

# **MDRFD0**

## **Hair Dryer**

### **Application Note**

Sensorless Based High-Speed PMSM Solution

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## 1. Basic specification parameter configuration

### 1.1 Motor parameter configuration

- Configuration file : MOTOR.h <Configuration Wizard>
- Set motor parameters

Parameter	Value range/option	Description	Default value
Motor Pole	0~30(multiple of 2)	Number of motor poles	2
Motor SMO_G	0~32767	$G = Ts / Ls/2$	16000
Motor SMO_F	0~32767	$F = 1 - (G * Rs/2)$	32346
Motor SMO_Kslf	0~32767	Low Pass Filter Gain	8000
Motor SMO Kslide	0~32767	Linear Gain	16000
MaxSmcError	0~32767	Judgment value of SMO current tolerance	32767

Suggestions for adjusting direction :

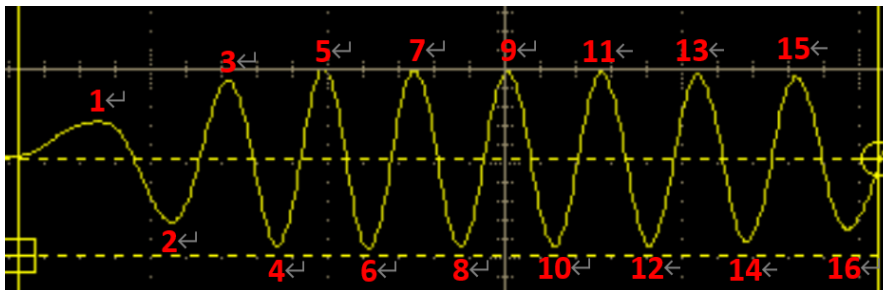
Measure the Motor poles :

When the exact number of poles of the motor cannot be known, the number of poles can be obtained by measuring the back EMF, methods as below:

Step1. Oscilloscope carbon rod randomly selects between any two phases of the motor (ex: U to V or V to W...), the motor does not need to be connected to the control board

Step2. Make the motor rotate one circle by hand or external force

Step3. According to the figure below, calculate the total number of positive and negative half cycles of the counter electromotive force, that is, the number of poles of the motor (The number of poles is a multiple of 2)



SMO:

Sliding-Mode Current Observer Mainly used to estimate the motor rotor position , A certain degree of toughness to parameter change disturbances , So the SMO\_G & SMO\_F parameters do not need to be calculated by the R and L parameters.

When the motor runs to the rated power , if the current diverges abnormally, it will cause shutdown protection , dSMO parameters can be tuned by try and error (**G must be less than F**).

SMO\_Kslf is the filter coefficient of the sliding mode current observer when estimating the rotor position , This parameter is linear with the electrical frequency of the motor , also indirectly affects the phase relationship between the actual rotor position and the estimated rotor position .

When the motor runs to the rated power , if the current diverges abnormally, it will cause shutdown protection , SMO\_Kslf parameters can be tuned by try and error .

Kslide is SMO linear gain , SMO\_Gain is the actual gain value of the internal mathematical model , its formula is:

$$SMO\_Gain = Kslide/MaxSmcError$$

## 1.2 MOC and hardware parameter configuration

### ■ Configuration file : Pwm.h <Configuration Wizard>

#### ■ Set MPWMDATA

Parameter	Value range/option	Description	Default value	Unit
Set PWM Frequency	12000~40000(multiple of 10)	Carrier frequency	27000	Hz

#### ■ Set MPWMDDB

Parameter	Value range/option	Description	Default value	Unit
Set Deadband Time	1us/1.5us/2us/3us/4us/5us	Set dead-time	1.5us	--

Suggestions for adjusting direction :

PWM output frequency :

The higher the PWM frequency setting , although it will increase the switching loss of the MOSFET and the heat of the motor , affecting the system efficiency , but it can effectively suppress the current/power/speed ripple, vibration and noise when the motor is running in high-speed applications , and improve the overall performance of the system . And the frequency setting is low, it is easy for the human ear to hear (below 16K) , the maximum speed of the motor can be increased , It is recommended that a motor with a small inductance value should be set to a higher carrier frequency .

Set dead-zone :

Determine the required dead zone range according to the measured output waveform of the upper and lower arms , excessive dead zone will affect the speed characteristics of the motor , may not increase to rated top speed.

### ■ Configuration file : Motor.h <Configuration Wizard>

#### ■ Set Rshunt and OPA Gain

Parameter	Value range/option	Description	Default value	Unit
Rshunt	--	Set the sampling phase resistance value	1000	0.1mR
OPA GAIN	1 Gain /2.5 Gain /5 Gain /10 Gain	Internal OPA Gain	5 Gain	--

Suggestions for adjusting direction :

Sensorless Series Internal OPA Gain have 1 、 2.5 、 5 、 10 four Amplification Gain Values to Choose , the matching principle depends on the current sampling resolution and the rated phase current of the motor .

**ShuntR \* motor maximum current (I\_Peak) < 0.5V**

Both ends of the differential will be limited to less than 0.5V because the maximum voltage across the internal OPA is 0.5V.

**OPA Gain \* ShuntR \* motor maximum current (I\_Peak) < 2.5V**

The 2.5V is limited because the internal A/D is offset by 2.5V .

Phase current has positive/negative, 0~2.5V is negative current, 2.5V~5V is positive current.

Suggestions for Sampling Resistor Selection :

The recommended maximum value of the general current sampling A/D corresponds to twice the motor I\_peak(max), for example :

DC24 V motor , Phase current at maximum rated speed I\_peak = 2.7A , choose 3A , then sample twice the maximum current to 6A . R\_Shunt = 2.5V / Gain / 6A , Gain choose 5 first , then Rshunt = 83mR , take 0.1R for use .



The larger the resistance value of the sampling resistor, the higher the sampling accuracy. However, the temperature rise caused by the power dissipation of the sense resistor also needs to be considered. In the case of ensuring that the temperature rise of the resistance meets the requirements, the resistance value should be increased as much as possible.

■ **Configuration file : Pwm.h <Configuration Wizard>**

■ **Gate driver output mode**

Parameter	Value range/option	Description	Default value
Set MPWM SWAP	MDRFD0	Gate Driver output mode	MDRFD0

Suggestions for adjusting direction :

When use MDRFD0 (MCM : built-in N/N-type Gate-Driver , need external MOSFET) , select " MDRFD0 " . ( **Note: This option must not be selected wrongly, otherwise it may cause MOSFET damage** )

■ **Configuration file : Moc.h <Configuration Wizard>**

■ **Space Vector Pulse Width Modulation (SVPWM) configuration**

■ **Set MOTOR\_CONT2**

Parameter	Value range/option	Description	Default value
SVPWMMODE	7-SVPWM 5-SVPWM	SVPWM mode	<b>5-SVPWM</b>

Suggestions for adjusting direction :

(a). When product or system prioritizes efficiency , optional " **5-SVPWM** " , then SVPWM will switch the output in 5 segments , reduce MOSFET switching loss and heat generation , conversely, when the product or system takes silence, vibration and interference as the appeal and key indicators , optional " **7-SVPWM** " .

