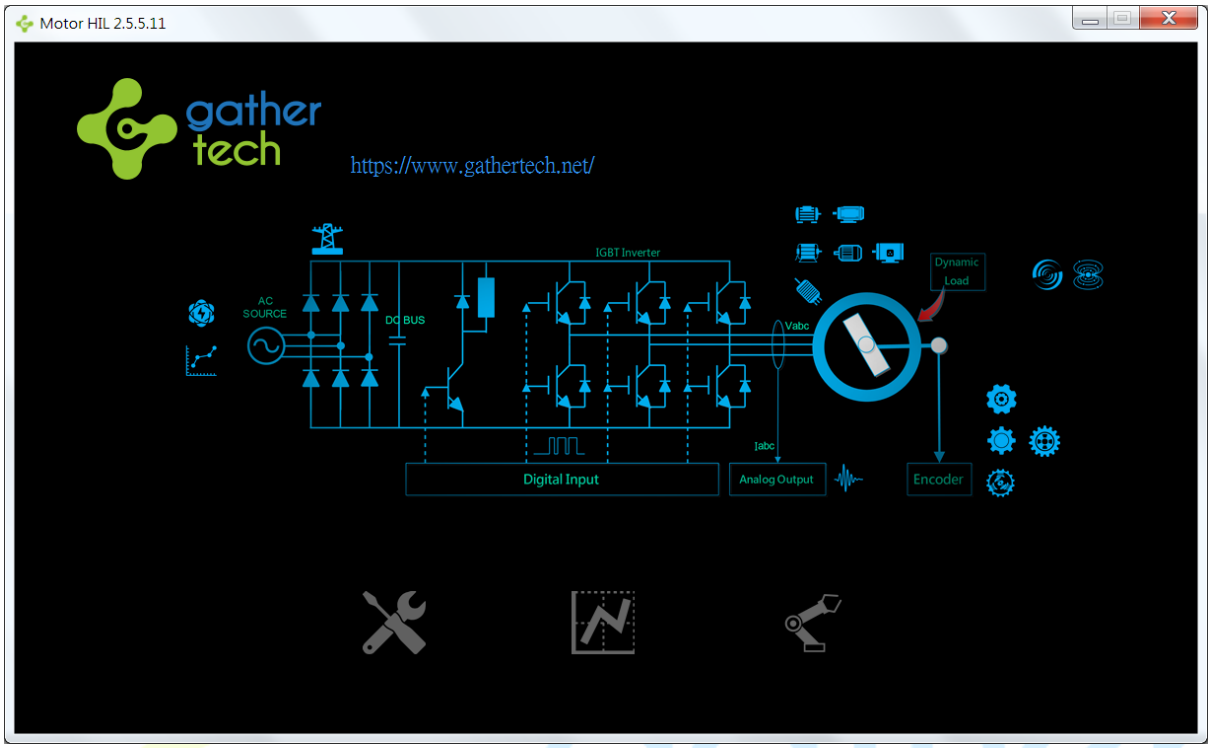
2. Execute the operation software

Before executing “Motor HIL.exe”, please make sure the “MR Serial.LIC” file has been copied and pasted to the folder named “data.”





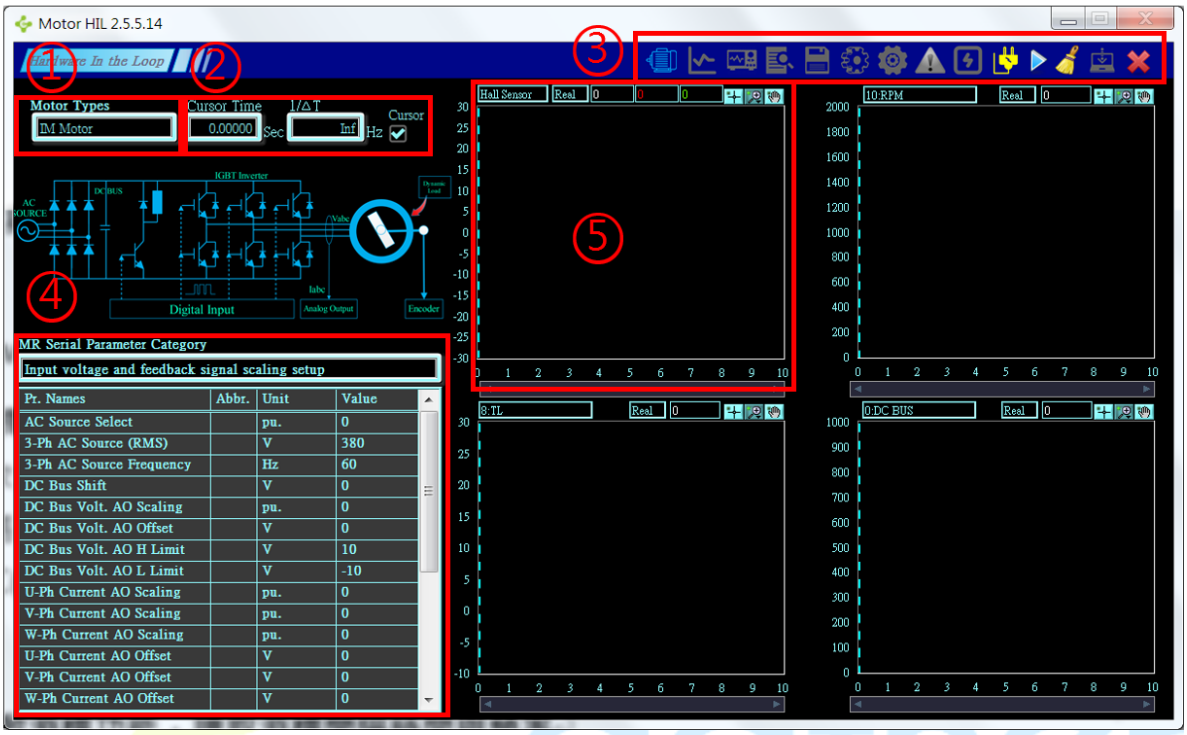
3.2 Software Main Page



Note: The illuminated icon indicates that the module has been purchased

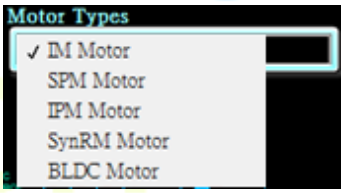
Icon	Function	Description
	MR2 System Environment Settings and Monitoring	The MR2 can emulate the motor drive system from the input power source, motor, mechanical load, and feedback quantities, which can be set up individually. After clicking this icon, every parameter and function can be set, such as motor type, motor parameters, load torque, the parameters of mains electricity input power etc. During the emulation, most system status can be monitored in real time.
	Add-ons Module: Load Torque Module Settings (optional)	After clicking this icon, various types of load torque which is corresponding to the actual working situation could be set. In addition to the built-in curves, the users can also build his/her own loading curve by external analog signals or series communication commands.
	Robotic Arm Test Module (optional)	This is merely a demonstrated case for customized modules. If required, please contact us by service@gathertech.net

3.2.1 MR2 System Environment Settings and Monitoring



3.2.1.1 ① Select Motor Type

Users can select the motor types, including induction motor (IM), surface-mounted permanent magnet synchronous motor (SPM), interior permanent magnet motor (IPM), synchronous reluctance motor (SynRM), brushless dc motor (BLDC)



3.2.1.2 ② Call-out the cursors, and show the time and frequency between two cursors

<u>Cursor Time</u>

This value represents the time, in seconds, between the two cursors (dotted line) in the monitoring chart.

<u>Cursor Check Box</u>

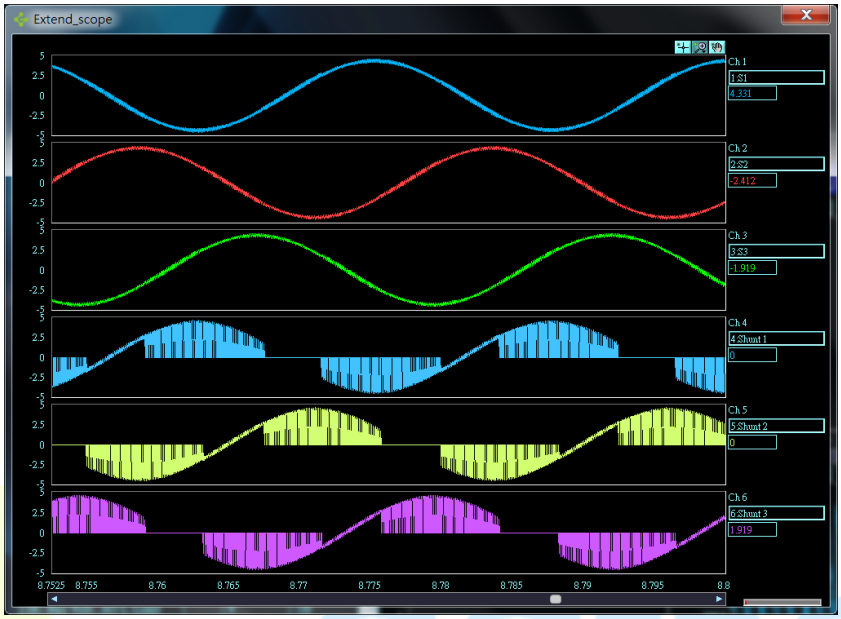
Display/hide the cursors (dotted line) in the monitoring chart.

3.2.1.3 ③ Hotkeys

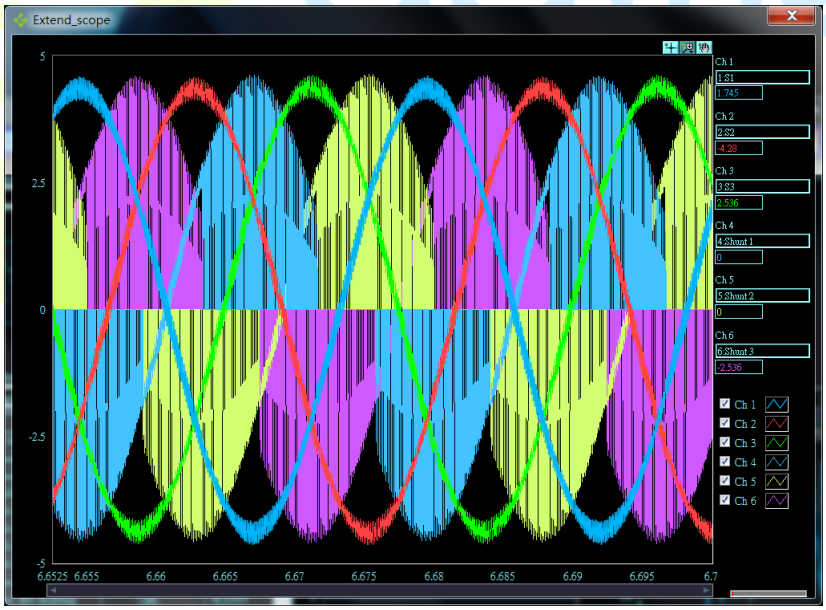
: MR2 motor stops computing when user turns off.

: Open the auxiliary 6 channels. Including the main screen, up to 10 system states (variables) can be monitored and saved at the same time.

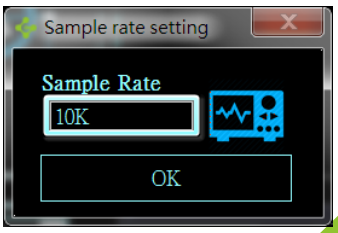
Stack Plots:



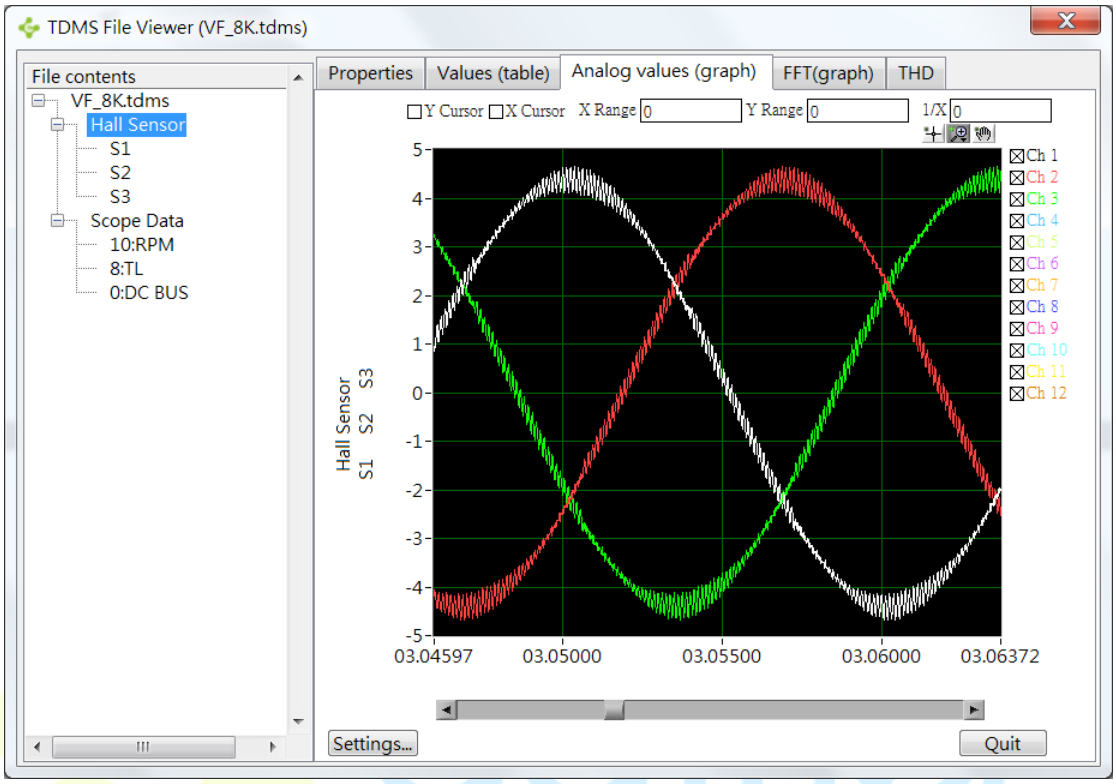
Overlay Plots:



: Select the sampling rate of monitoring. 500Hz / 1k / 5k / 10k / 25k / 50k / 100k Hz sampling rate are available. To avoid overloading the memory of PC, the data storage is limited, e.g. monitoring variables with 100 seconds when sampling rate is 10kHz, and monitoring variables with 10 seconds when sampling rate is 100kHz, and so on.



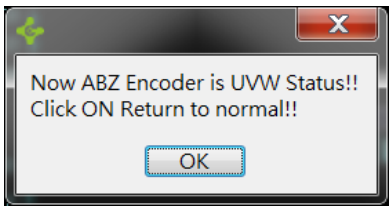
: View *.tdms Files. It could open saved *.tdms Files promptly.(multiple windows).



: Save Scope Data. The monitored system states (variables) can be saved as *.tdms file, which can be opened with the function above or with Excel.

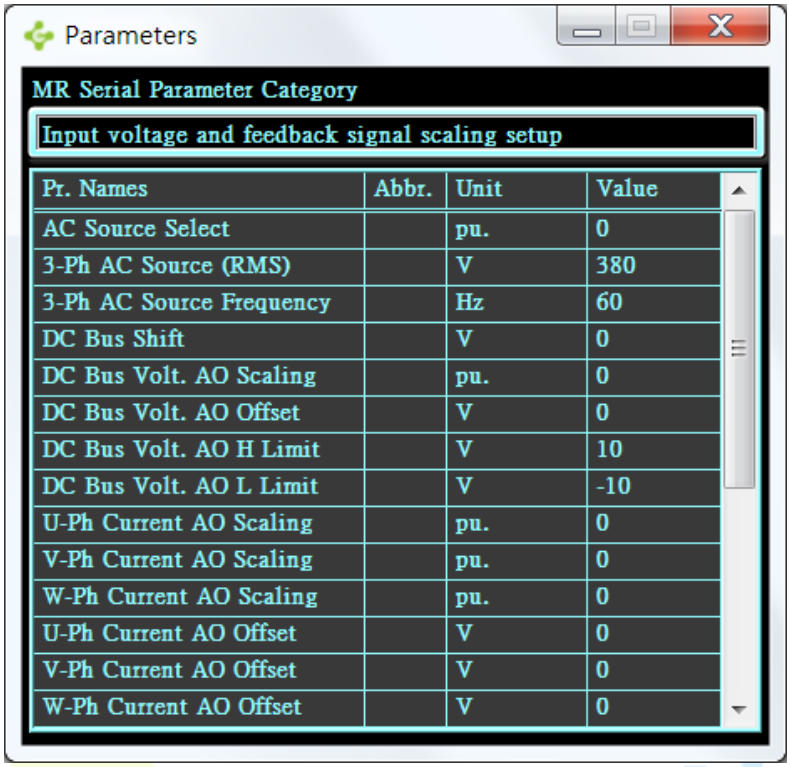
: Reset motor angle. All the emulation variables related to motor angle will be reset, including rotor position, pulse counts of ABZ encoder, rotor cycles, and encoder position etc. Please refer to Section 3.2.2.4 for reset angle setting.

: Turn on Wire-Saving incremental encoder. The Pulse-output incremental rotary encoder (A-B-Z) terminal block will be used to deliver the UVW status instead of A-B phase pulses until this function is turned off.



: Open Parameters chart, it could be revised promptly.

:



Pr. Names	Abbr.	Unit	Value
AC Source Select		pu.	0
3-Ph AC Source (RMS)		V	380
3-Ph AC Source Frequency		Hz	60
DC Bus Shift		V	0
DC Bus Volt. AO Scaling		pu.	0
DC Bus Volt. AO Offset		V	0
DC Bus Volt. AO H Limit		V	10
DC Bus Volt. AO L Limit		V	-10
U-Ph Current AO Scaling		pu.	0
V-Ph Current AO Scaling		pu.	0
W-Ph Current AO Scaling		pu.	0
U-Ph Current AO Offset		V	0
V-Ph Current AO Offset		V	0
W-Ph Current AO Offset		V	0

:

:

: The emulated motor needs to be dragged to a specific rotational speed (including standstill) for some test conditions, e.g. motor with locked rotor, or motor generation mode. Click this hotkey to enable the motor traction, which is as same as setting the parameter Traction Enable=1 (Enable), and the emulated motor will run at the rotational speed set by the parameter Traction Speed (RPM). Noted that the rotor is locked when this parameter is set to 0.

: DC Bus Clamp. The DC bus voltage can be set as a fixed value without any fluctuation due to charging/discharging of the DC bus capacitor for trouble-shooting. The function of this hotkey is same as setting the parameter DC Bus Clamp=1 (Enable), please refer to Section 3.2.2.2 for more details.

: The three-phase input power can be cut off during operation for some test conditions. Click this icon to cut off the three-phase input power at the same time, which is same as setting the parameters R Phase Enable=0, S Phase Enable=0, T Phase Enable=0 at the same time. Noted that the three phase input power can be cut off individually by parameter setting.

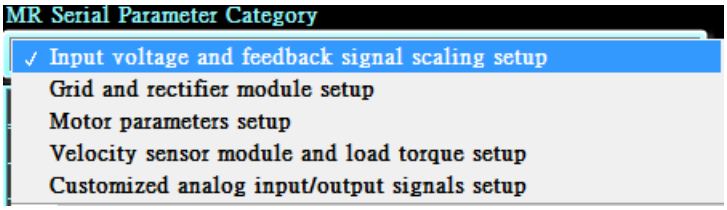
: Start/stop the monitoring. When the monitoring is started, the four channels on the main screen and the six auxiliary channels (if opened) will show the monitored system states in real time simultaneously. Noted that the emulation is still functioning when the monitoring is stopped, such that the monitored system states will show up its instant values again when re-starting.

: Clear the monitoring screen data. It will not stop the monitoring and the monitoring screen will continue to display the instant values after clearing.

: Reload MR2 parameter setting profile. Please refer to the next Section for more details on the parameter setting profile.

: Go back to the main page.

3.2.1.4 ④ System Parameter Settings



The system parameters are classified into five categories:

1. Input voltage and feedback signal scaling setup
2. Grid and rectifier module setup
3. Motor parameters setup
4. Velocity sensor module and load torque setup
5. Customized analog output signals setup

Parameter Chart:

Each parameter classification is followed by parameter content below. *Motor parameters setup* depends on the motor type you selected. Please refer to the parameter description section for details.

MR Serial Parameter Category

Input voltage and feedback signal scaling setup

Pr. Names	Abbr.	Unit	Value
AC Source Select		pu.	0
3-Ph AC Source (RMS)		V	220
3-Ph AC Source Frequency		Hz	60
DC Bus Shift		V	0
DC Bus Volt. AO Scaling		pu.	0
DC Bus Volt. AO Offset		V	0
DC Bus Volt. AO H Limit		V	10
DC Bus Volt. AO L Limit		V	-10
U-Ph Current AO Scaling		pu.	0
V-Ph Current AO Scaling		pu.	0
W-Ph Current AO Scaling		pu.	0
U-Ph Current AO Offset		V	0
V-Ph Current AO Offset		V	0
W-Ph Current AO Offset		V	0

Right-clicking on the two menu pages:

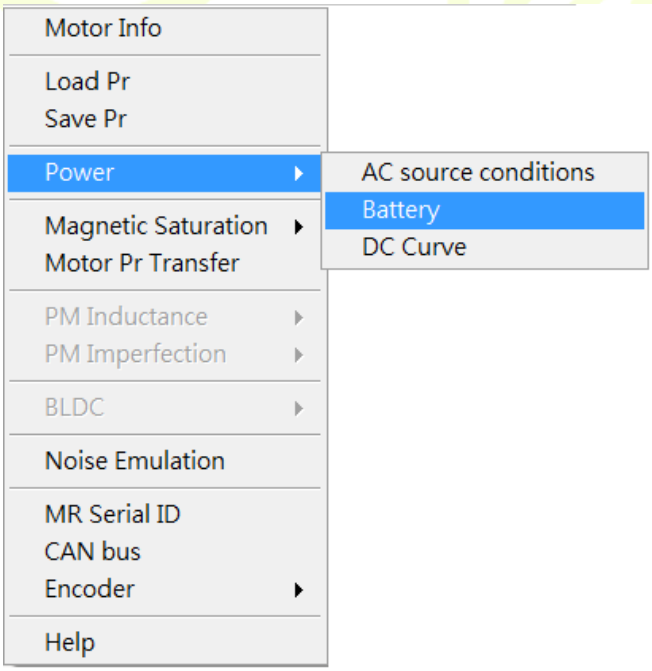
(1) right-clicks on the Motor Parameter Category menu page

For convenience, users can save and load the setting profiles separately. Such that specific controller with its setting profiles can be used to drive different motor types with motor setting profiles, and vice versa.

