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

Contents

List of tables

List of figures

1 Software and hardware requirements

A BLDC, AT-Link or Jlink, AT motor development board and AT motor control library are required. It is not necessary to set up the software; instead, run the executable program “MotorMointor.exe” directly.

1.1 Hardware requirements

- 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 third-party programmer
- 3-phase AC motor with 12 V~ 60 V rated voltage and below 30 A rated current
- DC power supply
- ARTERY evaluation board

1.2 Software requirements

- 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/Jlink and board power supply to the motor development board, and connect USART interface and USB cable to PC.

STEP-2

Use MDK to compile demo project code, and use Jlink or AT_Link to download to the on-board chip.

STEP-3

Run ArteryMotorMonitor_V2.0.1.exe (software version: V2.0.1); click File -> Open Project and select ArteryMotorMonitor_V2.0.1.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.

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, debugging current PID parameters, monitoring parameters and drawing waveform.

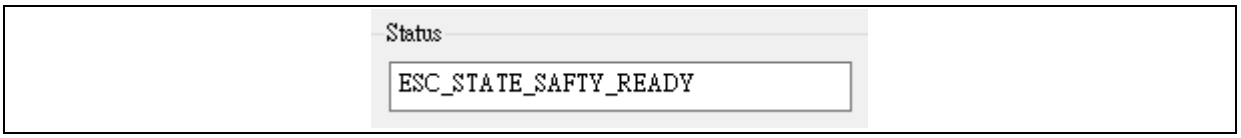
2.2 Control and status display list

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, D/Q shaft current debugging, torque control, speed control and position control.

2.2.1 Status machine display

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

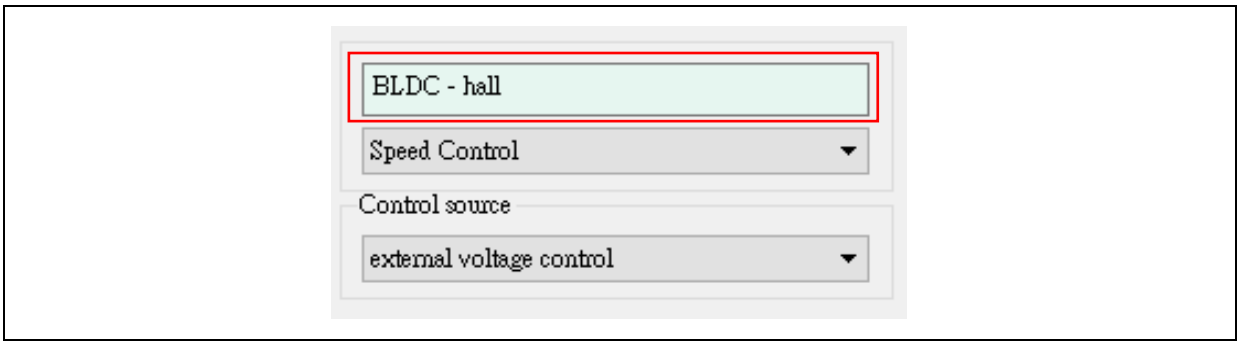
Figure 2 Status machine display area



2.2.2 Firmware control mode display

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

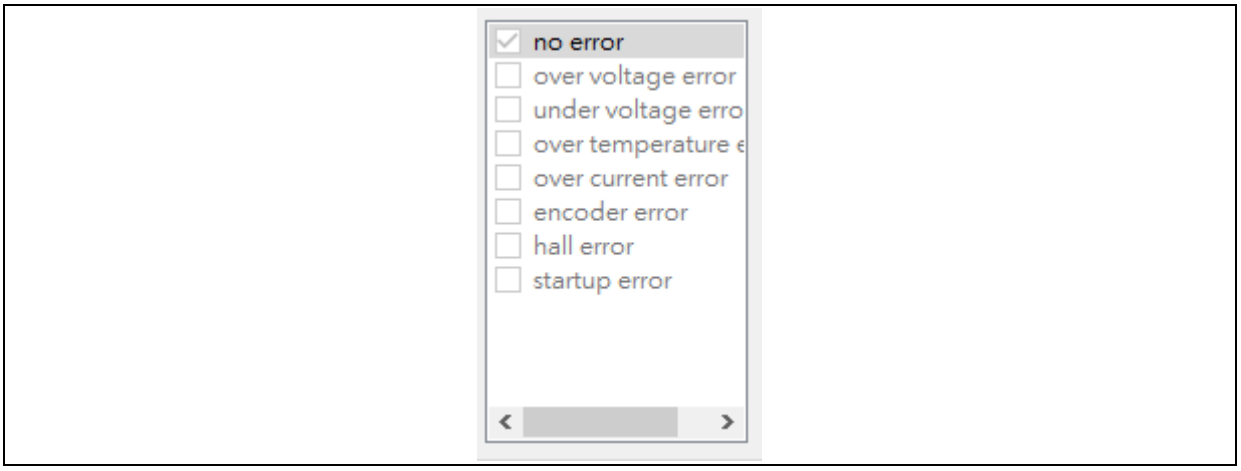
Figure 3 Firmware control mode display area



2.2.3 Error type display

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

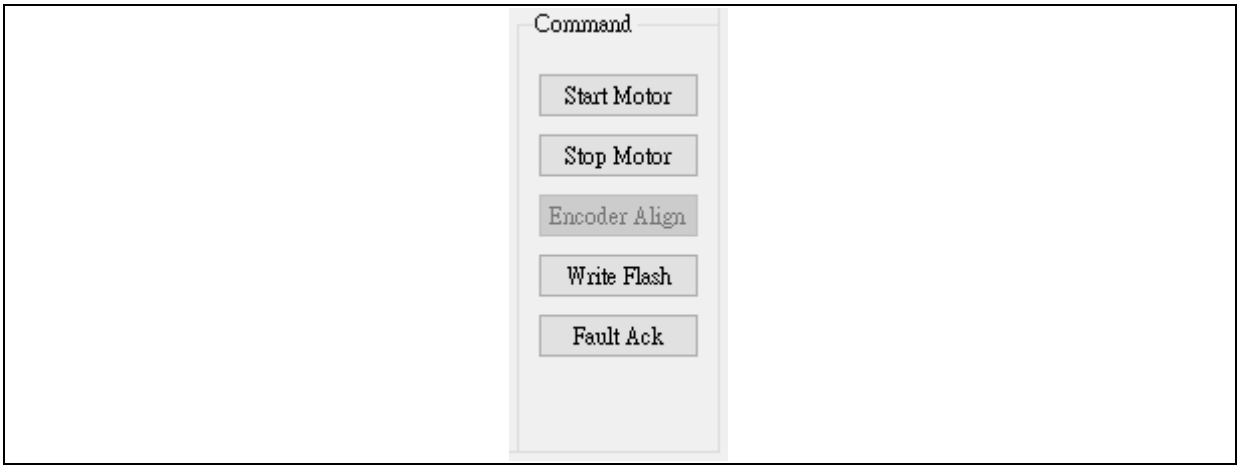
Figure 4 Error type display area



2.2.4 Control command button operation

1) This application software contains 5 control command buttons that are used for motor startup/stop, encoder calibration, writing parameters to Flash, error clearing, etc.