### 1.3 Protection parameter configuration

- Configuration file : Motor.h <Configuration Wizard>
- **Protection / Error status identification (ErrorStatus)**
- **Error code(MotorErrorState)**


Error code(MotorErrorState)
<b>Error code (MotorErrorState)</b>
Clear = 0x00 (no error)
OverVbus = 0x01 (OV)
UnderVbus = 0x02 (UV)
OverTemperature = 0x04 (OT)
FaultLock = 0x08 (block)
AOCP = 0x10 (OC)
POCP = 0x20 (Abnormal phase current)
LackPhase = 0x40 (Static phase loss)
LackPhaseRun = 0x80 (Dynamic phase loss)

Suggestions for adjusting direction :

When the system stops abnormally or fails to start , protection status flag can be used , it is known that currently Error\_Code output code name , determine the protection status of the system . Available in main.c file (line 182) , look for if(UartFlag == 1) this judgment , below line 187 the Debug\_(A~F) any parameter make it equal to " **MotorErrorState** " this variable , the example is as follows :

```
if(UartFlag == 1){  
    SFR_PAGE = 0; Debug_A = eprom_data;  
    SFR_PAGE = 0; Debug_B = PI_OUT;  
    SFR_PAGE = 1; Debug_C = PI_OUT;  
    SFR_PAGE = 2; Debug_D = PI_OUT;  
    SFR_PAGE = 2; Debug_E = PI_UI;  
    SFR_PAGE = 3; Debug_F = MotorErrorState;  
  
    Uart_Package_Build();  
    UartFlag = 0;  
}
```

Add this variable

In UartSystem.h <Configuration Wizard> UART function Enable , and open "  DataLogger.exe " software can monitor this variable .

### Configuration file : Motor.h <Configuration Wizard>

- Set motor protection function
- Overvoltage/Undervoltage protection (OVP/UVLP) (✓)

Parameter	Value range/option	Description	Default value	Unit
Set Vbus A/D Channel	CH0~CH7	Sampling V-bus voltage A/D channel	CH2	--
Set Vbus rate parameter	0~65535	Sampling V-bus voltage calibration parameters = (Vbus_avg / Input voltage)*1000	2160	--
OVP Values	0~4000	Overvoltage value	3800	0.1V
OVP recovery Values	0~4000	Overvoltage recovery value	3750	0.1V
UVP recovery Values	0~4000	Undervoltage recovery value	1450	0.1V
UVP Values	0~4000	Undervoltage value	1400	0.1V
BUS_VOLT_DURATION	10~30000	OVP/UVLP judgment cycle	50	ms

Suggestions for adjusting direction :

#### Vbus rate parameter :

Confirm the sampling Vbus AD channel first , and fill in V\_BUS\_CH , later " Vbus\_avg " this variable put UART Debug monitor (as above) . Divide the obtained Vbus\_avg by the current input voltage after power-on , multiplied by 1000, the value obtained is the **Vbus rate parameter** , the example is as follows :

Suppose the working voltage is DC 310V , the resulting Vbus\_avg is 670 · 670 / 310 = 2.16

2.16 \* 1000 = 2160 · **Vbus rate parameter** = 2160

#### OVP /UVLP setting :

Set the required overvoltage protection value and undervoltage protection value , fill in separately **OVP Values** 、 **UVP Values** parameter , overvoltage recovery value and undervoltage recovery value , fill in separately **OVP recovery Values** 、 **UVP recovery Values** .

**BUS\_VOLT\_DURATION** the parameter is judged OVP/LVP total cycle , the number of judgments is judged every 10ms .

- Locked-rotor protection (LRP) (✓)

Parameter	Value range/option	Description	Default value	Unit
Motor speed abnormally high value	--	Abnormally high value of motor speed	13000	10rpm
Motor speed abnormally low value	--	Abnormally low value of motor speed	600	10rpm
LRP DURATION	10~30000	Motor blocked judgment cycle	500	ms

Suggestions for adjusting direction :

#### LRP setting :

According to the highest/lowest rated speed of the motor , add or subtract a value , to judge that the motor is blocked . Higher than **Motor speed abnormally high value** is over speed protection , lower than **Motor speed abnormally low value** is under speed protection .

**LRP judgment cycle** parameter is the cycle of judging LRP , it is recommended not to set too small to avoid misjudgment .

#### ■ Over temperature protection (OTP) (✓)

Parameter	Value range/option	Description	Default value	Unit
Set OTP A/D Channel	CH0~CH7	Sampling OTP A/D channel	CH5	--
OTP A/D Values	0~1023	Overheating A/D value	670	--
OTP recovery A/D Values	0~1023	Over temperature recovery A/D value	620	--
OVER_TEMPERTURE_LOAD_REDUCE_VALUE	0~1023	Over temperature derating A/D value	670	
TEMPERTURE_DURATION	10-30000	OTP judgment cycle	500	ms

Suggestions for adjusting direction :

#### OTP setting :

Confirm the OTP AD channel first , and fill in **Set OTP A/D Channel** .

**OTP A/D Values** : is the A/D value of over-temperature protection

**OTP recovery A/D Values** : is the A/D value to clear the over-temperature protection

**OVER\_TEMPERTURE\_LOAD\_REDUCE\_VALUE** : Exceeding this A/D value starts load shedding (reducing MOSFET loss)

If you can know the R/T table of NTC, you can directly use the partial pressure formula to make calculations.

**TEMPERTURE\_DURATION** parameter is the total period for judging OTP , judged every 10ms.

Generally, the NTC is placed near the mos , sed to detect relative temperature near mos (unless used otherwise) , which confirms the A/D value. The motor can be overloaded first , actual use of K-type to measure mos surface temperature. When the mos surface temperature reaches the position where OTP protection should be jumped , detect the A/D value read by NTC and fill in the parameters.

#### ■ Heat\_Temperture\_Protect Enable/Disable (✓)

Parameter	Value range/option	Description	Default value	Unit
Set Heat Temperture A/D Channel	CH0~CH7	Sampling heater temperature A/D channel	CH3	--
OVER_HEAT_TEMPERTURE A/D Values	0~1023	Heater over temperature A/D value	150	--
HEAT_TEMPERTURE_OPEN_CIRCUIT A/D Values	0~1023	Heater open circuit A/D value	1000	--
HEAT_TEMPERTURE_DURATION	10-30000	OTP judgment cycle	500	ms



Suggestions for adjusting direction :

#### Heat Temperature setting :

Confirm the AD channel first , and fill in **Set Heat Temperture A/D Channel** .

**OVER\_HEAT\_TEMPERTURE A/D Values** : This value is the A/D value for judging the overheating of the heater , **lower** <sup>\*1</sup> is considered overheating .

**HEAT\_TEMPERTURE\_OPEN\_CIRCUIT A/D Values** : When the A/D value **over** <sup>\*1</sup> this value, it is considered that the heater is disconnected or faulty .

\*1 : When the NTC divider is to ground, if the divider is to Vcc . Then it is necessary to go to the subroutine of the code to judge the overtemperature, and exchange the signs of greater than and less than.