Drop down menu functions:

- Save VFD Pr: To save the setting profiles about the motor drive controller, including first two classifications: *1. Input voltage and feedback signal scaling setup* and *2. Grid and rectifier module setup*.
- Save Motor Pr: To save the setting profiles about the motor, which is *3. Motor parameters setup*.
- Save Feedback Pr: To save the setting profiles about the other classification of parameters, including the rest two: *4. Velocity sensor module and load torque setup* and *5. Customized analog output signals setup*.
- Load Pr: To load the setting profiles. various categories of parameter settings, the system will automatically identify file extension differences and overwrite parameters.

(2) right-clicks on the parameter content page



** This example of drop down menu is the case that the motor type is selected as IM, such that the items associated with the other motor types is disabled.

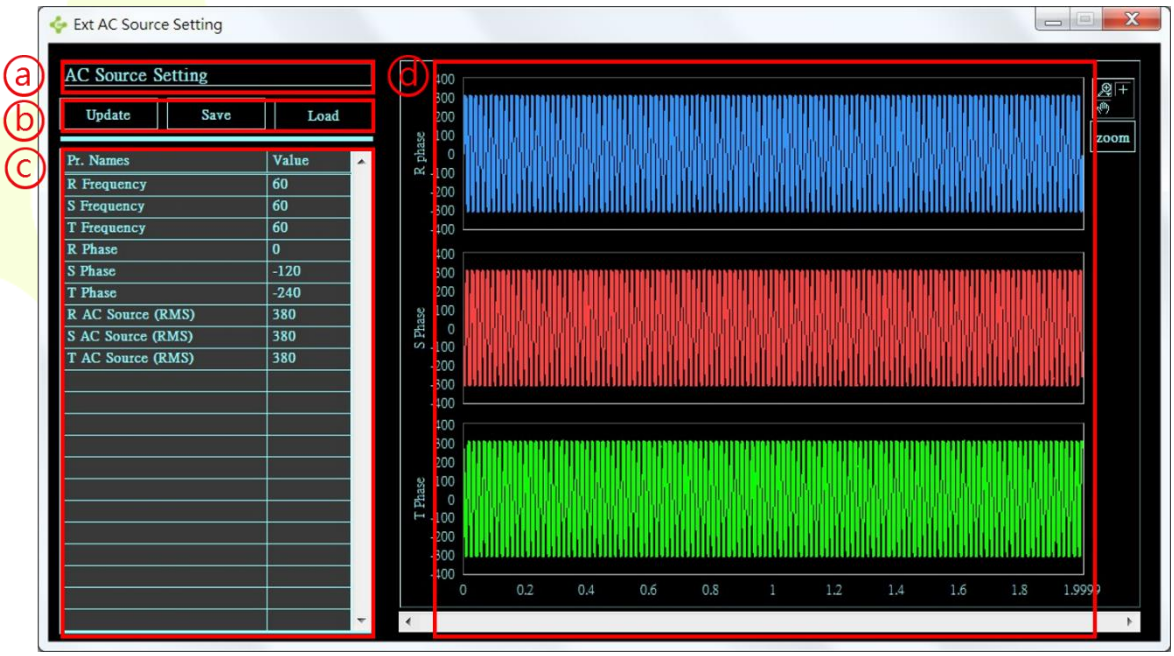
Drop down menu functions:

- Motor Info: As saving some information of the emulated motor nameplate, the setting will exist until you read all setting via high speed external communication module(optional) as well.

- Load Pr: To load **all** setting profiles, including the five categories.
- Save Pr: To save **all** settings, including the five categories.
- Power

■ <u>AC Source Conditions</u>

To inject some non-ideal conditions of the three-phase power supply voltage.



ⓐ The types and characteristics of injected non-ideal conditions of the three-phase power supply voltage can be selected and set by the drop down menu.

AC Source Setting: To set the Frequency/Phase/Amplitude of the input voltage.

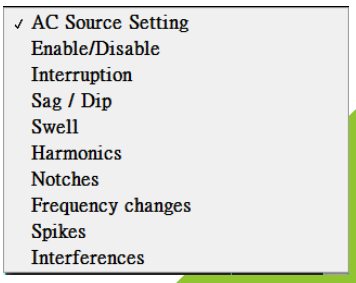
Enable/Disable: To Enable/Disable settings of the AC Source Conditions.

Interruption: To set the interrupt time and duration of the input power.

Sag/Dip: To set sag of the input power.

Swell: To set swell of the input power.

Harmonics: To add harmonic voltage of the input power.



Notches: To set notch of the input power.

Frequency changes: To set the variations of frequency of the input power voltage.

Spikes: To add some spikes of the input voltage.

Interferences: To add some noise of the input power voltage.

ⓑ The configured non-ideal conditions can be saved, loaded, or updated to MR2

Update: **Please make sure to click the Update button to update the configured non-ideal conditions after setting or loading.**

Save: To save the configured non-ideal conditions of the input power.

Load: To load the configured non-ideal conditions of the input power.

Note: By setting Enable in the drop-down menu and clicking the Update button, the configured non-ideal conditions will be downloaded to MR2. Otherwise, the ideal input power will be restored after Disable set and Update button click.

ⓒ Parameter list

Each type of non-ideality in ⓐ is followed by its parameter content in this menu pane.

ⓓ Configured AC Source Conditions Preview

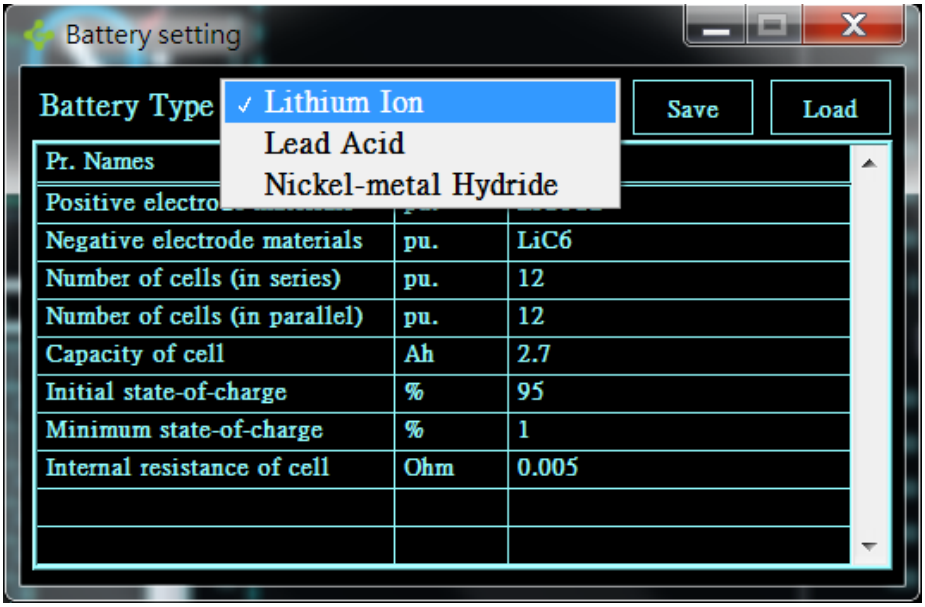
The users can double check the configured non-ideal conditions of the input power in this window before saving or updating.

Note: If the motor type is changed, this setting must be updated again (click the Update button).

■ <u>Battery</u>

To set the parameters of Battery module (optional module).

1. Battery type:
   Lithium Ion/Lead Acid/Nickel-metal Hydride



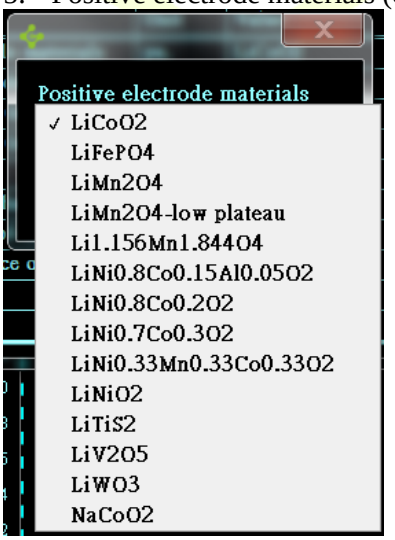
2. Battery Enable:

   : ON

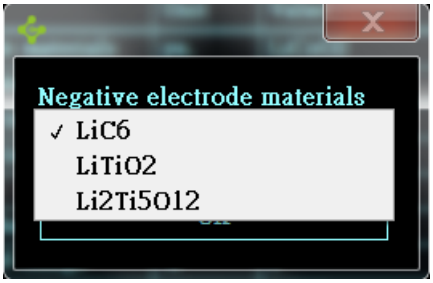
   : OFF

   Click ON to start simulaiton, OFF to stop simulation. Battery setting is changeable, to load new setting and start new simulation, please reactivate your battery. Only in condition AC= Source Select = 3, Battery Enable could be set to activate.

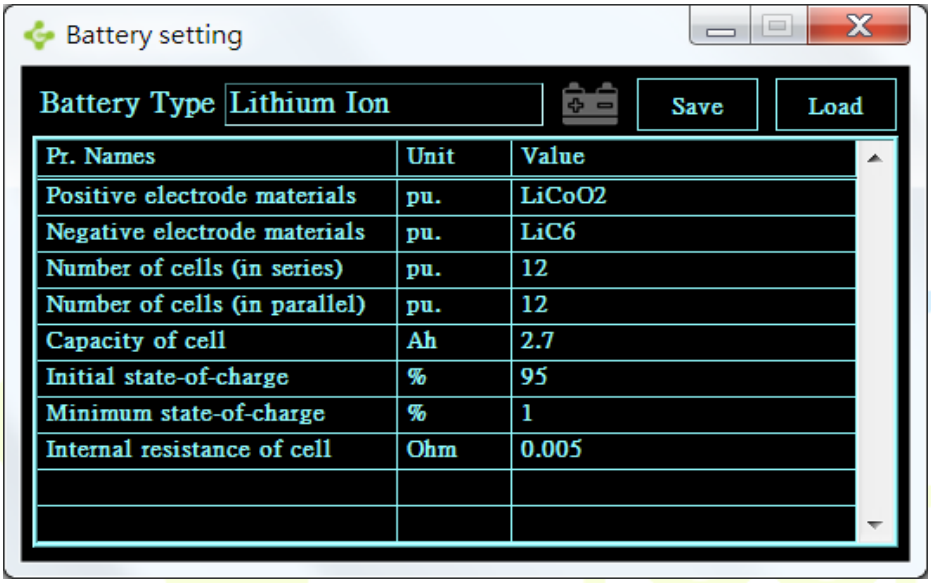
3. Save: saved setting*.Battery
4. Load: loaded setting*.Battery
5. Positive electrode materials (only Lithium Ion)



6. Negative electrode materials (only Lithium Ion)

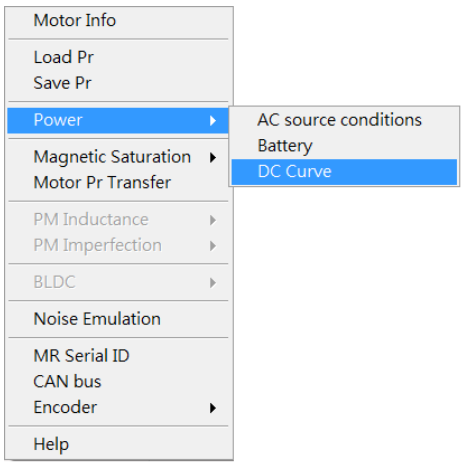


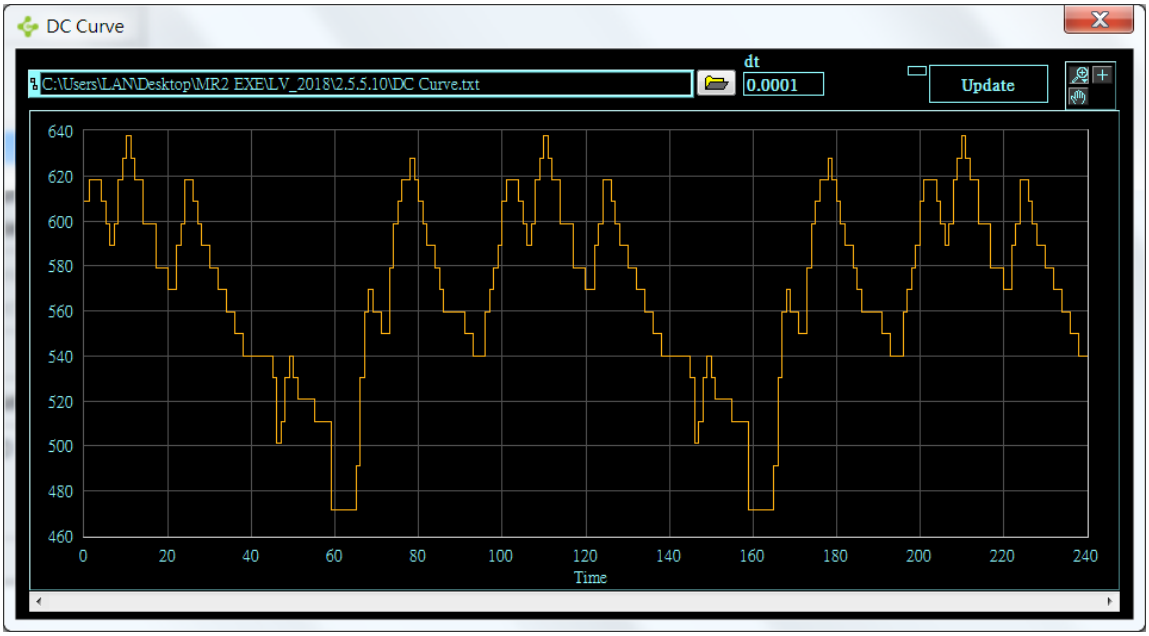
7. Number of cells (in series)
8. Number of cells (in parallel)
9. Capacity of cell
10. Initial state-of-charge
11. Minimum state-of-charge
12. Internal resistance of cell



Pr. Names	Unit	Value
Positive electrode materials	pu.	LiCoO2
Negative electrode materials	pu.	LiC6
Number of cells (in series)	pu.	12
Number of cells (in parallel)	pu.	12
Capacity of cell	Ah	2.7
Initial state-of-charge	%	95
Minimum state-of-charge	%	1
Internal resistance of cell	Ohm	0.005

■ DC curve

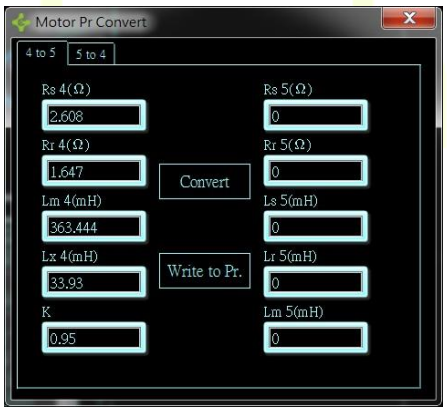




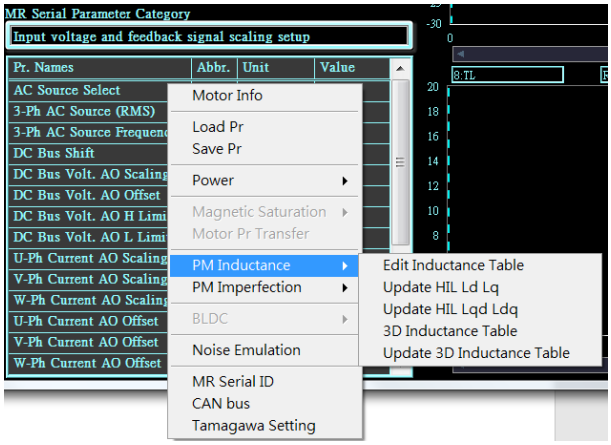
1. Please click text file on this page, then setting time interval and clicking Update. After Powerline Voltage could output curve repeatly, and the capacity is depends on PC RAM storage.

- Magnetic Saturation: (not activated yet)

- Motor Pr Transfer: To convert the Induction Motor equivalent circuit parameters between two common definitions, 4-parameter and 5-parameter models. This function is available when the IM is selected in motor type.



- PM Inductance



■ Edit Inductance Table

To edit the inductance saturation profiles of d-axis and q-axis equivalent inductance of IPMSM (Ld & Lq), which is proportional to d-axis and q-axis current (Id & Iq) percentage of rated current, i.e. Ld is function of Id; Lq is function of Iq. The cross inductance saturation profiles (Ldq & Lqd) caused by non-sine-distributed windings of motor can also be edited, as long as you click Update HIL Lqd Ldq instead of Update HIL Ld Lq. **Please make sure to change the parameter *dq-axis Inductance Source* to 1 to enable this saturable inductance during emulation.**

ⓐLoad/Save: users could load or save data. **This function is available when the IPM or SynRM is selected in motor type.**

■ Update HIL Ld Lq

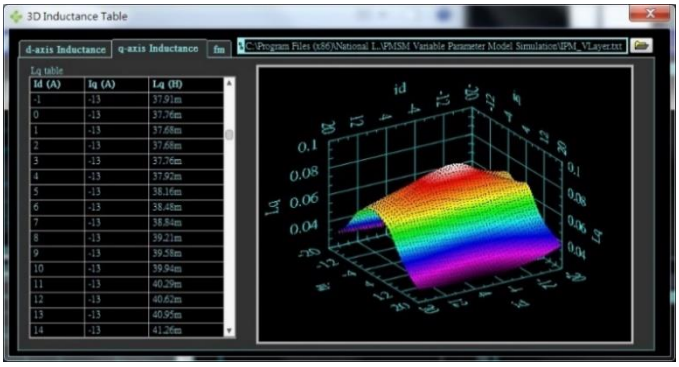
To update the edited inductance table to MR2 as saturable (Ld & Lq).

■ Update HIL Lqd Ldq

To update the edited inductance table to MR2 as saturable (Lqd & Ldq).

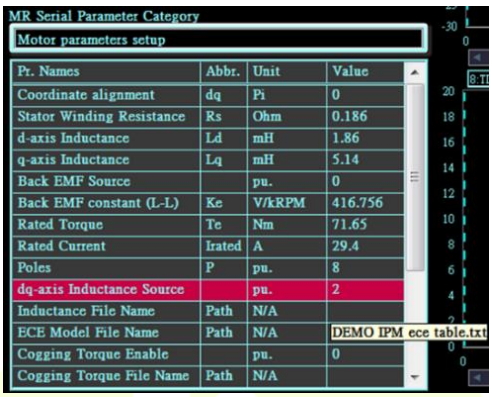
■ 3D Inductance Table

To import 3D inductance table file, which is generated by the Equivalent-Circuit Extraction (ECE) model from the popular software, ANSYS. By this inductance table, Ld and Lq are both function of (Id, Iq). The Ld and Lq plane can be shown in the preview window when the ECE model file (Ld, Lq, Fm) is loaded.

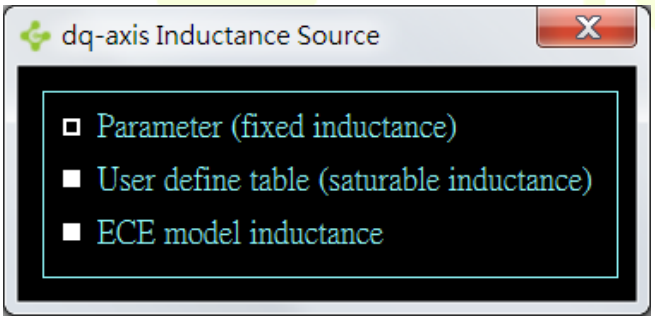


- Update 3D Inductance Table

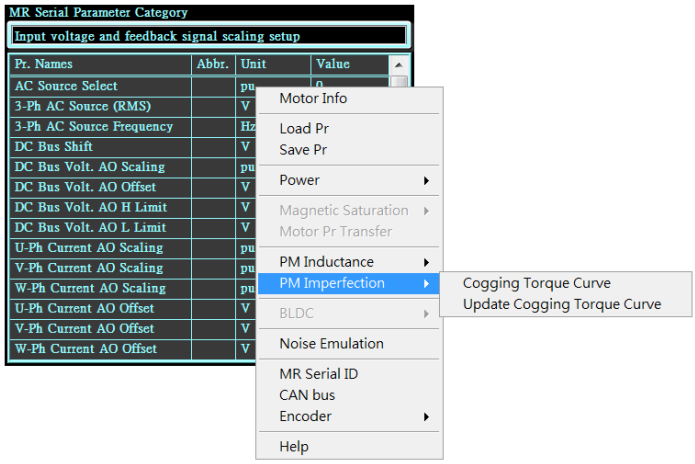
To update the 3D inductance table to MR2.



Note: **Please make sure to change the parameter *dq-axis Inductance Source* to 2 to enable this saturable inductance during emulation.**

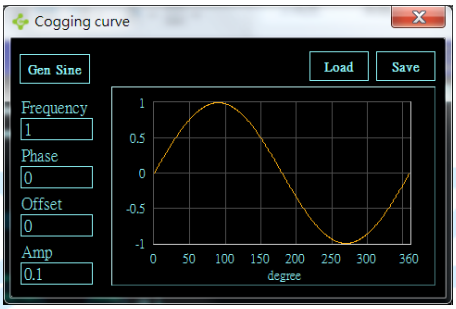


- PM Imperfection



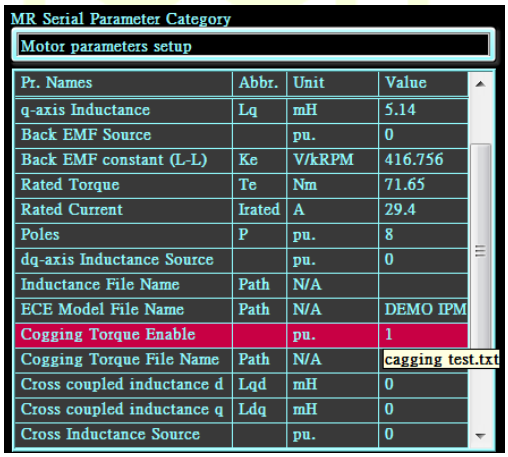
- Cogging Torque Curve

  To edit the cogging torque caused by the interaction between the stator air-gap permeance and permanent magnet MMF. The cogging torque varies with electric angle of the motor.



