EVAL Kit Manual
KTX9312

3-phase BLDC Motor Controller for 3-wire with Built-in Gate Drivers

Brief Description

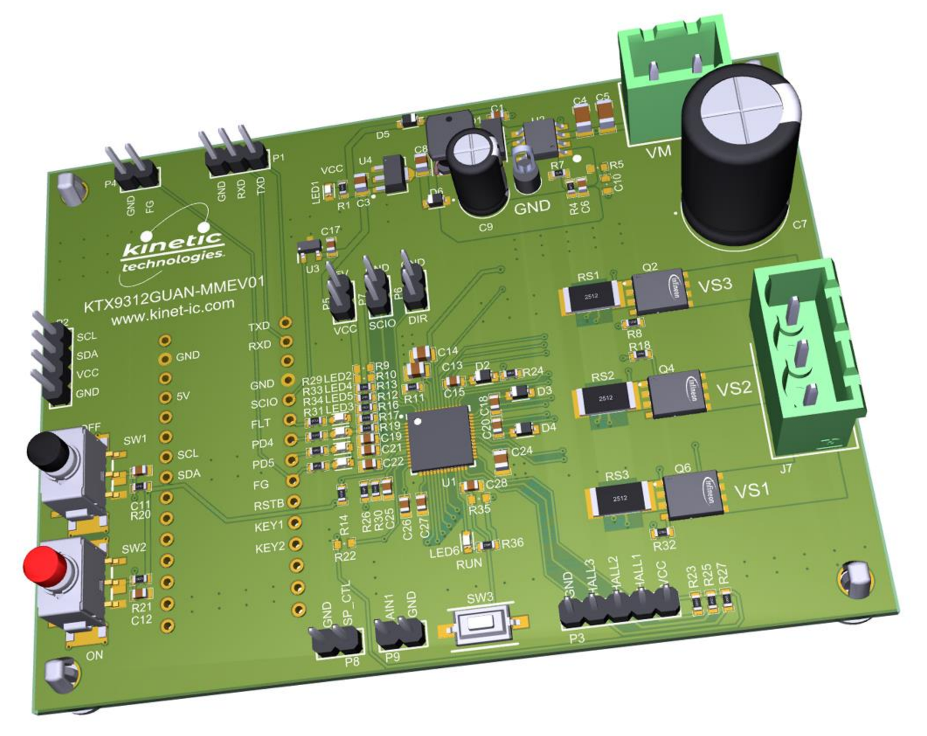
This Evaluation (EVAL) kit is used to demonstrate and evaluate the functionality, performance, and programmability of the Kinetic KTX9312 3-phase brushless motor controller. The user manual fully describes how the KTX9312 can control a 40V, 20A brushless DC motor (BLDC[1]\PMSM[2]) using Field Oriented Control[3] (FOC). It will also show how to detect the actual parameters of the motor, how to configure the KTX9312 chip register parameters through the Kinetic motor control GUI[4] allowing users to drive motors with less time and effort.

The KTX9312 motor drive control includes overcurrent protection, overvoltage and undervoltage protection, temperature protection, initial angle detection, initial speed detection, open-loop control, direct torque control[5], constant torque control, constant speed control, constant power control, flux-weakening control, and supports PWM/Analog control interface, Hall sensor assistance, plus one run/stop button.

Ordering Information

Part Number	Description	IC Package
KTX9312GUAN-MMEV01	KTX9312 EVAL Kit	QFN72L 8mm x 8mm x 0.75mm

3D CAD Image



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[1] BLDC: Brushless DC Motor.

[2] PMSM: Permanent Magnet Synchronous Motor.

[3] FOC: Field Oriented Control - achieves precise control by controlling the direction and size of the motor's magnetic field.

[4] GUI: Graphical User Interface - a visual interface for interacting with software programs.

[5] Direct Torque Control: - motor control mode that provides maximum torque at start-up to ensure the motor can quickly reach the desired programmed speed.

EVAL Kit Physical Contents

Item #	Description	Quantity
1	KTX_9312 EVAL fully assembled PCB	1
2	Arduino Nano	1
3	USB 2.0 Type A to Mini B cable	1
4	2 Position Terminal Block Plug, Female Sockets (5.08mm) 180° Free Hanging	1
5	3 Position Terminal Block Plug, Female Sockets (5.08mm) 180° Free Hanging	1
6	Anti-static bag	1
7	EVAL Kit box	1

QR Links for Documents

IC Datasheet	EVAL Kit Landing Page
https://www.kinet-ic.com/ktx9312/	https://www.kinet-ic.com/ktx9312guan-mmev01/

User-Supplied Equipment

Required Equipment

1. Oscilloscope (20~50A current probe)
2. LCR Meter (Test frequency up to 20KHz^{+})
3. Adjustable DC power supply (40V/30A)
4. Tachometer
5. Dynameter
6. Motor Fixed Bracket
7. USB-SERIAL CH340 Driver
8. KTX_GUI

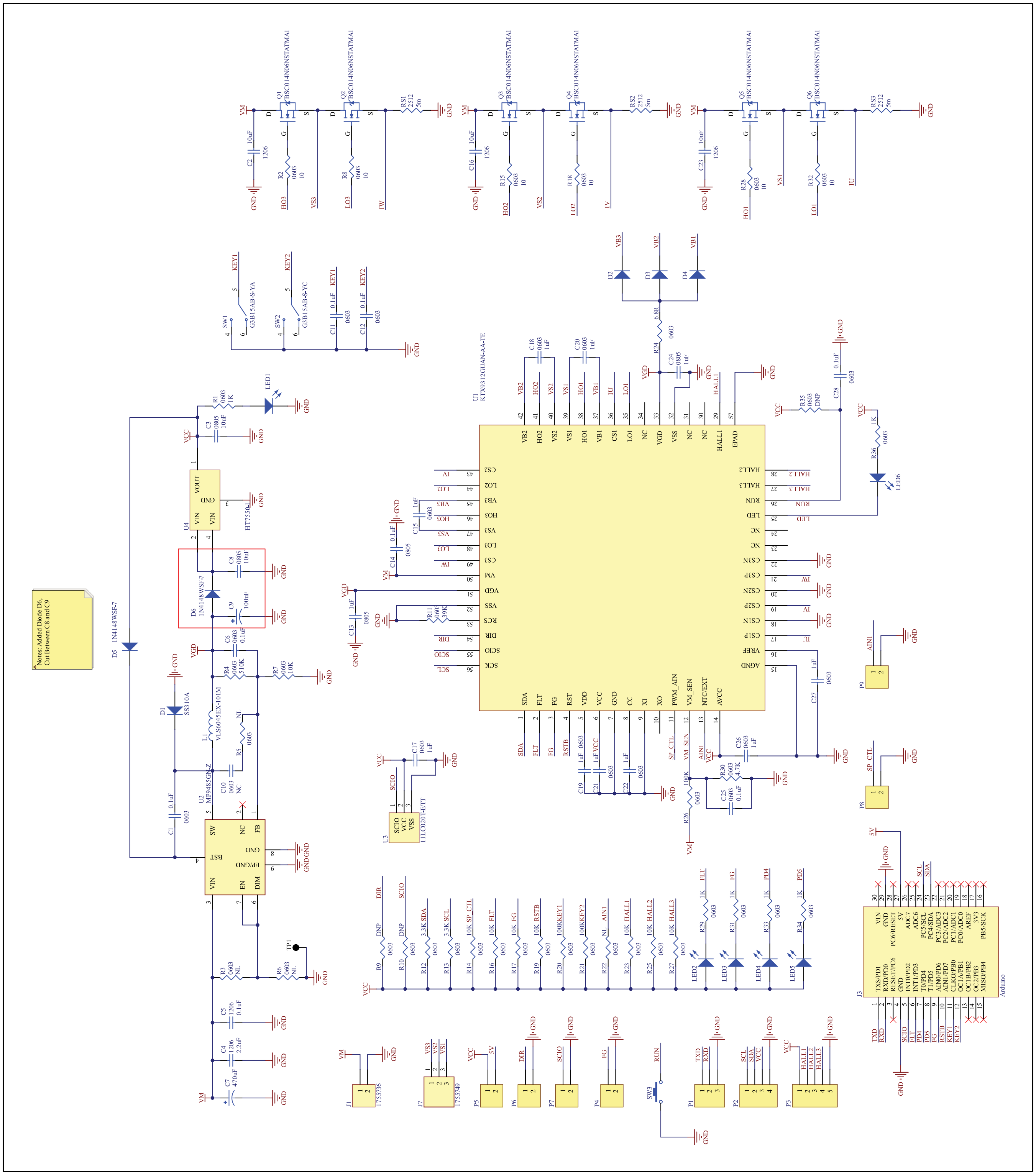
System Requirements

Supports windows 10 operating systems 64-bit and above.

Recommended Operating Conditions

Symbol	Description	Value	Units
V_M	Motor Voltage Operating Range	12-40	V
I_M	Maximum Motor Current	20	A

Electrical Schematic

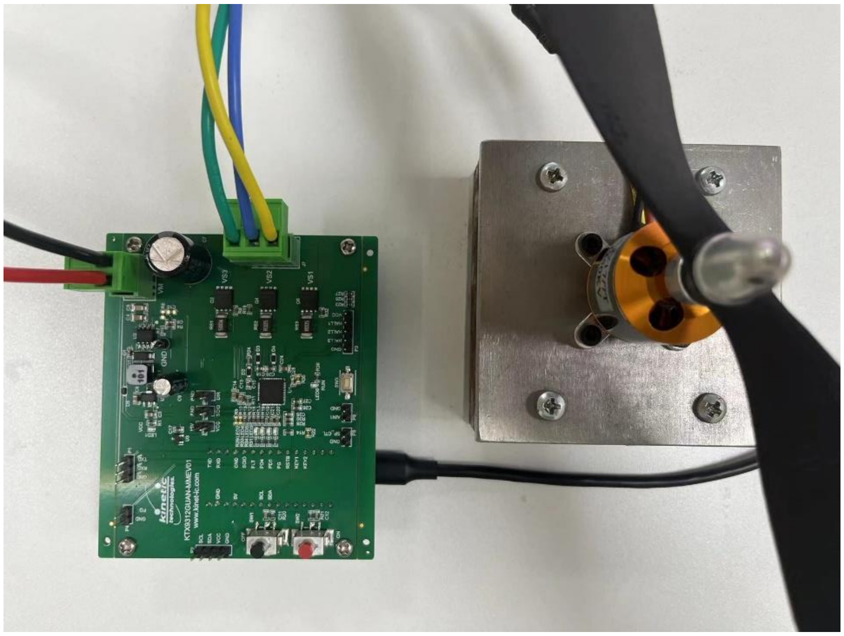


EVAL Board Test Procedures

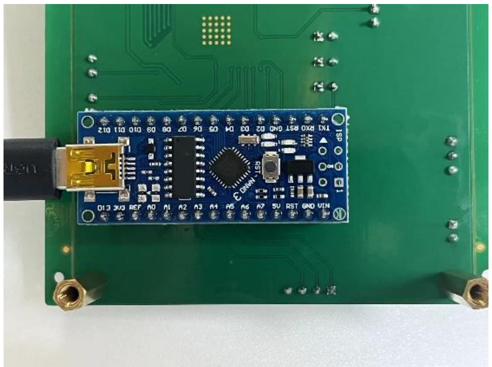
1. Hardware Connection

Step 1: Motor Wiring

Connect the motor 3-phase windings to J7, on the EVAL board. The motor rotation direction will be reverse if the phase connection sequency is not right. that can be adjusted by software, Jumper P6 on the EVAL board, or motor wire swap.



Step 2: Mount the Arduino Nano board to the back of the EVAL board.



The Arduino Nano can be powered from either the USB V_{BUS} or from the EVAL board V_{CC}. If the KTX_GUI is being used, then the Nano must be powered from the USB V_{BUS}. To avoid V_{BUS} and V_{CC} interacting P5 jumper should be removed.

Step 3: DC power supply

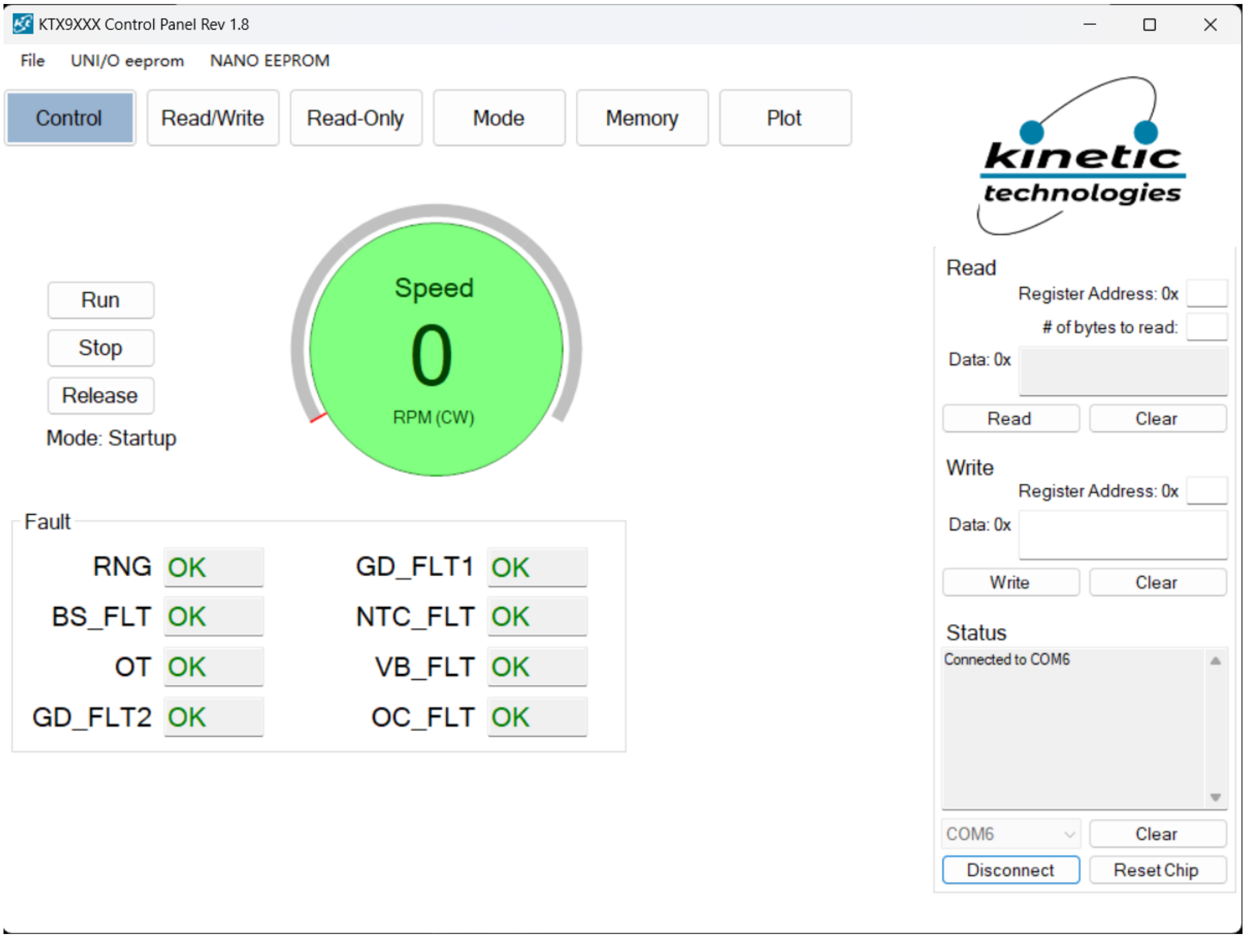
Connect VM to a DC power supply to socket J1.

2. Software Connection

Before launching the KTX_GUI, please ensure that the CH340 USB-SERIAL drivers have been correctly installed.

Open the KTX_GUI software, that is already installed in your computer. There is the detailed information in the later chapter about KTX_GUI software.

The main interface is shown below:



Speed: 0 RPM (CW)

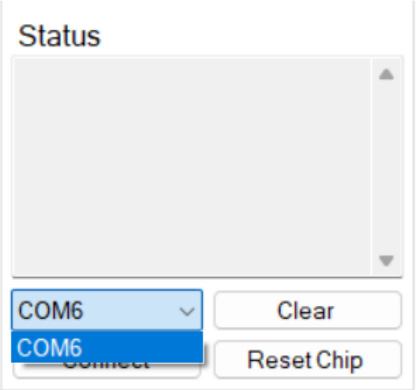
Mode: Startup

RNG	OK	GD_FLT1	OK
BS_FLT	OK	NTC_FLT	OK
OT	OK	VB_FLT	OK
GD_FLT2	OK	OC_FLT	OK

Status: Connected to COM6

COM6

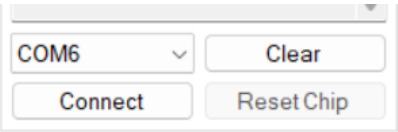
1. At the right corner of <Control>, select the detected COM port in the scroll bar.



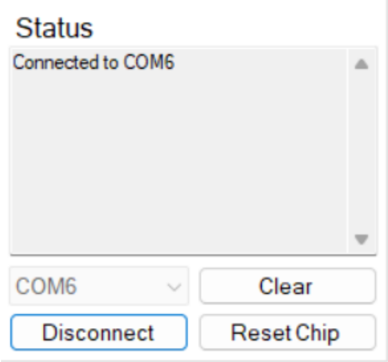
COM6

COM6

2. Then click <Connect>.



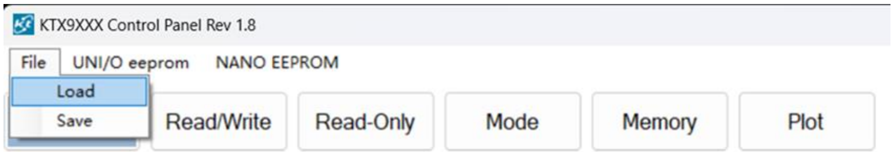
3. If the communication is successful, shows the information in the status box.



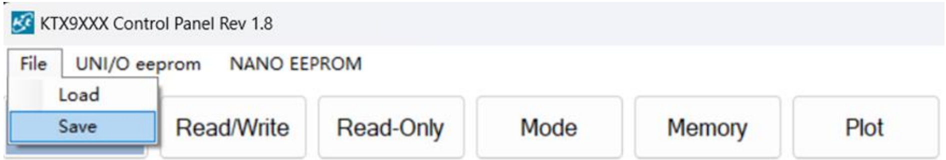
Connected to COM6

4. Wait two seconds for the communication to succeed, then click <memory>, which will show the default or loading values of the registers.

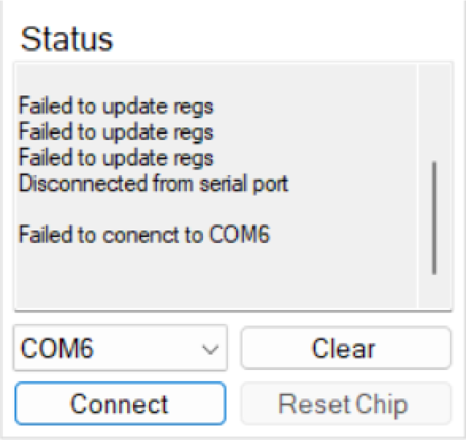
5. In the main menu, select <File>, then <load> to load the parameters from existing EXCEL file and then click <memory> to update the registers' value for checking.



6. To save the motor control parameters, select <save> to the designated Excel file.



7. If a communication failure occurs, please check to ensure that both the power supply and serial port connection are normal.



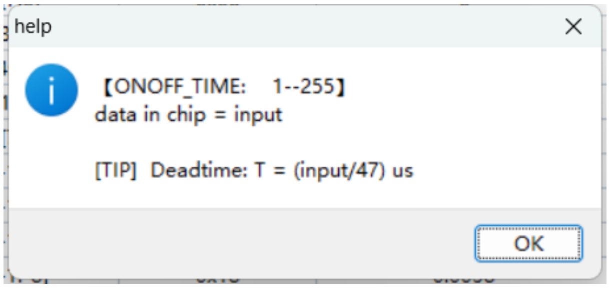
```
Failed to update regs
Failed to update regs
Failed to update regs
Disconnected from serial port

Failed to conenct to COM6
```

3. Checking Registers' Value

Click <Read-Only> to check all read-only register's value.

Click <Read/Write> to check all R/W registers' value.

If you right mouse clicking on any register, there is a pop-up box that displaying more information about this register, including "tips".



