High Speed 12-Bit Magnetic Rotary Encoder IC

1. Features

- Contactless 12-bit resolution rotational encoder
- Programmable resolution, pole-pairs and zero position
- 12-bit absolute outputs
  - SPI interface
  - PWM interface
- Incremental outputs
  - A/B/Z interface(Up to 1024 wires)
  - U/V/W interface(1~16 pairs of pole)
  - A+/B+/Z+ and A-/B-/Z- differential output
- Sincosine difference
- Sincosine amplitude: 2V(Vpp)
- Angle linearity error < ±0.35°
- Maximum tracking speed: 20K rpm
- Wide temperature range: -40℃ to 125℃
- Package available.
  - SSOP16(SS)
  - SOP8(DC)

2. Applications

- Contactless rotary position sensing
- Brushless DC motor commutation
- Robotics
- Angular encoder
- Rotational speed control

3. Description

SC6022X is a contactless high-speed, high-precision magnetic encoder chip. Hall induction point matrix is built into the center of the chip, which generates sine and cosine position signals by sensing a pair of pole magnets above. The analog to digital conversion circuit inside the chip samples the amplified sine and cosine signals, and the DSP circuit performs Angle calculation, and finally outputs various position signals.SC6022X has a resolution of 12 bits, and each circle can generate 4096 incremental Angle signals. The position of zero signals can be programmed through SPI interface, and the maximum support is 20K RPM.

SC60220/1/4 uses 16-pin SSOP package, matte tin plating, halogen-free green material, to meet the environmental requirements. SC60228 uses 8-pin SOP8 package, matte tin plating, halogen-free green material, to meet the environmental requirements.

