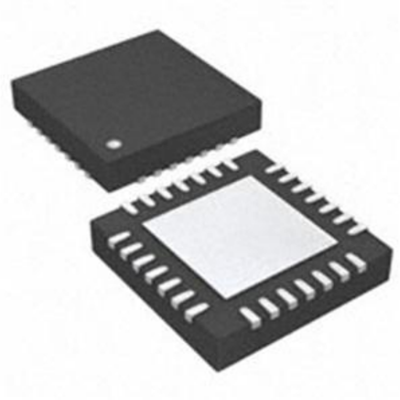
Low noise stepping motor driver

DESCRIPTION

MS35775 is a high precision and low noise two-phase stepping motor driver.The chip integrates fast mode and silent mode to meet different applications at high speed and low speed.The fast mode uses fast current rectifier, which can achieve better dynamic characteristics.Silent mode has lower noise and higher efficiency.The power MOSFET is built into the chip, and the average current can reach 1.4A and the peak current is 2A.

The chip integrates over- temperature protection, under - voltage protection, over-current protection, short ground protection and short power supply protection.The UART bus can be used to set tuning drivers for best performance, and these settings can also be written to a one-time programmer (OTP).The driving mode adopts the industrial standard interface of step / dir, which is simple and convenient for application



APPLICATIONS

- 3D printers
- Robot, precision industrial equipment
- Surveillance camera
- Medical equipment
- Office and home automation

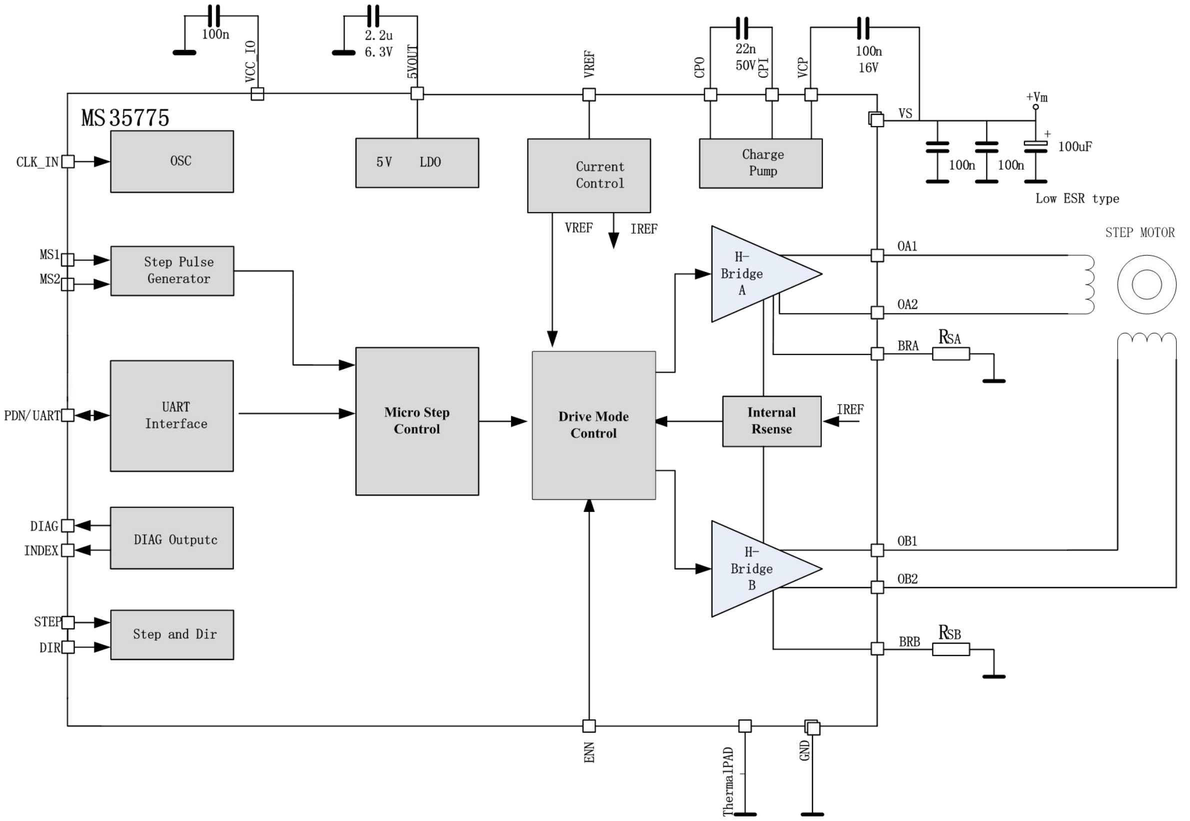
FEATURES AND BENEFITS

- 2-Phase stepping motor, can reach the peak current of 2A
- Step / dir interface, you can choose 2, 4, 8, 16, or 32 micro step
- Internal 256 micro steps
- Quiet mode
- Fast mode
- HS Rdson 0.29 Ω ,LS Rdson 0.28 Ω
- The voltage range is 4.75 ~ 36V
- When the motor is still, it will enter into the power saving mode automatically
- Internal resistor mode is optional (no need for external sense resistor)
- Single wire UART bus and OTP control
- QFN28 package (Back Thermal PAD)

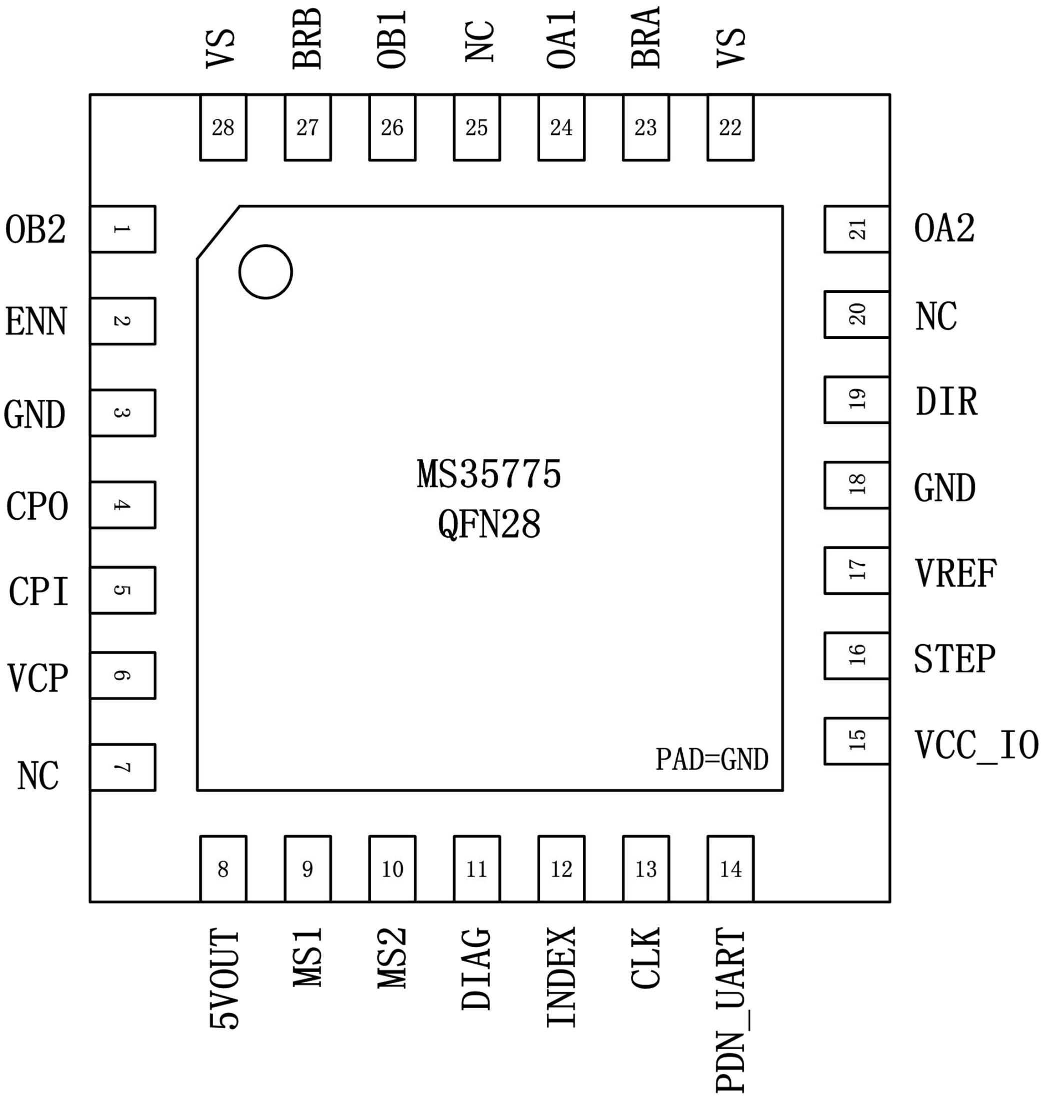
PRODUCT SPECIFICATION

Product	Package	Print Name
MS35775	QFN28	MS35775

BLOCK DIAGRAM



PACKAGE REFERENCE



PIN FUNCTIONS

PIN No.	PIN NAME	Type	Description
1	OB2	IO	H-Bridge B output 2
2	ENN	DI	Enable input pin, turn off output for high level
3	GND	GND	GND
4	CPO	IO	Charge pump capacitor output.
5	CPI	IO	Charge pump capacitor input,connected to CPO with 22nf (50V) capacitor.
6	VCP	IO	Charge pump voltage, connected to VS with 100nf capacitor.
7	NC	NC	Unused pin,can be suspended or grounded.
8	5VOUT	IO	Internal LDO 5v output,connected to ground with 2.2uf to 4.7uf capacitor .
9	MS1	DI	Microstep configuration pin (built-in pull-down resistor) MS2,MS1: 00:1/8 ,01:1/2,10:1/4,11:1/16
10	MS2	DI	
11	DIAG	DO	Internal diagnostic signal output.Driver error flag.Can be reset by ENN=high.
12	INDEX	DO	Configurable index output.Provide index pulse.
13	CLK	DI	Clock input.Grounding is possible when using the internal clock.
14	PDN_UART	DIO	Power down not control input (automatic standstill current reduction at low level) can be selected as UART input and output.The power down function does not work in UART mode.
15	VCC_IO	POWER	1.8V to 5V power supply for each digital input and output pin
16	STEP	DI	Micro step input pin
17	VREF	AI	Analog reference voltage for current scaling or reference current for use of internal sense resistors (optional mode)
18	GND	GND	GND
19	DIR	DI	DIR input pin (built-in pull-down resistor)
20	NC	NC	Unused pin,be open or grounded.
21	OA2	IO	H-Bridge A output 2
22	VS	POWER	Motor supply voltage
23	BRA	IO	Sense resistor connection for coil A. Place sense resistor to GND near pin. Direct grounding in internal sense resistor mode.
24	OA1	IO	H-Bridge A output 1
25	NC	NC	Unused pin,be open or grounded.
26	OB1	IO	H-Bridge B output 1
27	BRB	IO	Sense resistor connection for coil B. Place sense resistor to GND near pin. Direct grounding in internal sense resistor mode.
28	VS	POWER	Motor supply voltage

LIMITED PARAMETER

Absolute Maximum Rating

Parameters	Symbol	Rating	Unit
supply voltage	V_S	-0.5...39	V
IO supply voltage	V_{VIO}	-0.5...5.5	V
Digital power supply voltage (using external power supply)	V_{5VOUT}	-0.5...5.5	V
Logic input voltage range	V_I	-0.5...V_{IO}+0.5	V
VREF input voltage (VCC_IO and 5VOUT voltage do not exceed 10% at the same time, which will enter the test mode)	V_{VREF}	-0.5...6	V
Maximum current of analog digital port	I_{IO}	+/-10	mA
Output current capacity of 5V internal power supply	I_{5VOUT}	25	mA
Power drive output current	I_{OX}	2.5	A
Junction temperature	T_J	-50...150	℃
Storage temperature	T_{STG}	-55...150	℃
ESD capability (HBM)	V_{ESD}	4K	V

Operational Range

Parameters	Symbol	Parameter Range			Unit
		Min	Typ	Max	
Power supply voltage range (using internal 5vout)	V_S	5.5	-	36	V
Power supply voltage range for OTP programming (using internal 5vout)	V_S	6	-	36	V
Power supply voltage range (VS and 5vout connected together)	V_S	4.7	-	5.4	V
I / o supply voltage range	V_{VIO}	1.8	-	5.25	V
RMS current per motor coil	I_{RMS}			1.2	A
One second on, one second off RMS current	I_{RMS}			1.4	A
Peak current per motor coil	I_{OX}			2	A
Junction temperature	T_J	-40		125	℃

ELECTRICAL CHARACTERISTICS

VS=24V

Note: if no special mention, the ambient temperature Ta = 25 ℃± 2 ℃.

Current Consumption :

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Current consumption(No load)	I_S	Fclk = 12Mhz. No chopping		10	14	mA
Current consumption(No load)	I_S	Fclk = 12Mhz, 35kHz chopping		11		mA
5VOUTsupply current	I_{VCC}	Fclk = 12Mhz, 35kHz chopping		10		mA
IO supply current	I_{VIO}	IO without any load		30		uA

Digital Input And Output:

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Input low level	V_{INLO}		-0.3		0.3Vio	V
Input high level	V_{INHI}		0.7Vio		Vio+0.3	V
Input SMIT hysteresis	V_{INHYST}			0.12Vio		V
Output voltage high level	V_{OUTLO}	I=2mA	Vio-0.2			V
Output voltage low level	V_{OUTHI}	I=2mA			0.2	V
Input leakage current	I_{ILEAK}		-10		10	uA
Pull up and pull down resistance	R_{PU}/R_{PD}			150		kΩ
Digital port capacitance	C			8		pF

H-Bridge :

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Low side rdson	R_{ONL}	I=100mA		0.28	0.38	Ω
High side rdson	R_{ONH}	I=100mA		0.29	0.39	Ω
Rise time	t_{SLPON}	I=700mA	40	80	160	ns
Fall time	t_{SLPOFF}	I=700mA	40	80	160	ns
Source current at drive off	I_{OIDLE}	Oxx connected to GND	120	330	400	uA

Charge Pump：

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Charge pump output voltage	V_{VCP}-V_S	Working at fchop < 40KHz	4	Vcc-0.3	VCC	V
Charge_Pump output under voltage threshold	V_{VCP}-V_S	Use internal 5V LDO	3.7	4	4.3	V
Charge pump frequency	f_{CP}			1/16CLK		

5VLDO：

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
output voltage	V_{5VOUT}	I5v=0mA	4.8	5	5.2	V
Output resistance	R_{5VOUT}	Static load		1		Ω
Deviation over the whole temperature range	$V5_{VOUT(DEV)}$	I=5mA,T_J=full range		±90	±200	mV
Deviation over the whole voltage range	$V_{5VOUT(DEV)}$	I=5mA,V_{VS}=variable		±100	±150	mV/10V

OSC：

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Clock frequency (factory setting)	f_{CLKOSC}	T=50℃		11.7		MHz
	f_{CLKOSC}	T=25℃	11.5	12.0	12.5	MHz
	f_{CLKOSC}	T=150℃		12.1		MHz
Additional clock frequency	f_{CLK}		4	10-16	18	MHz
Additional clock frequency rise and fall time	t_{CLK}	CLK from 0.1vio to 0.9vio	10			ns
External clock timeout detection	$X_{timeout}$		32		48	Fclk cycles

Protection：

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Under-voltage protection	V_{UV_VS}	Supply voltage rising	3.5	4.3	4.6	V
5VOUT under-voltage protection	V_{UV_5VOUT}	5V LDO voltage risng		4.2		V
Over current protection voltage of high side	V_{OS2G}		2	2.5	3	V
Over current protection voltage of low side	V_{OS2VS}		1.6	2	2.3	V
Short detector delay(high side or low side short)	t_{S2G}	High side output clamped to V_S-3V	0.8	1	2	us
Over temperature warning	t_{OTPW}	Temperature rising	100	120	140	℃
Over temperature shutdown or over temperature pre-warning	t_{OT143}	Temperature rising	128	143	163	℃
Over temperature shutdown	t_{OT150}	Temperature rising	135	150	170	℃
Over temperature shutdown	t_{OT157}	Temperature rising	142	157	177	℃

Sense：

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Sense voltage peak voltage (low sensitivity)	V_{SRTL}			300		mV
Sense voltage peak voltage (high sensitivity)	V_{SRTH}			165		mV
Sense input tolerance(internal sense resistor)	I_{COIL}	I_scale_analog=0, VSENSE=0	-5		5	%
Sense input tolerance (external sense resistor)	I_{COIL}	I_scale_analog=1, V_{AIN}=2V, VSENSE=0	-2		2	%
Internal resistance between internal BRX and external sense resistance	R_{BRxy}			30		mΩ

AIN And IREF：

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
AIN_IREF input resistance to 2.5V	R_{AIN}	internalRsense=0	260	400	450	kΩ
AIN_IREF input voltage range for liner current scaling	V_{AIN}	IscaleAnalog=1	0	0.5-2.4	$V_{5VOUT}/2$	V
AIN_IREF open input voltage	V_{AINO}	internalRsense=0		$V_{5VOUT}/2$		V
AIN_IREF input resistance to GND	R_{IREF}	internalRsense=1	1	1.3	1.5	kΩ
AIN_IREF current amplification	$I_{REFAMPL}$	IREF=0.25mA		4500		Times
Motor current full scale tolerance	I_{COIL}	Internal_Rsense=1, VSENSE=0, IIREF = 0.25mA	-10		+10	%

FUNCTION DESCRIPTION

1.Basic Functions

The MS35775 is a stepper motor driver, and its quiet characteristics are particularly suitable for home or office application. With small package, the MS35775 can provide high density output current .It requires a few control pins on its tiny package.The number of microsteps can be 2,4,8,16 or 32 to fit different motion control.

There are three working modes of MS35775:

Mode 1: Independent step / dir mode (classic mode)

The CPU generates step and direction signal to synchronize other motors or systems.Current can be controlled by the pin VREF. PDN_UART selects automatic standstill current reduction function.The status information fed back to CPU driver can be obtained from index and Diag pins.We can enable or disable the motor through the ENN pin.

Mode 2: Independent step / dir mode with OTP preset.

Additional settings are achieved by OTP preset (via UART & OTP function)

- Chopper parameters can be adjusted for special applications.
- Internal sense resistance can be used to reduce the cost.
- Adjust the degree of automatic power saving and timing to get the most effective application.

For the above settings, the settings can be stored in the OTP memory or stored in the CPU, and need be written into the chip register when the power is turned on. OTP programming does not need to be on the application side, and can be completed on the test PCB.Generally, the driver is set by a CPU firmware instruction.Multiple drivers can be written at the same time through the TXD line.

