# Application Note

## Document No.: AN1096

## APM32F035_HvMOTOR EVAL Senseless Vector Control Scheme

**Version: V1.1**

# Contents

# 1 General Introduction

## 1.1 Project Overview

APM32F035 is a specialized chip launched by Geehy Semiconductor Co., Ltd. for motor control. Based on APM32F035, this design provides a dual-resistance sampling vector control scheme and uses the closed-loop sliding-mode observer estimation scheme. The detailed design specifications are shown in the table below:

Table 1 Design Specifications

| | |
|---|---|
| Control mode | Sensorless Field Oriented Control (FOC) |
| Observer | Back electromotive force observer |
| PWM modulation mode | SVPWM |
| PWM frequency | 8KHz |
| Motor speed | 100~1000RPM (5 pairs of poles) |
| Starting mode | Open-loop starting |
| Protection function | Overvoltage, undervoltage, overcurrent, locked rotor |
| Code size | 11Kbytes |
| Development software | Keil C (V5.23 version and above) |

## 1.2 APM32F035 Chip Resources

APM32F035 is a high-performance special MCU for motor control which is based on the Arm Cortex-M0+ core, integrates the mathematical operation accelerators (Cordic, Svpwm, hardware divider, etc.) commonly used in FOC algorithms, and integrates such analog peripherals as amplifiers and comparators, as well as CAN controllers.

Table 2 Functions and Peripherals of APM32F035 Series Chip

| **Product** | | **APM32F035** | |
|---|---|---|---|
| **Model** | | **C8T7** | **K8T7** |
| Package | | LQFP48 | LQFP32 |
| Core and maximum working frequency | | Arm® 32-bit Cortex®-M0+@72MHz | |
| M0CP Co-processor | | **1** | |
| Flash memory (KB) | | 64 | |
| SRAM(KB) | | 10 | |
| Timer | 32 bit/16 bit universal | 1/2 | |
| | 16-bit advanced | 1 | |
| | 16-bit basic | 2 | |

| Product | | APM32F035 | |
|---|---|---|---|
| **Model** | | **C8T7** | **K8T7** |
| | 24-bit counter | 1 | |
| | Watchdog (WDT) | 2 (1 independent watchdog +1 window watchdog) | |
| | Real-time clock | 1 | |
| Communication interface | USART | 2 | |
| | SPI/I2S | 1/1 | |
| | I2C | 1 | |
| | CAN | 1 | |
| 12-bit ADC | Unit | 1 | |
| | External channel | 16 | 12 |
| | Internal channel | 3 | |
| Comparator (COMP) | | 2 | |
| Operational amplifier (OPA) | | 4 | 2 |
| GPIOs | | 42 | 27 |
| Operating temperature | | Ambient temperature: -40℃ to 105℃<br>Junction temperature: -40℃ to 125℃ | |
| Working voltage | | 2.0~3.6V | |

# 2 Hardware Introduction

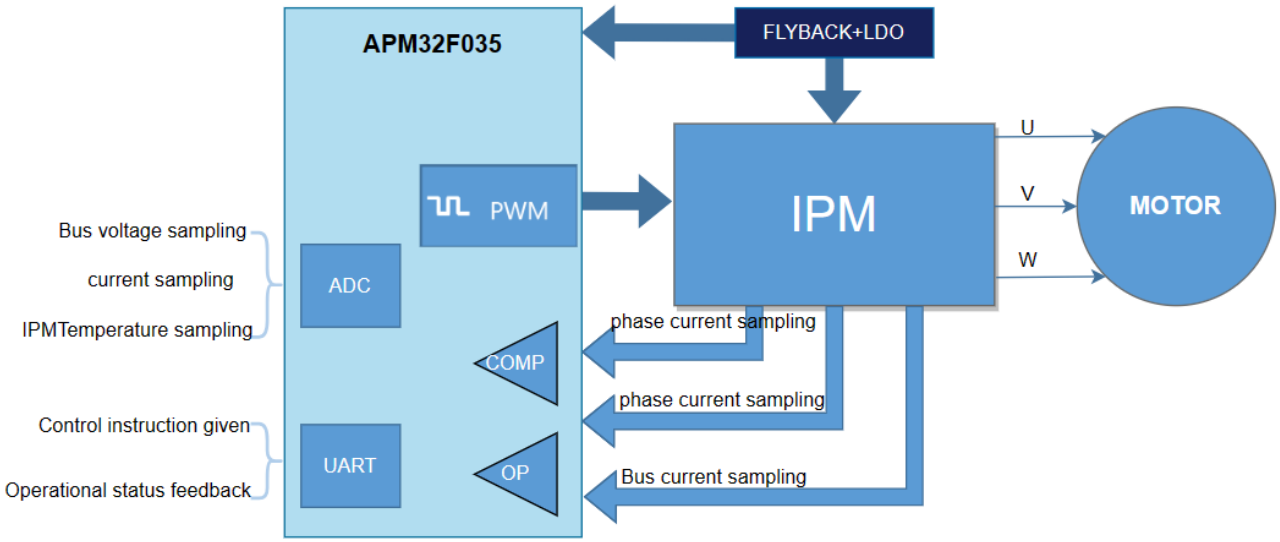
## 2.1 Overall Hardware Circuit

The overall hardware system is powered by an external AC power supply, and after control conversion through the corresponding rectifier filter and switching power circuits, it will output stable 5V and 3.3V voltages. Users can use the isolated serial port to send data to set the motor speed. At the same time, when the set speed exceeds the starting threshold, the motor will start running, and when the voltage value is below the threshold, the motor will stop running.

After the motor is started, the APM32F035 processor can obtain the phase currents Iu, Iv, and Iw of three phases through the built-in operational amplifier and corresponding sampling circuit, and convert this data through the coordinate axis to control the torque current and phase of the motor. After the FOC control calculation link, adjust the TMR1 peripheral to output the corresponding three-way complementary PWM waves to control the switching components of the inverter.

The hardware block diagram is shown in the figure.