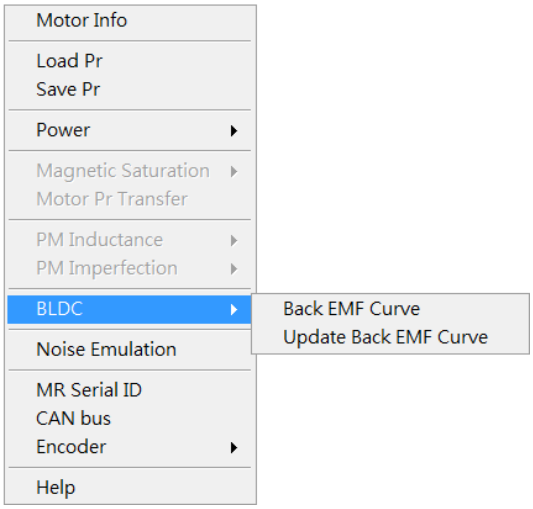
- Update Cogging Torque Curve

  To update the edited cogging torque to MR2.

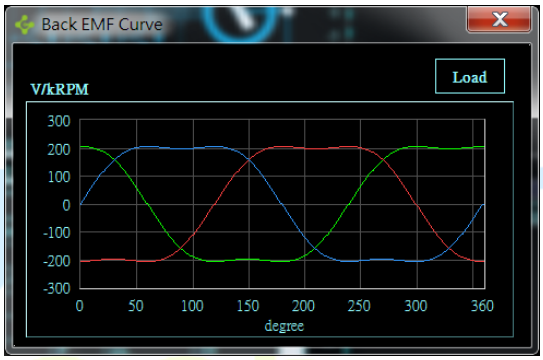


Note: **Please make sure to set the parameter *Cogging Torque Enable* to 1 to enable this function during emulation.**

- BLDC

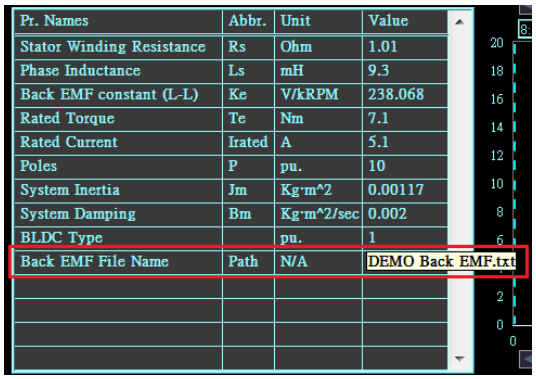


- Back EMF Curve: To load the text file (*.txt) of the back-EMF constant (Ke). The constant varies with electric angle of the motor.



Note: **This function is available when the BLDC is selected in motor type.**

- Update Back EMF Curve
  To update the edited back EMF curve to MR2.

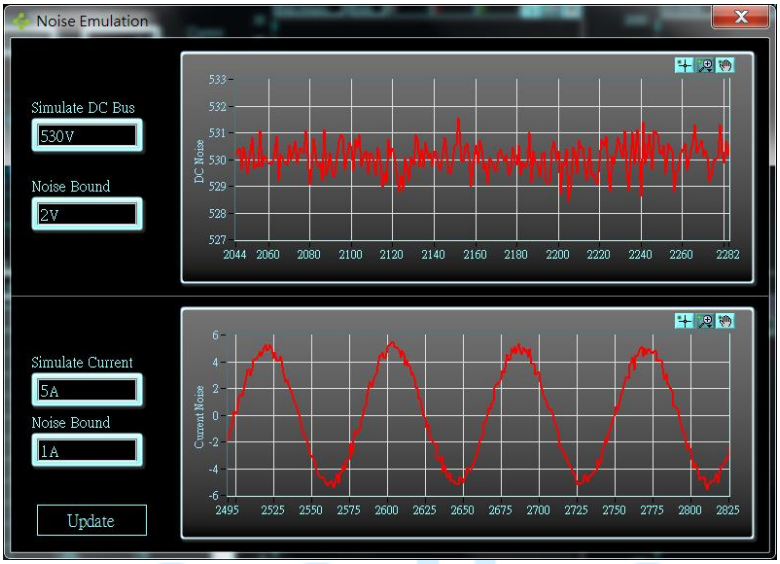


Pr. Names	Abbr.	Unit	Value
Stator Winding Resistance	Rs	Ohm	1.01
Phase Inductance	Ls	mH	9.3
Back EMF constant (L-L)	Ke	V/kRPM	238.068
Rated Torque	Te	Nm	7.1
Rated Current	Irated	A	5.1
Poles	P	pu.	10
System Inertia	Jm	Kg·m^2	0.00117
System Damping	Bm	Kg·m^2/sec	0.002
BLDC Type		pu.	1
Back EMF File Name	Path	N/A	DEMO Back EMF.txt

Note: **Please make sure to set the parameter *BLDC Type* to 2 to enable this function during emulation.**

- Noise Emulation

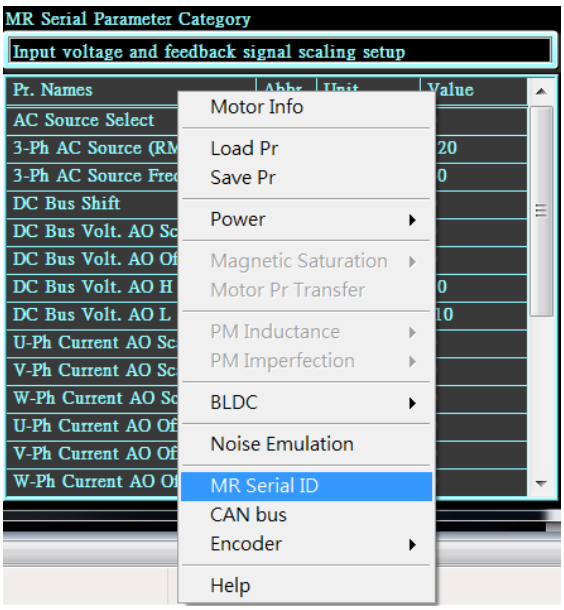
To add Gaussian distributed noise in the analog output signals, including DC bus voltage and three-phase current. The noise amplitude is bounded by the setting of *Noise Bound*. Noted that the *Simulate DC Bus* and the *Simulate Current* is only for the user to double check in the preview window. The nominal values of analog output signal are determined by the emulation results.

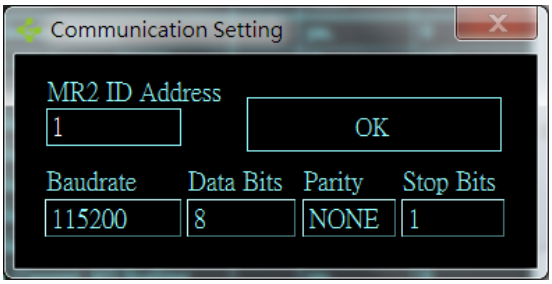


- Simulate DC Bus: stimulate the value of DC Bus, see the result on emulation.
- Noise Amp: set the range of amplitude, the unit of DC Bus terminal is V.
- Simulate Current: stimulate the value of Current, see the result on emulation.
- Noise Amp: set the range of amplitude, the unit of Current terminal is A.

The Gaussian distributed noise is mixed into the analog output signals when the Update button is clicked. If you would like to eliminate the emulated noise from the analog output signals, please set the *Noise Bound* to 0 and **click the Update** button again.

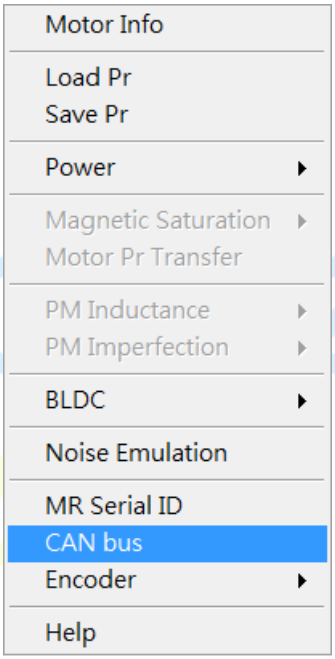
- MR Serial ID: set MR2 communication address from 1~255, Baud, format



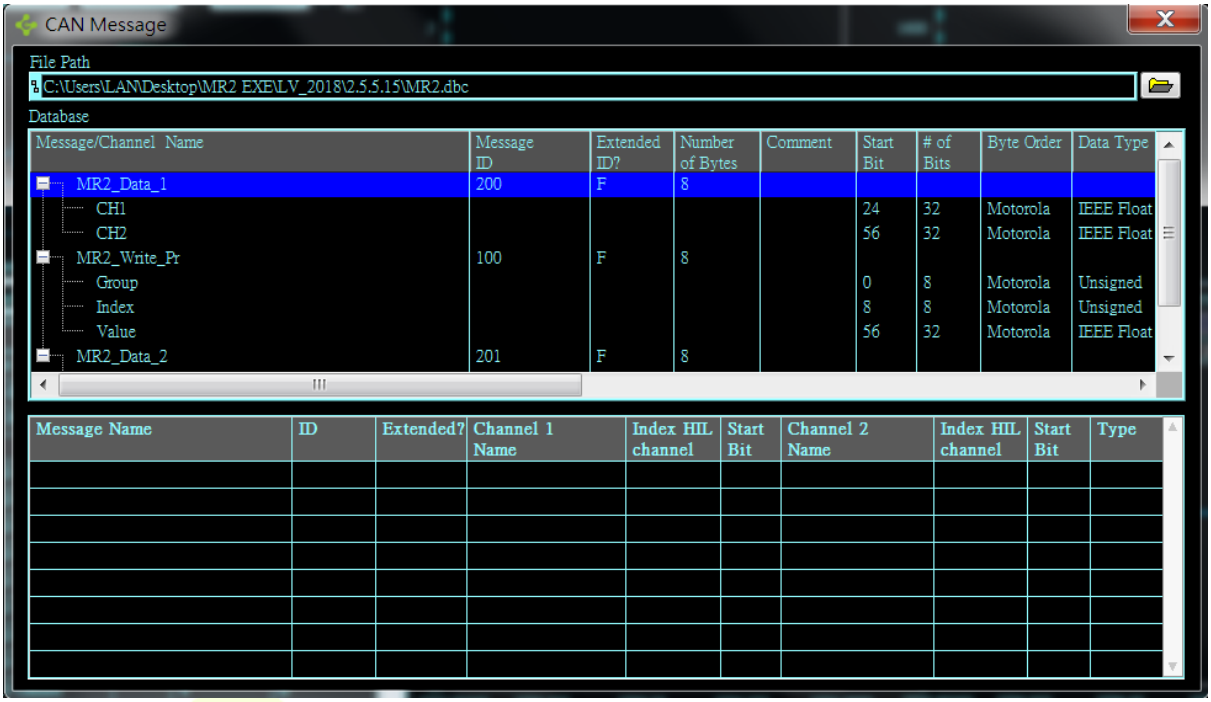


If one or more MR2 are accessed by RS-485 serial communication with the add-ons module *Communication module*, the communication address for MR2 must be set via this parameter and each MR2 communication address must be different. Please contact to service@gathertech.net (Need to co-functioning with *Communication module*.)

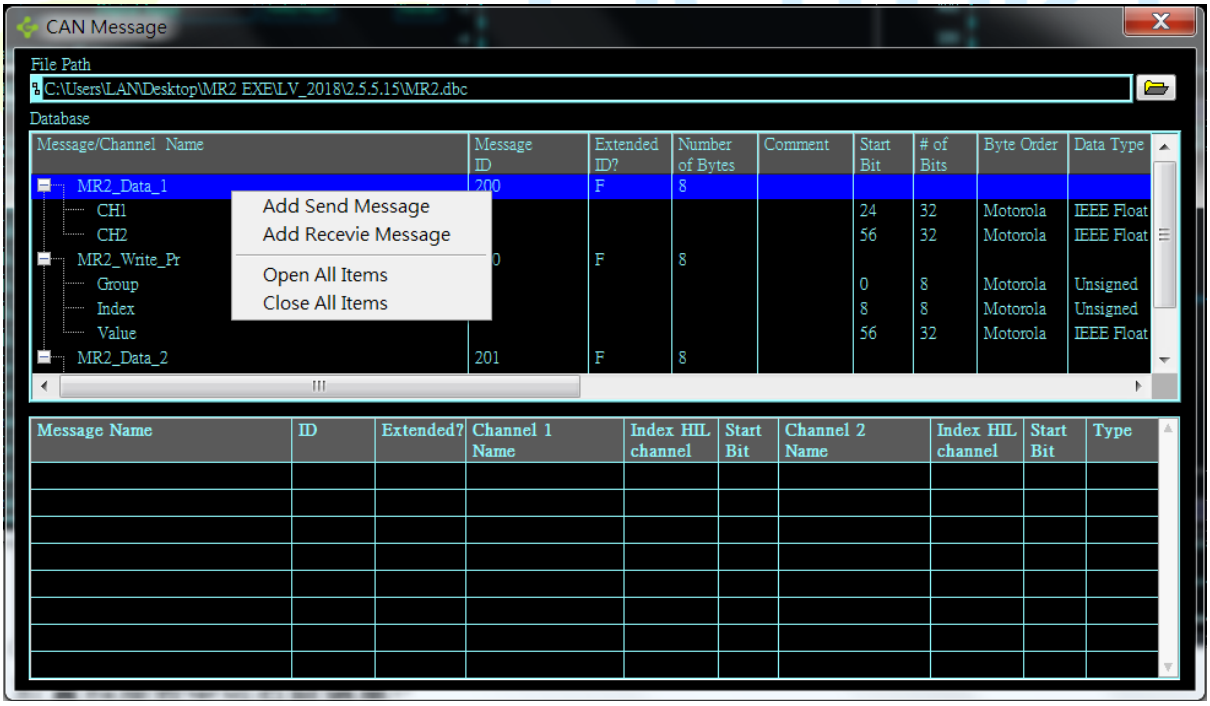
- CAN Bus



The setting about CAN is called out by clicking this item of drop-down menu.



MR2 can be accessed by serial communication with the add-ons modules. In addition to RS-485, it can also be accessed via CAN bus. Two modes (*.dbc/ *.nbd) are supported at present version.



The setting about CAN communication is called out by clicking this item of drop-down menu.

- Add Send Message
  The format must correspond to MR2 setting, and the maximum channels of SCOPE to each message is 2. The length used to be 32bits, SGL data types.
  Choose designated MR2 Scope data in drop-down menu, set message frequency in Period.
  If it is set to 0, MR2 will respond after receiving Remote request.

這個為CAN模組接收到詢問資料時回應給上位機

- Data Field:0-8bytes的資料。

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Byte1~4為SGL				Byte5~8為SGL			

- Add Receive Message
  The format must correspond to MR2 setting, it receives the order which mainly modify parameter. To in accordance with communication protocol, the format of Message is
  Group (1byte)+ Index (1byte) + None (1byte) + None (1byte) + Data(SGL=4bytes)

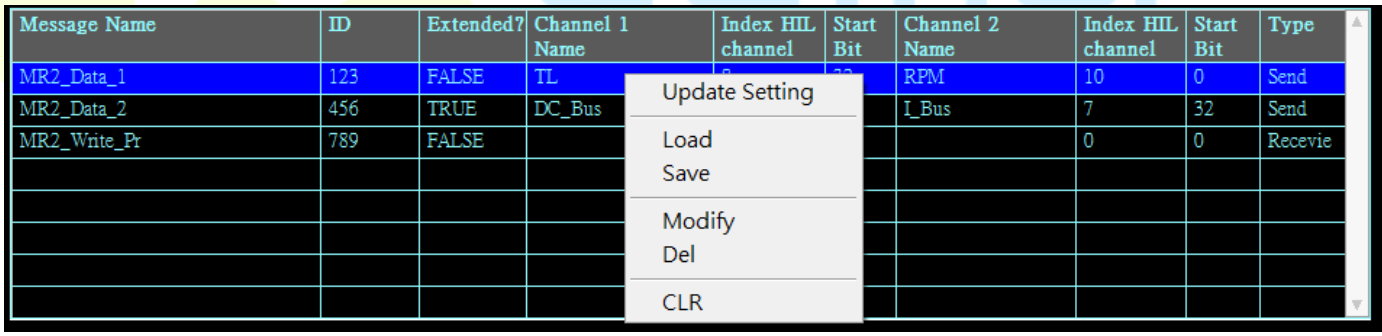
這個為當CAN模組收到上位機寫參數資料時，解開的格式

- Data Field:0-8bytes的資料。

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Group	Index	xx	xx	Byte5~Byte8=>SGL			

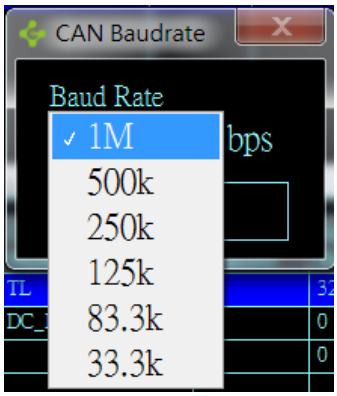
- Open All Items
- Close All Items

Please confirm CAN Message is already listed.



The setting about CAN Message is called out by clicking this item of drop-down menu.

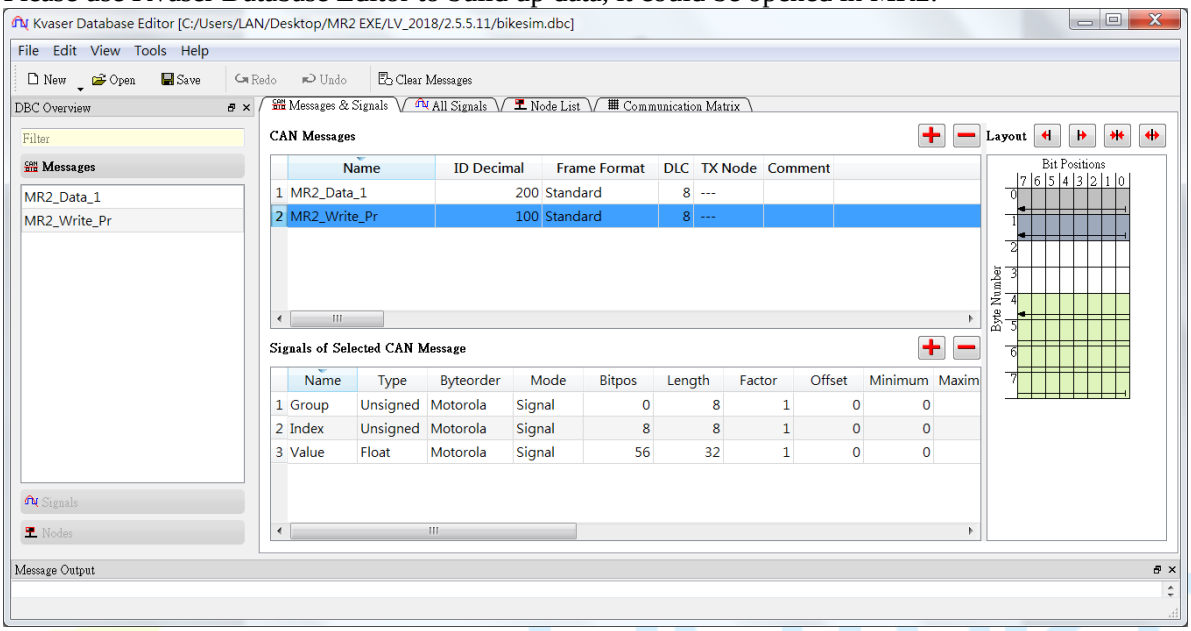
- Update Setting : CAN speed is called out by clicking this item of drop-down menu.



- Load: load MR2 Can Message file, *.can

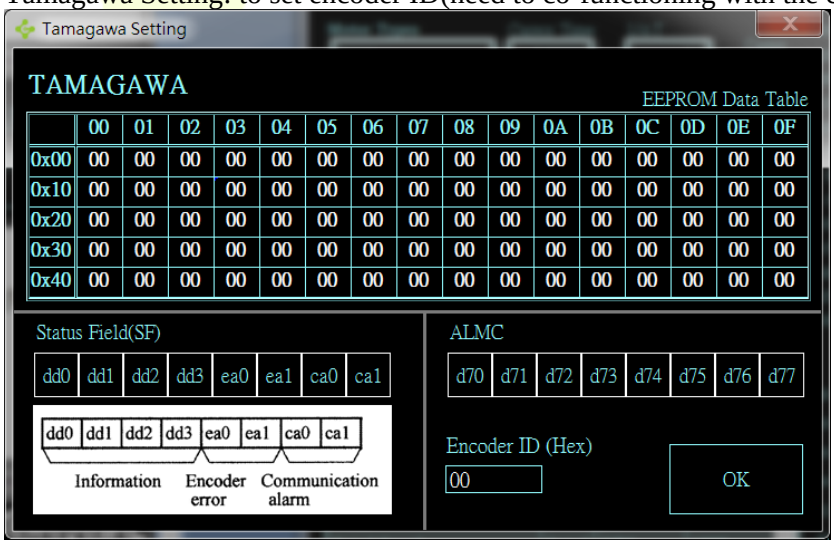
- Save: save MR2 Can Message file,*.can
- Modify: modify message setting(in message sent)
- Del: delete chosen message
- CLR: clear all message

Please use Kvaser Database Editor to build up data, it could be opened in MR2.