Mode 3: step / dir drive, using full angle control.

Similar to mode 2, but PDN_UART and CPU need to be connected.

Additional optional configuration:

- Detailed diagnosis and temperature management.
- Passive braking mode, flexible free rotation and low power consumption stop mode.
- More options for microstep settings (fullstep to 256 microstep).
- Software controls motor current and more chopper control options.

This mode does not need ENN, diag, index, MS1, MS2, VREF and other control pins, but only needs a communication bus PDN_UART plus step and dir.This mode can even use the internal step signal to set the speed without the step signal.One bus can control different ICs by multiplexer chip.

1.1 Important Concepts

MS35775 has the following important features, the stepper motor movement will be more precise, efficient, reliable, smooth and energy-saving.

Silent Mode: Ultra low noise, high precision.Faster motor acceleration and deceleration, and lower stand still motor current.

Fast Mode: High precision, closed-loop current control mode, can achieve the highest dynamic performance.

Micro Step Control: The internal micro step of 256 microstep is obtained by micro step interpolation method, and only low precision step control is needed outside, starting from fullstep.

In addition, the MS35775 also integrates output short circuit protection, over temperature protection and under voltage protection to enhance the high reliability of the chip.

1.2 Control Interface

The basic mode adopts discrete control line, and UART mode signal line interface has CRC verification function.When the correct UART data is sent, the UART interface automatically becomes valid.

1.2.1 UART Interface

The UART interface allows baud rates from 9600 baud to 500K baud or higher (using an external clock).MS35775 can automatically adapt to host baud rate.The chip has a fixed slave address, in the case of no read register operation, multiple slaves can be connected in parallel.The analog multiplexer can provide any slave address, such as 74hc4066.

1.3 Motor Movement And Control

1.3.1 Step / Dir Interface

The motor movement is controlled by step and dir input pin.A special bit (DEDGE) controls whether the effective edge of the step is a rising edge or a double edge.Double edge trigger is used in slow communication interface.Each step can be full step and micro step. A full step can be equal to 2,4,8,16,32,64,128,256 microsteps. The internal table is converted to sine and cosine values to control the motor current.

1.3.2 Internal Step Pulse Generator

Some applications don't need very high precise coordinate movement.The MS35775 has an internal step pulse generator to meet this requirement: just control the speed by UART interface,so the motor can move.The velocity sign automatically controls the direction of the motion. However, the pulse generator does not integrate a ramping function. Motion at higher velocities will require ramping up and ramping down the velocity value via software.

Step / dir mode and internal pulse generator mode can be mixed in one application

1.4 Silent Mode And Fast Mode

The silent mode is based on the principle of voltage control to ensure that the motor is absolutely quiet at rest and at low speed, except for the bearing noise of the motor.Unlike other voltage modes, it learns the best setting after the first action of power on and uses this setting in subsequent movements.The initial parameters can be written and stored in the OTP register.The silent mode can respond to the change of motor speed immediately, so as to realize the high dynamic characteristics of the motor.

In high-speed applications, fast mode is more suitable than silent mode, which can be switched through UART or OTP.These two modes can also be applied in combination.The fast mode is an enhanced current feedback mode that provides smooth handling and resonance rejection over a wide range of speeds and loads.The fast mode chopper can automatically adjust the fast decay period to ensure smooth zero crossing.

1.5 Automatic Standstill Current Reduction

Automatic standstill current reduction greatly reduces power consumption.In non UART mode, through the pull-down PDN_UART pin enables the function of current reduction.It can reduce the power consumption to 33% when the operating current is about 50%.

1.6 Precision Clock Generator And Clock Input

The MS35775 provides an accurate internal clock generator to ensure chopper frequency and performance stability.However, when higher oscillator precision are required, an external clock is required.For safety, the clock input has the function of time-out detection and switches back to the internal clock in case of external source failure.

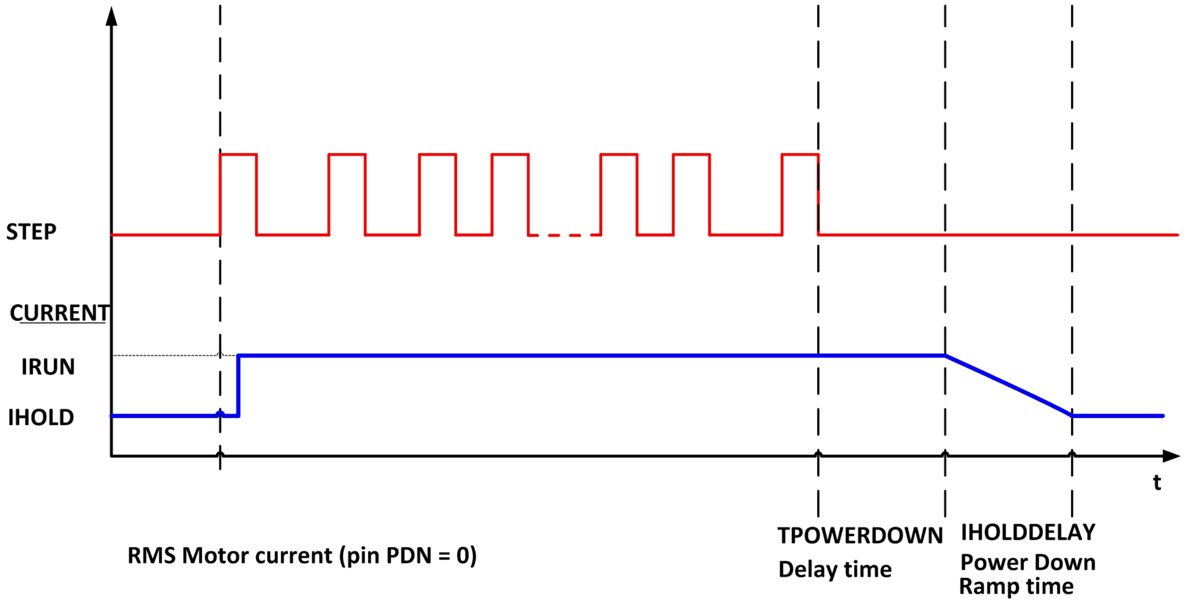


Figure 1.1 Automatic Motor Current Power Down

1.7 Index Output

One turn of the index gives a pulse, that is, one pulse every four full steps.It shows the internal sequencer microstep 0 position (mstep close to 0).Combined with mechanical origin switch, more accurate homing can be achieved.

2.UART Single Bus Interface

UART single line interface allows the MS35775 to be controlled by any microcontroller.It shares the transmit line and receiving line like the RS485 basic interface.Using CRC redundancy check makes data transmission more secure and reliable. Therefore, increasing the interface distance (the line between two PCB boards) can avoid errors, even out of control due to magnetic interference.Automatic baud rate detection makes the interface more convenient to use.

2.1 Datagram Structure

2.1.1 Write Access

<table>
<tr><th colspan="20">UART write register data structure</th></tr>
<tr><td colspan="20">Each byte is transmitted from LSB... MSB, and the high byte is transmitted first</td></tr>
<tr><td colspan="20">0...63</td></tr>
<tr><td colspan="8">Synchronization + reservation</td><td colspan="3">8-bit slave address</td><td colspan="3">Read write bit + 7-bit register</td><td colspan="3">32 bit data</td><td colspan="3">CRC</td></tr>
<tr><td colspan="8">0...7</td><td colspan="3">8...15</td><td colspan="3">16...23</td><td colspan="3">24...55</td><td colspan="3">56...63</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td colspan="4">Reserved (no</td><td colspan="3">Slave address = 0</td><td colspan="2">register address</td><td>1</td><td colspan="3">Data byte 3,2,1,0 (high to low)</td><td colspan="3">CRC</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>...</td><td>15</td><td>16</td><td>...</td><td>23</td><td>24</td><td>...</td><td>55</td><td>56</td><td>...</td><td>63</td></tr>
</table>

A synchronous half byte is at the front of each transmission of MS35775 and is loaded into the first byte, followed by a slave address byte (MS35775 is 0).Each transmission allows the internal baud rate synchronizer to synchronize to the host clock frequency.The actual baud rate can adapt to the change of internal clock frequency, so the baud rate can be freely selected within the effective range.Each transfer byte starts with a start bit (logic 0) and ends with an end bit (logic 1).The bit time is calculated by measuring the start of the start bit (transition from 1 to 0) to the end of the synchronization frame (transition from the second bit to the third bit 1 to 0).All data is transmitted in bytes, and 32-bit data is transmitted from the high byte.

The minimum baud rate is 9000 and the maximum baud rate is fclk / 16.

The slave address of MS35775 is always 0.

If the pause time between two consecutive start bits exceeds 63 bits, the communication will be reset.This timing condition is that the last transmission data is correct, in this case, the transmission restart requires at least 12 bit fault recovery time.This circuit allows the host to reset communication. In case of transmission error, any pulse less than 16 clocks will be regarded as interference signal and cause a 12 bit pause time.Other errors, such as CRC errors, are handled the same way.Allow resynchronization after any transmission errors.

The UART line must be set high when the bus is idle, so the standby function cannot pass through PDN during data transmission_UART pins enable.In the application of UART interface, PDN is set by register_Disable bit to disable PDN_Functions of UART pins.

2.1.2 Read Access

<table>
<tr><th colspan="17">UART read register data structure</th></tr>
<tr><td colspan="17">Each byte is transmitted from LSB... MSB, and the high byte is transmitted first</td></tr>
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<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>...</td><td>15</td><td>16</td><td>...</td><td>23</td><td>24</td><td>...</td><td>31</td></tr>
</table>

Reading registers requires the same data structure as writing registers, but requires fewer bits.Its function is to address the slave address and register address to achieve the read function.The MS35775 responds with the same baud rate as the host computer.

In order to ensure that the bus transmission from the master to the slave is not disturbed, MS35775 cannot send the response immediately.However, it uses a programmable delay time after the first reply byte is sent. The delay time is a multiple of 8 bits by setting the value of the register senddelay according to the needs of the host.

<table>
<tr><th colspan="20">UART read response data structure</th></tr>
<tr><td colspan="20">Each byte is transmitted from LSB... MSB, and the high byte is transmitted first</td></tr>
<tr><td colspan="20">0...63</td></tr>
<tr><th colspan="8">Synchronization + reservation</th><th colspan="3">8-bit host address</th><th colspan="3">Read write bit + 7-bit register</th><th colspan="3">32 bit data</th><th colspan="3">CRC</th></tr>
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<tr><td>1</td><td>0</td><td>1</td><td>0</td><td colspan="4">Reserved</td><td colspan="3">Host address = 0xff</td><td colspan="2">register address</td><td>0</td><td colspan="3">Data byte 3,2,1,0 (high to low)</td><td colspan="3">CRC</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>...</td><td>15</td><td>16</td><td>...</td><td>23</td><td>24</td><td>...</td><td>55</td><td>56</td><td>...</td><td>63</td></tr>
</table>

The read response sent address code% 11111111 to the host, and the transmission time of four bits after the last bit is sent is invalid.

2.2 CRC Calculation

An 8 bit CRC is used to read and write the CRC registers.The initial value of crc8-atm polynomial is zero. In application, it includes synchronization and address bytes from low bit to high bit.The synchronous half byte is assumed to be always correct. MS35775 only responds to correct data telegrams. A counter is added inside to count the correct number of register writes.

$$CRC=x^8+x^2+x^1+x^0$$

Examples

CRC = （CRC<<1） OR (CRC.7 XOR CRC.1 XOR CRC.0 XOR [new incoming bit])

Example of CRC computing C language:

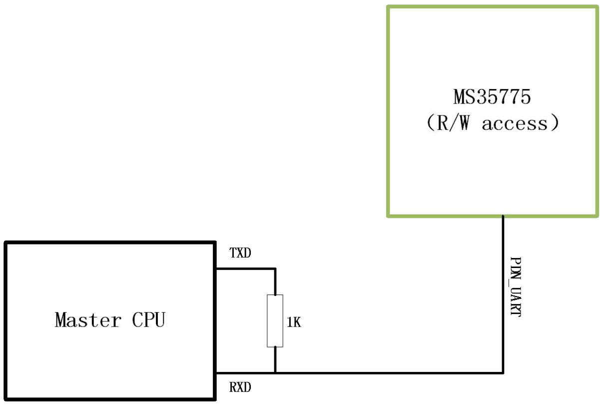
```
void swuart_calcCRC(UCHAR* datagram, UCHAR datagramLength)
{
int i,j;
UCHAR* crc = datagram + (datagramLength-1); // CRC located in last byte of message
UCHAR currentByte;
*crc = 0;
for (i=0; i<(datagramLength-1); i++) {        // Execute for all bytes of a message
currentByte = datagram[i];    // Retrieve a byte to be sent from Array
for (j=0; j<8; j++) {
if ((*crc >> 7) ^ (currentByte&0x01))      // update CRC based result of XOR operation
{
*crc = (*crc << 1) ^ 0x07;
}
else
{
*crc = (*crc << 1);
}
currentByte = currentByte >> 1;
} // for CRC bit
} // for message byte
}
```

2.3 UART signal

A bidirectional pin is used for UART interface in the MS35775.

UART Interface	
PDN_UART	Non reverse input and output.

Chip check PDN_UART pin input to ensure that the correct data message is received.It can adapt to input data baud rate by synchronous half byte.When reading the register, the pin changes to the output state and sends the response at the same baud rate. After the last bit is transmitted, the pin state changes to output off after delaying four bits.



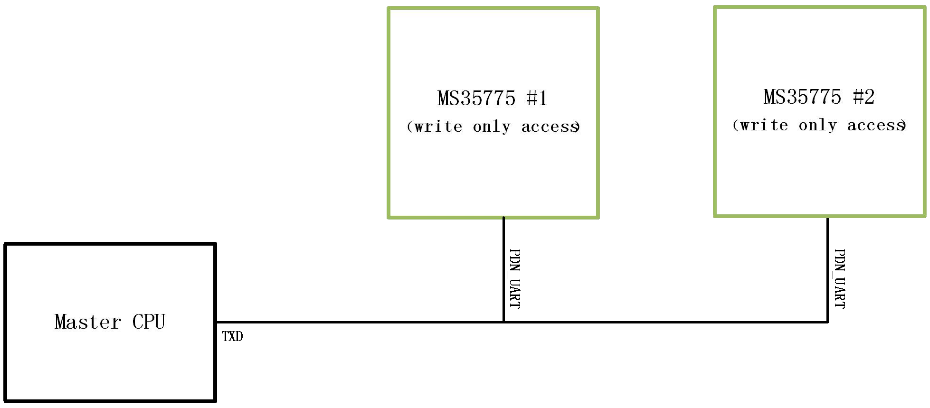


Figure 2.1 microcontroller control MS35775

2.4 Multiple Slave Addresses

Write Only Access:

If no read register is used and all slaves are given the same initial value, there is no address requirement.All slaves are connected in parallel.(Figure 2.1)

Multi slave address:

MS35775 uses a fixed slave address. In principle, only one chip can be connected to each UART interface channel.By adding analog switches, multiple chips can work independently.(Figure 2.2)

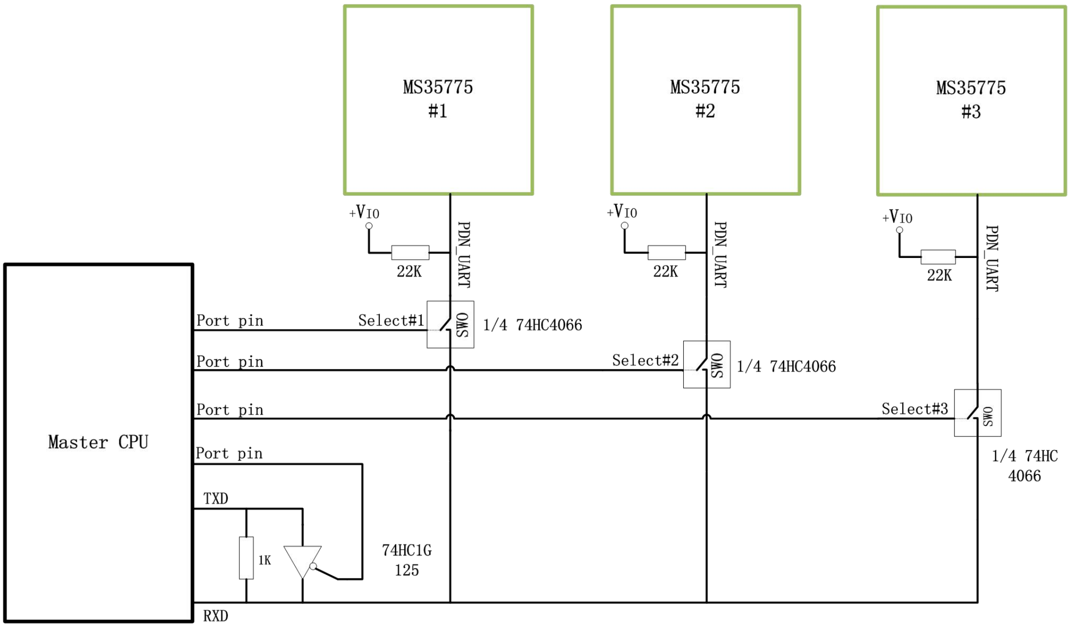


Figure 2.2 multi address slave controlled by analog switch

- Select a reliable baud rate within the valid range, such as 250K, and it takes 320us to write a register （=8 Bytes*（8+2）bits*4us）。
- Before the transmission starts, the analog switch is turned on by setting the port pin to high, and all other slaves will not work unless requested.
- When the optional buffer is used, MS35775 is allowed to set an appropriate transmission delay time after receiving the reply data.
- At the beginning of transmission, the TXD line is activated by setting the port pin low.
- When a read register request is sent, the optional buffer is closed when the end bit of the last bit of transmission is completed.
- Note that all transmitted data is received by the RXD line.

3.Register Map

3.1 General Register Table

Register Configuration (0x00... 0x0F)					
R/W	**Addr**	**n**	**Register**	**Description / bit name**	
RW	0x00	10	GCONF	**Bit**	**GCONF- Global Configuration**
				0	I_scale_analog (default = 1) 0: internal reference voltage (derived from 5VOUT) 1: Using VREF pin input as current reference
				1	Internal_Rsense (default: OTP) 0: external induced resistance mode 1: Internal induced resistance mode In the internal induced resistance mode, VREF current input is used as the reference, and the VREF pin is approximately grounded.
				2	EN_QUICK (default: OTP) 0: mute mode enabled 1: Fast mode enable
				3	Shaft 1: Change motor direction
				4	index_OTPW 0: index displays the position of the first microstep of the sequencer 1: Index display overheating warning signal
				5	index_step 0: index as index_OTPW 1: Index displays the step signal generated by the internal generator
				6	pdn_disable 0:PDN_UART pin control stop current mode 1:PDN_UART input is disabled. Set this bit to high when using UART interface mode.
				7	mstep_reg_select 0: microstep resolution is set by MS1 and MS2 pins. 1: Microstep resolution is set by register MSTEP.
				8	multistep_filt (default = 1) 0: step pulse is not filtered 1: Software pulse generator optimization enabled,when the full step frequency is greater than 750hz, TStep will display the time value of filtering step when it is enabled
				9	test_mode 0: normal operation 1: Test mode, mode test signal is output from ENN.