Figure 5 Control command button

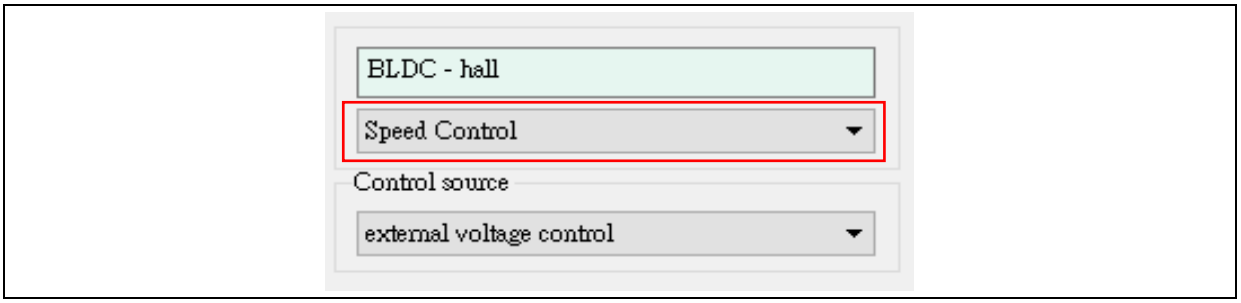


2) Start Motor
   Click this button to start up motor.
3) Stop Motor
   Click this button to stop motor.
4) Encoder Align
   Click this button to perform encoder zero calibration (invalid in open loop control mode).
5) Write Flash
   When parameters have been debugged or in case of modifying motor parameters, 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 available, including open loop control, voltage control, D/Q shaft current debug, torque control, speed control and position control. In different mode, parameters displayed on the debug page are different in different modes; therefore, this area should be used together with the parameter debug page, which is detailed in Section **錯誤! 找不到參照來源。**.

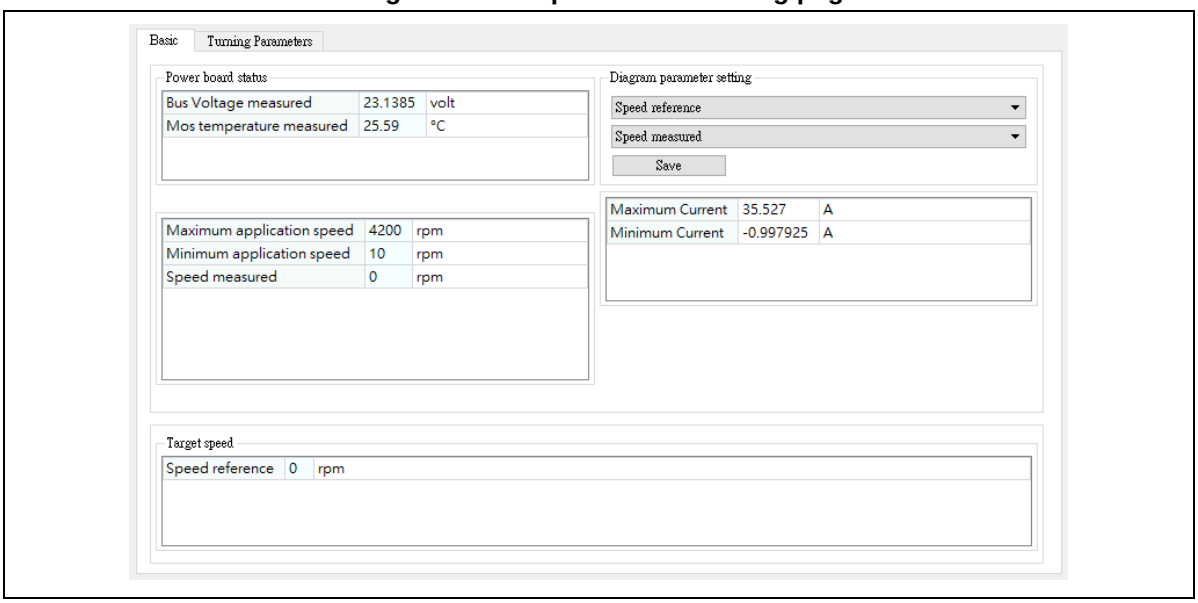
Figure 6 Control mode droplist



2.3 Basic parameters

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

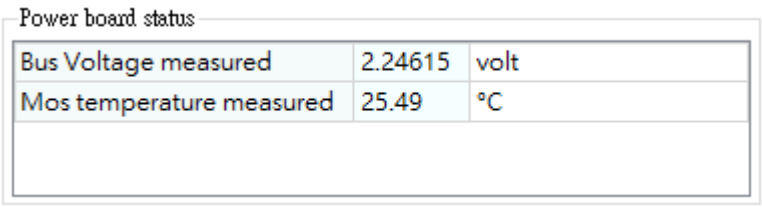
Figure 7 Basic parameters setting page



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 **錯誤! 找不到參照來源。**.

Figure 8 Voltage and temperature display area



2.3.2 Maximum/minimum speed

The maximum/minimum speed and current speed (unit: rpm) of motor can be read in this area. This application interface only has reading function, and the maximum/minimum speed need to be modified in firmware. If it is necessary to modify speed, please modify the MAX_SPEED_RPM and MIN_SPEED_RPM in *mc_ctrl_param.h*.