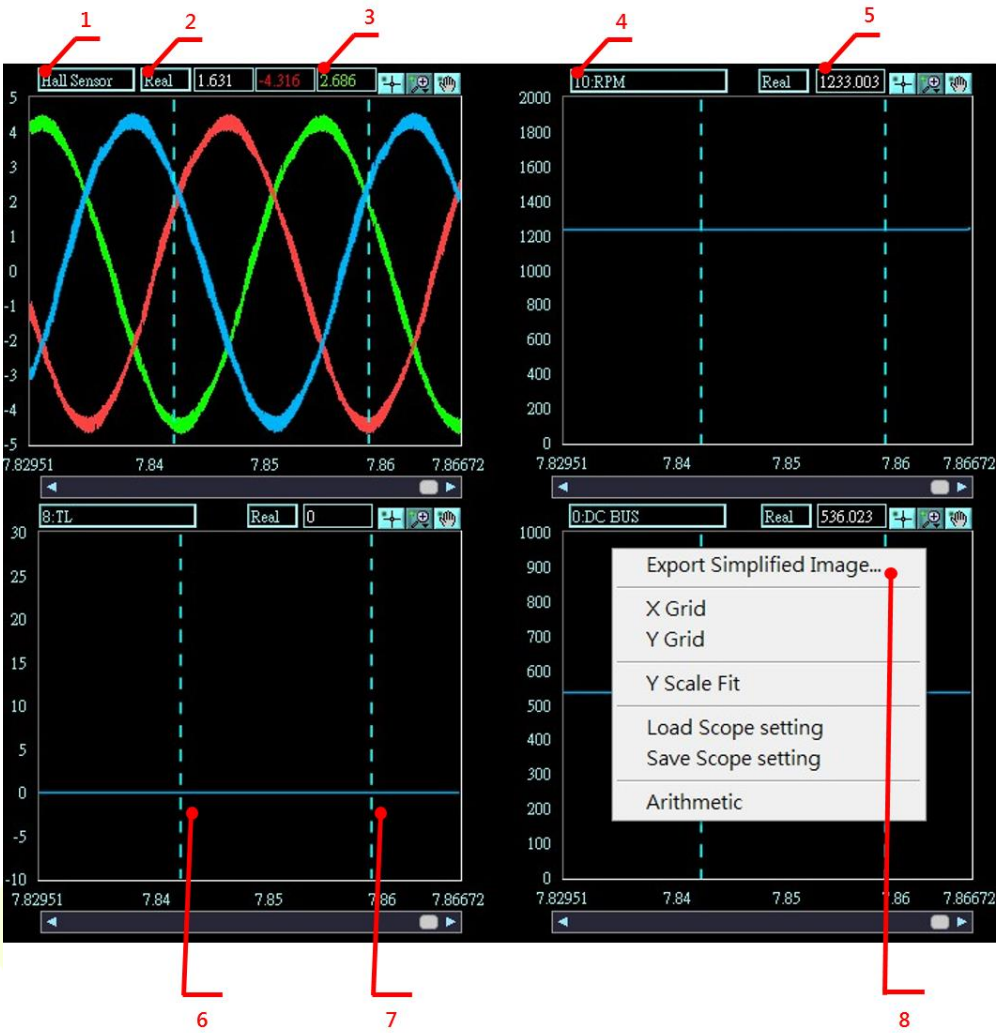


Note the mode switch and the format of Byte order should be Motorola. If you need example file *.dbc, please contact us.

- ENCODER:
  Tamagawa Setting: to set encoder ID(need to co-functioning with the communication encoder add-ons).

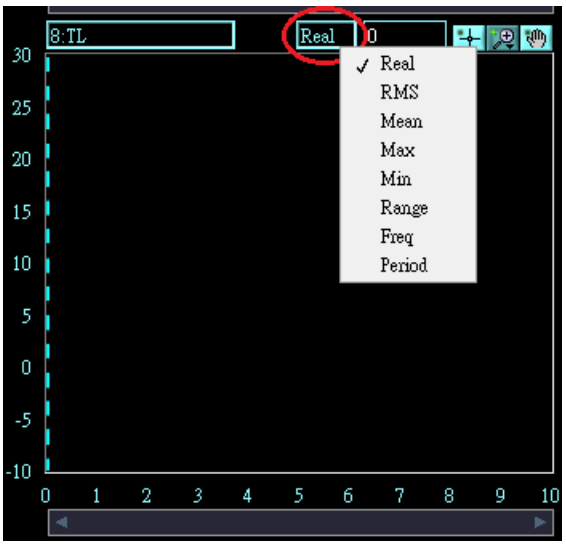


Scope function



1. To monitor three-phase states of the emulated motor, including three-phase currents (by Hall-effect current sensor or shunt resistor), line-to-line voltages, three-phase back EMF. The emulated input voltages from power grid of the drive can also be shown here when the non-ideal conditions are involved.

2. To display the values of the data.



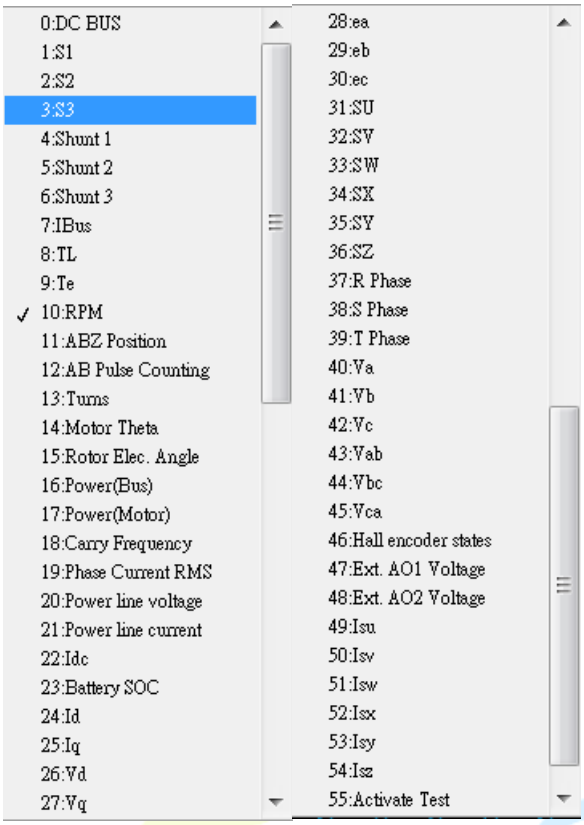
- Real: three instantaneous values are shown when monitoring is running (updating data); instead, three history values are shown at the time where the cursor pointing at when the monitoring stops;
- RMS: three effective values of the data on the screen;
- Max: the maximum value of the data on the screen;
- Min: the minimum value of the data on the screen;
- Range: the range between the maximum and minimum value of the data on the screen;
- Freq: the frequency of the data on the screen;
- Period: the cycle time of the data on the screen;

3. To monitor three-phase states of the emulated motor, three instantaneous values are shown when monitoring is running (updating data); instead, three history values are shown at the time where the cursor pointing at when the monitoring stops;

4. To select the monitored system status. Noted that the index of system status is compatible with the *Customized analog output module* where users can select the analog output status by these indices. **The setup is shown below:**[2]

Pr. Names	Abbr.	Unit	Value
Customized AO1 Index		pu.	0
Customized AO1 Scaling		pu.	0
Customized AO1 Offset		pu.	0
Customized AO1 H Limit		V	10
Customized AO1 L Limit		V	-10
Customized AO2 Index		pu.	0
Customized AO2 Scaling		pu.	0
Customized AO2 Offset		pu.	0
Customized AO2 H Limit		V	10
Customized AO2 L Limit		V	-10
AI TL Enable		pu.	0
AI TL Scaling		pu.	0
AI TL Offset		V	0

The selectable emulated system status is[3]:

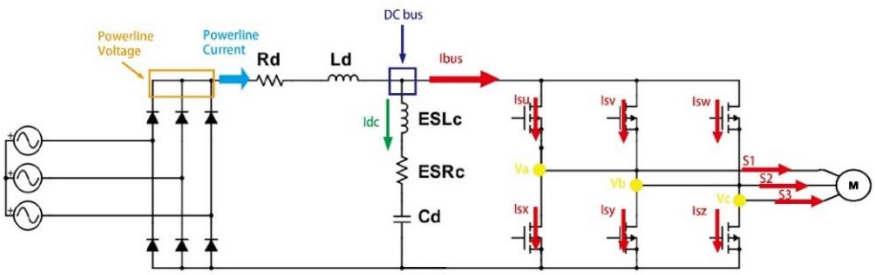


[2]If the *Customized analog output module* is included in your package, you can select the system status output from the analog output terminals AO1 or AO2. For example, if AO1 Index sets 11 and AO2 Index sets 10, the emulated motor rotational speed in RPM will be sent out from AO1 and the emulated motor torque will be sent out from AO2.

[3]The content of the selectable system status varies with the version of the operation software and the emulated motor types. Please contact our customer service for more details.

- Phase Current RMS
- Power line voltage
- Power line current
- Idc: capacitive current
- Battery SOC: battery power
- Vd: the d-axis voltage
- Vq: the q-axis voltage
- ea: U Back EMF
- eb: V Back EMF
- ec: W Back EMF
- SU: (ON: 1/OFF: 0)
- SV: (ON: 1/OFF: 0)
- SW: (ON: 1/OFF: 0)
- SX: (ON: 1/OFF: 0)
- SY: (ON: 1/OFF: 0)
- SZ :(ON: 1/OFF: 0)
- R phase: R phase input power generated depends on power quality
- S phase: S phase input power generated depends on power quality

- T phase: T phase input power generated depends on power quality
- Va: U phase voltage
- Vb: V phase voltage
- Vc: W phase voltage
- Vab: (U-V) line-to-line voltage
- Vbc: (V-W) line-to-line voltage
- Vca: (W-U) line-to-line voltage
- Hall encoder States: (bit0:U bit2:V bit3:W)
- Ext. AO1 Voltage: auxiliary external voltage 1 setting
- Ext. AO2 Voltage: auxiliary external voltage 2 setting
- Isu: U phase high side current
- Isv: V phase high side current
- Ivw: W phase high side current
- Isx: U phase low side current
- Isy: V phase low side current
- Isz: W phase low side current
- Ld: The d-axis inductance
- Lq: The q-axis inductance
- d-axis flux: The d-axis magnetic flux
- q-axis flux: The q-axis magnetic flux
- Active Test: 1: enable, 0: disable
- Arithmetic: To show the arithmetic operation of different monitored system status on the screen



5. To display the values of the data. The values are the same as described in 2.

6. Cursor1: Left cursor of x-axis

7. Cursor2: Right cursor of x-axis

8. To manipulate the diagram displayed on the screen, including: scaling, fit to scope etc.

9. Right-click on the scope to call out the drop-down menu:
   - Export Simplified Image… : To export the diagram of the monitoring screen.
   - X Grid: To show the x-axis grid on the monitoring screen.
   - Y Grid: To show the y-axis grid on the monitoring screen.

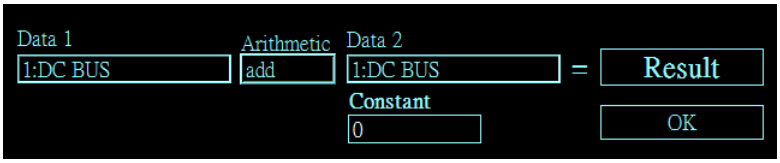
- Y Scale Fit: To scale the y-axis in a fitting range

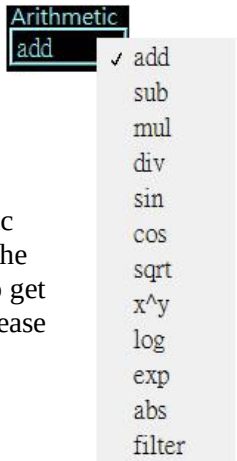
  Please scale the x-axis by scrolling mouse wheel.

- Load Scope setting: To load the setting

  Save Scope setting: To save the setting: Including extend scope and Arithmetic, and different motor types will give different file extension.

- Arithmetic: To call out the simple calculation functions.





Please select the data to be calculated in *Data 1*, and select the arithmetic operator in *Arithmetic*. The other operand in *Data 2* can be selected by the index or be entered a constant. After the expression is done, click OK to get the result. If you would like to show this result on monitoring screen, please make sure to select the *Arithmetic* described in 4.

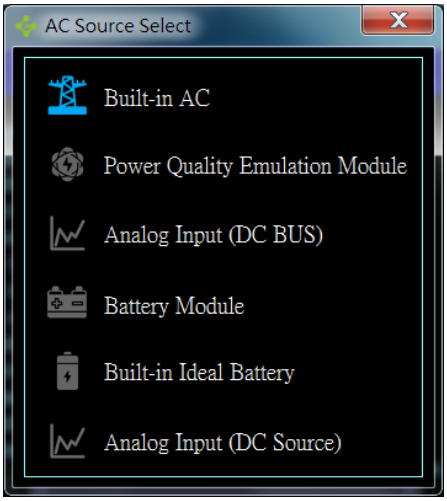
3.2.2 Parameter Description

The following parameters of the emulation system/environment, except for some functions of standard module, depend on the functions of the modules in your package. The details of functions of each module are described on Table 3 and Table 4 in Section 3.1. If the parameters of your package are unable to set up or change, please contact our service staff.

Note: **The default value (Value) in the following description is the setting value that will appear when induction motor (IM) is selected in motor type.**

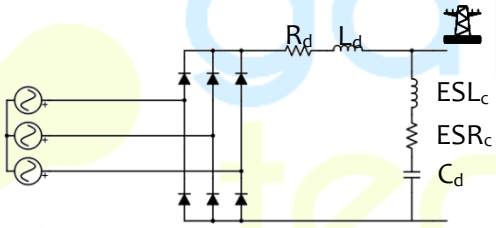
3.2.2.1 Input voltage and feedback signal scaling setup

Pr. Names	Abbr.	Unit	Value
AC Source Select		Pu.	0

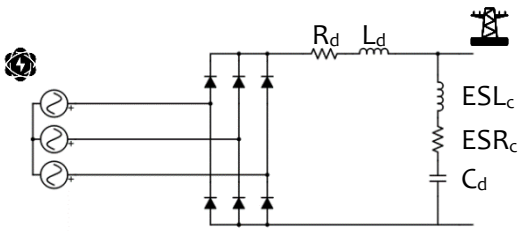


Drives input power source	Setting range	0 / 1 / 2/ 3 / 4

- The types of input power, **including AC, DC, or Battery**, to the emulated drive can be selected by this parameter.
- **0: Single-phase / three-phase AC power supply**: The three-phase AC power supply, RST, is a standard function of MR2, and connected to a bridge rectifier and filter to DC bus. The equivalent circuit of the input power structure is shown below. Some related parameters are described in Section 3.2.2.2.



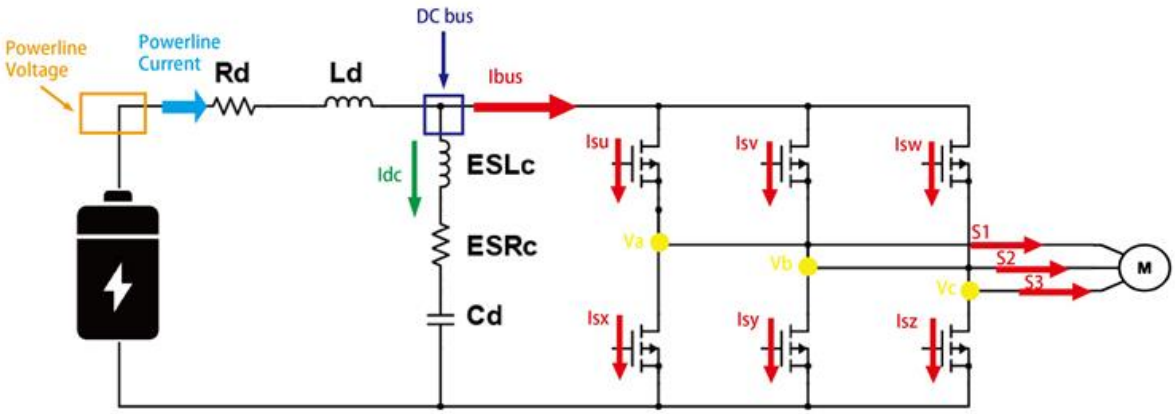
- **1: Single-phase / three-phase AC power supply with non-ideal conditions**: The three-phase AC power supply generated by the core module *AC source conditions* is connected to a bridge rectifier and filter to DC bus. The equivalent circuit of the input power structure is the same with the standard structure, except the input AC voltage is configurable. This function needs to co-function with *AC source conditions*. Please refer to Section 3.2.1.4 for more details.



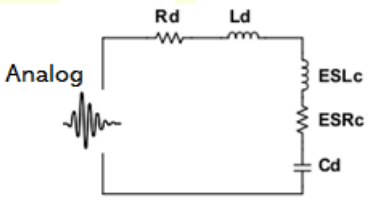
- **2. DC power supply via analog input signal:** The DC bus voltage of the emulated system can be designated by the external analog input voltage. This function skip input power structure, such that there is no parameter to set. The input terminal is described as *Ext. DC Bus* in Section 2.3 (This function can be used for very complicated input power scheme, where the modeling and emulation should be executed in an independent real-time system (computer). And the real-

time system is co-functioning with MR2 by the analog input/output terminals. If you have any question, please contact our technical team.)

- **3. DC power supply by Battery**: Three common types of battery, Lithium-ion (Li-ion), Nickel Metal Hydride (NiMH), Lead Acid battery can be selected. The equivalent circuit of the input power structure is similar to *Ideal DC power supply* below, except the DC source. It needs to co-function with the Add-ons Battery module.
- **4. Ideal DC power supply**: When this option is selected, the parameter *3-Ph AC Source (RMS)* is then used to set the DC voltage rather than its literal meaning. The equivalent circuit of the input power structure is shown below.



- **5. DC power supply via analog input signal:** The DC bus voltage of the emulated system can be designated by the external analog input voltage. The equivalent circuit of the input power structure is shown below.



Note: If a strictly ideal DC power supply (without any component) is needed in trouble-shooting of controller, the *DC Bus Clamp* must be enabled by setting the parameter *DC Bus Clamp* to 1 or using the hotkey in Section 3.2.1.3.

Pr. Names	Abbr.	Unit	Value
3-Ph AC Source (RMS)		V	380

Power capacity setting — Setting range 0V~2000V

- The input power capacity can be set by this parameter.
- If the drives input power source (AC Source Select) is AC (option 0 or 1), this parameter represents the effective value (RMS) of the AC power supply; if the power source is DC (option 3 or 4), then this parameter represents the voltage of DC power supply.
- The common settings of AC power supply are: 220 V, 380V, 440V, 690V, etc.…
  The common settings of DC power supply are: 48V, 96V, 311V, 537V, 622V, etc....

Tips: When the *DC Bus Clamp* is set to 1, the DC bus voltage can be changed by changing this parameter.

Pr. Names	Abbr.	Unit	Value
3-Ph AC Source Frequency		Hz	60

AC power supply frequency Setting range 0~1000

- The frequency of the AC power supply can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
DC Bus Shift		V	0

DC Bus voltage shift Setting range 0V~2000V

- The shift voltage of the sensing circuit of the DC bus voltage can be set by this parameter. (Note: Some sensing circuits are designed to improve the accuracy by reducing the range of signal conversion, so that the minimum DC bus voltage is not 0 V.)
- For example, if the actual minimum DC bus voltage of 200V corresponds to the analog input is 0V to the control board, then this parameter is set to 200. If the *DC Bus Volt. AO Offset* is zero, the actual voltage 200V-1000V will correspond to the analog input 0V-10V.

Pr. Names	Abbr.	Unit	Value
DC Bus Volt. AO Scaling		Pu.	0.01

DC bus voltage analog output signal scaling Setting range --

- The analog output voltage scaling of the emulated DC bus voltage can be set by this parameter. This ratio should match to the sensing circuit on the control board.
- For example, if the actual DC bus voltage range is 0V-1000V and the analog input of the DC bus voltage sensing circuit on the control board is 0V-10V, then this parameter is set to 0.01.

Note: This setting is generally for the external terminal of the control board to the power stage of the drive. For some compact designs where the control board and power stage are integrated on the same circuitry, it is recommended to directly connect the MR2 analog output voltage of the emulated DC bus voltage to the corresponding analog input of the MCU on the control board.

Pr. Names	Abbr.	Unit	Value
DC Bus Volt. AO Offset		V	0

DC bus voltage analog output signal offset Setting range -10V~+10V

- The analog output voltage offset of the emulated DC bus voltage can be set by this parameter. This value should match to the sensing circuit on the control board.

> Combining the above three parameters, the analog output signal of the emulated DC bus voltage of MR2 is set as follows:
> (DC bus voltage - ***DC Bus Shift***) * ***DC Bus Volt. AO Scaling*** + ***DC Bus Volt. AO Offset***

Pr. Names	Abbr.	Unit	Value
DC Bus Volt. AO H Limit		V	10
DC Bus Volt. AO L Limit		V	-10

DC bus voltage analog output signal limits Setting range -10V ~ +10V

- The voltage limits of the analog output voltage of the emulated DC bus voltage can be set by these parameters. (Note: The analog input voltage may be limited to 5V or 3.3V in some control board designs. This setting ensures that the analog voltage from MR2 is never over the limits.)

Pr. Names	Abbr.	Unit	Value
U-Ph Current AO Scaling		Pu.	-0.2358
V-Ph Current AO Scaling		Pu.	-0.2358
W-Ph Current AO Scaling		Pu.	-0.2358

Phase current analog output signal scaling Setting range --

- The analog output voltage scaling of the emulated three-phase currents can be set by these parameters.
- The scaling and direction of the three-phase currents should match to the sensing circuit designs on the control board.
- For example, if the actual phase current is 9A and the corresponding analog input voltage on the control board is 3V, then this parameter is set to 0.3333 (9 * Scaling = 3 .) Noted that the definition of current flow direction is positive for the current flowing from drive to motor. The scaling should be -0.3333 if your definition is opposite.

> Note: This setting is generally for the external terminal of the control board to the power stage of the drive. For some compact designs where the control board and power stage are integrated on the same circuitry, it is recommended to directly connect the MR2 analog output voltage of the emulated current to the corresponding analog input of the MCU on the control board.