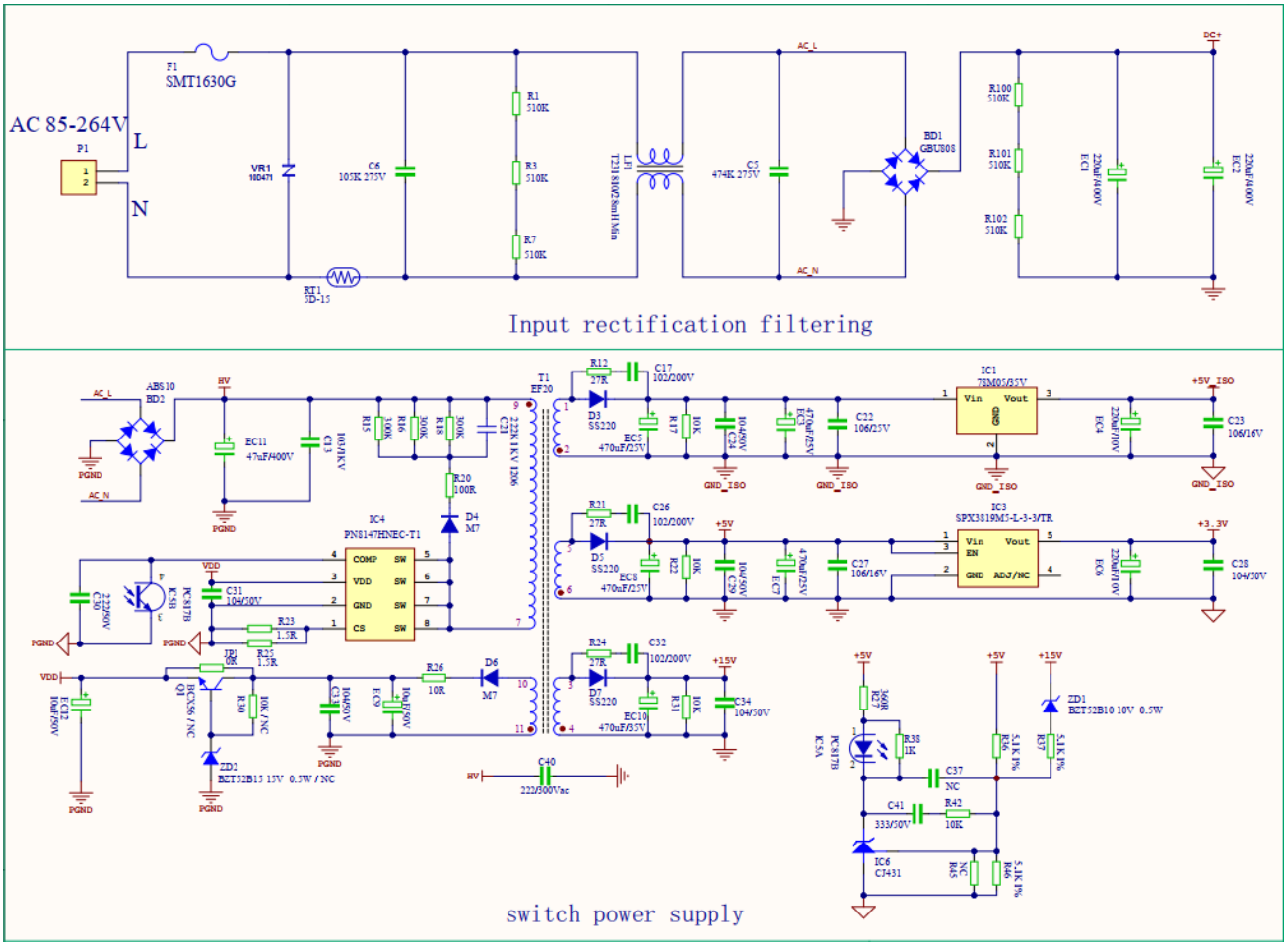
Figure 1 Hardware System Block Diagram



## 2.2 Interface Circuits and Settings

### 2.2.1 Power circuit

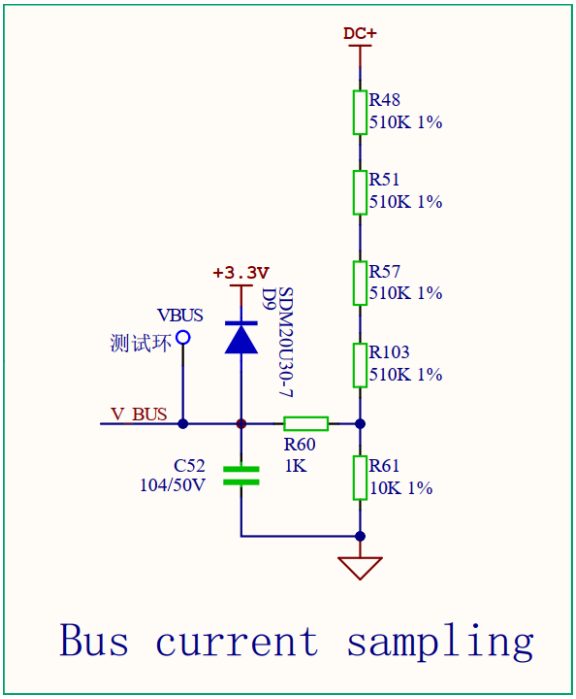
Figure 2 Power Circuit




As shown in the figure, the input AC voltage range is 85~264V, which can be stabilized and output stable 5V and 3.3V voltage supply through the rectifier filter circuit and the switching power supply.