#### ■ MotorLackPhase\_Fun Enable/Disable (✓)

Parameter	Value range/option	Description	Default value	Unit
MotorLackPhase_SOP	LEVEL1/ LEVEL2	Step for judging static phase loss	Level2	--
Set Vq Detection Value	0~4000	Set the amount of given Vq	2000	--
Set abs(IaFb) Detection Value	0~1000	IaFb value judged as static phase loss	25	mA
Set abs(IbFb) Detection Value	0~1000	IbFb value judged as static phase loss	25	mA
LackPhase_Duration	10~30000	Static phase loss judgment cycle	500	mS

Suggestions for adjusting direction :

#### MotorLackPhase setting :

This protection is used to set the state of judging whether the three-phase line of the motor is open-phase (broken) when the motor is stationary.

Set MotorLackPhase\_SOP to Level1first , and add IaFb , IbFb parameters to Uart observation , and record the value change when any phase line is removed . Assuming that there is no phase loss, the IaFb and IbFb of the motor at rest are both 500 . When any phase wire is removed, IaFa/IaFb drops to 110 , at this time, it can be estimated that when IaFb/IbFb is lower than 160 , judged as static phase loss. Convert its value to current value **Set abs(IaFb) Detection Value & Set abs(IbFb) Detection Value** , the formula is as follows:

**Set abs(IaFb) Detection Value = (Static phase loss value (IaFb) / I\_AMPLIFIER) \* 1000**

**Set abs(IbFb) Detection Value = (Static phase loss value (IbFb) / I\_AMPLIFIER) \* 1000**

**I\_AMPLIFIER = (((R\_SHUNT \* OPA\_GAIN \* 1023))/5)\*64**

Suppose R\_SHUNT = 0.1 ; OPA\_GAIN = 5 ; then **I\_AMPLIFIER = (0.1\*5\*1023)/5\*64 = 6,547.2**

**Set abs(IaFb) Detection Value = (160 / 6547.2) \* 1000 = 24.4 , integer 25**

**Set abs(IbFb) Detection Value = (160 / 6547.2) \* 1000 = 24.4 , integer 25**

**Vq Detection Value** : Used to adjust the feedback current when judging static phase loss , it is found that when the current variation of the missing phase is not large, can moderately increase the amount of Vq .

**LackPhase\_Duration** : Judging the total period of static phase loss , increasing this parameter can avoid misjudgment of phase loss caused by noise .

After the above parameters are adjusted, please set MotorLackPhase\_SOP to Level2 .

## ■ MotorLackPhase\_Run\_Fun Enable/Disable (✓)

Parameter	Value range/option	Description	Default value	Unit
Set abs(IaFb) Detection Value	0~1000	IaFb value judged as dynamic phase loss	50	mA
Set abs(IbFb) Detection Value	0~1000	IbFb value judged as dynamic phase loss	50	mA
Set abs(IaFb-IbFb) Detection Value	0~1000	IaFb-IbFb value judged as dynamic phase loss	100	mA
LackPhase_Run_Duration	10~30000	Dynamic phase loss judgment cycle	100	ms

Suggestions for adjusting direction :

### MotorLackPhase Run setting :

This protection is used to set the motor run state , judging whether the three-phase line of the motor has a phase loss (disconnected) state .

The parameter setting method is the same as judging static phase loss , put IaFb, IbFb, and IcFb into Uart for observation first , and record the current value when the motor is running . The phase lines corresponding to sampling Ia and Ib can be disconnected first , for example, the phase line of sampling Ia is U phase, then the U phase line can be disconnected during motor operation . Observe the change of current value in Uart , conversely, Ib and Ic are also (Ic is the phase line without sampling resistor) . When Ic is disconnected, Ia and Ib will differ by 180 degrees due to the different current directions , abs(Ia-Ib) is close to 0 .

For the parameter value judged as dynamic phase loss, its value is converted into the current value and filled in. The formula is as follows:

**Set abs(IaFb) Detection Value** = (Dynamic phase loss value (IaFb) / I\_AMPLIFIER) \* 1000

**Set abs(IbFb) Detection Value** = (Dynamic phase loss value (IbFb) / I\_AMPLIFIER) \* 1000

**Set abs(IaFb-IbFb) Detection Value** = (Dynamic phase loss value (IaFb -IbFb) / I\_AMPLIFIER) \* 1000

**I\_AMPLIFIER** = (((R\_SHUNT \* OPA\_GAIN \* 1023))/5)\*64

**LackPhase\_Run\_Duration** : Judging the total period of dynamic phase loss, increasing this parameter can avoid misjudgment of phase loss caused by noise °

## ■ Phase current protection (✓)

Reserved; pending verification of necessity

- Phase Ia 、 Ib 、 Ic parameter (unit : mA) (700)
- PHASE\_OCP\_DURATION parameter (unit : ms) (50)

Suggestions for adjusting direction :

(a). Abnormal phase current protection , the three-phase current is greater than the set **Phase Ia & Ib & Ic parameter** considered abnormal current protection , Set the direction to place IaFb, IbFb on UART for observation . Record the average value when the motor is running at the rated speed, and fill in this parameter by about 1 times.

(b). **PHASE\_OCP\_DURATION parameter** : Judgment phase current delay time

- **Set Protection to retry**
  - AOC\_Pretry\_Enable (✓)
  - POCP\_Retry\_Enable (✓)
  - FaultLock\_Retry\_Enable (✓)
  - MotorLackPhase\_Retry\_Enable(✓)
  - MotorLackPhase\_Run\_Retry\_ENABLE (✓)

Parameter	Value range/option	Description	Default value	Unit
Set the number of retries	0~255	Number of restarts after error	10	times
Set retry delay time	0~32767	restart delay time	3000	ms

Suggestions for adjusting direction :

After the corresponding protection function Retry Enable is triggered , then when the protection occurs, it will automatically restart, otherwise, it needs to be powered off again .

**Set the number of retries :** It is the number of restarts of the motor when an error occurs. Once this value is exceeded, it needs to be powered off and restarted.

**Set retry delay time :** It is the delay time between restart after an error occurs.

- **Configuration file : Ocp.h <Configuration Wizard>**
- **Hardware over-current protection setting**
- **Set AOCPCONT**

Parameter	Value range/option	Description	Default value
I_SHORT	0.15V/0.2V/0.25V/0.3V/0.35V/0.4V/0.45V/0.5V	Overcurrent reference voltage	0.3V
AOCPEN	Enable/Disable	Analog overcurrent function	Enable
DOCPEN	Enable/Disable	Digital overcurrent function	Disable

Suggestions for adjusting direction :

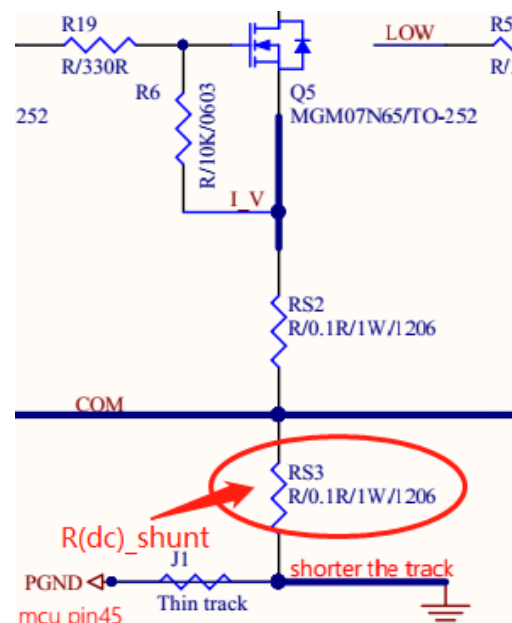
MDRFD0 provide 8 channel of equivalent overcurrent voltage gears for configuration , the calculation of the bus current

protection point is :  $I\_SHORT = I_{ocp} * R(dc\_shunt)$

AOCPEN is analog input for OCP · DOCPEN is digital input for OCP . If the plug-in Driver is IPM, generally is set DOCPEN , otherwise is set AOCPEN.