<table>
<tr><th colspan="6">Register Configuration（0x00...0x0F）</th></tr>
<tr><th>R/W</th><th>Addr</th><th>N</th><th>Register</th><th colspan="2">Description / bit name</th></tr>
<tr><td rowspan="4">R+
WC</td><td rowspan="4">0x01</td><td rowspan="4">3</td><td rowspan="4">GSTAT</td><td>Bit</td><td>GSTAT- global status</td></tr>
<tr><td>0</td><td>reset
1: Indicates that the chip has been reset and all registers return to the reset value.</td></tr>
<tr><td>1</td><td>drv_Err
1: Indicates that the chip stops driving due to overheating or short circuit detection. Read DRV for details_Status register. This flag can only be cleared after all errors have been eliminated.</td></tr>
<tr><td>2</td><td>uv_cp
1: Indicates that the charge pump is under voltage, in which case the drive stops.This flag will not latch, so it does not need to be cleared.</td></tr>
<tr><td>R</td><td>0x02</td><td>8</td><td>IFCNT</td><td></td><td>Interface transfer counter.This register value increases with the number of successful register writes.Read this register to check for lost data in successive transfers.Reading the register does not change this value, which loops from 255 to 0.</td></tr>
<tr><td rowspan="2">W</td><td rowspan="2">0X03</td><td rowspan="2">4</td><td rowspan="2">SLAVE
CONF</td><td>Bit</td><td>SLAVECONF</td></tr>
<tr><td>11..8</td><td>Read register send delay (after response is sent)
0,1: 8 bit times
2,3: 3*8 bit times
4,5: 5*8 bit times
6,7: 7*8 bit times
8,9: 9*8 bit times
10,11: 11*8 bit times
12,13: 13*8 bit times
14,15: 15*8 bit times</td></tr>
<tr><td rowspan="4">W</td><td rowspan="4">0x04</td><td rowspan="4">16</td><td rowspan="4">OTP_
PROG</td><td>Bit</td><td>OTP_Program - programmable OTP</td></tr>
<tr><td>2..0</td><td>OTPBIT
Select the OTP bit to be programmed</td></tr>
<tr><td>5..4</td><td>OTPBYTE
Select OTP bytes to program</td></tr>
<tr><td>15..8</td><td>OTPMAGIC
Set the register value to 0xbd to enable OTP programming.The programming time should be at least 10ms.</td></tr>
<tr><td rowspan="4">R</td><td rowspan="4">0x05</td><td rowspan="4">24</td><td rowspan="4">OTP_
READ</td><td>Bit</td><td>OTP_Read (read the value of OTP memory)</td></tr>
<tr><td>7..0</td><td>OTP0 read data</td></tr>
<tr><td>15..8</td><td>OTP1 read data</td></tr>
<tr><td>23..16</td><td>OTP2 read data</td></tr>
</table>

<table>
<tr><th colspan="6">Register Configuration（0x00...0x0F）</th></tr>
<tr><th>R/W</th><th>Addr</th><th>N</th><th>Register</th><th colspan="2">Description / bit name</th></tr>
<tr><td rowspan="12">R</td><td rowspan="12">0x06</td><td rowspan="12">10+
8</td><td rowspan="12">IOIN</td><td>Bit</td><td>Input (read the status of all input pins)</td></tr>
<tr><td>0</td><td>ENN</td></tr>
<tr><td>1</td><td>-</td></tr>
<tr><td>2</td><td>MS1</td></tr>
<tr><td>3</td><td>MS2</td></tr>
<tr><td>4</td><td>DIAG</td></tr>
<tr><td>5</td><td>STEP</td></tr>
<tr><td>6</td><td>PDN_UART</td></tr>
<tr><td>7</td><td>STEP</td></tr>
<tr><td>8</td><td>-</td></tr>
<tr><td>9</td><td>DIR</td></tr>
<tr><td>31..24</td><td>-</td></tr>
<tr><td rowspan="2">RW</td><td rowspan="2">0x07</td><td rowspan="2">5
+
2</td><td rowspan="2">FACTORY_
CONF</td><td>4..0</td><td>FCLKTRIM (default: OTP)
0...31: lowest to highest frequency.Check the output of the charge pump. The frequency range is not guaranteed, but it can be tested. The internal clock may be adjusted to 12Mhz. The clock frequency of 12Mhz can be preset by OTP programming.</td></tr>
<tr><td>9..8</td><td>OTTRIM (default: OTP)
00： OTP=143℃，OTPW=120℃
01： OTP=150℃，OTPW=120℃
11： OTP=150℃，OTPW=143℃
10： OTP=157℃，OTPW=143℃</td></tr>
</table>

3.1.1 OTP_READ-OTP Configuration Memory

The default value of all OTP memories is 0. Only 1 bit can be set for each time, and the set bits cannot be cleared.The factory adjusts the clock frequency by setting OTP0.0-OTP0.4.

<table>
<tr><th colspan="5">0x05:OTP_READ-OTP Memory Table</th></tr>
<tr><th>Bit</th><th>Name</th><th>Function</th><th colspan="2">Description</th></tr>
<tr><td rowspan="3">23</td><td rowspan="3">OTP2.7</td><td rowspan="3">OTP_EN_QUICK</td><td colspan="2">Set the default working mode: fast mode or silent mode.</td></tr>
<tr><td>0</td><td>Default: silent mode (EN_QUICK=0)
OTP1.0 to 1.7 and 2.0 are used in silent mode
Fast mode setting: HEND = 0;HSTAR = 5; TOFF = 3</td></tr>
<tr><td>1</td><td>Default: quick mode (EN_QUICK=1)
OTP1.0 to 1.7 and 2.0 are used in fast mode
Mute mode setting:
PWM_GRAD=0;TPWM_THRS=0;
PWM_OFS=36;PWM_AUTOGRAD=1</td></tr>
<tr><td>22</td><td>OTP2.6</td><td rowspan="2">OTP_IHOLD</td><td colspan="2" rowspan="2">The default standby current is determined by IHOLD (only works when the standby function is on, pin PDN_UART is set to 0).
00:IHOLD = 16(53% of IRUN)
01:IHOLD = 2 (9% IRUN)
10:IHOLD = 8 (28% IRUN)
11:IHOLD = 24 (78% IRUN)
(default operating current IRUN = 31)</td></tr>
<tr><td>21</td><td>OTP2.5</td></tr>
<tr><td>20</td><td>OTP2.4</td><td rowspan="2">OTP_IHOLDDELAY</td><td colspan="2" rowspan="2">Default IHOLDDELAY
00:IHOLDDELAY=1
01:IHOLDDELAY=2
10:IHOLDDELAY=4
11:IHOLDDELAY=8</td></tr>
<tr><td>19</td><td>OTP2.3</td></tr>
<tr><td>18</td><td>OTP2.2</td><td>OTP_PWM_FREQ</td><td colspan="2">Default PWM_FREQ
0: PWM_FREQ=01=2/683
1: PWM_FREQ=10=2/512</td></tr>
<tr><td>17</td><td>OTP2.1</td><td>OTP_PWM_REG</td><td colspan="2">Default PWM_REG
0: PWM_REG=1000: 4 increment/cycle
1: PWM_REG=0010: 1 increment/cycle</td></tr>
<tr><td rowspan="3">16</td><td rowspan="3">OTP2.0</td><td rowspan="2">OTP_PWM_OFS</td><td colspan="2">Depending on OTP_EN_QUICK</td></tr>
<tr><td>0</td><td>0：PWM_OFS=36
1：PWM_OFS=00 (no early adjustment);
PWM_AUTOGRAD=0</td></tr>
<tr><td>OTP_CHOPCONF8</td><td>1</td><td>The default value is HEND1</td></tr>
</table>

0x05:OTP_READ-OTP Memory Table				
Bit	**Name**	**Function**	**Description**	
15	OTP1.7	OTP_TPWMTHRS	Depending on OTP_EN_QUICK	
14	OTP1.6		0	Default TPWM_THRS 0:TPWM_THRS =0 1:TPWM_THRS =200 2:TPWM_THRS =300 3:TPWM_THRS =400 4:TPWM_THRS =500 5:TPWM_THRS =800 6:TPWM_THRS =1200 7:TPWM_THRS =4000
13	OTP1.5			
		OTP_CHOPCONF7..5	1	Default HSTRT1, HSTRT2, HEND0
12	OTP1.4	OTP_PWM_AUTOGRAD	Depending on OTP_EN_QUICK	
			0	0: PWM_AUTOGRAD=1 1: PWM_AUTOGRAD=0
		OTP_CHOPCONF4	1	Default HSTRT0 (PWM_AUTOGRAD=1)
11	OTP1.3	OTP_PWM_RGAD	Depending on OTP_EN_QUICK	
10	OTP1.2		0	Default PWM_RGAD 0: PWM_RGAD= 14 0: PWM_RGAD= 16 0: PWM_RGAD= 18 0: PWM_RGAD= 21 0: PWM_RGAD= 24 0: PWM_RGAD= 27 0: PWM_RGAD= 31 0: PWM_RGAD= 35 0: PWM_RGAD= 40 0: PWM_RGAD= 46 0: PWM_RGAD= 52 0: PWM_RGAD= 59 0: PWM_RGAD= 67 0: PWM_RGAD= 77 0: PWM_RGAD= 88 0: PWM_RGAD= 100
9	OTP1.1			
8	OTP1.0			
		OTP_CHOPCONF3..0	1	Reset default for CHOPCONF.0 to CHOPCONF.3(TOFF)

0x05:OTP_READ-OTP Memory Table			
Bit	**Name**	**Function**	**Description**
7	OTP0.7	OTP_TBL	Default TBL 0: TBL=10 1: TBL=01
6	OTP0.6	OTP_internalRsense	Default internalRsense 0: external sense resistor 1: Internal sense resistor
5	OTP0.5	OTP_OTTRIM	Default OTTRIM 0: OTTRIM=00(143℃) 1: OTTRIM=01(150℃)
4	OTP0.4	OTP_FCLKTRIM	Default FCLKTRIM 0: minimum frequency 31: highest frequency
3	OTP0.3		
2	OTP0.2		
1	OTP0.1		
0	OTP0.0		

3.2 Speed Control

<table>
<tr><th colspan="6">Speed Control Register Setting（0x10...0x1F）</th></tr>
<tr><th>R/W</th><th>Addr</th><th>n</th><th>Register</th><th colspan="2">Description / bit name</th></tr>
<tr><td rowspan="4">W</td><td rowspan="4">0x10</td><td rowspan="4">5
+
5
+
4</td><td rowspan="4">IHOLD_
IRUN</td><td>Bit</td><td>IHOLD_IRUN drive current control</td></tr>
<tr><td>4..0</td><td>IHOLD (default: OTP)
Stall current (0 = 1 / 32... 31 = 32 / 32)
If IHOLD = 0 is set in silent mode, free rotation or passive braking mode can be selected under stall condition.</td></tr>
<tr><td>12..8</td><td>RUN (default = 31)
Motor running current (0 = 1 / 32... 31 = 32 / 32)
Tip: the normal IRUN value is 16 to 31 when the induction resistance is selected.</td></tr>
<tr><td>19..16</td><td>IHOLDDELAY (default: OTP)
When the motor is standstill detected (stst = 1), the current decreases steadily to avoid the jump of current.</td></tr>
<tr><td>W</td><td>0x11</td><td>8</td><td>TPOWERDOWN</td><td colspan="2">TPOWERDOWN (default = 20)
Set the delay time from the detection of the stall condition (stst) to the beginning of the current reduction.The range is from 0 to 5.6 s.
0...((2^8)-1)*2^18 tclk
Note: in silent mode, the minimum TPOWERDOWN value is 2.</td></tr>
<tr><td>R</td><td>0x12</td><td>20</td><td>TSTEP</td><td colspan="2">TSTEP = (fclk / fstep) / (256 / fraction) (fstep: input step frequency)
TSTEP uses a 1 / 16 hysteresis to compensate for the current jump.
The TSTEP value is compared with (TPWMTHRS * 15 / 16) - 1.
Deceleration switching mode switching point: TSTEP = set value
Switching point of accelerated switching mode:TSTEP < set value</td></tr>
<tr><td>W</td><td>0x13</td><td>20</td><td>TPWM
THRS</td><td colspan="2">Set the maximum speed limit of silent mode
TSTEP>=TPWMTHRS
When silent mode is enabled, if the motor speed exceeds the limit value set by TPWMTHRS, switch to fast mode.
0：Disabled</td></tr>
<tr><td>W</td><td>0x22</td><td>24</td><td>VACTUAL</td><td colspan="2">VACTUAL allows motors to be driven with UART interface
The velocity range is 0 - (+ - (2 ^ 23-1) * (usteps / t))
0: normal operation, external step works.
The motor rotation is controlled by VACTUAL, and the internal step can be monitored through the index pin.
The motor direction is controlled by vacuum symbol bit.</td></tr>
</table>

3.3 Sequencer Register

Microstep Control Register Setting（0x60-0x6B）					
R/W	**Addr**	**N**	**Register**	**Description / bit name**	**Range**
R	0x6A	10	MSCNT	Micro step counter.Indicates CUR_A's position in the microstep table, CUR_B is obtained by shifting a 256 in the microstep table.	0...1023
R	0x6B	9 + 9	MSCURACT	Bit8..0: CUR_A (signed) Motor a phase current, read from internal sine wave table Out.(no current reduction) Bit24..16: CUR_B (signed) Motor B phase current, read from internal sine wave table Out.(no current reduction)	+/-0...255

3.4 Chopper Control Register

Drive Register Setting（0x6C-0x7F）						
R/W	**Addr**	**N**	**Register**	**Description / bit name**		**Range**
RW	0x6C	32	CHOPCONF	Chopper and drive settings		
R	0x6F	32	DRV_STATUS	Drive status flag and current value reading		
RW	0x70	22	PWMCONF	Silent mode chopper configuration		
R	0x71	9 + 8	PWM_SCALE	The amplitude adjustment results of silent mode.This value is used to monitor the calculation of automatic PWM amplitude reduction.(255 = maximum voltage)		
				bit7...0	PWM_SCALE_SUM: This value is used to scale down cur_A and CUR_B。	0...255
				bit24...16	PWM_SCALE_AUTO： 9bit signed number is added into the calculation of PWM duty cycle.	Signed -255...+255
R	0x72	8 + 8	PWM_AUTO	bit7...0	PWM_OFS_AUTO: Automatic calculation of offset value	0...255

3.4.1 CHOPCONF-Chopper Configuration

0x6C:CHOPCONF-Chopper Configuration

Bit	Name	Function	Description
31	diss2vs	Low side short circuit Protection failure	0: low side short circuit protection on 1: low side short circuit protection off
30	diss2g	High side short circuit Protection failure	0: high side short circuit protection on 1: high side short circuit protection off
29	dedge	Enable Step double edge pules	1:This function is not compatible with step filtering function
28	intpol	Interpolation to 256 Microstep	The actual micro step resolution (MRES) is extended to 256, which makes the motor operate more smoothly.
27	mres3	MRES Microstep resolution	0000: 256Microstep resolution
26	mres2		
25	mres1		0001...1000:128,64,32,16,8,4,2,FULLSTEP microstep resolution decreasing Microstep resolution indicates how many microsteps there are in a quarter of a sine wave. Each step is equal to 2 ^ MRES microsteps
24	mres0		
23...18		reserved	Set to 0
17	VSENSE	Voltage induced resistance	0: low sensitivity, high induced resistance voltage 1: high sensitivity, low induced resistance voltage
16	tbl1	TBL Blank time selection	00...11 Set the blank time of comparator to 16, 24, 32 and 40 clocks.
15	tbl0		
14...11		reserved	Set to 0
10	HEND3	HEND Hysteresis low value OFFSET Sine wave offset	0000...1111 The hysteresis is - 3, - 2, - 1,0,1,..., 12 (1 / 512 is the scale of hysteresis and calculation of current added)
9	HEND2		
8	HEND1		
7	HEND0		
6	HSTRT2	HSTRT Hysteresis start value Add to HEND	000...111 Add 1,2,..., 8 to low hysteresis HEND (1 / 512 is the scale of hysteresis and calculation of current added) Note: HEND+HSTRT< = 16 The hysteresis decays every 16 clocks (default: OTP, the default value of silent mode is 0)
5	HSTRT1		
4	HSTRT0		

0x6C:CHOPCONF-Chopper Configuration			
Bit	**Name**	**Function**	**Description**
3	TOFF3	TOFF off time and driver enable	Off time setting to control the duration of hysteresis decay. 0000: drive off 0001: only when TBL > = 2 0010...1111: 2 ...15 (default: OTP, in silent mode default value is 3)
2	TOFF2		
1	TOFF1		
0	TOFF0		

3.4.2 PWMCONF-Silent Mode

0x70:PWMCONF-Silent Mode

Bit	Name	Function	Value	Description
31 ... 28	PWM_LIM	Automatic limit of PWM amplitude during mode switching		Limit for PWM_SCALE_AUTO when switching back from fast mode to silent mode, This value defines the upper limit for bits 7 to 4 of the automatic current control when switching back.It can reduce the current jerk when switching from fast mode to silent mode.PWM_GRAD and PWM_GRAD_AUTO offset will not be limited.(default 12)
27 ... 24	PWM_REG	Adjust the gradient		PWM amplitude define per half wave when using PWM_AUTOSCALE=1(1...15) 1: 0.5 increments (default with OTP2.1=1) ... 8: 4 increments (default with OTP2.1=0) ... 15: 7.5 increments (each bit + 0.5)
23		reserved		Set to 0
22		reserved		Set to 0
21	free_wheel1	Different standstill modes		Stand still option (I_HOLD=0). 00: normal operation 01: free rotation 10: coil shorted using LS drivers 11: coil shorted using HS drivers
20	free_wheel0			
19	PWM_AUTOGRAD	PWM automatic gradient adaptation	0	PWM_GRAD_AUTO=PWM_GRAD
			1	Automatic tuning (only with PWM_AUTOSCALE=1) PWM_GRAD_ AUTO is initialized, it is adjusted to the best value in motion. PWM_OFS_AUTO has been automatically initialized. This requires standstill at IRUN for >130ms in order to a) detect standstill b) wait > 128 chopper cycles at IRUN and c) regulate PWM_OFS_AUTO so that -1 < PWM_SCALE_AUTO < 1 2.Motor running and 1.5*PWM_OFS_AUTO<PWM_SCALE_SUM<4*PWM_OFS_Auto and PWM_SCALE_SUM<255 PWM_GRAD_AUTO changes 1 every 8 full steps.
18	PWM_autoscale	Automatic reduction of PWM amplitude	0	User defined expected amplitude, current settings IRUN and IHOLD do not affect.The results of PWM amplitude are as follows: PWM_OFS*((CS_ACTUAL+1)/32)+PWM_GRAD*256/TSTEP
			1	Enable automatic current adjustment (default)