### 2.2.2 Bus Voltage Detection Circuit

Figure 3 Bus Voltage Detection Circuit



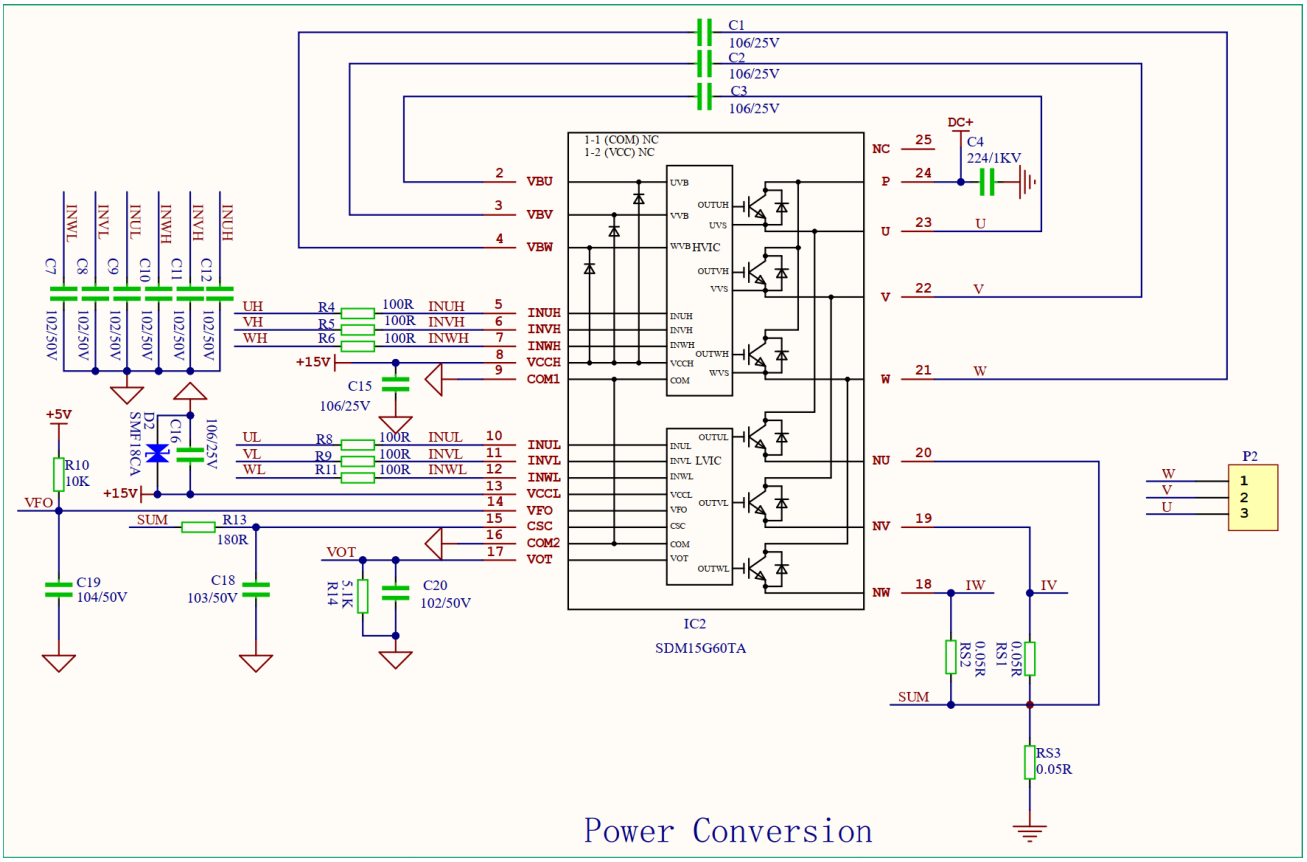

As shown in the figure, the power supply voltage
V_BUS=DC/((510K+510K+510K+510K+10K)/10K)=DC/205

A 12-bit ADC is adopted, and the sampling range 0-3.3V corresponds to 0-4096

Then the maximum sampling voltage corresponding to 3.3V is: DC=3.3 *205 =676.5V

### 2.2.3 IPM Circuit

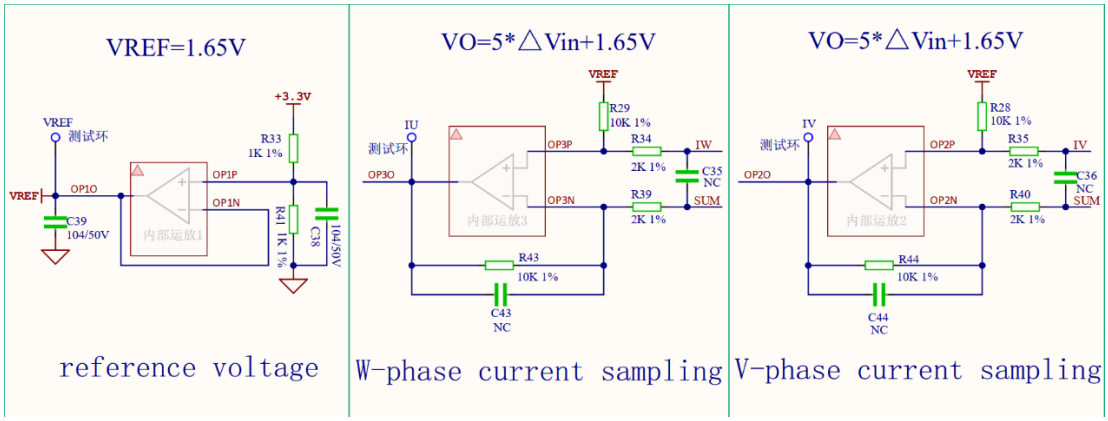
Figure 4 IPM Circuit




As shown in the figure, IPM is used to implement power conversion control, and it also has a protection mechanism. If overcurrent protection occurs, it will be input to the Break In pin of the chip through the VFO port.

### 2.2.4 Current Sampling Circuit

Figure 5 Current Sampling Circuit



As shown in the figure, IV=VI*5+1.65

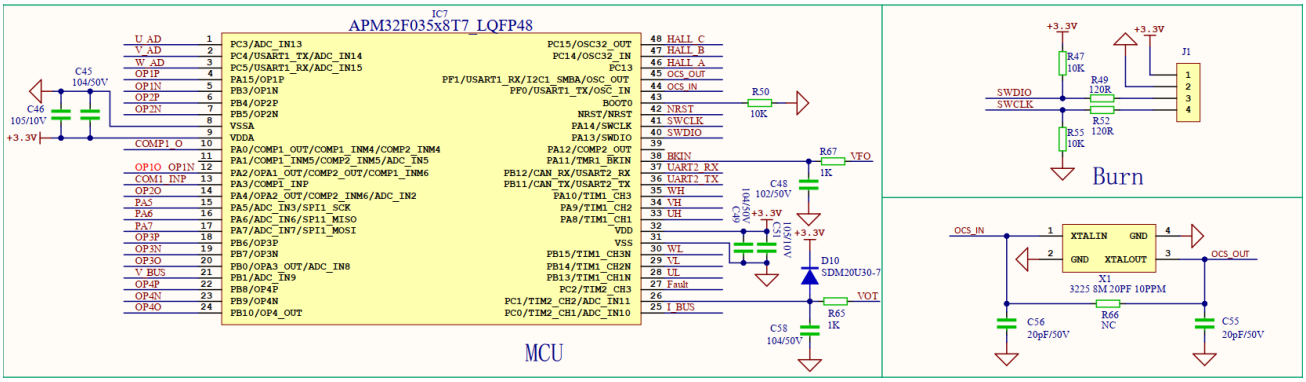
A 12-bit ADC is adopted, and the sampling range 0-3.3V corresponds to 0-4096

As shown in the figure, when the sampling resistance is selected as 0.02R,

the maximum peak-to-peak current corresponding to 3.3V is (3.3-1.65)/5/0.02=16.5A

