SY21604

Three Phase Sensorless Sine Wave Motor Driver with Integrated Power MOSFETs

General Description

The SY21604 is designed for sensorless control of three-phase brushless DC (BLDC) motor, especially for low noise, low external component count and high efficiency applications. The SY21604 also integrates three half-H-bridges, which have low turn on resistances. A 180° modified SPWM is used for reducing the motor noise and torque ripple. The device can be easily configured through an I^2C interface to drive different motors.

The SY21604 provides several protections and abnormal state detections to ensure reliable operation of the motor. Such as over current protection, short circuit protection, under voltage lockout, thermal shutdown and abnormal motor states protection. A low-power sleep mode is also provided.

To be compatible with industry-standard devices, the SY21604 package is 24-pin TSSOP24E

Ordering Information

SY21604 □(□ □)□

- └ Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY21604HHC	TSSOP24E	

Features

- Power Supply Voltage Range from 5V to 40V
- Integrated Three Half-H-Bridge Motor Driver
  - Low MOSFET on-Resistance: HS + LS < 250mΩ
- Maximum Drive Current of 2A RMS, 3A Peak Current
- Sensorless or Single Hall Sensor/Element Control
- Sine Wave Driver
- Integrated 5V or 3.3V Buck Regulator
- I^2C Interface
- Speed Setting: PWM/ Analog/I^2C
- Forward/Reverse Control
- Sleep Mode
- Over Current Protection
- Motor Lock Protection
- Under Voltage Protection
- Thermal Shutdown
- TSSOP24E Package

Applications

- Appliance Fan
- HVAC

Typical Applications

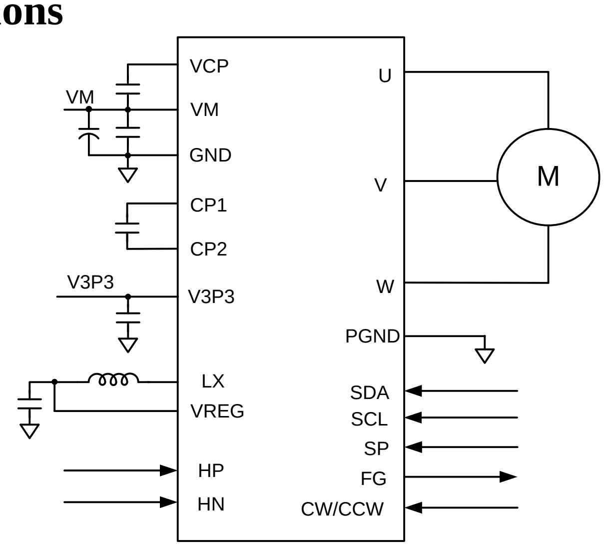
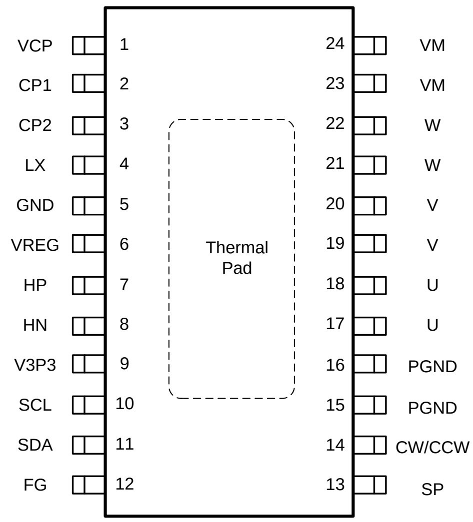


Figure1. Typical Application Circuit

Pin out (Top View)



(TSSOP24E)

Top Mark: **BKG*xyz***, **(**Device code: BKG; ***x=year code, y=week code, z= lot number code*****)**

Name	No	Description
VCP	1	High side gate drive voltage supply. Connect a 100nF capacitor to VM.
CP1	2	Charger pump capacitor. Connect a 100nF capacitor between CP1 and CP2.
CP2	3	
LX	4	Internal regulator switching node. Connect a 47μH inductance at this PIN.
GND	5	Step down regulator ground.
VREG	6	Step down regulator output and feedback pin. Connect a 10μF/6.3V ceramic capacitor at this pin.
HP	7	Positive hall signal input of phase A. If a hall sensor is used, connect this PIN to hall sensor input; if a hall element is used, connect this pin to positive hall signal. And if hall is not used, connect this to GND or floating.
HN	8	Negative hall signal input of phase A. If a hall sensor is used, connect this PIN to GND; if a hall element is used, connect this pin to negative hall signal. And if hall is not used, connect this to GND or floating.
V3P3	9	3.3V LDO output pin. Connect a 1μF/6.3V capacitor to GND.
SCL	10	I^2C clock input pin.
SDA	11	I^2C data signal pin.
FG	12	Motor electrical period output pin, open drain output, need a pull up resistor.
SP	13	Speed control signal input pin. This pin supports PWM or analog speed control signal input.
CW/CCW	14	Motor direction control pin.
PGND	15,16	Power ground.
U	17,18	Motor U phase driver pin.
V	19,20	Motor V phase driver pin.
W	21,22	Motor W phase driver pin.
VM	23,24	Motor power supply pin. Decouple this pin to GND pin with at an least 2.2μF ceramic capacitor and a sufficient electrolytic capacitor.
Thermal Pad	-	The exposed pad must be connected to PGND through soldering PCB for better thermal spreading.

Block Diagram

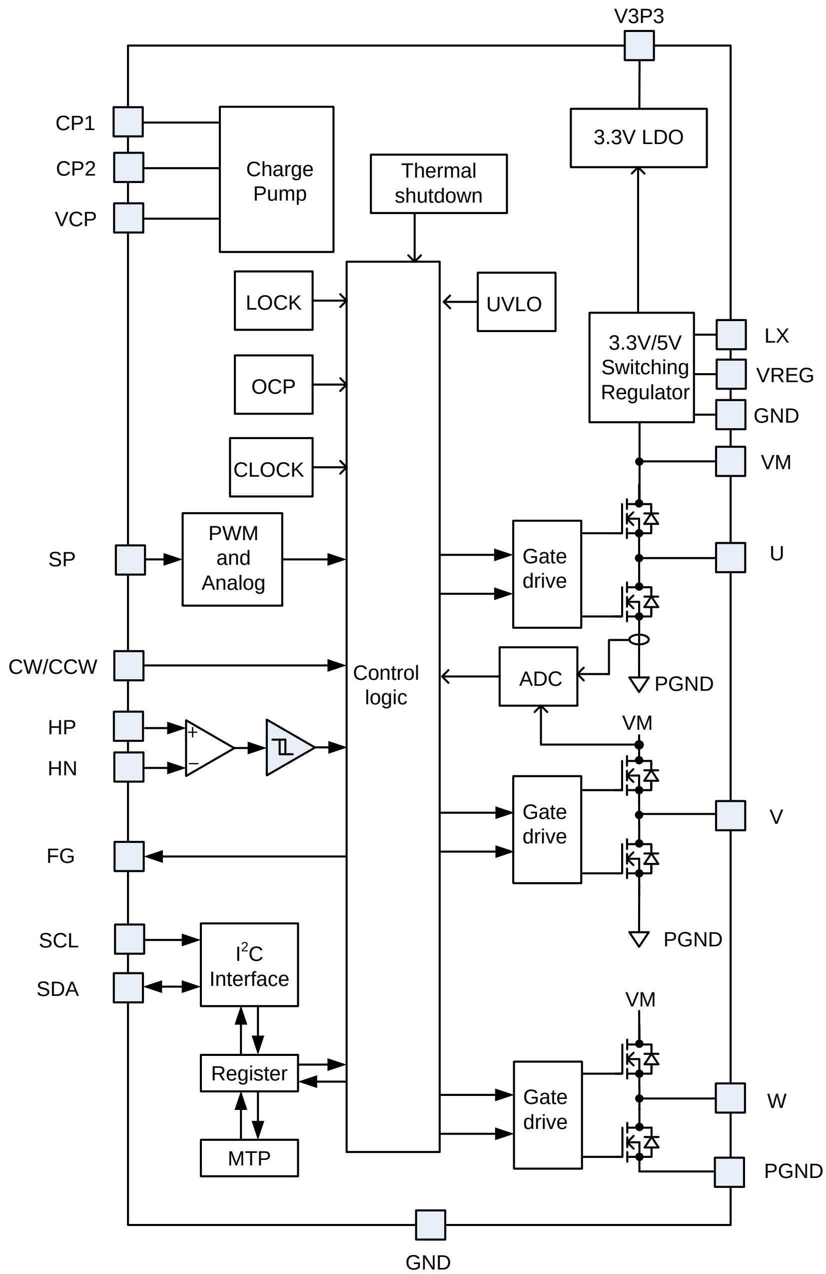


Figure 2. SY21604 Block Diagram

Absolute Maximum Ratings (Note 1)

