AN0063
Application Note

AT32 Motor Monitor Application Note

Introduction

This application note mainly introduces how to use AT32 MCU with motor control library and PC software, how to debug control parameters and how to control the motor, helping users to have a better understanding of PC software features, operation methods and usage precautions, and use PC software for debugging of motor parameters and control parameters.

Applicable products:

Part number	AT32F4xx, AT32L0xx

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1 Software and hardware requirements

A BLDC, AT-Link or J-Link, AT motor development board and AT motor control library are required. Run the executable “ArteryMotorMonitor.exe” directly, without the need for installation.

1.1 Hardware

- Windows®-based PC (Windows 8, Windows 10, Windows 11) to install user control interface program
- Micro-B USB cable to connect the development board with PC for communication
- ARTERY AT-Link or 3rd-party programmer
- 3-phase AC motor with 12V~60V rated voltage and below 30A rated current
- DC power supply
- ARTERY motor development board

1.2 Software

- ARTERY AT32 motor control demonstration project program
- Keil® µvision IDE (µvision V5.36.0.0 is used in this example)

2 User interface operation

2.1 Connection settings

After the hardware and software are well prepared, set up connection between UI and the control board as follows:

STEP-1

Connect the motor, AT-Link/J-Link and board power supply to the motor development board, and connect USART interface to PC via an USB cable.

STEP-2

Use MDK to compile demo project code, and use J-Link or AT-Link to download to the on-board chip.

STEP-3

Run ArteryMotorMonitor_V2.1.1.exe (software version: V2.1.1); click File -> Open Project and select ArteryMotorMonitor_V2.1.1.atmcx-> Open.

STEP-4

Click the update icon(1.) of Serial Port and select the corresponding serial port (2.); then click Open(3.) to enable real-time communication, as shown in Figure 1 below.

Figure 1 Communication setting

STEP-5

Click the Play button (4.) to update UI data periodically and start real-time communication with the target board, such as sending a motor startup/stop command, real-time speed adjustment, setting current PID parameters, monitoring parameters and drawing waveform.

2.2 Control and status display list

This region contains the display area of status machine and error type, and the operation area of control command button and droplist of control mode to perform motor startup/stop, encoder calibration, writing parameters to Flash, etc., or switch control mode, such as open loop control, voltage control, ID/IQ tune, torque control, speed control and position control.

2.2.1 Status machine

It displays the current status of motor control program, including the Idle, Safety ready, Angle init, Starting, Running, Free run, I_tune, Enc_align and Error.

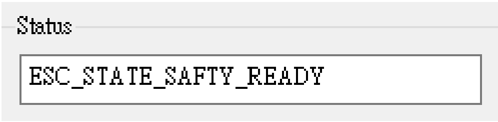


Figure 2 Status machine display area

2.2.2 Firmware control mode

It displays the firmware control mode, as shown in Figure 3. In this example, it is the six-step square-wave + Hall sensor.

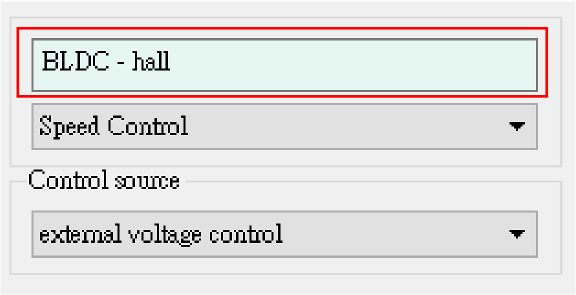


Figure 3 Firmware control mode display area

2.2.3 Error type

It displays the type of error in motor running process, including over-voltage, under-voltage, over-temperature, encoder error, Hall error and startup error.

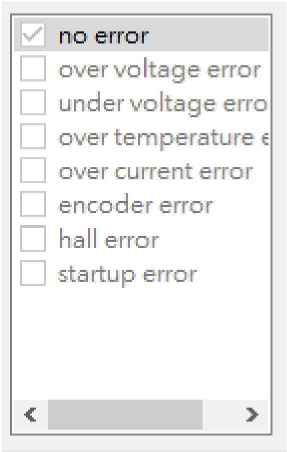


Figure 4 Error type display area

2.2.4 Control command button operation

1) This application software contains five control command buttons that are used for motor startup/stop, encoder calibration, write operation to Flash, error clearing, etc.

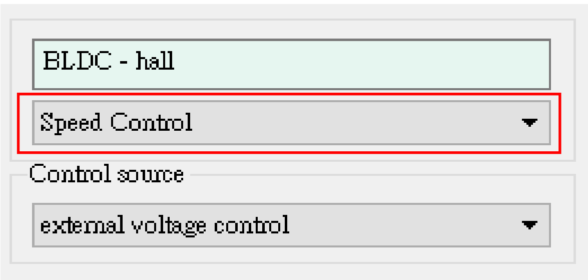
Figure 5 Control command buttons

2) Start Motor
   Click this button to start up motor.
3) Stop Motor
   Click this button to stop motor.
4) Encoder Align
   Click this button to perform encoder zero calibration (invalid in open loop control mode).
5) Write Flash
   When parameters have been debugged or in case of modifying motor parameters, click this button to write parameters to Flash. After this command is executed, the controller will remember these parameters so that users do not need to re-debug motor parameters for the next operation.
6) Fault Ack
   Click this button to clear the current error status.

2.2.5 Control mode droplist

Totally seven control modes are optional, including open loop control, voltage control, ID/IQ tune, torque control, speed control and position control, and parameters are different in different modes. Therefore, this area should be used together with the parameter setting page, which is detailed in Section 2.4.

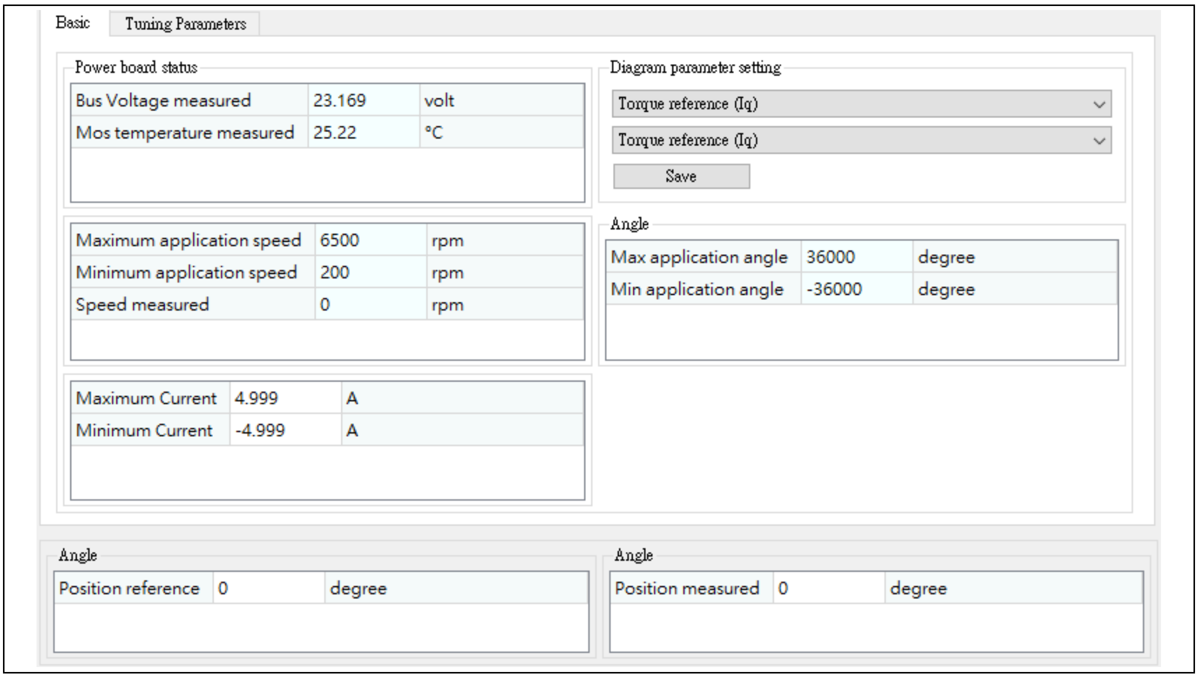
Figure 6 Control mode droplist



2.3 Basic parameters

The basic parameters display/setting page contains Vdc voltage and MOS temperature monitoring, maximum/minimum application speed, maximum/minimum current, maximum/minimum application angle, target angle/speed/torque, and drawing area channel selection.