#### OCP setting :

The overcurrent value is set at about **1.5 to 2 times the maximum motor current (I\_Peak)**.



## 2. Hair dryer parameter adjustment process

### 2.1 Start parameter adjustment

#### Step1. Alignment start

- Configuration file : Motor.h <Configuration Wizard>
- Set the motor tuning process

Parameter	Value range/option	Description	Default value	Unit
Set IQ parking duration	1-32767	IQ positioning duration	10	ms

- Set FOC LOOP Parameter
  - IQ
    - ✓ Set IQ Current parameter

Parameter	Value range/option	Description	Default value	Unit
Set IQ Initial current	--	IQ initial current	0	mA
Set IQ Starting current	--	IQ start current	440	mA

Suggestions for adjusting direction :

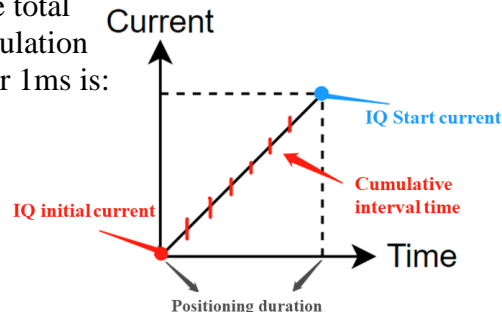
If the load inertia is large, the starting current or torque during startup needs to be larger. Appropriately adjust according to the size of the load, which can effectively complete the start, reduce the vibration and reverse probability . Moderately increasing the time can increase the startup failure rate .

The acceleration slope and time of the bit current are described as follows:

As shown in the figure on the right, the positioning duration is the total time from the initial current to the starting current, and the accumulation interval time is Timer0 time (1ms), so the accumulated current per 1ms is:

$(\text{IQ start current} - \text{IQ initial current}) / \text{positioning duration}$

**positioning duration** minimum is 1ms , If positioning is not required, the initial current = start current .



#### Step2. Position open loop operation(Open loop)

- Configuration file : Motor.h <Configuration Wizard>
- Set the motor tuning process

Parameter	Value range/option	Description	Default value	Unit
FOC_Control_Stage	Standby/ OpenLoop/ CloseLoop	FOC control Stage	CloseLoop	--
Set SMO_RAMP acceleration slope	1~32767	PLL accumulation slope	1	ms
Set PLL accumulation	1~100	PLL accumulation	2	--
Set SMO_PLL initial speed	--	PLL initial speed	1	10rpm
Set SMO_PLL end speed	--	PLL end speed	300	10rpm

Suggestions for adjusting direction :

#### FOC Control Stage :

OpenLoop : During open loop, it is current closed loop and position open loop . When adjusting for open loop at the initial stage of adjustment, it is recommended to first adjust **FOC\_Control\_Stage** to **OpenLoop** . In this way, the motor will only run in an open loop state , when an irreversible phenomenon occurs during the operation of the motor . **FOC\_Control\_Stage** can also be used to analyze the problem of open loop or closed loop.

CloseLoop : Optional speed outer ring , or power outer ring .

#### PLL :

The reduction of **SMO\_RAMP** can effectively improve the convergence speed of the position observer and reduce the open-loop startup time . But if it is too small, it may cause the startup too fast to fail . It should be noted that this variable value also includes the PLL acceleration slope under the downwind or headwind. The open-loop acceleration slope and time description are as follows:

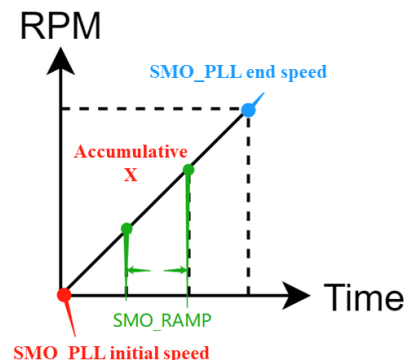
As shown on the right , it is the slope from the initial speed of SMO\_PLL to the end speed of SMO\_PLL

Every SMO\_RAMP time to accumulate a PLL amount (for the accumulation number X in the figure)

Therefore, **the total time of PLL open loop is calculated as:**

$$[(\text{SMO\_PLL end speed} - \text{SMO\_PLL initial speed}) / (\text{PLL accumulation} / \text{POLE PAIRS})] * \text{SMO\_RAMP}$$

Example :  $[(30-5)/(1/7)] * 15\text{ms} = 2625\text{ms}$



### Step3. Open loop to closed loop

- **Configuration file : Motor.h <Configuration Wizard>**
- **Set the motor tuning process**

Parameter	Value range/option	Description	Default value	Unit
<del>Set SMO_DELAY Delay time</del>	<del>1-32767</del>	<del>Open loop into closed loop delay time</del>	<del>10</del>	<del>ms</del>

~~SMO\_DELAY is the delay time for the inner loop to prepare to enter the closed loop, and this parameter can be adjusted appropriately.~~ Parameters are reserved and not used for now.

- **Set FOC LOOP Parameter**
  - **IQ>**
    - ✓ **Set IQ Current parameter**

Parameter	Value range/option	Description	Default value	Unit
Set IQ End current	--	Initial value of closed loop current	450	mA

Suggestions for adjusting direction :

The current after the end of the open loop is the IQ end current , after this value enters the closed loop, it will be directly filled in the integral value and output value of the closed loop . When the position open loop (current closed loop) cuts into the closed loop, since the integrator of the initial outer loop PI controller is zero . In order to avoid the abnormal ripple of the speed during the connection process, it is necessary to provide an initial value for the integrator of the outer loop PI controller.

## Step5. Closed loop operation (Close loop)

- Configuration file : Motor.h <Configuration Wizard>
- Set motor control program
  - Set the main control loop
    - ✓ Phase Current control
    - ✓ Speed control
    - ✓ Power limit
    - ✓ Power control