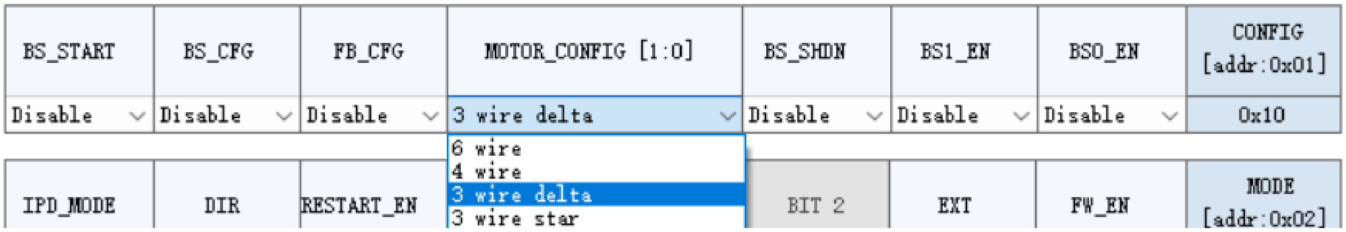
【ONOFF_TIME: 1--255】
data in chip = input

[TIP] Deadtime: T = (input/47) us

Setting the Basic Parameters of the Motor

Have the system configuration of motor control in <Mode>

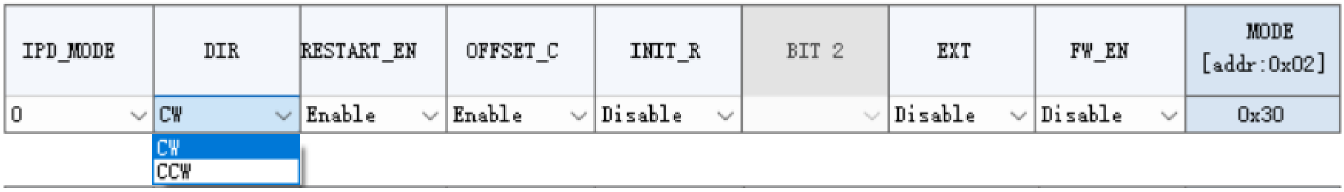
1. Motor Control Mode Selection



BS_START	BS_CFG	FB_CFG	MOTOR_CONFIG [1:0]	BS_SHDN	BS1_EN	BS0_EN	CONFIG [addr:0x01]
Disable	Disable	Disable	3 wire delta	Disable	Disable	Disable	0x10

2. Motor Rotation Direction Selection

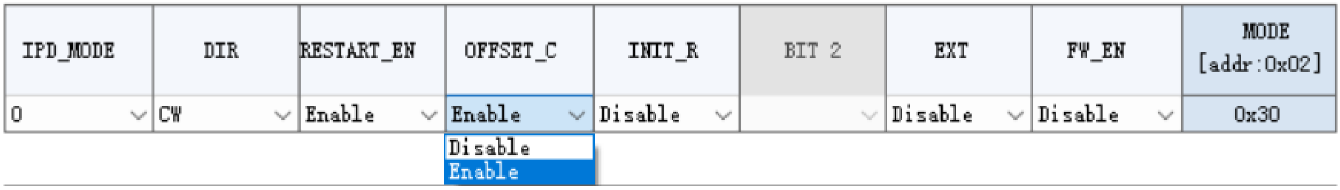
Motor can be set to run either clockwise (CW) or counter-clockwise (CCW). In some applications, it is required to switch CW\CCW to change direction directly, when the motor is running.



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
0	CW	Enable	Enable	Disable		Disable	Disable	0x30

3. ADC Offset Cancellation

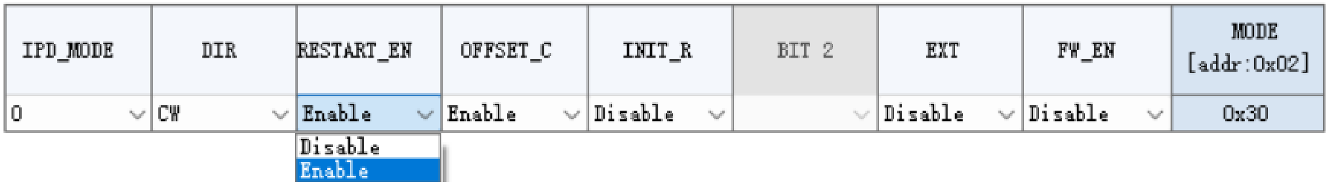
Enable the ADC calibration to eliminate the ADC voltage offset.



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
0	CW	Enable	Enable	Disable		Disable	Disable	0x30

4. Restart/Stop Setting for Flux Error

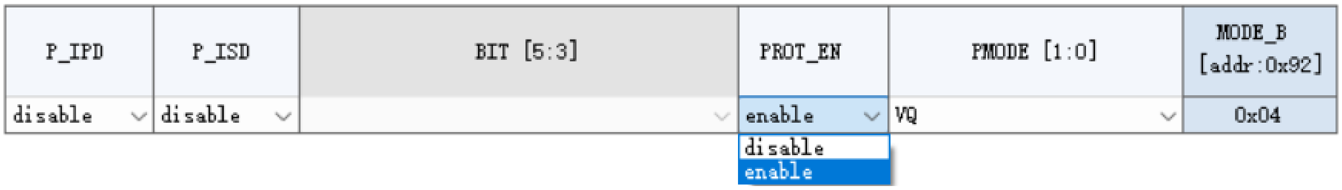
The magnetic flux magnitude will always be checked. When F AMG is lower than the set FMAG_LOW value, the motor will keep trying to start (RESTART_EN is enable) or stop (RESTART_EN is disable). In the RESTART process, ISD is not implemented.



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
0	CW	Enable	Enable	Disable		Disable	Disable	0x30

5. Protection Enable

To activate protection on NTC overtemperature, over-voltage, under-voltage, and over-current, it sets "PORT_EN" - bit 2 of MODE_B (0x92) to enable all protection.



P_IPD	P_ISD	BIT [5:3]	PROT_EN	PMODE [1:0]	MODE_B [addr:0x92]
disable	disable		enable	VQ	0x04

6. Control Board Shunt Resistance, ADC Range Selection

The shunt resistor is a component used to sample the motor current. Its magnitude directly affects the accuracy of sampling and signal quality. The ADC range selection is related to the input voltage range; the wider the voltage range, the larger the sampling current value.

The resistance value of the motor's windings is given in the motor parameter data. Generally, the shunt resistor value chosen should be approximately less than 10% of the resistance value of the windings. To allow the motor to run at its maximum rated phase current, the shunt resistor should be greater than the maximum rated current of the motor, i.e. greater than the stalled phase current. If the selection of the shunt resistance value is too small, then the motor cannot be controlled to run at its rated current. If the selection of the shunt resistance value is too large, it will greatly impact the accuracy of the control system. Therefore, choosing the right shunt resistor is very important.

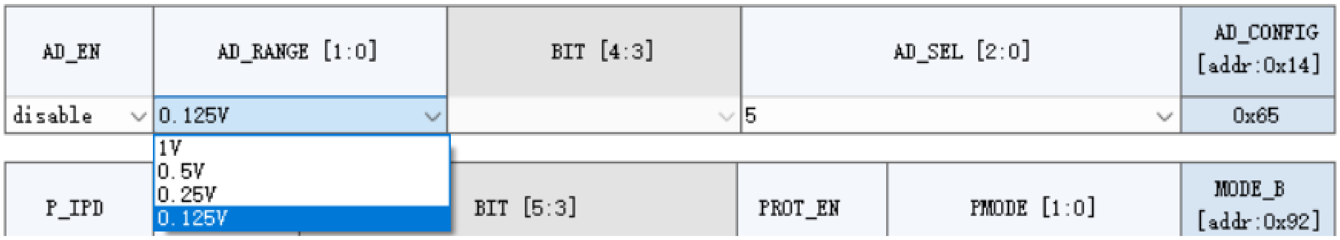
If a 5mΩ resistor is selected, and the programmed AD voltage is 0.125V (default), the sense phase current range is 25A (I = V/R = 0.125V/0.005Ω).

If the rated power of the shunt resistor is 3W, then the rated motor phase current cannot exceed 24.49A (I=$\sqrt[2]{P/R}$). Peak-to-peak = 2 * peak, rms = peak/1.414 = 0.707 * peak, i.e., the peak-to-peak of motor phase current cannot exceed 69.3A.

In practical applications, the phase current is prevented from being too large to prevent the shunt from over-heating, and the rated power of 3W is normally controlled within 2W, then the rms of phase current within 20A to ensure normal operation.

Relevant Parameters

AD_CONFIG(0x14): There are four selections for ADC voltage input range:



AD_EN	AD_RANGE [1:0]	BIT [4:3]	AD_SEL [2:0]	AD_CONFIG [addr:0x14]
disable	0.125V		5	0x65

P_IPD		BIT [5:3]	PROT_EN	PMODE [1:0]	MODE_B [addr:0x92]

RSENSE (0x74: 0x75): The value of the shunt resistor.

7. MOSFET Related Settings

The KTX9xxx series have a system clock of 47MHz, which indirectly sets the PWM frequency.

PWM frequency is = $\frac{\text{System clock}}{PWM_{PERIOD}*64}$ = 47MHz/32*64 = 22949Hz, and all subsequent calculation times are based on this PWM frequency.

MOSFET parameters are distinguished according to the characteristics of the device itself, and the following parameters are set in the demo board:

Set values: OFF_WIDTH (48) 1µs, ONOFF_TIME (12) 255ns, PWM_PERIOD (32).

Relevant Parameters

ONOFF_TIME (0x04): Dead time is required when changing the duty cycle of PWM output, to prevent the driver from being damaged by high shoot-through current, should both MOSFETs be turned on simultaneously. It is therefore necessary to stagger the switching time of the high-side and low-side MOSFETs. Deadtime allows time for the switch to break before the next switch turns on. As a result, both outputs will be temporarily turned off to ensure that the two drivers will not conduct at the same time. This is called "deadtime", and will ensure the safety of the circuit.

OFF_WIDTH (0x05): The minimum on-time (also known as the minimum on-off time) of the low-side MOSFET refers to the time required to charge the bootstrap capacitor. This time is also known as the high-side bootstrap capacitor charging time. As the top MOSFET switch uses a bootstrap capacitor, this must be charged with energy that supplies high-side drive bias current over the time when high-side MOSFET is turned on. Typically, the minimum on-time of low-side MOSFET is in the range of hundreds of nanoseconds to thousands of nanoseconds, depending on the characteristics of the MOS and bootstrap capacitors.

PWM_PERIOD (0x06): It is used to set the total counters of master clock cycle in one PWM cycle as 64 times the set value. Default value (32) refers to 22949Hz PWM frequency.

8. Overcurrent Protection

When the motor is running, if the total phase current exceeds the set threshold at a period of time, the overcurrent protection function is triggered to protect the motor and other equipment from damage.

C_FAULT – When the current is higher than IMAX (0xDE: 0xDF), bit 0 of STATUS (0x00) is triggered.

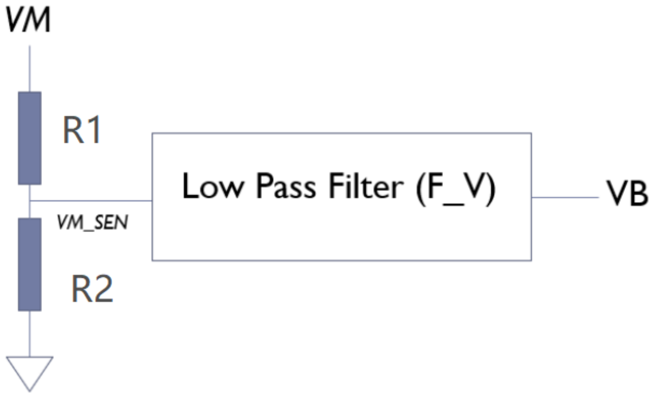
Relevant Parameters

IMAX (0xDE: 0xDF): The current threshold for overcurrent protection, compared to the sum of unsigned three-phase currents, nominal unitary (range 0-4). Per-unit value 1.0 is set as ADC input range / Rsense.

OC_TIME(0x2A): The length of overcurrent duration, the unit is 128/PWM Freq, with the range (0-256). The maximum time is 256*128/22949 = 1.4seconds

9. Overvoltage, Undervoltage Related

The voltage is detected by the voltage divider circuit on the VM_SEN pin. The ADC input range is between 0V and 2.0V.



Bus Voltage Sensing

The specific parameters can be read from the VB register (0xB6:0xB7), as shown in the circuit of the voltage divider resistor R1R2 above (R1 = 100kΩ, R2 = 4.7kΩ). If the value of VB (VM_SEN) is read as 0.5, the actual power supply voltage of VM (VB*V_RATION = 0.5*2(R1+R2)/R2 = 0.5*44.55 = 22.28V) can be obtained. If the overvoltage voltage is set to 24V, the parameter is set to VBH_LMT (24*256/44.55 = 138) or (24/44.55 = 0.539). If the undervoltage current is set to 18V the parameter is set to VBL_LMT (18*256/44.55 = 104) or (18/44.55 = 0.404).

In the application, the power supply or battery voltage is in the range between VBH_LMT and VBL_LMT that defined by user. VB0 is set as the rated voltage. (Note: When input voltage to VM_SEN is below 0.125V, the voltage value of VDC is used to calculate the voltage internally by the IC, and no VB feedforward compensation is used in the control algorithm).

To turn on undervoltage and overvoltage protection, set bit 2 of PROTECT_EN - MODE_B (0x92) to enable all protection. V_FAULT - When VB(0xB6:0xB7) is above HIGE_LMT or below LOW_LMT, the bit 1 of STATUS(0x00) is triggered.

Relevant Parameters

VB0(0x1A): The actual reference voltage value of the chip, range (0-1), specific parameters can be read from readable register VB.

V_RATIO (0x54: 0x55): Based on the resistance value of the VM_SEN pin, this value is equal to 2(R1+R2)/R2 = 44.55

VDC (0x72: 0x73): DC supply voltage.

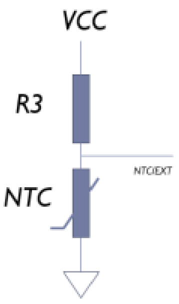
VBL_LMT(0x9A): Minimum VB value for under-voltage protection, the specific parameters are adjusted according to the actual application.

VBH_LMT (0x9B): Maximum VB value for over-voltage protection, the specific parameters are adjusted according to the actual application.

Complete the following parameters. Name	Address	Register meaning
ONOFF_TIME	0x04	Dead time setting to protect the MOSFETs from shoot-through. The time unit is 1/Master clock. Set it as MOSFETs' spec
OFF_WIDTH	0x05	Low-side MOSFET minimum on-time (high-side bootstrap capacitor charge time). The time unit is 1/Master clock. In general, the value is set from 32 ~ 192. Try from 64.
PWM_PERIOD	0x06	To set PWM frequency, that equals to Master Clock/(64 * PWM_PERIOD). The default value is 32
AD_CONFIG	0x14	The ADC input range for shunt current sampling
POLE_PAIR	0x61	Number of the motor's pole pairs
VDC	0x72 : 0x73	The DC voltage value of the bus voltage
RSENSE	0x74 : 0x75	The resistance of shunt for current sampling

10. Temperature Protection

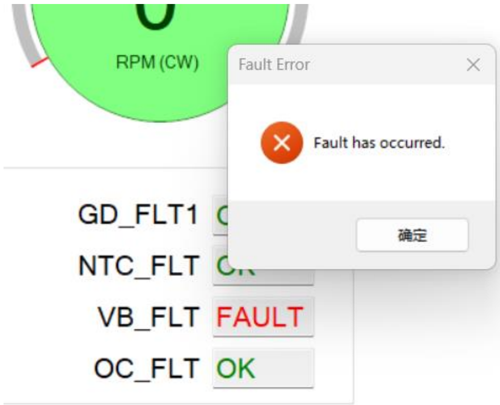
A external thermistor can be used to monitor temperature inside the motor or the PCB board. The voltage is detected by the voltage divider circuit on the NTC/EXT pin, and the ADC input range is from 0V to 2.0V.



Relevant Parameters

NTCH_LMT(0x9C): Used to set the limit, the ADC input range is from 0V to2V.

When the internal protection of the chip is triggered, the KTX_GUI will flag the issue.



Fault has occurred.

GD_FLT1
NTC_FLT
VB_FLT FAULT
OC_FLT OK

11. Motor's Parameters for the Control

The resistance and inductance value of windings is required to be set properly for the flux and angle estimation. The relative registers are R_STARTUP/L_STARTUP (VQ Startup Control), R_VQ/L_VQ (VQ Control) and R_FOC/L_FOC (FOC).

In general, the value is set as the specification provided by motor's vendor. Be minded that it is phase parameters, so the value is half of resistance (line-line) if it is star connection, or 3/2 of resistance (line-line) if it is delta connection. The inductance value is similar as resistance. After considering the effect of MOSFETs Rd_{on} and shunt/lead-out wire, the value may be a little larger. Also, the value for VQ Start-up control is larger than VQ control and FOC control, the value with 1.1 ~ 1.3 time phase resistance is used in most case.

Torque Constant ①	±10%	K_t	Nm/A_{rms}	0.124	0.087	0.201	0.142	0.265	0.196
			lb-in/A_{rms}	1.10	0.766	1.78	1.261	2.34	1.731
Back EMF Constant ②	±10%	K_e	V_{rms}/k_{rpm}	8.09	5.64	13.09	9.28	17.2	12.7
Motor Constant ⑥	Nom	K_m	N-m/√W	0.211	0.210	0.335	0.332	0.422	0.428
			lb-in/√W	1.87	1.85	2.97	2.94	3.74	3.79
Resistance (line-line) ②	±10%	R_m	Ohm	0.230	0.114	0.240	0.122	0.262	0.139
Inductance Q-Axis (line-line)		Lqll	mH	0.54	0.26	0.57	0.29	0.61	0.33
Inductance D-Axis (line-line)		Ldll	mH	TBD	TBD	TBD	TBD	TBD	TBD

For example, the motor of first column: 0.230 Ohm – Resistance (line-line), 0.54mH – Inductance (line-line)

R_FOC=R_VQ=0.115ohm, L_FOC=L_VQ=0.27mH. R_STARTUP=0.125ohm, L_STARTUP=0.27mH.