### 2.2.5 Minimum system circuit

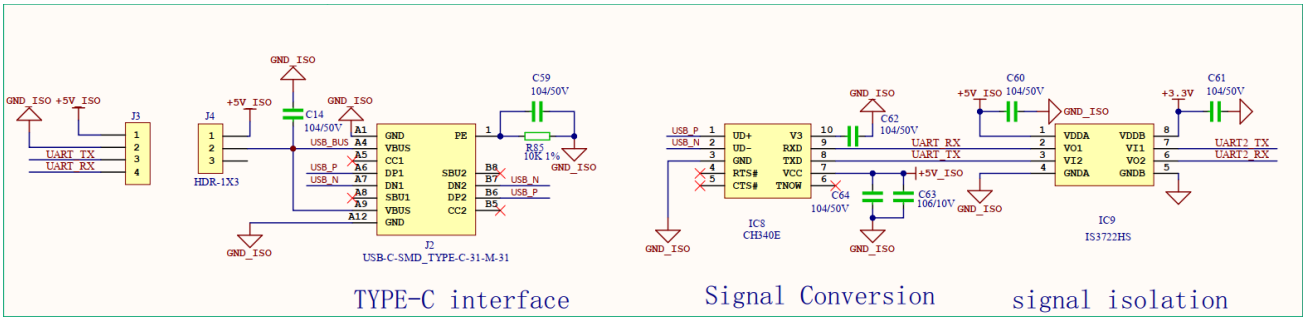
Figure 6 Minimum System Circuit




As shown in the figure, the utilization of APM32F035 MOTOR EVAL V1.0 board hardware interface resources is described in the above figure. The external crystal oscillator input of HSE is 8MHz, and SWD burning interface is adopted for burning.

### 2.2.6 Communication Interface and Button Circuit

Figure 7 Communication Interface and Button Circuit




As shown in the figure, a USB-to-serial port and a fault indicator light are reserved in the APM32F035 MOTOR EVAL V1.0 board hardware for debugging by developers.

## 2.3 Physical System Hardware

The picture of the system is shown in the figure, and it mainly includes the following five interfaces:

(1) AC power input interface

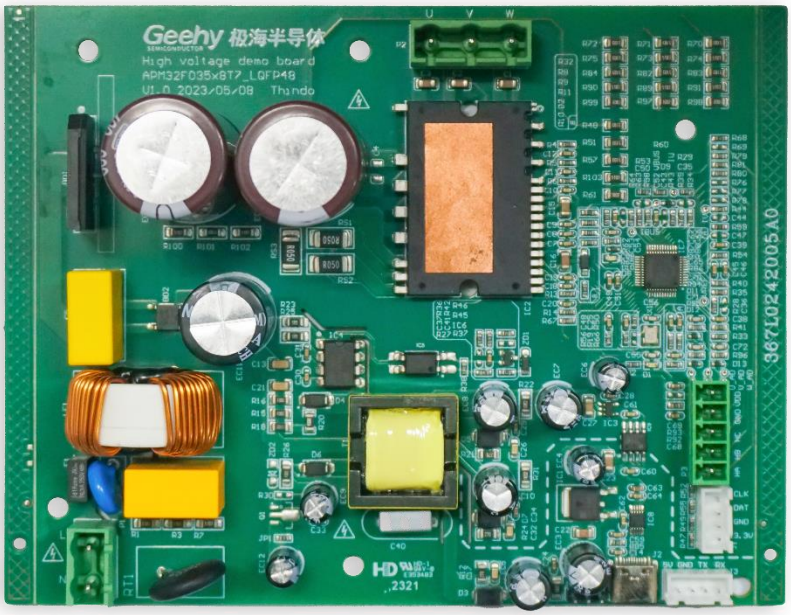
(2) Three phase motor interface (phase sequence only affects the direction of rotation)

(3) HALL input interface

(4) SWD debugging interface

(5) Isolated USB-to-UART interface

Figure 8 Hardware Picture



# 3 Software Introduction

## 3.1 Overall Program Architecture

The overall code architecture of this project can be divided into four layers: user layer, peripheral driver layer, motor control driver layer, and motor algorithm layer. The specific functional descriptions are as follows:

### 3.1.1 USER Layer

main.c: The main function entry is responsible for switching of motor initialization parameters, underlying peripherals, interrupt priority, while cycle, and low-speed state machine loop;

apm32f035_int.c: All interrupt handling functions, mainly including TMR1 interrupt function and ADC interrupt handler function;

user_function.c: Includes initialization configuration, parameter reset, and other handler functions of motor parameters;

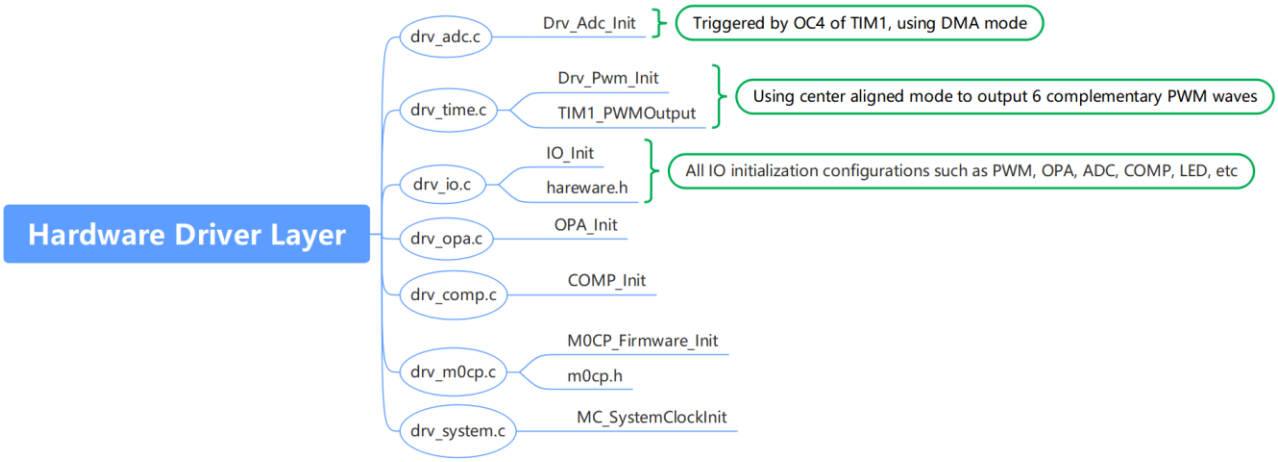
parameter.h: Includes all required configuration parameter information;

board.c: Includes initialization configuration functions of board-level underlying peripheral.