VM	-0.3 to 40V
U, V, W	-0.7 to 40V
VCP, CP1, CP2	-0.3 to 40V
SP	-0.3 to 5.5V
HP, HN	-0.3 to 5.5V
SCL, SDA, CW/CCW	-0.3 to 5.5V
FG	-0.3 to 5.5V
LX	-0.3 to 40V
VREG	-0.3 to 6V
V3P3	-0.3 to 4V
Junction Temperature (T_J)	-40°C to +150°C
Storage Temperature	-55°C to +150°C
Package Thermal Resistance	
θ_{JA} (Note 2)	36.1°C/W
θ_{JC}	17.4°C/W

Recommended Operating Conditions

VM	5 to 32V
U, V, W	-0.5 to 32V
SP	-0.1 to 4V
FG	-0.1 to 5V
HP, HN	-0.1 to 5V
SCL, SDA, CW/CCW	-0.1 to 5V
Step down regulator output current (I_{Buck}) (Note 3)	0 to 50mA
V3P3 LDO output current (I_{3P3_LDO})	0 to 5mA
Junction Temperature Range	-40°C to 125°C

Electrical Characteristics

(T_A = 25°C, VM=24V, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Supplies						
VM Operating Supply Current	I_{VM}	VM=24V, Buck disable		10	14	mA
VM Sleep Mode Current	I_{VMSLP}	VM=24V, SP=0V,sleep mode		200	250	µA
VCC Undervoltage Lockout Voltage	V_{UVLO_RISE}	VM Rising	4.1	4.5	4.9	V
	V_{UVLO_HYS}	VM Hysteresis		300		mV
Stepdown Regulator						
Step-down Regulator Output voltage	V_{REG}		4.5	5	5.5	V
			3	3.4	3.6	V
3.3V LDO						
3.3V LDO Output Voltage	V_{3P3}	Iout=0 to 5mA	3	3.3	3.6	V
3.3V LDO Output Current	I_{3P3_LDO}	(Note 5)			5	mA
H-Bridge MOSFETs						
High Side+ Low Side MOSFETs on Resistance	R_{dson}			200	250	mΩ
Off-State Leakage Current	I_{OFF}		-2		2	µA
Output Deadtime	T_D	(Note 5)		100		ns
SPEED Control---Analog						
Analog Full Speed Voltage	V_{AFS}	(Note 5)		V_{3P3}×0.9		V
Analog Zero Speed Voltage	V_{AZS}			0.2		V
Analog Voltage Resolution	V_{AVR}			10.8		mV
SPEED Control---Digital						
Input High Voltage	V_{DSPH}		2.2			V
Input Low Voltage	V_{DSPL}				0.6	V
Input Frequency	F_{DSPF}	(Note 5)	1		100	kHz
CW/CCW Input						
Input High Voltage	V_{CWH}		2.2			V
Input Low Voltage	V_{CWL}				0.6	V
FG Output						
FG Output Sink Current	I_{FG}		5			mA
SLEEP Condition						
Analog Voltage to Enter Sleep Mode	V_{AENSLP}	Spctrmd=0(analog mode)	50			mV
Analog Voltage to Exit Sleep Mode	V_{AEXSLP}	Spctrmd=0(analog mode)	2.2	3.3		V
Time to Exit from Sleep Mode	T_{EXSLP}	Spctrmd=0(analog mode) V_{SP}> V_{DSPH}, (Note 5)		1		us
Time to Enter Sleep Mode	T_{ENSLP}	Spctrmd=1(digital mode), V_{SP}< V_{DSPL}, (Note 5)		5		ms
Hall Element/Sensor Input						
Hall Effect Inputs: Input Sensitivity	V_{HL_S}	Differential inputs, (Note 5)	100			mV
Hall Effect Inputs: Common Mode Input	V_{HL_COM}	(Note 5)	1		3.5	V
Hall Effect Inputs: Input Hysteresis	V_{HL_HYS}	(Note 5)	3	6	9.5	mV
Lock Detection						
Lock Release Time	T_{LCKR}	(Note 5)		5		s
Lock Enter Time	T_{LCKEN}	(Note 5)		0.3		s
Protection						
Output over Current Limit	I_{OCP}		3.5	4.5		A
Thermal Shutdown Temperature	T_{SD}	(Note 5)		150		°C
Thermal Shutdown Hysteresis	T_{HYS}	(Note 5)		10		°C
I²C INTERFACE						
Input High Voltage	V_{I2CH}		2.2			V
Input Low Voltage	V_{I2CL}				0.6	V
SCL Clock Frequency	f_{SCL}	(Note 5)	0		400	kHz
Bus Free Time between Stop/Start	t_{BUF}	(Note 5)	1.3			µs
Start Condition(Repeated) Hold Time	$t_{HD,STA}$	(Note 5)	600			ns
Repeat START Set up Time	$t_{SU,STA}$	(Note 5)	600			ns
Set up Time for STOP	$t_{SU,STO}$	(Note 5)	600			ns

Data Set up Time	$t_{SU,DAT}$	(Note 5)	100			ns
Data Hold Time	$t_{HD,DAT}$	(Note 5)	0		900	ns
Data Output Fall Time	t_{Of}	(Note 4,5)	$20+0.1C_B$		300	ns

Note 1: Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 3: Power dissipation and thermal limits must be observed.

Note 4: C_B is total capacitance of one bus line in pF (C_B<=400pF).

Note 5: Guaranteed by design, not subject to test.

Functional Description

The SY21604 is designed for sensorless or single hall sensor/element control of three-phase BLDC motor, especially for low noise, low external component count and high efficiency applications. A 180° modified SPWM is used for reducing the motor noise and torque ripple. The device can be easily configured through an I^2C interface to drive different motors.
The device provides several protection and abnormal state detection to ensure reliable operation of the motor. Over current, under voltage lockout, hall signal abnormal, thermal shutdown and motor lock detection.
A Buck regulator steps down the input voltage efficiently to provide power for the internal circuits. The output can also be used to power the external circuit such as a microcontroller.
Flexible interfaces have designed in this device. In addition to the I^2C interface, the system also provides discrete SP pin, CW/CCW pin and FG pin. The SP is the speed command input pin both for digital PWM input and analog input. CW/CCW pin controls the motor direction. FG pin is the speed output pin which shows the motor communication frequency. The user can adjust the motor speed by varying the supply voltage (VM) or by controlling the speed command. The speed command can be controlled through the digital PWM input, the analog input or the I^2C command.

Motor Parameters

Three parameters of the motor need to be configured in the registers to successfully control the motor: motor resistance, inductance, and velocity constant. The motor resistance is programmed by writing Rm[11:0] in the MotorPara register. The motor inductance is programmed by writing Lm[11:0] in the MotorPara register. The motor velocity constant is programmed by writing Kt[11:0] in the MotorPara register.

Motor Resistance

The resistance Rm[11:0] is the phase resistor of the motor. Rm[11:0] could be configured from 0 to 4095, which represents the phase resistor changes from 0Ω to 32Ω. The LSB is 1/128Ω.

Motor Inductance

The inductance Lm[11:0] is the phase inductance of the motor. Lm[11:0] could be configured from 0 to 4095, which represents the phase inductance changes from 0mH to 32mH. The LSB is 1/128mH.