At the same time, the KINV parameter, that is used in Open-Loo, can be calculated with Back EMF Constant and Pole pair information by following formula.

$$KINV = 60 * VDC * \frac{SPEED\_CONSTANT}{FREQ} * \frac{Frequency\_BEMF}{VPEAK\_BEMF}$$

Frequency_BEMF: The Frequency of phase's Back EMF

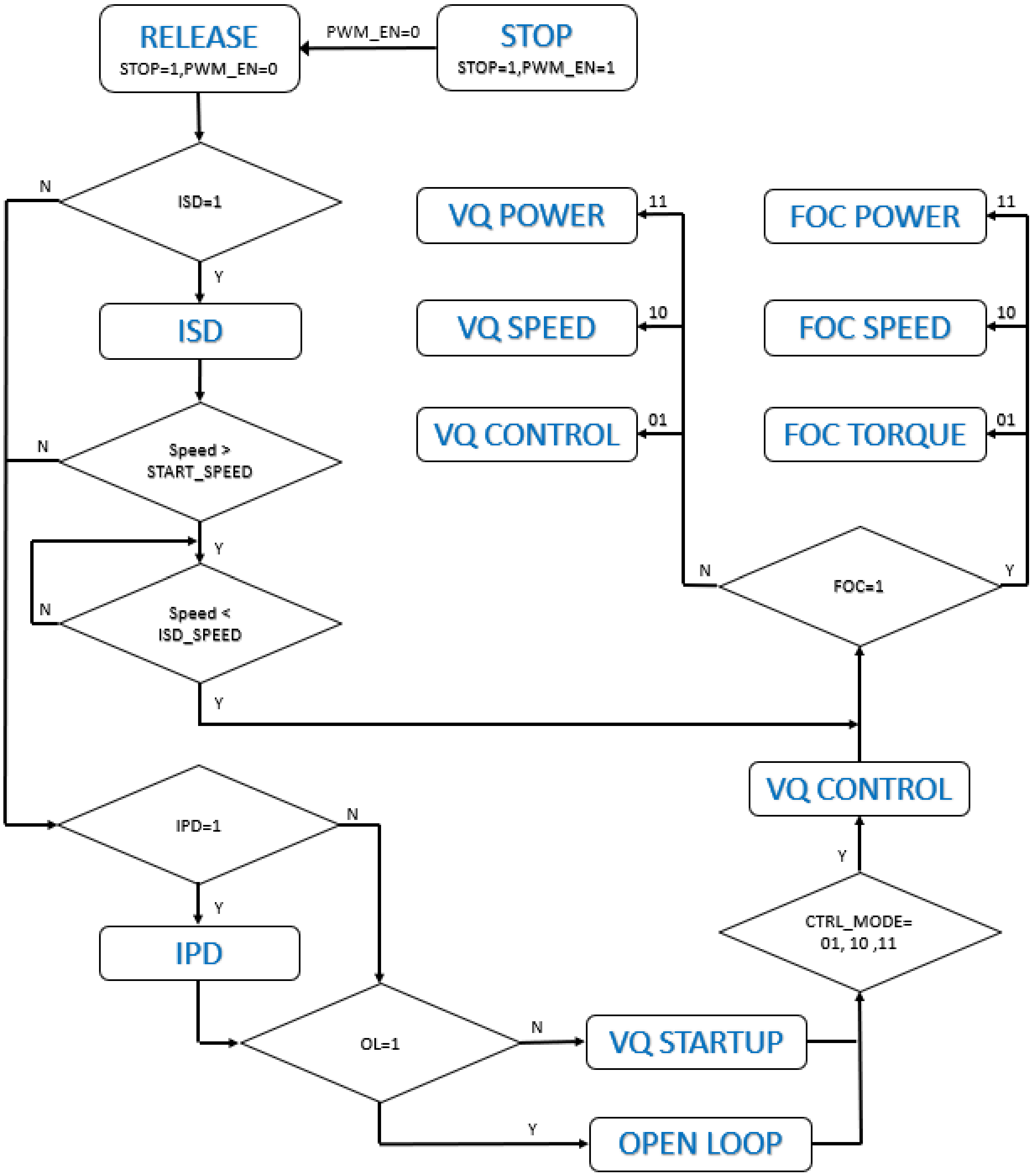
VPEAK_BEMF: The Peak Voltage of phase's Back EMF

For example, the motor of first column: K_e = 8.09 Vrms/Kpm (line-line), 4 pole pairs. VDC=48V

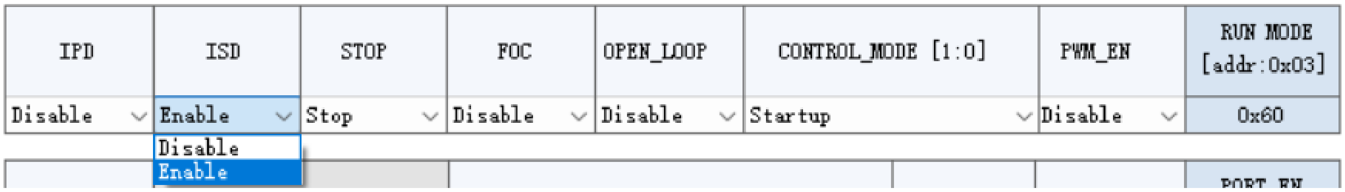
By using the default value of SPEED_CONSTANT (546), and FREQ (22950),

$KINV = 60 * 48 * (546/22950) * ((1000*4/60)/(8.09*\sqrt{2}/\sqrt{3}) = 691.5$

Motor Control Scheme



12. Initial Speed Detection (ISD)



IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Enable	Stop	Disable	Disable	Startup	Disable	0x60

To detect the initial speed of the motor before start-up, ISD_EN needs to be enabled.

This function is used to detect the initial speed. If the detected speed in first stage is lower than START_SPEED (0x42,0x43), it will end this detect function, and treats the motor as it is stationary. Otherwise, it detects the higher speed limit in second stage. If the detected speed is lower than ISD_SPEED (0xF6,0xF7), it will transit directly into the close loop running state without needing to run through the start-up procedure. Otherwise, it will repeat the second process until the speed decelerates to defined speed range, then transit to close loop running state.

Relevant Parameters

ISD_TIME1 (0x20): Duration time for the first round – low speed detection, 256/PWM Freq.

ISD_TIME2 (0x21): Duration time for the second round – high speed detection, 256/PWM Freq.

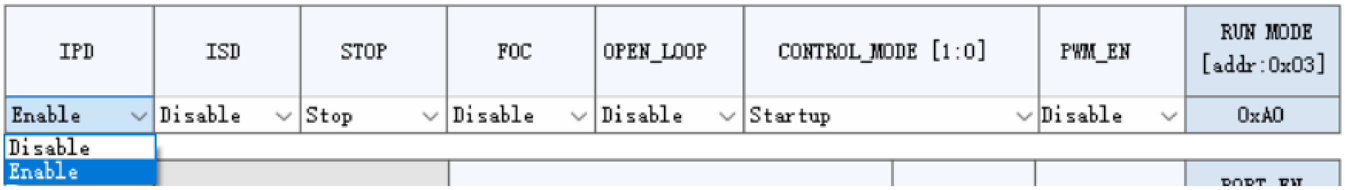
START_SPEED (0x42: 0x43): Lower speed limit in ISD speed range.

ISD_SPEED (0XF6: 0XF7): Higher speed limit in ISD speed range.

13. Initial Position Detection (IPD)

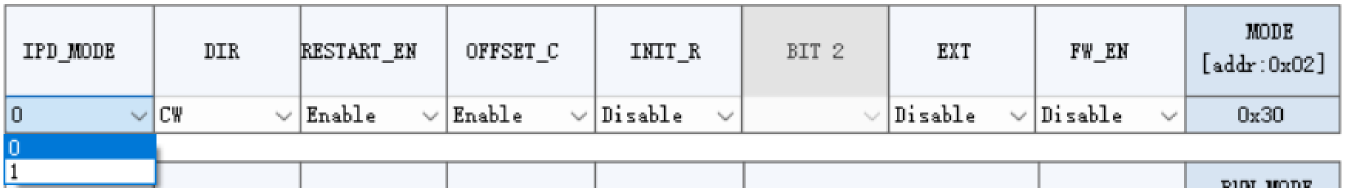
If it is necessary to detect the initial position of the motor before the motor starts, IPD_EN needs to be enabled, and IPD mode 0 is normally used.

IPD mode Selection:

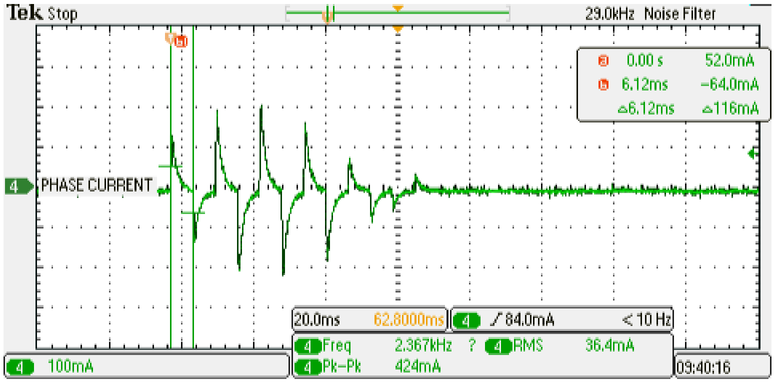


IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Enable	Disable	Stop	Disable	Disable	Startup	Disable	0xA0

For IPD mode 0 , angles 0 >> 180 >> 30 >> 210 >> 60 >> 240 >> 90 >> 270 >> 120 >> 300 >> 150 >>330, PWM is injected once at each angle.

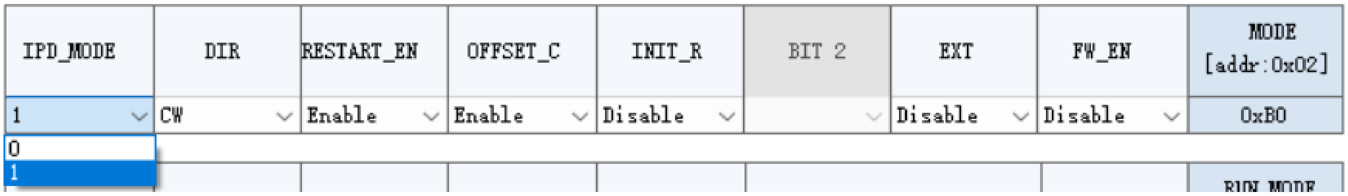


IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
0	CW	Enable	Enable	Disable		Disable	Disable	0x30

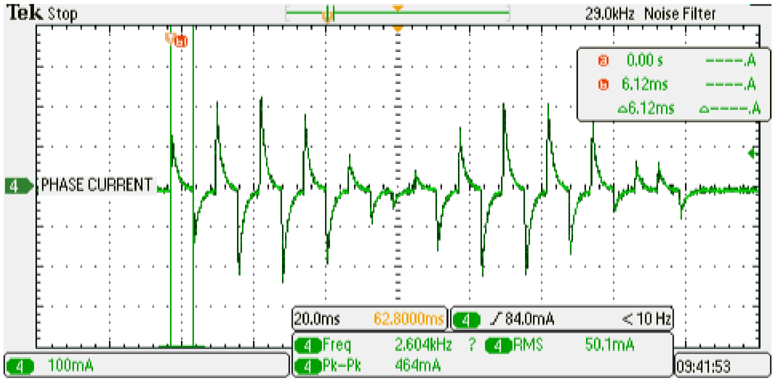


IPD0 IPD_TIME=12 OFF_TIME=2

For IPD mode 1 (IPD_MODE enable), angles 0 >> 30 >> 60 >> 90 >> 120 >> 150 >> 180 >> 210 >> 240 >> 270 >> 300 >> 330, PWM will be injected twice for each angle.



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
1	CW	Enable	Enable	Disable		Disable	Disable	0xB0



IPD1 IPD_TIME=12 OFF_TIME=2

If the PARK_PWM value is too large, the motor will produce noise with slight rotation. If it is too small, the Theta value can be unreliable with indistinguishable current reading. Adjust the PARK_PWM and charging time, to have consistent Theta value when the motor keeps still and quiet.

Relevant Parameters

IPD_TIME (0X27): Duration time of parking pulse applied to the motor in each angle, the time unit is 1/PWM Freq. In general, the value is from 4 to 48. Try from 12.

OFF_TIME (0X28): Resting time for releasing inductance current before next detection pulse, the time unit is 64/PWM Freq. In general, the value is from 1 to 8, Try from 2.

PARK_PWM(0X1F): PWM output amplitude in 1.0 scaler for parking. In general, the value is from 0.025 to 0.25. Try from 0.05.

Open Loop Control

In open-loop control mode, the controller outputs sinusoidal PWM signal with given frequency. Open-loop control is an start control scheme in the KTX9xxx IC. In general, it can be used to determine whether the three phases of the motor is balanced by observing three-phase currents. Also the rotating direction can be simply checked in this V/F mode.

1. Parameter Settings Required for Opening the Loop

The first step is to set the speed parameters according to the following equation:

$$\boldsymbol{ENDSPEED = STARTSPEED + A1 * t + \frac{1}{2}\ (A2 * t^2)}$$

where t = OL_TIME, and the minimum step size is 1*256/23000 = 11ms.

If the final speed is 200 RPM, the starting speed is 16 RPM, the first order acceleration A1 =1, and the second order acceleration A2 = 0,

then to accelerate to 200 RPM takes:

(200-16)/1*11 = 2.024s.

The second step is to set the VQ value. The applied VQ value is calculated according to the following equation:

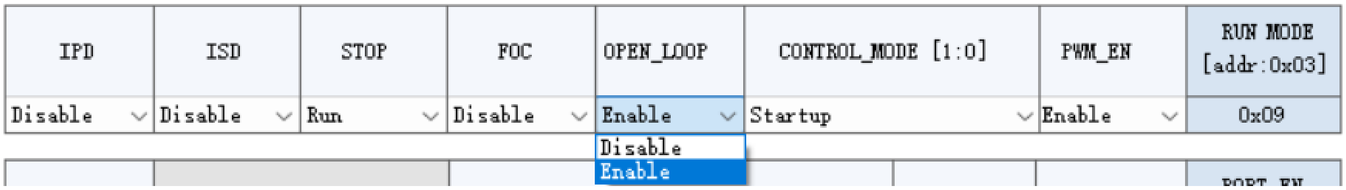
$$VQ = START\_VQ + \frac{\omega ol}{KINV}$$

The first applied VQ is START_VQ. The VQ value is changed at each step as the above equation to have enough phase current (torque) in the acceleration process.

In most case, STARTVQ value is less than 0.075. It may be lower with high speed motor, or higher in high torque application.

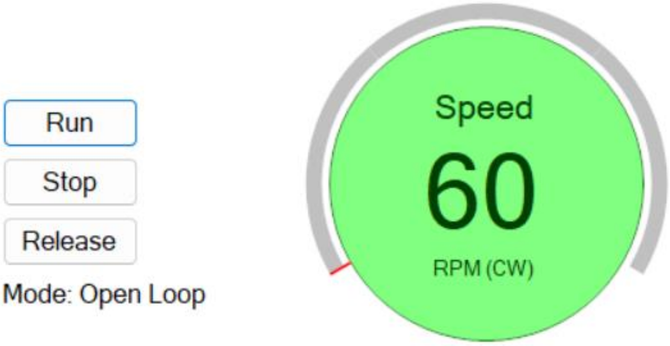
Name	Address	Register meaning
OL_TIME	0x23	The time interval of the acceleration process in the open loop. The unit time is 256/PWM Freq. The larger the parameter, the longer the acceleration process.
START_SPEED	0x42: 0x43	Start speed of the open loop. Try from 10 to have stable and smooth rotation from still.
END_SPEED	0x44: 0x45	The target speed of the open loop. Set from 1/10 to 1/6 of maximum speed of the motor to have enough BEFM for the transition to FOC.
A1	0x46: 0x47	First order acceleration parameter. Try from 1.0 to have stable and quick acceleration.
A2	0x48: 0x49	Second order acceleration parameter. Try from 0.05 to have stable and quick acceleration.
START_VQ	0x4A: 0x4B	The initial VQ value in the open loop. Try from 0.025 to have stable and smooth rotation from still.
KINV	0x4C: 0x4F	Motor back EMF parameters, used for the calculation of VQ in Open Loop operation.

2. <Run_mode> Mode Selection: <OPEN_LOOP> Enable



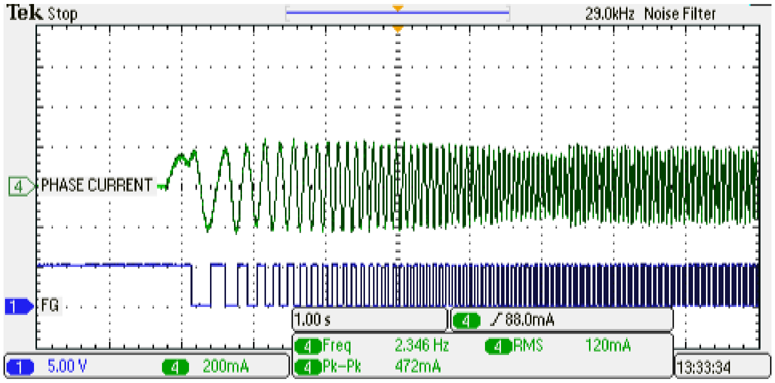
IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Run	Disable	Enable	Startup	Enable	0x09

After selecting the motor control mode, return to the KTI_GUI home page to control the motor rotation.



Mode: Open Loop

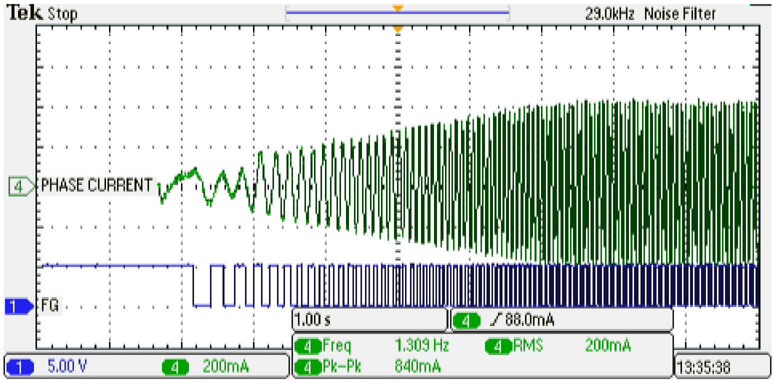
3. Phase Current and FG Waveform with All Suitable Parameters.



OPEN-LOOP – Suitable parameters

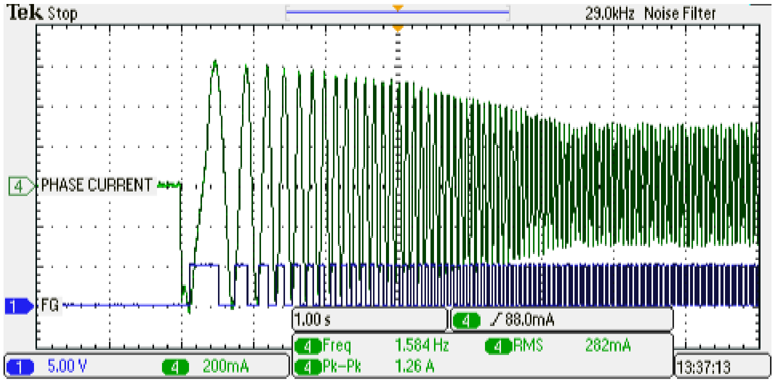
The phase current and FG waveform with different START_VQ:

The START_VQ is Small



OPEN-LOOP START_VQ is too smaller

START_VQ is Large

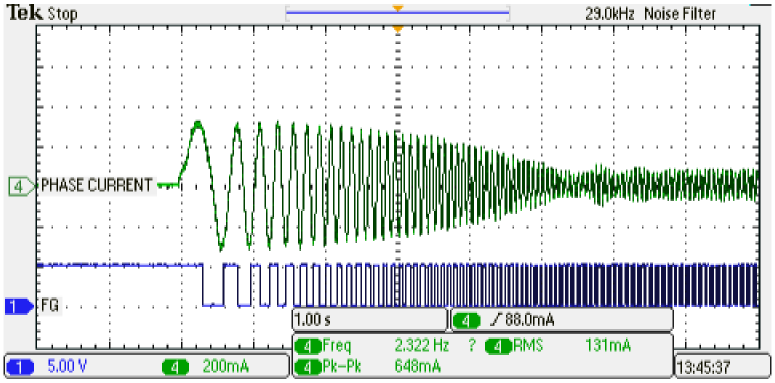


OPEN-LOOP START_VQ is larger

A large START_VQ will cause the starting current to be excessive and may even trigger the current protection. If it is too small, the motor will stop before reaching the end speed since there is not enough torque for this acceleration.

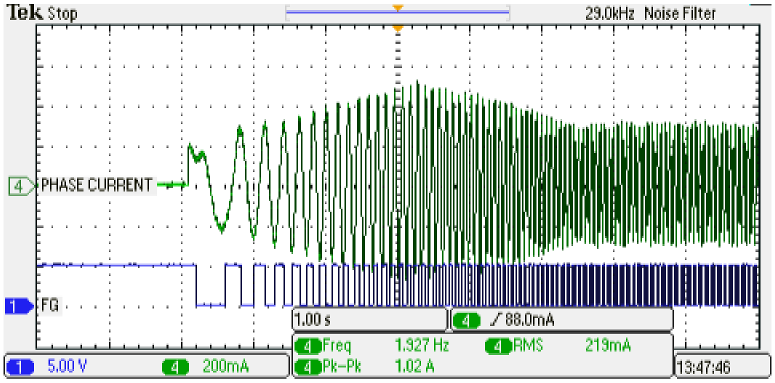
The phase current and FG waveform with different KINV:

The KINV is Large



OPEN-LOOP KINV is large

The KINV is Small



OPEN-LOOP KINV is small

When the KINV is larger, the phase current will be reduced gradually, the motor may be stopped if the torque is not enough to support the acceleration in the open loop. When the KINV is smaller, the phase current will be increased gradually, sometimes overcurrent protection will be triggered.

VQ STARTUP

VQ Startup is another start-up scheme of the KTX9xxx IC. In this stage, the motor is driven with specific angle for certain period. And the motor will be secured to rotate at given direction even there is torque change by observing the flux magnitude information.

1. VQ Start-up Basic Parameter Setting

Step 1: Set the OL_TIME to 0 to skip open-loop process.