3.4.2 PWMCONF-Silent Mode

0x70:PWMCONF-silent mode			
Bit	**name**	**function**	**Description**
17	PWM_freq1	PWM frequency selection	00： fPWM=2/1024 fclk 01： fPWM=2/683 fclk 10： fPWM=2/512 fclk 11： fPWM=2/410 fclk
16	PWM_freq0		
15	PWM_ GRAD	User defined amplitude gradient	The influence of amplitude gradient on amplitude is as follows PWM_GRAD*256/TSTEP This value is added to the calculation of the amplitude to compensate the back EMF of the motor. With automatic scaling (PWM_AUTOSCALE=1) the value is used for first initialization.Set PWM_Grad and PWM_GRAD_AUTO ratio to speed up the automatic adjustment process.You can store an approximate value into the OTP.
14			
13			
12			
11			
10			
9			
8			
7	PWM_ OFS	User defined amplitude	User defined amplitude, under the condition of stall, the current should be full current (CS_ACTUAL=31）(default = 36) When automatic current regulation is used, this value is only used for initialization.Auto scale function starts with PWM_SCALE_AUTO=PWM_OFS。 If PWM_OFS = 0, the automatic current adjustment will be invalid. PWM_OFS > 0 allows automatic adjustment to PWM low duty cycle, even below the threshold.
6			
5			
4			
3			
2			
1			
0			

3.4.3 DRV_STATUS- Drive Status Flag

0x6F:DRV_STATUS-driver status flag and current reading			
Bit	**name**	**function**	**Description**
31	stst	Stand still indicator	This flag indicates that the motor has a stall condition, which occurs when the step length is greater than 2 ^ 20 clocks.
30	silent	Silent mode indicator	1: the driver works in silent mode 0: the drive works in fast mode
29... 24		reserved	Ignore these bits
23... 21		reserved	Ignore these bits
20	CS_ ACTUAL	True motor current	Real current, control current reduction, used to monitor automatic current adjustment.
19			
18			
17			
16			
15... 12		reserved	Ignore these bits
11	t157	157C comparator	1: Temperature threshold exceeded
10	t150	150C comparator	1: Temperature threshold exceeded
9	t143	143C comparator	1: Temperature threshold exceeded
8	t120	120C comparator	1: Temperature threshold exceeded
7	OLB	Phase B open circuit indicator	Phase A and phase B open circuit detection.(1:open) Note: Error detection may occur in the state of fast motion and stall, and can only be detected at low speed.
6	OLA	Phase A open circuit indicator	
5	s2vsb	B phase low side short circuit indicator	A phase and B phase low side short circuit detection, the driver turned off.The error flag remains until the drive is closed due to TOFF = 0 or ENN set high.This sign is independent of the dual chopper mode.
4	s2vsa	A phase low side short circuit indicator	
3	s2gb	Phase B earth short circuit indicator	Phase A and phase B ground short circuit detection, the driver turns off.The error flag remains until the drive is closed due to TOFF = 0 or ENN set high.This sign is independent of the dual chopper mode.
2	s2ga	Phase a ground short circuit indicator	
1	Ot	Over-temperature	The selected over temperature limit is exceeded until the OTPW is cleared due to chip cooling and the driver is turned on.
0	OTPW	Over-temperature warning	The selected over temperature warning temperature limit has been exceeded.

4.Silent Mode

Silent mode is a very low noise control mode of stepper motor.It is based on PWM voltage control mode.The motor is almost no noise even working in static or low speed.Thus, the silent mode is suitable for indoor or home applications.The vibration of the motor at low speed is also small.The voltage mode of silent mode obtains current by driving subdivided voltage to the coil.The driver can automatically adapt to the environment without additional setting.For some special cases, some optional configurations are provided.For high speed drives, the combination of fast mode and silent mode should be considered.

4.1 Automatic Adjustment

Silent mode integrates an automatic adjustment program, which can adjust the most important parameters to adapt to most motors.In this way, silent mode allows high dynamic characteristics and can support operation at very low current.There are two steps to get good control results: the motor starts from the static state and at the nominal run current (at AT#1).The motor runs at medium speed and is automatically adjusted (at AT#2).

Fig. 4.1 shows the adjustment sequence diagram.

The following table shows the conditions of at AT#1 and at AT#2.

Step	Parameter	Condition	Duration
AT#1	PWM_OFS_AUTO	The motor is at rest and the current adjustment value is equal to the running current setting (*IRUN)* If the standstill current reduction function is enabled (PDN_UART = 0), an initial step pulse will make the current return to the operating current. Pins VS and VREF pins are in normal level	≥2^20+2*2^18 t_{clk}， ≥130ms (use internal clock)
AT#2	PWM_GRAD_AUTO	The motor must operate at a speed with a significant amount of back EMF and the maximum run current.Conditions: 1.5*PWM_OFS_AUTO< PWM_SCALE_SUM <4 *PWM_OFS_AUTO PWM_SCALE_SUM<255 Suggestion: the motor works best at 60 to 300 rpm	It takes 8 fullsteps to achieve + / - 1. For a standard motor with PWM_GRAD_AUTO value at 64 or less, it needs 400 full step adjustments when starting from OTP default 14.

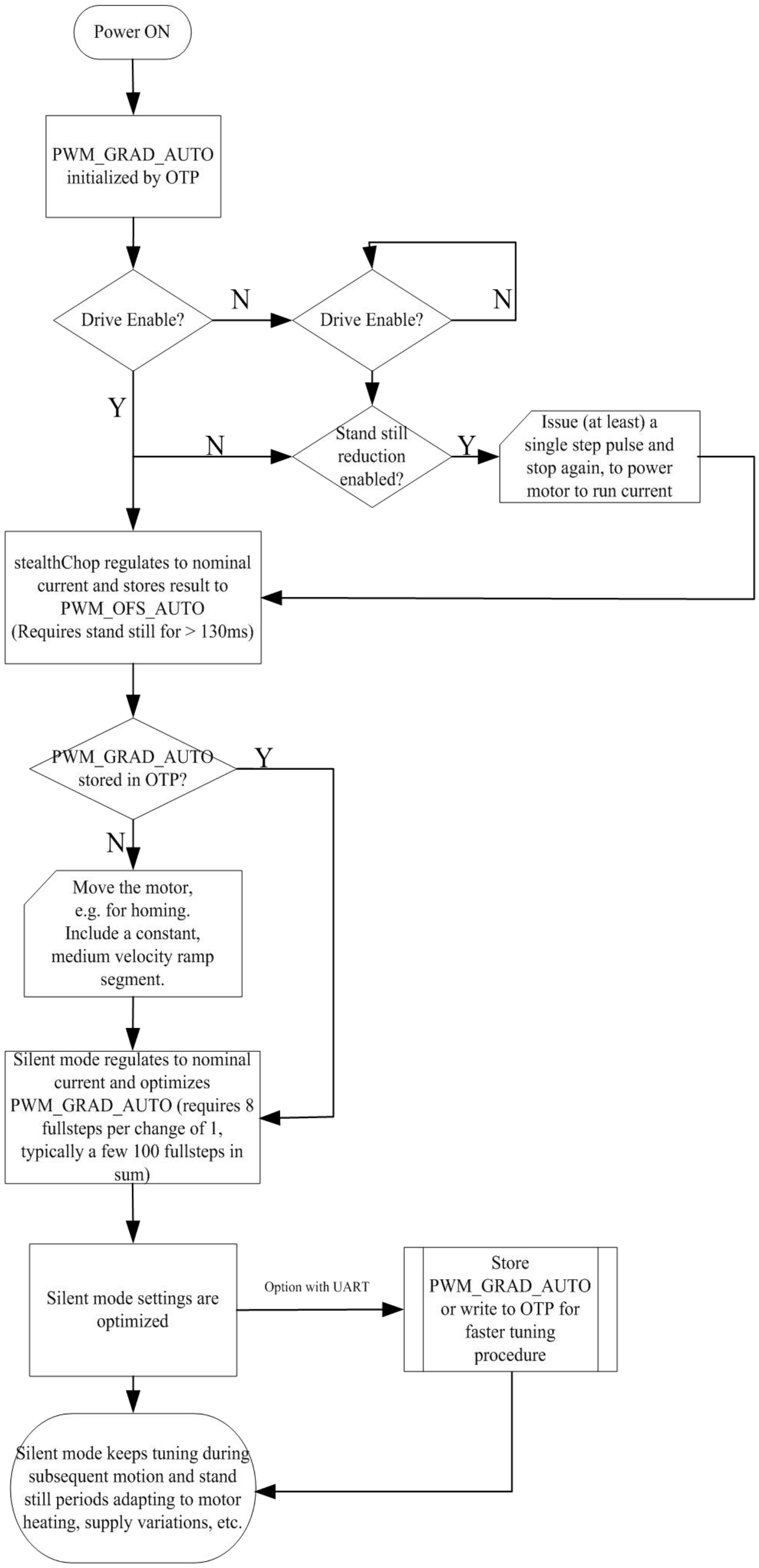


Figure 4.1 automatic adjustment procedure of silent mode

Attention:

Changing VREF and power VS will make the result of automatic adjustment invalid.Motor current regulation cannot compensate for this significant adjustment until the arrival of the next AT#1.

4.2 Silent Mode Options

In order to match the current to a fixed value, the effective PWM voltage needs to be adjusted according to the actual speed of the motor.Several additional conditions affect the actual effective voltage: the motor impedance, the reverse electromotive force (EMF) of the motor (i.e. proportional to the speed).
There are two PWM adjustment methods: automatic adjustment mode using current feedback (PWM_AUTOSCALE=1, PWM_AUTOGRAD=1) and a forward speed control mode.The forward speed control mode is not affected by the power supply voltage, such as motor stall.But it provides a very stable amplitude. It does not need any current detection.Thus, it is suitable for common motor types and voltage environment.Therefore, we suggest to use the automatic adjustment mode, unless current stall can not meet the given working conditions.

Customers are advised to use automatic adjustment mode.The forward speed control mode is a non-automatic adjustment mode (PWM_AUTOSCALE = 0) which can only be used in the normal motor and operating conditions.In this case, it is needed to program through UART interface.The operating parameters PWM_GRAD and PWM_OFS can be initialized in automatic control mode.In the non automatic mode, the power supply current directly reflects the mechanical load change of the motor.

The PWM frequency selection in silent mode is obtained by different frequency division of clock frequency. Setting the frequency at 20-50 kHz meets most requirements. This setting mainly considers the balance between low current ripple, high-speed characteristics and dynamic power consumption.

Silent Mode Frequency Selection				
Clock frequency f_{clk}	**PWM_FREG=%00** **$f_{PWM}=2/1024f_{CLK}$**	**PWM_FREG=%01** **$f_{PWM}=2/683f_{CLK}$**	**PWM_FREG=%10** **$f_{PWM}=2/512f_{CLK}$**	**PWM_FREG=%11** **$f_{PWM}=2/410f_{CLK}$**
18MHz	35.2kHz	52.7kHz	70.3kHz	87.8kHz
16MHz	31.3kHz	46.9kHz	62.5kHz	78.0kHz
12MHz	23.4kHz	35.1kHz	46.9kHz	58.5kHz
10MHz	19.5kHz	29.3kHz	39.1kHz	48.8kHz
8MHz	15.6kHz	23.4kHz	31.2kHz	39kHz

4.3 Silent Mode Current Regulator

In silent mode, automatic regulation function (PWM_AUTOSCALE=1, PWM_AUTO_GRAD = 1) adjust the current to the required setting value.Automatic regulation is used as part of the automatic adjustment program to track the parameter changes of the motor.The driver detects the actual current during the chopper on time and uses a proportional regulation to adjust the PWM_SCALE_AUTO value to match the motor current to the target value.PWM_REG is the setting register for the proportionality factor.In theory, the smaller the proportionality factor , the better.So that a more stable and gentle adjustment process can be obtained.And at the same time, it should be large enough to make the driver respond quickly to the current change of the motor (such as changing VREF).In the initial stage of automatic adjustment of at AT#2, PWM_REG is also used to compensate for motor speed changes.Therefore, the fast acceleration during AT#2 devices requires a larger PWM_REG value.PWM_REG setting needs to meet the slope requirements of acceleration and deceleration.The value of PWM_REG during AT#2 and the finished automatic adjustment program (or non-automatic settings for PWM_OFS and PWM_GRAD)) can be judged by monitoring the current in acceleration period.As shown in Fig. 4.2 :

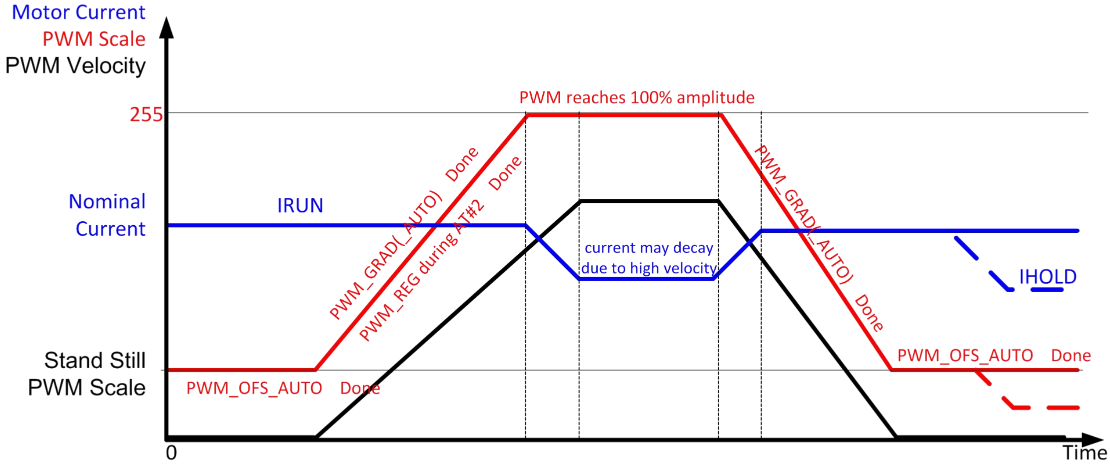


Figure 4.2 PWM_GRAD and PWM_OFS setting

4.3.1 Minimum Current Limit

The silent mode chopper current regulator requires a minimum motor current value.Since the coil current can only be obtained by detecting the voltage on the sampling resistor when the chopper controller is on, the minimum chopping regulator current is determined by the blank time TBL and the chopping frequency.The increase of supply voltage and chopping frequency will increase the minimum current, while the small TBL setting will decrease the minimum current.Correct determination of PWM_OFS_AUTO is very important. In the automatic adjustment at AT#1 stage, the current is determined by the sampling resistance, VREF and IRUM.Lower current (such as static low power state) is controlled by PWM_OFS_AUTO and PWM_GRAD_AUTO, which are determined by PWM_OFS and PWM_GRAD.The motor current can reach zero in the free rotation state.

When the minimum coil current is in automatic regulation mode, the limit formula is as follows:

$$I_{lowerlimit}=t_{BLANK}*f_{PWM}*V_M/R_{COIL}$$

V_M is the power supply voltage of the motor and R_{coil} is the internal resistance of the motor coil.The $I_{lowerlimit}$ can be considered as the minimum normal operating current set by the IRUN.

Examples are as follows:

The internal resistance of the motor is 5Ω and the power supply voltage is 24 V.TBL = %01, PWM_FREQ= %00, t_{BLANK} is equal to 24 clock cycles, f_{PWM} is equal to 2 / (1024 clock cycles)

$$I_{lowerlimit}= 24*t_{CLK}*2/1024/t_{CLK}*24V/5\Omega=225mA$$

This means, the target current for automatic adjustment of the motor needs to be larger than 225mA.The minimum current will also affect the current setting of VREF.

Note: when in automatic adjustment mode, pay attention to the minimum current limit.In AT#1 stage of automatic adjustment, it must be larger than this minimum current.This minimum current can be measured with a current probe by setting the operating current IRUN or holding current IHOLD.

4.4 Speed Regulation

The silent mode speed regulation function is based on the time between two step signals, such as TSTEP, which is measured in clock cycle.In principle, the current test is not required for the feedback loop is not necessary.When PWM_AUTOSCALE = 0,a pure velocity based scaling is available via UART programming.The basic theory is that an approximate linear voltage is needed to obtain a target motor current.The internal

resistance of the motor is R. according to the current formula I = U / R, U is the value after the power supply voltage being modulated by PWM.Initial PWM_AMPL is calculated as follows: PWM_APML=374*R_{COIL}*I_{COIL}/V_M
The effective PWM voltage U_{PWM} (0.707 x peak voltage) is obtained by subdividing the sinusoidal wave with peak value of 248 by 8bit:

$$U_{PWM}=V_M*PWM\_SCALE/256*248/256*0.707=V_M*PWM\_SCALE/374$$

When the motor speed increases, the motor will produce a reverse electromotive force. The value of the electromotive force is proportional to the motor speed, which will reduce the limited voltage loaded on the coil resistance and reduce the current.The MS35775 provides a second speed parameter PWM_GRAD to compensate for this reverse electromotive force.The total effective PWM amplitude (PWM_SCALE_SUM) in this mode is depended on the frequency of the subdivision micro-step.The calculation is as follows:

$$PWM\_SCALE\_SUM=PWM\_OFS+PWM\_GRAD*256*f_{STEP}/f_{CLK}$$

The first order approximate calculation formula of PWM_GRAD：

$$PSM\_GRAD=C_{BEMF}[V/（rad*s）]*2\pi*f_{CLK}*1.46/（V_M*MSPR）$$

C_{BEMF} is the reverse electromotive force constant, in volts per rad per second, and MSPR is the number of subdivided steps per rotation, such as 51200 = 256 microsteps x 200 whole steps per rotation (1.8 ° motors)

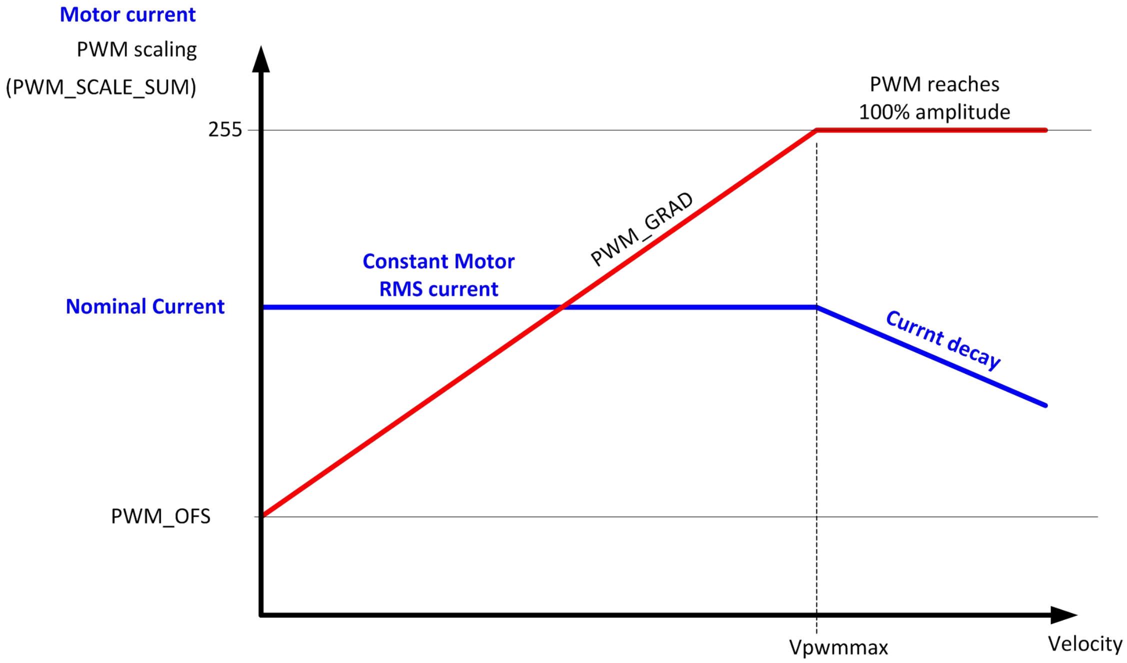


Figure4.3 Velocity based PWM scaling (PWM_AUTOSCALE=0)

Summary: PWM_OFS and PWM_GRAD can get the appropriate value by tracking the motor current with an oscilloscope.Automatic adjustment mode can be selected to determine this values and they also can be read from PWM_OFS_AUTO and PWM_GRAD_AUTO.