### 3.1.2 Peripheral Driver Layer (HARDWARE Layer)

The peripheral driver layer is mainly responsible for the peripheral driver functions and configuration of the APM32F035 chip, mainly including GPIO, PWM, ADC, OPA, COMP and M0CP coprocessors, as shown in the following figure.

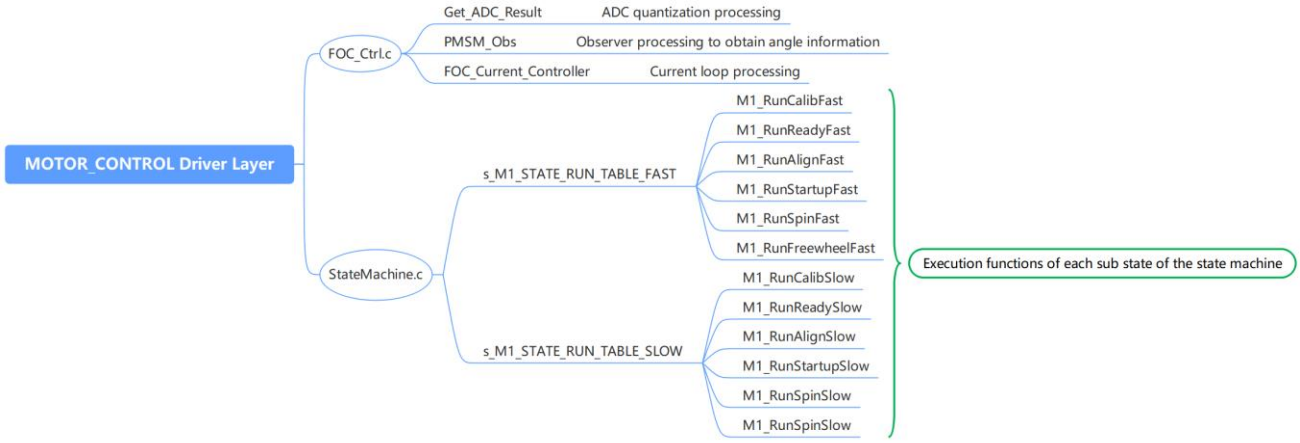
Figure 9 Peripheral Driver Layer



### 3.1.3 Motor Control Drive Layer (MOTOR_CONTROL Layer)

The motor control driver layer is mainly responsible for the control run logic and core processing algorithm call of the motor, as shown in the following figure.

Figure 10 Motor Control Driver Layer




### 3.1.4 Geehy Motor Algorithm Layer (Geehy_MCLIB Layer)

The motor algorithm layer includes coordinate transformation, vector control and other related functions, as well as math libraries, sliding-mode observer and other library functions.

## 3.2 Introduction to State Machine

In this case, the structure of embedding the sub-state machine into the main state machine is adopted, as shown below:

Four main states: INIT, STOP, FAIL, and RUN;

The six RUN sub-states of the main state are **run calib, run-ready, run-align, run-startup, run-spin, and run-freewheel**.

The main state machine is described below:

**Fault:** When an error occurs in the system, it will remain in this state until the error flag bit is cleared.

Then after delay for a period of time, it will jump from the Fault state to the STOP state and wait for the start command.

**Init:** This main state executes variable initialization.

**Stop:** The system waits for the speed command after completing initialization. In this state, the PWM output is turned off.

**Run:** In the running state, if a Stop command is issued, the system will stop running.

When the system is running in the Run state, its sub-states will be called and executed:

**Run-Calib:** The current biased ADC self-calibration function can be executed. After this state is executed, the system will switch to the Ready state and disable the PWM output.

**Ready:** Enable PWM output, synchronously sample the current, and conduct abnormal state inspection.

**Align:** Execute sampling current, call pre-positioning algorithm, and update the PWM. Execute the state within the specified time, and the system will switch to the Startup sub-state and sample the DC bus voltage for filtering.

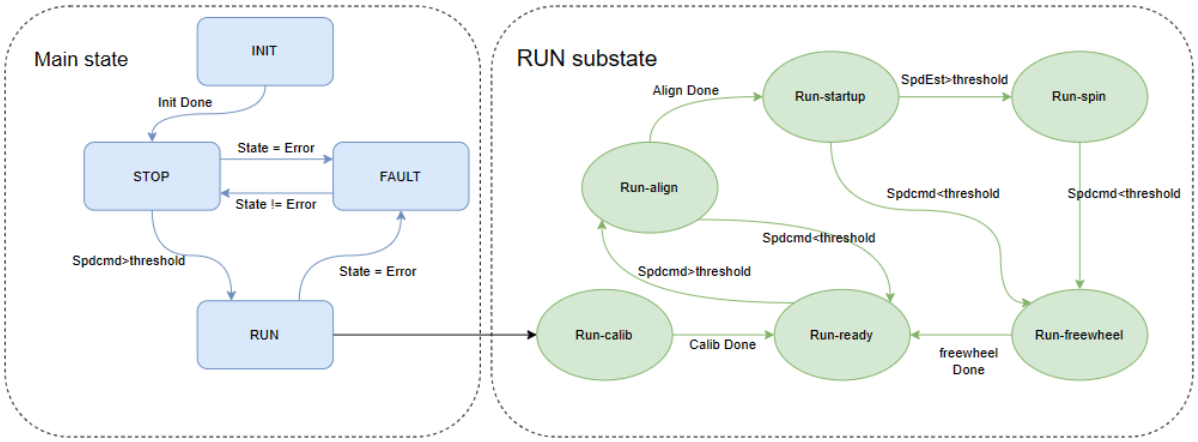
**Startup:** Sample the current, use an open-loop starting motor, and call the observer to estimate the rotor speed and position, call the corresponding algorithm, and update the PWM. If the motor is started successfully, the system will spin the sub-state and sample the DC bus voltage for filtering.

**Spin:** Sample the current, call the observer to estimate the rotor speed and position, call the corresponding algorithm, update the PWM, and the motor starts to switch to closed-loop operation.

**Freewheel:** Enable PWM output and stop the machine through shorting the brake. Due to rotor inertia, the state can be switched only after the motor stops running and further switched to Ready state. If an error occurs, the system will enter the Fault state.

To sum up, the state machine flowchart of the system is shown in the figure below.

Figure 11 State Machine Flowchart



## 3.3 Top-layer Peripheral Configuration

### 3.3.1 PWM Output Configuration

void Drv_Pwm_Init(uint16_t u16_Period,uint16_t u16_DeadTime)

1. The general configuration of PWM is as follows:

Set the PWM clock frequency division to 1, select the center-aligned mode 2, and set the repeat counter to 1, as shown in the figure below.