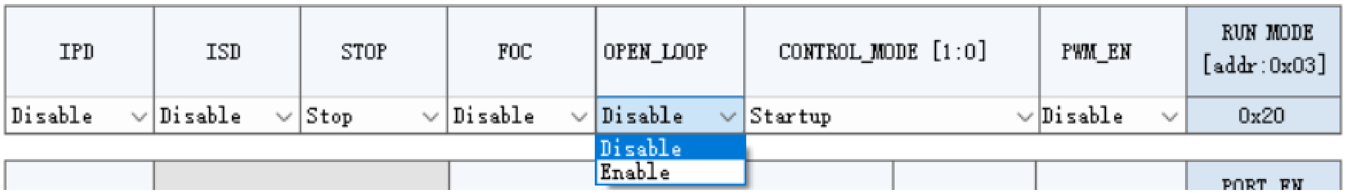
Step 2: Set R_STARTUP & L_STARTUP as the measured motor parameters.

Step 3: Use 0.05 as START_VQ at first, then adjust it by 0.01 step with observing the phase current, Reduce START_VQ when the phase current is higher, or vice versa.

Step 4: Adjust STARTUP_TIME between 6 and 40 for the time of each step. Small value for high-speed motor, large value for high-torque one.

Name	Address	Register Meaning
START_VQ	0x4A : 0x4B	The fixed VQ used in this operation.
STARTUP_TIME	0x22	The time of each step driving with same specific angle. The time unit is 9/PWM Freq.
OL_TIME	0x23	The time interval of the acceleration process in the open loop. The unit time is 256/PWM Freq. This open loop may be running for a short period as this register set to have smooth rotating from still. It can be set as 0 to run the VQ startup directly.
R_STARTUP	0x78 : 0x79	The resistance value of the motor windings used in the VQ Startup stage.
L_STARTUP	0x7A : 0x7C	The inductance value of the motor windings used in the VQ Startup stage.
MIN_DTHETA	0x7D	Minimum angle change between steps in this operation. If the estimated angle change is greater than the set value, the estimated angle is used. If it is less than this angle, the new angle is updated with this adding angle.
F_A	0x64 : 0x65	The coefficient of first-order HPF for Position/Angle Estimation. In general, it is selected in the range of 1/128 ~ 1/2048. Try from 1/256.
F_B	0x66 : 0x67	The coefficient of first-order LPF for Position/Angle Estimation. In general, it is selected in the range of 1/16 ~ 1/128. Try from 1/16.

2. <Run_mode> Mode Selection: <OPEN_LOOP> Disable



IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Disable	Disable	Startup	Disable	0x20

After selecting the motor control mode, return to the KTI_GUI home page to control the motor rotation.

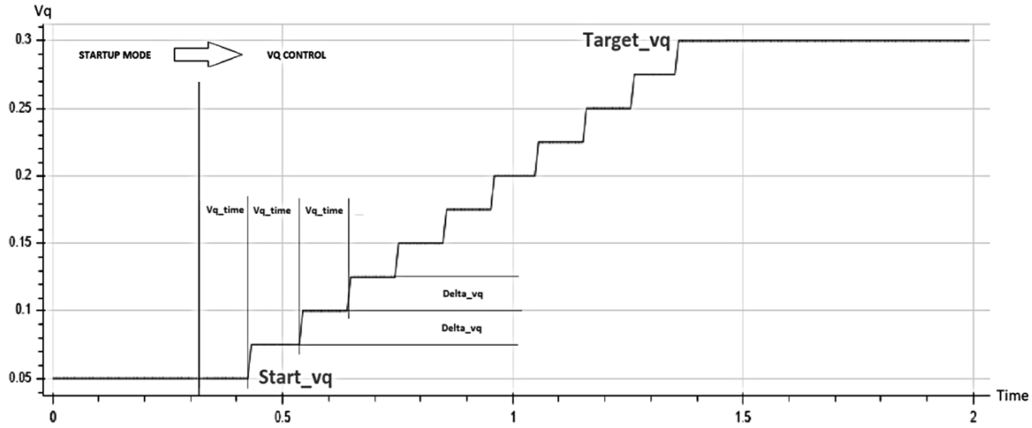
VQ Control

VQ control is a closed loop system that is an alternative scheme to field-oriented control with faster response.

During control, VQ will rise from "START_VQ" to "TARGET_VQ" by the following equation:

$$VQ = Start_{vq} + (delta\ vq)\ x\ t$$

Where t is the number of Vq_time



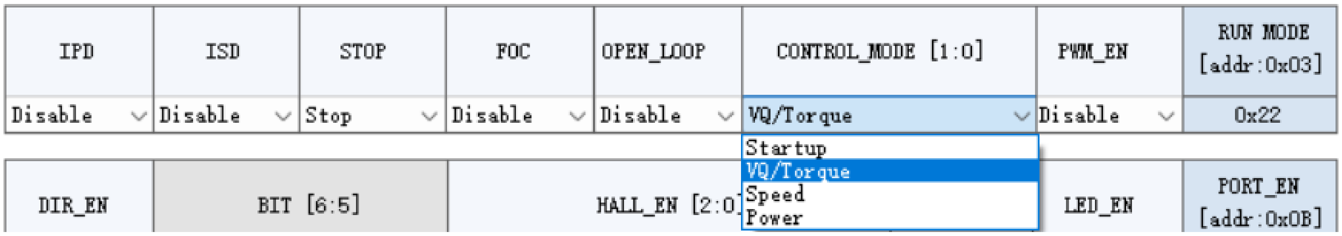
1. Basic Parameter Setting

1. Set the TARGET_VQ, DELTA_VQ - the incremental VQ value per step, V Q_TIME - the step time.

2. Set R_VQ and L_VQ, by using R_STARTUP and L_STARTUP as reference.

Name	Address	Register Meaning
DELTA_VQ	0x6A : 0x6B	The step VQ increasing from START_VQ to TARGET_VQ. In general, it is from 0.005 to 0.1. Try from 0.01.
TARGET_VQ	0x6C : 0x6D	The goal of VQ in this VQ Control operation. If the control is transiting to FOC, it is set from 0.1 to 0.2. Otherwise, it is set as required, from 0.025 to 1.0.
VQ_TIME	0x24	The step time for VQ ramping up in VQ control. The unit time is 256/PWM Freq. In general, it is set from 1 to 16. Try from 2.
LOCK_TIME	0x1E	The process time of VQ start-up before transitioning to VQ control. The unit time is 256/PWM Freq. In general, it is set from 1 to 32, Try from 8.
FAMG	0x96 : 0x97	Current flux magnitude (read-only)
FMAG_LOW	0x6E : 0x6F	The flux magnitude threshold for the detection of normal operation. If it detects that FMAG is lower than this set value, it means the abnormal operation, and the motor will be stopped or re-start the motor control through start sequence without ISD, which is selected by the RESTART_EN bit in MODE. In general, it is set from 0.5 to 16. Try from 1.0. The value is smaller in high-speed/low torque application, and higher in high torque/low speed application.

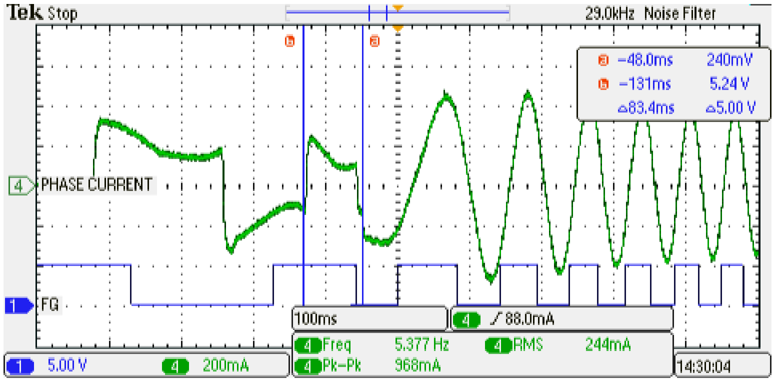
2. Run_mode Mode Selection



IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Disable	Disable	VQ/Torque	Disable	0x22

3. Motor Phase Current and FG Waveform

Set LOCK_TIME (8) to have the stable flux amplitude in VQ startup stage before transition to VQ control. The specific time is 8*256/22950=81.9ms. Under normal circumstances, it gets enough flux information for the angle estimation used for VQ control in this VQ start-up operation.



VQ Control transition

Constant Torque Control (FOC Torque Control)

1. FOC Parameter Setting

To have smooth transition from VQ control or Open-Loop to to FOC closed loop control mode, the maximum value of the VQ - VQ_MAX will be increased from "VQM_START" to "VQ_MAX" by the following formula:

$$Q = VQMSTRT + VQMRAMP * VQMTIME$$

Name	Address	Register Meaning
VQM_RAMP	0x2C	The step incremented from VQMSTART to VQM while entering FOC. In general, the value is set from 0.005 to 0.1. Try from 0.02.
VQM_TIME	0x2D	The time step for VQM ramping up while entering FOC. The time unit is 256/PWIM Freq. In general, the value is set from 1 to 32. Try from 2.
VQ_MAX	0x50: 0x51	Maximum VQ limit. In general, the value is set as 0.975, or any logical value for the VQ max limitation.
VQ_MIN	0x52: 0x53	Minimum VQ limit. In general, the value is set as 0.05, or any logic value for the VQ min limitation.
VD_MAX	0xC8: 0xC9	Maximum VD limit. In general, the value is set as 0.25, or any logic value for the VD max limitation.
VD_MIN	0xCA: 0xCB	Minimum VD limit. In general, the value is set as -0.5, or any logic value for the VD min limitation. It should be negative value in most cases.

2. Constant Torque Parameter Setting

FOC current closed loop mode, which provides constant torque control as a first-order control loop. Motor torque is defined by the following formula:

$$torqueMotor = Ktorque * Iq$$

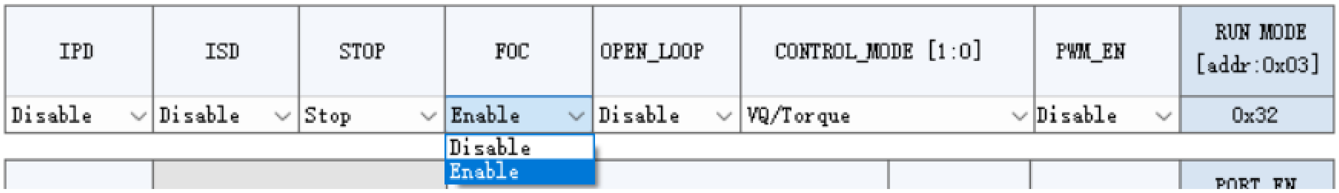
where K_{torque} is the torque constant of the motor and I_q is the quadrature current, which is used to control the torque.

Name	Address	Register Meaning
R_FOC	0x5C: 0x5D	The winding's resistance used in the FOC operation, for flux and angle estimation.
L_FOC	0x5E: 0x60	The winding's inductance used in the FOC operation, for flux and angle estimation.

Name	Address	Register Meaning
TARGET_IQ	0xC0: 0xC1	The torque command which is presented as IQ value used in current/torque regulator. In general, the value is from 0.05 to 0.75. Try from 0.1.
TARGET_ID	0xDC: 0xDD	The flux command which is presented as ID value used in current/torque regulator. It is 0 in normal operation.

Name	Address	Register Meaning
KP_IQ	0xC2: 0xC3	The proportional gain of PI control for IQ in current/torque regulator. In general, the value is from 0.05 to 1.5. Try from 0.125.
KI_IQ	0xC4: 0xC5	The integral gain of PI control for IQ in current/torque regulator. In general, the value is from 0.0005 to 0.005. Try from 0.001
KE_IQ	0xC6: 0xC7	The sum of error of PI control for IQ in current/torque regulator. It is 1.0 in normal operation.
KP_ID	0xCC: 0xCD	The proportional gain of PI control for ID in current/torque regulator. In general, the value is from 0.05 to 1.5. Try from 0.125.
KI_ID	0xCE: 0xCF	The integral gain of PI control for ID in current/torque regulator. In general, the value is from 0.0005 to 0.005. Try from 0.001
KE_ID	0xD0: 0xD1	The sum of error of PI control for ID in current/torque regulator. It is 1.0 in normal operation.

3. Run_mode Mode Selection

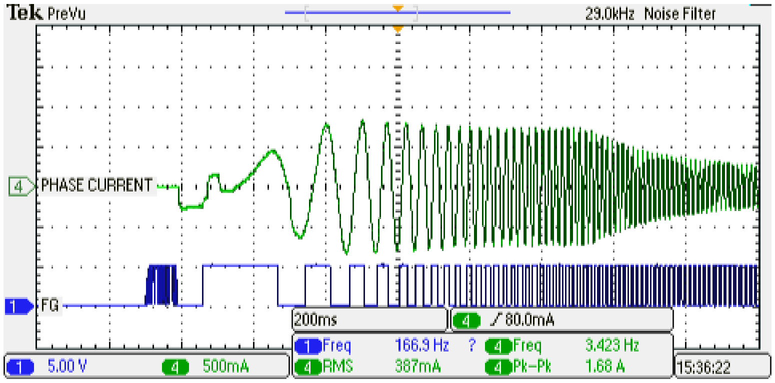


IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Enable	Disable	VQ/Torque	Disable	0x32

3. Motor Phase Current and FG Waveform

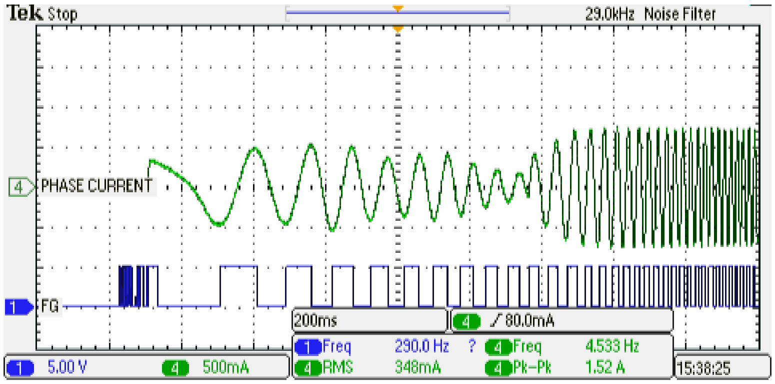
By selecting OPEN_LOOP bit or not, the process time to FOC torque control and the trend of phase current is as below.

ISD -> VQ Startup -> VQ Control -> FOC Torque Control



FOC Torque Control

ISD -> Open Loop -> VQ Control -> FOC Torque Control



FOC Torque Control from Open-Loop

Constant Speed, Constant Power Control (FOC Speed\Power Control).

1. Basic Parameter Setting

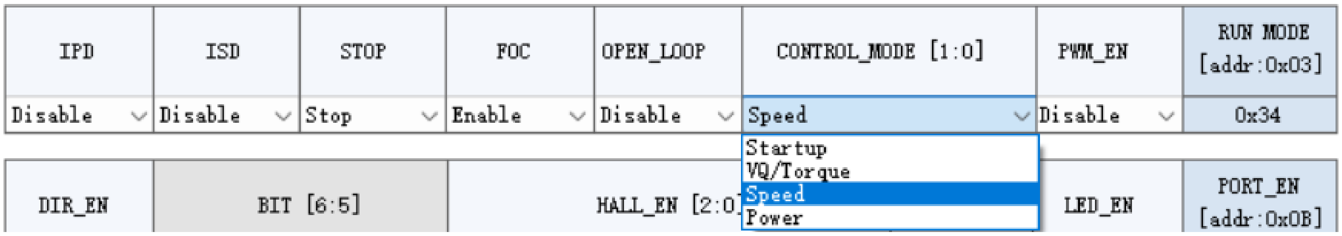
Name	Address	Register Meaning
FT_TIME	0x25	The time of duration for torque/current loop control before transiting to second-order speed/power control loop. The unit is 256/PWM Freq. In general, it is set from 4 to 32. Try from 8.
MAX_ERR	0x76 : 0x77	The maximum limit of error in the PI control of second-order speed/power regulator. In general, it is set from 4 to 128 in speed control, and 0.5 to 8 in power control. Try from 32 in speed control, and 2 in power control.
SP_TIME	0x26	The time interval of the PI control in second-order speed/power regulator. The unit is 16/PWM Freq. In general, the value is from 4 to 132. Try from 8.
IQ_MAX	0xD2 : 0xD3	The maximum IQ limit used in second-order speed/power regulator. In general, the value is from 0.2 to 0.75. Try from 0.4.
IQ_MIN	0xD4 : 0xD5	The minimum IQ limit used in second-order speed/power regulator. In general, the value is from 0.001 to 0.1. Try from 0.02.
KP_SP	0xD6 : 0xD7	The proportional gain of PI control for speed/power in second-order speed/power regulator. In general, the value is from 0.001 to 0.05. Try from 0.004
KI_SP	0xD8 : 0xD9	The integral gain of PI control for speed/power in second-order speed/power regulator. In general, the value is from 0.00006 to 0.0005. Try from 0.00025.
KE_SP	0xDA : 0xDB	The sum of error of PI control for speed/power in second-order speed/power regulator. It is 1.0 in normal operation.
F_C	0x68 : 0x69	The coefficient of first-order LPF for Speed/Power Estimation. In general, the value is from 0.005 to 0.1. Try from 0.015.
TARGET_SPEED	0x5A : 0x5B	The target value for speed
TARGET_POWER	0x56 : 0x57	Target value for power, unitary value (0-1).

Angle Adjustment

Considering the inductive effect of the motor's windings, it is often desirable to control the drive state of the motor so that the phase current of motor is aligned with the BEMF voltage of the motor. The KTX parts provides the configuration for controlling the timing adjustment between the driving voltage and phase current.

Name	Address	Register Meaning
TIME_ADJ	0x7E : 0x7F	The ratio of time adjustment. In general, the value is set from 0.1 to 3.0. Try from 0.4. The value is higher when the inductance of winding is small. For example, it is set as 1.6 when the inductance of winding is 33uH, and the spinning speed of motor (one pole pair) is 80,000rpm. The value is smaller when the inductance of winding is large. For example, it is set as 0.2 when the inductance of winding is 45mH, and the spinning speed of motor (4 pole pair) is 1000rpm.

2. Run_mode Mode Selection: Speed Control

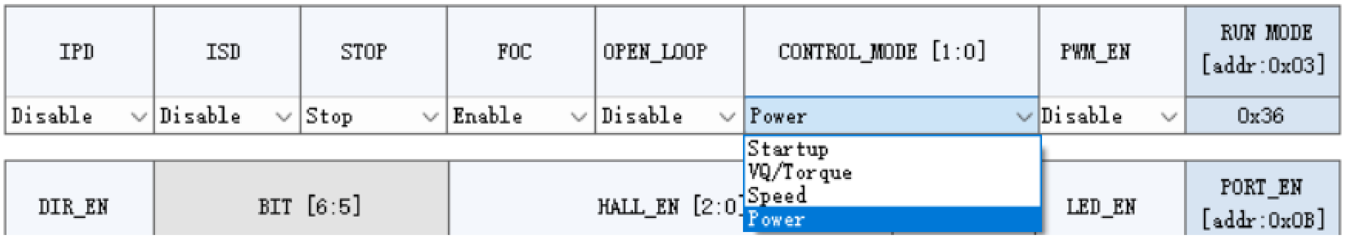


IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Enable	Disable	Speed	Disable	0x34

Startup
VQ/Torque
Speed
Power

DIR_EN	BIT [6:5]	HALL_EN [2:0]	LED_EN	PORT_EN [addr:0x0B]

3. Run_mode Mode Selection: Power Control



IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Enable	Disable	Power	Disable	0x36

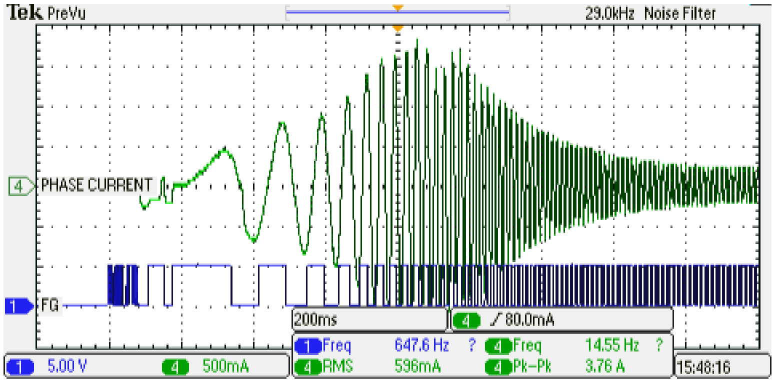
Startup
VQ/Torque
Speed
Power

DIR_EN	BIT [6:5]	HALL_EN [2:0]	LED_EN	PORT_EN [addr:0x0B]

4. Motor Phase Current and FG Waveform

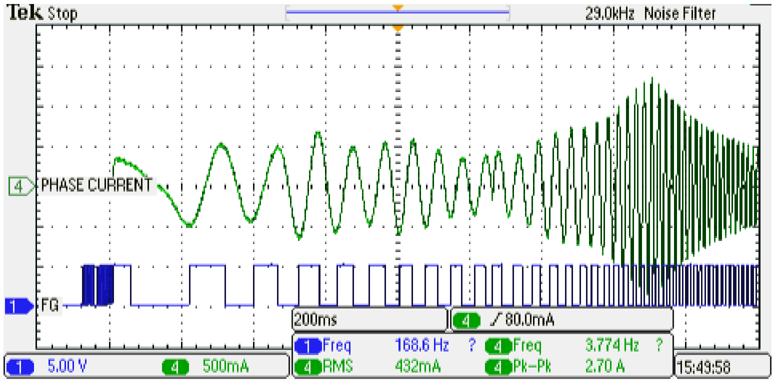
By selecting OPEN_LOOP bit or not, the process time to FOC Speed control and the trend of phase current is as below.