Figure 9 Real-time maximum/minimum speed display area

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

Figure 10 Modify 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) of motor can be read and set in this area. The current can be adjusted according to the motor characteristics or the drive 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 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 Target speed/torque

Different control parameters are set for different control sources. For example, the “Target speed” is displayed in Speed Control mode as shown in Figure 13, and “Torque reference” is displayed in Torque Control mode, as shown in Figure 14.

The unit of target speed if rpm, and the unit of target torque is ampere. This application software has two control sources, including the external source control and software control.

1) External voltage control

This application software supports external source control. Open the droplist of “Control source” and select to switch to the “external voltage control” to adjust the speed or torque via the external voltage. The target speed/target torque field will display the converted control speed/torque at the current control voltage.

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

Figure 13 Speed control mode (external voltage control source)

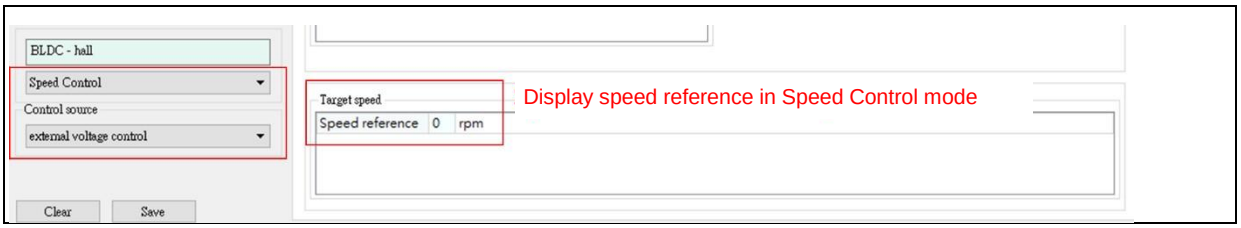
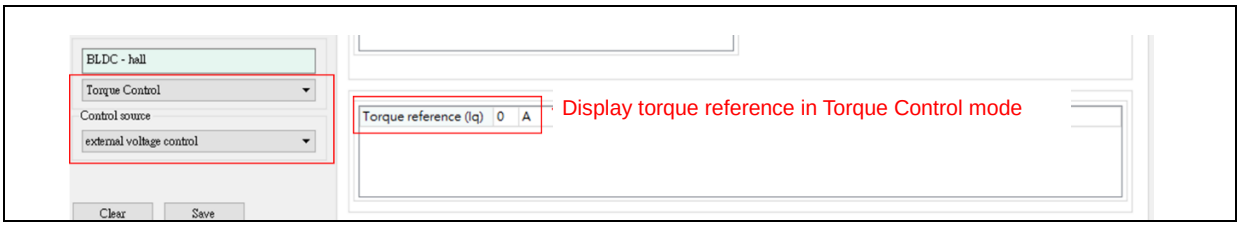


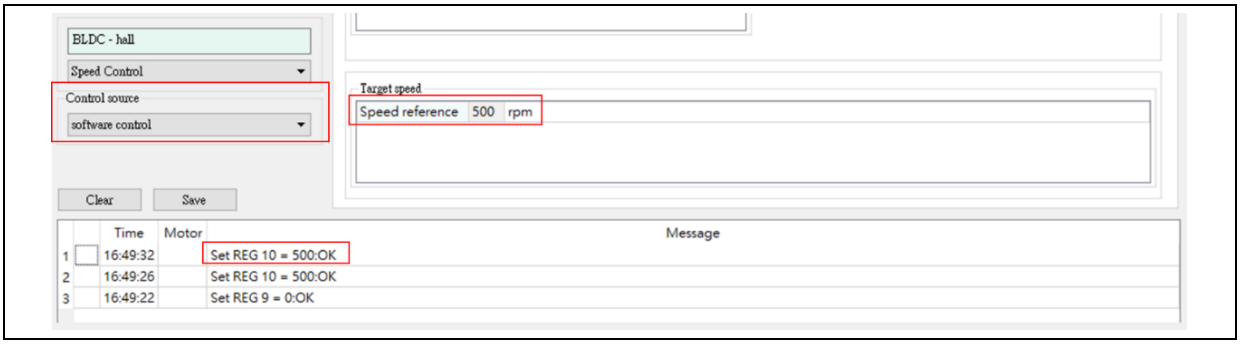
Figure 14 Torque control mode (external voltage control source)



2) Software control

It is the software control mode, by default. Open the droplist of “Control source” to select to switch to the “Software control”, as shown in Figure 15. In this mode, users can change the target speed/torque in UI interface to adjust the motor control speed/torque (double click this field to change the value). The bottom field displays a message after successful setting.

Figure 15 Set target speed in software control mode



2.3.5 Waveform drawing and parameter setting

This application supports dual-channel waveform drawing, with the brief mode (long-term monitoring) and detailed mode (short-term response) in which two parameters can be selected for drawing, as shown in Figure 16. Select channel 1 parameter in droplist 1, and select channel 2 parameter in droplist 2, as shown in Figure 17. Click “Save” button after the parameter is set in detailed mode.

1) brief mode

The sampling rate in this mode is 1 ms/time, which is suitable for long-term multi-point drawing, such as speed monitoring, speed loop PID parameter debugging and long-term temperature monitoring.

2) detailed mode

The sampling rate in this mode is relevant to PWM interruption frequency. If the PWM interruption frequency is 20 KHz, the sampling rate is 50 us/time, which can be used to record detailed changes in parameters for a short time of period. The maximum sampling number is 2048, so that this mode is suitable for current PID parameter debugging or other conditions requiring immediate response.

Figure 16 Drawing mode selection

Figure 17 Drawing channel parameter selection

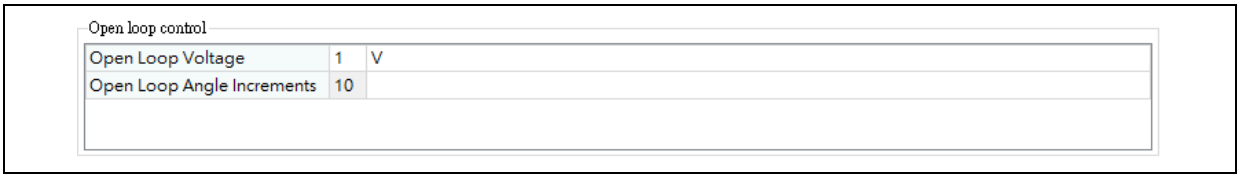
2.4 Parameter debug

It is an advanced debugging page. Users can refer to Section 錯誤! 找不到參照來源。 to modify parameters on this page, and start motor to confirm response or click drawing function to view the response waveform after debugging. For details about waveform drawing, please refer to Section 2.3.5.