Figure 12 General Configuration of PWM

```
/* Time Base configuration ,init time1 freq*/
TIM_TimeBaseInitStructure.period          = u16_Period;
TIM_TimeBaseInitStructure.div             = 0;
TIM_TimeBaseInitStructure.counterMode     = TMR_COUNTER_MODE_CENTERALIGNED2;
TIM_TimeBaseInitStructure.clockDivision   = TMR_CKD_DIV1;
TIM_TimeBaseInitStructure.repetitionCounter = 1;
TMR_ConfigTimeBase(TMR1, &TIM_TimeBaseInitStructure);
```

Figure 13 Center-aligned Mode Selection

Center-Aligned Mode Select

In the Center-aligned mode, the counter counts up and down alternately; otherwise, it will only count up or down. Different Center-aligned modes affect the timing of setting the output comparison interrupt flag bit of the output channel to 1; when the counter is disabled (CNTEN=0), select the Center-aligned mode.

00: Edge-alignment mode

01: Center-aligned mode 1 (the output comparison interrupt flag bit of output channel is set to 1 when counting down)

10: Center-aligned mode 2 (the output comparison interrupt flag bit of output channel is set to 1 when counting up)

11: Center-aligned mode 3 (the output comparison interrupt flag bit of output channel is set to 1 when counting up/down)

2. PWM output status configuration

Set the output status of upper and lower tubes of PWM and enable the configuration of PWM output of the upper and lower tubes to be effective,

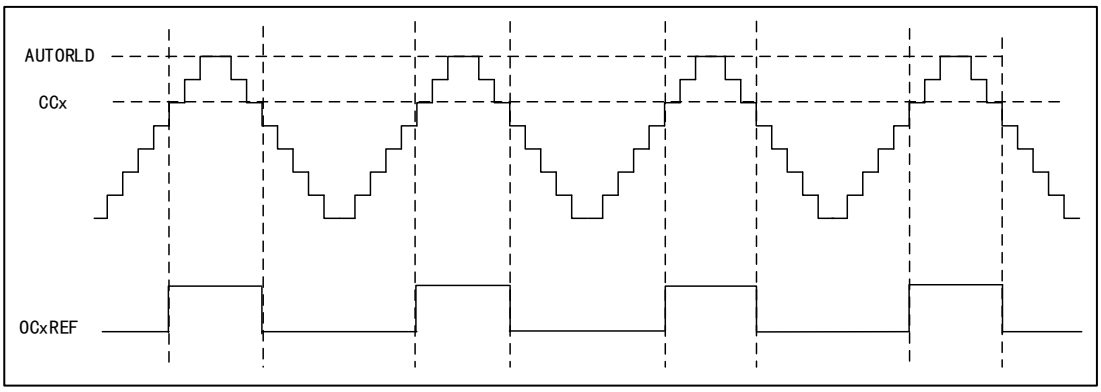
Configure the enabled brakes, configure the brake input polarity, and disable automatic recovery of brake hardware;

Figure 14 PWM Output Status Configuration

```
/* Automatic Output enable, Break, dead time and lock configuration*/
TIM_BDTRInitStructure.RMOS_State       = TMR_RMOS_STATE_ENABLE;
TIM_BDTRInitStructure.IMOS_State       = TMR_IMOS_STATE_ENABLE;
TIM_BDTRInitStructure.lockLevel        = TMR_LOCK_LEVEL_OFF;
TIM_BDTRInitStructure.deadTime         = u16_DeadTime;//
/**
  * Brake configuration: enable brake
  * Brake input polarity: active in low level
  * Auto output enable configuration: Disable MOE bit hardware control
  */
TIM_BDTRInitStructure.breakState       = TMR_BREAK_STATE_ENABLE;
TIM_BDTRInitStructure.breakPolarity    = TMR_BREAK_POLARITY_LOW;
TIM_BDTRInitStructure.automaticOutput  = TMR_AUTOMATIC_OUTPUT_DISABLE;
TMR_ConfigBDT(TMR1, &TIM_BDTRInitStructure);

/*pwm driver set, channel 1,2,3,4set pwm mode*/
TIM_OCInitStructure.OC_Mode        = TMR_OC_MODE_PWM2;
TIM_OCInitStructure.OC_OutputState = TMR_OUTPUT_STATE_ENABLE;  //TMR_OUTPUT_STATE_DISABLE;
TIM_OCInitStructure.OC_OutputNState= TMR_OUTPUT_NSTATE_ENABLE; //TMR_OUTPUT_NSTATE_DISABLE;
TIM_OCInitStructure.Pulse          = 0;
TIM_OCInitStructure.OC_Polarity    = TMR_OC_POLARITY_HIGH;
TIM_OCInitStructure.OC_NPolarity   = TMR_OC_NPOLARITY_HIGH; //
TIM_OCInitStructure.OC_Idlestate   = TMR_OCIDLESTATE_RESET; // TMR_OCIDLESTATE_SET; //
TIM_OCInitStructure.OC_NIdlestate  = TMR_OCNIDLESTATE_RESET; // TMR_OCNIDLESTATE_SET;//
```

Figure 15 Timing Diagram of PWM2 Center-aligned Mode




In count-up mode, when TMR1_CNT<TMR1_CCR1, Channel 1 is invalid level; otherwise it is valid level;

In count-down mode, when TMR1_CNT>TMR1_CCR1, Channel 1 is valid level; otherwise it is invalid level.

### 3.3.2 ADC Configuration

void Drv_Adc_Init(void)

(1) ADC underlying configuration

DMA mode is adopted, and the quantized data of ADC is directly transported to the ADC_ConvertedValue array for storage. The ADC trigger condition uses CC4 of TMR1 as the trigger source, to enable ADC and configure ADC interrupt priority and its enable. Details are

shown below:

Figure 16 ADC Underlying Configuration

```
void Drv_Adc_Init(void)
{
    ADC_Config_T    ADC_InitStructure;
    DMA_Config_T    DMA_InitStructure;
    DMA_InitStructure.peripheralAddress   = (uint32_t)&(ADC->DATA);//
    DMA_InitStructure.memoryAddress       = (uint32_t)&ADC_ConvertedValue[0];
    DMA_InitStructure.direction           = DMA_DIR_PERIPHERAL; //
    DMA_InitStructure.bufferSize          = 4;//TOTAL_CHANNEL; //
    DMA_InitStructure.peripheralInc       = DMA_PERIPHERAL_INC_DISABLE; //
    DMA_InitStructure.memoryInc           = DMA_MEMORY_INC_ENABLE;//DMA_MEMORY_INC_ENABLE;
    DMA_InitStructure.peripheralDataSize  = DMA_PERIPHERAL_DATASIZE_HALFWORD ;
    DMA_InitStructure.memoryDataSize      = DMA_MEMORY_DATASIZE_HALFWORD ;
    DMA_InitStructure.circular            = DMA_CIRCULAR_ENABLE  ;
    DMA_InitStructure.priority            = DMA_PRIORITY_LEVEL_VERYHIGH ;
    DMA_InitStructure.memoryTomemory      = DMA_M2M_DISABLE;

    DMA_Config(DMA_CHANNEL_1, &DMA_InitStructure);
    DMA_Enable(DMA_CHANNEL_1);
    ADC_ClockMode(ADC_CLOCK_MODE_ASYNCLK);
    ADC_ConfigStructInit(&ADC_InitStructure);
    ADC_InitStructure.convMode      = ADC_CONVERSION_SINGLE;
    ADC_InitStructure.scanDir       = ADC_SCAN_DIR_UPWARD;
    ADC_InitStructure.extTrigConv1  = ADC_EXT_TRIG_CONV_TRG1; //  timer1 CC4
    ADC_InitStructure.extTrigEdge1  = ADC_EXT_TRIG_EDGE_RISING;
    ADC_InitStructure.dataAlign     = ADC_DATA_ALIGN_RIGHT;
    ADC_InitStructure.resolution    = ADC_RESOLUTION_12B;
    ADC_Config(&ADC_InitStructure);
    ADC_ConfigChannel(ADC_CHANNEL_2 | ADC_CHANNEL_8 | ADC_CHANNEL_7 | ADC_CHANNEL_9 ,ADC_SAMPLE_TIME_1_5);
    ADC->CFG1_B.OVRMAG = 1;
    ADC_EnableInterrupt(ADC_INT_CS);
//=========================ADC                ================================================
    NVIC_EnableIRQ(ADC_COMP_IRQn);
    NVIC_SetPriority(ADC_COMP_IRQn,0);
    ADC_DMARequestMode(ADC_DMA_MODE_CIRCULAR);
    ADC_EnableDMA();
    ADC_Enable();
    ADC_StartConversion();//
}
```

### 3.3.3 OPA and COMP Underlying Configuration

(1) OPA underlying configuration

To configure the underlying configuration of OPA, first configure the OPA pin, DISABLE the operational amplifier OPA, configure to use an external resistor network, and then ENABLE it, as shown in the figure below;

Figure 17 OPA Underlying Configuration

```
void OPA_Init(void)
{
    OPA_Disable(OPA1);
    OPA_Disable(OPA2);
    OPA_Disable(OPA3);
    OPA_Disable(OPA4);
    OPA_SelectGainFactor(OPA1,OPA_GAIN_FACTOR_0);
    OPA_SelectGainFactor(OPA2,OPA_GAIN_FACTOR_0);
    OPA_SelectGainFactor(OPA3,OPA_GAIN_FACTOR_0);
    OPA_SelectGainFactor(OPA4,OPA_GAIN_FACTOR_0);
    OPA_Enable(OPA1);
    OPA_Enable(OPA2);
    OPA_Enable(OPA3);
    OPA_Enable(OPA4);
}
```

(2) COMP underlying configuration

COMP is used for overcurrent anomaly detection. To configure the underlying configuration of COMP, first configure the COMP pin, set the COMP output to the BKIN connected to TMR1, set the output reverse, and trigger the BKIN of TMR1 at a low level, as shown in the following figure;

Figure 18 COMP Underlying Configuration

```
void COMP_Init(void)
{
    COMP_Config_T   compConfig;
    /*  Configure COMP1 */
    COMP_ConfigStructInit(&compConfig);
    compConfig.invertingInput = COMP_INVERTING_INPUT_PA1;
    compConfig.output         = COMP_OUTPUT_TIM1BKIN;
    compConfig.outputPol      = COMP_OUTPUTPOL_NONINVERTED;
    compConfig.hysterrsis     = COMP_HYSTERRSIS_NO;
    compConfig.mode           = COMP_MODE_HIGHSPEED;
    COMP_Config(COMP_SELECT_COMP1,&compConfig);
    /* Enable COMP2 */
    COMP_Enable(COMP_SELECT_COMP1);
}
```

## 3.4 Settings and Configuration Methods of Key Parameters

All parameters in this system are configured in parameter.h of the user layer, mainly including system parameters, related parameters of backplane, related parameters of state machine, and related parameters of motor, as follows:

### 3.4.1 System Parameters

Table 3 System Parameters

| Parameter name | Parameter description | Set value |
|---|---|---|
| SYS_REFV | Supply voltage of the system | 3.3 (V) |
| SYSCLK_HSE_72MHz | Main frequency of the system | 72000000 (Hz) |
| PWMFREQ | PWM frequency | 8000 (Hz) |
| DEAD_TIME | PWM dead band time | 1.0 (μs) |
| SLOWLOOP_FREQ | Control frequency of slow loop | 1000 (Hz) |

### 3.4.2 Backplane Hardware Parameters

Table 4 Parameters of Backplane Hardware

| Parameter name | Parameter description | Set value |
|---|---|---|
| ADC_REFV | ADC reference voltage | 3.3 (V) |
| R_SHUNT | Sampling resistance value | 0.02 (Ω) |
| CURRENT_OPA_GAIN | Amplification factor of operational amplifier | 4.86 |
| I_MAX | Current standardization reference value | 16.46 (A) |
| UDC_MAX | Voltage standardization reference value | 676.5 (V) |

### 3.4.3 Parameters of State Machine

Table 5 Parameters of State Machine

| Parameter name | Parameter description | Set value |
|---|---|---|
| STOP_TO_RUN_SPEED | Threshold for speed command of jumping from Stop to Run state | 180 (rpm) |
| STARTUP_TO_SPIN_SPEED | Threshold for actual speed of jumping from Startup to Spin state | 150 (rpm) |
| FREEWHEEL_SPEED | Stop after the speed command is below the threshold | 30 (rpm) |
| IQ_ALIGN | IQ command value in Align state | 0.25 (A) |
| STARTUP_SPEED_RAMP | Slope value of speed command under open loop | 50 (rpm/s) |
| SPIN_SPD_INC | Closed-loop slope acceleration | 150.0 (rpm/s) |

| Parameter name | Parameter description | Set value |
|---|---|---|
| SPD_DEC | Closed loop slope deceleration | 150.0 (rpm/s) |