Motor Velocity Constant

The motor velocity constant Kt[11:0] is the peak value of the motor phase to phase BEMF divided by the frequency of the BEMF. Kt [11:0] could be configured from 0 to 4095, which represents the motor velocity constant changes from 0mV/Hz to 2000mV/Hz. The LSB is 1000/2048 mV/Hz.

PWM Output Modulation

The output voltage applied to the motor is a series of PWM signals modulated by a sine wave so that the output phase-to-phase voltage is sinusoidal. Figure 3 shows the sinusoidal modulating wave and the PWM output. Figure 4 shows the sinusoidal modulating wave with third harmonics from phase to GND.

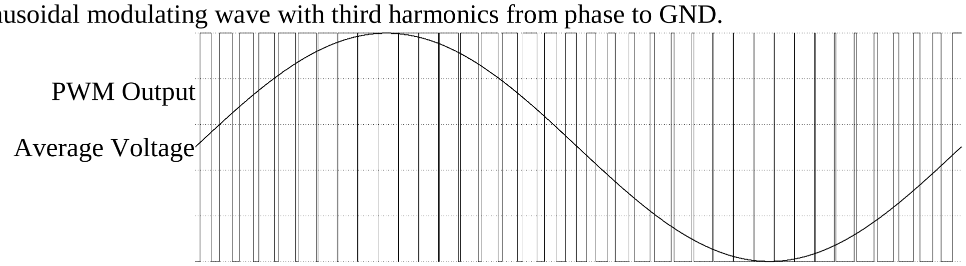


Figure 3. The Modulating Wave and the Output PWM

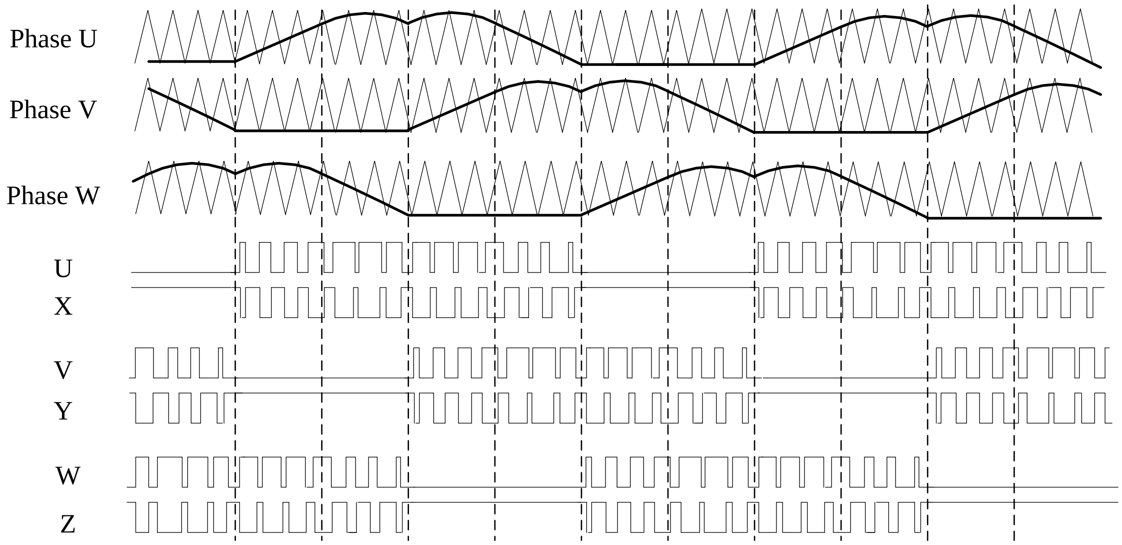


Figure 4. PWM signals modulated by sinusoidal with third harmonics

Motor Drive Direction

The motor drive direction is determined by the combination CW/CCW pin and the control register Direction. The logic of the drive direction is shown in Tab 1.

Tab 1. The Logic of Drive Direction

CW/CCW	Direction	Drive Direction
0	0	Forward (Drive Direction=1)
0	1	Reverse (Drive Direction=0)
1	0	Reverse (Drive Direction=0)
1	1	Forward (Drive Direction=1)

Start the Motor under Different Initial Conditions with Sensorless Control Method

This section introduces the startup of the motor under different initial conditions. There are three different states of the motor before the device attempts to exceed the startup process: stationary, spinning in the forward direction or spinning in the reverse direction. Several options are provided to make sure the motor can start up successfully.

Motor Initial State Detect

The motor initial state is essential for the startup process. Two phase to phase comparators are used to detect the motor initial state while it is coasting (motor phase are in high impedance state before the start). The zero crossings of the phase-to-phase BEMF voltage can be detected if the motor is spinning. Figure 5 shows the comparators and the phase-to-phase voltage and the outputs of the comparators.

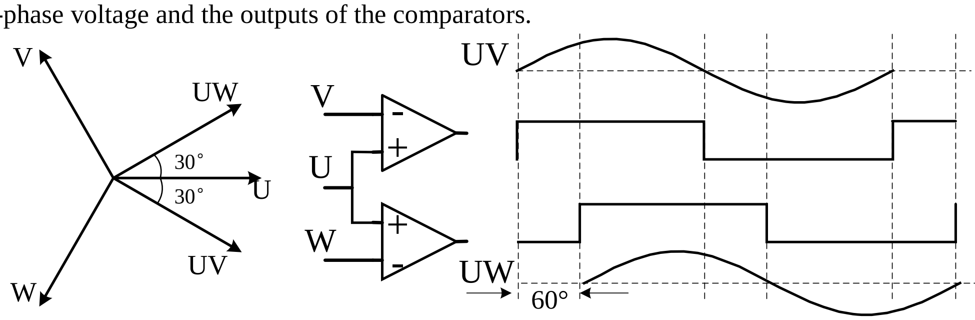


Figure 5. Initial State Detect Function

Start the Motor under the Stationary State

If the motor is stationary, two methods are available to get the initial position of the rotor: The Align method and the PSD (position state detect) method. The Align method forces the rotor to an align position by supplying a voltage with given position and amplitude for a certain time. This method will cause the rotor rotating through a small angle and oscillation during the align time. If the rotation and oscillation is not acceptable, the PSD method can be used.

The PSD method detects the initial rotor position based on the inductance variation around the electrical cycle by injecting a sequence of high frequency voltage pulses.

Align

The device aligns a motor by injecting a DC voltage with the current flowing from phase W to phase V for a certain time. The amplitude and duration of the voltage should change with different applications. The motor with bigger inertia needs a bigger voltage and longer time. In order to avoid a sudden current change, current ramp is used during the alignment and the ramp is adjustable.

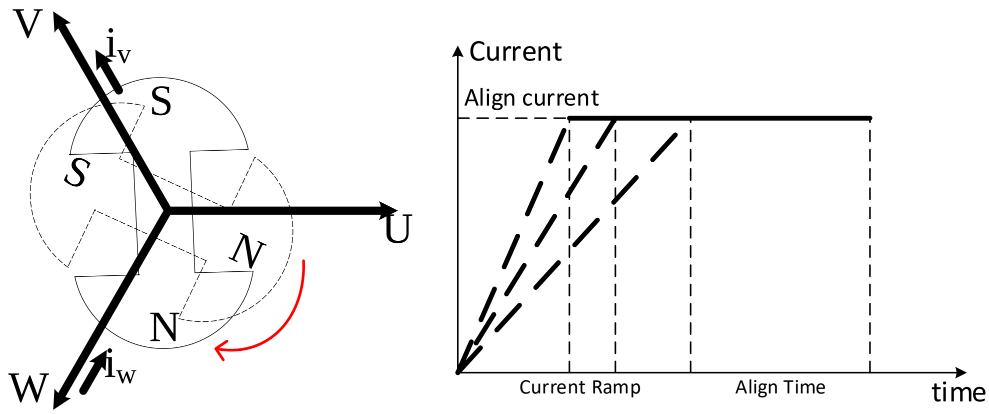


Figure 6. Align Voltage and Rotor Position Synchronization

PSD

The PSD method is used where the rotor reverse rotation and oscillation are not acceptable because this method does not need to align the rotor to a given position. The PSD obtains the rotor position by injecting six voltage pulses and detecting the bus current. The voltage pulses are generated by applying voltage across two motor phases as follows: UV, VU, UW, WU, VW and WV. The device measures the time from when the voltage is applied until the current reaches the threshold. The PSD current threshold is determined by the PSD current threshold setting.