ISD -> VQ Startup -> VQ Control -> FOC Torque Control -> FOC Speed Control



FOC Speed Control

ISD -> Open Loop -> VQ Control -> FOC Torque Control -> FOC Speed Control

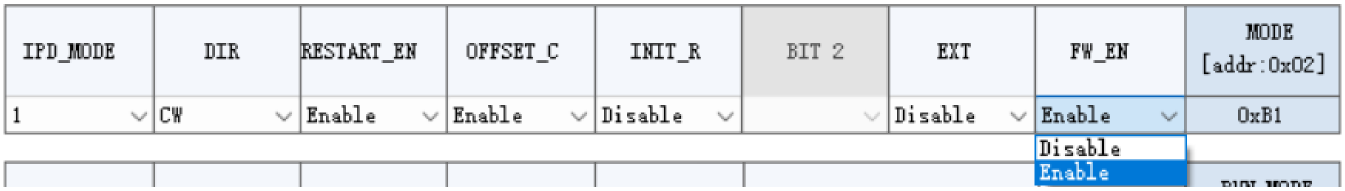


FOC Speed Control from Open-Loop

MTPA (Maximum Torque Per Ampere) & Flux Weakening

MTPA and one Flux Weakening method share the same Look-Up Table (MTPA0 to MTPA7), the address is from 0x30 to 0x3F.

It is selected by FW_EN bit in MODE (0x02)



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
1	CW	Enable	Enable	Disable		Disable	Enable	0xB1

Name	Address
MTPA0_IQ	0x30
MTPA0_ID	0x31
MTPA1_IQ	0x32
MTPA1_ID	0x33
MTPA2_IQ	0x34
MTPA2_ID	0x35
MTPA3_IQ	0x36
MTPA3_ID	0x37
MTPA4_IQ	0x38
MTPA4_ID	0x39
MTPA5_IQ	0x3A
MTPA5_ID	0x3B
MTPA6_IQ	0x3C
MTPA6_ID	0x3D
MTPA7_IQ	0x3E
MTPA7_ID	0x3F

MTPA Mode:

- By default, MTPA[0] = [IQ = 0.0, ID = 0.0], such that normal FOC control with TARGET_ID = 0 is implemented
- In case that MTPA table has data points, TARGET_ID will be calculated by linear approximation based on the MTPA IQ-ID pair listed in MPTA table.
- For IQ smaller than the MTPA_IQ0, TARGET_ID = 0.
- For IQ larger than the MTPA_IQ of end point, TARGET_ID = MTPA_ID of end point.
- MTPA_IQ : [0:0.99], MTPA_ID range : [-0.99:+0.99].
- TARGET_ID $\neq$ 0, MTPA feature will be disable.

Flux-Weakening Mode: (* FW as replacement of MTPA, FW_SPEED as replacement of MTPA_IQ)

- By default, FW[0] = [FW_SPEED = 0.0, ID = 0.0] and other Field Weakening Feature is implemented.
- In case that FW table has data points, TARGET_ID2 will be calculated by linear approximation based on the FW_SPEED-ID pair listed in FW table.
- For speed smaller than the FW_SPEED0, TARGET_ID2 = 0.
- For speed larger than the FW_SPEED of end point, TARGET_ID2 = FW_ID of end point.
- FW_SPEED range : [0:65,280] in resolution of 256rpm, FW_ID range : [-0.99:+0.99] in resolution of 0.0078125.
- FW_SPEED is calculated by the below formula with VB0 - the range of [0:1] in resolution of 1/256.

$$FW\_SPEED = \frac{VB0 \times SPEED}{VB}$$

External Signal Input Control

There are 2 external signal input control mode except the IIC command mode. All of parameters should be set correctly as IIC command mode.

1. PWM Duty Control Mode

1. Selects VQ, Torque, Speed, or Power modes, in MODE_B (0x92).

VQ mode: TARGET_VQ is set as Duty Ratio.

Torque mode: TARGET_IQ is set as Duty Ratio.

SPEED mode: TARGET_SPEED is set as 4096 * Duty Ratio.

Power mode: TARGET_SPEED is set as Duty Ratio/2.

2. Set DUYT_MIN (0x29)

When Duty Ratio is 0%, the KTX9312 enters sleep mode.

When 0% < Duty Ratio <1.5%, the KTX9312 is stop mode.

When 1.5% < Duty Ratio < DUTY_MIN (0x29), the Duty Ratio value that used for the target setting is DUTY_MIN.

3.Provides external PWM signal (1~50KHz) to P8 connector.

4.Set RUN_MODE (0x03) = 0x0.

IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Run	Disable	Disable	Startup	Disable	0x00

2. Key Control Mode

Run/Stop the motor driving by simply pushing button – SW3.

1. Enable ON_EN, DIR_EN and LED_EN bit in PORT_EN (0x0B).

DIR_EN	BIT [6:5]	HALL_EN [2:0]	ON_EN	LED_EN	PORT_EN [addr:0x0B]
Enable		Disable	Enable	Enable	0x83

2. Set the RUN_MODE (0x03) as the IIC command except PWM_EN bit is disable.

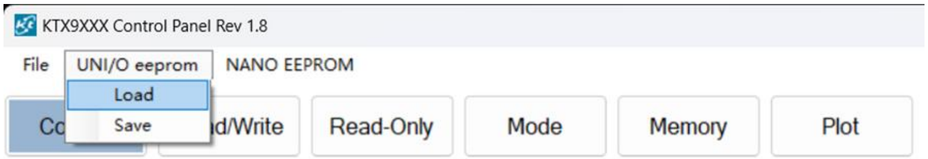
3. Select the direction, CCW - P6 Open, CW – P6 Closed.

4. Push the button – SW3.

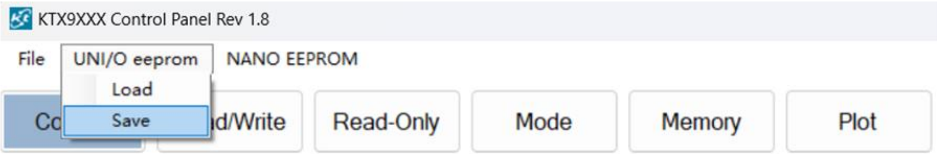
External UNI/O EEPROM

In this evaluation board, there is one UNI/O Serial EEPROM – 11LC020 (256 x 8 bits) to store user-defined parameters. Through GUI, the user can save to and load from this EEPROM.

1. Select <Load> from the UNI/O EEPROM menu.



2. Select <Save> from the UNI/O EEPROM menu.

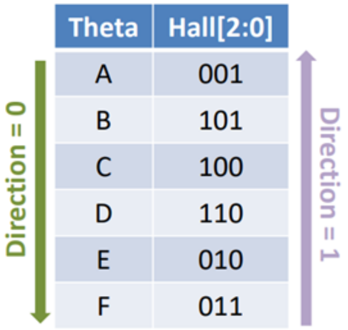


After programed this EEPROM with user-defined parameters, it can run at standalone mode with external input signal. The Arduino Nano board should be removed, and there is no GUI control.

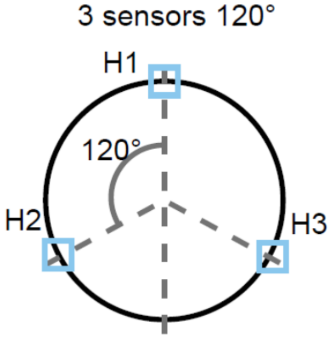
Hall Setting

To have robust and stable control across all speed and changing dynamics, the digital Hall sensor signals are used as amendment of angle estimation.

it is necessary to set the electric angle range of sector defined by hall sensor with the variation, and offset for CW/CCW direction if the angle of each sector is not same as defined in KTX9312 as below.



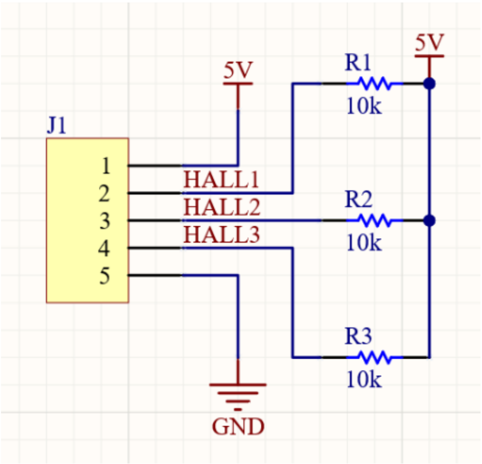
Theta	Hall[2:0]
A	001
B	101
C	100
D	110
E	010
F	011



This function can only be used when the three switching Hall sensors are at an electrical angle of 120°.

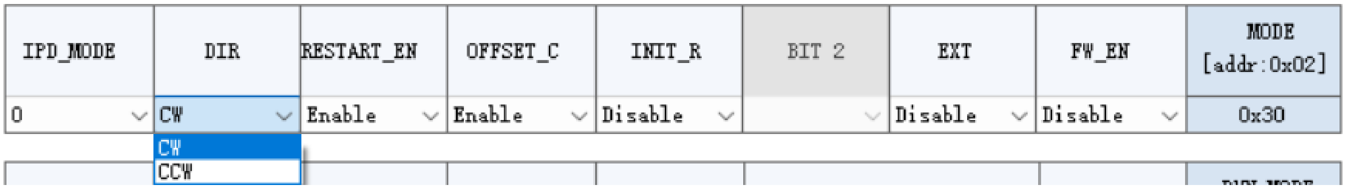
1. Connection of Digital Hall Sensor

All Hall sensors should have external pull-up resistors connected to 5V power supply as shown in the schematic below:



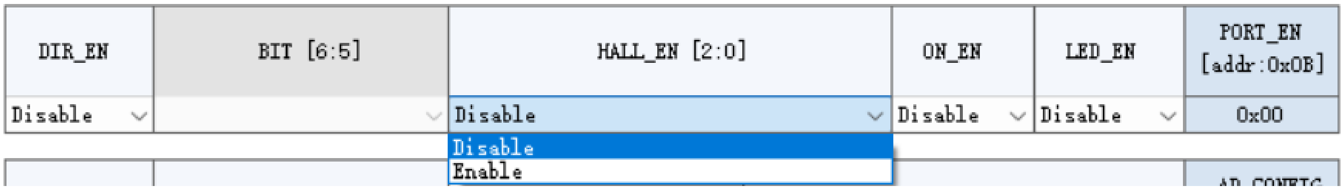
Connect oscilloscope probes to the three Hall signals and the FG signal from EVK9312 board.

Select the direction from RUN_MODE.



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
0	CW	Enable	Enable	Disable		Disable	Disable	0x30

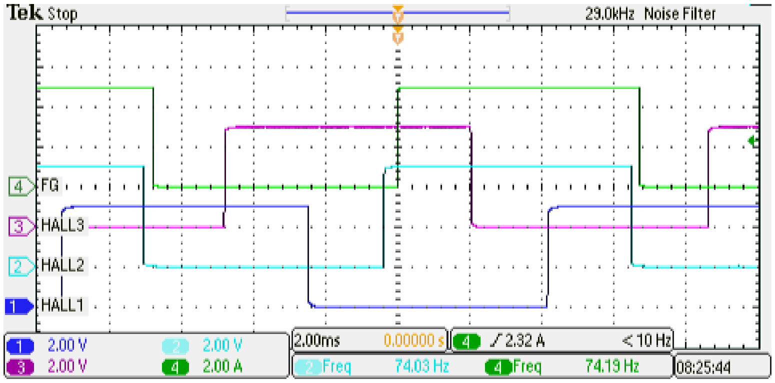
To disable HALL_EN[2:0] in this detection process.



DIR_EN	BIT [6:5]	HALL_EN [2:0]	ON_EN	LED_EN	PORT_EN [addr:0x0B]
Disable		Disable	Disable	Disable	0x00

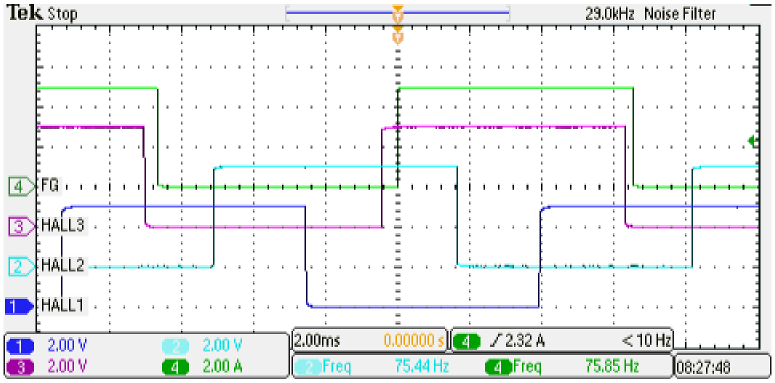
2. Capture the Digital Hall Sensors and FG Signals while the FOC Control is Running Well

The following is an example of the motor test waveform: 3/Purple is HALL3 signal, 2/Light Blue is HALL2 signal, 1/Dark Blue is HALL1 signal, and 4/Green is the FG signal.



HALL1/2/3 and FG - CW

Observe the FG signal, the falling edge of FG at the electrical angle 0° and Hall3/Hall2/Hall1 with at least one FG cycle - 360°. The corresponding sequence of the six sectors is 001→101→100→110→010→011 in the CW direction.



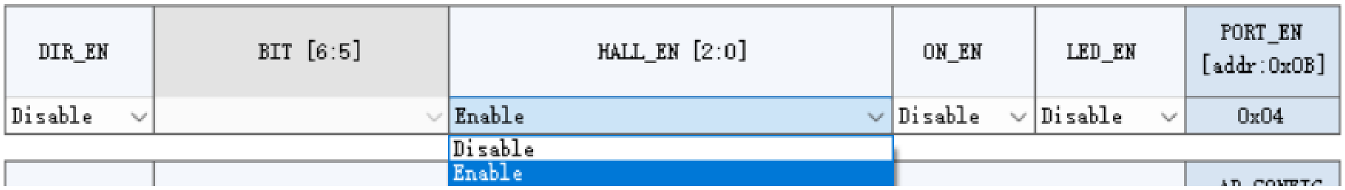
HALL1/2/3 and FG - CCW

Observe the FG signal, the falling edge of FG at the electrical angle 0° and Hall3/Hall2/Hall1 with at least one FG cycle - 360°. The corresponding sequence of the six sectors is 001→011→010→110→100→101 in the CCW direction.

To have +/- 7.5 degree margin, and considering -10 degree offset, it is set as below:

HALL_ANGLE = 75 degree, HALL_OFFSET0 = 350 degree (CW), HALL_OFFSET1 = 350 degree (CCW)

Change HALL_EN[2:0] to Enable as below.



DIR_EN	BIT [6:5]	HALL_EN [2:0]	ON_EN	LED_EN	PORT_EN [addr:0x0B]
Disable		Enable	Disable	Disable	0x04

Name	Address	Register meaning
HALL_RANGE	0x2E	The allowable hall range for each angle sector.
HALL_OFFSET0	0xF8	The hall angle offset for Clockwise direction
HALL_OFFSET1	0xF9	The hall angle offset for Counterclockwise direction.

$$Hall\ Range\ =\frac{HALL\_RANGE}{255} * 360\ ^{\circ}$$

$$Hall\ Offset\ =\frac{HALL\_OFFSET}{255} * 360\ ^{\circ}$$

KTX9xxx Motor Control GUI User Guide

Introduction

The KTX_GUI provides a pc graphic user interface to communicate with KTX9xxx evaluation boards via a UART COM port. Through this software, the user can configure the KTX9xxx chip, read the memory, and monitor the real time status including speed, fault, etc.

1. Getting Started

This section describes the requirements and procedures to use the KTX_GUI, which support Kinetic motor driver ICs with version C and later.

1.1 System Requirement

The GUI supports 64-bit Windows 10 and above.

1.2 Hardware Requirements

- USB 232 adapter
- KTX9xxx Evaluation board
- 3-Phase Brushless Motor

1.3 Software Requirements

Download the installation package from the EVAL kit page (https://www.kinet-ic.com/ktx9312guaan-mmev01)

Then install GUI software.

2. GUI Operation

This section describes the function of the KTX_GUI and its operation.

2.1 Main GUI Window

The GUI window consists of six control panel which can be selected by relative buttons at the top of the window.