The reverse electromotive force constant of the motor:

The source of back EMF is related to the rotation of the motor. The general motor does not indicate this parameter, but indicates the attenuation of torque and current.In SI units, the back electromotive force constant C_{BEMF} is consistent with the unit of torque constant.For example, if the motor rotates at 1rps (1 rps per second = 6.28rad/s), it will produce a back electromotive force of 6.28v.Therefore, the formula for calculating the constant of reverse electromotive force is:

$$C_{BEMF}\,[V/\ (rad/s)] = Holding\ Torque[Nm]/I_{COILNOM}[A]/2$$

$I_{COILNOM}$ is the holding torque which is corresponding to the specific phase current of the motor.HoldingTorque is the holding torque of the motor, and two coil currents are all $I_{COILNOM}$.The unit of torque is [Nm], 1Nm = 100Ncm = 1000mNm.

Voltage is the effective voltage, which is valid in every coil, so the current in the formula needs to be multiplied by 2.

4.5 Combination Of Silent Mode And Fast Mode

In some high-speed motion modes, fast mode is more stable.MS35775 can combine silent mode and fast read mode by setting a speed conversion point.This speed conversion point (TPWMTHRS) can be written to the OTP.In this mode, silent mode works at low speed.

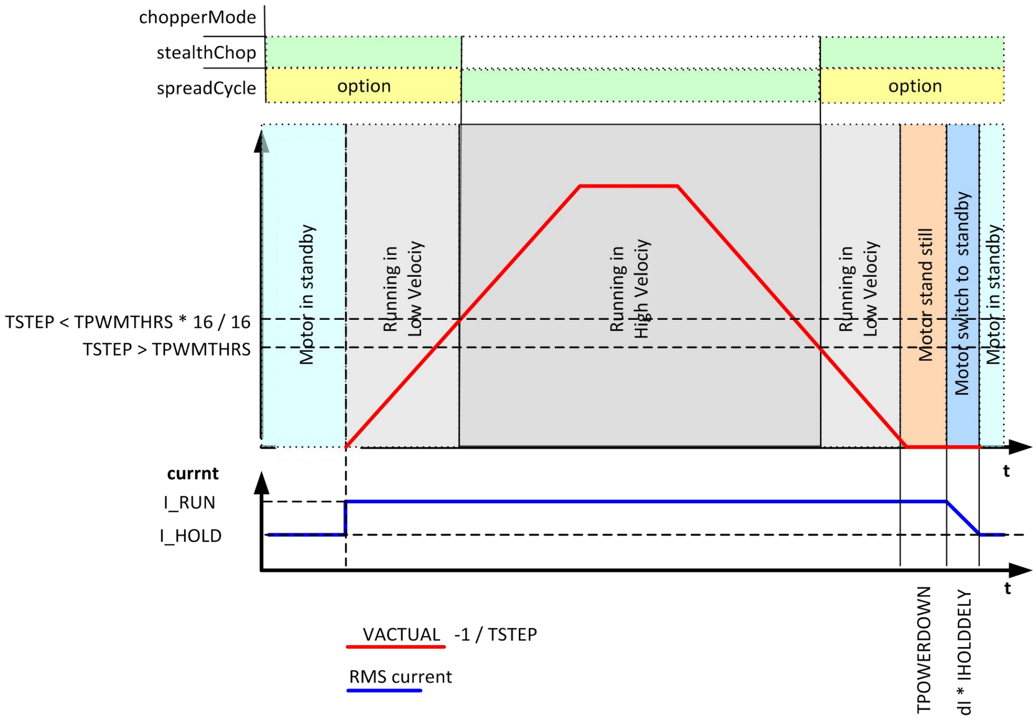


Figure 4.4 optional TPWMTHRS control mute and fast mix mode

In the first step, the parameters of the two modes need to be set separately (the parameters of fast mode can be written into OTP), and the next step is to set a conversion speed so that the low-speed mode works in silent mode and the high-speed mode works in the fast mode.TPWMTHRS is used to set the conversion speed.TSTEP can be read out at the required speed of the motor, and then written into TPWMTHRS.Using a low conversion speed to avoid the current overshoot during reversal.

There will be large current overshoot burr when the mode conversion is carried out at high speed. This is due to the back electromotive force worked(with the increase of speed), the voltage and current phase difference of the motor will be 90° .So the switching between the two modes will lead to the sharp increase of burr.The burr current is large enough to even exceed the over-current point (depending on the motor impedance).At low speeds (e.g. 1 to 10 RPM), this burr is negligible for most motors.Thus, with this current glitch in mind, if you just need silent mode, set TPWMTHRS to 0.

When the silent mode is used for the first time, the motor needs to be at rest for proper current adjustment.When the motor changes from high speed to silent mode, the chopper logic loads the result of the last current rectification until the motor returns to a lower speed.In this way, at the beginning of silent mode, the regulator has a known starting point when it returns to low speed.Therefore, when switching mode, it is not necessary to consider the speed conversion point and voltage change, because the motor will not lose step or the transient current will not be too large or too small.

Motor stalling or sudden change of speed may be considered as detection of short circuit or automatic adjustment of current, which cannot be recovered by itself.At this time, it is necessary to clear the wrong indication signal and restart the motor to recover to this state from zero speed.

Motor stalling may cause over-current condition, which depends on motor speed and motor coil impedance.At low speed, the back EMF is only a small part of the supply voltage, and there is no risk of a short circuit.

Summary: When switching to silent mode for the first time, start motor and stop at least 128 chopping cycles for initial silent mode to do standstill current control.

4.6 Indication Signal Of Silent Mode

The silent mode is driven by voltage mode, and the state indicator is based on current detection which is slow, especially due to the sudden change of back EMF, such as motor stall, the driver will delay the indicator.

4.6.1 Load Open Circuit Indication Signal

In silent mode, the status indication information is different from that in speed mode.

-- Unsymmetrical detection resistors or coils produce flashing OLA or OLB

-- Interrupted motor coils provide a continuous open indication of the output coil

-- If the current regulation fails to reach the target current (no motor contact or speed exceeds PWM limit) in the past several full steps, one or two indicators will be effective.

If necessary, doing a load open circuit output test by using fast mode, because it outputs the safest results.By reading the value of PWM_SCALE_SUM in static mode can detect the coil internal resistance.

4.6.2 PWM_SCALE_SUM Feedback Motor Status

In automatic regulation mode, PWM_SCALE_SUM can feed back the working state of the motor.Because this parameter reflects that the effective voltage applied to the motor at a specific current, it depends on several factors: motor load, coil impedance, supply voltage, current setting, etc.When the detection value reaches the limit (255), the current regulator cannot meet the current requirements.

4.7 Free Rotation And Passive Braking

The silent mode provides different modes for the static state of the motor.These modes are selected by setting the standstill current IHOLD to 0 and selecting the desired mode through FREEWHEEL.These patterns become enable over a period of time specified by TPOWERDOWN and IHOLD_DELAY.When the target current of the motor is zero, the current regulator is closed to ensure a quick start.Free rotation mode can realize free rotation and passive braking.Passive braking is a rotary socket current brake, which consumes very little current for there is no actual current injected into the coil.Therefore, the passive brake can allow the motor slow commutation under continuous torque.

Summary: when using the motor to operate in silent mode, carrying mechanical load can make the motor performance be better, which also can prevent mechanical oscillation when no-load.

Parameters Related To Silent Mode			
Parameter	**Function description**	**value**	**explain**
EN_QUICK	Silent mode invalid bit, input pin QUICK and this register signal do XOR operation	1	Do not use silent mode
		0	Use silent mode
TPWMTHRS	Set the maximum speed of silent mode. Entry the TSTEP reading (time between two microsteps) when operating at the desired threshold velocity	0 … 1048575	Silence mode is invalid when TSTEP is lower than TPWMTHRS
PWM_LIM	Set to limit current jerk when switching from fast mode to silent mode.Reduce the value to yield a lower current jerk.	0 … 15	The upper 4 bits of 8 bit output amplitude register (default = 12)
PWM_AUTOSCALE	Enable automatic current scaling using current measurement or use forward controlled velocity based mode.	0	forward controlled mode
		1	Automatic current mode
PWM_ AUTOGRAD	Enable automatic tuning of PWM_GRAD_AUTO	0	Non-automatic mode, using Value of PWM_GRAD
		1	Automatic mode
PWM_FREQ	PWM frequency selection.The lower the setting, the better. The chopper frequency measured at the output is 1 / 2 of f_{PWM}.	0	f_{PWM}=2/1024 f_{CLK}
		1	f_{PWM}=2/683 f_{CLK}
		2	f_{PWM}=2/512 f_{CLK}
		3	f_{PWM}=2/410 f_{CLK}
PWM_REG	User defined PWM amplitude (attenuation) when PWM_AUTOSCALE = 1, based on speed or loop modulation attenuation	1 … 15	Results in 0.5 to 7.5 steps for PWM_SCALE_AUTO regulator per fullstep
PWM_OFS	The user-defined PWM amplitude (offset) is based on the initial value of speed modulation and automatic speed modulation *PWM_OFFS_AUTO*	0 … 255	*PWM_OFS*=0 will disable the linear current scaling based on current setting
PWM_GRAD	User defined PWM amplitude (gradient) for velocity based scaling and initialization value for automatic tuning of PWM_GRAD_AUTO.	0 … 255	The reset value can be preset by OTP
FREEWHEEL	Stand still option when current is zero (IHOLD=0）。Only in silent mode.This option will allow the motor to rotate easily, and the two coil	0	Normal operation
		1	Free rotation

	short circuit setting enables passive braking.	2	The coil is shorted via LS MOS
		3	The coil is shorted via HS MOS
PWM_SCALE_AUTO	It can read the actual adjustment and correction value of PWM voltage in silent mode	-255...255	This value is frozen in fast mode
PWM_SCALE_AUTO，PWM_OFS_AUTO	Allows monitoring of automatic regulation and determination of initial values for PWM_OFS and PWM_GRAD.	0...255	read-only
TOFF	Generally, as an enable drive, the actual value has no effect on the silent mode	0	Drive off
		1...15	Drive enable
TBL	Comparator blank time.This time needs to safely cover the switching time and the ringing time on the sense resistor.Generally set 1 or 2. For high load capacitance, set 3. Low setting allows mute mode	0	$16t_{CLK}$
		1	$24t_{CLK}$
		2	$32t_{CLK}$
		3	$40t_{CLK}$

5. Fast Mode

If the silent mode is a voltage mode PWM controlled chopper, the fast mode is a periodic current control.It can react very quickly to the current speed and current of the motor.Therefore, for resonance control, the effect of fast mode application in medium and high speed situations will be better.The current through the motor coil is controlled by chopper.And this chopper works independently of each other.The phase of chopper is shown in the figure below:

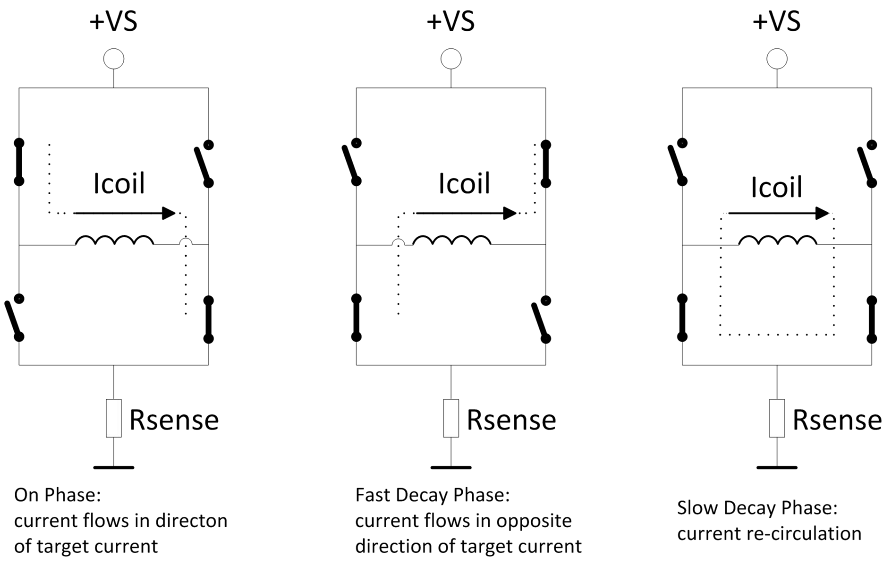


Figure 5.1 chopping phase

1.Current operation phase: the coil current works to the target current value

2.Fast decay phase: turn on two MOS opposite to the current direction for fast decay

3.Slow decay phase: open the two LSIDE MOS for slow decay

Although only using the working phase and fast decay can control the coil current, but if the slow decay phase is added, it can effectively reduce the electrical loss and the current ripple in the motor.The duration of slow decay can be set by the upper limit parameter of chopping frequency.The built-in current comparator can calculate the current coil current by detecting the current flowing through the sense resistor, while it will not be detected in the slow decay phase. So the slow decay phase time is controlled by a counter.The working phase is controlled by the current comparator. When the coil current reaches the target current value, the phase ends.The fast decay phase may be controlled by comparison or another counter at the same time.

Due to the charge and discharge of parasitic capacitor, the sense resistance will produce large spikes when coil current is switched.During this period, the current cannot be calculated in 1 to 2 microseconds.So a blank time is needed to shield these spikes.

For a motor drive, chopping frequency is a very important parameter.Too low a frequency may produce audible noise.Higher frequency will reduce the current ripple, but it will increase the magnetic loss at the same time. the power consumption of the output switch is increased by increasing the frequency.So a compromise is needed.Most motors choose to operate between 16KHz and 30kHz.The chopping frequency is affected by many parameter settings, as well as the motor inductance and supply voltage.

Tips:

When using the fast mode, the chopping frequency should be between 16KHz and 30kHz.Higher frequency will bring higher switching loss.

5.1 Quick Mode Setting

The fast mode uses a simple and accurate algorithm to automatically select the optimal fast decay phase time length.Even under the default settings, fast mode can provide better micro stepping quality.There are several parameters for setting the chopper to suit the application.

Each chopping cycle includes a working phase, a full decay phase, a fast decay phase and a second slow decay phase.Two slow decay phases and two blank times in each chopping cycle are set with an upper limit according to the chopping frequency.The slow decay phase usually accounts for 30% to 70% of the whole chopping cycle, which is very important to reduce the power consumption of motor and drive.

An example of the time calculation of slow decay is as follows TOFF:

example:

Typical chopping frequency: 25kHz

Assumption: Two slow decay period is 50% of the total chopping period.

$$t_{OFF} = \frac{1}{25kHz} * \frac{50}{100} * \frac{1}{2} = 10us$$

$$T_{OFF} = (\mathrm{t}_{OFF} * \mathrm{f}_{\mathrm{CLK}} - 12) / 32$$

When the clock is 12Mhz and TOFF = 3.4, the value is 3 or 4

When the clock is 16mhz and TOFF = 4.6, the value is 4 or 5

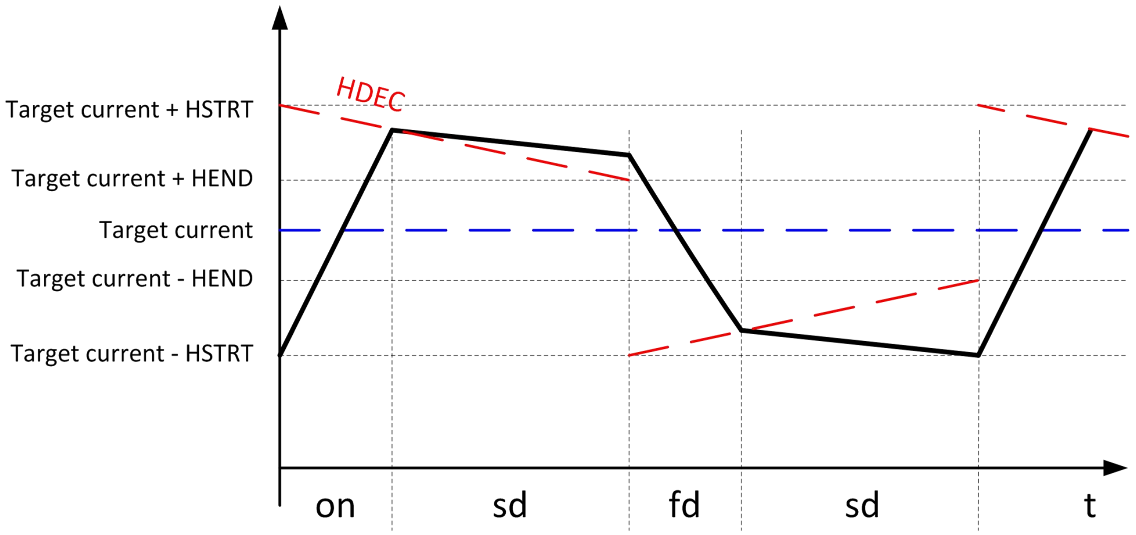
The start lag can minimize the ripple introduced by the drive.In order to obtain the best micro-step condition, the current ripple must be higher than that caused by resistive loss in the motor.This will allow the chopper to accurately control the rising and falling currents.The time required to introduce the current ripple to the motor coil will also reduce the chopping frequency.Therefore, a higher hysteresis setting results in a lower chopping frequency.The inductance of the motor itself limits the performance of the chopper to follow a variable motor current.In addition, the time of working mode and quick response mode must exceed the blank time for the duration which the comparator is not working.