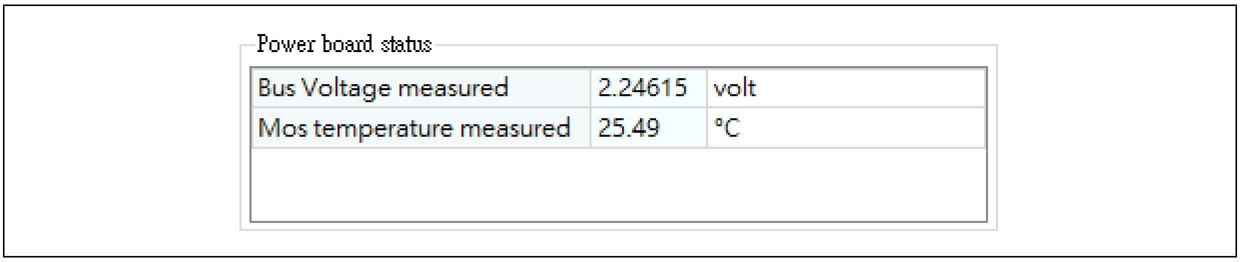
Figure 7 Basic parameters setting page



2.3.1 Voltage and temperature display

It displays the real-time voltage (unit: Volt) and MOS temperature (unit: °C) to monitor and check for over-voltage, under-voltage or over-temperature. In case of any error, it will be displayed in the error list as mentioned in Section 2.2.3.

Figure 8 Voltage and temperature display area



2.3.2 Maximum/minimum speed

The maximum/minimum speed and current speed (unit: rpm) are displayed in this area. This interface only supports read access, and modification to the maximum/minimum speed should be performed in firmware, for example, modifying the MAX_SPEED_RPM and MIN_SPEED_RPM in *mc_ctrl_param.h* file.

Figure 9 Maximum/minimum/current speed display area

Maximum application speed	4200	rpm
Minimum application speed	10	rpm
Speed measured	0	rpm

Figure 10 Modify the maximum/minimum speed definition

mc_ctrl_param.h

```
63  #define MIN_SPEED_RPM                    (10)
64  #define MAX_SPEED_RPM                    (4200)
65  #define MIN_CONTROL_SPEED                (120)
```

2.3.3 Maximum/minimum current

The maximum/minimum current (unit: ampere) for motor control can be read and set in this area. The current can be adjusted according to the motor characteristics or the driver board. By default, the maximum/minimum current set by firmware is read. To adjust the current, double click to change the value, and the bottom LOG displays a message after successful setting.

Figure 11 Maximum/minimum current display area

Maximum Current	4.98962	A
Minimum Current	0.997925	A

Figure 12 LOG message after successful current setting

	Time	Motor	Message
1	17:28:59		Set REG 36 = 3932.16:OK
2	17:28:52		Set REG 36 = 3276.8:OK

2.3.4 Maximum/minimum application angle (encoder mode)

The maximum/minimum application angles (unit: degree) for motor control are displayed in this area. This interface only supports read access, and modification to the maximum/minimum application angles should be performed in firmware, for example, modifying the MAX_POSITION_ANGLE and MIN_POSITION_ANGLE in *mc_ctrl_param.h* file.

Figure 13 Maximum/minimum application angle display area

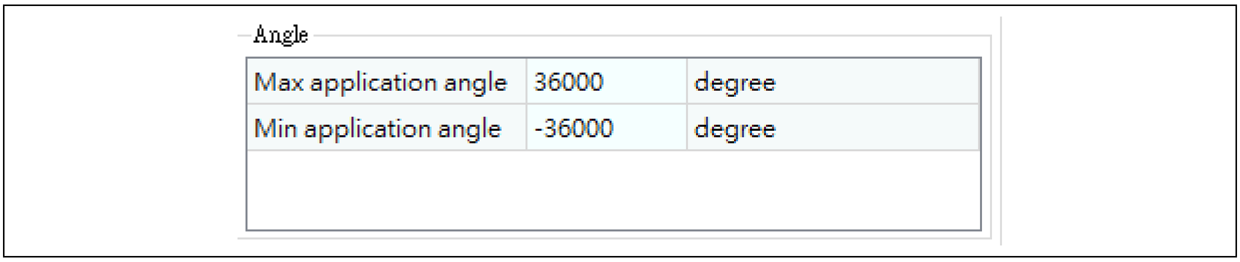
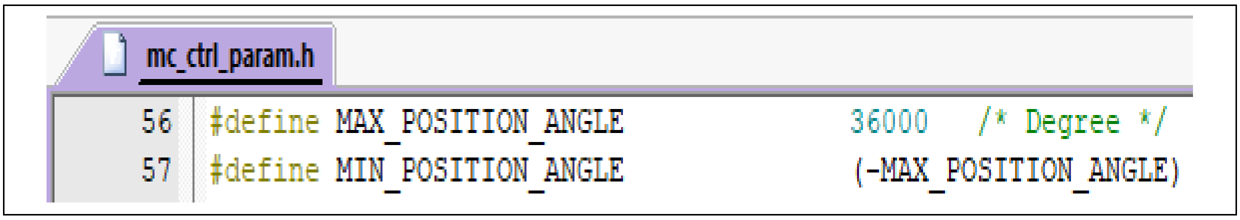


Figure 14 Modify the maximum/minimum application angle



2.3.5 Target speed/torque setting

Different control parameters are set for different control sources. For example, the "Target speed" is displayed in Speed Control mode, as shown in Figure 15, and the "Torque reference" is displayed in Torque Control mode, as shown in Figure 16.

The target speed is communicated in rpm, and the torque reference is communicated in amperes. There are two available control sources, including the external control and software control.

1) External voltage control

This application software supports external control source. Open the droplist of "Control source" and select "external voltage control", so that users can adjust the speed or torque via external voltage. The target speed or torque reference field displays the converted control speed or torque at the current control voltage.

Note: This field cannot be modified in the external control source mode.