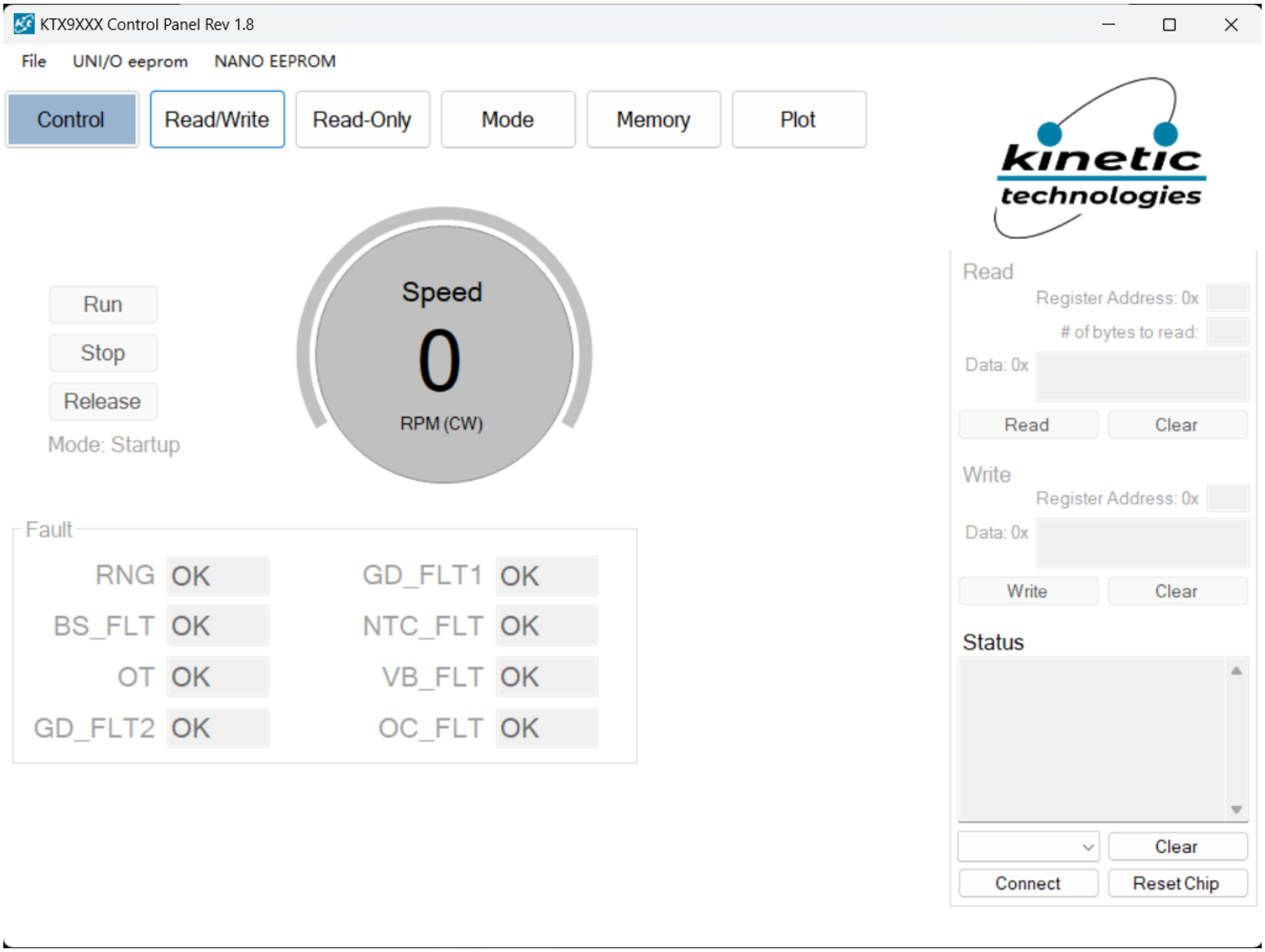


Figure 1. Main GUI Window

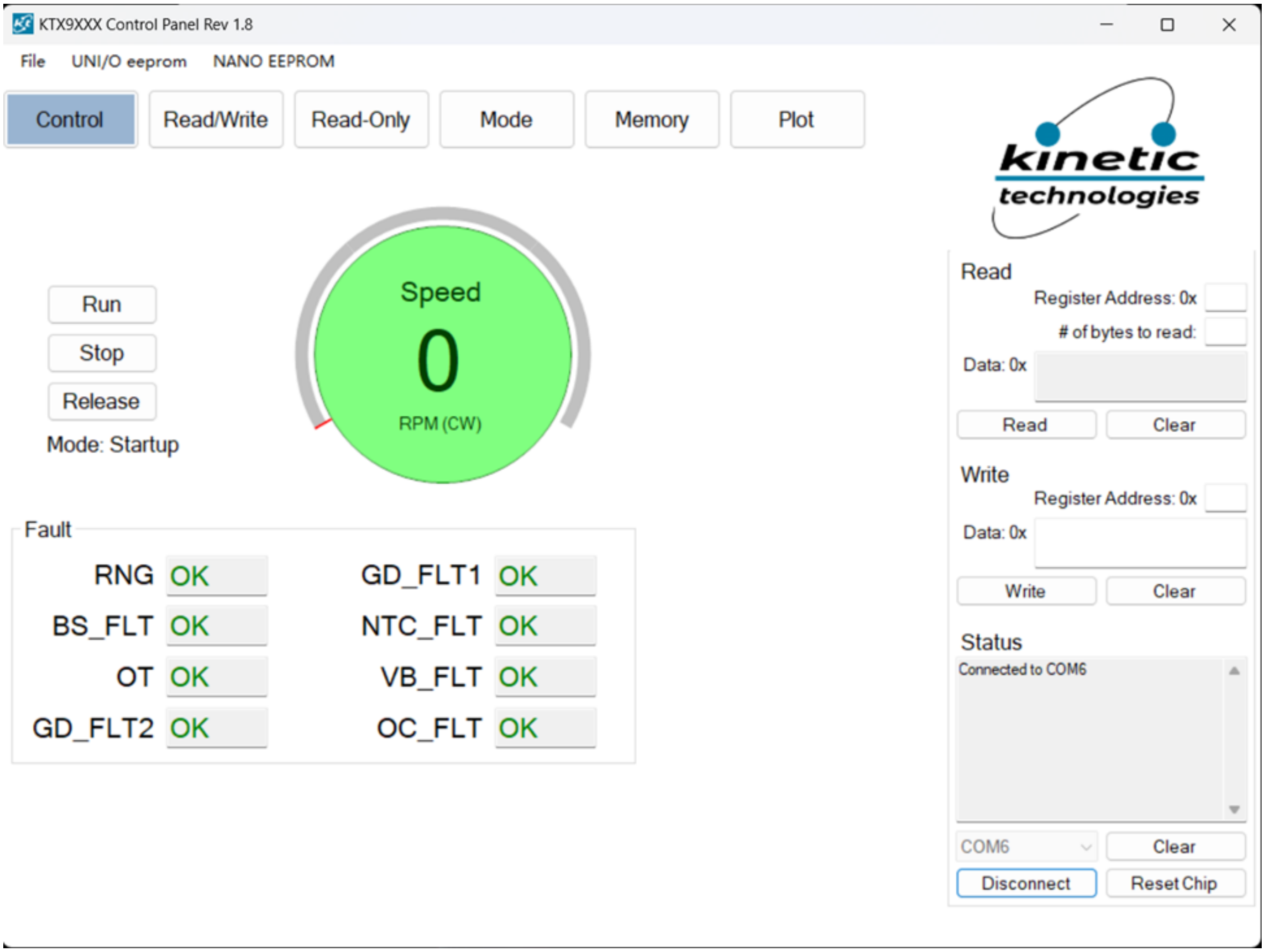
2.2 GUI Panel Toolbar

The toolbar provides a range of options for controlling and monitoring the motor. These are <Control>, <Read/Write>, <Read-Only>, <Mode>, <Memory>, and <Plot>. Each button provides a dedicated control or monitor panel as shown below.

Figure 2. GUI Toolbar

2.2.1 Control Panel

The control panel allows the user to monitor the status of the motor in real-time, while viewing registers such as speed, run mode, and fault status. There are five modules on this panel: serial port, button, faults, tachometer, and run mode.



Speed
0
RPM (CW)

Mode: Startup

Fault

RNG	OK	GD_FLT1	OK
BS_FLT	OK	NTC_FLT	OK
OT	OK	VB_FLT	OK
GD_FLT2	OK	OC_FLT	OK

Connected to COM6

COM6

Figure 3. GUI Control Panel

2.2.1.1 Serial Port

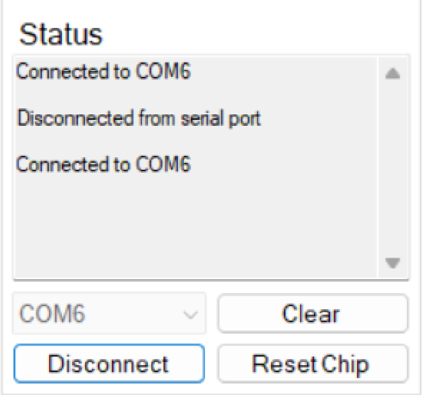
To select the available serial port of the computer and connect it with KTX9xxx EVAL kit:

Step 1: In the serial port module, click on the <down> arrow to view the available serial ports.

Step 2: Select the port which connects with your platform.

Step 3: To connect the computer to the EVAL board by clicking <connect> button.

Step 4: see “connected to COM” for a successful connection in the status box.



Status

Connected to COM6

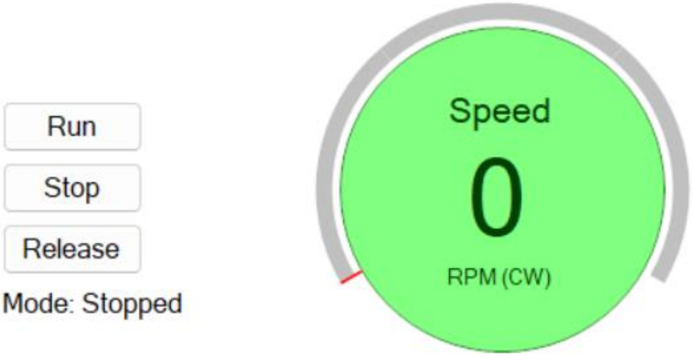
Disconnected from serial port

Connected to COM6

Figure 4. Connection between PC COM port and EVKs

2.2.1.2 Button

To set the motor as run/stop/release mode by clicking on the corresponding button.

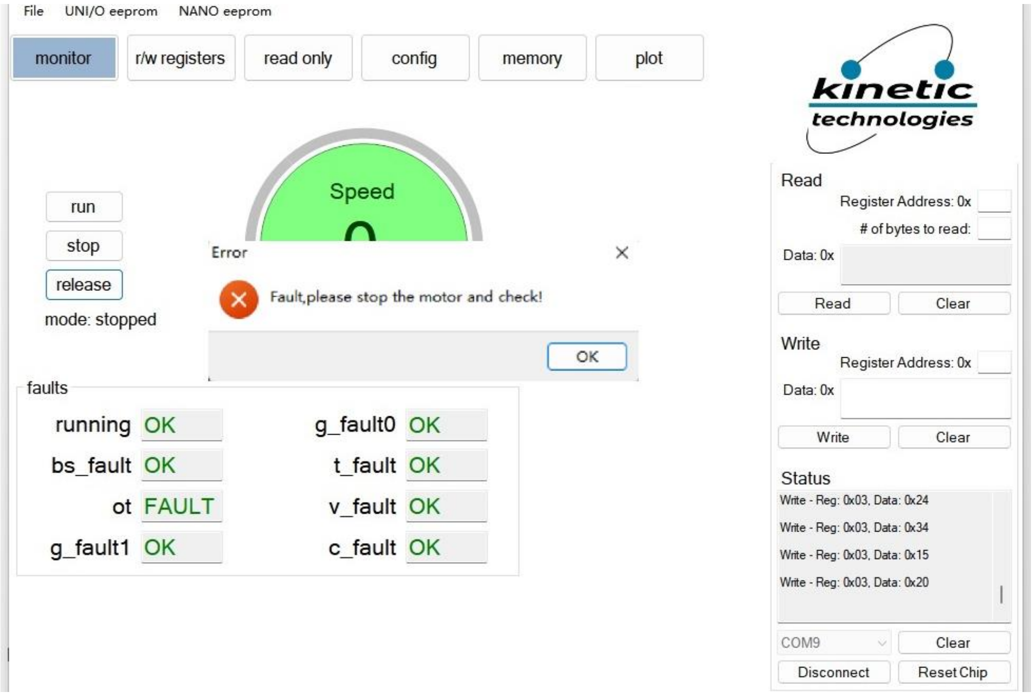


Mode: Stopped

Speed 0 RPM (CW)

Faults

The <Faults> module indicates whether the motor is running normally or there is a fault. If a fault occurs, will show “FAULT’ in the message box and an error box will be opened. In the case of a critical fault, the system will be shutdown.



Fault,please stop the motor and check!

mode: stopped

faults

running OK
bs_fault OK
ot FAULT
g_fault1 OK
g_fault0 OK
t_fault OK
v_fault OK
c_fault OK

Data: 0x

Data: 0x

Status

Write - Reg: 0x03, Data: 0x24
Write - Reg: 0x03, Data: 0x34
Write - Reg: 0x03, Data: 0x15
Write - Reg: 0x03, Data: 0x20

Figure 5. Error Notification for the “Fault” Event

2.2.1.3 Tachometer

The “tachometer” panel shows the motor speed (RPM) in real time. More information can be found in the PLOT panel.

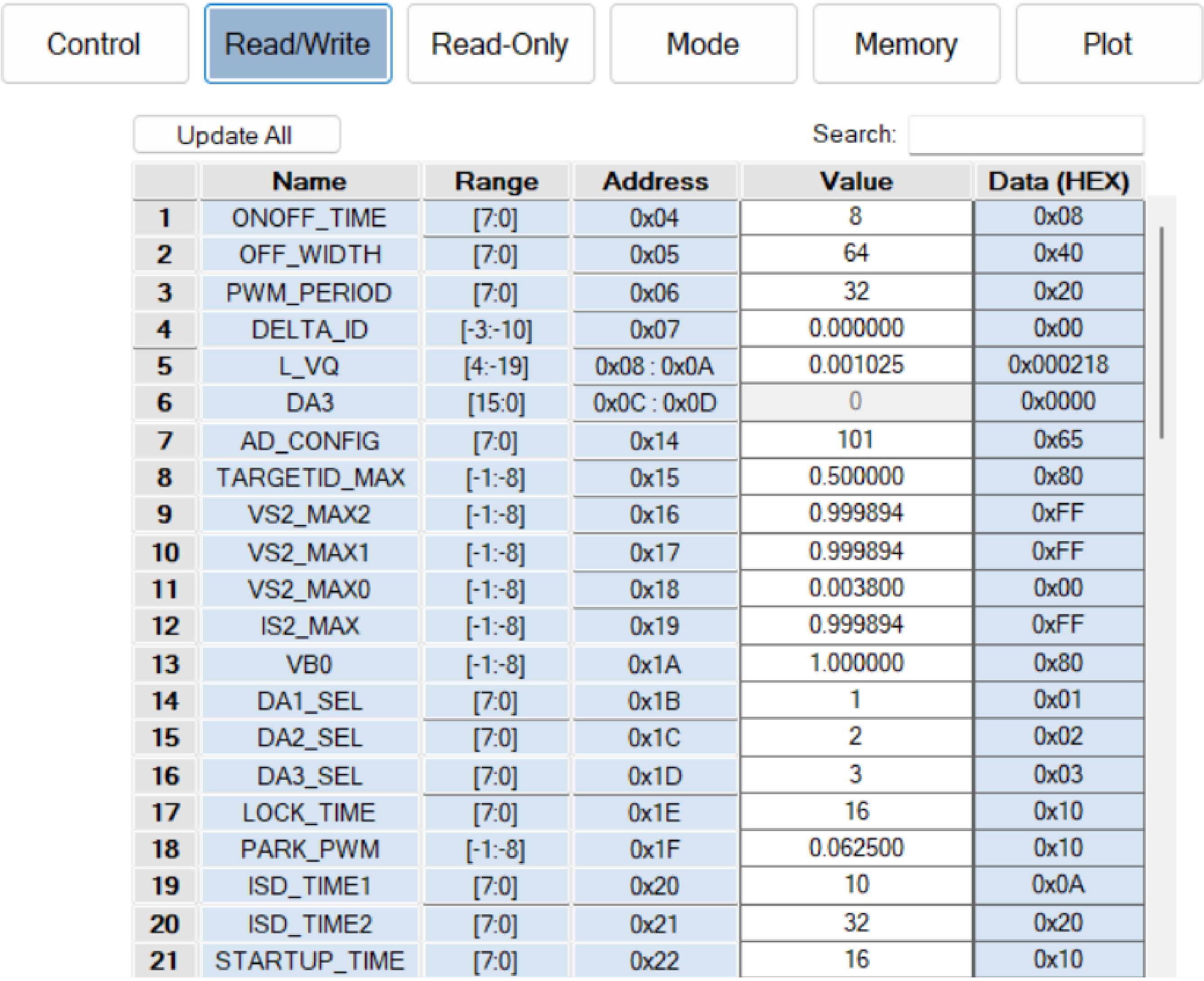
2.2.1.4 Run Mode

The “run mode” panel shows the control mode, including the combination of IPD, ISD, FOC, Open-loop, Startup, VQ/Torque, Speed and Power.

2.2.2 Read/Write Registers

The <Read/Write> panel gives users the ability to read and write the Motor driver IC registers. It is used to modify the configurations and tune the motor. This panel consists of a table with 5 columns:

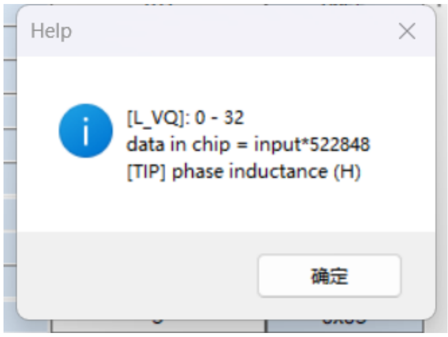
Column Header	Description
Name	Function register name
Range	Register data range
Address	KTX9xxx register address
Value	Value to be input by the user. This shaded one indicates that it is not allowed to be edited.
Data (HEX)	KTX9xxx register data with hex format. This column will update once new value input is completed.



	Name	Range	Address	Value	Data (HEX)
1	ONOFF_TIME	[7:0]	0x04	8	0x08
2	OFF_WIDTH	[7:0]	0x05	64	0x40
3	PWM_PERIOD	[7:0]	0x06	32	0x20
4	DELTA_ID	[-3:-10]	0x07	0.000000	0x00
5	L_VQ	[4:-19]	0x08 : 0x0A	0.001025	0x000218
6	DA3	[15:0]	0x0C : 0x0D	0	0x0000
7	AD_CONFIG	[7:0]	0x14	101	0x65
8	TARGETID_MAX	[-1:-8]	0x15	0.500000	0x80
9	VS2_MAX2	[-1:-8]	0x16	0.999894	0xFF
10	VS2_MAX1	[-1:-8]	0x17	0.999894	0xFF
11	VS2_MAX0	[-1:-8]	0x18	0.003800	0x00
12	IS2_MAX	[-1:-8]	0x19	0.999894	0xFF
13	VB0	[-1:-8]	0x1A	1.000000	0x80
14	DA1_SEL	[7:0]	0x1B	1	0x01
15	DA2_SEL	[7:0]	0x1C	2	0x02
16	DA3_SEL	[7:0]	0x1D	3	0x03
17	LOCK_TIME	[7:0]	0x1E	16	0x10
18	PARK_PWM	[-1:-8]	0x1F	0.062500	0x10
19	ISD_TIME1	[7:0]	0x20	10	0x0A
20	ISD_TIME2	[7:0]	0x21	32	0x20
21	STARTUP_TIME	[7:0]	0x22	16	0x10

Figure 6. R/W Register Panel

Further information on each name function can be obtained by right mouse-clicking on the desired parameter. This will result in a pop-up box displaying more information including “tips”. An example for register “L_VQ” is shown below. For detailed information on the registers, please refer to the latest revision of the IC datasheet:

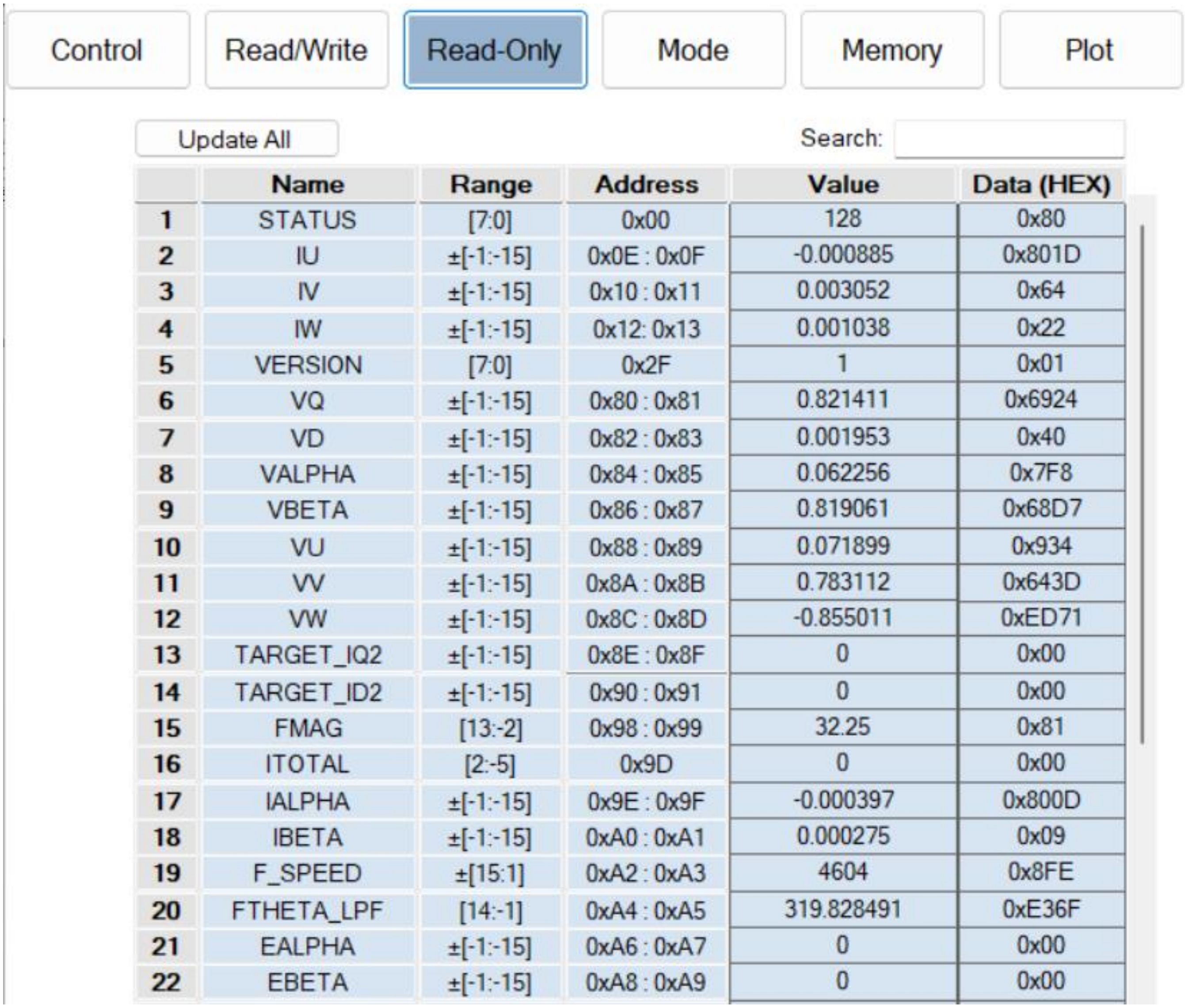


[L_VQ]: 0 - 32
data in chip = input*522848
[TIP] phase inductance (H)

Figure 7. Tips for Input

2.2.3 Read-Only Registers

The <Read-Only> panel shows all the read-only registers of the IC. These are registers in the motor driver IC that shows current value of the process variables in the control algorithm. This panel also includes 5 columns, and the type of each column is the same as <Read/Write> panel with the exception of the <Value> column which is shaded to indicated that it cannot be edited.