Pr. Names	Abbr.	Unit	Value
U-Ph Current AO Offset		V	0
V-Ph Current AO Offset		V	0
W-Ph Current AO Offset		V	0

Phase current analog output signal offset Setting range -10V ~ +10V

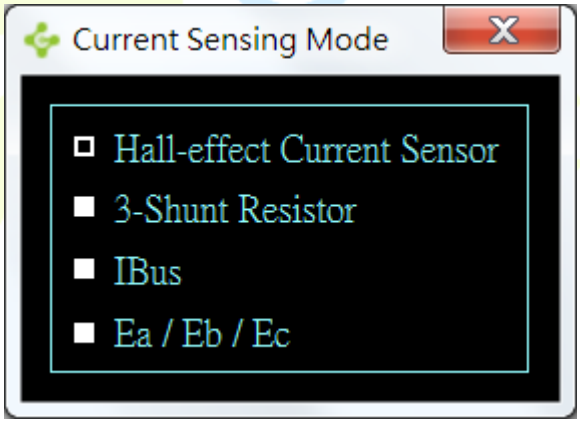
- The analog output voltage offset of the emulated three-phase currents can be set by these parameters. These values should match to the sensing circuit on the control board. (Note: For example, if the actual phase current is 0A and the corresponding analog input voltage on the control board is 2.5V, then this parameter is set to 2.5.)

Pr. Names	Abbr.	Unit	Value
U-Ph Current AO H Limit		V	10
U-Ph Current AO L Limit		V	-10
V-Ph Current AO H Limit		V	10
V-Ph Current AO L Limit		V	-10
W-Ph Current AO H Limit		V	10
W-Ph Current AO L Limit		V	-10

Phase current analog output signal limits Setting range -10V ~ +10V

- The voltage limits of the analog output voltage of the emulated three-phase currents can be set by these parameters. To avoid any damage of your control board, this setting ensures that the analog voltage from MR2 is never over the limits.

Pr. Names	Abbr.	Unit	Value
Current Sensing Mode		Pu.	0



Current detection mode selection Setting range 0 ~ 3

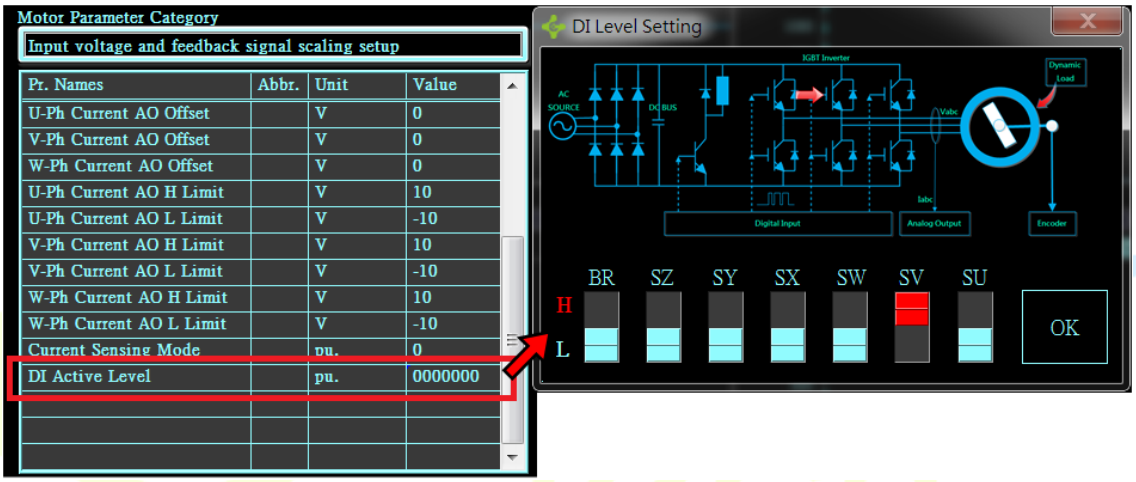
- Different types of current sensing structure can be selected by this parameter. The analog output voltage of the emulated three-phase current will send out in the form you selected.
- 0: Hall-effect Current Sensor, the three-phase currents are continuous sine waves.
- 1: 3-Shunt Resistors, the three-phase currents are discontinuous signals which is related to the ON/OFF status of the lower arm of the power devices (e.g. IGBT).
- 2: IBus (1-Shunt Resistor), the emulated current between DC bus and power devices. When the option is selected, the analog output signal is sent by the S1 terminal, and S2 and S3 are disabled.

- 3: Back EMF voltage outputs, the back EMF Ea/Eb/Ec are sent from S1/S2/S3 terminals. **When this option is selected, the parameter *Current Sensing Mode* is then used to set the back EMF rather than its literal meaning.**

Pr. Names	Abbr.	Unit	Value
DI Active Level		Pu.	0

Digital input active level — Setting range 0 / 1

- The active level of digital inputs for power devices (SX/SY/SZ/SU/SV/SW) and braking resistor (BR) can be set by this parameter.
- The setting window is popped-out when clicking this parameter. The active level of each terminal can be set individually. After setting, press OK button and the setting is downloaded to MR2 immediately.



Pr. Names	Abbr.	Unit	Value
Transistor Resistance	Ron	Ω	0

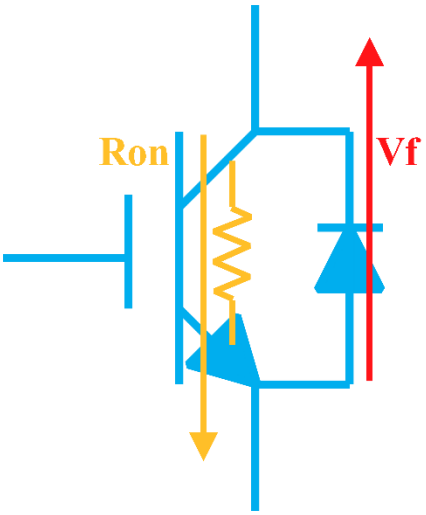
Transistor Resistance setting — Setting range 0 >=0

- The transistor resistance can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
Diode Transistor Voltage	Vf	v	0

Diode Transistor setting — Setting range 0 >=0

- The diode transistor voltage can be stimulate by this parameter as shown below:



Pr. Names	Abbr.	Unit	Value
Ignore short circuit		Pu.	0

Ignore short circuit setting Setting range 0 / 1

- In general, PWM will be output after six switches are enabled and cause short circuit initially. As set to 1, ignore short circuit setting will be set by this parameter. Noted that strong current short circuit will be triggered while short circuit occurs in any two of six switches. It is disabled in short circuit. The high/ low level trigger setting is depends on " DI Active Level".

3.2.2.2 Grid and rectifier module setup

Pr. Names	Abbr.	Unit	Value
R Phase Enable		Pu.	1
S Phase Enable		Pu.	1
T Phase Enable		Pu.	1

Three-phase input AC power source enabling Setting range 0 / 1

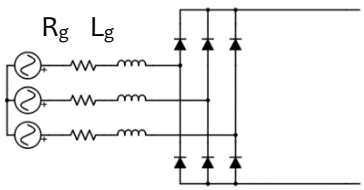
- The three-phase input AC power can be enabled or disabled by these parameters individually, where 1 is enable and 0 is disable.
- These parameters are used to inject some basic fault scenarios, e.g. interruption or phase loss, when the controller works. If more complicated non-ideal conditions are needed in controller verification, please consider the *AC source conditions* in the core module (optional module).
- The corresponding hotkey is shown in the upper right corner icon 。

Pr. Names	Abbr.	Unit	Value

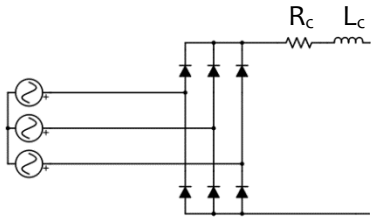
Equiv. Source Resistance	Rd	Ω	0.2

Equivalent resistance of the input power Setting range 0 ~ 100

- The equivalent resistance of the input power or the resistance of DC choke can be set by this parameter. The resistance resolution is 10^{-10}.
- The common structure of the input power is as follows:

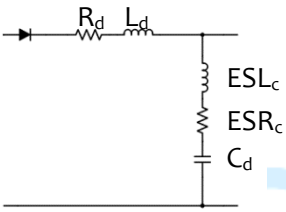


AC reactors



DC choke

- The equivalent circuit of input power in MR2 is shown as below:



- Such that the equivalent resistance can be regarded as combination of resistance of input power source and the DC choke, $R_d = R_c + 2R_g + \frac{3\omega_g L_g}{\pi}$, or only be regarded as resistance of DC choke $R_d = R_c$.

Pr. Names	Abbr.	Unit	Value
Equiv. Source Inductance	Ld	H	0.00001

Equivalent inductance of the input power Setting range 0 ~ 1

- The equivalent inductance of the input power or the inductance of DC choke can be set by this parameter. The resolution is 10^{-10}.
- As shown above, the equivalent inductance can be regarded as combination of inductance of input power source and the DC choke, $L_d = L_c + 2L_g$, or only be regarded as inductance of DC choke $L_d = L_c$.

Pr. Names	Abbr.	Unit	Value
DC Bus Capacitance	Cd	μF	800

Equivalent capacitance of DC bus capacitor Setting range 1 ~ 1000000

- The equivalent capacitance of the DC bus can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
Capacitor ESR	ESRc	Ω	0

Equivalent series resistance of the DC bus capacitor Setting range 0 ~ 100

- The equivalent series resistance of the DC bus capacitor can be set by this parameter. The resistance resolution is 10^{-10}。

Pr. Names	Abbr.	Unit	Value
Capacitor ESL	ESLc	μH	0

Equivalent series inductance of the DC bus capacitor Setting range 0 ~ 1000000

- The equivalent series inductance of the DC bus capacitor can be set by this parameter. The resistance resolution is 10^{-10}。

Pr. Names	Abbr.	Unit	Value
Current Consumption	Icons	A	0.020004

DC bus current consumption by system Setting range 0 ~ 1

- The energy consumption can be regarded as a consumption current,
- Many components of the drive, like: display panel of the operational keypad and the cooling fan, are always drawing out energy from the DC bus even when the drive is in the standby. and it can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
Braking Unit Enable		Pu.	0

Brake resistor enable Setting range 0 / 1

- The braking resistor can be enabled by this parameter. **The activation signal should be input via the BR terminal.**
- 0: Brake resistor is disabled, even when the activation signal is input via the BR terminal.
- 1: Brake resistor is enabled (the emulation depends on the value set by *Braking Unit Resistance*).

Pr. Names	Abbr.	Unit	Value
Braking Unit Resistance		Ω	100

Equivalent resistance of the braking resistor Setting range >= 1

- The equivalent resistance of the braking resistor can be set by this parameter. **The activation signal should be input via the BR terminal and set the *Braking Unit Enable* to 1.**

Pr. Names	Abbr.	Unit	Value
DC Bus Clamp		Pu.	0

DC bus voltage lockout Setting range 0 / 1

- The DC bus voltage can be kept in a fixed value. When this parameter is set to 1, the DC bus voltage is a fixed value, which is only related to the set value of *3-Ph AC Source (RMS)*; When this parameter is set to 0, the, DC bus voltage is affected not only by the set value of *3-Ph AC Source (RMS)* but also by the motor dynamics and the equivalent circuit parameters, such as equivalent resistance, inductance, capacitance.
- The corresponding hotkey is the upper right corner icon.

Pr. Names	Abbr.	Unit	Value
U Phase Cable Loss		Pu.	0
V Phase Cable Loss		Pu.	0
W Phase Cable Loss		Pu.	0

Three-phase output enable Setting range 0 / 1

- When this parameter is set to 1, three-phase output can be emulated to disconnect the motor.

Pr. Names	Abbr.	Unit	Value
Power Line Cable Loss		Pu.	0

Cable disconnection Setting range 0 / 1

- The connection or disconnection between the drive and the motor can be set by this parameter. The three-phase cables can be set individually. These parameters are used to inject some basic fault scenarios, e.g. cable loose.

3.2.2.3 Motor parameters setup

Pr. Names	Abbr.	Unit	Value
Motor OFF		Pu.	0

Motor module stop computing function Setting range 0 / 1

- Motor OFF: MR2 motor will stop computing by setting this parameter. While connect to control board in Unknow state which is not power on, it may occur short circuit. To start computing setting, please enable *stop MR2 module computing function* before power on.

Induction Motor (IM)

Pr. Names	Abbr.	Unit	Value
Stator Winding Resistance	Rs	Ω	2.608
Rotor Winding Resistance	Rr	Ω	1.71072

Stator Winding Inductance	Ls	mH	397.374
Rotor Winding Inductance	Lr	mH	377.505
Magnetizing Inductance	Lm	mH	370.408
Poles	P	Pu.	4
System Inertia	Jm	Kg·m^2	0.033
System Damping	Bm	N*m/(rad/s)	0.00825

Rotor poles of Induction Motor	Setting range	2 ~ 512
Other equivalent circuit parameters of Induction Motor		--

- If the motor type is selected as IM in the upper left corner of the operating software (Section 3.2.1.1), the equivalent circuit parameters of Induction Motor can be set in the lower left parameter pane (Section 3.2.1.4). The default parameter values are extracted from a real motor. It is convenient for first-time users to try out. Other motor information from nameplate can be called out by right-clicking on the parameter content pane and selecting "Motor Info."
- The above parameters are defined as **Line-to-Line** parameters.
- Rs is stator winding resistance; Rr is rotor winding resistance; Ls is stator winding inductance (Note: This is **NOT** leakage inductance); Lr is rotor winding inductance (Note: This is **NOT** leakage inductance); Lm is magnetizing inductance; P is rotor poles (Note: This is **NOT** pole pairs); Jm is moment of inertia of system; Bm is damping ratio of system.

Surface-mounted Permanent Magnet Synchronous Motor (SPMSM)

Pr. Names	Abbr.	Unit
Coordinate alignment	dq	pi
Stator Winding Resistance	Rs	Ω
d-axis Inductance	Ld	mH
q-axis Inductance	Lq	mH
Back EMF Source		Pu.
Back EMF constant (L-L)	Ke	V/kRPM
Rated Torque	Te	Nm
Rated Current	Irated	A
Poles	P	Pu.
System Inertia	Jm	Kg·m^2
System Damping	Bm	N*m/(rad/s)

Coordinate alignment	Setting value	0.5 / -0.5 / 1
Back EMF Source		0 / 1
SPMSM Poles		2 ~ 512
SPMSM other equivalent circuit parameters		--

- If the motor type is selected as SPM in the upper left corner of the operating software (Section 3.2.1.1), the equivalent circuit parameters of Surface-mounted Permanent Magnet Synchronous Motor can be set in the lower left parameter pane (Section 3.2.1.4). The default parameter values are extracted from a real motor. It is convenient for first-time users to try out. Other motor information from nameplate can be called out by right-clicking on the parameter content pane and selecting "Motor Info."

- Since the initial rotor position is usually required in control of PMSM and this position (angle) in control algorithm is related to the definition of coordinate transformation, the parameter *Coordinate alignment* can be used to shift the definition. The multiples of ($\frac{\pi}{2}$) are available in this parameter setting, like: 0.5 ($\frac{\pi}{2}$) 、-0.5 (- $\frac{\pi}{2}$) 、1 (π). The default coordinate transformations between three-phase and d-q axis in MR2 are as follows:

$$\text{abc to dq}: \begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\theta+\emptyset) & \cos\left(\frac{2}{3}\pi-\theta+\emptyset\right) & \cos\left(\frac{4}{3}\pi-\theta+\emptyset\right) \\ -\sin(\theta+\emptyset) & \sin\left(\frac{2}{3}\pi-\theta+\emptyset\right) & \sin\left(\frac{4}{3}\pi-\theta+\emptyset\right) \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\text{dq to abc}: \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} \cos(\theta+\emptyset) & -\sin(\theta+\emptyset) \\ \cos\left(\frac{2}{3}\pi-\theta+\emptyset\right) & \sin\left(\frac{2}{3}\pi-\theta+\emptyset\right) \\ \cos\left(\frac{4}{3}\pi-\theta+\emptyset\right) & \sin\left(\frac{4}{3}\pi-\theta+\emptyset\right) \end{bmatrix} \begin{bmatrix} V_d \\ V_q \end{bmatrix} \text{Coordinate}$$

Noted that the parameter *Coordinate alignment* is for setting $\emptyset$ in the matrix above.

- When *Back EMF Source* is set to 0, the default value calculated by the rated torque and rated current is used for back EMF constant in MR2; when *Back EMF Source* is set to 1, the *Back EMF constant (L-L)* set by user is used instead.

Default back EMF constant: $K_e = \frac{T_e}{I_{rated} \cdot \sqrt{2}} \cdot \frac{4}{3P}$

- *Back EMF constant (L-L)* is defined as the line-to-line measurement of peak-to-peak voltage when the mechanical rotational speed is 1000 RPM.

How do I measure and use the Back EMF constant?

1. Rotate the PMSM by the other motor or mechanism to its rated rotational speed;
2. Measure the voltage by any two terminals of the PMSM and read the peak-to-peak voltage ($V_{p\text{-}p}$) with an oscilloscope;
3. Convert this value to the voltage under KRPM by: $V_{p\text{-}p} \cdot \frac{1000\ \text{RPM}}{\text{Rated Speed}}$
4. Input the converted voltage into *Back EMF constant (L-L)* **and set the *Back EMF Source* to 1.**

- Rs is stator winding resistance; Ld is d-axis inductance; Lq is q-axis inductance; Te is rated torque; Irated is rated current; P is rotor poles (Note: This is **NOT** pole pairs); Jm is moment of inertia of system; Bm is damping ratio of system.
- The above parameters are defined as **Phase** parameters, except the *Back EMF constant (L-L)*.

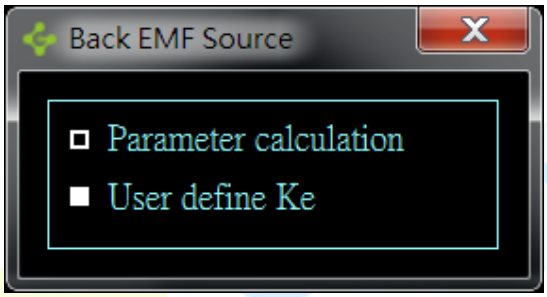
Interior-mounted Permanent Magnet Synchronous Motor (IPMSM)

Pr. Names	Abbr.	Unit
Coordinate alignment	dq	pi
Stator Winding Resistance	Rs	Ω

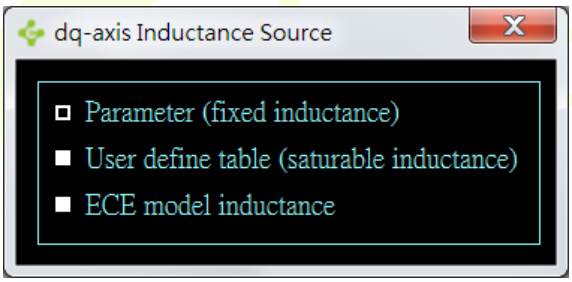
d-axis Inductance	Ld	mH
q-axis Inductance	Lq	mH
Back EMF Source		Pu.
Back EMF constant (L-L)	Ke	V/kRPM
Rated Torque	Te	Nm
Rated Current	Irated	A
dq-axis Inductance Source		Pu.
Inductance File Name	Path	--
Poles	P	Pu.
System Inertia	Jm	Kg·m^2
System Damping	Bm	N*m/(rad/s)

Coordinate alignment	Setting range	0.5 / -0.5 / 1
Back EMF Source		0 / 1
IPMSM dq-axis Inductance Source		0 / 1 / 2
IPMSM Poles		2 ~ 512
IPMSM other equivalent circuit parameters		--

Back EMF Source:



dq-axis Inductance Source:



- If the motor type is selected as IPM in the upper left corner of the operating software (Section 3.2.1.1), the equivalent circuit parameters of Interior-mounted Permanent Magnet Synchronous Motor can be set in the lower left parameter pane (Section 3.2.1.4).
- The default parameter values are extracted from a real motor. It is convenient for first-time users to try out. Other motor information from nameplate can be called out by right-clicking on the parameter content pane and selecting "Motor Info."
- Coordinate alignment can be used to shift the definition of coordinate transformation. The multiples of ($\frac{\pi}{2}$) are available in this parameter setting, like: 0.5 ($\frac{\pi}{2}$) 、 -0.5 (- $\frac{\pi}{2}$) 、 1 (π). Please refer to the SPMSM description for more details.
- The definition and usage of back EMF is the same as in SPMSM.
- The inductance variation due to magnetic saturation effect can be customized by the user. *Edit Inductance table* and *3D Inductance Table* settings can be called out from drop-down menu by right-clicking on the parameter content pane, please refer to Section 3.2.1 for more details.

- The motor inductance characteristics used in emulation can be selected by the parameter *dq-axis Inductance Source*
  - 0: Constant Ld and Lq set by user
  - 1: Ld Lq tables edited by user (saturable inductance) where the inductance values are function of d-axis and q-axis currents. The inductance table should be loaded by *Inductance File Name*, where the file name of the table is shown in its Unit pane.
  - 2: Ld Lq tables generated by ANSYS (ECE model inductance) where the inductance values are function of d-axis and q-axis currents. The inductance table should be loaded by *Inductance File Name*, where the file name of the table is shown in its Unit pane.
- The above parameters are defined as **Phase** parameters, except the *Back EMF constant (L-L)*.
- The remaining parameters are defined similarly as SPMSM.

> The default value of Back EMF constant in IPMSM is calculated by the same equation as in SPMSM, such that the default Ke for IPMSM is probably too large. It is recommended that the user manually modify the *Back EMF constant (L-L)* according to the measurement.

Synchronous Reluctance Motor (SynRM)

Pr. Names	Abbr.	Unit
Coordinate alignment	dq	pi
Stator Winding Resistance	Rs	Ω
d-axis Inductance	Ld	mH
q-axis Inductance	Lq	mH
Rated Torque	Te	Nm
Rated Current	Irated	A
dq-axis Inductance Source		Pu.
Inductance File Name	Path	--
Poles	P	Pu.
System Inertia	Jm	Kg·m^2
System Damping	Bm	N*m/(rad/s)

Coordinate alignment	Setting range	0.5 / -0.5 / 1
SynRM dq-axis Inductance Source		0 / 1 / 2
SynRM Poles		2 ~ 512
SynRM other equivalent circuit parameter		--

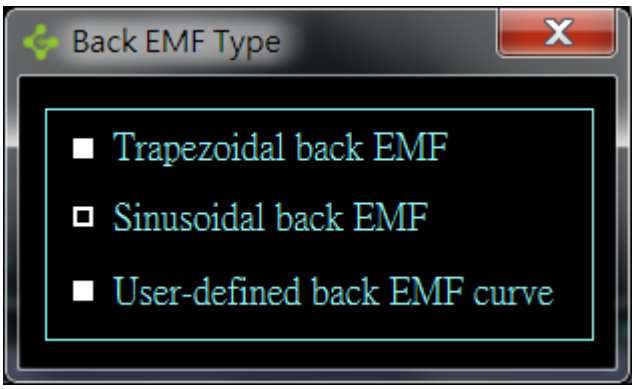
- If the motor type is selected as SynRM in the upper left corner of the operating software (Section 3.2.1.1), the equivalent circuit parameters of Synchronous Reluctance Motor can be set in the lower left parameter pane (Section 3.2.1.4).
- The parameters definition is similar to the IPMSM.