Figure 15 Speed control mode (external voltage control)

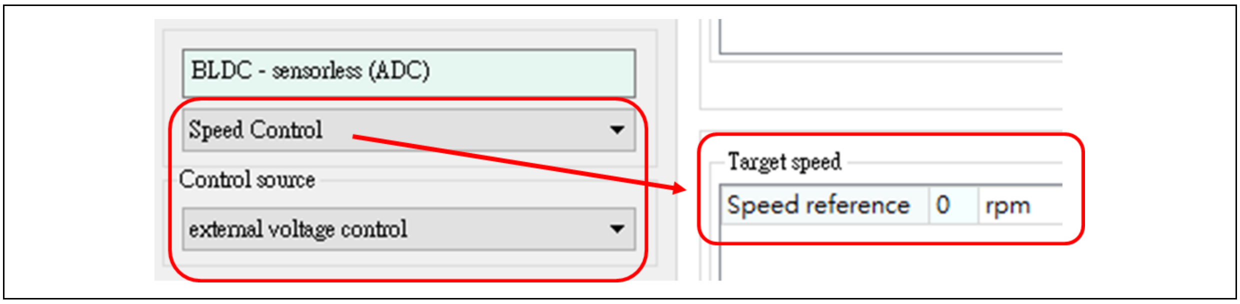
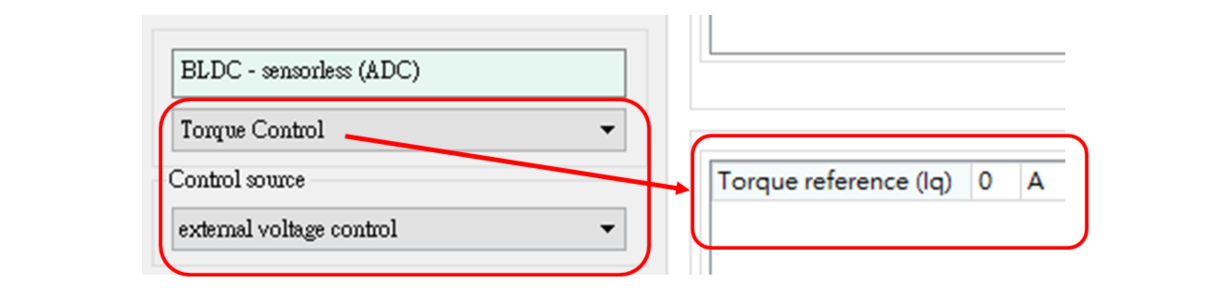


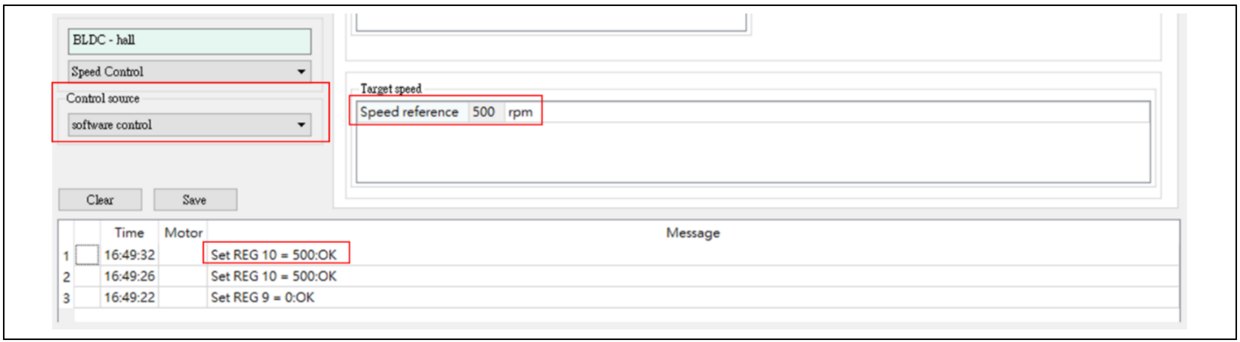
Figure 16 Torque control mode (external voltage control)



2) Software control

The software control mode is selected, by default. Open the droplist of “Control source” and select “Software control”, as shown in Figure 17. In this mode, users can change the target speed/torque (double click this field to change the value) in UI interface to adjust the motor control speed/torque. The bottom field displays a message after successful setting.

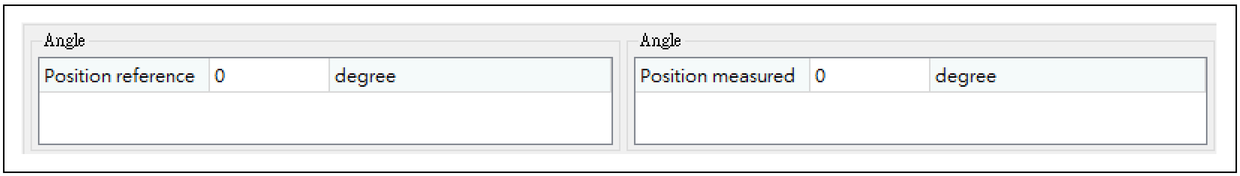
Figure 17 Set target speed in software control mode



2.3.6 Position reference/position measured (encoder mode)

The position reference and position measured are displayed when the position control mode is selected, as shown in Figure 18. The position reference is communicated in degrees. In position control mode, users can change the position reference (double click this field to change the value) in UI interface to adjust the motor rotor position. The bottom field displays a message after successful setting.

Figure 18 Position reference and position measured



2.3.7 Waveform drawing and parameter setting

This application supports dual-channel waveform drawing, as shown in Figure 19. The droplists “Ia” and “Ib” are used to select channel 1 and channel 2 related parameters, respectively. Select the required parameters and then click “Save”.

Click the drawing icon as shown in Figure 20 to generate a new window and draw the waveform.

Figure 19 Set drawing channel parameters

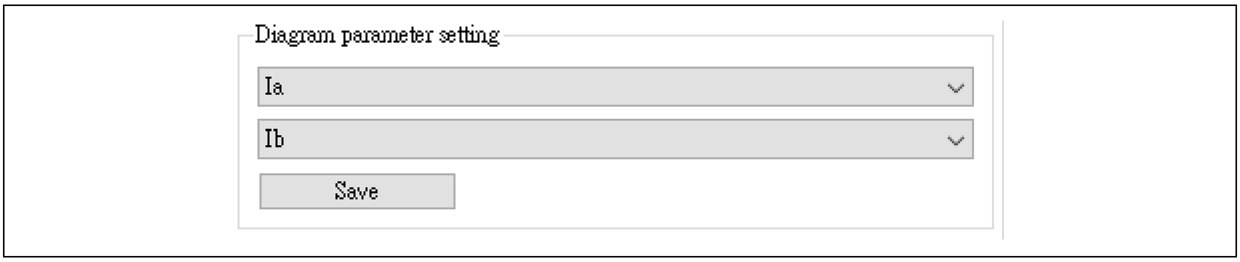
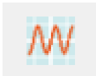


Figure 20 Waveform drawing icon



As shown in Figure 21, the left vertical axis represents channel 1 and the right represents channel 2. The waveform color is the same as that of the axis. For example, channel 1 is represented by “Ia (A)”, and the corresponding waveform is drawn in green; channel 2 is represented by “Ib (A)”, and the corresponding waveform is drawn in purple. Besides, the sampling rate of the waveform is correlated to the PWM interrupt frequency. If the PWM interrupt frequency is 20 KHz, the sampling period is 50 us (maximum 32s can be recorded).