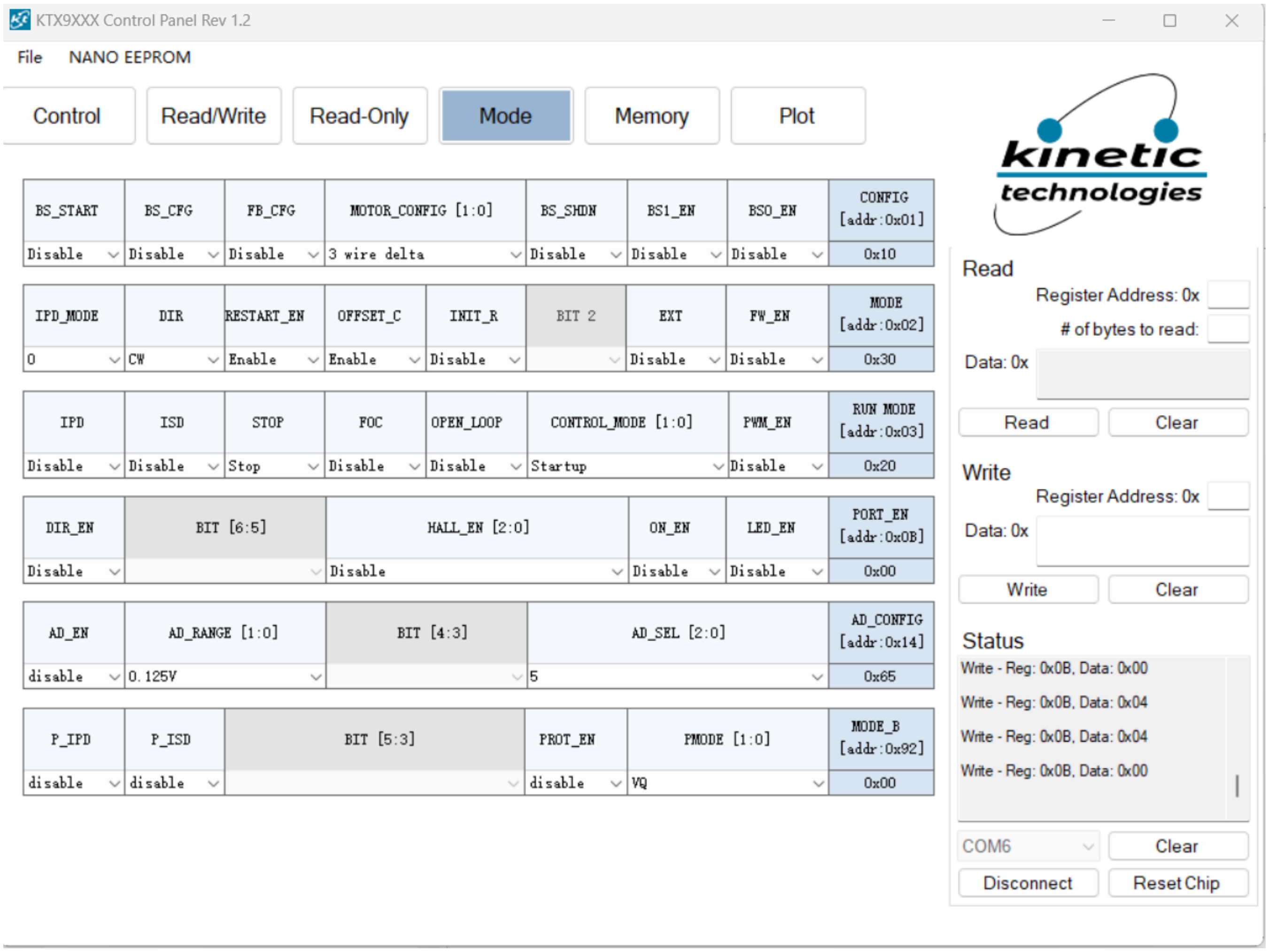


	Name	Range	Address	Value	Data (HEX)
1	STATUS	[7:0]	0x00	128	0x80
2	IU	±[-1:-15]	0x0E : 0x0F	-0.000885	0x801D
3	IV	±[-1:-15]	0x10 : 0x11	0.003052	0x64
4	IW	±[-1:-15]	0x12: 0x13	0.001038	0x22
5	VERSION	[7:0]	0x2F	1	0x01
6	VQ	±[-1:-15]	0x80 : 0x81	0.821411	0x6924
7	VD	±[-1:-15]	0x82 : 0x83	0.001953	0x40
8	VALPHA	±[-1:-15]	0x84 : 0x85	0.062256	0x7F8
9	VBETA	±[-1:-15]	0x86 : 0x87	0.819061	0x68D7
10	VU	±[-1:-15]	0x88 : 0x89	0.071899	0x934
11	VV	±[-1:-15]	0x8A : 0x8B	0.783112	0x643D
12	VW	±[-1:-15]	0x8C : 0x8D	-0.855011	0xED71
13	TARGET_IQ2	±[-1:-15]	0x8E : 0x8F	0	0x00
14	TARGET_ID2	±[-1:-15]	0x90 : 0x91	0	0x00
15	FMAG	[13:-2]	0x98 : 0x99	32.25	0x81
16	ITOTAL	[2:-5]	0x9D	0	0x00
17	IALPHA	±[-1:-15]	0x9E : 0x9F	-0.000397	0x800D
18	IBETA	±[-1:-15]	0xA0 : 0xA1	0.000275	0x09
19	F_SPEED	±[15:1]	0xA2 : 0xA3	4604	0x8FE
20	FTHETA_LPF	[14:-1]	0xA4 : 0xA5	319.828491	0xE36F
21	EALPHA	±[-1:-15]	0xA6 : 0xA7	0	0x00
22	EBETA	±[-1:-15]	0xA8 : 0xA9	0	0x00

Figure 8. R Only Regs Panel

2.2.4 Mode

The “Config” panel is composed of four special registers: CONFIG, MODE, RUN MODE, and PORT_EN. Users can configure the settings of their motor drive IC bit-by-bit by double clicking the bit box. The register value which is in blue will be updated once the bit value is changed. See the screenshots below for details:



BS_START	BS_CFG	FB_CFG	MOTOR_CONFIG [1:0]	BS_SHDN	BS1_EN	BS0_EN	CONFIG [addr:0x01]
Disable	Disable	Disable	3 wire delta	Disable	Disable	Disable	0x10

IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
0	CW	Enable	Enable	Disable		Disable	Disable	0x30

IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Disable	Disable	Startup	Disable	0x20

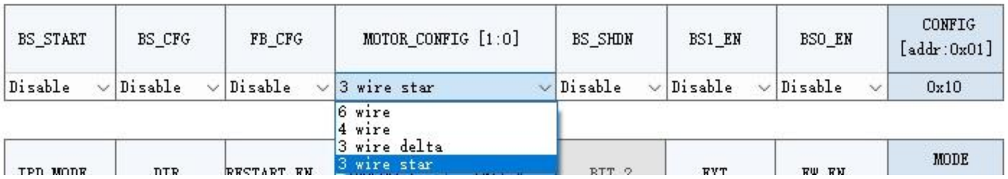
DIR_EN	BIT [6:5]	HALL_EN [2:0]	ON_EN	LED_EN	PORT_EN [addr:0x0B]
Disable		Disable	Disable	Disable	0x00

AD_EN	AD_RANGE [1:0]	BIT [4:3]	AD_SEL [2:0]	AD_CONFIG [addr:0x14]
disable	0.125V		5	0x65

P_IPD	P_ISD	BIT [5:3]	PROT_EN	PMODE [1:0]	MODE_B [addr:0x92]
disable	disable		disable	VQ	0x00

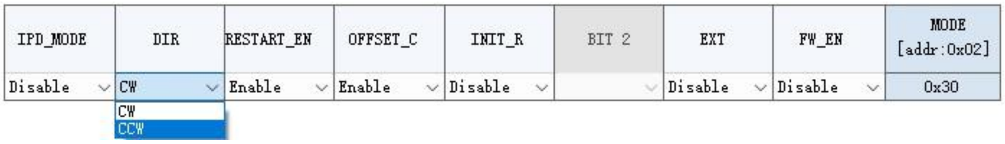
```
Write - Reg: 0x0B, Data: 0x00
Write - Reg: 0x0B, Data: 0x04
Write - Reg: 0x0B, Data: 0x04
Write - Reg: 0x0B, Data: 0x00
```

Figure 9. Config Panel



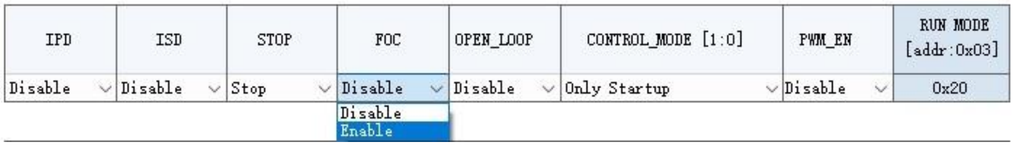
BS_START	BS_CFG	FB_CFG	MOTOR_CONFIG [1:0]	BS_SHDN	BS1_EN	BS0_EN	CONFIG [addr:0x01]
Disable	Disable	Disable	3 wire star	Disable	Disable	Disable	0x10

Figure 10. CONFIG Register



IPD_MODE	DIR	RESTART_EN	OFFSET_C	INIT_R	BIT 2	EXT	FW_EN	MODE [addr:0x02]
Disable	CW	Enable	Enable	Disable		Disable	Disable	0x30

Figure 11. MODE Register

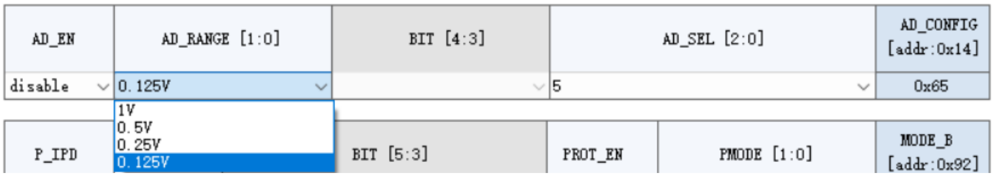


IPD	ISD	STOP	FOC	OPEN_LOOP	CONTROL_MODE [1:0]	PWM_EN	RUN MODE [addr:0x03]
Disable	Disable	Stop	Disable	Disable	Only Startup	Disable	0x20

Figure 12. RUN MODE Register

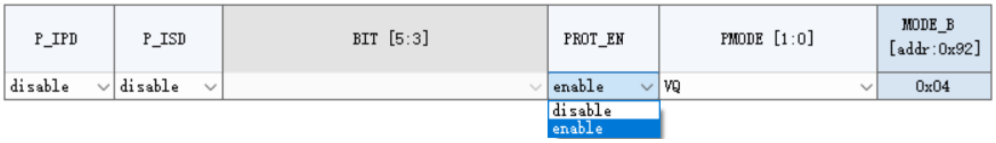
DIR_EN	BIT [6:5]	HALL_EN [2:0]	ON_EN	LED_EN	PORT_EN [addr:0x0B]
Disable		Disable	Disable	Disable	0x00

Figure 13. PORT_EN Register



AD_EN	AD_RANGE [1:0]	BIT [4:3]	AD_SEL [2:0]	AD_CONFIG [addr:0x14]
disable	0.125V		5	0x65

Figure 14. AD_CONFIG Register

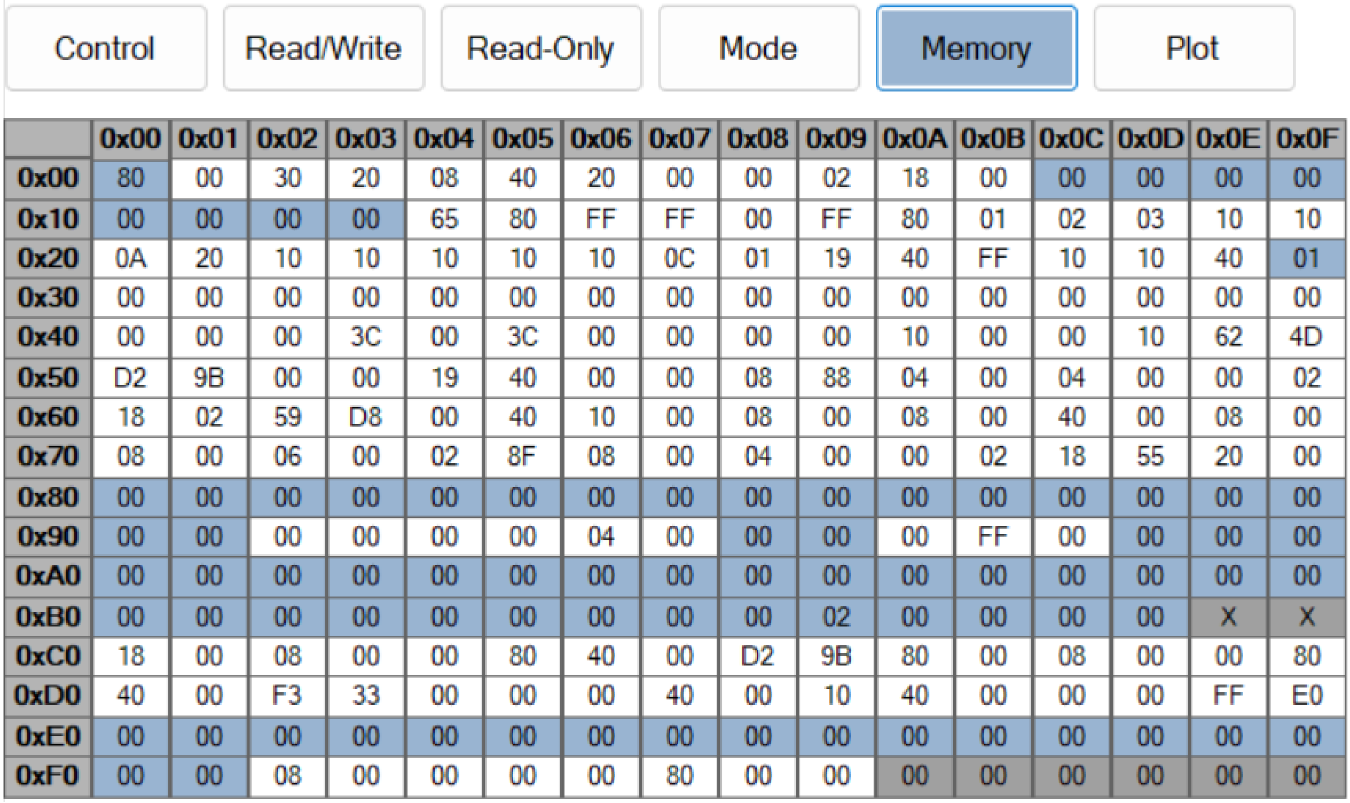


P_IPD	P_ISD	BIT [5:3]	PROT_EN	PMODE [1:0]	MODE_B [addr:0x92]
disable	disable		enable	VQ	0x04

Figure 15. MODE_B Register

2.2.5 All registers' value in Hex

The <Memory> panel shows all KTX9xxx registers' Hex value in numerical order. Those values shaded in light blue are only readable, with those shaded grey, reserved. All others are R/W.



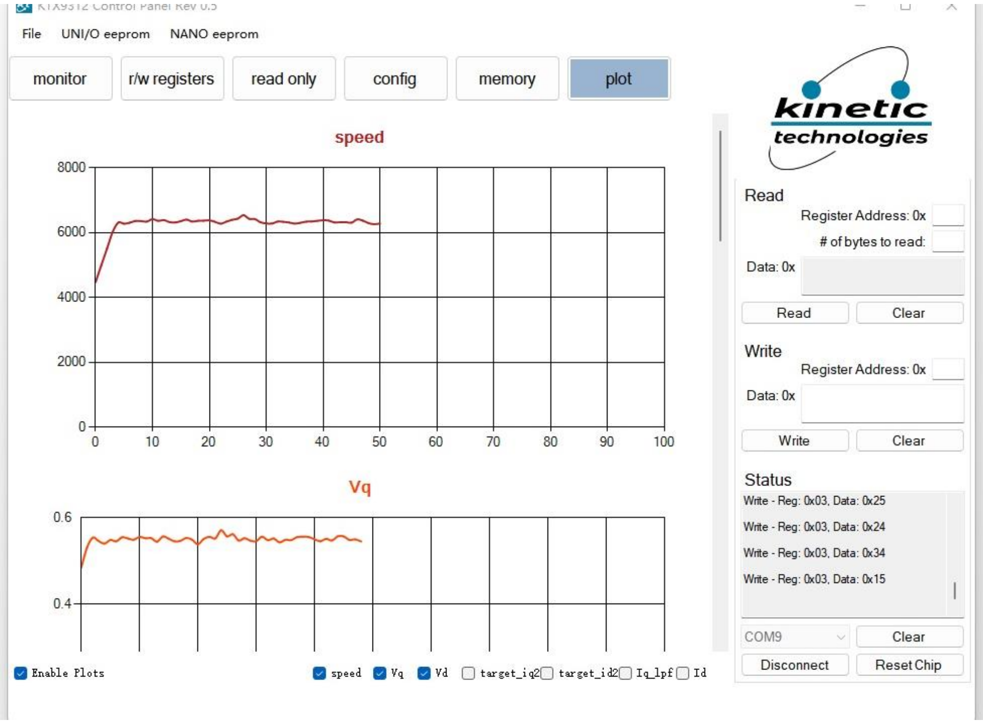
	0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09	0x0A	0x0B	0x0C	0x0D	0x0E	0x0F
0x00	80	00	30	20	08	40	20	00	00	02	18	00	00	00	00	00
0x10	00	00	00	00	65	80	FF	FF	00	FF	80	01	02	03	10	10
0x20	0A	20	10	10	10	10	10	0C	01	19	40	FF	10	10	40	01
0x30	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0x40	00	00	00	3C	00	3C	00	00	00	00	10	00	00	10	62	4D
0x50	D2	9B	00	00	19	40	00	00	08	88	04	00	04	00	00	02
0x60	18	02	59	D8	00	40	10	00	08	00	08	00	40	00	08	00
0x70	08	00	06	00	02	8F	08	00	04	00	00	02	18	55	20	00
0x80	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0x90	00	00	00	00	00	00	04	00	00	00	00	FF	00	00	00	00
0xA0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0xB0	00	00	00	00	00	00	00	00	00	02	00	00	00	00	X	X
0xC0	18	00	08	00	00	80	40	00	D2	9B	80	00	08	00	00	80
0xD0	40	00	F3	33	00	00	00	40	00	10	40	00	00	00	FF	E0
0xE0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0xF0	00	00	08	00	00	00	00	80	00	00	00	00	00	00	00	00

Figure 16. Memory

2.2.6 Plot

The <PLOT> gives users the ability to select a limited range of custom plots by clicking the checkboxes which are shown at the bottom of the panel. check the <Enable Plots> to begin plotting and uncheck to freeze the plot.

Below is a screenshot of the plot functionality:



```
Write - Reg: 0x03, Data: 0x25
Write - Reg: 0x03, Data: 0x24
Write - Reg: 0x03, Data: 0x34
Write - Reg: 0x03, Data: 0x15
```

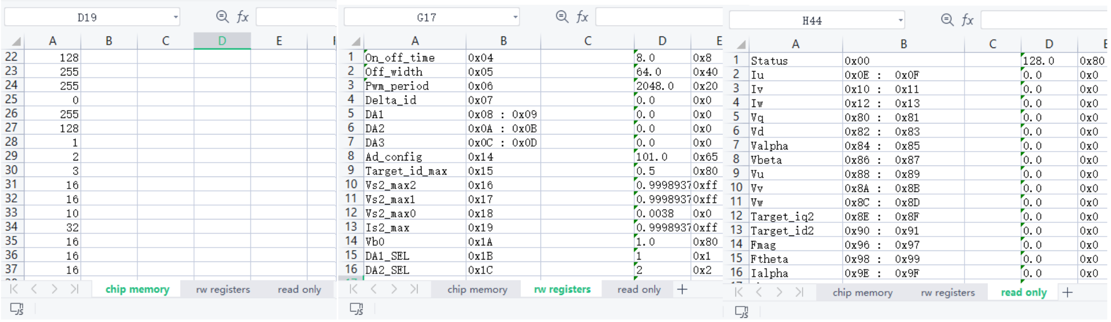
Figure 17. An Example of PLOT

2.3 Menu

The main menu has 2 items, which are File, NANO EEPROM. This allows the user to load and save data to the KTX9xxx motor control IC.