Tab 2 shows the corresponding between the shortest rising and the rotor position.

Tab 2. The Shortest Pulse and Rotor Position

Shortest Pulse	UV	VU	UW	WU	VW	WV
Rotor Position	300°~360°	120°~180°	0°~60°	180°~240°	60°~120°	240°~300°

Start the Motor with the Detected Position

If the motor is stationary, the rotor position is obtained after align or PSD process. The device begins to accelerate the motor from a certain position. The motor is accelerated by applying a rotating voltage vector given by open loop setting. The amplitude of the voltage is determined by the open loop current setting. The rotating speed of the voltage vector is determined by the open loop start acceleration setting. As the motor needs a minimum speed to generate sufficient BEMF for the communication logic, an open to close threshold speed need to be set. Figure 7 shows the open loop start up process of the motor.

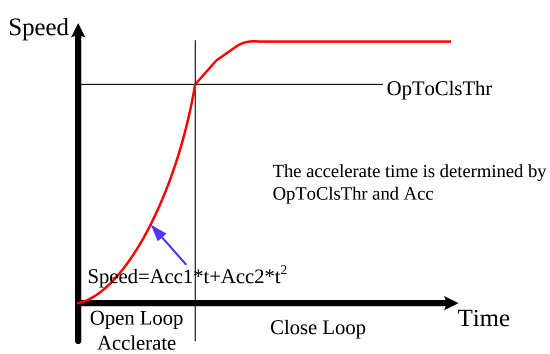


Figure 7. Open Loop Motor Start Up

The amplitude of the open loop voltage is given by Equation 1, where U_{st} is the open loop voltage amplitude, Kt is motor velocity constant configured by Kt[11:0], Rm is the motor resistance configured by Rm[11:0], I_{st} is the open loop current configured by OpenLCurr[2:0]. The motor with large inertia need a big I_{st}

$$U_{st}=I_{st}\times Rm+Kt\times Speed \quad (1)$$

Start up When the Motor is Spinning in the Forward Direction

If the motor is spinning forward, the initial state detect function can get the rotor communication period and the rotor position when the comparator's outputs changed. According to the rotor communication, two options are provided to start the motor: Brake or Wait speed down. If the rotor speed is less than the SpdStartBrake[2:0],the device brakes the motor by turning on all the low-side MOSFETs. If the rotor speed is higher than the SpdStartWait[1:0], the device waits rotor speed slow down and then continue accelerating the motor to close loop.

Start up When the Motor is Spinning in the Reverse Direction

If the motor is spinning in the reverse direction, two options will be provided to start the motor: Brake or Reverse drive. The Reverse drive is enabled if RvsDrEn=1. The reverse drive voltage can be selected by setting the VolReverseSel[2:0]. The device applies a reverse rotated voltage to drive the motor reversely through the zero speed and continue accelerating the motor to close loop. If RvsDrEn=0, the device brakes the motor by turning on all the low-side MOSFETs. When initial state detect function detects the motor has stopped spinning, the device begins to start up the motor.

Figure 8 shows the startup of the motor under different conditions.

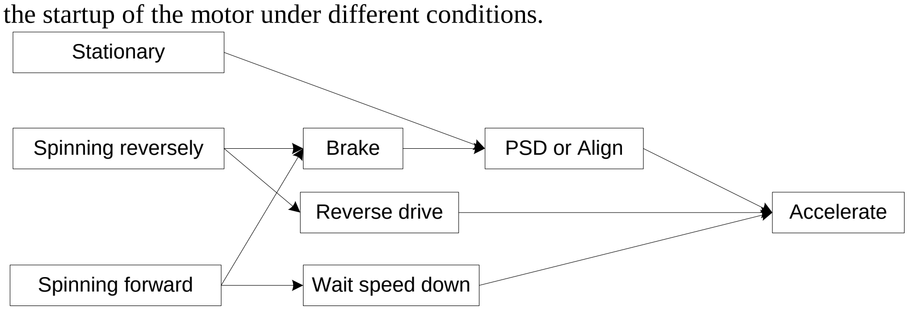


Figure 8. Startup of the Motor under Different Conditions

Start the Motor under Different Initial Conditions with Single Hall Control Method

When the single hall control method is enabled, the device can obtain the rotor position through the hall sensor during the open loop start. If the motor is spinning, the device gets the motor state through the Initial Position Detect function.

Start the Motor under the Stationary State

If the single hall mode is enabled, the rotor is aligned to a specific position for a certain time and then the motor is driven with 2-step current control mode. The communication setting is based on the hall position and the drive direction. The hall position has two options: 0° or 30°. The hall position is selected by setting the register HallPos. If the hall placement is 0° position, HallPos is set to 0. If the hall placement is 30° position, HallPos is set to 1. Tab 3 is the start logic with different hall position and drive direction. The position of the voltage vector is the degree between the motor U phase coil and the composite voltage vector.

Tab 3. Start Logic with Single Hall Control

Hall Placement	HallPos	Hall Signal	Voltage Vector Position	
			Drive Direction=1	Drive Direction=0
0°	0	1	0°	180°
0°	0	0	180°	0°
30°	1	1	330°	150°
30°	1	0	150°	330°
Align			270°	270°

The device switches to sinusoidal control when the speed reaches the open to close loop speed set by the register Op2ClsThr[4:0]. Rotor lock is detected when there is no hall signal change in 1.6s.

Start Up When the Motor is Spinning

Same as the sensorless control method, the device gets the rotor speed with ISD. When the rotor is spinning forward, the device starts the motor immediately with the detected speed at the falling edge of hall signal. When the rotor is spinning reversely, the device slows down the motor by reverse drive or braking down based on the register RvsDrEn and then drives the motor in the forward direction.

Closed Loop Control

In the closed loop operation, the BEMF information is essential to adjust the communication logic. In the sensorless control method, the device continually samples the motor current of U phase and periodically samples the bus voltage to estimate the BEMF. In the single hall control method, the BEMF information can be directly obtained from the hall signal. Several methods are used to adjust motor speed.

Closed Loop Speed Control

The user can adjust the motor speed by varying the supply voltage (VM) or by controlling the speed command. The device offers three approaches to control the speed command: the PWM input, the analog input or the I²C command.

Analog Mode Speed Control

The SP input pin can be set for analog input by configuring SpdCtrlMd to 0. If SP < V_{ana_min}, the speed command will stop the motor. If SP > V_{ana_max}, the motor will run at the highest speed. If V_{ana_min} < SP <V_{ana_max}, the speed command changes linearly according to the voltage on the SP pin.

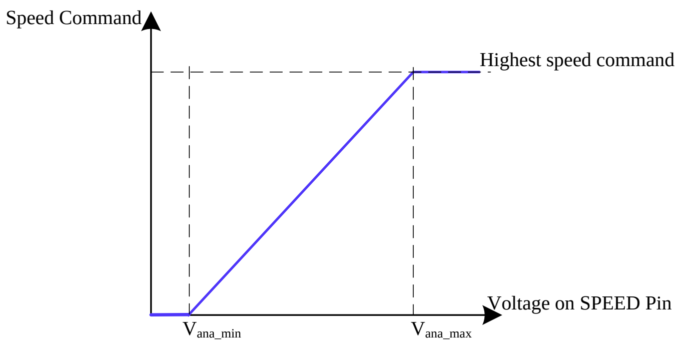


Figure 9. Analog Input and Speed Command

Digital PWM Input Mode Speed Control

When the SpdCtrlMd is configured to 1, the SP pin is set to a digital PWM input pin. The range of PWM duty cycle applied to the SP pin is 0 to 100%. The frequency of the input PWM is defined as f_{PWM}. The device can only recognize PWM of this frequency to control the speed command. If the input signal keeps low for a certain time ($t_{EN\_SL\_SB}$), the speed command will stop the motor.