2.4.1 Open loop control

The “Open Loop Voltage” is selected 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 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.

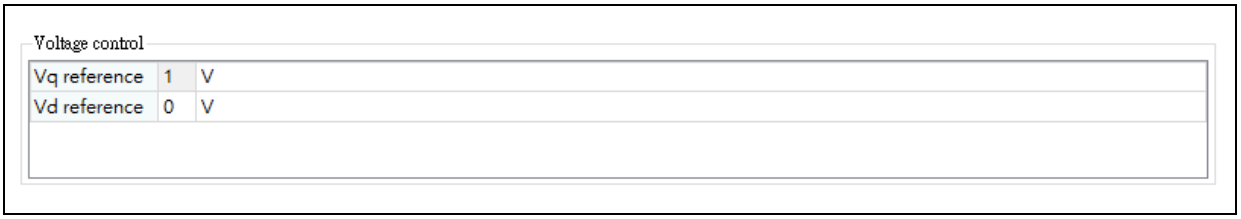
Figure 18 Open loop control parameters



2.4.2 Voltage control

Based on the position sensor, the voltage control ode is used to control motor D/Q shaft voltage (control Q shaft voltage to drive the motor; control D shaft voltage to position the motor magnetic pole to D shaft).

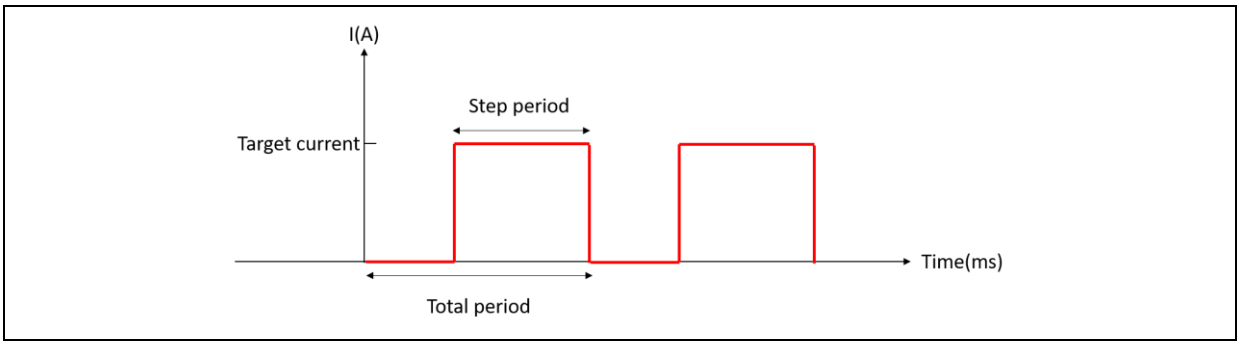
Figure 19 Voltage control parameters



2.4.3 Q shaft current control

A step current is generated in this mode, as shown in Figure 20. Parameters relevant to the step current can be adjusted. The step current is generated to check the current response after adjusting the PID current parameter of Q shaft current.

Figure 20 Schematic diagram of step current



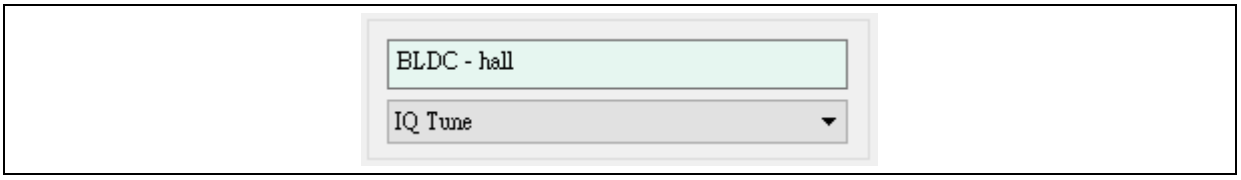
The Y axis current value in this diagram is a converted value, and the conversion formula is as follows:

$$\text{Actual current (A)} = \frac{Digital\ current}{32767} * Maximum\ current\ (A)$$

Operate as follows:

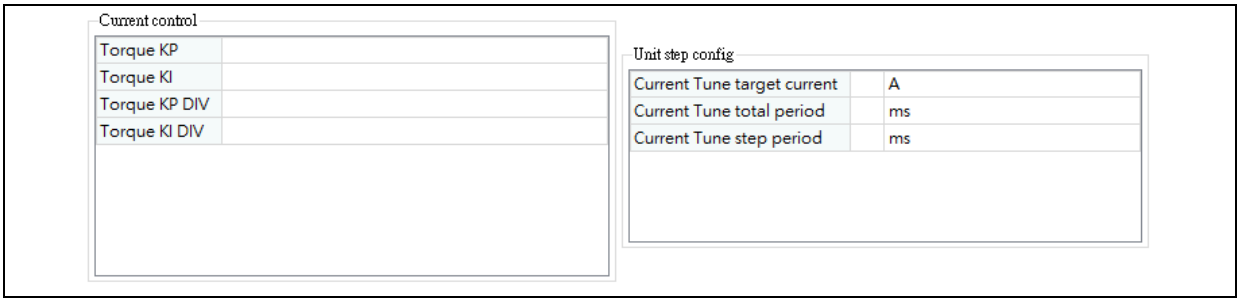
STEP-1: Select “IQ tune” in the droplist in control mode.

Figure 21 Select IQ tune in control mode



STEP-2: Set PID parameters and step current parameters, as shown in Figure 22.

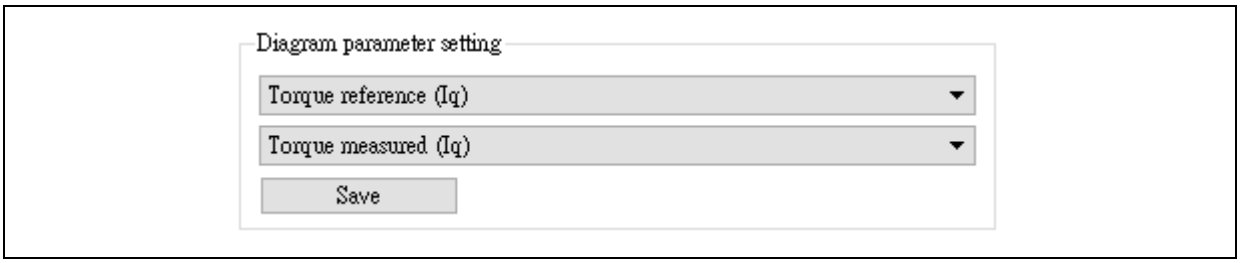
Figure 22 PID and step current parameters



STEP-3: Click the “Start Motor” button.