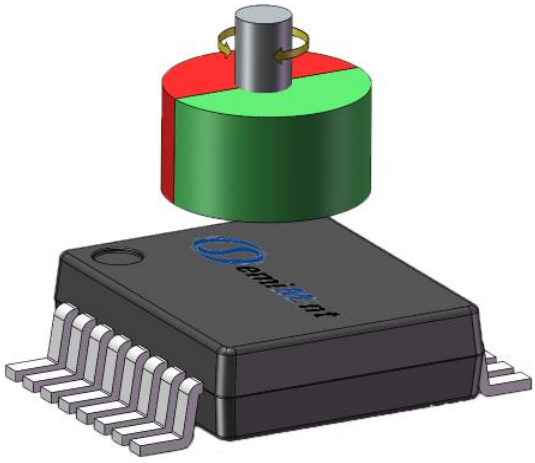

Fig.1 Schematic diagram of the work

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4. Terminal Configuration

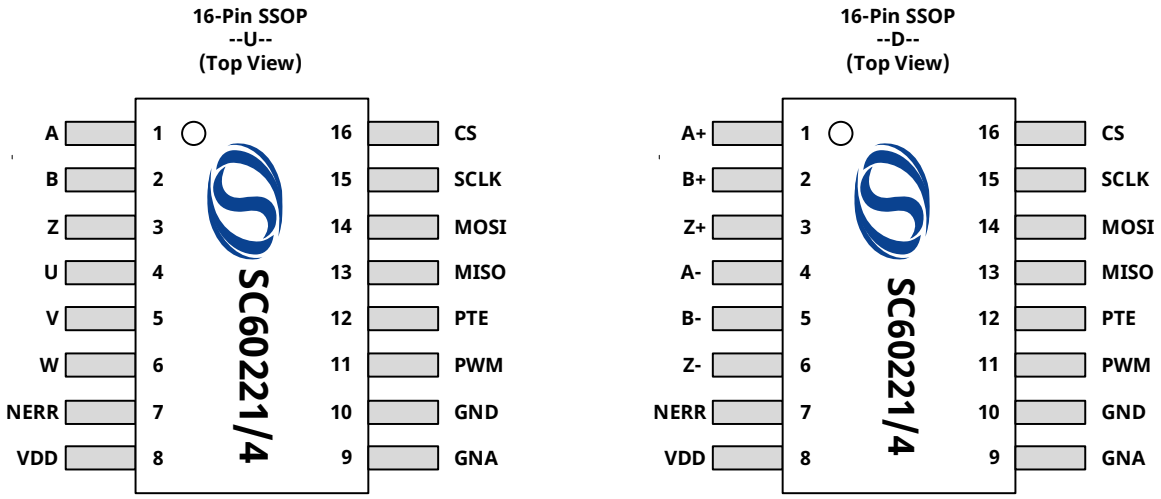


Fig.2 SC60221/4 Terminal Configuration

No.	Pin Name		I/O	Type	Description
	SC60221/4-U	SC60221/4-D			
1	A	A+	Output	Digital	A phase Pulse Signal
2	B	B+	Output	Digital	B phase Pulse Signal
3	Z	Z+	Output	Digital	C phase Pulse Signal
4	U	A-	Output	Digital	U/A- phase Pulse Signal
5	V	B-	Output	Digital	V/B- phase Pulse Signal
6	W	Z-	Output	Digital	W/Z- phase Pulse Signal
7	NERR	NERR	Output	Digital	Error output (active low)
8	VDD	VDD	-	Power	Power Supply PIN
9	GNA	GNA	-	GND	Analog Ground PIN
10	GND	GND	-	GND	Digital Ground PIN
11	PWM	PWM	Output	Digital	PWM Pulse Output PIN
12	PTE	PTE	Input	Digital	EEPROM Programming Protection PIN
13	MISO	MISO	Output	Digital	SPI Output Data Signal
14	MOSI	MOSI	Input	Digital	SPI Input Data Signal
15	SCLK	SCLK	Input	Digital	SPI Clock Signal
16	CS	CS	Input	Digital	SPI Chip Select Signal

16-Pin SSOP
(Top View)

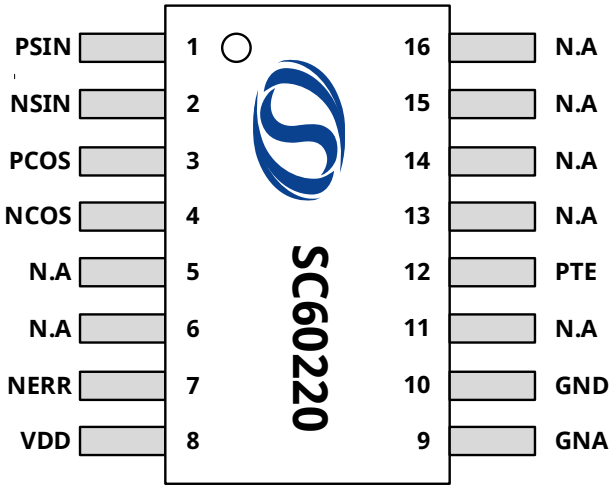


Fig.3 SC60220 Terminal Configuration

No.	Pin Name	I/O	Type	Description
1	PSIN	Output	Digital	SIN(+)
2	NSIN	Output	Digital	SIN(-)
3	PCOS	Output	Digital	COS(+)
4	NCOS	Output	Digital	COS(-)
5	N.A.	-	-	Not connected
6	N.A.	-	-	Not connected
7	NERR	-	Digital	Error output (active low)
8	VDD	-	Power	Power
9	GNA	-	GND	Analog Ground PIN
10	GND	-	GND	Digital Ground PIN
11	N.A.	-	-	Not connected
12	PTE	Input	Digital	EEPROM Programming Protection PIN
13	N.A.	-	-	Not connected
14	N.A.	-	-	Not connected
15	N.A.	-	-	Not connected
16	N.A.	-	-	Not connected

SOP8
DC Package
(Top View)