I²C Mode Speed Control

The speed can also be controlled through the I²C interface. When the OverRide bit is set to 1, this feature is enabled. The device will ignore the input of the SP pin if it is configured in I²C mode. The speed command of the I²C can be set from 0 to 255 by configuring the SpdCtrl[7:0].

Closed Loop Accelerate Limit

Sudden change of the speed command may cause noises and vibration on the motor. A maximum rate of change is limited in this device. The value of the rate is decided by ClsLpAccel[2:0]. The input speed command and the speed command after rate limit are shown in Figure 10.

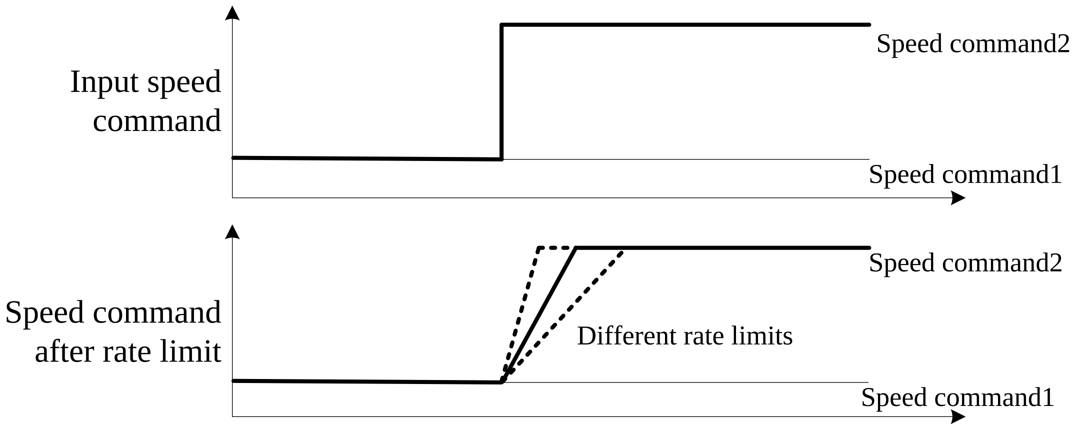


Figure 10. Rate limit of the speed command

BEMF Information with Single Hall Control Method

If the single hall control is enabled, the device obtains the BEMF information from the hall signal. The corresponding between the phase U, V, W and the hall signal of phase U needs to follow the definition of the device.

(1) Phase U is leading phase V by 120°. Phase V is leading phase W by 120°. The hall positive output is aligned with BEMF of phase U in the opposite direction. Set the register HallPos to 0. The sequence is shown in Figure 11.

(2) Phase U is leading phase W by 120°. Phase W is leading phase V by 120°. The hall positive output is aligned with BEMF of phase U. Set the register HallPos to 0. The sequence is shown in Figure 12.

(3) Phase U is leading phase V by 120°. Phase V is leading phase W by 120°. The hall positive output is 30° leading of BEMF of phase U in the opposite direction. Set the register HallPos to 1. The sequence is shown in Figure 13.

(4) Phase U is leading phase W by 120°. Phase W is leading phase V by 120°. The hall positive output is 30° lagging of BEMF of phase U. Set the register HallPos to 1. The sequence is shown in Figure 14.

The sequence is also suitable for the hall IC input. Figure 15 and Figure 16 show the hall IC input with 30° placement.