Figure 21 Waveform drawing

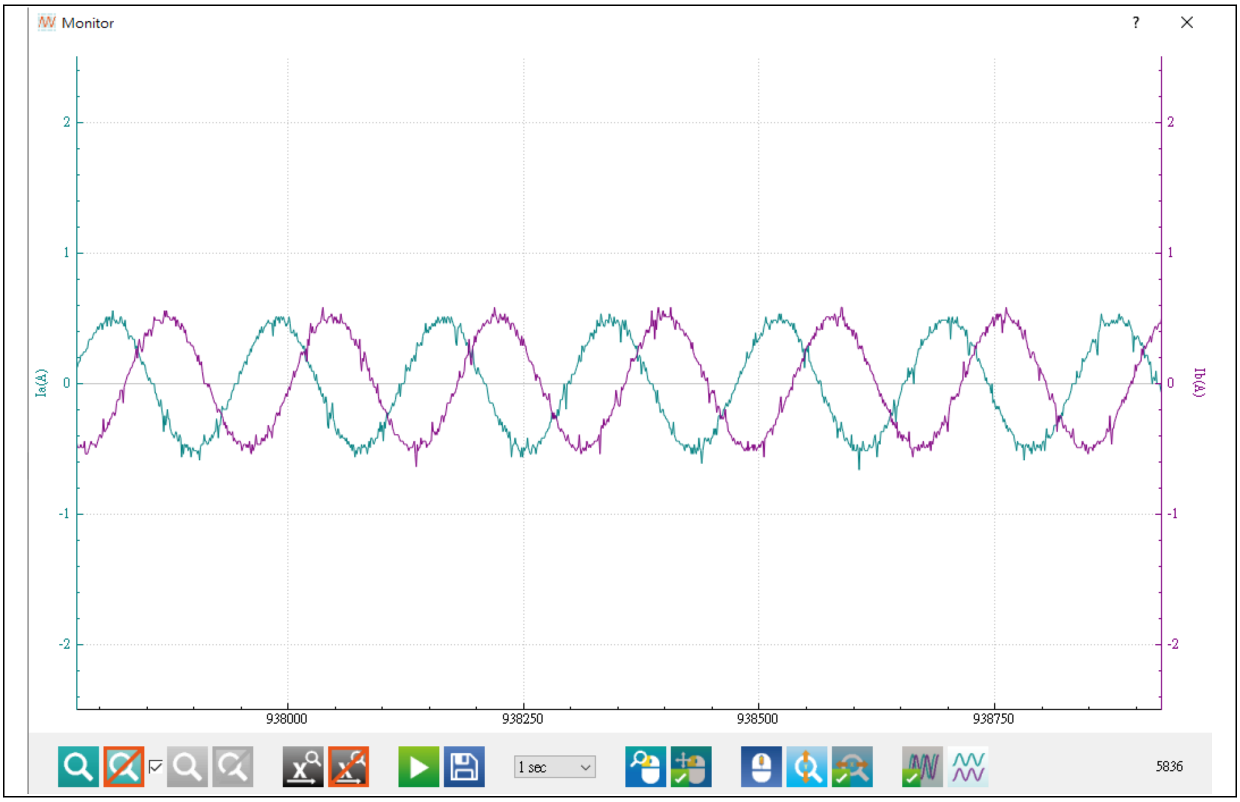
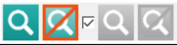
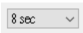


Table 1 lists the waveform drawing buttons.

Table 1. Waveform drawing buttons

Icon	Description
	Set the display range of channel 1 vertical coordinate
	Disable zoom-in (channel 1 vertical coordinate)
	Set the display range of channel 2 vertical coordinate
	Disable zoom-in (channel 2 vertical coordinate)
	Tick to synchronize channel 1 and channel 2 coordinates
	Untick to cancel synchronization of channel 1 and channel 2 coordinates
	Set the display range of horizontal coordinate
	Disable horizontal axis zoom-in
	Start waveform update
	Stop waveform update
	Save the current waveform (after waveform update is stopped)
	Display range of waveform horizontal coordinate (drop-down menu: 1s, 2s, 4s, 8s, 16s and 32s)
	Right click to zoom in
	Right click to move up/down and left/right
	Switch mouse wheel functions (zoom in/out, or move horizontally/vertically)
	Slide the mouse wheel to zoom in/out the horizontal and vertical axes simultaneously
	Slide the mouse wheel to zoom in/out the vertical axis
	Slide the mouse wheel to zoom in/out the horizontal axis
	No reaction when slide the mouse wheel
	Slide the mouse wheel to move the horizontal and vertical axes simultaneously
	Slide the mouse wheel to move the vertical axis
	Slide the mouse wheel to move the horizontal axis
	No reaction when slide the mouse wheel
	Waveforms of channel 1 and channel 2 are displayed on the same coordinate axis
	Waveforms of channel 1 and channel 2 are displayed on different coordinate axes

2.4 Parameter setting

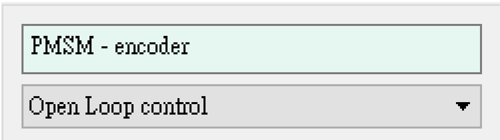
It is an advanced parameter setting page. Users can refer to Section 2.2.5 to modify parameters on this page, and start motor to confirm response or click drawing icon to view the response waveforms after debugging. For details about waveform drawing, please refer to Section 2.3.7.

2.4.1 Open loop control

Select "Open loop voltage" in the open loop control mode to drive the motor without position sensor, and check whether the motor runs properly and whether the running direction is correct. The encoder also can be used to check whether the running direction in encoder mode is correct. In sensorless FOC mode, the "Open loop voltage" mode is also used for preliminary adjustment of estimator parameters. The open loop voltage and open loop angle increment are increased from 0 according to the motor running speed and motor phase current value.

STEP-1: Select "Open Loop control".

Figure 22 Select open loop control



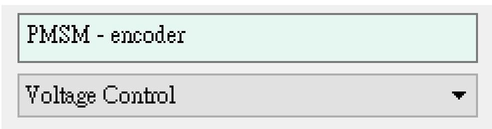
STEP-2: Slowly increase the "Open Loop Voltage" and "Open Loop Angle Increments" values and observe the current until the motor starts running properly (set the open loop voltage value appropriately to prevent overheating damage to the motor).

Figure 23 Open loop control parameters

2.4.2 Voltage control

Based on the position sensor, the voltage control mode can be selected to control motor D/Q shaft voltage.
STEP-1: Select "Voltage Control".

Figure 24 Select voltage control



STEP-2: Adjust the Q shaft voltage to drive the motor to run; set the D shaft voltage to position the motor magnetic pole to D shaft.

Figure 25 Voltage control parameters

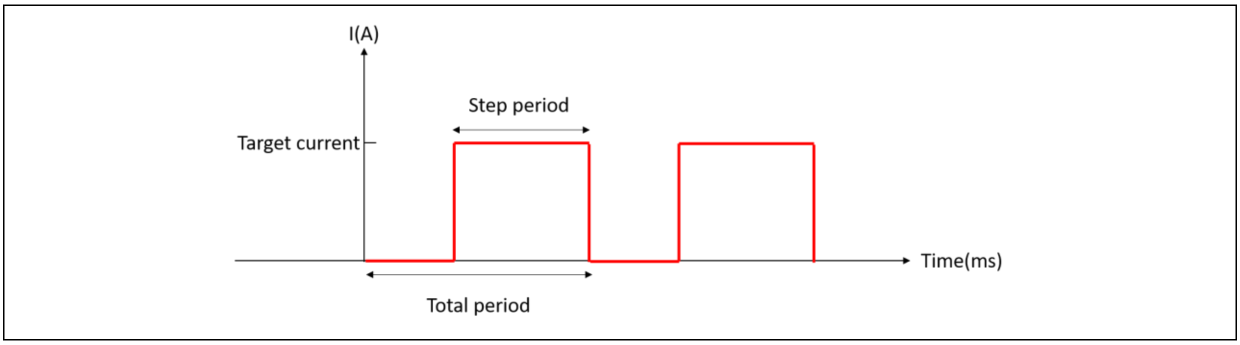
Voltage control

Vq reference	1	V
Vd reference	0	V

2.4.3 IQ tune

A step current is generated in IQ Tune mode, as shown in Figure 26. Parameters related to the step current are adjustable. The step current is generated to help check the current response after adjusting PID parameters of Q shaft current.

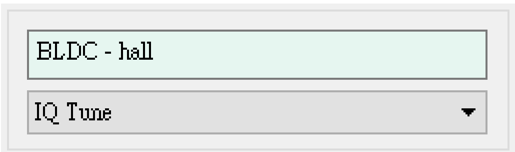
Figure 26 Schematic diagram of step current



Follow the below steps:

STEP-1: Select “IQ Tune”.

Figure 27 Select IQ Tune



STEP-2: Set PID parameters and step current related parameters, as shown in Figure 28.