2.3.1 File Menu

Users can both load from and save to an Excel file. The Excel file includes three worksheets: IC Register values, R/W registers information and read only register information.



	A	B	C	D	E
22	128				
23	255				
24	255				
25	0				
26	255				
27	128				
28	1				
29	2				
30	3				
31	16				
32	16				
33	10				
34	32				
35	16				
36	16				
37	16				

	A	B	C	D	E
1	On_off_time	0x04		8.0	0x8
2	Off_width	0x05		64.0	0x40
3	Pwm_period	0x06		2048.0	0x20
4	Delta_id	0x07		0.0	0x0
5	DA1	0x08 : 0x09		0.0	0x0
6	DA2	0x0A : 0x0B		0.0	0x0
7	DA3	0x0C : 0x0D		0.0	0x0
8	Ad_config	0x14		101.0	0x65
9	Target_id_max	0x15		0.5	0x80
10	Vs2_max2	0x16		0.9998937	0xff
11	Vs2_max1	0x17		0.9998937	0xff
12	Vs2_max0	0x18		0.0038	0x0
13	Is2_max	0x19		0.9998937	0xff
14	Vb0	0x1A		1.0	0x80
15	DA1_SEL	0x1B		1	0x1
16	DA2_SEL	0x1C		2	0x2

	A	B	C	D	E
1	Status	0x00		128.0	0x80
2	Iu	0x0E : 0x0F		0.0	0x0
3	Iv	0x10 : 0x11		0.0	0x0
4	Iw	0x12 : 0x13		0.0	0x0
5	Vq	0x80 : 0x81		0.0	0x0
6	Vd	0x82 : 0x83		0.0	0x0
7	Valpha	0x84 : 0x85		0.0	0x0
8	Vbeta	0x86 : 0x87		0.0	0x0
9	Vu	0x88 : 0x89		0.0	0x0
10	Vv	0x8A : 0x8B		0.0	0x0
11	Vw	0x8C : 0x8D		0.0	0x0
12	Target_iq2	0x8E : 0x8F		0.0	0x0
13	Target_id2	0x90 : 0x91		0.0	0x0
14	Fmag	0x96 : 0x97		0.0	0x0
15	Ftheta	0x98 : 0x99		0.0	0x0
16	Ialpha	0x9E : 0x9F		0.0	0x0

Figure 18. Data in Excel File

Save to File:

1. Choose <Save> in the file menu.

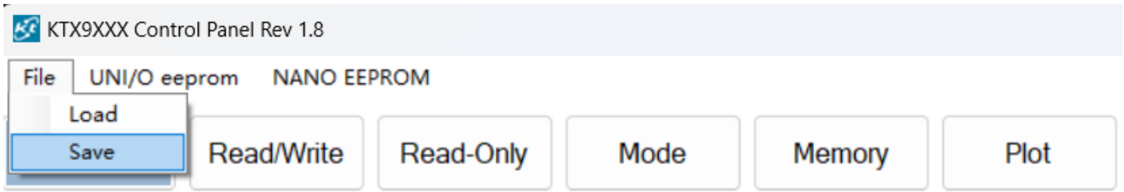


Figure 19. Save to File

2. Select the desired Excel file[6] or create a new file. Click the <Save> and a pop-up information box will be shown if the save is successful.

Load from file:

3. Choose <Load> in the file menu.

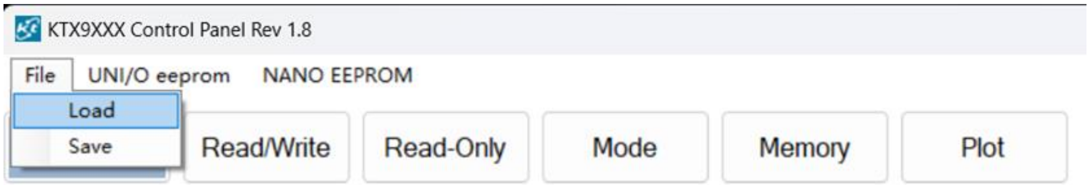


Figure 20. Load from File

4. Select the desired Excel file[7]. Click the <Load> button and a pop-up information box will be shown if the file imported is successful.

2.3.2 UNI/O EEPROM

---

[6] Ensure the file is not open in another application.

[7] Ensure the file is not open in another application.

Users can both load from and save to the external UNI/O EEPROM – 11LC020. The data format in the EEPROM is the same as which is in KTX9xxx register memory.

Load from UNI/O EEPROM

1. Select <Load> from the UNI/O EEPROM menu.

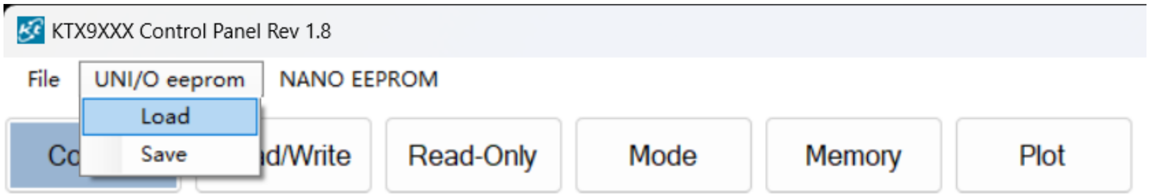


Figure 21. Load from UNI/O Menu

2. Check and confirm that you wish to load the UNI/O EEPROM data and overwrite the registers.
3. A popup Information box will show if the upload was successful.
4. A popup warning message will be shown if the data fails to load, and requests that you check your platform hardware.

Save to UNI/O EEPROM

1. Select <Save> from the UNI/O EEPROM menu.

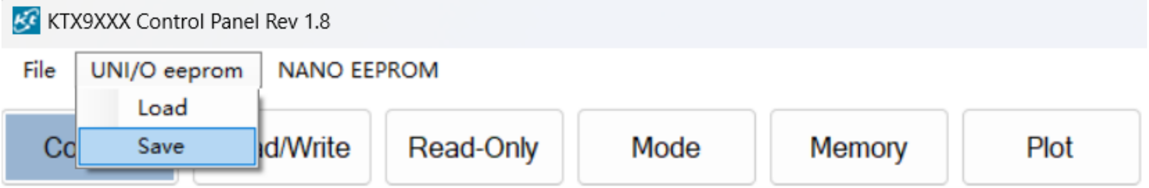


Figure 22. Save to NANO Menu

2. Check and confirm that you wish to write to the UNI/O EEPROM
3. A popup Information box will show if the write was successful.
4. A popup warning message will be shown if the data fails to save, and requests that you check your platform hardware.

2.3.3 NANO EEPROM

Users can both load from and save to the EEPROM in Arduino Nano board. The data format in the EEPROM is the same as which is in KTX9xxx register memory.

Load from NANO EEPROM

5. Select <Load> from the NANO EEPROM menu.

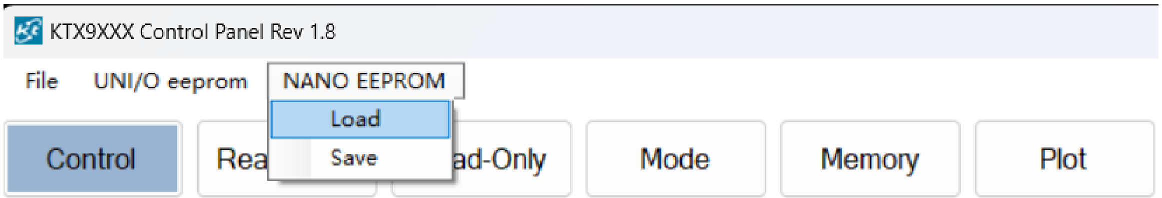


Figure 23. Load from NANO Menu

6. Check and confirm that you wish to load the NANO EEPROM data and overwrite the registers.
7. A popup Information box will show if the upload was successful.
8. A popup warning message will be shown if the data fails to load, and requests that you check your platform hardware.

Save to NANO EEPROM

9. Select <Save> from the NANO EEPROM menu.

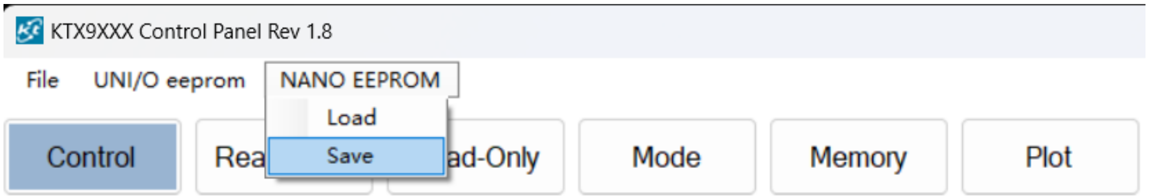


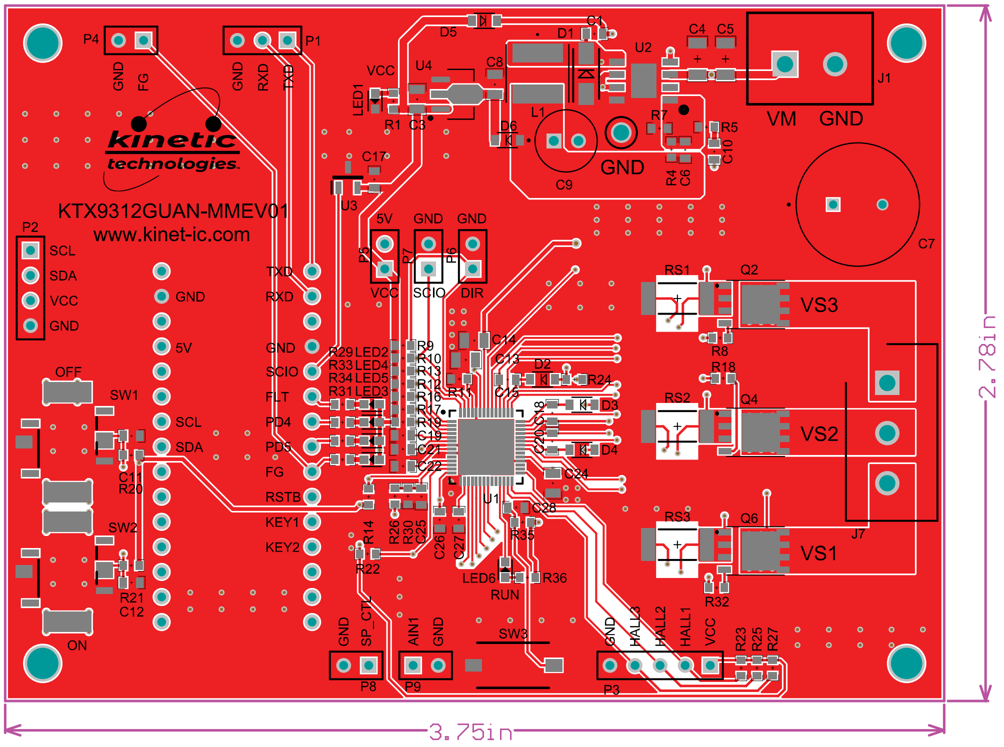
Figure 24. Save to NANO Menu

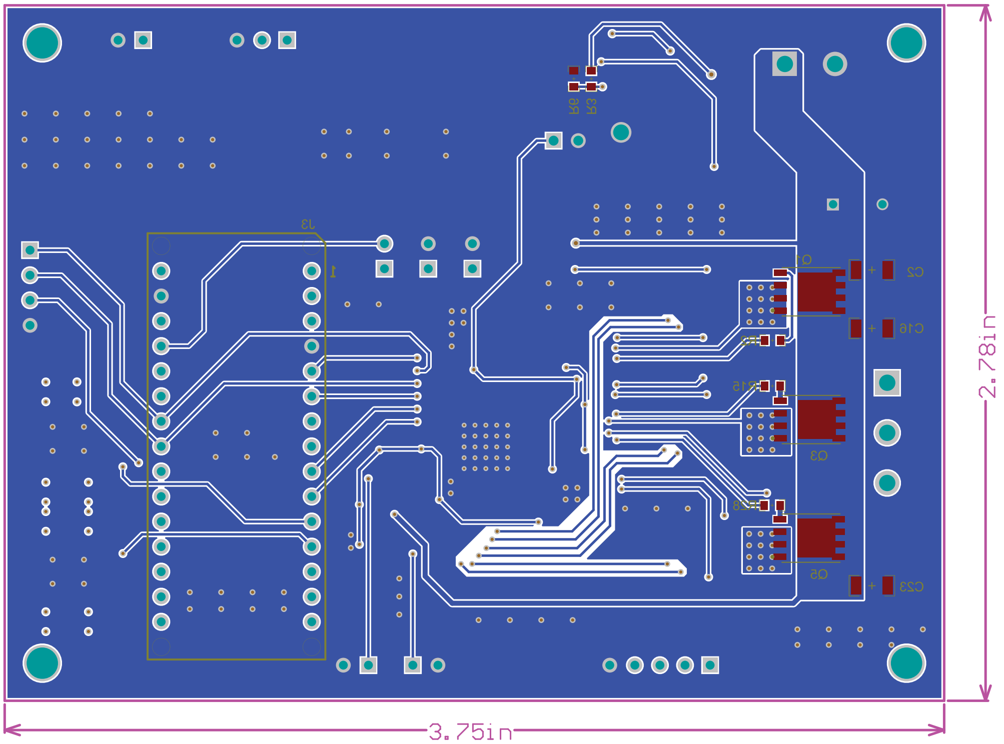
10. Check and confirm that you wish to write to the NANO EEPROM
11. A popup Information box will show if the write was successful.
12. A popup warning message will be shown if the data fails to save, and requests that you check your platform hardware.

Bill of Materials (BOM)

Item #	Quantity	Designator	Description	Value	Package	Manufacturer	Manufacturer Part Number
1	6	C1, C6, C11, C12, C25, C28	CAP CER 0.1µF 25V X7R 0603	0.1µF	0603	Samsung	CL10B104KA8NNNC
2	3	C2, C16, C23	CAP CER 10µF 50V X7R 1206	10µF	1206	Samsung	CL31B106KBHNNNE
3	2	C3, C8	CAP CER 10µF 25V X5R 0805	10µF	0805	Samsung	CL21A106KAYNNNE
4	1	C4	CAP CER 2.2µF 50V X7R 1206	2.2µF	1206	Samsung	CL31B225KBHNNNE
5	1	C5	CAP CER 0.1µF 50V X7R 1206	0.1µF	1206	Samsung	CL31B104KBCNNNC
6	1	C7	CAP ALUM 470µF 20% 50V RADIAL	470µF	RADIAL-2	Rubycon	50YXJ470M12.5X20
7	1	C9	CAP ALUM 100µF 20% 25V RADIAL	100µF		Rubycon	25YXF100MEFC6.3X11
8	1	C10	CAP CER 0603	NC	0603		
9	2	C13, C24	CAP CER 1µF 50V X7R 0805	1µF	0805	Samsung	CL21B105KBFNNNE
10	1	C14	CAP CER 0.1µF 100V X7R 0805	0.1µF	0805	Samsung	CL21B104KCFWPNE
11	9	C15, C17, C18, C19, C20, C21, C22, C26, C27	CAP CER 1µF 25V X7R 0603	1µF	0603	Samsung	CL10B105KA8NNNC
12	1	D1	SCHOTTKY 1000V 3A DO-214AC			HY Electronic	SS310A
13	5	D2, D3, D4, D5, D6	DIODE GP 100V 250MA SOD323F		SOD-323F	Diodes Incorporated	1N4148WSF-7
14	4	H1, H2, H3, H4	BRD SPT SNAP LOCK REST MNT 4MM			Essentra Components	PSD-4M-19
15	1	J1	TERM BLOCK HDR 2POS 300V 5.08MM		TH	Phoenix Contact	1755736
16	1	J3	Arduino Mount				
17	1	J7	TERM BLOCK HDR 3POS 300V 5.08MM			Phoenix Contact	1755749
18	1	L1	FIXED IND 100µH 900MA 611MΩ SM			TDK	VLS6045EX-101M
19	1	LED1	LED RED CLEAR 0603 SMD		0603	Würth Elektronik	150060RS75000
20	5	LED2, LED3, LED4, LED5, LED6	LED BLUE CLEAR 0603 SMD		0603	Würth Elektronik	150060BS75000
21	1	P1	CONN HEADER VERT 3POS 2.54MM		TH	Sullins	PREC003SAAN-RC
22	1	P2	CONN HEADER VERT 4POS 2.54MM		TH	Sullins	PREC004SAAN-RC
23	1	P3	CONN HEADER VERT 5POS 2.54MM		Through Hole	Sullins	PREC005SAAN-RC
24	6	P4, P5, P6, P7, P8, P9	CONN HEADER VERT 2POS 2.54MM		TH	Sullins Connector Solutions	PREC002SAAN-RC
25	6	Q1, Q2, Q3, Q4, Q5, Q6	MOSFET N-CH 60V 100A TDSON-8 FL		TDSON7	Infineon Technologies	BSC014N06NSTATMA1
26	6	R1, R29, R31, R33, R34, R36	RES SMD 1KΩ 1% 1/10W 0603	1K	0603	Yageo	RC0603FR-071KL
27	6	R2, R8, R15, R18, R28, R32	RES SMD 10Ω 1% 1/10W 0603	10	0603	Yageo	RC0603FR-0710RL
28	4	R3, R5, R6, R22	RES SMD 0603	NL	0603		
29	1	R4	RES SMD 510K 1% 1/10W 0603	510K	0603	Yageo	RC0603FR-07510KL
30	8	R7, R14, R16, R17, R19, R23, R25, R27	RES SMD 10K 1% 1/10W 0603	10K	0603	Yageo	RC0603FR-0710KL
31	3	R9, R10, R35	RES SMD 10K 1% 1/10W 0603	DNP	0603	Yageo	RC0603FR-0710KL
32	1	R11	RES SMD 39K 1% 1/10W 0603	39K	0603	Yageo	RC0603FR-0739KL
33	2	R12, R13	RES SMD 3.3K 1% 1/10W 0603	3.3K	0603	Yageo	RC0603FR-073K3L
34	3	R20, R21, R26	RES SMD 100K 1% 1/10W 0603	100K	0603	Yageo	RC0603FR-07100KL
35	1	R24	RES SMD 6.8Ω 1% 1/10W 0603	6.8R	0603	Yageo	RC0603JR-076R8L
36	1	R30	RES SMD 4.7K 1% 1/10W 0603	4.7K	0603	Yageo	RC0603FR-074K7L
37	3	RS1, RS2, RS3	RES 0.005Ω 1% 3W 2512	5m	2512	YAGEO	PA2512FKF7T0R005E
38	1	SW1	SWITCH PUSHBUTTON SPDT 0.4VA 28V		SMD	NKK Switches	G3B15AB-S-YA
39	1	SW2	SWITCH PUSHBUTTON SPDT 0.4VA 28V		SMD	NKK Switches	G3B15AB-S-YC
40	1	SW3	Tactile Switch SPST-NO Top Actuated Surface Mount		SMD	Hanxia	HX TS3625A 250gf
41	1	TP1	PC TEST POINT MULTIPURPOSE BLACK		TH	Keystone	5011
42	1	U1	3-phase BLDC Motor Controller for 3-wire with Built-in Gate Drivers		QFN56L		KTX9312GUAN-AA-TE
43	1	U2	100V INPUT, 500MA, STEP-DOWN CONVERTER		MP9485GN-Z	Monolithic Power Systems (MPS)	MP9485GN-Z
44	1	U3	IC EEPROM 2KBIT SGL WIRE SOT23-3		SOT23-3	Microchip Technology	11LC020T-E/TT
45	1	U4	Linear Voltage Regulator IC Positive Fixed 1 Output 100mA SOT-89-3		TO-243AA	UMW	HT7550-1

Printed Circuit Board (PCB)





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