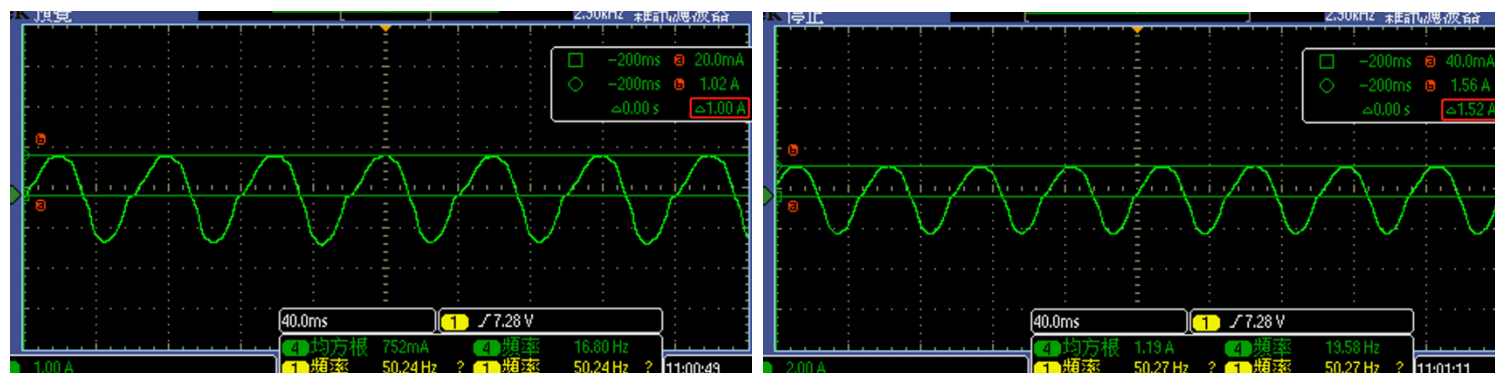
There are three control modes in the closed-loop control, which are **Phase Current control** & **Speed control** & **Power control**, described below.

### Phase Current control

Parameter	Value range/option	Description	Default value	Unit
Set the rated output phase current (max)	0~30000	output phase current rated value (max)	540	mA
Set PHASE CURRENT_RAMP slope	1~32767	Phase current control cycle	20	ms
Set PHASE CURRENT_CMD accelerate RAMP	0~32767	Accumulated amount of phase current	5	--
Set PHASE CURRENT_CMD decelerate RAMP	0~32767	Decelerate of phase current	10	--

Suggestions for adjusting direction :

Fill in the setting value according to the maximum rated phase current of the motor. The current controlled here is the peak value of the phase current, as shown in the figure below:



Set the rated output phase current (max) = 1A

Set the rated output phase current (max) = 1.5A

The current control slope can be adjusted according to **CURRENT\_RAMP** & **CURRENT\_CMD accelerate RAMP** & **CURRENT\_CMD decelerate RAMP**. Direction is every **CURRENT\_RAMP** time, to add or subtract the amount of **CURRENT\_CMD**. The conversion formula of accumulated subtracted phase current and actual accumulated/subtracted phase current is:

Actual accumulative or subtractive phase current = (Accumulation or decrement phase current) / [(R\_SHUNT \* OPA\_GAIN) \* (1023/5) \* 64]

### Speed control

Parameter	Value range/option	Description	Default value	Unit
Set the rated output speed (max)	0~(32767/ Motor Pole/2)	rated speed (max)	10500	10rpm
Set SPEED_RAMP slope	1~32767	speed control cycle	20	ms
Set SPEED_CMD accelerate RAMP	0~32767	accumulated speed	15	--
Set SPEED_CMD decelerate RAMP	0~32767	decrement speed	5	--

Suggestions for adjusting direction :

Fill in the setting value according to the maximum rated speed of the motor, it is recommended to reserve some margin . The maximum speed command control can be set by **Set the rated output speed (max)**.

The speed control slope can be adjusted according to **SPEED\_RAMP & SPEED\_CMD accelerate RAMP & SPEED\_CMD decelerate RAMP** . Direction is every **SPEED\_RAMP** time , to add or subtract the amount of **SPEED\_CMD** . The addition and subtraction here are divided by Pole pairs to get rpm.

The maximum output value of the internal angular velocity is 32767 . So fill in the upper limit of the maximum value of the rated speed is 32767 divide by number of pole pairs . If the rated speed of the motor exceeds this upper limit, please go to **Pwm.h <Configuration Wizard>** . Fill in the parameter of Set Base Angular Velocity = rated maximum speed \* Pole Pairs.

### Power control

Parameter	Value range/option	Description	Default value	Unit
Set the rated output power (max)	0~10000	rated power (max)	1800	0.01W
Set power magnification parameters	--	power correction value	100	--
Set I_BUS A/D Channel	CH0~CH7	Sampling Ibus A/Dchannel	CH2	--
POWER_SOP	LEVEL1/LEVEL2		LEVEL2	

Suggestions for adjusting direction :

Fill in the set value according to the rated power of the motor . The power command control of the motor can be set by Set the rated output power (max).

If there is a gap between the actual power value and the filled power output , you can use the power correction value to make fine adjustments . If the actual power is smaller than the target power, increase the correction value, and vice versa . In the initial adjustment, you can first set POWER\_SOP to LEVEL1 to confirm the accuracy of the power.



## 2.2 Peripheral Control Function

### VSP speed control

#### ■ Configuration file : Motor.h <Configuration Wizard>

- Set motor control program
  - ✓ Set Peripheral Control
    - VSP control commands Enable/Disable (✓)

Parameter	Value range/option	Description	Default value	Unit
Set VSP_CH	CH0~CH7	VSP A/D	CH7	--

- ✓ VSP\_CH\_Inver Enable/Disable  
Reverse A/D input value function

- ✓ Vsp\_LookUpTable Enable/Disable

Suggestions for adjusting direction :

VSP external control function , first confirm the A/D Channel of VSP , and fill in VSP\_CH .

Check the **Vsp\_LookUpTable Enable/Disable** function , and open **LookupTable.h<Configuration Wizard>**

Parameter	Value range/option	Description	Default value	Unit
Output : LookupTable_Data[1] (unit : Iq_Cmd, SPd_Cmd)	0~32767	Current / speed output value 1	600	--
Output : LookupTable_Data[2] (unit : Iq_Cmd, SPd_Cmd)	0~32767	Current / speed output value 2	700	--

It by analogy .

Parameter	Value range/option	Description	Default value	Unit
Input : Vsp_Data[1] (unit : Vsp_Val)	0~1023	VSP1 input value	204	--
Input : Vsp_Data[2] (unit : Vsp_Val)	0~1023	VSP2 input value	350	--

It by analogy

Applied as , the VSP input of each gear corresponds to the output value of the gear. For example, when  $Vsp\_avg \geq VSP1$  input value, the value of Out1 will be output at this time, VSP2 corresponds to Out2, and so on . The input value setting of VSP can put Vsp\_avg into Uart to observe this parameter . The output value depends on whether it is current control or speed control. If it is current control, the conversion formula corresponding to the output corresponding to the actual phase current is:

**Output value parameter = Actual phase current (mA)/1000 \* I\_AMPLIFIER**

If it is speed control, the conversion formula corresponding to the output to the actual speed is:

**Output value parameter = Actual speed (rpm)/10**

For example, if you want to output a peak phase current of 100mA when VSP1=204, then Output1 =  $100/1000 * 6547.2 = 654.72$ .

For example, if you want to output a speed of 6000rpm when VSP1=204, then Output1 =  $6000/10 = 600$ .



## Switching speed control

### ■ Configuration file : Application.h <Configuration Wizard>

#### ● Set the switch speed value

Parameter	Value range/option	Description	Default value	Unit
Speed_Lever_1	0~(32767/ Motor Pole/2)	switch speed gear 1	8500	10rpm
Speed_Lever_2	0~(32767/ Motor Pole/2)	switch speed gear 2	10500	10rpm

#### ● Define GPIOs

Parameter	Value range/option	Description	Default value	Unit
SPEED_ZC_PIN	P0_4/P0_5/P0_6 /P0_7 /P3_2/P3_3/P3_4/P3_5	Switch speed input pin setting	P3_3	--

Suggestions for adjusting direction :

First set SPEED\_ZC\_PIN as the pin of Switch input , speed\_Level1/2 is the gear speed value of the switch.