It is the easiest way to find the best setting through a low hysteresis setting (e.g. HSTRT = 0, HEND = 0), and then continuously increase HSTRT until the motor operates smoothly at a low speed setting.This can be detected by a current probe or sense resistance voltage.Check that there is a small step where the sine wave shape is close to 0, which is to prevent the hysteresis setting from being too small.At moderate speeds (100 to 400 full steps per second), a low hysteresis setting can cause vibration and low noise in the motor.

There is no step in the current with an effective hysteresis setting, and a too large hysteresis setting will reduce the chopping frequency and increase the chopping noise without any benefit to the waveform.

Experiments have shown that the settings between different motors are independent, because high current motors usually have lower resistance.Therefore, choosing a low to medium hysteresis value can usually satisfy most applications.This setting can be optimized by continuous experiments with the motor.A too low setting will reduce the accuracy of the micro-step, and then too high settings will lead to more chopping noise and motor power consumption.When we observe the voltage of sense resistance under the standstill of a medium current motor on the oscilloscope, a too low setting shows that a fast decay time is not as long as the blank time.This setting is optimal only if the fast decay time is slightly longer than the blank time.If it is difficult to achieve, you can reduce the turn off time setting.

Hysteresis principle can result in very low chopping frequencies in some cases, such as high coil resistance compared to the supply voltage.It is necessary to avoid dividing the hysteresis settings into start setting (HSTRT + HEND) and end setting (HEND).An automatic hysteresis attenuator (HDEC) is interleaved between the two settings to reduce the value of hysteresis each 16 clocks.At the beginning of each chopping cycle, the hysteresis begins at the sum of a start value and an end value (HSTRT + HEND), and decreases during the cycle until the end of the chopping cycle or the end of hysteresis value (HEND) reaches.In this way, the chopping frequency can work stably in high amplitude and low power supply occasions, if the chopping frequency is too low.This prevents the frequency from reaching the audible range.



Parameter	Description	Set up	Explain
TOFF	Set the slow decay time (turn off time).This setting also limits the maximum chopping frequency. In silent mode, this parameter is not used, but it is necessary to start the motor.In silent mode, any setting is OK. Setting this parameter to 0 causes the drive tube to close and the motor to free-wheel.	0	Chopper off
		1...15	Turn off time setting: nclk = 12 + 32 * TOFF (when equal to 1, it will work at the minimum blank time of 24 clocks)
TBL	Blank time of Comparator.The value of this time needs to be set carefully to cover the entire process.In most applications, set 1 or 2.For high capacity loads, you need to set 2 or 3	0	16 t_{CLK}
		1	24t_{CLK}
		2	32t_{CLK}
		3	40t_{CLK}
HSTRT	Hysteresis start setting.This value is a compensation for the end value of hysteresis HEND.	0...7	HSRT=1...8 This value needs to be added with HEND
HEND	Hysteresis end setting.Set the end value of hysteresis after a period of amplitude reduction.The sum of HSTRT + HEND must be ≤ 16. When a current is set to a maximum of 30 (the amplitude is reduced to 240), this sum value is unlimited.	0...2	-3... - 1: negative HEND
		3	0:0HEND
		4...15	1...12 Positive HEND

When HSTRT = 0 and HEND = 0, a minimum hysteresis is set.

give an example:

If it is necessary to design a hysteresis of 4, and it is not necessary to decide to use hysteresis decay.It can be set as follows:

HEND = 6 (valid end value is 6-3 = 3)

HSTRT = 0 (set minimum hysteresis, 1:3 + 1 = 4)

In order to make full use of variable hysteresis, we can set most values to HSTRT, such as 4,:

HEND = 0 (set valid end value to - 3)

HSTRT = 6 (set valid start value of hysteresis end as + 7: 7-3 = 4)

6.Sense Resistance

The maximum motor current required can be set by selecting a suitable sense resistor.The following table shows the corresponding relationship between the average current and the selected sense resistor.

Selection of R_{sense} resistance and corresponding maximum motor current

R_{SENSE} [Ω]	RMS current [a] VREF = 2.5V or open; IRUN=31， V_{sense} = 0 (standard)	Applicable motor type
1.00	0.23	300mA motor
0.82	0.27	
0.75	0.30	
0.68	0.33	400mA motor
0.50	0.44	500mA motor
0.47	0.47	
0.39	0.56	600mA motor
0.33	0.66	700mA motor
0.27	0.79	800mA motor
0.22	0.96	1A motor
0.18	1.15	1.2A motor
0.15	1.35	1.5A motor
0.12	1.64	
0.10	1.92	

Sense resistors are need to be carefully selected.All the motor current flows through the sense resistor.Due to the chopper switch output power transistor, pulse current will be see at the sense resistor.Therefore, a low inductance type such as thin film or composite resistor is needed to prevent voltage spikes causing ringing at the induced voltage input, resulting in unstable measurement results.In addition, low inductance, low resistance PCB layout is essential.Any common GND path between the two sense resistors must be avoided, because this will result in coupling between the two current sensing signals.A huge ground level is the best.

In the standby state of the motor, the sense resistor needs to be able to transmit the peak coil current unless the standby power consumption is reduced.Under normal conditions, the conductivity of the sense resistor is less than the root mean square current of the coil because there is no current flowing through the sense resistor in the slow decay stage.For most applications, the 0.5W type is sufficient to achieve a current of 1.2A RMS.

Attention should be paid to symmetrical sense resistor layout and short and straight sense resistor tracks of the same length.Well matching sense resistors ensure optimal performance. Compact layout and large grounding area can avoid parasitic resistance effect.

7.Motor Current Control

The current of the motor is set by the resistance of the sense resistor.There are several conditions that allow to reduce the motor current, for example, to accommodate different motors, or under static or low load conditions.

Method Of Measuring Motor Current			
Method	**Parameter**	**Range**	**Basic application**
VREF Pin voltage (Chapter 9.1)	VREF can be used to adjust IRUN and IHOLD, and can be control through GCONF. I_scale_Analysis enable	2.5V: 100%... 0.5V: 20% >2.5V or suspended: 100% < 0.5V: not recommended	-Fine tune motor current to suit motor type -Manual adjustment via poti -Delay or soft start -Quiescent current reduction (extended cycle only)
ENN Pin	Disable / enable output driver	0: Motor enable 1: Motor disabled	Disable the motor to allow free rotation
PDN_UART Pin	Disable / enable quiescent current reduction to IHOLD	0: Current reduction enabled 1: Disabled	Enable current reduction to reduce temperature rise in stand still
OTP storage	OTP_IHOLD OTP_IHOLDDELAY	9% to 78% quiescent current. Reduction in about 300 ms to 2.5 s	Adjust the current to suit various applications to achieve high efficiency and low heating
OTP storage	OTP_internalRsense	0: Use external inductive resistance 1: Use internal inductive resistance	Save two sense resistors on the BOM and set the current through a cheap 0603 resistor
UART interface	IHOLD_IRUN TPOWERDOWM OTP	IRUN,IHOLD 1 / 32 to 32 / 32 of full scale current	-Fine programming of run and hold (quiescent) current -Changing the IRUN of the motor current under certain conditions -Setting OTP options
UART interface	CHOPCONFIG.VSENSE flag	0: normal, most stable 1: Reduce the voltage	-Use a smaller 0.25W resistor to set VSENSE for get lower voltage

Select suitable sense resistor to provide sufficient current for the motor at full current scale (VREF = 2.5 V).The default scale (IRUN = 31).

Calculation formula of RMS operating current in independent mode

$$I_{RMS} = \frac{300mV}{R_{SENSE} + 30m\Omega} * \frac{1}{\sqrt{2}} * \frac{V_{VREF}}{2.5V}$$

RMS current calculation formula of UART configuration or holding current setting:

$$I_{RMS} = \frac{CS + 1}{32} * \frac{V_{FS}}{R_{SENSE} + 30m\Omega} * \frac{1}{\sqrt{2}}$$

CS is the current scale setting forIHOLD and IRUN

V_{FS} is the full amplitude voltage controlled by the VSENSE (refer to electrical characteristics,V_{SRTL} and V_{SRTH}).The default value is 325mv.

When set to analog VFS (I_scale_analog=1,default).The calculation formula of voltage V_{FS} is as follows:

$$V_{FS}' = V_{FS} * \frac{V_{VREF}}{2.5V}$$

Where V_{VREF} is the voltage on the pin VREF, between 0 and 2.5V.

In order to get the best accuracy of current setting, it is necessary to continuously measure and fine tune the current in the application.

Motor Current Control Parameters			
Parameter	**Description**	**Setting**	**Explain**
IRUN	The current scale when the motor is running.The coil current value is generated according to the internal sine wave meter.For high-precision motor operation, a current scale factor between 16 and 31 is used, because reducing the current value will make the microstep coarser, thus reducing the effective microstep resolution.	0...31	Scale factor 1/32，2/32，...32/32 IRUN is full scale in stand-alone mode (setting 31)
IHOLD	Like the IRUN, the motor operates in a stationary state.		
IHOLD DELAY	It is allowed to decrease smoothly from running current to holding current.IHOLDDELAY controls the number of clock cycles of motor power failure after TPOWERDOWN in increments of 2 ^ 18 clock: 0 = instantaneous power off, 1.. 15: the per current step of current reduction delay is a multiple of 2 ^ 18 clock. Example: when using IRUN = 31 and IHOLD = 16, 15 current steps are required to keep the current down.Therefore, setting IHOLDDELAY to 4 will results in a power-off time of 4 * 15 * 2 ^ 18 clock cycles, which is about one second at 16 MHz clock frequency	0	InstantIHOLD
		1 ... 15	1*218 ...15*218 Clock number per current decay
TPOWER DOWN	Set the delay time from static mode (stst) to motor off.The time range is about 0 to 5.6 seconds.	0 ... 255	0 ... ((2^8)-1)*2^18 tCLK The minimum setting is 2 to allow automatic PWM_OFFS_AUTO adjustment
VSENSE	The sense resistor voltage range that allows control of full scale current.Low voltage range can reduce the power consumption of sensing resistor.	0	V_{FS}=0.3V
		1	V_{FS}=0.165V

7.1 Analog Current Setting VREF

When we need high flexibility output current, we can control the current through the analog input of the driver, instead of selecting a set of different sensing resistors or using the IRUN or IHOLD parameters through the interface to reduce the operating current.In this way, a simple voltage divider realizes that a circuit board to adapt to different motors.

Adjust The Motor Current

The MS35775 provides an internal reference voltage for current control, dividing directly from a 5VOUT supply.Alternatively, an external reference voltage can be used.The reference voltage applied to the chopper comparator will decrease proportionally.The chopper comparator compares the voltages on the BRA and BRB with the scale reference voltage used for current regulation.When I_scale_analog in GCONF is enabled （default).The external voltage on VREF is amplified and filtered and used as a reference voltage.A 2.5 V voltage (or any voltage between 2.5 V and 5 V) provides the same current scale as the internal reference voltage.A voltage between 0 V and 2.5 V can scales the current linearly, between 0 and the current scale defined by the induced resistance setting.It is not recommended to operate the reference voltage below 0.5 V to 1 V, because the chopping accuracy at low VREF voltages is greatly affected by the relative analog noise caused by digital circuitry and power supply ripple .In order to obtain the best accuracy, select the sense resistor in the way of the required maximum value, choose VREF between 2V and 2.4V to ensure the normal operation current of the motor.

Driving Method

The simplest way to supply voltage to VREF is to use a voltage divider from a stable supply voltage.Or DAC output of microcontroller.At the same time, PWM signal is allowed for current control.PWM uses additional R / C low-pass conversion to analog voltage on VREF pin.The PWM signal controls the analog voltage.Selecting R and C values to form a low-pass filter, using PWM frequency needs to be much higher than 10 kHz.In addition, VREF provides an internal low-pass filter with a bandwidth of 3.5khz.

Using a low reference voltage (e.g. less than 1V), if a high current driver is used to adapt to a low current motor, the simulation performance will be degraded.In order to achieve the best results, adjust the sense resistor to suit the required motor.

8.Internal Sense Resistor

MS35775 provides an internal sense resistors, which can save external sense resistors.In this mode, the external sense resistor is omitted (short circuit), and the internal on-resistance of the power field effect transistor is used for current measurement (see Chapter 3.2).Because MOSFETs are temperature dependent and easy to produce impurities, a micro external resistor connected from + 5VOUT to VREF provides an accurate absolute current reference.This resistor converts 5V voltage into a reference current.Ensure that in this mode, the BRE pin and BRB pin are directly connected to GND near the IC package.This mode is enabled by setting the internal sensor in GCONF (OTP option).

Comparison of internal and external sensitive resistance modes		
Content	**Internal sense resistor mode**	**External sense resistor mode**
Ease of use	OTP parameters need to be set	default
cost	Save 2 sense resistors	
Current accuracy	Slightly lower	good
Recommended current operating range	200mA to 1.2A	50mA to 1.4A
Recommended working mode	silent mode, In fast mode, the performance is slightly reduced when the current exceeds 1A	Silent mode or fast mode

Although RDSON based measurement brings benefits which related to the cost and size of the driver, it provides a slightly lower accuracy of coil current regulation than the external sense resistor.The internal sense resistor has a certain temperature dependence, which is automatically compensated by the driver chip.However, for high current motors, the temperature gradient between the sense resistor inside the IC and the compensation circuit will cause about 10% initial current overshoot during driver IC heat up. Although this phenomenon is shown for about one second, it may even help to increase torque during initial motor acceleration.

Working Principle:

The current flowing into the VREF pin can be used as the reference current of the motor.When setting the current, a resistor (R_{REF}) needs to be connected between 5VOUT and VREF (PLS)(Please refer to table for resistor selection).The input resistance of VREF is about 1kΩ.The resulting current flowing into VREF is amplified about 3000 times.Therefore, a current of 0.5mA can produce a peak motor current of 1.5A.The internal resistance of VREF should be considered when calculating the reference resistance.

Selection of R_{REF} resistor		
R_{REF}[Ω]	**Peak current [A]（CS=31，VSENSE=0）**	**RMS current[A]（CS=31，VSENSE=0）**
6.8k	1.92	1.35
7.5k	1.76	1.24
8.2k	1.63	1.15
9.1k	1.49	1.05
10K	1.36	0.96
12K	1.15	0.81
15K	0.94	0.66
18K	0.79	0.55
22K	0.65	0.45
27K	0.60	0.42
33K	0.54	0.38

VSENSE = 1 allows a lower peak current setting, approximately 55% of the value generated at VSENSE = 0 (as specified by vsrth / vsrtl).In RDSON measurement mode, connect the bra and BRB pins to GND using the shortest possible path (i.e., the lowest possible PCB resistance), the combination of RDSON based measurement and silent mode is the best.When using the fast mode mode of RDSON based current measurement, chopper noise may be caused by slight asymmetry of positive current (phase) and negative current (fast decay phase).Especially when the mold temperature is high and the motor current increases.

Note: the absolute current level achieved using RDSON based current sensing may be exactly the same as the external sense resistor, depending on the PCB layout, because the tracking resistance on the BR pin will increase the effective sense resistor. Therefore, we recommend measuring and calibrating the current settings in the application.

RDSON based current sensing is suitable for motors with currents up to 1A RMS.Combined with RDSON current sensing, the effect of silent mode is better.In order to achieve the most accurate current control and the best effect of fast mode, it is recommended to use external 1% inductive resistance instead of RDSON based current control.

9.STEP/DIR Interface

STEP and DIR input provide a simple standard interface, compatible with many motor motion control.The micro step interpolator makes the motor move more smoothly.

9.1 TIMING

Figure 9.1 shows the timing parameters of STEP and DIR signals, which are Descriptiond in detail in the following table.The step signal is only valid at the rising edge.STEP and DIR signals are sampled and synchronized to the system clock. An analog filter is used to filter out the signal interference.