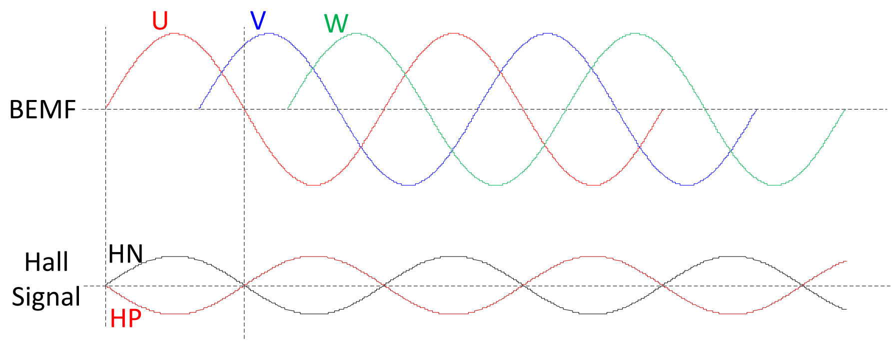


Figure 11. Hall Placement=0°   HallPos=0   Hall Element Input

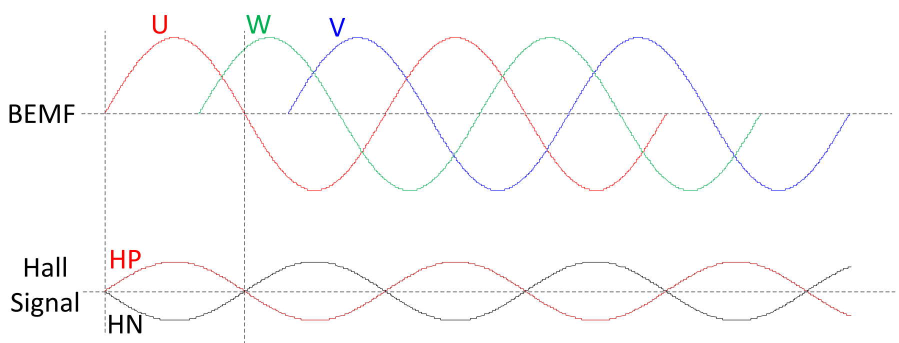


Figure 12. Hall Placement=0°   HallPos=0   Hall Element Input

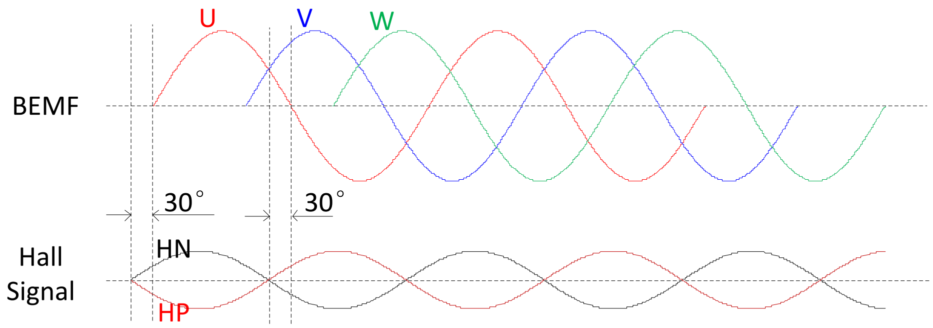


Figure 13. Hall Placement=30° HallPos=1 Hall Element Input

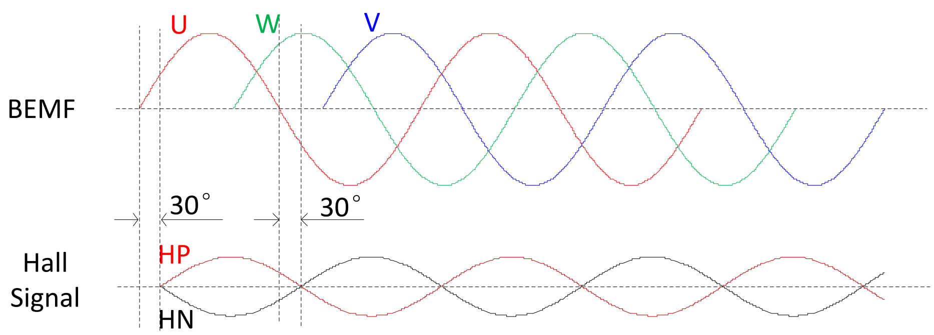


Figure 14. Hall Placement=30° HallPos=1 Hall Element Input

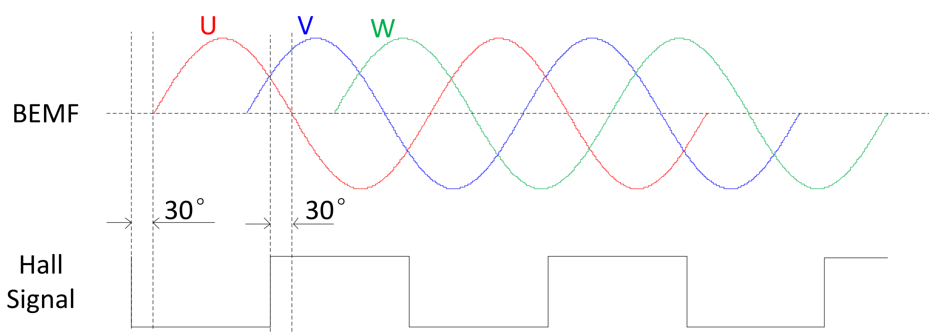


Figure 15. Hall Placement=30° HallPos=1 Hall IC Input

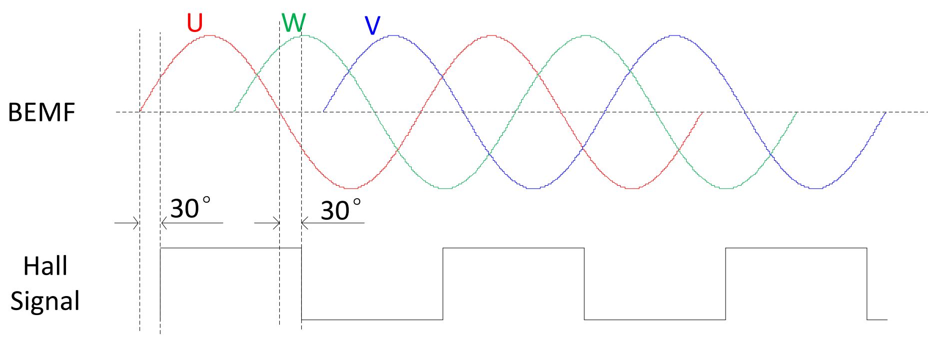


Figure 16. Hall Placement=30° HallPos=1 Hall IC Input

Closed Loop Angle Control of the Voltage

For a non-salient pole motor, the best efficiency will be achieved when the current and BEMF have the same phase position. The device adjusts the angle of the voltage every electrical cycle based on the zero crossing points of the BEMF and the sampled current. If the BEMF is leading the current, the voltage needs to be advanced with a corresponding angle in the next cycle. On the other hand, if the BEMF is lagging the current, the voltage needs to be delayed with a corresponding angle in the next cycle. Figure 17 shows the adjustment of the voltage angle with different phase position of the current and BEMF.

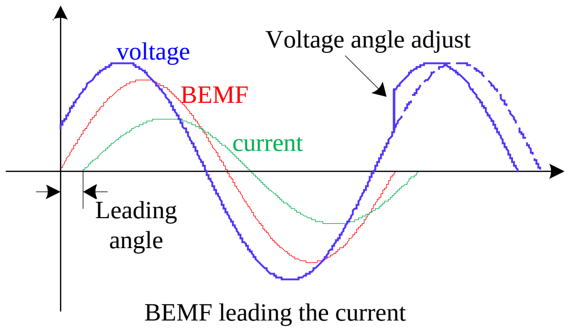


Figure 17. Adjust of the Voltage Angle

Abnormal State Detection and Protection

The device provides several protection and abnormal state detection to ensure reliable operation of the motor. Voltage surge protection is used to prevent the VM input capacity from being overcharged during the stop and deceleration of the motor. The abnormal rotor lock state is detected through different methods.

Lock Detection and Fault Handling

The device provides several different methods to detect whether the motor is locked by some external torque. Six different methods are used to make sure the detection is quick and reliable. If any of the lock conditions happens, the device will stop driving the motor and try to restart it after a certain time. Figure 18 shows the detect logic of the device.

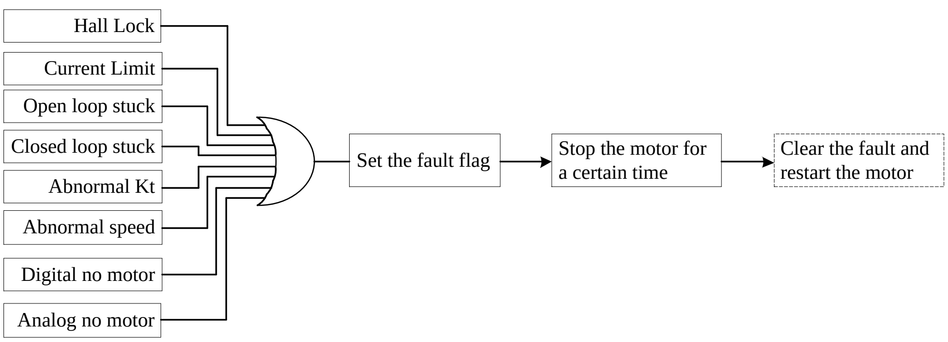


Figure 18. Lock Detect and Fault Handling

Current Limit

If a sudden lock happens when the motor is rotating, the current will be much big which could damage the system. The device provides a configurable current threshold which is set by CurrLimitThr[2:0] to detect the sudden lock. If the current is higher than the threshold, the device will stop the motor and a lock condition will be reported. The device will try to restart the motor after the time t_{lock_off}.

Open Loop Stuck

If the motor is successfully started up to the closed loop speed, the motor speed will be equal to the given closed loop speed and the BEMF is detected. Otherwise, if the BEMF is not detected for one electrical period, the startup is failure and the device will stop the motor and report a lock condition. The device will try to restart the motor after t_{lock_off}.

Closed Loop Stuck

If a stuck happens when the motor operates in the closed loop state, the motor speed will suddenly become very low or even become 0. As the period of the BEMF is related to the motor speed, the zero crossing point of the BEMF will delay or even undetected. A closed loop stuck happens if the period of the BEMF is 1.5 longer than the previous period or the zero crossing point of the BEMF is not detected during that time.

Abnormal Kt

The device calculates the Kt_est with the BEMF and compares it with the Kt[11:0] programmed by the user. If the Kt_est is smaller than 0.5×Kt[11:0] or bigger than 2×Kt[11:0], a lock condition is reported.

Abnormal BEMF

When the motor is normally running, the BEMF must be smaller than the amplitude of the output voltage. If the estimated BEMF is larger than the output voltage, the motor must get out of phase.

Digital No Motor detect

If the motor is not connected, no current will be detected. The device checks the U phase current through the ADC sample when the motor reaches the closed loop threshold, if the current is less than 140mA, the no motor fault is reported.

Analog No Motor detect

The device also detects the current of three phases by a comparator. If the current of any phase is lower than 100mA for 400ms, a no motor protection will occur and the motor will be stopped.

Hall Lock Protection

When single hall control method is enabled, the device detects the hall signal. And if there is no hall switch for 1.6s, a hall lock protection occurs and the motor will be stopped.

Mechanical Voltage Surge Protection

When the motor speed command suddenly drops or the drive signals turn from driving the motor state to a high impedance state, the mechanical energy stored in the rotor will return back to the power supply, which could lead to dc voltage surge and damage the system.

When the motor speed command suddenly drops, the BEMF generated by the motor is higher than the voltage applied to the motor. The energy returns to the power supply and the VM voltage surges. To avoid the energy returns back to the VM, there should be a minimal voltage supplied to the motor.

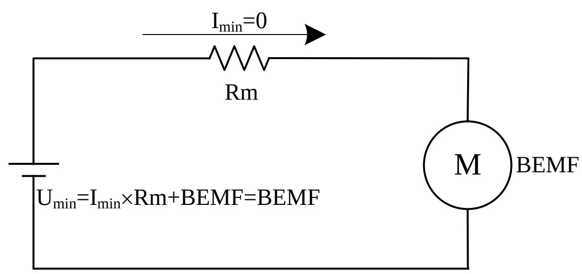


Figure 19. Voltage Supply When Motor Speed Command Suddenly Drops

As shown in Figure 19, when the motor speed command drops, the minimal voltage equals to the motor BEMF. So the voltage threshold is set to the BEMF of the motor which is calculated with the programmed Kt[11:0] set by the user.

Diagnostics and Visibility

The device has a FG output pin to provide the speed information. The motor information such as motor speed, lock information and others can also be monitored through the I^2C serial interface.