Figure 28 Q shaft PID parameters and step current related parameters

Current control

Flux KP	25000	
Flux KI	3000	
Flux KP DIV	2048	
Flux KI DIV	4096	

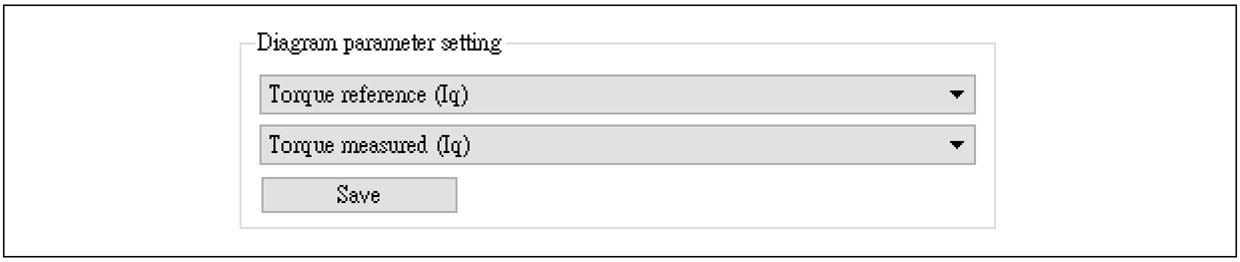
Unit step config

Current Tune target current	0.999	A
Current Tune total period	100	ms
Current Tune step period	2	ms

STEP-3: Click “Start Motor”.

STEP-4: Set “Torque reference(Iq)” and “Torque measured(Iq)” in “Diagram parameter setting”, and then click “Save”.

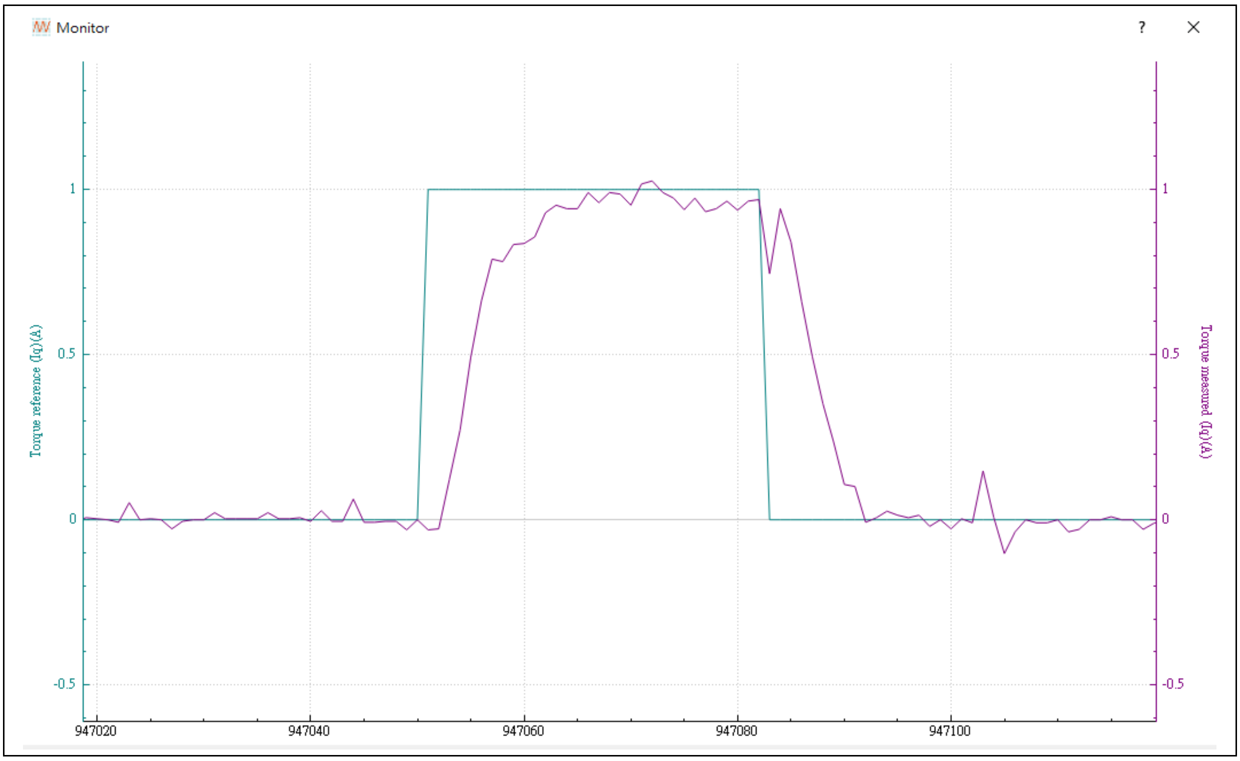
Figure 29 Modify channel monitoring parameters (IQ Tune)



STEP-5: Click the drawing icon to open the waveform window.

STEP-6: Check whether the current response is as expected, as shown in Figure 30. If it is not as expected, click to stop the motor and repeat STEP-2~STEP-6.

Figure 30 IQ tune waveform



2.4.4 ID tune

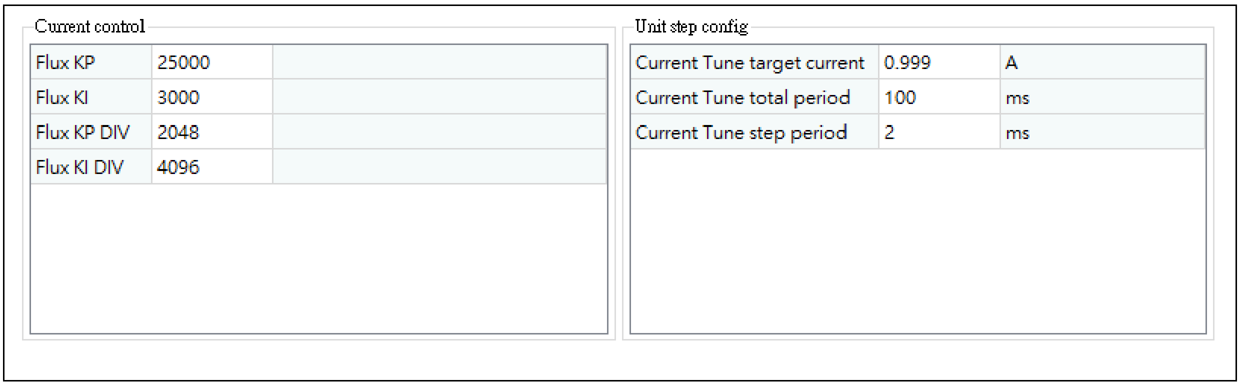
A step current is generated in ID Tune mode, as shown in Figure 26. Parameters related to the step current are adjustable. The step current is generated to help check the current response after adjusting PID parameters of D shaft current.

Follow the below steps:

STEP-1: Select “ID Tune”

STEP-2: Set PID parameters and step current related parameters, as shown in Figure 31.

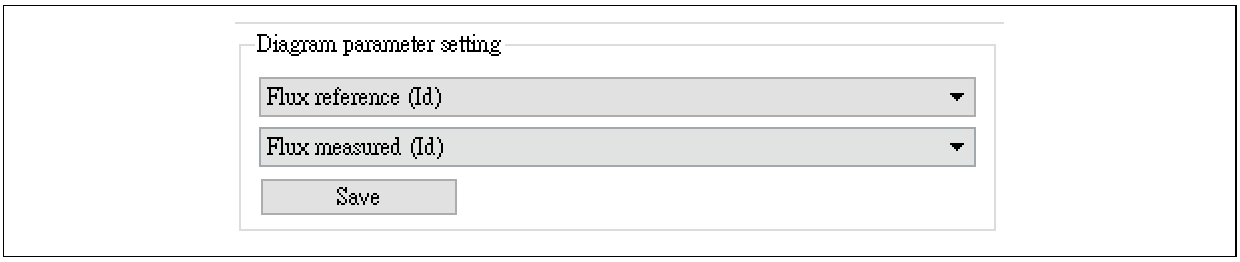
Figure 31 D shaft PID parameters and step current related parameters



STEP-3: Click “Start Motor”.