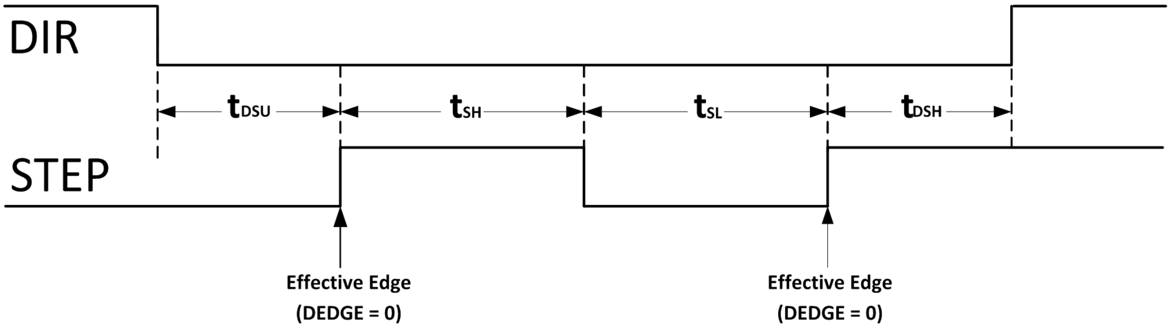


Figure 9.1 step and dir timing parameters

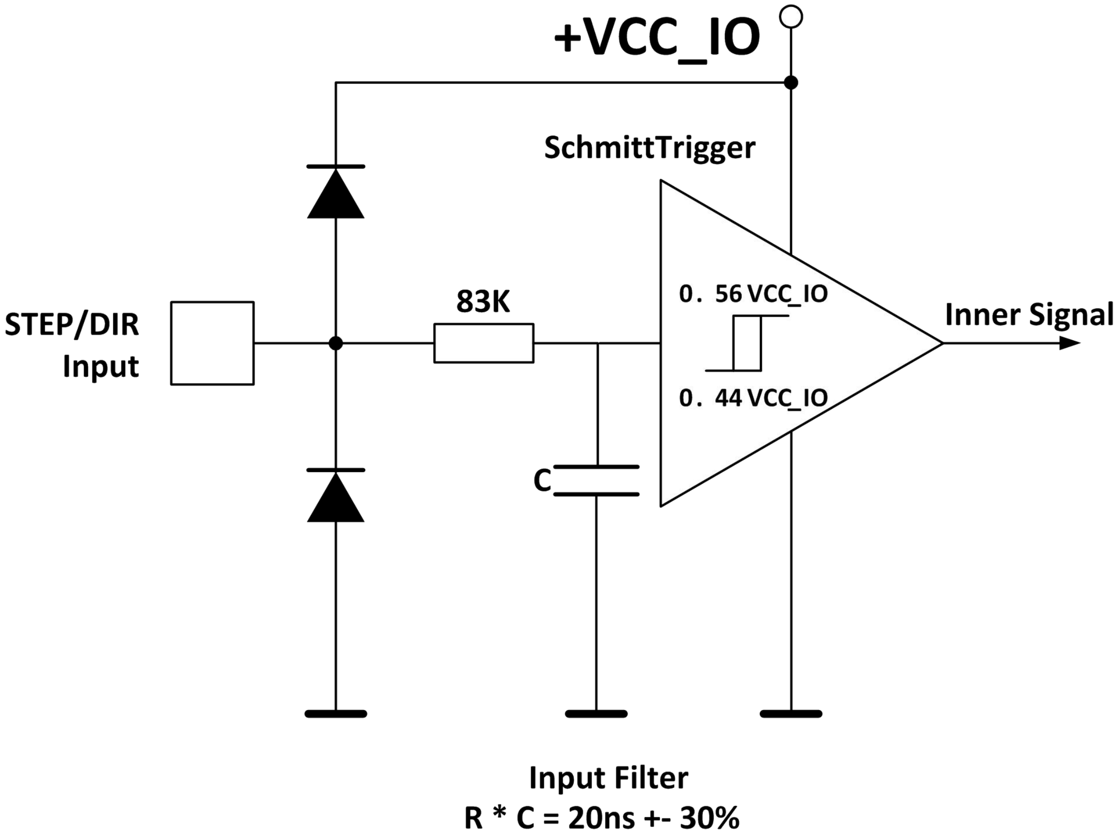


Figure 9.2 input pin filtering

STEP And DIR Interface Timing	Specification					
Parameter	Symbol	Condition	Min	Typ	Max	Unit
STEP frequency	f_{STEP}				1/2 f_{CLK}	
Full STEP frequency	f_{FS}				f_{CLK}/512	
STEP minimum low level time	t_{SL}		max(t_{FILTSD},t_{CLK}+20)	100		ns
STEP minimum high level time	t_{SH}		max(t_{FILTSD},t_{CLK}+20)	100		ns
Establishment time of DIR to STEP	t_{DSU}		20			ns
Hold time from DIR to STEP	t_{DSH}		20			ns
STEP and DIR burr filtering time	t_{FILTSD}	Rising or falling edge	13	20	30	ns
The time of STEP and DIR relative to the rising edge of sampling clock	$t_{SDCLKHI}$	Before the rising edge of the clock		t_{FILTSD}		ns

9.2 Changing Resolution

MS35775 contains an internal sine wave table with 1024 points to generate a sinusoidal motor coil current.The 1024 points correspond to one revolution or four full steps of the motor. The micro step resolution determines the width of the STEP in the table.Depending on the DIR input, the microstep counter increases (DIR = 0) or decreases (DIR = 1).Microstep resolution determines the increment and decrement. At the maximum resolution, the sequencer advances one step for each step pulse. At the half maximum resolution, the sequencer advances two step for each step pulse ,and the increment is 256 at full step.The sequencer allows two different microstep resolutions to switch seamlessly at any time.When switching to low microstep resolution, it calculates the nearest step and reads the current vector at this position.This behavior is particularly important when the resolution is low, such as full step or half step, because any fault in the sequencer can cause the motor to run asymmetrically.

Step Position	Table Location	Phase A Current	Phase B Current
Half step 0	64	38.3%	92.4%
Full step 0	128	70.7%	70.7%
Half step 1	192	92.4%	38.3%
Half step 2	320	92.4%	-38.3%
Full step 1	384	70.7%	-70.7%
Half step 3	448	38.3%	-92.4%
Half step 4	576	-38.3%	-92.4%
Full step 2	640	-70.7%	-70.7%
Half step 5	704	-92.4%	-38.3%
Half step 6	832	-92.4%	38.3%
Full step 2	896	-70.7%	70.7%
Half step 7	960	-38.3%	92.4%

9.3 Micro Step Interpolator And Static Detection

The time interval of 2 to 256 microsteps inserted by the micro step interpolator is determined by the time interval of the STEP cycle, which is divided into 256 equal parts. The maximum time interval between the two steps is 2^{20} system clocks. Under the 12M system clock, the minimum input STEP frequency is about 12Hz. Less than this frequency, quiescent events will be detected.When a quiescent event is detected, the motor current automatically changes to standby current (if through PDN_UART selection).

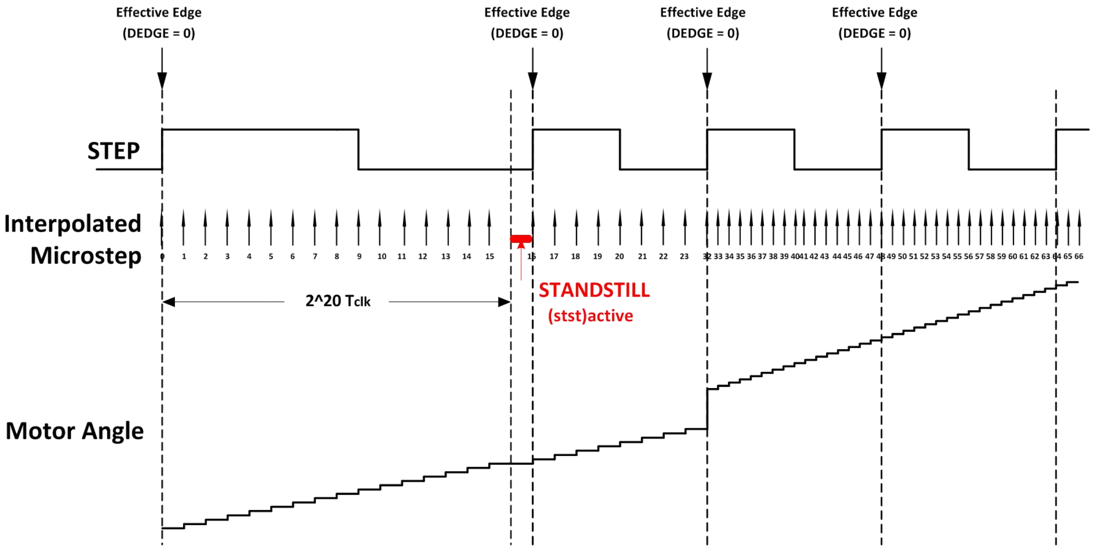


Figure 9.3 microstep interpolation with rising STEP frequency (Example 16 to 256)

In Figure 9.3, the first step is long enough to reach the static condition. When the static condition is detected, the motor will enter the standby current state, and the flag bit stst will appears.This flag bit will be cleared when the next significant edge comes. Then, external STEP frequency increases. After one step, the micro step interpolator adapts to the larger step frequency.The microstep interpolator cannot produce a complete 16 microsteps at the first STEP with higher frequency, so there is a small motor angle jump between the first and second step.

9.4 Index Output

The INDEX signal is valid at the forward zero crossing of motor coil A, which is related to the zero point of Microstep sequencer.INDEX output can help to detect motor position with higher accuracy.

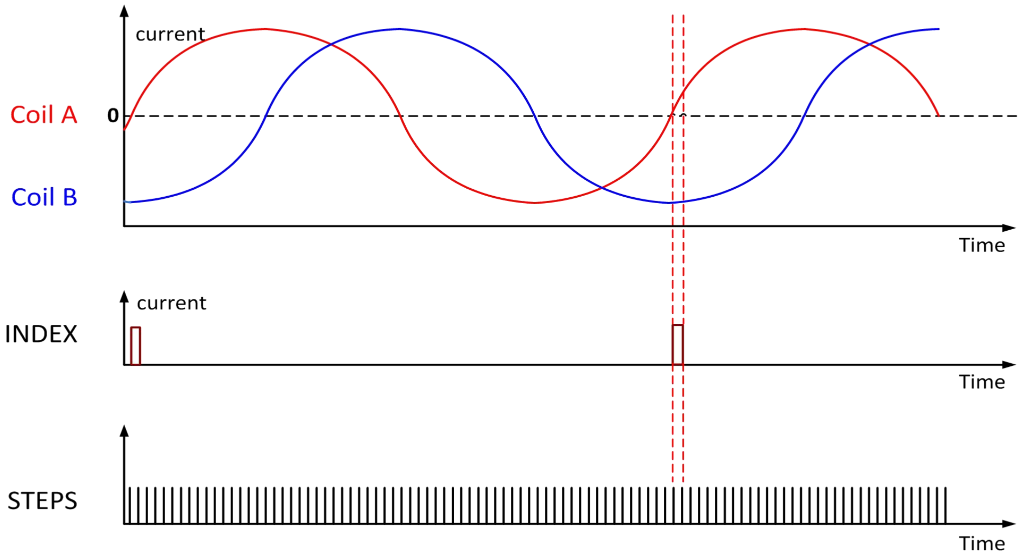
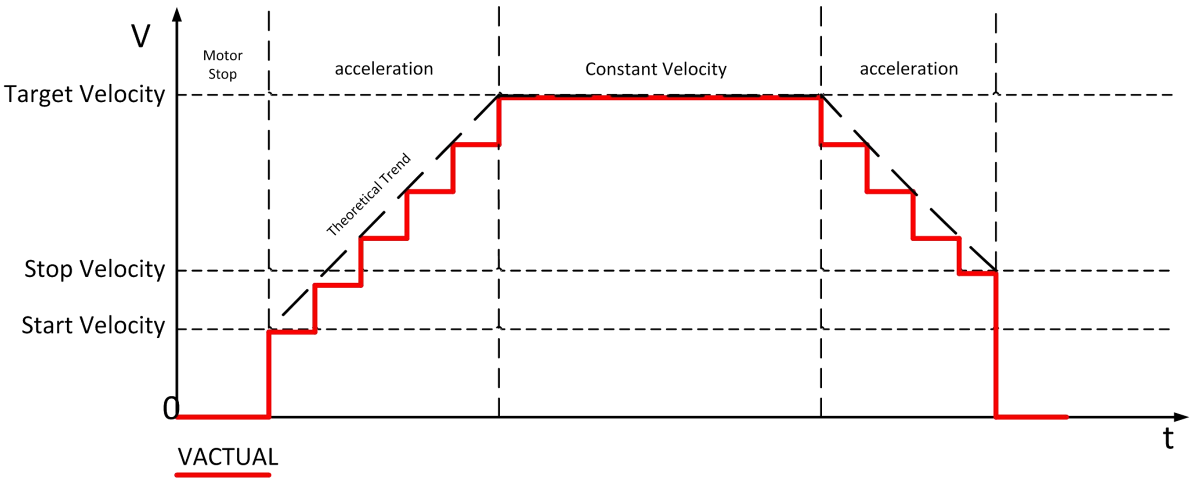


Figure 9.4 pulse of index signal at zero crossing point of sine curve of motor coil A

10.Internal Step Signal Generator

There is a STEP signal generator in MS35775, which allows UART interface to control motor movement.However, not provides speed trim ramp. When the target speed is higher than the start and stop speed, the motor are accelerated and decelerated by small steps.Select a step slightly less than the maximum starting speed to prevent the motor torque jump and load increase.



10.1 software generated motion description

Parameters / symbols	Company	Operation / description / annotation
f_{CLK}[Hz]	[Hz]	MS35775 system clock frequency
ustep velocity v[Hz]	usteps/s	V[Hz]=VACTUAL*(f_{CLK}[Hz]/2/2^23) Internal clock: V[Hz]=VACTUAL*0.715Hz
USC microstep count	counts	Microstep resolution, the number of STEP between two full steps.
Rotations per second v[rps]	rotations/s	v[rps]=v[Hz]/USC/FSC FSC: e.g.200
VACTUAL		VACTUAL=(f_{CLK}[Hz]/2/2^23)/v[Hz] Internal clock: V[Hz]=0.715Hz/v[Hz]

11.Driver Characteristic Signal

The MS35775 driver provides a complete set of diagnosis and protection functions, such as short circuit protection to ground, short circuit protection to Vs and under-voltage detection.If the motor coil connection is broken, the open load condition can be detected.For more information, see DRV_STATUS table.

11.1 Temperature Measurement

The driver integrates a four stage temperature sensor (early warning and thermal shutdown) to diagnose and protect the IC from overheating.The threshold can be adjusted by UART or OTP programming.The heat is mainly generated by the motor drive stage and when the voltage rises generated by the internal voltage regulator.In most cases, the driver MOSFET may overheat, which can be avoided by short circuit to ground protection.For many applications, over-temperature alerts will indicate abnormal operating conditions and can be used to initiate user warnings or power reduction measures, such as motor current reduction.Thermal shutdown is only an emergency measure, so the temperature should be prevented by design from rising to the shutdown level.

Temperature Threshold	
Temperature Setting	**Comment**
143℃ （OTPW：120℃）	Default settings.Before the IC is damaged due to overheating, it is the safest setting to turn off the drive stage.On a large printed circuit board, when the temperature detector is triggered by this setting, the power MOSFET reaches a peak temperature of about 150℃.This is a typical trip point for over temperature shutdown.The over temperature warning threshold of 120 ℃ provides a lot of space to respond to high drive temperatures, for example by reducing motor current.
150℃ （OTPW：120℃ or 143℃ ）	Optional settings (OTP or UART). This setting provides some additional space for small PCBs with high thermal resistance between the PCB and the environment. The small printed circuit board shows a small temperature difference between the MOSFET and the sensor.
157℃ （OTPW：143℃）	Optional setting (UART). This setting provides the highest temperature threshold for applications that cannot allow the motor to stop, for example at high ambient temperature ratings.Use 143℃ over-temperature warning to reduce motor current to ensure motor does not reach thermal threshold shutdown.

Attention
Pay attention to overheat protection, which can not avoid IC thermal damage under any circumstances.If the motor current exceeds the rated value, e.g. in the case of parameter errors, or in cases where the automatic adjustment of parameters is not suitable for operating conditions, excessive heat generation can heat the drive quickly before the overheat sensor reacts.This is due to the heat conduction delay of the integrated circuit chip.

When the over-temperature sensor (OT flag) is triggered, the drive will remain closed until the system temperature drops below the warning level (OTPW) to avoid continuous heating to the shutdown level.

11.2 Short Circuit Protect

The MS35775 power stage prevents short circuit by measuring the current flowing through each power stage MOSFET.This is important because most short circuit conditions are caused by defective motor cable insulation, for example, when touching conductive parts which connected to system ground. short circuit detection can be protected from spurious triggering by retrying three times before shutting down the motor, for example by ESD discharges.

Once a short circuit is detected, the corresponding drive axle (a or b) becomes switched off.The s2vsa or s2vsb or s2ga or s2gb flags are generated respectively.disable and re-enable the drive for restart the motor.Note that short circuit protection can not protect the system and power supply from all possible short circuit events because short circuit events are quite uncertain and are a complex network that may involve external components.Therefore, short circuit should be avoided basically.

11.3 Open Circuit Diagnosis

A broken cable is a common cause of system failure, for example, when the connector is not secure.MS35775 detects open load by checking that if the required motor coil current is achieved.In this way, under voltage conditions, high motor speed settings or short circuit and over temperature conditions may trigger an open circuit flag and notify the user.Motor torque may be affected.When the motor is stationary, the open load cannot always be measured because the coil may end up with zero current.

To safely detect a broken coil connection, read the open load at low speed or rated motor operating speed.If possible, use quick mode for testing because it provides the most accurate testing.However, the ola and olb flags are informative and do not result in any action of the driver.

11.4 Diagnostic Output

Diagnostic output DIAG and indicator output INDEX provide important status information.A valid DIAG output display driver does not work properly.INDEX outputs the zero position of the microstep counter.The function of INDEX output can be modified through UART.Figure 11.1 shows the available signals and control bits.

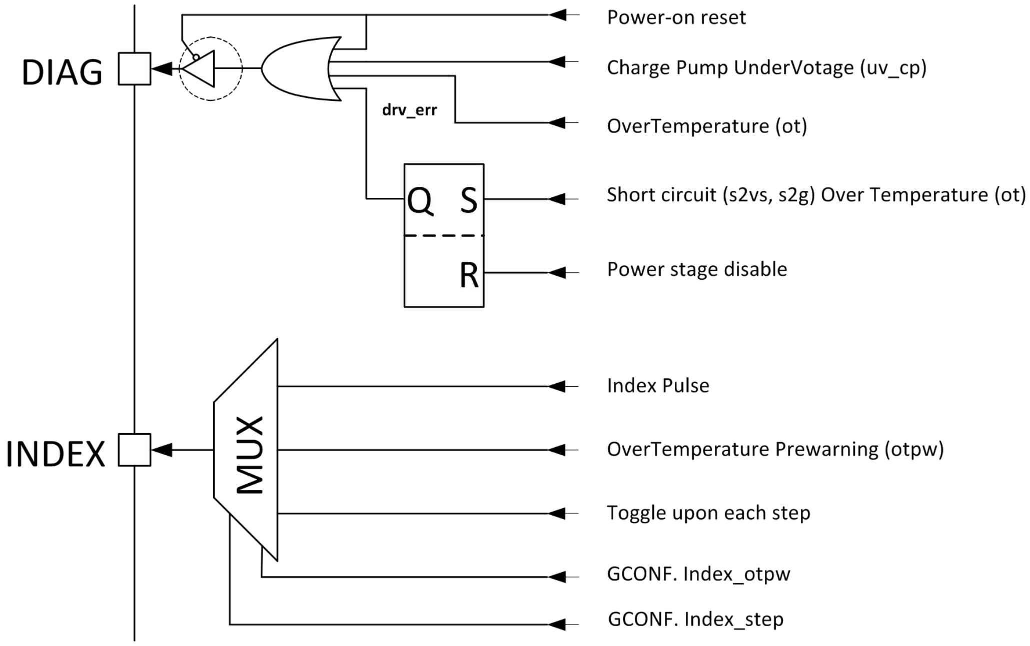


Figure 11.1 INDEX and DIAG status information

12.Quick Setup Guide

This setup can be used as a guide for the first time.Parameters can be set by UART or OTP. The following flow chart considers the basic function setting that make the motor run smoothly.In addition, after the motor is running, you need considered the controls such as idle.Current probes are good aids to get the best settings, but they are unnecessary.