FG Output

The FG (frequency generator) output signal is a square wave based on the driving frequency. The output signal toggles every electrical cycle regardless of the pole pairs of the motor. If any of the lock condition happens, the signal is driven high.

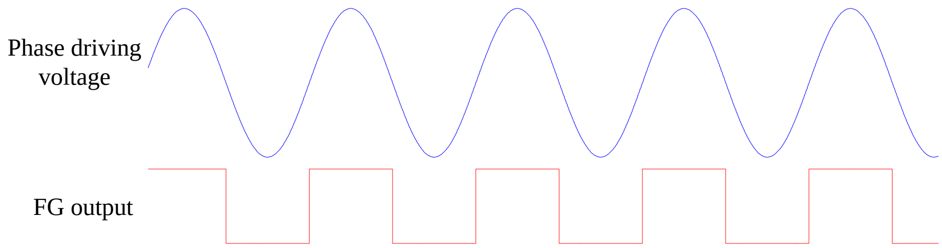


Figure 20. FG Output Signal

Motor Status Read Back

The motor status register provides information on over temperature (OverTemp), sleep state(Slp_Stdby), over current (OverCurr) and locked rotor (MtrLck).

Motor Electrical Speed Read Back

The motor electrical speed is calculated by the period of the zero crossing point of the estimated BEMF. The value is automatically updated in register MotorSpeed[15:0]. The electrical speed need to be divided by the motor pole pairs to get the mechanical speed.

Motor Electrical Period Read Back

The motor electrical period is the time between two zero crossing points of the estimated BEMF. The value is automatically updated in register MotorPeriod[15:0].

Motor Velocity Read Back

The motor velocity is a constant for a certain motor. The motor velocity is automatically updated in register MotorKt[15:0].

I^2C Compatible Interface

The SY21604 features an I^2C interface that allows the HOST processor to program or to control the motor. The I^2C interface supports clock speeds up to 400kHz and uses standard I^2C commands. The SY21604 always operates as a slave device, and is addressed using a 7-bit slave address followed by an 8th bit, which indicates whether the transaction is a read-operation or a write-operation.

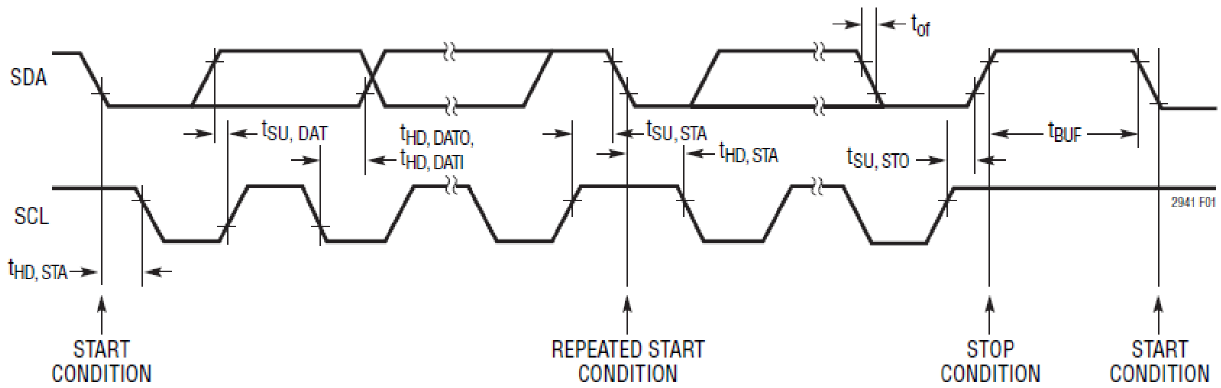


Figure 21. I^2C Timing Diagram

START and STOP Conditions

The SY21604 is controlled via an I^2C compatible interface. The START condition is a HIGH to LOW transition of the SDA line while SCL is HIGH. The STOP condition is a LOW to HIGH transition on the SDA line while SCL is HIGH. A STOP condition must be sent before each START condition. The I^2C master always generates the START and STOP conditions.

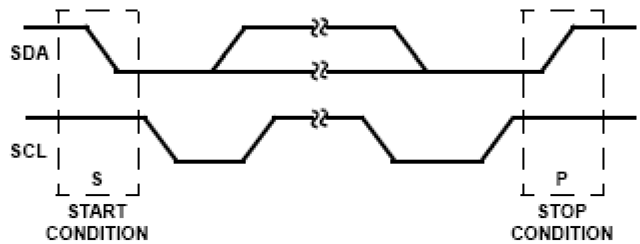


Figure 22. I^2C Timing Diagram

Data Validity

The data on the SDA line must be stable during the HIGH period of the SCL, unless generating a START or STOP condition. The HIGH or LOW state of the data line can only change when the clock signal on the SCL line is LOW.

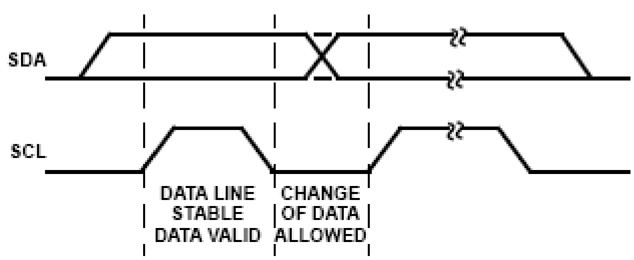


Figure 23. I^2C Timing Diagram

Acknowledge

Each address and data transmission uses 9-clock pulses. The ninth pulse is the acknowledge bit (ACK). After the START condition, the master sends 7-slave address bits and an $R/\overline{W}$ bit during the next 8-clock pulses. During the ninth clock pulse, the device that recognizes its own address holds the data line low to acknowledge. The acknowledge bit is also used by both the master and the slave to acknowledge receipt of register addresses and data.

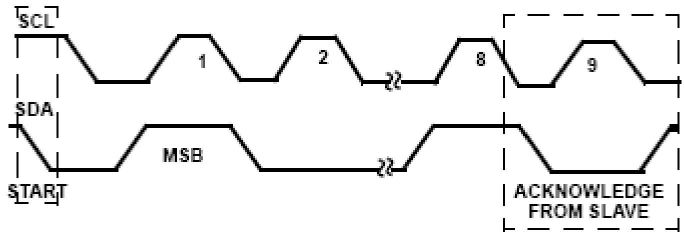


Figure24. I^2C Timing Diagram

Data Transactions

All transactions start with a control byte sent from the I^2C master device. The control byte begins with a START condition, followed by 7-bits of slave address (0110100x) followed by the 8th bit, $R/\overline{W}$ bit. The $R/\overline{W}$ bit is 0 for a write or 1 for a read. If any slave devices on the I^2C bus recognize their address, they will acknowledge by pulling the SDA line low for the last clock cycle in the control byte. If no slaves exist at that address or are not ready to communicate, the data line will be 1, indicating a Not Acknowledge condition. Once the control byte is sent, and the SY21604 acknowledges it, the 2nd byte sent by the master must be a register address byte. The register address byte tells the SY21604 which register the master will write or read. Once the SY21604 receives a register address byte it responds with an acknowledge signal.

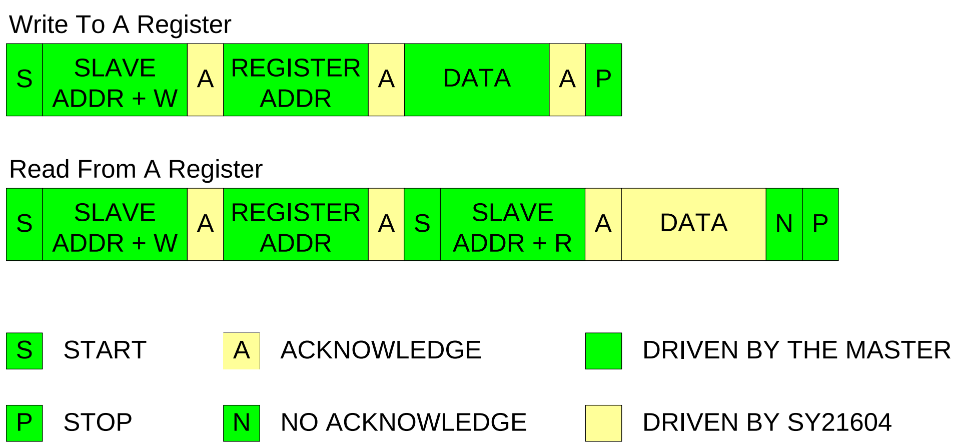


Figure26. I^2C Logic Diagram

Sleep Mode

When SY21604 enters Sleep Mode, three half-H-bridges gate drivers are disabled, all internal logic and any register data not stored in MTP is reset.