STEP-4: Set “Flux reference(Id)” and “Flux measured(Id)” in “Diagram parameter setting”, and then click “Save”.

Figure 32 Modify channel monitoring parameters (ID Tune)



STEP-5: Click the drawing icon to open the waveform window.

STEP-6. Check whether the current response is as expected. If it is not as expected, click to stop the motor and repeat STEP-2~STEP-6.

Note: Six-step square-wave control mode does not have D shaft current adjusting function (ID Tune); therefore, the ID tune waveform diagram is not applicable in this case.

2.4.5 Current loop control

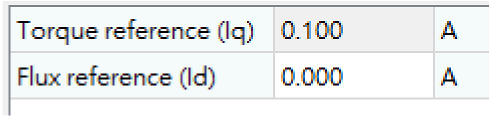
In current loop control mode, users can adjust the torque reference to control the torque, and check the response through waveform drawing.

Follow the below steps:

STEP-1: Select “Torque Control”.

STEP-2. Select “Software control” in “Control source” and then set the “Torque reference”.

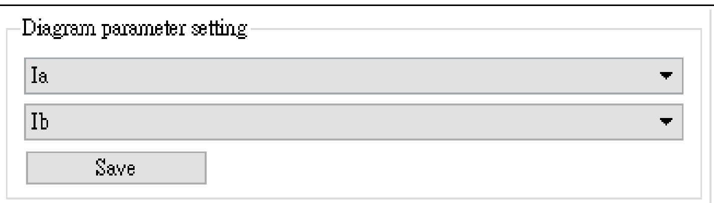
Figure 33 Set torque/flux reference



STEP-4: Click “Start Motor”.

STEP-5: Set the “Ia” and “Ib” in “Diagram parameter setting”, and then click “Save”.

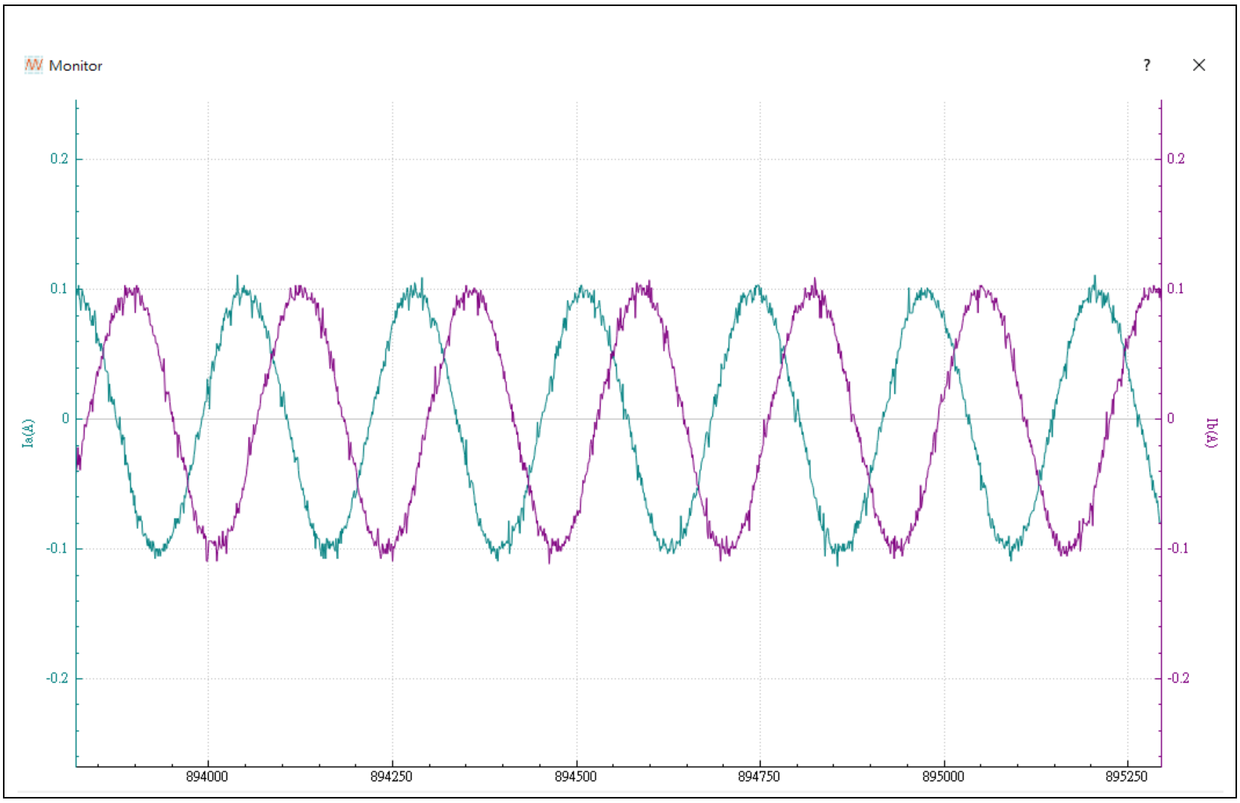
Figure 34 Modify channel monitoring parameters (current loop control)



STEP-6: Click the drawing icon to open the waveform window.

STEP-7: Check whether the current waveform is as expected, as shown in Figure 35.

Figure 35 Waveform in current loop control mode



2.4.6 Speed control

In speed control mode, users can adjust the speed PID parameters, acceleration and deceleration, and check the response after adjustment through waveform drawing.

Follow the below steps:

STEP-1: Select “Speed Control”.

STEP-2: Set speed PID parameters, acceleration and deceleration.

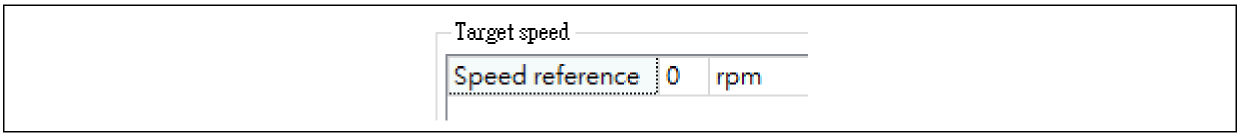
Figure 36 Set PID parameters, acceleration and deceleration

Speed control

Speed KP	1000	
Speed KI	4	
Speed KP DIV	1024	
Speed KI DIV	1024	
Speed acceleration	8	rpm/ms
Speed deceleration	8	rpm/ms

STEP-3. Select “Software control” in “Control source” and set the target speed (Speed reference).

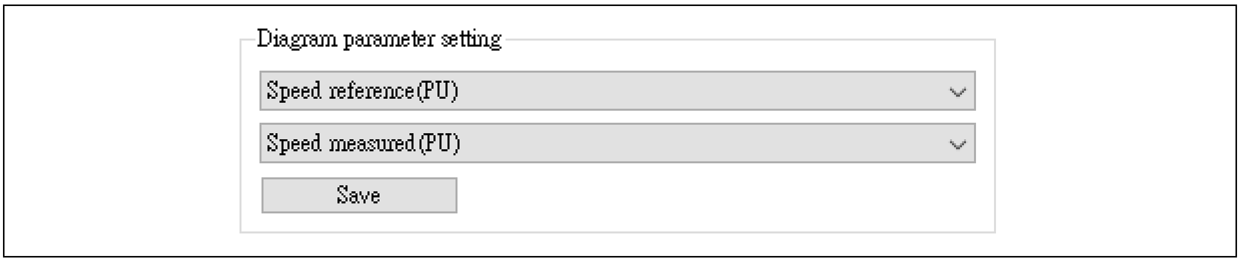
Figure 37 Set target speed



STEP-4: Click “Start Motor”.