Brushless DC Motor (BLDCM)

Pr. Names	Abbr.	Unit
A Phase Stator Resistance	Rsa	Ω
B Phase Stator Resistance	Rsb	Ω
C Phase Stator Resistance	Rsc	Ω
A Phase Stator Inductance	Lsa	mH
B Phase Stator Inductance	Lsb	mH
C Phase Stator Inductance	Lsc	mH
Back EMF Source		Pu.
Back EMF constant (L-L)	Ke	V/kRPM
Rated Torque	Te	Nm
Rated Current	Irated	A
Poles	P	Pu.
System Inertia	Jm	Kg·m^2
System Damping	Bm	N*m/(rad/s)
BLDC Type		Pu.
Back EMF File Name	Path	N/A
	Setting range	2 ~ 512
BLDC Poles		0 / 1 / 2
BLDC Type		
BLDC other equivalent circuit parameter		--

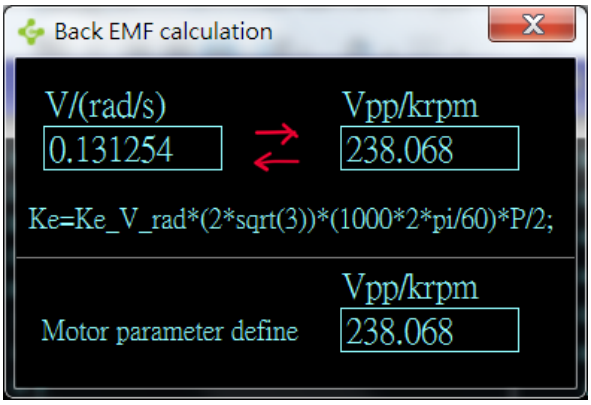
- If the motor type is selected as BLDC in the upper left corner of the operating software (Section 3.2.1.1), the equivalent circuit parameters of Brushless DC Motor can be set in the lower left parameter pane (Section 3.2.1.4).
- Different forms of back EMF of BLDC can be selected by the parameter *BLDC Type*
  - 0: Trapezoidal back EMF
  - 1: Sinusoidal back EMF
  - 2: User-defined back EMF curve. The *Back EMF Curve* settings can be called out from drop-down menu by right-clicking on the parameter content pane, please refer to Section 3.2.1 for more details.

Back EMF Type:



- Rs is stator winding resistance (phase resistance); Ls is stator winding inductance (Note: this is self-inductance minus mutual inductance, Ls=L-M); Ke is back EMF constant, and the other parameters are the same as the definition of SPMSM.

- Back EMF constant(L-L): Back EMF calculation window will pop out after clicking parameter in parameter chart. Users can see converting function in this window, between V/(rad/s) and Vpp(krpm).



3.2.2.4 Velocity sensor module and load torque setup

Pr. Names	Abbr.	Unit	Value
Motor reset position enable		pu.	0

Motor reset position enable Setting range 0 /1

- The motor reset position can be set by this parameter, enable by setting 1 and it will automatically return to 0 while disable.

Pr. Names	Abbr.	Unit	Value
Motor reset position		degree	0

Initial angle of hotkey of *Reset motor angle* Setting range 0 ~ 360

- The initial mechanical angle of the emulated motor as clicking the hotkey Motor Angle Reset (, see Section 3.2.1.3) can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
Speed Change Gears		Pu.	1

Rotational speed output ratio Setting range 0.001~1000

- The rotational speed of the emulated motor output from Encoder/Resolver can be changed by this parameter. The speed changing is like that the motor is connected by a gear box or accelerator, and the Encoder/Resolver is mounted on the gear box or accelerator.
- If the value is set to <1, such as 0.1, it will act as a gear box with gear ratio of 10:1; if the value is set to >1, such as 10, it will act as an accelerator of 1:10.

Pr. Names	Abbr.	Unit	Value
Encoder shift angle		degree	0

Encoder angle shift Setting range 0 -360

- Initial angle (mechanical angle) of the emulated motor output by the velocity sensors signal can be shifted by this parameter. The velocity sensor modules include: Incremental encoder (ABZ), Resolver, Absolute encoder with PWM outputs, Serial interface encoder, and Analog encoder.

  Please noted that the angle of Hall-effect sensor installation is about electric angle instead of mechanical angle here, such that the angle shift should be set by the other parameter: *Hall sensor shift angle*.

Pr. Names	Abbr.	Unit	Value
Encoder Type		Pu.	0

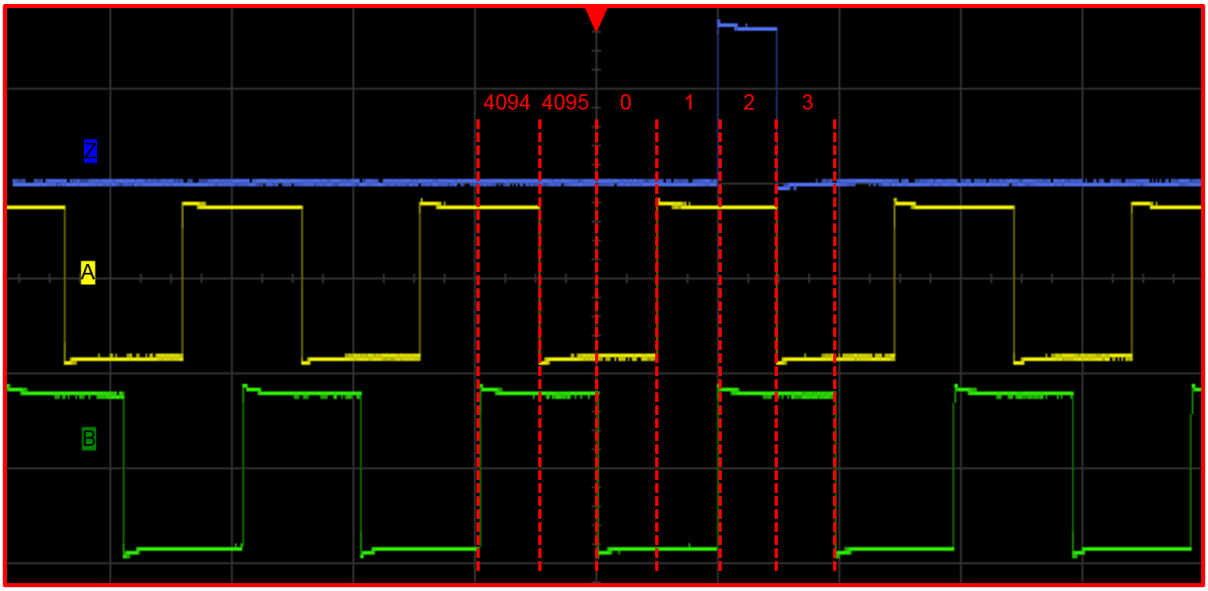
Incremental encoder (ABZ) output type setting Setting range 0 / 1 / 2 / 3

- Different types of AB pulse signals of incremental encoder can be selected by this parameter.
- 0: Pulse A leads pulse B output when the emulated rotational speed is positive (forward).
- 1: Pulse B leads pulse A output when the emulated rotational speed is positive (forward).
- 2: A for pulse output and B for voltage level, and the voltage level is HIGH when the emulated rotational speed is positive (forward).
- 3: A for pulse output and B for voltage level, and the voltage level is LOW when the emulated rotational speed is positive (forward).

Pr. Names	Abbr.	Unit	Value
Encoder Pulse/Rev.		Pu.	1024

Incremental encoder pulse number per revolution (PPR) Setting range 1 ~ 100000

- The pulse number per revolution of the emulated incremental encoder can be set by this parameter. Common settings are: 600, 1024, 2500 and so on.
- The default value is 2, meaning the trigger position of pulse Z in encoder (ABZ). It is shown as below: (in 4096 PPR)



Pr. Names	Abbr.	Unit	Value
A Pulse Duty		%	50
A Pulse shift		%	0
B Pulse Duty		%	50
B Pulse shift		%	0
Z Pulse Duty		%	25
Z Pulse shift		%	0

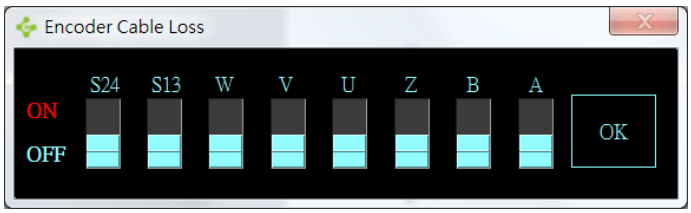
ABZ Encoder Pulse Duty	Setting range	0 ~100%
ABZ Encoder Pulse shift	Setting range	0 ~100%

- To set ratio of pulse duty and pulse shift in ABZ Encoder, visualizing it via using parameter function in software windows. Select “Reinitialize”, all parameters are reset to default setting.

Pr. Names	Abbr.	Unit	Value
Encoder Cable Loss		Pu.	0

Incremental encoder cable loss emulation Setting range 0 /1

- One of common fault injection of incremental encoder, cable loss, can be set by this parameter. Setting this parameter to 1 can enable the cable loss, which means that the pulse signal is lost (low voltage level), and disable automatically after a time period set by *ABZ Cable Loss Duration*.
  This parameter can enable different combination of cable loss by the different number:



Pr. Names	Abbr.	Unit	Value
Encoder Cable Loss Duration		mSec.	100

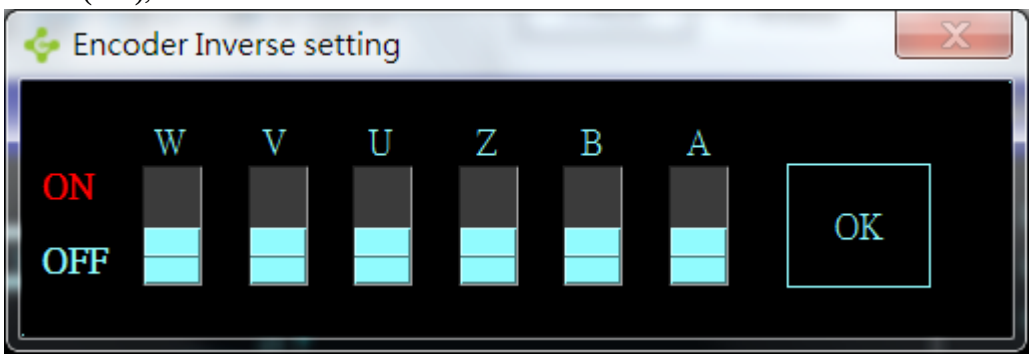
Duration of increment encoder cable loss Setting range 0 ~ 100000

- The duration of *ABZ Cable Loss* can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
Encoder Inverse		Pu.	000000

Encoder(A/B/Z/U/V/W) Inverse setting Setting range 0 /1

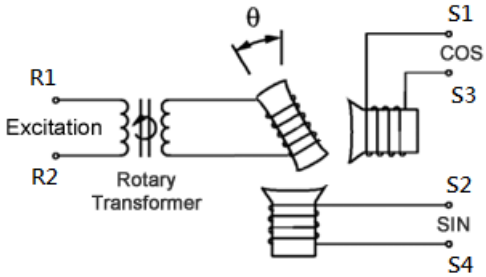
- To conform in practical application, encoder inverse output level is changeable by users. When it is set to 1(ON), the level is inverse.



Pr. Names	Abbr.	Unit	Value
Resolver angle multiple		pu.	1

Resolver angle multiple Setting range 0 ~ 20

- Angle of the emulated motor output by resolver signals can be manipulated by this parameter. Setting 1 is to maintain its original signal; setting 2 or other constant is to change its output multiples. The signal loss can be emulated by setting to 0.



Definition of MR2 Resolver

Pr. Names	Abbr.	Unit	Value
S13 Gain		Pu.	0.5
S24 Gain		Pu.	0.5

Transformer of resolver S13/S24 encoder ratio output Setting range 0 ~ 2

- To set resolver amplitude by this parameter

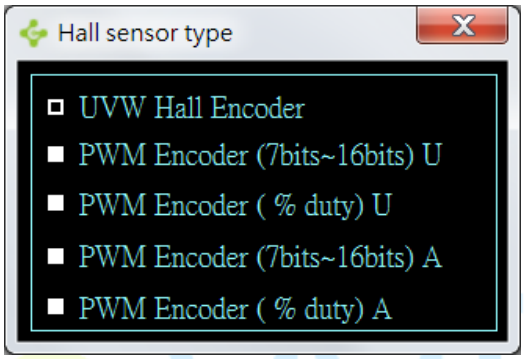
Pr. Names	Abbr.	Unit	Value
S13 shift angle		degree	0
S24 shift angle		degree	0

Phase angle shift in resolver S13/S24 encoder Setting range 0 ~ 360

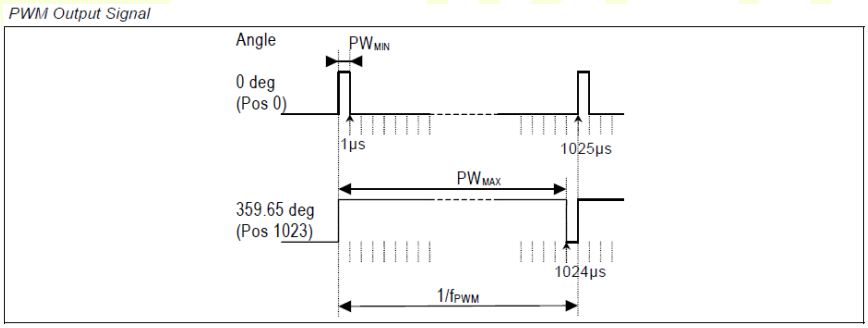
- Output signal phase angle shift in resolver S13/S24 encoder could be set by this parameter.

Pr. Names	Abbr.	Unit	Value
Hall sensor type		pu.	0

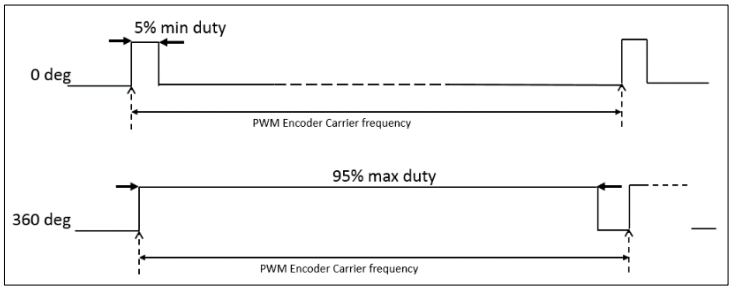
Hall sensor output signal type Setting range 0 -5



- 0: Common Hall sensor signal (UVW). The definition can be set by *Hall sensor states*.
- 1: PWM signal for absolute angle (as shown below) where the resolution can be set by bits (7bits~16bits). The signal is output from U-phase terminal.



- 2: PWM signal for absolute angle (as shown below) where the Max. and Min. effective duty ratio can be set by this parameter. The signal is output from U-phase terminal.

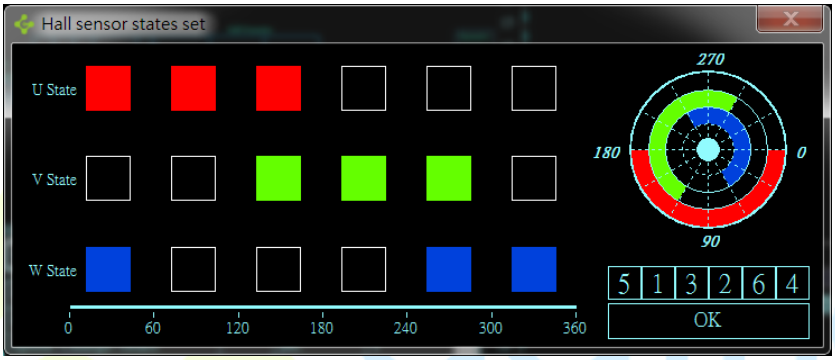


- 3: The resolution of a revolution (PWM signal) is adjustable from 7bits to 16bits, the signal output from A-phase terminal. (It is shown as below)
- 4: The maximum and the minimum effective duty ratio can be set by this parameter, the signal output from A-phase terminal. (It is shown as below)

Pr. Names	Abbr.	Unit	Value
Hall sensor states		pu.	5,1,3,2,6,4

Hall sensor output signal sequence Setting range --

- The Hall sensor output signal sequence may be altered for different motor due to different installation process. The definition can be changed arbitrarily by this parameter. The setting window pops-out as below:



Pr. Names	Abbr.	Unit	Value
U Hall sensor shift angle		degree.	0
V Hall sensor shift angle		degree.	0
W Hall sensor shift angle		degree.	0

Hall sensor corresponding angle shift Setting range 0 ~ 360

- The Hall sensor output signal corresponding angle of the motor may be altered for different motor due to different installation process. The initial angle of electric angle of the first state can be changed by this parameter. (e.g. The "5-state", where the U and W terminals is high voltage level and V terminal is low voltage level, in the *Hall sensor states* setting window shown above is corresponding to 0 degree by the default value.)

Pr. Names	Abbr.	Unit	Value
PWM Encoder resolution		bit.	10

PWM encoder resolution set by bits Setting range 7 ~ 16

- **When the *Hall sensor type* is set to 1,** the resolution can be set by this parameter (7bits~16bits).

Pr. Names	Abbr.	Unit	Value
PWM Encoder Carrier freq		Hz	1000

PWM encoder carrier frequency Setting range 600 ~ 10000

- **When the *Hall sensor type* is set to 2**, the carrier frequency can be set by this parameter. Noted that there is a conversion between these two types, e.g. 10 bits (*Hall sensor type* = 1) is corresponding to 976 Hz (*Hall sensor type* = 2). where the Max. = 1024 μs.

Pr. Names	Abbr.	Unit	Value
PWM Encoder max duty		%	95

PWM encoder maximum effective duty ratio Setting range 0 ~ 100

- **When the *Hall sensor type* is set to 2**, the maximum effective duty ratio can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
PWM Encoder min duty		%	0

PWM encoder minimum effective duty ratio Setting range 0 ~ 100

- **When the *Hall sensor type* is set to 2**, the minimum effective duty ratio can be set by this parameter.

Pr. Names	Abbr.	Unit	Value
PWM Encoder Direction		pu.	0

PWM encoder direction Setting range 0 /1

- It is set to switch direction of encoder assembling. 0: positive,1: opposite

Pr. Names	Abbr.	Unit	Value
1Vpp Encoder AB PPR		pu.	1024

Pulse number per revolution in HEIDENHAIN encoder Setting range 0 ~

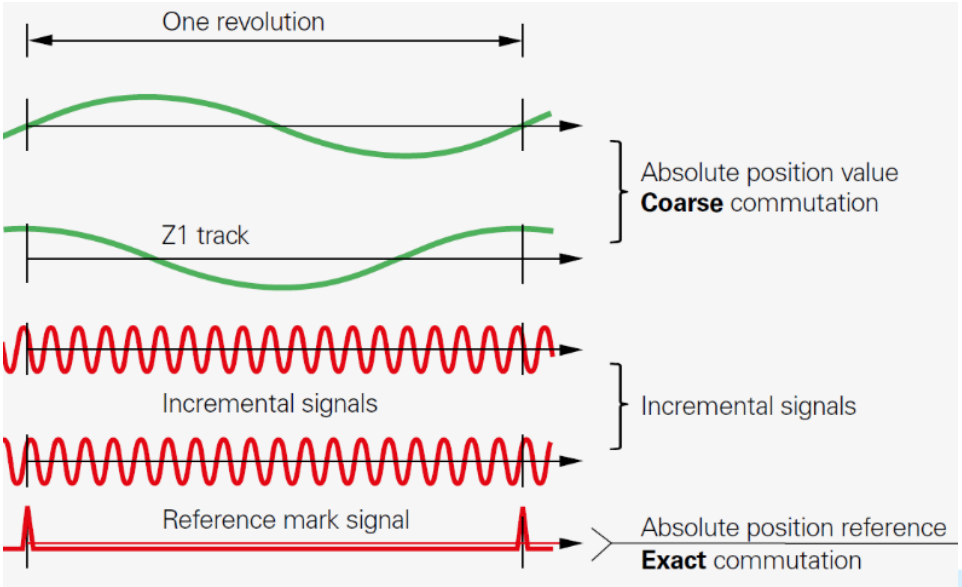
- Common setting are 1024,2048..,with pulse number per revolution in HEIDENHAIN 1Vpp encoder.

Pr. Names	Abbr.	Unit	Value
1Vpp Encoder A Gain		pu.	1
1Vpp Encoder B Gain		pu.	1
1Vpp Encoder C Gain		pu.	1
1Vpp Encoder D Gain		pu.	1

Amplitude output for HEIDENHAIN encoder Setting range 0 ~2.5

- The amplitude output limit to A,B,C,D-phase in HEIDENHAIN encoder is 2.5V.