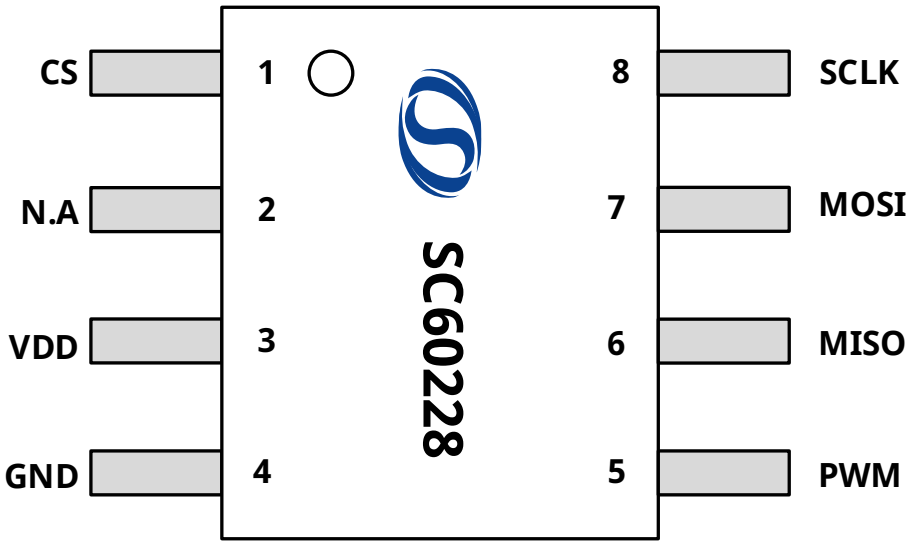


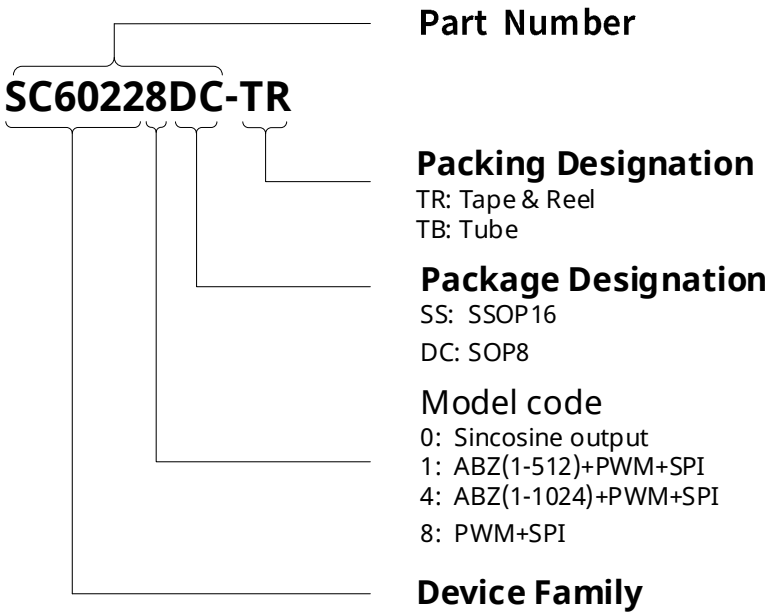
Fig.4 SC60228 Terminal Configuration

No.	Pin Name	I/O	Type	Description
1	CS	Input	Digital	SPI Chip Select Signal
2	N.A	-	-	Not connected
3	VDD	-	Power	Power
4	VSS	-	GND	GND
5	PWM	Output	Digital	PWM Pulse Output PIN
6	MISO	Output	Digital	SPI Output Data Signal
7	MOSI	Input	Digital	SPI Input Data Signal
8	SCLK	Input	Digital	SPI Clock Signal

5. Ordering Information

Ordering Information	Mark	Ambient(℃)	Package	Pack	Amount
SC60220SS-TB	60220	-40-125	SSOP16	Tube	80 Pcs/Tube
SC60221SS-TB	60221	-40-125	SSOP16	Tube	80 Pcs/Tube
SC60224SS-TB	60224	-40-125	SSOP16	Tube	80 Pcs/Tube
SC60228DC-TR	60228	-40-125	SOP8	Reel	3000 Pcs/Reel

Ordering Information Format



Note:
The specific parameters of the chip must be clearly noted when placing the order, such as examples: SC60224-U-P4-1024-244
SC60224: Part Number;
U: Not differential;
P4: 4 Polar UVW;
1024: 1024 pulse;
244: PWM frequency 244Hz.

6. Absolute Maximum Ratings

Symbol	Parameter	Test Conditions	Min.	Max.	Unit
$V_{()}$	Voltage at VDD, A, B, Z, U, V, W, MOSI, MISO, SCLK, CS, NERR		-0.3	6	V
$I_{()}$	Current in VDD		-10	20	mA
$I_{()}$	Current in A, B, Z, U, V, W, MISO,NERR		-100	100	mA
$I_{()}$	Current in SCLK, CS, MOSI, PTE		-10	10	mA
	EEPROM Write Cycles		-	100	cycle
T_A	Operating ambient temperature		-40	125	℃
T_{STG}	Storage temperature		-65	165	℃
$T_{J(max)}$	Operating junction temperature		-	165	℃

Note:
Stresses above those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

7. ESD Protection

Symbol	Parameter	Test Conditions	Min.	Max.	Unit
V_{ESD}	HBM	ANSI/ESDA/JEDEC-001	-4	4	kV
	CDM	ANSI/ESDA/JEDEC-002	-750	750	V

8. Operating Characteristics

valid through the full operate temperature range, V_{DD}=5V, C_{BY}=0.1μF, unless otherwise specified