## Heat control

### ■ Configuration file : Application.h <Configuration Wizard>

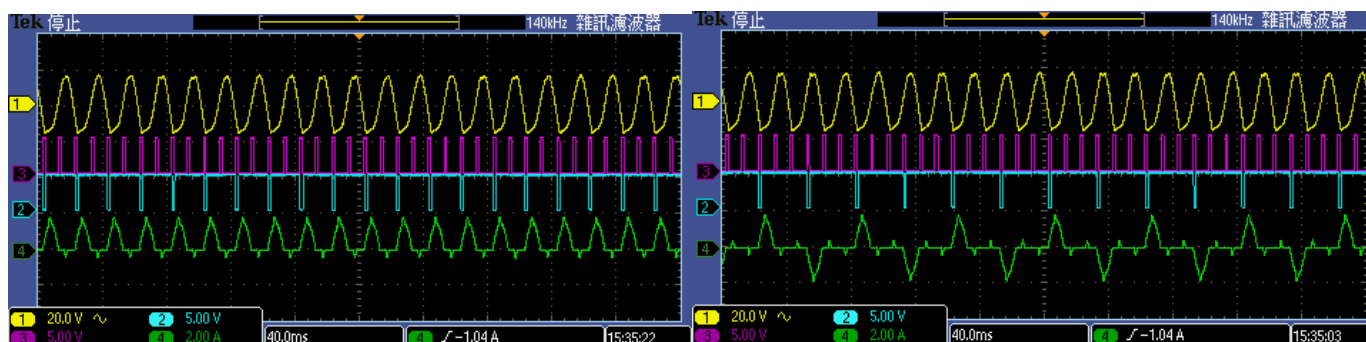
#### ● Set the HEAT value

Parameter	Value range/option	Description	Default value	Unit
Heat_Level_1	0~1023	Heating temperature gear 1	500	--
Heat_Period_1	2~20	Turn-on cycle times	3	--
Heat_Sin_Period_1	1~5	Turn-on times	1	
Heat_Level_2	0~1023	Heating temperature gear 2	200	--
Heat_Period_2	2~20	Turn-on cycle times	2	--
Heat_Sin_Period_2	1~5	Turn-on times	1	
Heat_Level_Error	0~1023	Heating temperature gear 2	150	
Heat_Period_Max	2~20	Higher limit number of turn-on cycle	12	
Heat_Period_Min	2~20	Lower limit number of turn-on cycle	2	

#### ● Define GPIOs

Parameter	Value range/option	Description	Default value	Unit
HEAT_PIN	P0_4/P0_5/P0_6 /P0_7 /P3_2/P3_3/P3_4/P3_5	Heat output pin setting	P3_4	--
HEAT_SW_PIN	P0_4/P0_5/P0_6 /P0_7 /P3_2/P3_3/P3_4/P3_5	Heat switch input pin setting	P3_5	--
ZERO_PIN	P0_4/P0_5/P0_6 /P0_7 /P3_2/P3_3/P3_4/P3_5	AC zero detection input pin setting	P3_2	--

Suggestions for adjusting direction :



## 2.3 Tailwind/headwind start parameter adjustment

- Configuration file : Motor.h <Configuration Wizard>
- Set Fairwind and Headwind judgment function
  - BEMF Fairwind/Headwind judgment (resistance) Enable/Disable (✓)
  - BEMF Fairwind/Headwind judgment (Diode) Enable/Disable(✓)
  - BEMF TailWind Fun (One BEMF) Enable/Disable(✓)

Suggestions for adjusting direction :

The hair dryer platform will not be used for the time being.

## 2.4 Protection parameter adjustment

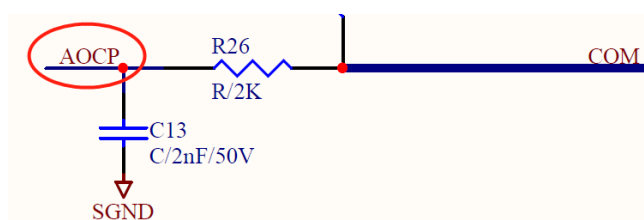
- Configuration file : Motor.h <Configuration Wizard>
- Set motor protection function
- Over/under voltage protection
  - The parameter configuration is shown in section 1.3 (protection parameter configuration)

Suggestions for adjusting direction :

1. Set according to the overvoltage, undervoltage and recovery voltage conditions provided by the customer.
  2. Overvoltage and recovery test : After starting the hair dryer, increase the voltage of the power supply to the overvoltage level . Confirm whether the hair dryer enters shutdown protection. The voltage of the power supply is then reduced to the overvoltage recovery level , determine whether the hair dryer is running normally .
  3. Undervoltage and recovery test : After starting the hair dryer, increase the voltage of the power supply to the undervoltage level . Confirm whether the hair dryer enters shutdown protection. Then raise the voltage of the power supply to the undervoltage recovery level , determine whether the hair dryer is running normally .
- **Overcurrent protection - hardware test (key test)**
    - The parameter configuration is shown in section 1.3 (protection parameter configuration)

Adjust the verification direction :

1. Verify hardware . Short-circuit the AOCP point and 5V first , the motor can be unconnected. Use UART to monitor whether there is OCP occurs. After confirming that there is no problem, do the following short circuit test.
2. After starting the hair dryer, short-circuit the two-phase (UV or UW or VW) output at will. Judgment whether the hair dryer enters shutdown protection. Then turn on the power again to confirm whether the fan can work normally. And repeat this step several times to ensure that the MOSFET is adequately protected.
3. If the hair dryer cannot be restarted after the short circuit test , check that the specifications of the MOSFET meet or not , whether the AOCP feedback signal has interference on the wiring path , the time constant of the AOCP feedback signal is too long (time constant:  $RC \leq 2k * 2nf = 4us$ ).



## ■ Motor blocked protection

- The parameter configuration is shown in section 1.3 (protection parameter configuration)

Suggestions for adjusting direction :

Can use hands to hold the fan blades to confirm that the air duct enters the out-of-step/high-frequency state, and whether the blocked protection works normally.

## 2.5 Other parameter configuration

### ■ Configuration file : Motor.h <Configuration Wizard>

#### ■ Set motor control program

- Set other functions

Parameter	Value range/option	Description	Default value	Unit
Set CW/CCW steering	CW/CCW	Steering direction setting	CW	--
Set Stop_Fun stop speed	--	PWM stop output	400	10rpm

Suggestions for adjusting direction :

Set CW/CCW steering is modified according to the desired blade orientation

Stop\_Fun the stop speed here refers to when the remote control presses the stop button and the motor speed is lower than this parameter , PWM will stop output . When the speed value is higher than this parameter, PWM is still out put. This is set for a smooth connection with the wind. Its value can be set at the connection point where the tailwind speed cannot be judged at low speed.