The oscilloscope is shown as below:



Pr. Names	Abbr.	Unit	Value
Sin-Cos Encoder Multiple		pu.	1

Sin wave output value per revolution in Sin-Cos encoder Setting range 0 ~ 100

- To set the Sin wave output value in Sin-Cos encoder

Pr. Names	Abbr.	Unit	Value
Sin-Cos Encoder sin gain		pu.	1
Sin-Cos Encoder cos gain		pu.	1

Sin, cos wave amplitude output in Sin-Cos encoder Setting range 0 ~ 2.5

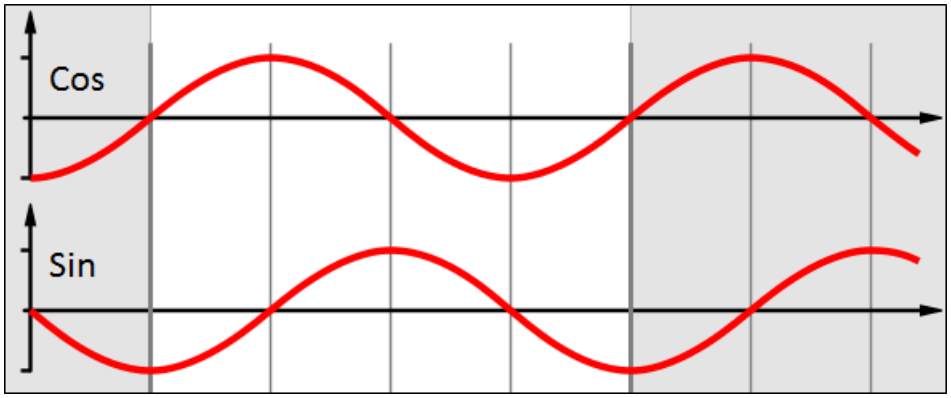
- To set sin, cous wave amplitude output in Sin-Cos encoder.

Pr. Names	Abbr.	Unit	Value
Sin-Cos Encoder sin offset		V	0
Sin-Cos Encoder cos offset		V	0

Sin, cos wave offset voltage output in Sin-Cos encoder Setting range 0 ~ 2.5

- To set sin, cos wave offset voltage output in Sin-Cos encoder.

The oscilloscope is shown as below:



Pr. Names	Abbr.	Unit	Value
Sin-Cos Encoder sin shift angle		degree	0
Sin-Cos Encoder cos shift angle		degree	0

Sin, cos wave shift angle in Sin-Cos encoder Setting range 0 ~ 360

- To set sin, cos wave shift angle in Sin-Cos encoder.

Pr. Names	Abbr.	Unit	Value
Mechanical Load	TL	Nm	0

Load torque applied to the emulated motor Setting range -10000 ~ 10000

- A constant load torque applied to the rotor of emulated motor can be set by this parameter.
- The motor is in motor mode when a positive load is applied, and the motor is in generator mode when a negative load is applied where the braking resistor should be used to prevent over voltage on DC bus.

Pr. Names	Abbr.	Unit	Value
Traction Enable		Pu.	0

Traction of motor rotor enable Setting range 0 / 1

- Enabling (set to 1) this function can drag the emulated motor to a specific rotational speed which is set by *Traction Speed*. For instance, the rotor of the emulated motor is locked when this function is enabled, and the *Traction Speed* is set to 0.
- 0: Disable
- 1: Enable

Pr. Names	Abbr.	Unit	Value
Traction Speed		RPM	0

Traction speed setup	Setting range	± 300000

- The rotational speed of motor rotor traction can be set by this parameter when *Traction Enable* is set to 1.
- When this function is enabled, the emulated encoder/resolver signals will output from its corresponding terminals if the Velocity Sensor Module (for encoder emulation) is included in your package. It can be used to verify the accuracy of the encoder card or the resolver card.

3.2.2.5 Customized analog input/output signals setup

Pr. Names	Abbr.	Unit	Value
Customized AO1 Index		Pu.	0

Customized analog output signal setting for AO1[4]	Setting range	0~41

- The categories of analog output signal can be set by this parameter.
- 0: DC BUS ; 1: S1 ; 2: S2 ; 3: S3 ; 4: Shunt 1 ; 5: Shunt 2 ; 6: Shunt 3 ; 7: IBus ; 8: TL ; 9: Te ; 10: RPM ; 11: ABZ Position ; 12: AB Pulse Counting ; 13: Turns ; 14: Motor Theta ; 15: Rotor Elec. Angle ; 16: Power(Bus) ; 17: Power(Motor) ; 18: Carry Frequency ; 19: Phase Current RMS ; 20: Power line voltage ; 21: Power line current ; 22: Idc ; 23: Id ; 24: Iq ; 25: Vd ; 26: Vq ; 27: ea ; 28: eb ; 29: ec ; 30: SU ; 31: SV ; 32: SW ; 33: SX ; 34: SY ; 35: SZ ; 36: R phase ; 37: S phase ; 38: T phase ; 39: Vab ; 40: Vbc ; 41: Vca ; Please refer to SCOPE content in chapter 3.2.1.5.

[4] [4]The content is continually being updated, different version is responds to different motor types. For more detailed information please contact our technical team.

Pr. Names	Abbr.	Unit	Value
Customized AO1 Scaling		Pu.	0

Customized analog output signal scaling for AO1	Setting range	0.0001 ~ 10000

- The analog output voltage scaling of the customized AO1 terminal can be set by this parameter. This ratio should match to the sensing circuit on the control board.

Pr. Names	Abbr.	Unit	Value
Customized AO1 Offset		V	0

Customized analog output signal offset for AO1	Setting range	-10 ~ +10

- This parameter sets the proportional value of the physical quantity of the output AO1 to the deflection quantity.

Pr. Names	Abbr.	Unit	Value
Customized AO1 H Limit		V	10
Customized AO1 L Limit		V	-10

Customized analog output signal limits for AO1 Setting range -10 ~ +10

- The voltage limits of the analog output voltage of the customized AO1 can be set by these parameters. To avoid any damage of your control board, this setting ensures that the analog voltage from MR2 is never over the limits.

Pr. Names	Abbr.	Unit	Value
Customized AO2 Index		Pu.	0
Customized AO2 Scaling		Pu.	0
Customized AO2 Offset		V	0
Customized AO2 H Limit		V	10
Customized AO2 L Limit		V	-10

Customized analog output signal settings for AO2 Setting range (Refer to AO1)

- All the parameter definitions of the customized AO2 are the same as the customized AO1.

Pr. Names	Abbr.	Unit	Value
AI TL Enable		Pu.	0

Motor load torque profile or Traction enable from analog input Setting range 0~2

- 0: Disable (The load torque is given by the other function.)
- 1: Enable (The load torque is given by analog input)
- 2: Enable (Traction Trigger is enabled by external trigger)
- If user set Traction Trigger designated by input voltage:

  ≧3.3V: Traction ON；

  ≦3.3: Traction OFF

Pr. Names	Abbr.	Unit	Value
AI TL Scaling		pu.	0
AI TL Offset		V	0

Analog input signals settings for AI TL Setting range --

- The analog input signal for AI TL is set as follows:

TL [N.m] = (Analog input voltage - ***AI TL Offset***) * ***AI TL Scaling***

Pr. Names	Abbr.	Unit	Value
AI IBus Enable		Pu.	0
AI IBus Scaling		Pu.	1
AI IBus Offset		V	0

Pumping current from emulated DC bus capacitor designated by analog input Setting range --

- Same as AI TL, the pumping current from the emulated DC bus capacitor can be designated by analog input voltage signal (terminal 23 in Section 2.3).[2] The signal is set as follows:

IBus [A] = (Analog input voltage - ***AI IBus Offset***) * ***AI IBus Scaling***

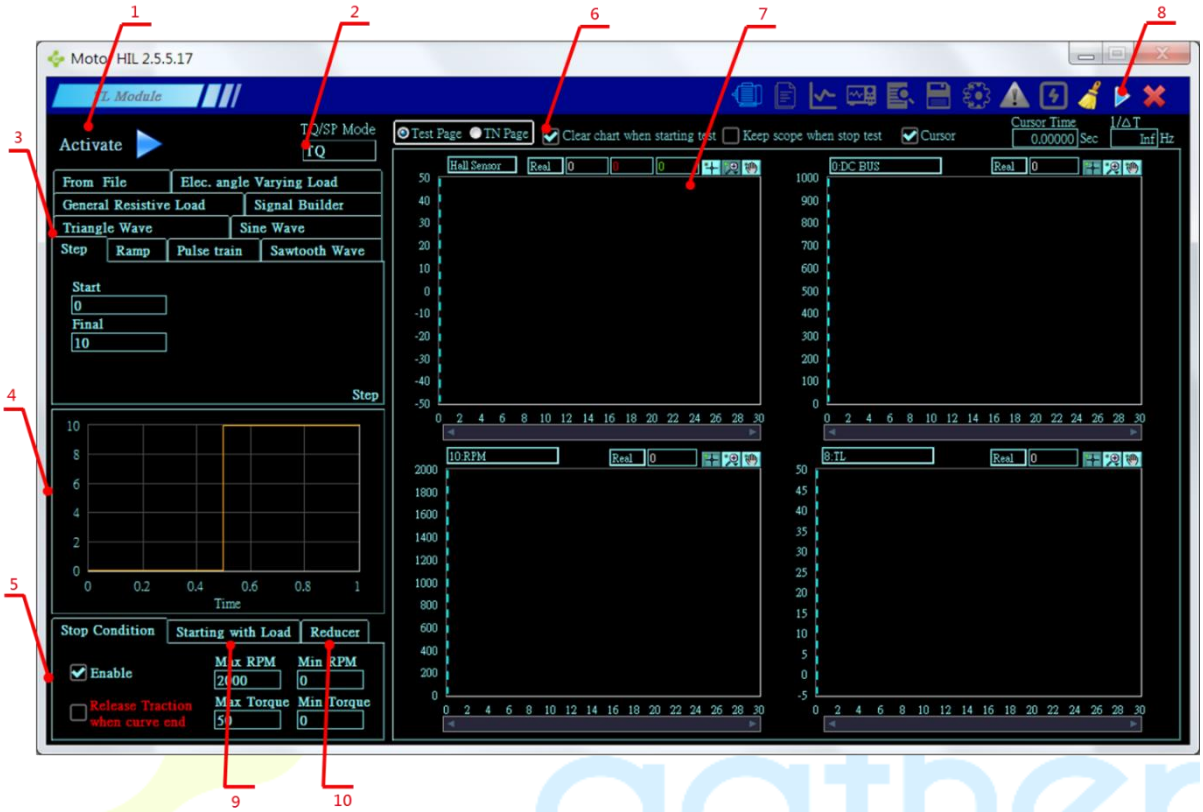
Pr. Names	Abbr.	Unit	Value
Traction delay time		ms	1
Release delay time		ms	1

Setting external trigger Traction delay time designated by analog input Setting range 0~10000

- To set external trigger Traction delay time ON/OFF.

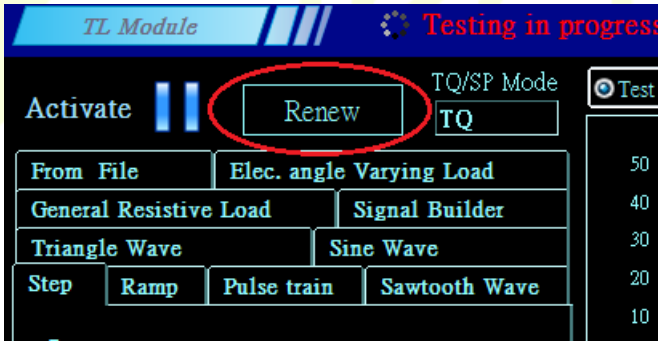
[2] This function is for a special application, it can be used for two MR2 HIL emulation with common DC bus, please contact our technical staff for more details.

3.2.3 Description of the Load Torque Module



① Activate the test (Start to apply the selected load torque (or load speed) to the emulated motor.)

Users could see *Renew* icon after activating the test. In this function, load curve will be output again with existing setting to help users connect each independent curve.



② Test mode selection

The selected curve can be used as a load torque (TQ) or a load speed (SP).

③ Load curve setting

Various signals used for load torque/speed can be selected and modified. The settings of each signal type are described later.

④ Load curve preview

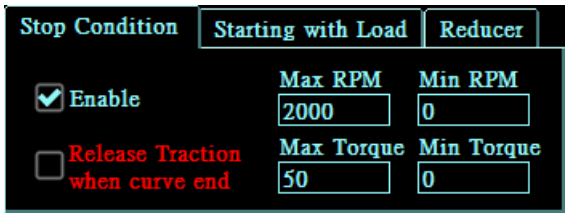
Display the setting curve.

⑤ Define the conditions to stop test

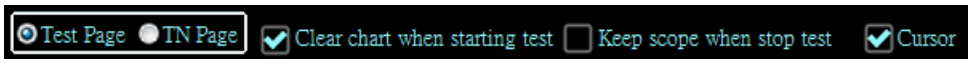
To avoid too much useless data from failure conditions (e.g. the emulated motor is not well controlled by the user's controller), some stop conditions can be set, such as upper and lower

limit of rotational speed of the emulated motor or the limits of the load torque. If the condition is met, the test is stopped immediately, and load torque/speed is released.

It is enable in SP mode only when users choose “Release Traction when curve end”. If users pick Repeat option in test mode, “Release Traction” function will be unable after speed curve is output. For example, it is available for users to lock motor in 0RPM and release in 100mSec via this test.



⑥ Test page switch



Test Page/TN Page: The test page is to monitor the motor status when the load torque/speed is activated. TN page is to show the test results on a torque-speed x-y table.
Clear chart when starting test: To clear the test results while activating the test.
Keep scope when stop test: To keep the test results while stopping the test.
Cursor: Show/hide the cursor grid in the monitor screen.(dashed line)

⑦ Monitor screen

The function of the monitor screen is the same as in the page of *MR2 System Environment Settings and Monitoring*, please refer to Section 3.2.1.5.

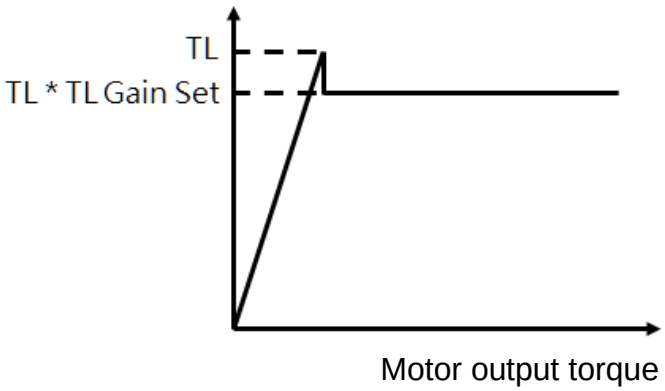
⑧ Hotkeys

The function of each hotkey is the same as in the page of *MR2 System Environment Settings and Monitoring*, please refer to Section 3.2.1.3.

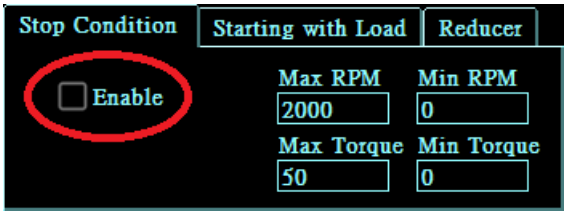
⑨ Starting with load

This function is used to simulate common motor drive applications, such as a conveyor with heavy objects and driven by a motor. When the motor drive starts slowly, the motor output torque (Te) is not large enough to overcome the static friction and the motor seems to “be locked.” The motor does not run until the motor output torque (Te) is larger than the static friction. The following are three examples of the operating mode setting:

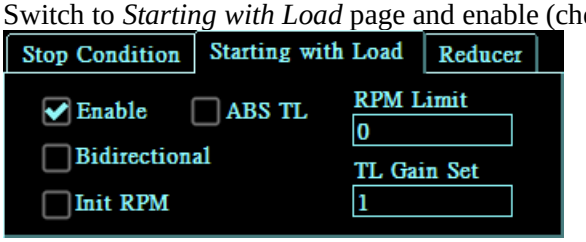
<u>Conveyor load simulation</u>



1. Disable (uncheck) the *Stop Condition* or set the condition to a wider range.

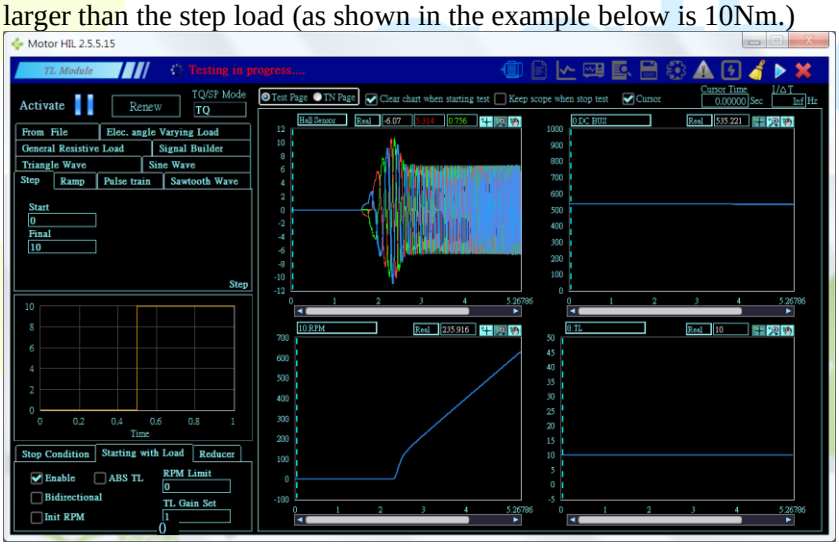


2. Switch to *Starting with Load* page and enable (check) it.



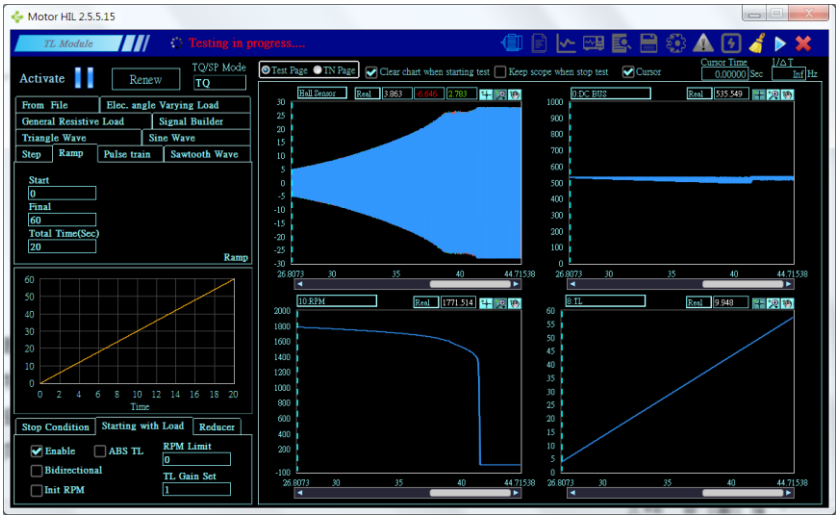
i. Scenario 1: *Starting with Load*

Choose and set the *Step* in the load curve setting, and then activate the test. (Noted that the step load here stands for the static friction force.) When the controller does not run, *Init RPM* is not Enable, and *RPM Limit* is set to 0, the rotational speed of the emulated motor will be limited to 0 RPM. After the motor drive controller starting and the motor torque increasing, the emulated motor runs when the motor torque is larger than the step load (as shown in the example below is 10Nm.)

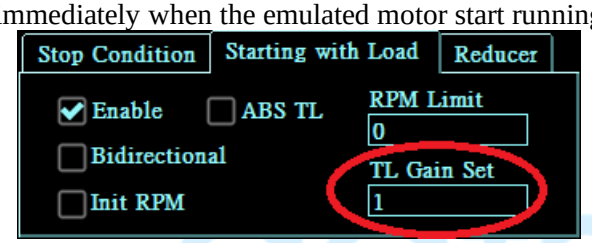


ii. Scenario 2: *Stopped by Load*

With the same setting, the controller is running before activating the test. Choose and set the *Ramp* in the load curve setting, and then activate the test. (Noted that the ramp load here stands for the gradually increased payload.) When the load torque is larger than the motor torque, the rotational speed of the emulated motor is limited by the *RPM Limit*. In this case (0 RPM), the emulated motor is blocked by the heavy load.



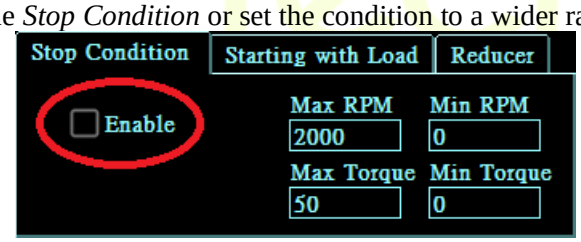
3. The *TL Gain Set* can be used to simulate the dynamic friction. If the gain is less than 1, the load torque shrinks immediately when the emulated motor start running.



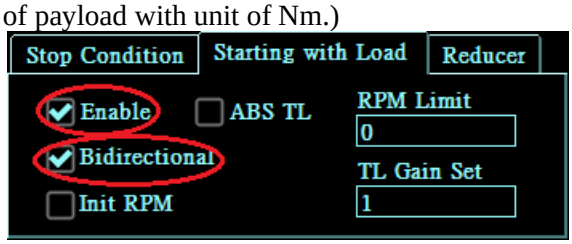
Crane lifting simulation

In addition to the conveyor load simulation, different operations can be simulated by proper settings, e.g. crane.

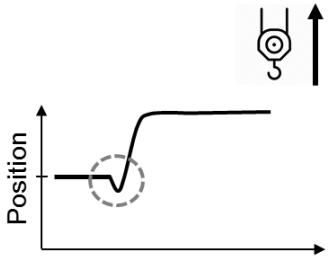
1. Disable (uncheck) the *Stop Condition* or set the condition to a wider range.



2. Switch to *Starting with Load* page and enable (check) it. Enable *Bidirectional* and set the *RPM Limit* with a non-zero constant. Define the downward of the lifting is positive, the 100 RPM in the example means the maximum rolling speed at the instant of the controller is running (the instant of MR2 receive PWM signal from controller). Choose and set the *Step* in the load curve setting, and then activate the test. (Noted that the step load here stands for the weight of payload with unit of Nm.)

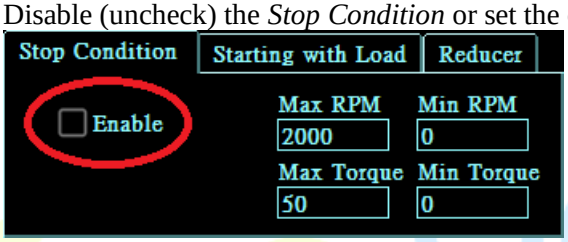


3. Without a mechanical brake, the motor torque at the instant of the controller running is less than the weight (torque) of payload, resulting in a motor torque not large enough to lift the payload. The motor starts to slide and accelerate downward until the specified limit value 100RPM. As long as the motor torque is larger than the payload, the motor starts to accelerate upward (negative speed) and controlled by the controller.