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

Figure 23 Modify channel monitoring parameters (IQ Tune)

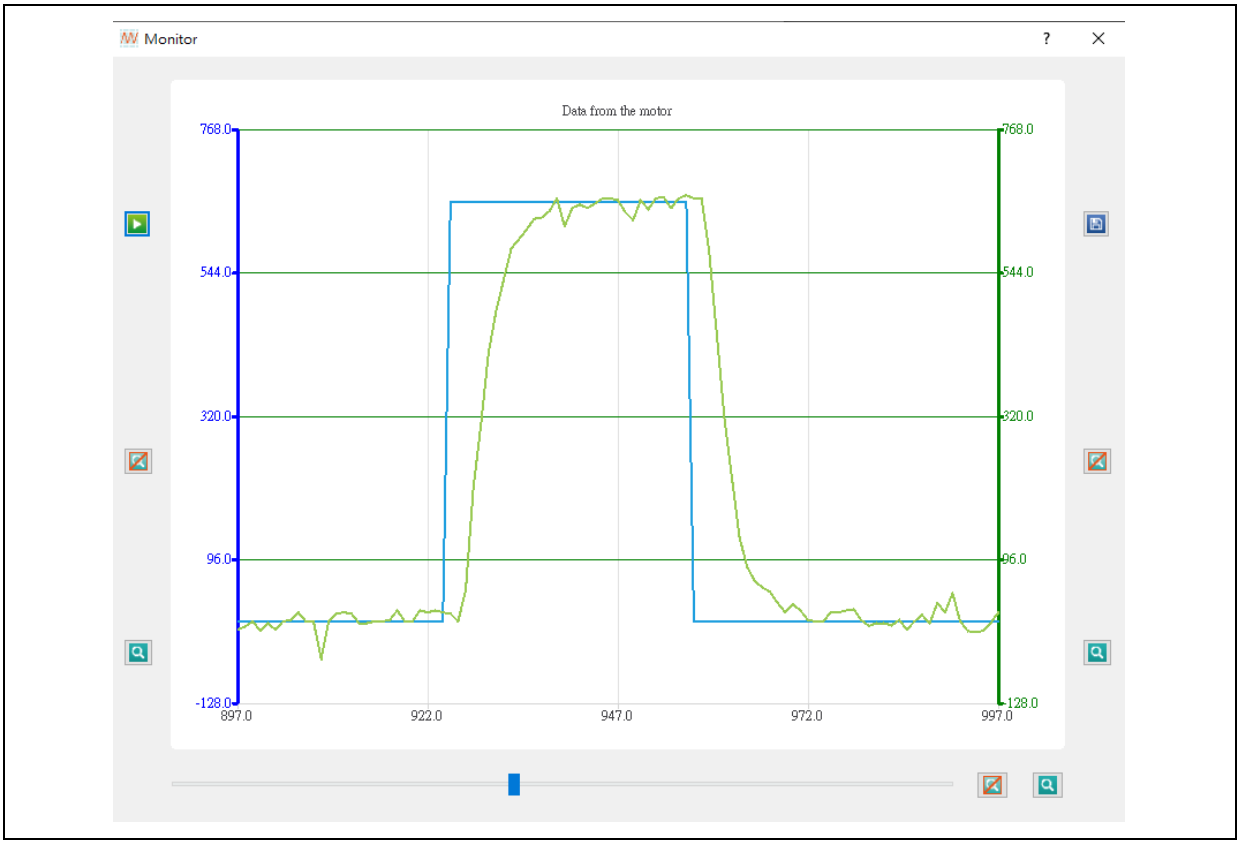


STEP-5: Set “detailed” and click the drawing button to call waveform window.

Figure 24 Drawing mode (IQ tune)

STEP-6: Check whether the current response is as expected, as shown in Figure 25. If it is not as expected, click to stop the motor, and repeat STEP-2~STEP-6.

Figure 25 Current loop tuning waveform



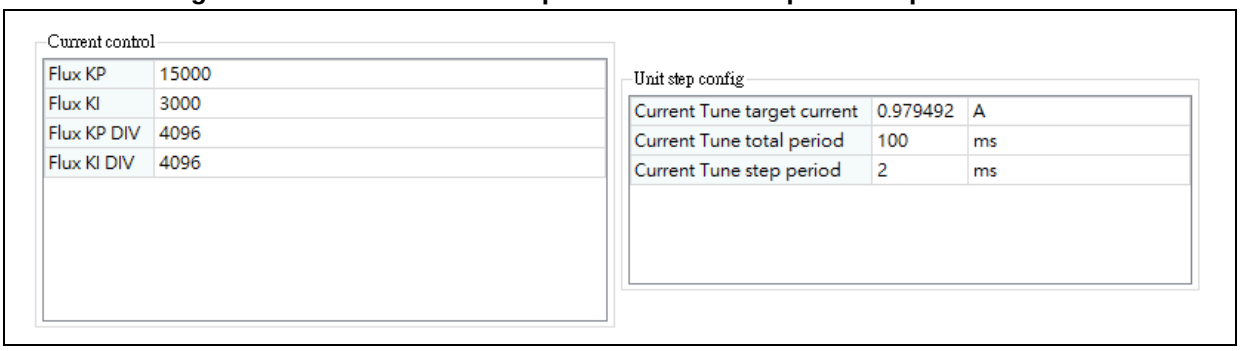
2.4.4 D shaft current control

A step current is generated in this mode, as shown in Figure 20. Parameters relevant to the step current can be adjusted. The step current is generated to check the current response after adjusting the PID current parameter of D shaft current.

STEP-1: Select “ID tune” in the droplist in control mode.

STEP-2: Set PID parameters and step current parameters.

Figure 26 D shaft current PID parameters and step current parameters



STEP-3: Click the “Start Motor” button.

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

Figure 27 Modify channel monitoring parameters (IQ Tune)

STEP-5: Set “detailed” and click the drawing button to call waveform window.