✓ IPD Enable/Disable(✓)

Suggestions for adjusting direction :

This IPD function needs to be adjusted with the configuration file IPD.h <Configuration Wizard> .

### ■ Configuration file : IPD.h <Configuration Wizard>

#### ■ Set IPD LEVEL

Parameter	Value range/option	Description	Default value	Unit
I_SHORT	0.15V/0.2V/0.25V 0.3V/0.35V/0.4V 0.45V/0.5V	IPD OCP LEVEL	0.15V	--
AOCPEN	Disable/Enable	Analog OCP function	Enable	--
DOCPEN	Disable/Enable	Digital OCP function	Disable	--
IPD Path Select	IPD Current Compare from AOC Path IPD Current Compare from OPA Path	IPD OCP judgment path	AOC Path	--

#### ■ Set IPD IAECYC

Parameter	Value range/option	Description	Default value	Unit
IAECYC	48MHz/24MHz/12MHz/6MHz	IPD Counter Frequency	24MHz	--

Suggestions for adjusting direction :

The sound produced by IPD is proportional to I\_SHORT. If it is set to 0.15V, the sound is still loud, and the resistance of Shunt R can only be increased (pay attention to the wattage of the resistance).

AOCPEN 、DOCPEN 、IPD Path Select : not to change recommended.

IAECYC : This parameter is an important parameter of IPD . Used to count the OCP dt value, the IPD performed by the steering at different positions, take the minimum Counter as the Pattern of the position . The maximum value of its Counter is 65535, according to the measured OCP dt width. Know the required

IAECYC, the maximum dt width that can be determined by different IAECYC is calculated as follows:

$48\text{MHz} : (1/48\text{MHz}) * 65535 \approx 1.3\text{ms}$   
 $24\text{MHz} : (1/24\text{MHz}) * 65535 \approx 2.6\text{ms}$   
 $12\text{MHz} : (1/12\text{MHz}) * 65535 \approx 5.2\text{ms}$   
 $6\text{MHz} : (1/6\text{MHz}) * 65535 \approx 10.4\text{ms}$

The picture on the right as an example, the yellow waveform is the OCP signal, the dt is 2.95ms. Assuming that IAECYC selects 48MHz or 24MHz at this time, because dt is higher than the maximum value of Counter and overflow . You will find that the motor will still reverse when the motor is started , so only dt is only suitable for choosing 12MHz.



✓ **Brake control**  
**Enable/Disable(✓)**

Parameter	Value range/option	Description	Default value	Unit
Set braking force	0~100	Brake Duty	10	%

Suggestions for adjusting direction :

Braking force, it is used by Diode structure or internal estimator against the wind, not used for the time being

## 3. Program structure

### 3.1 Program flow

#### ■ Configuration file : main.c

##### ■ Main Function

- System initialization settings
- while(1){
  - ✓ WatchDog\_Refresh (); // update watchdog
  - ✓ Heat\_Control (); // heater control
  - ✓ Judgment of zero-crossing point of idle start voltage and estimation of speed
- }

#### ■ Configuration file : Interrupt.c

##### ■ Timer 0 ISR(Time Based : 1ms)

- Motor\_Control(); // Motor error judgment, forward and reverse control, motor start
- MotorLackPhase\_Run\_Fun() // Phase loss judgment during motor operation
- UART output data

##### ■ Timer 1 ISR(Time Based : 10ms)

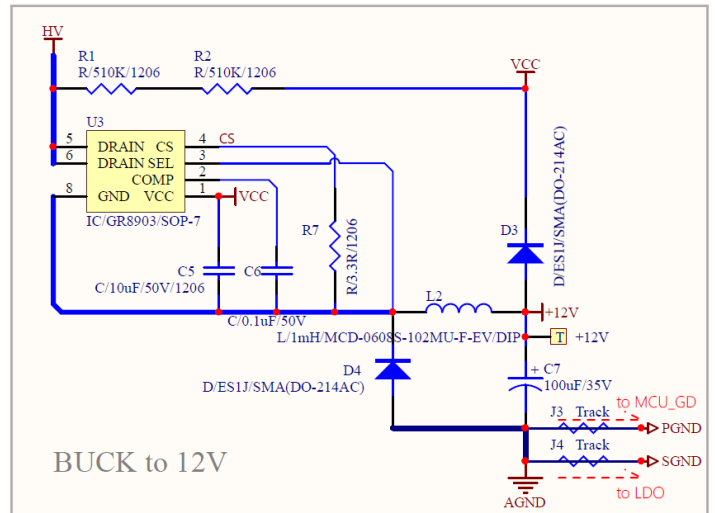
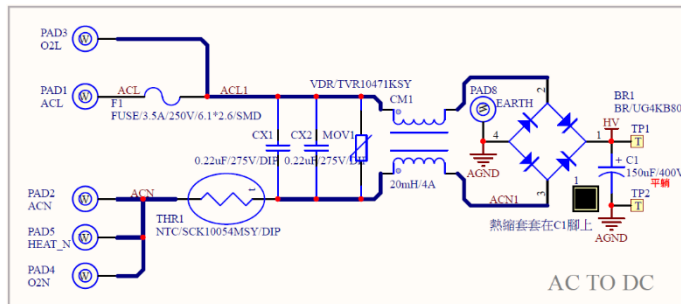
- Vsp\_Fun(); //External VSP command reception
- FaultLock\_Fun (); //System stall, over/low speed protection
- Vbus\_Protect\_Fun (Vbus\_avg); //V-bus voltage detection and protection judgment
- Temperture\_Protect\_Fun (Temperture\_avg); //System over temperature protection
- Phase\_OCP\_Protect\_Fun() //System phase current protection
- Heat\_Temperture\_Protect\_Fun() //Heater over temperature protection

##### ■ ADC\_ISR (Time Based : 1/PWM Frequency)

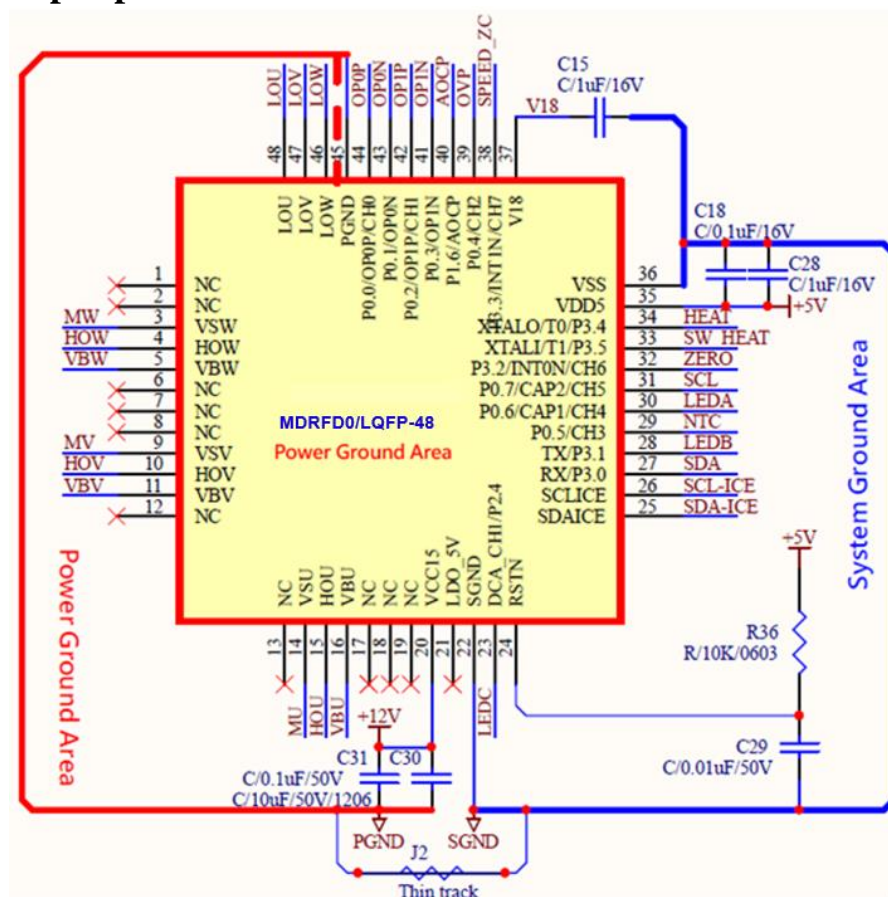
- Scan and measurement of all AD values
  - ✓ Vbus\_avg
  - ✓ Ibus\_avg
  - ✓ Vsp\_avg
  - ✓ Tmp
  - ✓ Speed