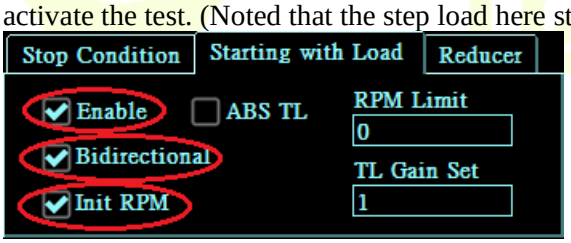


Fan with wind load simulation

1. Disable (uncheck) the *Stop Condition* or set the condition to a wider range.



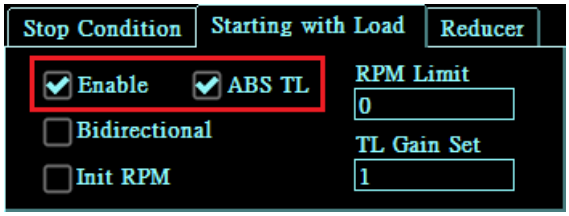
2. Switch to *Starting with Load* page and enable (check) it. Enable *Bidirectional* and *Init RPM* and set the *RPM Limit* with a non-zero constant. Define the direction of headwind is positive, the 100 RPM in the example means that the fan is blew to rotation with 100 RPM before the controller is running. Choose and set the *Step* in the load curve setting, and then activate the test. (Noted that the step load here stands for the windage with unit of Nm.)



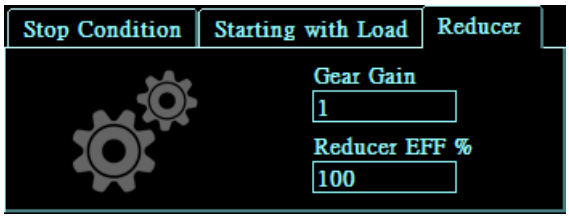
3. The motor torque at the instant of the controller running is less than the windage (torque) to the fan, resulting in a motor torque not large enough to overcome the windage load. The motor keeps reversing until the motor torque is larger than the windage load, the motor starts to accelerate (negative speed) and controlled by the controller.

Magnetic brake in simulation

1. Turn on ABS option, and the load curve will load in reverse direction as magnetic brake Load function.

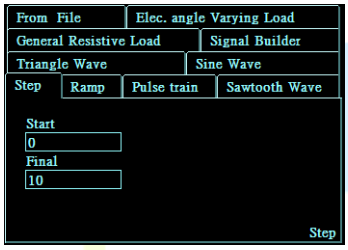


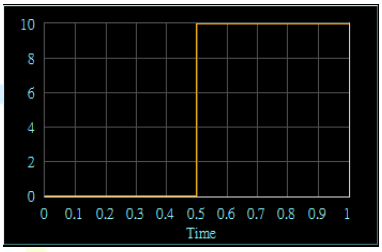
2. Speed Reduction Ratio: If Geer Reducer Ratio > 1, it is set as accelerator , If Geer Reducer Ratio < 1, it is set as reducer. Reducer EFF % represents accelerator/reducer efficiency. Put output torque multiple efficiency will get real output torque on motor.
For example, set Reducer EFF % = 100, Gear Reducer = 2, motor will make a revolution, back side motor will make two revolution, then output torque will cut to half. ; If set Reducer EFF % = 100, Gear Reducer=0.5, motor will make a revolution, back side motor will make half revolution, then output torque will switch to double. ; If set Reducer EFF % = 80, Gear Reducer=0.5, output torque will shorten from 2 times to 1.6 times(2 * 80%)



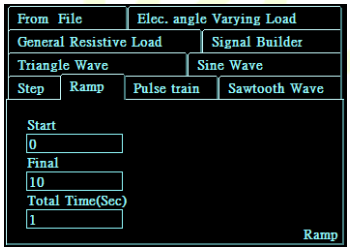
Load Curve Setting

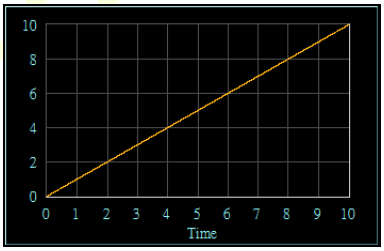
Step
The *Start* and *Final* values of the step signal can be set. The loading torque will jump from the *Start* value to the *Final* value after enabling.



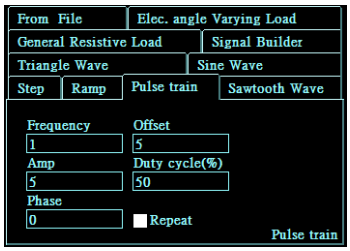


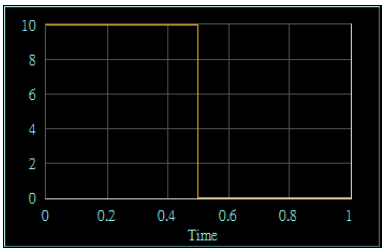
Ramp
The *Start* and *Final* values, and the duration (*Total Time*) can be set. The loading torque will increase within the duration from the *Start* value to the *Final* value after enabling.



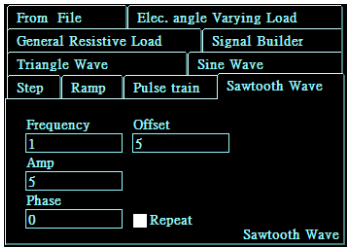


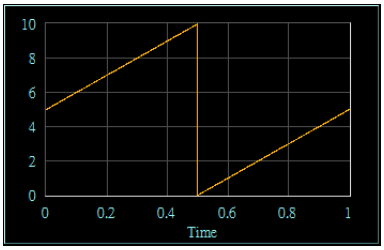
Pulse Train
The parameters of a pulse can be set, such as: the *Frequency*, *Amplitude*, *Phase*, *Offset*, and the *Duty cycle* of a pulse signal. Make sure to check the *Repeat* to enable the pulse train.



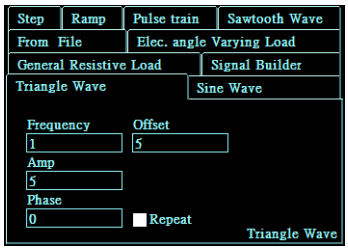


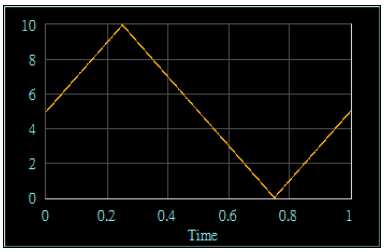
Sawtooth Wave
The parameters of a sawtooth can be set, such as: the *Frequency*, *Amplitude*, *Phase*, and *Offset*. Make sure to check the *Repeat* to enable the recursive signal.



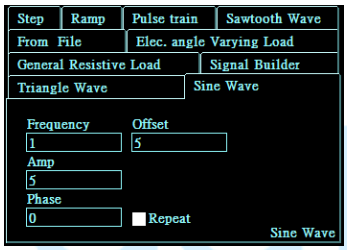


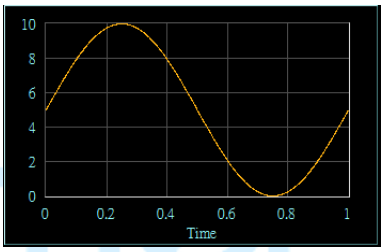
Triangle Wave
The setting of Triangle Wave is similar to Sawtooth Wave above.





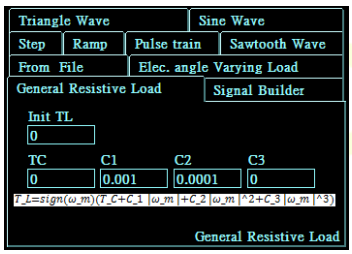
Sine Wave
The parameters of a sinusoidal signal can be set, such as: the *Frequency*, *Amplitude*, *Phase*, and *Offset*. Make sure to check the *Repeat* to enable the recursive signal.



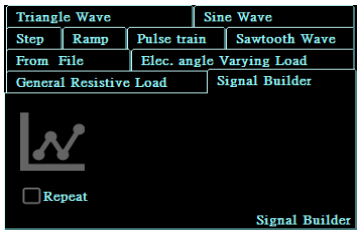


General Resistive Load
The loading torque which is proportional to the rotational speed (rad/s) of the motor can be set by this function. The initial loading torque can be specified individually, and the other parameters can be set according to the equation below:

$$T\_L=sign(\omega\_m)(T\_C+C\_1\,|\omega\_m|+C\_2\,|\omega\_m|^2+C\_3$$



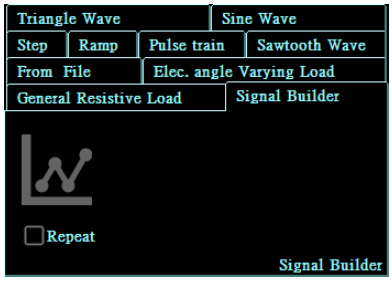
Signal Builder
An arbitrarily piecewise linear signal can be set by this function. Click on the icon and the setting window pops out as shown below.

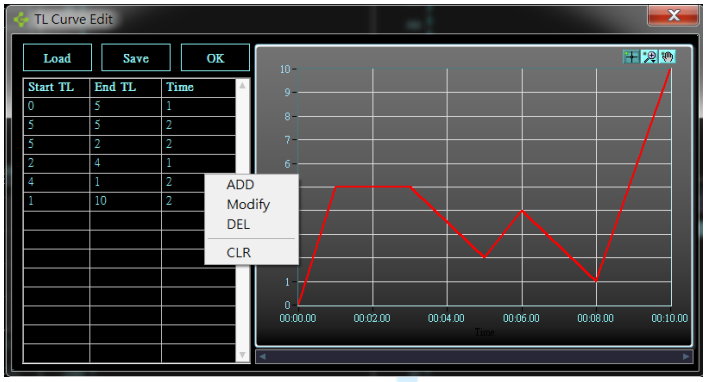


Signal Builder operation
After right-clicking on the sheet of the setting window:

ADD: Add new points
Modify: Modify the selected data
DEL: Delete the selected data
CLR: Delete all setting data

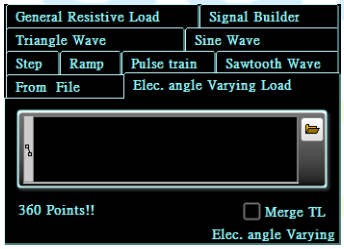
Load: Load signal data from exist file
Save: Save the setting data
OK: Update piecewise linear signal as a loading torque

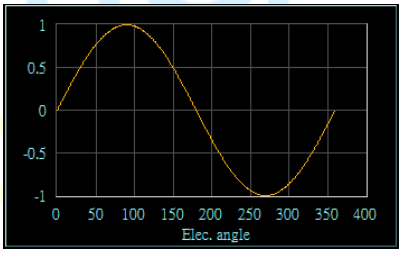




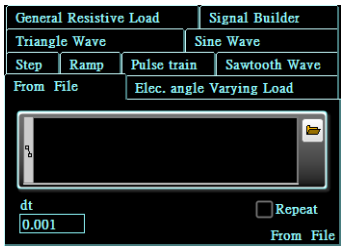
Rotor angle Varying TL
A loading torque which is varying with the mechanical angle of 0~360 degrees can be set by loading from a text file (ASCII) with a column of 360 points. This function is usually used to simulate the cogging torque of the motor.

When the *Merge TL* is checked, the users can set the other loading torque profile above. In other words, the *Elec. angle Varying TL* can be used with the other loading torque at the same time.





From File
An arbitrarily signal can be set by this function by loading from a text file (ASCII) with a column of 360 points. Different to *Elec. angle Varying TL* above, the loading torque varying with time instead of electric angle of the motor. The parameter *dt* is used to specify the time interval of each data.



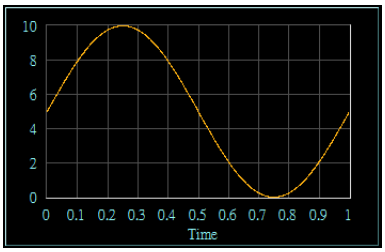
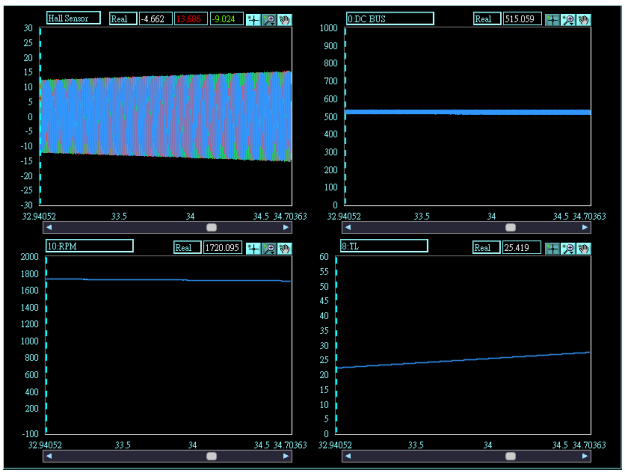


Chart
Test Chart

It contains function Cursor, Time Calculating, and Tool. When testing page is clicked, users could see the test process in analyzing.



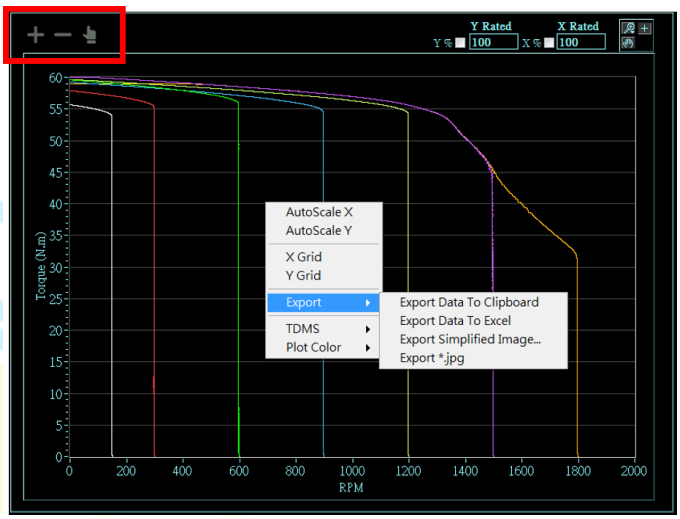
TN Curve

①Icon


: To export existed data (RPM and TL data) in TN chart.


: To delete the selected curve.

: Click and switch to different curve



② Data visualization

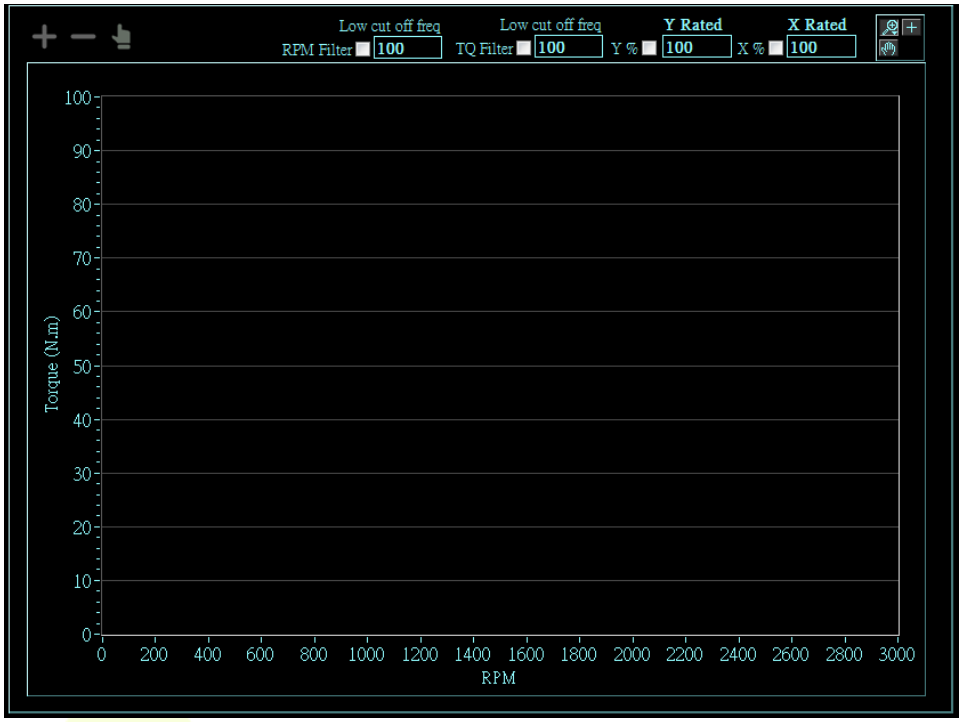
- X % : unit of X-axis
- X Rated : X-axis rated value

Value = Data_X / (X Rated) * 100%

- Y % : unit of Y-axis
- Y Rated : Y-axis rated value

Value = Data_Y / (Y Rated) * 100%

- RPM Filter : turn rotation speed into low pass filtering
- Low cut off freq : cut-off frequency of rotation speed
- Torque Filter : turn torque into low pass filtering
- Low cut off freq : cut-off frequency of Torque low pass filtering

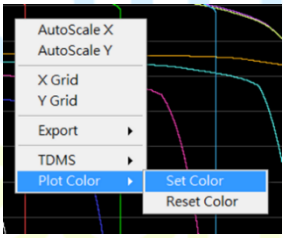


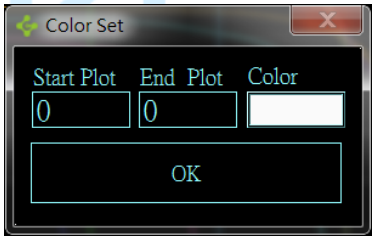
③ Right-click on Plot Color to call out the drop-down menu:

Export report in different format

To analyze testing result, users could save the load torque in *.tdms file. Additionally, for users identify each curve easier, color can be modified in this function.

It is shown as following:





1~6 is set in red, 7~12 is set in white

4 Quick Start Guide

4.1 Operation environment setup for first-time user

Only five steps are needed to connect MR2 with the controller (board) under test:

1. Motor drive controller preparing

   Please make sure the controller could work in normal operation under light-current system(ex. **±15V, ±24V**) before testing. (Note: Most motor drive controllers on the market are connected with power level, and receive voltage signal from power level. If users connect power level with controller improperly, the errors will show up. Therefore, users should prevent errors from setting hardware circuit or software installation to make system functional.)

2. Connecting

   Hardware in-the-loop system of MR series receive gate driving signal via six digital input terminals, and sent back three phase current and DC Bus as analog output terminal to motor drive controller. If users have needs for feedback signal(selected), please connect to ABZ/UVW terminal or Resolver terminal.

3. Power on

   To install the software properly please refer to chapter 3 and duplicate a copy of authorization file(MR Serial.LIC) into file "data". As enter the home page, users could see indicator which is correspond to purchased item presented on the screen.

4. Real-time emulation environment setting

   4.1 For setting motor three phase current and DC Bus voltage ratio, please refer to 3.2.2.1.

   4.2 For setting parameters related to power, please refer to 3.2.2.2.

   4.3 For setting motor equivalent circuit parameters, please refer to 3.2.2.3.

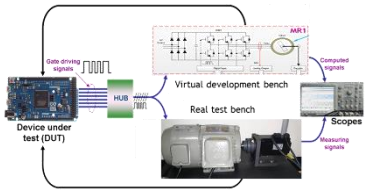
   4.4 For setting position feedback, please refer to 3.2.2.4.

   Please click the icon after setting completely, and check the motor speed and current changes while running.

5. Test start

   Click , and back to home page. After, click to enter Load Torque Module setting page. Users could complete different load tests in this setting. If users don't have Load Torque Module, please do load test with Mechanical Load. Please refer to 3.2.3.

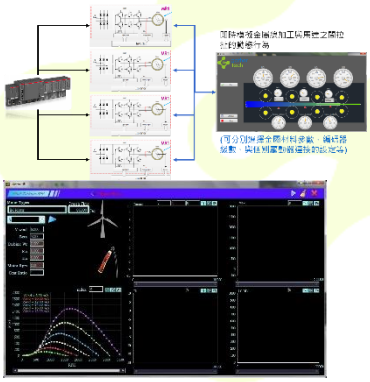
4.2 Applications



Motor drive controller development

MR2 is able to do real-time simulation on input power, power module, motor and loading operation. Besides, it will connect with the input and output terminal. Through immediately signal delivery and receiving, the motor drive controller will be operating as the entity. Before wiring up high power, it can execute performance test and primary controlling function test. Not only the risk of entity test in the initial stage can be highly decreased, but also increasing debugging efficiency and test coverage.

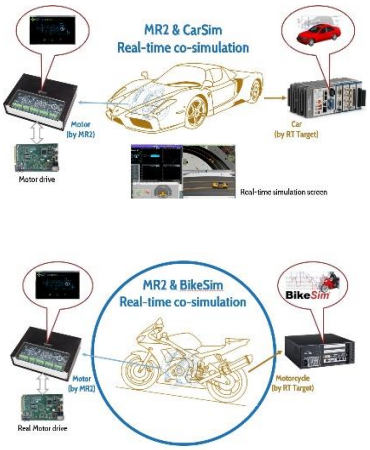
For example, the prevention of abnormal speed mode, protection mode, modulation mode, torque output performance, PID controller performance regulation, extreme performance test.



Host controller development

Besides the motor drive controller development that we mentioned, it is available to connect MR2 with dynamic system mounted at the rear of the motor, such as metal machining, crane system, wind turbine in wind field. Through connecting output and input terminal of control board circuit with MR2, users could get real-time signal in transmitting and receiving. Before the entity is installed on new equipment, users can do demonstration test and parameter adjustment via MR2. Not only lower the risk, but also shorten the time of wiring and performance tuning.

For example, via real-time simulation environment provided by MR2, users could do controller setting, testing and modifying in maximum power point tracking(MPPT)of wind drive generator, crane anti-sway system.



Electric vehicle motor drive controller development

MR2 remains expand flexibility that connecting with other real-time simulation systems. If users link MR2 to dynamic load simulation software, such as CarSim real-time co-simulation, and download data to computing platform, it will directly connect to MR2 and build a simulated environment. Note it both keeps motor dynamic simulation and mechanical dynamic simulation.

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Ver 3.0.1 Mar.2021