### 3.4.4 Motor Related Parameters

Table 6 Motor Related Parameters

| Parameter name | Parameter description | Set value |
|---|---|---|
| Rs | Phase resistance of motor | 15.4f (ohm) |
| Ls | Phase inductance of motor | 0.185 (H) |
| POLEPAIRS | Number of motor pole-pairs | 5 (unit) |
| SPEED_MAX | Speed calibration value | 1500 (rpm) |
| MAX_DUTY | Maximum duty cycle | 0.95 (unit) |
| M1_IQ_KP_Q15 | Q-axis current loop KP parameter Q15 format | 10000 |
| M1_IQ_KI_Q15 | Q-axis current loop KI parameter Q15 format | 1000 |
| M1_ID_KP_Q15 | D-axis current loop KP parameter Q15 format | 10000 |
| M1_ID_KI_Q15 | D-axis current loop KI parameter Q15 format | 1000 |
| M1_SPEED_KP_Q15 | Speed loop KP parameter Q15 format | 28383 |
| M1_SPEED_KI_Q15 | Speed loop KI parameter Q15 format | 300 |

# 4 Debugging Experience Sharing

## 4.1 Debugging Steps

(1) First, the parameters of the motor need to be clearly defined, such as phase resistance, phase inductance, and number of pole pairs of the motor, and confirm and modify them according to the parameters in "Motor Related Parameters" of Paramater.h;

(2) Before powering on the board, check whether the main elements are welded in correct position, and after confirming no abnormality, power on, test and confirm whether various voltages of the system are stable (5V, 2.5V, operational amplifier bias voltage, etc.);

(3) Based on the completion of the above steps, power on and try to run the motor for test. If the motor can run but the speed is unstable, further adjust the PI parameter of the SPEED LOOP. The PI regulator changes from small to large. Adjust KP first and then add KI;

(4) If the motor cannot run directly, first use the open-loop operation method to synchronously check whether the current sampling part is normal and check the current range of driving IQ_Align to ensure that the motor can run in the open loop first, and then synchronously check whether the current tracking response of the current loop is normal. In combination with the open-loop test, confirm the speed threshold parameter of switching from open loop to closed loop of the "STARTUP_TO_SPIN_SPEED", and then ensure that it can run in the closed loop. If there is speed fluctuation, please refer to Step (3) synchronously.

# 5 Revision History

Table 7 Document Revision History

| Date | Revision | Revision History |
|---|---|---|
| July 26, 2023 | 1.0 | New |
| August 14, 2023 | 1.1 | (1) Modified the format<br>(2) Modified the production information form |

# Statement

This document is formulated and published by Geehy Semiconductor Co., Ltd. (hereinafter referred to as "Geehy"). The contents in this document are protected by laws and regulations of trademark, copyright and software copyright. Geehy reserves the right to make corrections and modifications to this document at any time. Please read this document carefully before using Geehy products. Once you use the Geehy product, it means that you (hereinafter referred to as the "users") have known and accepted all the contents of this document. Users shall use the Geehy product in accordance with relevant laws and regulations and the requirements of this document.

1. Ownership

This document can only be used in connection with the corresponding chip products or software products provided by Geehy. Without the prior permission of Geehy, no unit or individual may copy, transcribe, modify, edit or disseminate all or part of the contents of this document for any reason or in any form.

The "极海" or "Geehy" words or graphics with "®" or "™" in this document are trademarks of Geehy. Other product or service names displayed on Geehy products are the property of their respective owners.

2. No Intellectual Property License

Geehy owns all rights, ownership and intellectual property rights involved in this document.

Geehy shall not be deemed to grant the license or right of any intellectual property to users explicitly or implicitly due to the sale or distribution of Geehy products or this document.

If any third party's products, services or intellectual property are involved in this document, it shall not be deemed that Geehy authorizes users to use the aforesaid third party's products, services or intellectual property, unless otherwise agreed in sales order or sales contract.

3. Version Update

Users can obtain the latest document of the corresponding models when ordering Geehy products.

If the contents in this document are inconsistent with Geehy products, the agreement in thesales order or the sales contract shall prevail.

4. Information Reliability

The relevant data in this document are obtained from batch test by Geehy Laboratory or cooperative third-party testing organization. However, clerical errors in correction or errors caused by differences in testing environment may occur inevitably. Therefore, users should understand that Geehy does not bear any responsibility for such errors that may occur in this document. The relevant data in this document are only used to guide users as performance parameter reference and do not constitute Geehy's guarantee for any product performance.

Users shall select appropriate Geehy products according to their own needs, and effectively verify and test the applicability of Geehy products to confirm that Geehy products meet their own needs, corresponding standards, safety or other reliability requirements. If loses are caused to users due to the user's failure to fully verify and test Geehy products, Geehy will not bear any responsibility.

5. Legality

USERS SHALL ABIDE BY ALL APPLICABLE LOCAL LAWS AND REGULATIONS WHEN USING THIS DOCUMENT AND THE MATCHING GEEHY PRODUCTS. USERS SHALL UNDERSTAND THAT THE PRODUCTS MAY BE RESTRICTED BY THE EXPORT, RE-EXPORT OR OTHER LAWS OF THE COUNTIRIES OF THE PRODUCTS SUPPLIERS, GEEHY, GEEHY DISTRIBUTORS AND USERS. USERS (ON BEHALF OR ITSELF, SUBSIDIARIES AND AFFILIATED ENTERPRISES) SHALL AGREE AND PROMISE TO ABIDE BY ALL APPLICABLE LAWS AND REGULATIONS ON THE EXPORT AND RE-EXPORT OF GEEHY PRODUCTS AND/OR TECHNOLOGIES AND DIRECT PRODUCTS.

6. Disclaimer of Warranty

THIS DOCUMENT IS PROVIDED BY GEEHY "AS IS" AND THERE IS NO WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, TO THE EXTENT PERMITTED BY APPLICABLE LAW.

GEEHY WILL BEAR NO RESPONSIBILITY FOR ANY DISPUTES ARISING FROM THE SUBSEQUENT DESIGN OR USE BY USERS.

7. Limitation of Liability

IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL GEEHY OR ANY OTHER PARTY WHO PROVIDE THE DOCUMENT "AS IS", BE LIABLE FOR DAMAGES,

INCLUDING ANY GENERAL, SPECIAL, DIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE DOCUMENT (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY USERS OR THIRD PARTIES).

8. Scope of Application

The information in this document replaces the information provided in all previous versions of the document.