STEP-6: Check whether the current response is as expected, as shown in Figure 25. 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 debugging function, so this page is not available in this case.

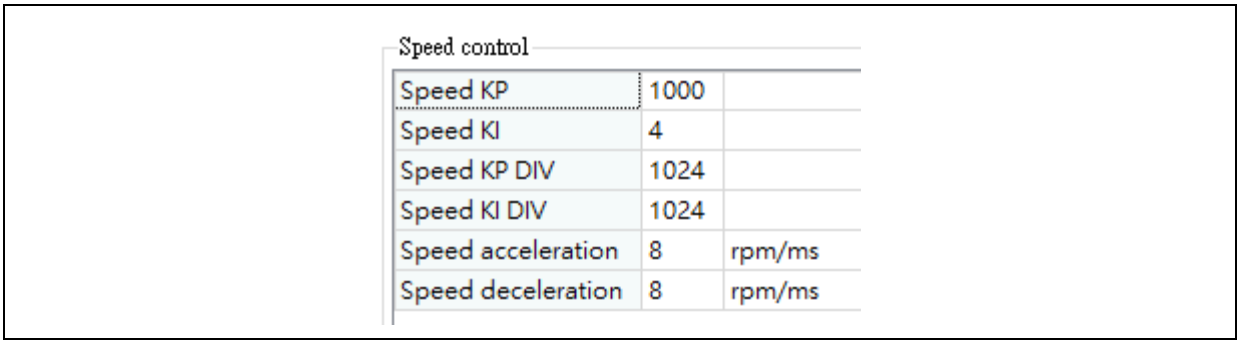
2.4.5 Speed loop control

In this mode, the speed loop PID parameters, acceleration and deceleration are adjustable, and check the response via waveform drawing after adjustment.

STEP-1: Set “Speed Control” in the droplist in control mode.

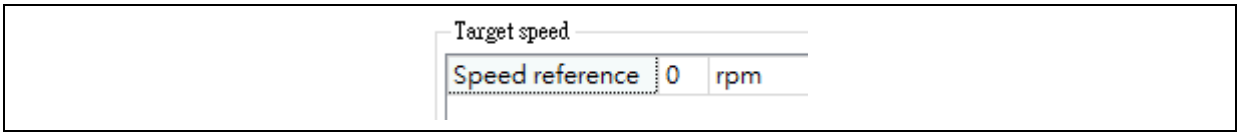
STEP-2: Set speed PID parameters and acceleration/deceleration.

Figure 28 Set PID parameters, acceleration and deceleration



STEP-3: Set “software control” as the control source, and set the speed reference.

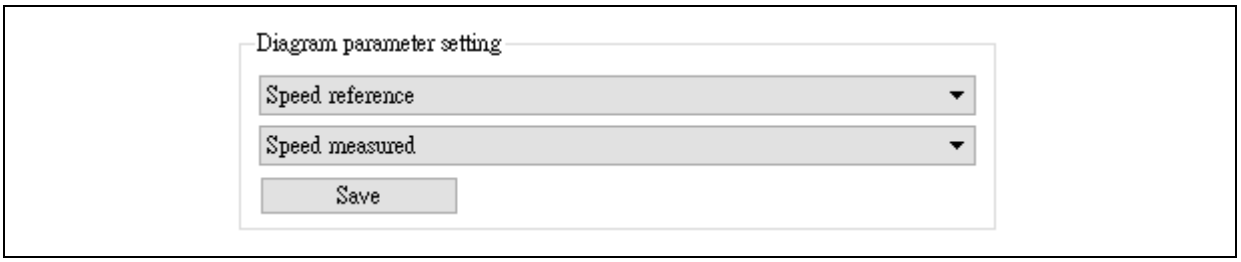
Figure 29 Set target speed



STEP-4: Click the “Start Motor” button.

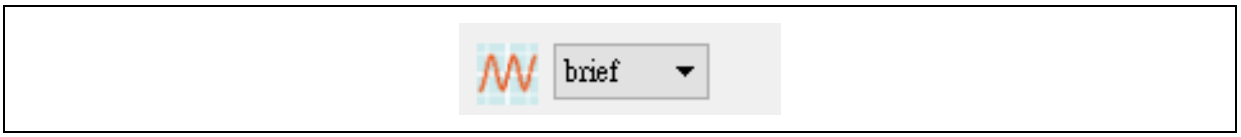
STEP-5: Set “Speed reference” and “Speed measured” in the “Diagram parameter setting”.

Figure 30 Adjust channel monitoring parameter (speed loop tune)