STEP-5: Set “Speed reference(PU)” and “Speed measured(PU)” in “Diagram parameter setting”, and then click “Save”.

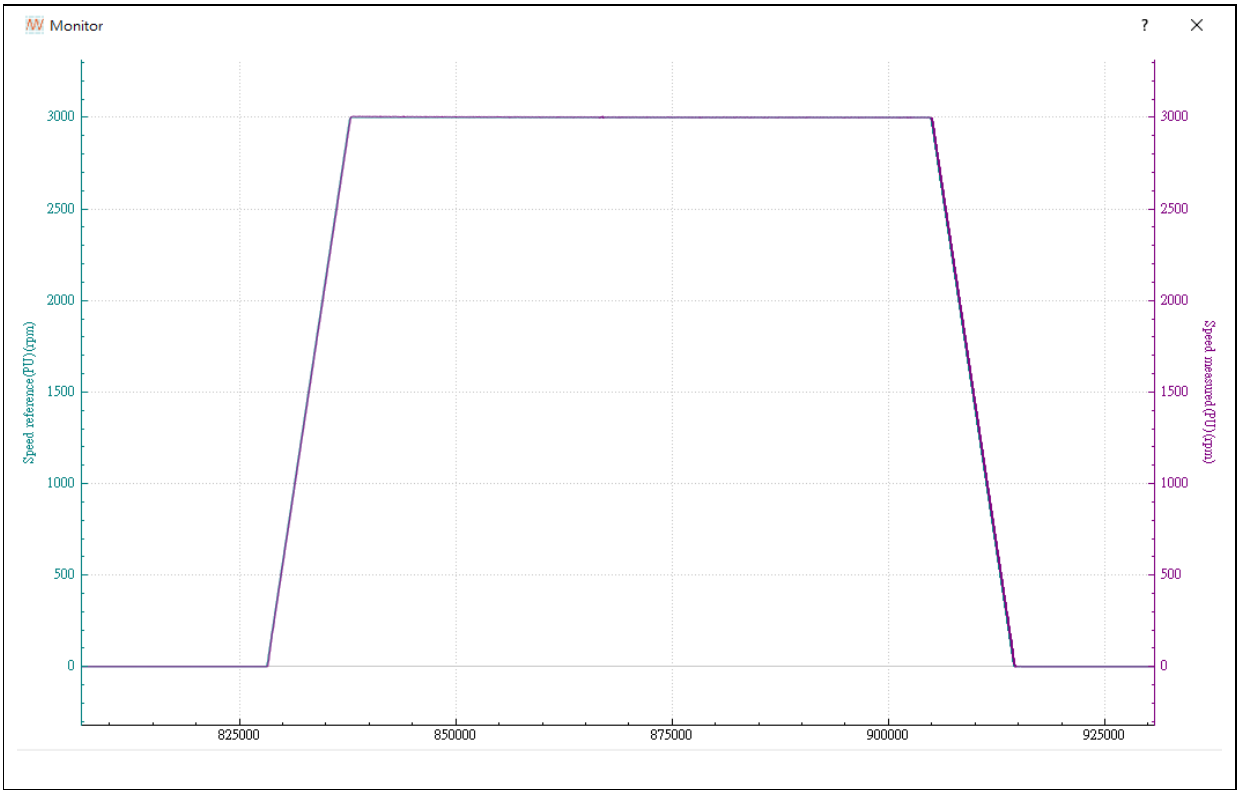
Figure 38 Modify channel monitoring parameters (speed control)



STEP-6: Click the drawing icon to open the waveform window.

STEP-7: Check whether the speed response is as expected, as shown in Figure 39. If it is not as expected, click to stop the motor and repeat STEP-2~STEP-7.

Figure 39 Waveform in speed control mode



2.4.7 Position control

In position control mode, users can adjust the position PID parameters, and check the response after adjustment through waveform drawing.

Follow the below steps:

STEP-1: Select “Position Control”. With the encoder aligned, the motor angle after rotation is not at the zero position exactly. In this case, both position reference and position measured are the angle after motor rotation.

Figure 40. Position reference and position measured

Angle

Position reference	361.71	degree

Angle

Position measured	361.71	degree

STEP-2: Set position PID parameters.

Figure 41. Set PID parameters

Position controller

Position KP	2000	
Position KI	1	
Position KI stable	800	
Position KD	100	
Position KP DIV	4096	
Position KI DIV	65536	
Position KD DIV	32	

STEP-3: Set “Position reference”, for example, 3600 degrees.

Figure 42. Set position reference

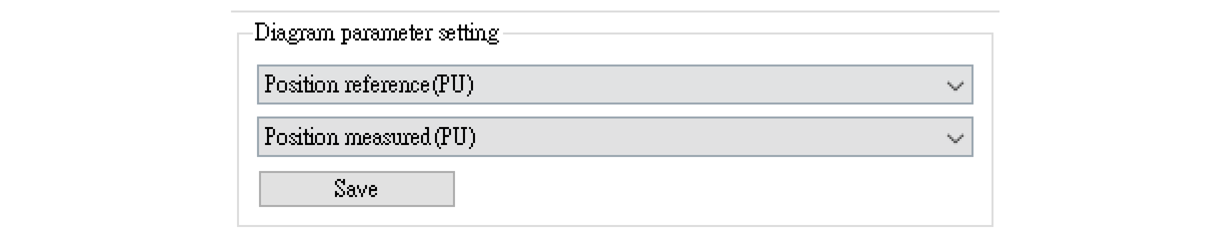
Angle

Position reference	0	degree

STEP-4: Click “Start Motor”.

STEP-5: Set “Position reference(PU)” and “Position measured(PU)” in “Diagram parameter setting”, and then click “Save”.

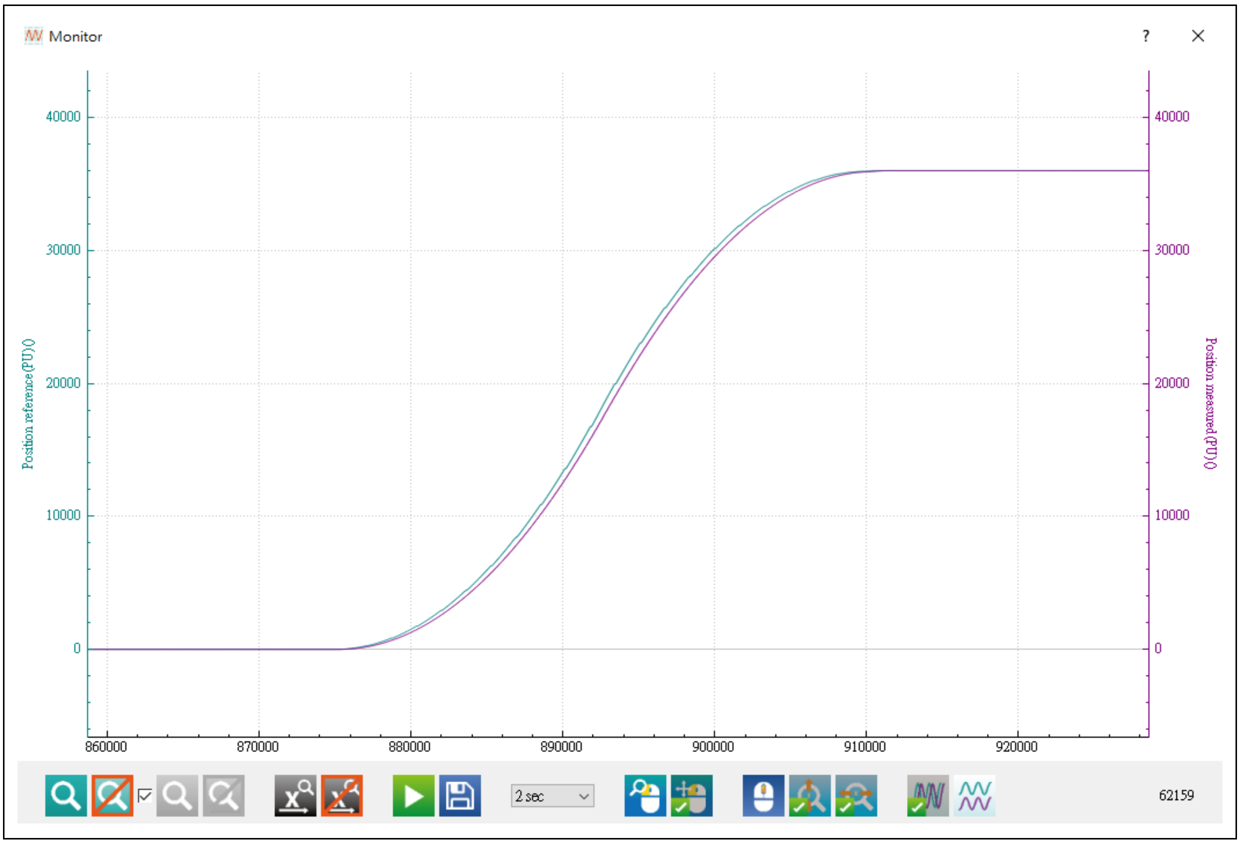
Figure 43. Modify channel monitoring parameters (position control)