## 4. Reference Circuit Design

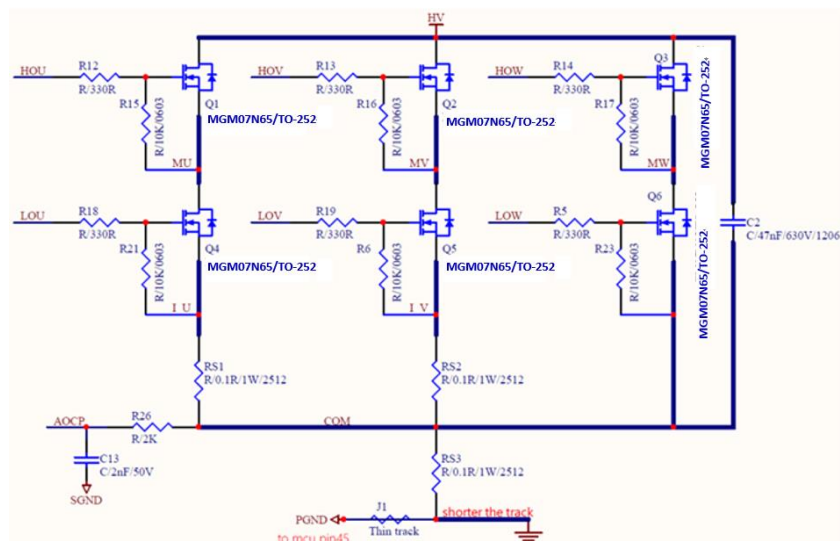
### 4.1 Power input circuit



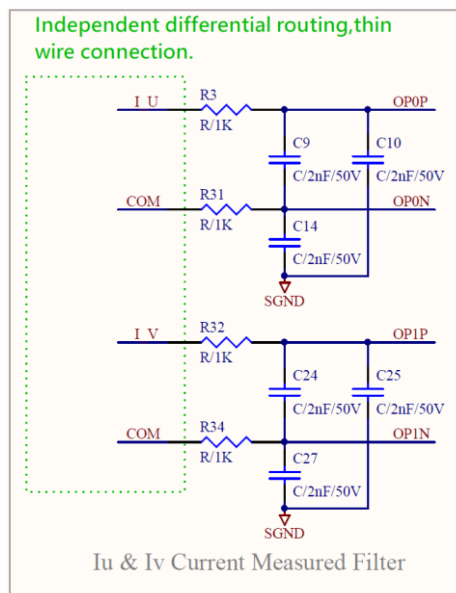
### 4.2 Core unit and peripheral circuits



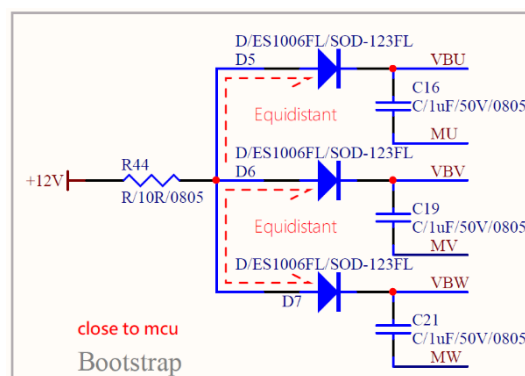
### 4.3 Three-phase full-bridge inverter



### 4.4 Two-phase sampling circuit

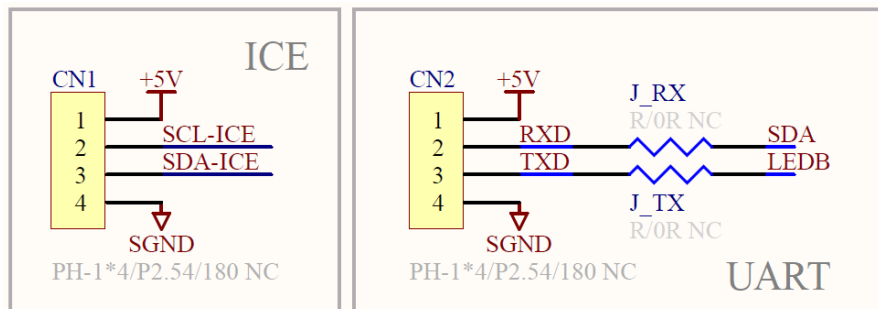


### 4.5 Bootstrap

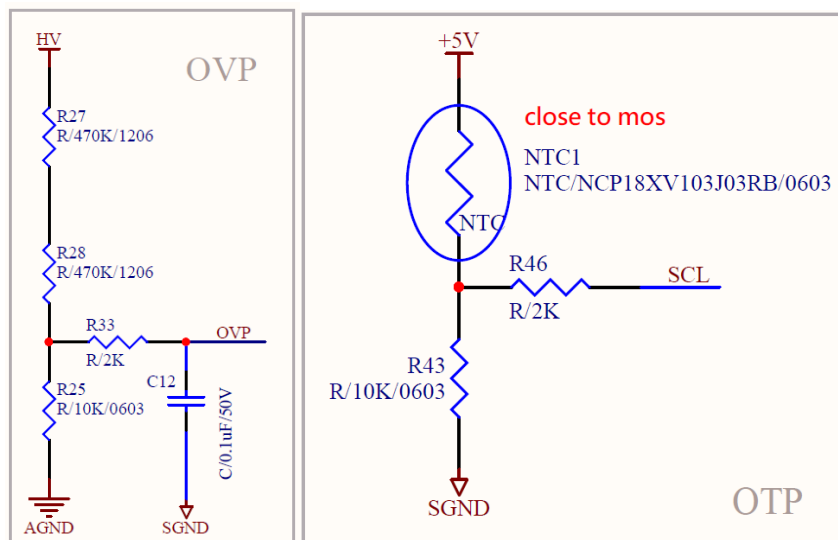




## 4.6 External port



## 4.7 Protection circuit



## 4.8 Other peripherals