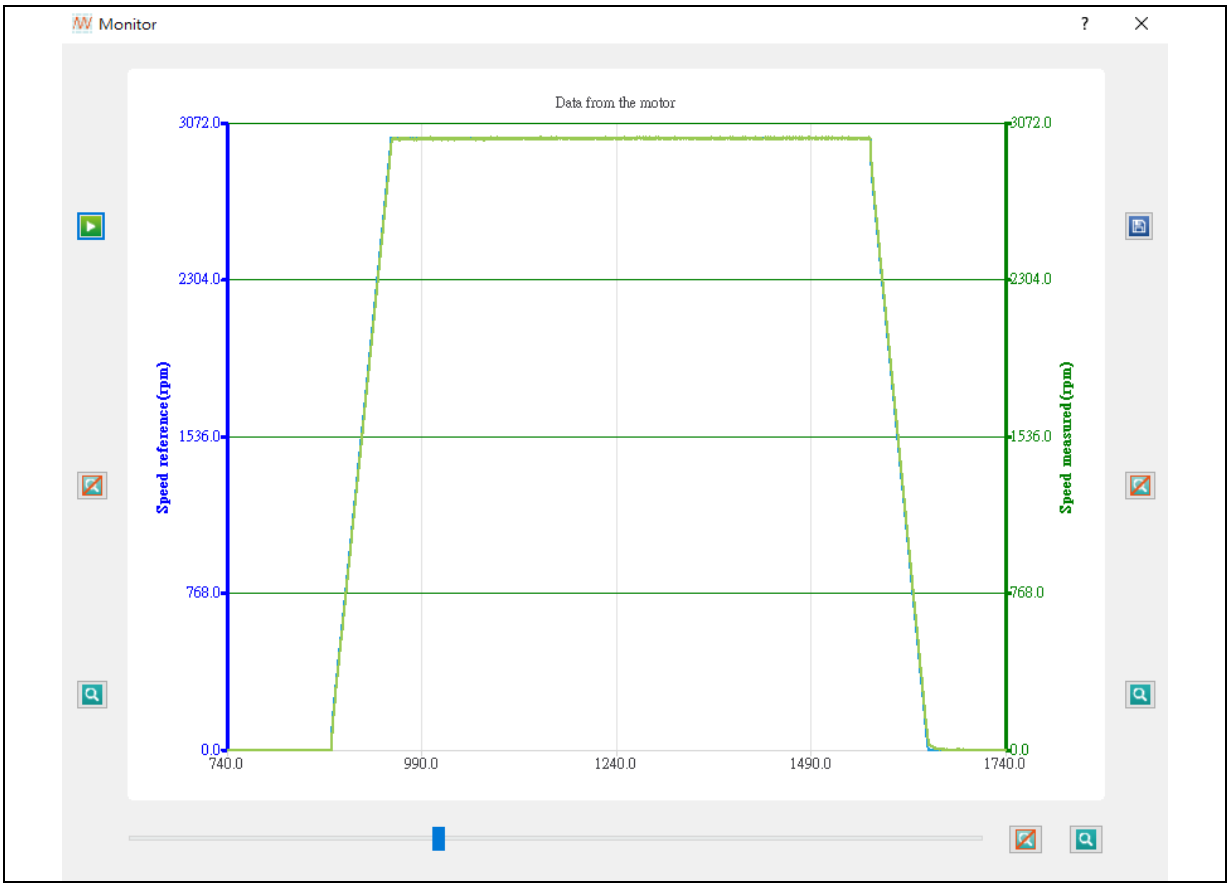
STEP-6: Set “detailed” and click the drawing button to call waveform window.

Figure 31 Adjust drawing mode and click drawing button



STEP-7: Check whether the speed response is as expected, as shown in Figure 32. If it is not as expected, click to stop the motor, and repeat STEP-2~STEP-7.

Figure 32 Speed loop tuning waveform



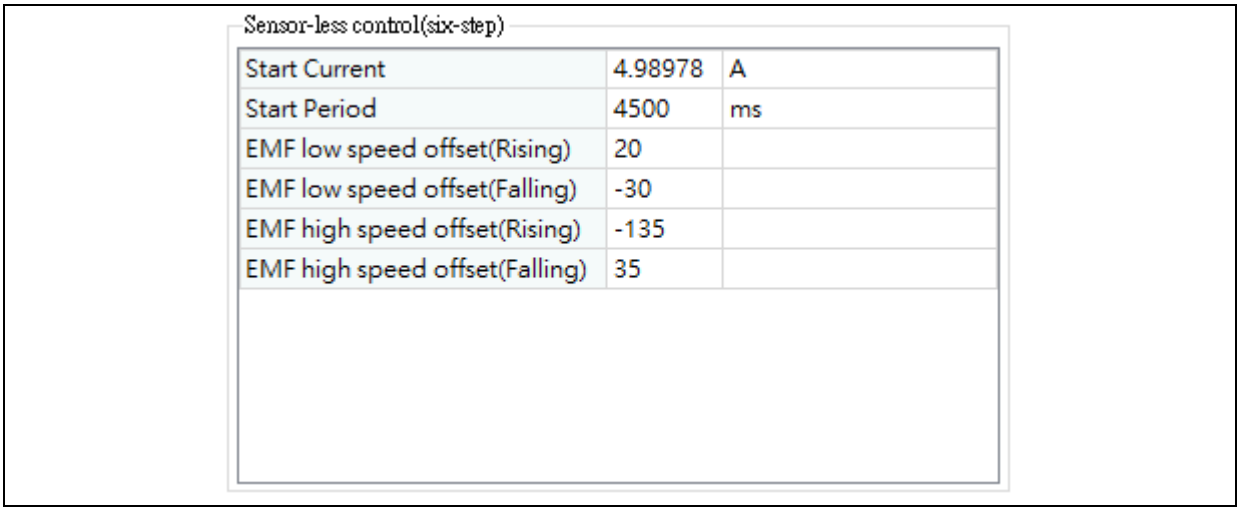
2.4.6 Position control

N/A.

2.4.7 Six-step square-wave sensorless control

Different from control with sensors, the sensorless control detects BEMF to estimate the rotor position, and adjusts the startup current and startup period for different motors. This interface application supports setting of the following parameters, as shown in Figure 33, including Start Current and Start Period, as well as EMF low speed offset(rising), EMF low speed offset(falling), EMF high speed offset(rising), EMF high speed offset(falling) for BEMF phase change with the method of ADC detection.

Figure 33 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: ms.

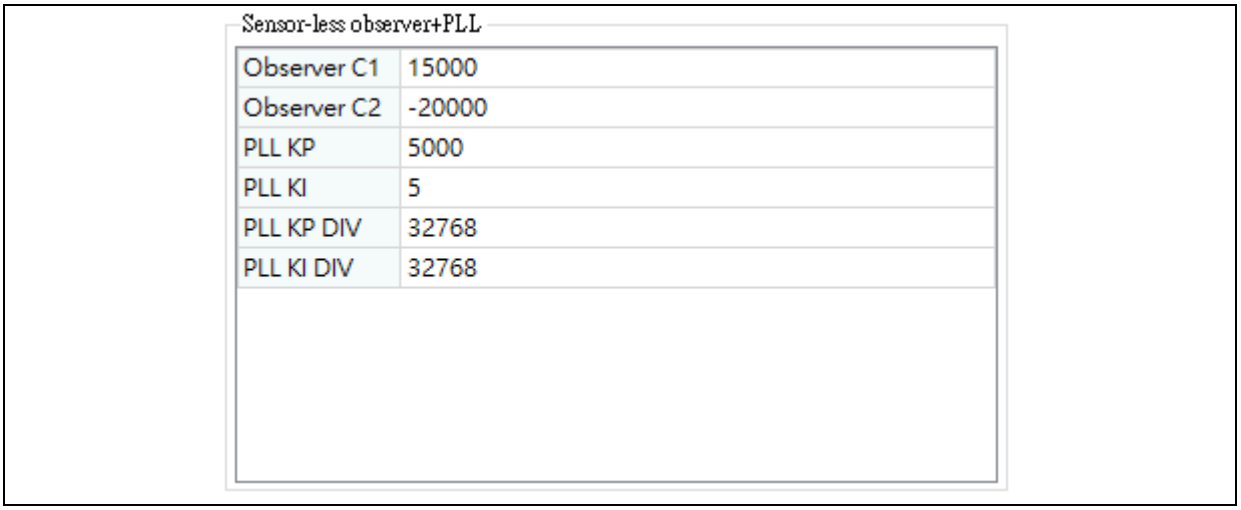
3. EMF low speed offset(rising), EMF low speed offset(falling)
   It is the level for BEMF zero crossing point measurement at low speed (rising: positive edge; falling: negative edge). It can be adjusted for different sensing circuit or motor characteristics. In this example, the rising is +20 and the falling is -30.