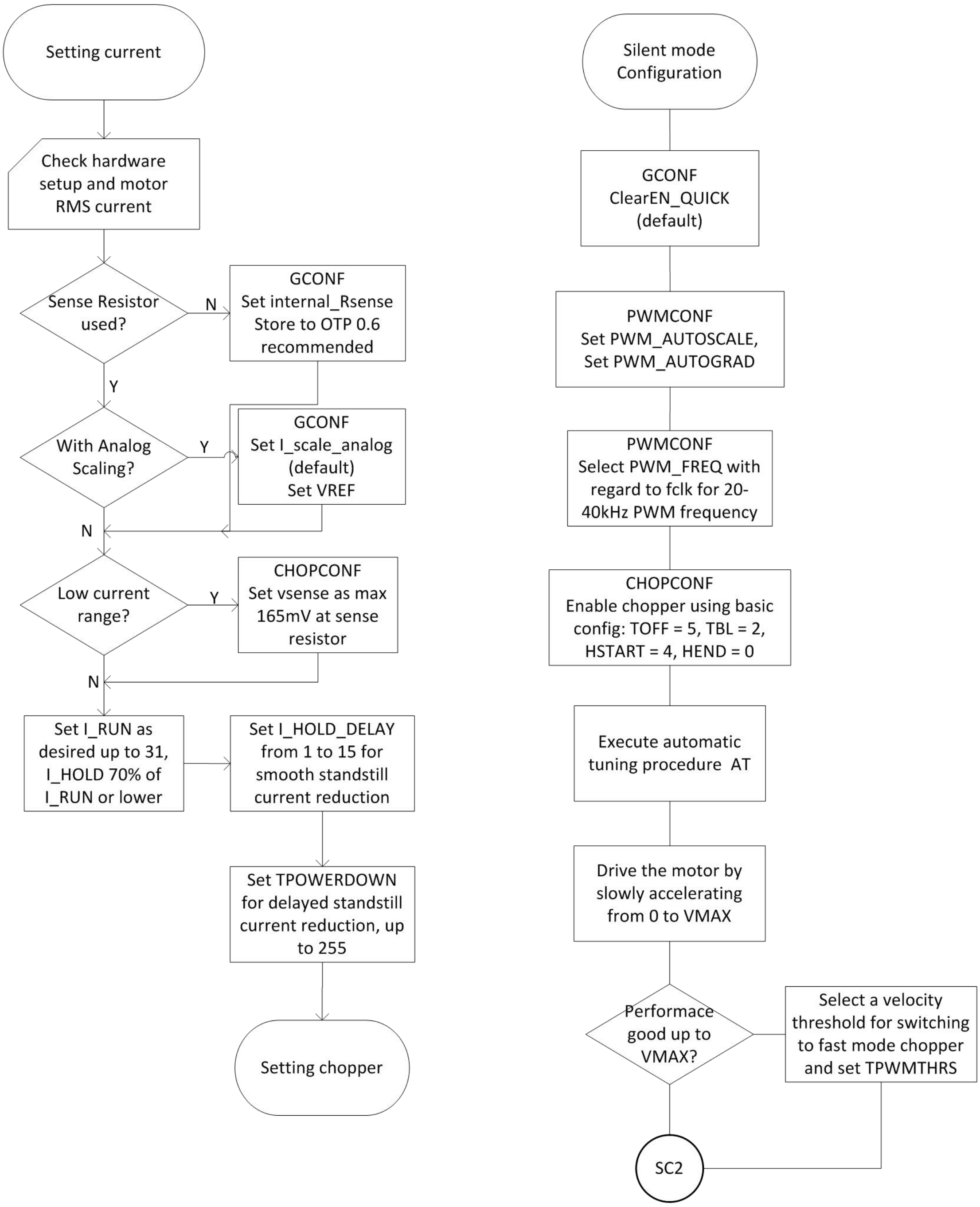


Figure 12.1 Silent mode setup guide

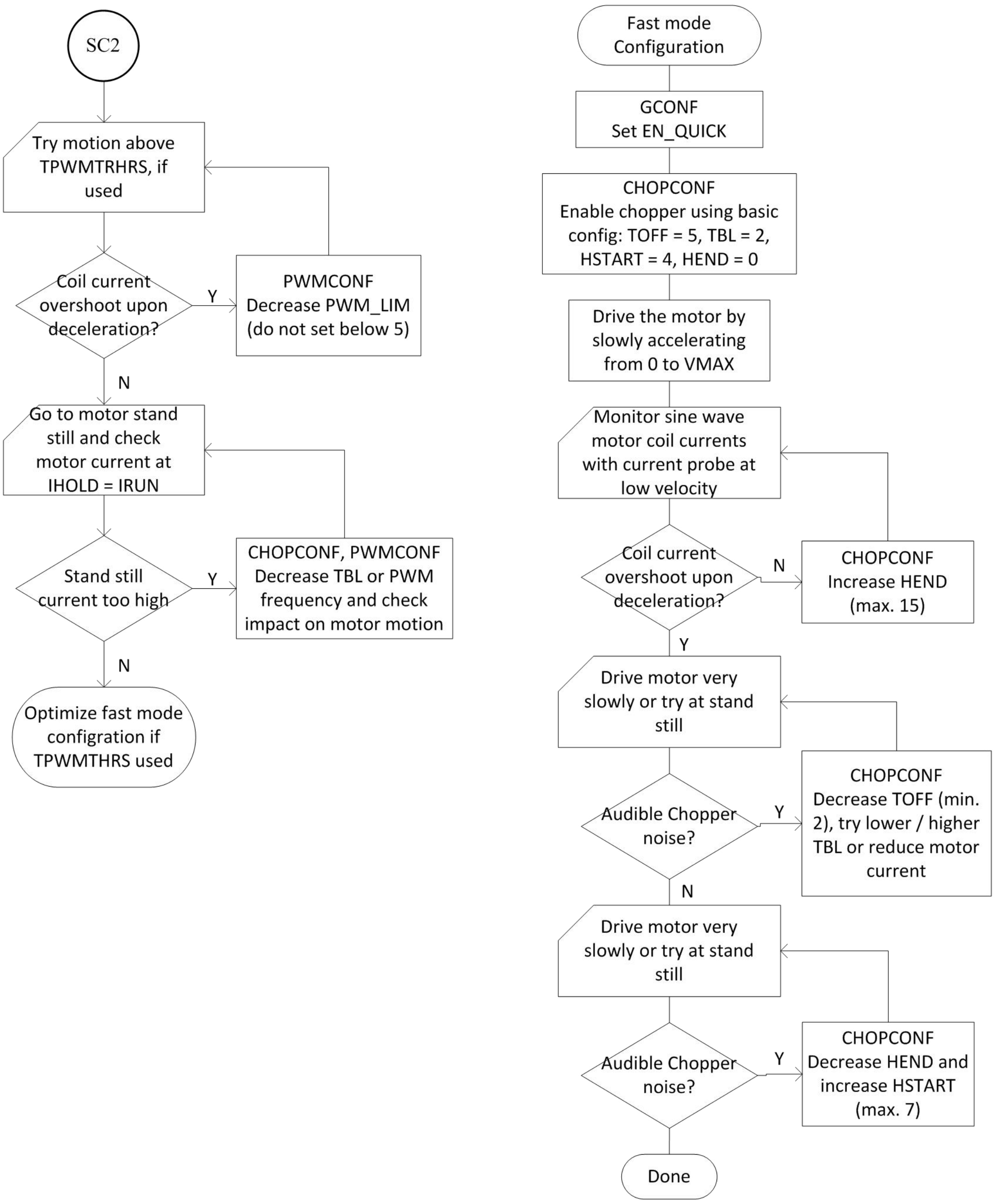


Figure 12.1 Fast mode setup guide

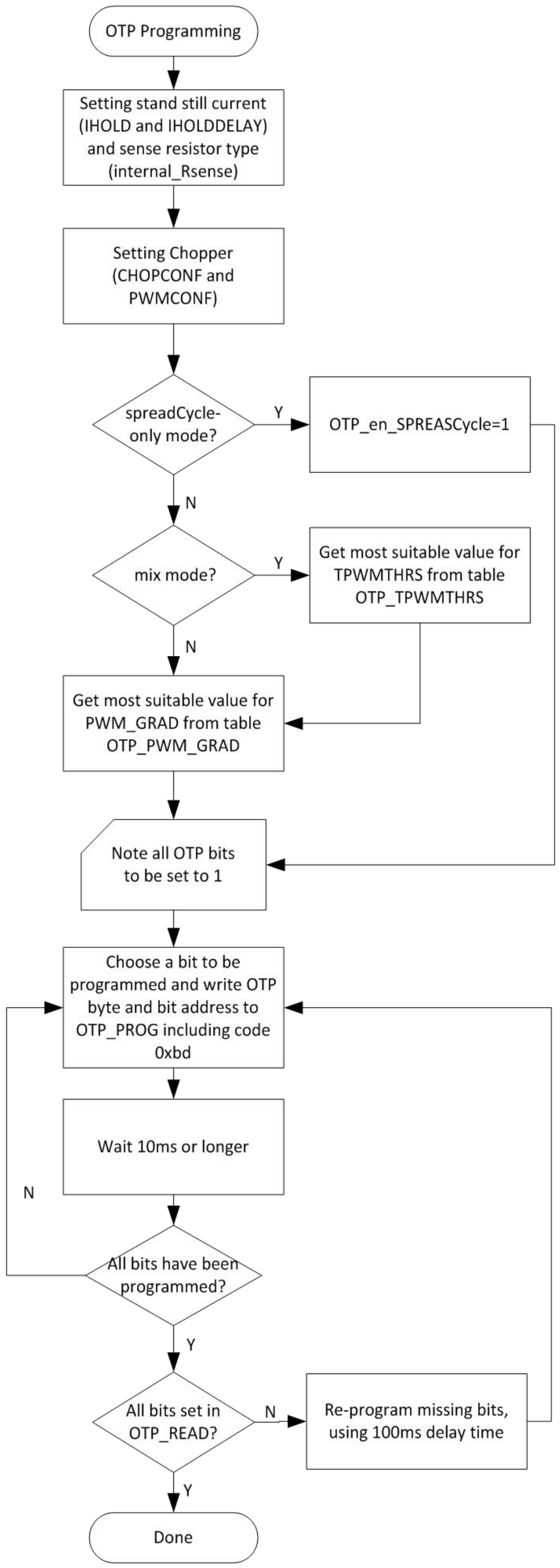


Figure 12.1 OTP programming guide

13.External Reset

The chip loads the default values through internal power on reset during power on.Some registers are initialized by the OTP at power up.In order to reset the chip to the power on defaults, any power supply voltage monitored by the internal reset circuit (VS, 5VOUT, or VCC_IO) must be cycled .Since + 5vout is the output of the internal voltage regulator, it cannot be cycled through an external power supply, unless it is cycled through vs .The cycling for VCC_IO is the simplest and safest to completely reset the chip.Also, VCC_IO consumes very low current, so it has simple driving requirements.Since the input protection diode not allowing the digital input to rise above the VCC_IO level, so all inputs must be set low during reset operation.When this is not possible, input protection resistors can be used to limit the current flowing into the relevant input.

14.Clock Oscillator And Input

The clock is the timing reference for all functions: chopping frequency, blank time, outage timing and internal step pulse generator.The on-chip clock oscillator is calibrated to provide timing precise enough for most operation cases.

Use Internal Clock

If you want to use an internal clock oscillator, connect the CLK pin directly to GND near the IC.Through OTP programming, the internal clock frequency is adjusted to 12Mhz for factory settings.

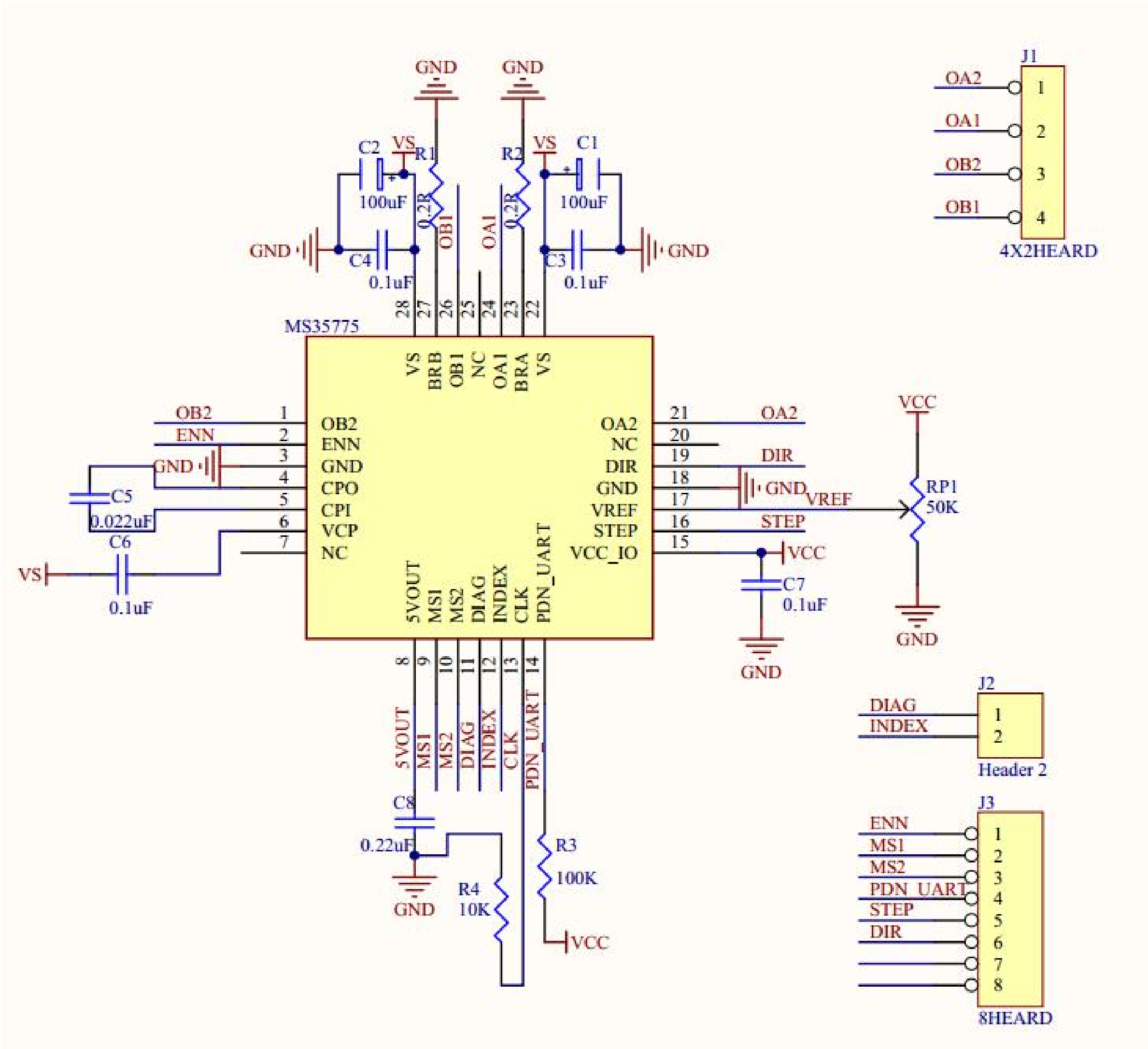
Use External Clock

When the external clock is available, the MS35775 can use any frequency clock between 8 and 18 MHz.The duty of the clock signal is not strictly required, as long as the minimum high or low input time is met (refer to the electrical characteristics table).Ensure that the clock source provides CMOS output logic level and steep slope when using high clock frequency.The external clock input is enabled by the first rising edge on the CLK input.Modifying the clock frequency is a simple way to adapt to the silent mode chopper frequency or to synchronize multiple drivers.Working in 4 MHz at a very low clock frequency can help reduce power consumption and electromagnetic radiation, but it will lose some performance.

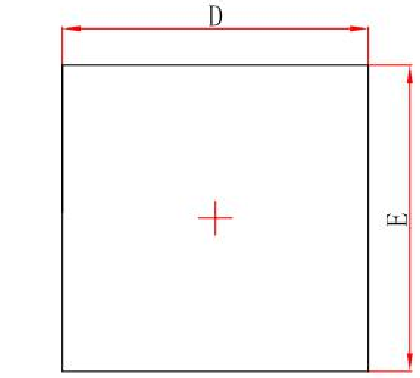
Use an external clock source to synchronize multiple drives, or using an internal pulse generator to obtain accurate motor motion .The external clock frequency selection also allows modification for power off time and chopper frequency.

The prompt to turn off the external clock frequency will stop the chopper and may cause an over-current condition.Therefore, the MS35775 has an internal timeout of 32 internal clocks.If the external clock fails, it switches back to the internal clock.

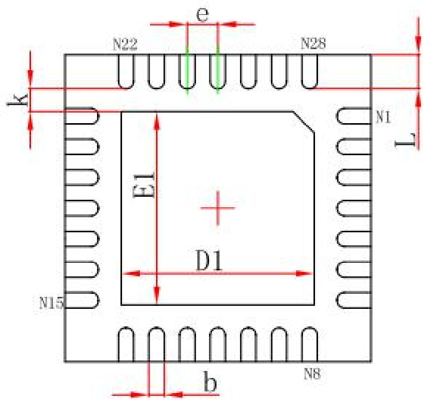
TYPICAL APPLICATION



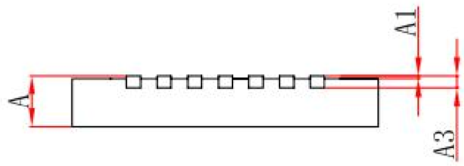
PACKAGE INFORMATION



Top View



Bottom View



Side View

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	4.900	5.100	0.193	0.201
E	4.900	5.100	0.193	0.201
D1	3.050	3.250	0.120	0.128
E1	3.050	3.250	0.120	0.128
k	0.200MIN.		0.008MIN.	
b	0.180	0.300	0.007	0.012
e	0.500TYP.		0.020TYP.	
L	0.450	0.650	0.018	0.026

SEAL AND PACKAGE SPECIFICATION

1.Introduction to seal content

Product Name: MS35775

Production batch No.: XXXXXX

2.Seal Specification

Laser printing, overall center and use Arial font.

3.Package description:

Name	Package	Piece / roll	Roll / box	Per box	Box / boxful	Piece / boxful
MS35775	QFN28	1000	8	8000	4	32000

MOS circuit operation precautions:

Static electricity can be generated in many places. Taking the following preventive measures can effectively prevent the damage of MOS circuit caused by electrostatic discharge:

1.Operators should be grounded through anti-static wrist strap.

2.Equipment shell must be wired to GND.

3.The tools used in the assembly process must be wired to GND.

4.Conductor packaging or antistatic materials must be used for packaging or transportation.

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