Tab 4. Sleep Mode

Speed Command	Enter Sleep Mode	Exit from Sleep Mode
Analog	SP pin voltage < V_{AENSLP} for T_{ENSLP}	SP pin High ($V>V_{DSPH}$) for T_{EXSLP}
PWM	SP pin Low ($V<V_{DSPL}$) for T_{ENSLP}	
I^2C	SpdCtrl[7:0] is set as 0 for T_{ENSLP}	

Protections

The device is fully protected against undervoltage, overcurrent, and overtemperature.

Overcurrent Protection (OCP)

An analog current limit circuit on each FET limits the current through the FET by turning off the gate drive. If this analog current limit persists for longer than the OCP deglitch time, all FETs in the three phase half-H-bridge will be disabled.

Over current conditions are detected independently on both high and low side devices; i.e., a short to ground, supply, or across the motor winding will all result in an overcurrent shutdown.

Undervoltage Lockout (UVLO)

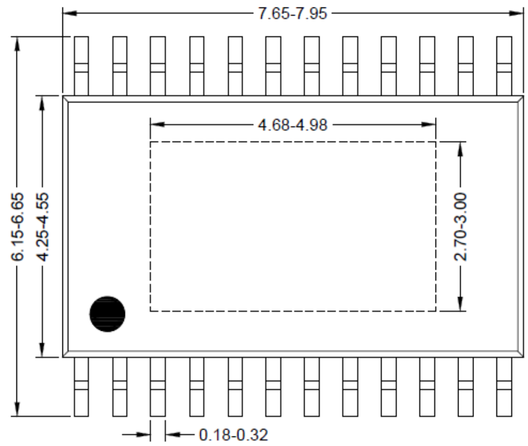
If at any time the voltage on the VM pin falls below the undervoltage lockout threshold voltage, all circuitry in the device will be disabled, and all internal logic will be reset. Operation will resume when VM rises above the UVLO threshold.

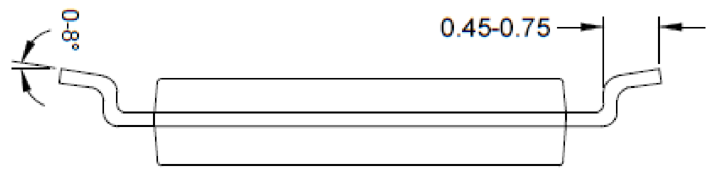
Thermal Shutdown(TSD)

If the die temperature exceeds approximately 150°C, the device is disabled until the temperature drops to a safe level.

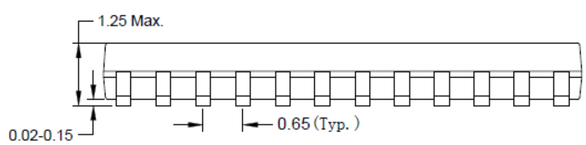
Any tendency of the device to enter thermal shutdown is an indication of either excessive power dissipation, insufficient heatsinking, or too high an ambient temperature.

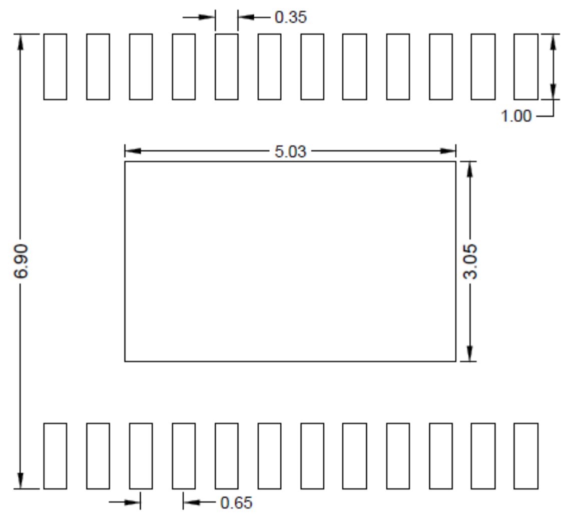
TSSOP24E Package Outline Drawing





Top View **Side View**



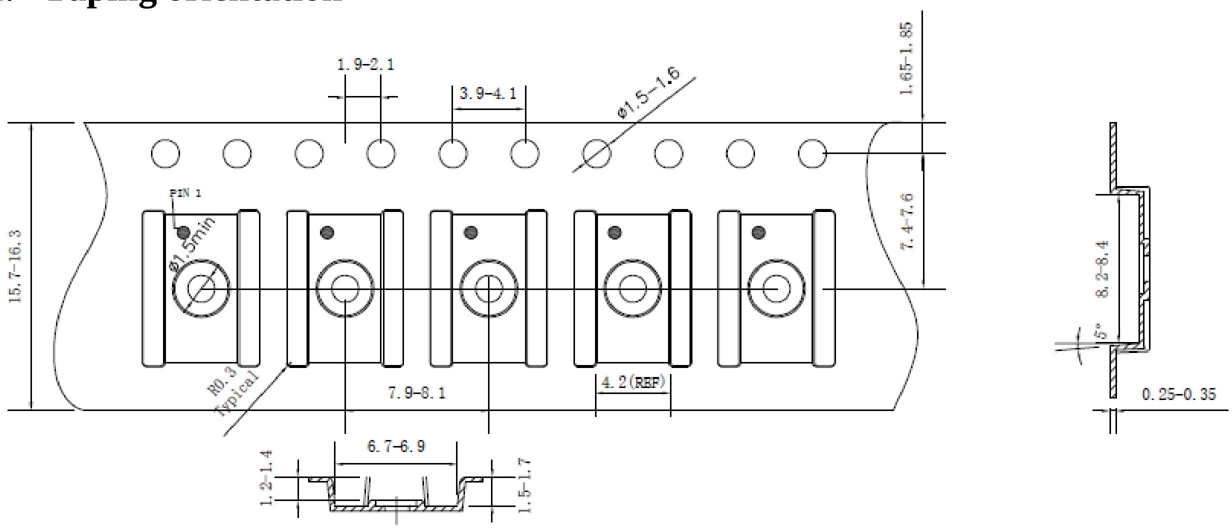


Front View **Recommended PCB Layout (Reference only)**

Notes: All dimension in millimeter and exclude mold flash & metal burr.

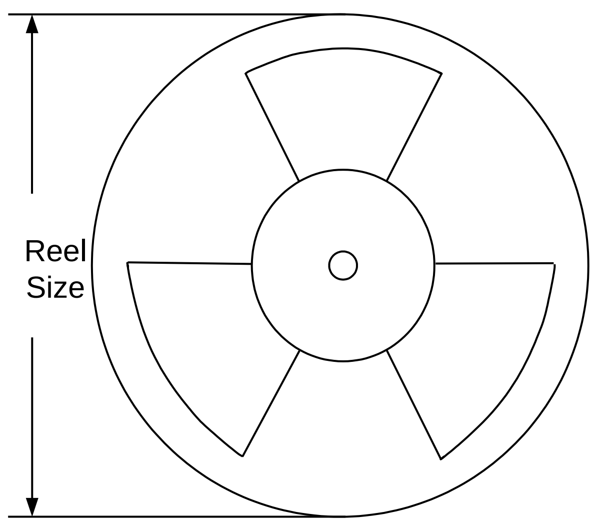
Taping & Reel Specification

1. Taping orientation



Feeding direction →

2. Carrier Tape & Reel specification for packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
TSSOP24E	16	12	13"	400	400	3000

3. Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Revision Number	Revision Date	Description
0.9	03/24/2021	Initial Release
1.0	03/24/2022	Production Release

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