STEP-6: Click the drawing icon to open the waveform window.

STEP-7: Check whether the position response is as expected, as shown in Figure 44. If it is not as expected, click to stop the motor and repeat STEP-2~STEP-7.

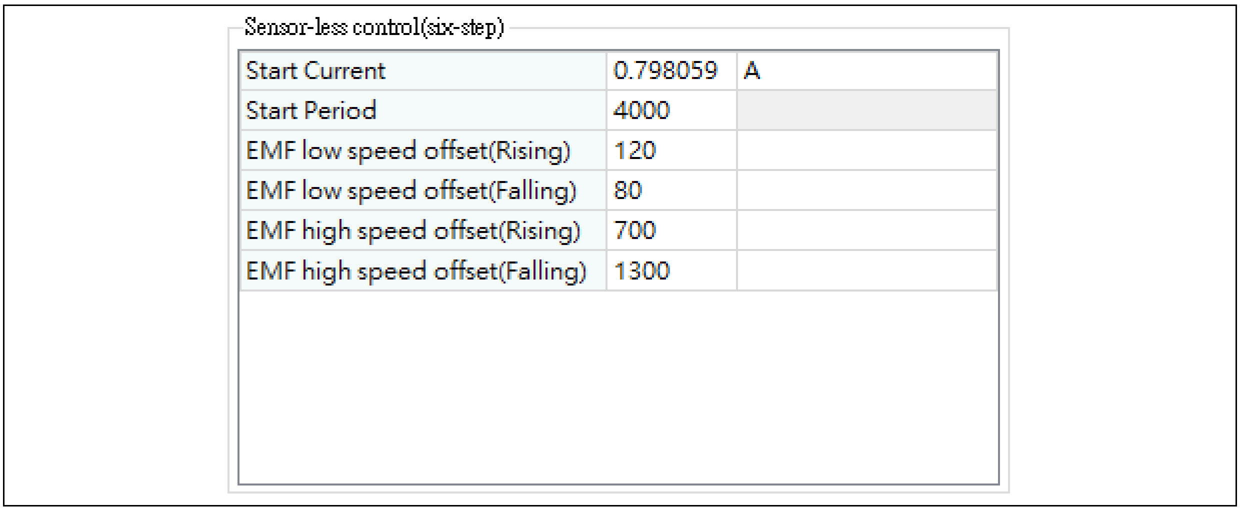
Figure 44. Waveform in position control mode



2.4.8 Six-step square-wave sensorless control

Different from control with sensors, the sensorless control detects BEMF to estimate the rotor position, and adjust the startup current and startup period for different motors. This interface application supports setting of parameters shown in Figure 45, including Start Current and Start Period, as well as EMF low speed offset(rising), EMF low speed offset(falling), EMF high speed offset(rising) and EMF high speed offset(falling) for BEMF phase change with the method of ADC detection.

Figure 45 Six-step square-wave sensorless control parameter setting (ADC detection)



1. Start Current
   Initial startup current value in sensorless control, unit: A (ampere).

2. Start Period
   Initial period for the specified initial current, unit: us.

3. EMF low speed offset(rising), EMF low speed offset(falling)
   It is the level for BEMF zero crossing point measurement at low speed (rising: positive edge; falling: negative edge). It can be adjusted for different sensing circuit or motor characteristics. In this example, the rising is 120 and the falling is 80.

4. EMF high speed offset(rising), EMF high speed offset(falling)
   It is the level for BEMF zero crossing point measurement at high speed (rising: positive edge; falling: negative edge). It can be adjusted for different sensing circuit or motor characteristics. In this example, the rising is 700 and the falling is 1300.

2.4.9 Sensorless vector control

Different from control with sensors, the sensorless control detects BEMF to estimate the rotor position. The AT motor library uses Luenberger observer and Q-PLL method for BEMF measurement. Parameters are as shown in Figure 46, and users can use open loop control to run the motor to adjust these parameters.

Figure 46 Sensorless observer + PLL parameters

Sensor-less observer+PLL

Observer C1	15000
Observer C2	-20000
PLL KP	5000
PLL KI	5
PLL KP DIV	32768
PLL KI DIV	32768

In addition, AT motor library provides three startup modes, i.e., open loop voltage, align and go, and initial angle detection, and relevant parameters are shown in Figure 47 and Figure 48, including the Startup Max. Speed, Startup Open Loop Voltage, Startup Open Loop Slope, Startup Align Time, Startup Align Voltage, Startup Start Time, and Startup Start Current.

1. Startup Max. Speed
   It is the maximum speed of motor before entering a closed loop at startup, unit: rpm.

2. Startup Open Loop Voltage
   It is the open loop voltage before the motor enters a closed loop at startup, unit: V.

3. Startup Open Loop Slope
   It is the open loop acceleration before the motor enters a closed loop at startup, unit: rpm/s.

4. Startup Align Time
   It is the align time at motor startup, unit: ms.

5. Startup Align Voltage
   It is the align/startup voltage at motor startup, unit: V

6. Startup Start Time
   It is the startup time before the motor entering a closed loop after alignment at startup, unit: ms.

7. Startup Start Current
   It is the current command to enter torque control after motor startup, unit: A (ampere).

Figure 47 Open loop voltage and initial angle detection modes

Start up

Startup Max. Speed	400	rpm
Startup Open Loop Voltage	1.021	V
Startup Open Loop Slope	800	rpm/s
Startup Start Current	0.150	A

Figure 48 Align and go mode

Start up

Startup Max. Speed	400	rpm
Startup Align Time	1000	ms
Startup Align Voltage	1.156	V
Satrtup Start Time	10	ms
Startup Start Current	0.150	A

3 Revision history

Table 2. Document revision history

Date	Version	Revision note
2022.11.18	2.0.1	Initial release.
2022.12.01	2.0.2	Optimized descriptions.
2023.01.06	2.0.3	Added current loop control, and parameters relevant to sensorless vector control.
2023.03.02	2.0.4	Modified relevant parameters in six-step square-wave sensorless control.
2023.04.20	2.1.0	Updated instructions to the new version of the upper computer; Added Section 2.4.7 “Position control”.

IMPORTANT NOTICE – PLEASE READ CAREFULLY