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 -135 and the falling is +35.

2.4.8 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 34, and users can use open loop control to run the motor to adjust these parameters.

Figure 34 Sensorless observer parameters



In addition, AT motor library provides three startup modes, i.e., voltage open loop, α shaft align and initial angle detection, and relevant parameters are shown in Figure 35 and Figure 36, including Startup Max. Speed, Startup Open Loop Voltage, Startup Open Loop Slope, Startup Align Time, Startup Align Voltage, and Startup Start Time.

1. Startup Max. Speed
   It is the maximum speed of motor before entering 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.

Figure 35 Voltage open loop and initial angle detection modes

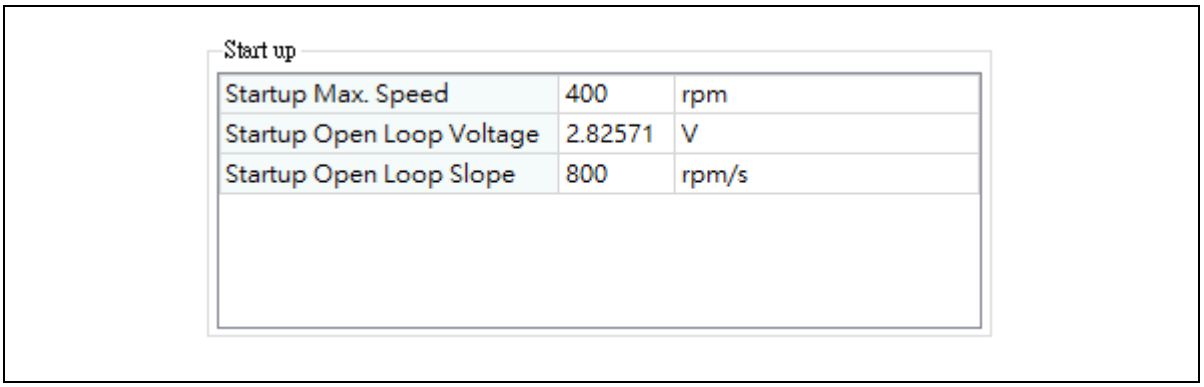
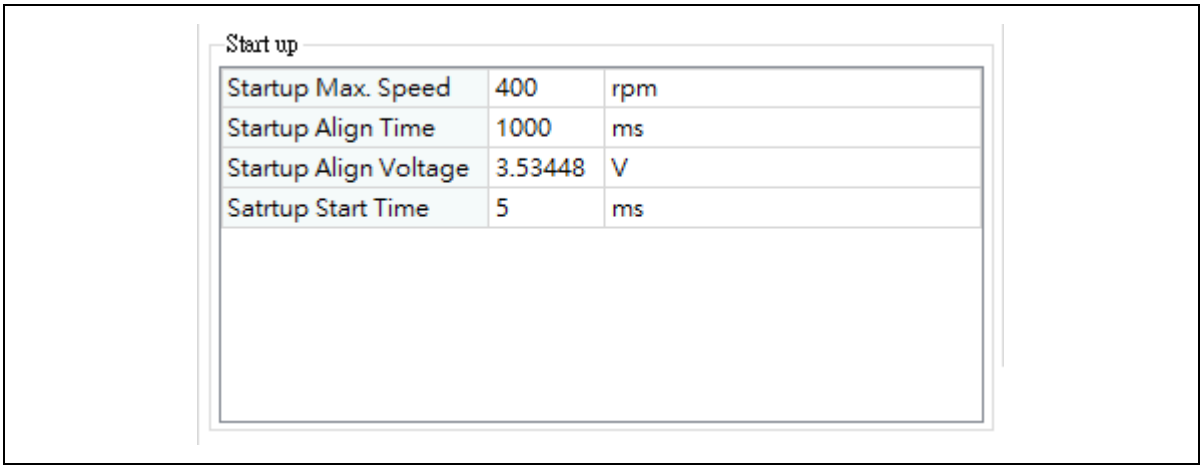


Figure 36 α shaft align mode



3 Revision history

Table 1. Document revision history

Date	Version	Revision note
2022.11.18	2.0.1	Initial release.

IMPORTANT NOTICE – PLEASE READ CAREFULLY

Purchasers are solely responsible for the selection and use of ARTERY's products and services, and ARTERY assumes no liability whatsoever relating to the choice, selection or use of the ARTERY products and services described herein.

No license, express or implied, to any intellectual property rights is granted under this document. If any part of this document deals with any third party products or services, it shall not be deemed a license grant by ARTERY for the use of such third party products or services, or any intellectual property contained therein, or considered as a warranty regarding the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

Unless otherwise specified in ARTERY's terms and conditions of sale, ARTERY provides no warranties, express or implied, regarding the use and/or sale of ARTERY products, including but not limited to any implied warranties of merchantability, fitness for a particular purpose (and their equivalents under the laws of any jurisdiction), or infringement of any patent, copyright or other intellectual property right.

Purchasers hereby agrees that ARTERY's products are not designed or authorized for use in: (A) any application with special requirements of safety such as life support and active implantable device, or system with functional safety requirements; (B) any air craft application; (C) any automotive application or environment; (D) any space application or environment, and/or (E) any weapon application. Purchasers' unauthorized use of them in the aforementioned applications, even if with a written notice, is solely at purchasers' risk, and is solely responsible for meeting all legal and regulatory requirement in such use.

Resale of ARTERY products with provisions different from the statements and/or technical features stated in this document shall immediately void any warranty grant by ARTERY for ARTERY products or services described herein and shall not create or expand in any manner whatsoever, any liability of ARTERY.