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Electrical Characteristics						
V_{DD}	Supply Voltage		3.0	5.0	5.5	V
I_{DD}	Supply Current	No load, fmag=0 rpm	10	16	22	mA
V_{bg}	Bandgap Reference		1.18	1.25	1.32	V
V_{ref}	Reference voltage		45	50	55	%V_{DD}
$V_{th(on)}$	Turn-on Threshold	Increasing voltage	2.6	2.75	2.9	V
$V_{th(off)}$	Turn-off Threshold	Decreasing voltage	2.4	2.6	2.8	V
$V_{th(Hys)}$	Hysteresis		0.15	-	-	V
$V_{R(offset)}$	Reference Voltage Offset		470	500	530	mV
Clock Generation						
$f_{(sys)}$	System Clock	Bias current adjusted	0.8	1	1.2	MHz
$f_{(sdc)}$	AD Converter Frequency	Bias current adjusted	13	16	19	MHz
Sine/Digital Converter						
$RES_{(sdc)}$	Sine/Digital Converter Resolution		-	12	-	bit
INL_{opt}	Integral non-linearity	V_{DD}=5V,Temp=25℃,Din=1.0mm	-0.5	-	0.5	Deg
INL_{temp}	Integral non-linearity	Maximum error with respect to the best line fit, Tamb=-40 to 125℃	-0.9	-	0.9	Deg
$AA_{(rel)}$	Relative Angular Accuracy	With reference to an output period at A, B	-20	0	+20	%
TD	Angle Output Delay Time	at ABZ hysteresis = "1LSB"	-	18.0	45.0	μs
Signal Level Control						
V_{pp}	Differential Peak-to-Peak Output Amplitude		3.2	4.0	4.8	V
$t_{(on)}$	Controller Setting Time	to ± 10% of final amplitude	-	-	300	μs
$Vt_{(lo)}$	Min. Amplitude error		1.0	-	2.8	V
$Vt_{(hi)}$	Max. Amplitude error		4.8	-	5.8	V
PWM Output						
$F_{(pwm)}$	PWM frequency(default)	V_{DD}=5V，Temp=25℃	927	976	1024	Hz
$F_{(pwm)}$	PWM frequency(optional)	V_{DD}=5V，Temp=25℃	232	244	256	Hz

Operating Characteristics (Continued)

valid through the full operate temperature range, V_{DD}=5V, C_{BYPASS}=0.1uF, unless otherwise specified

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Magnetic Input Specification						
dmag	Diameter	φ6mm x 2.5mm for cylindrica Magnets	4.0	6.0	10.0	mm
tmag	Thickness		-	2.5	-	mm
Din	Installation Distance	Recommended magnets	-	1.0	2.0	mm
Hext	Field Amplitude	At chip surface	25	-	125	mT
$f_{(mag)}$	Rotation Frequency		-	-	333	Hz
rpm	Rotating Speed of Magnet		-	-	10	krpm
x_{dis}	Lateral Displacement of Magnet Axis to Center of Hall Sensors		-	-	0.2	mm
x_{pac}	Displacement Chip Center to Package Center		-0.15	-	0.15	mm
φ_{pac}	Angular Alignment of Chip vs. Package		-3	-	3	Deg
h_{pac}	Displacement of Chip Surface to Package Surface		-	0.4	-	mm
Digital Inputs: CS,SCLK,MOSI						
$Vt_{(hi)}$	Threshold Voltage hi		-	-	2	V
$Vt_{(lo)}$	Threshold Voltage lo		0.8	-	-	V
$I_{pd()}$	Pull-down Current MOSI	V()=1 V...VPD	6	38	60	μA
$I_{pu()}$	Pull-up Current Source at CS,SCLK	V()=0...VPD − 1 V	-80	-140	-200	μA
Digital Inputs: PTE						
Ipd()	Drop-down current PTE	V()=1 V...VPD	1	4	10	μA
PTEon	Open the threshold		-	1.7	-	V
PTEoff	Close the threshold		-	1.3	-	V
Digital OUTPUTS: A,B,Z,U,V,W,PWM,MISO,NERR						
Vs()hi	Saturation Voltage hi	I()hi=-4 mA, with reference to VDD	-	-	200	mV
Vs()lo	Saturation Voltage lo	I()lo=4 mA, with reference to GND	-	-	200	mV
Ishort()hi	Short-Circuit Current hi	V()=GND;	10	-	20	mA
Ishort()lo	Short-Circuit Current lo	V()=VDD;	5	-	15	mA
t_{Rise}	Rise-Time lo to hi	R_L=100Ω to GND;	5	-	30	ns
t_{Fall}	Fall-Time high to lo	R_L=100Ω to VDD;	5	-	30	ns

9. Block Diagram

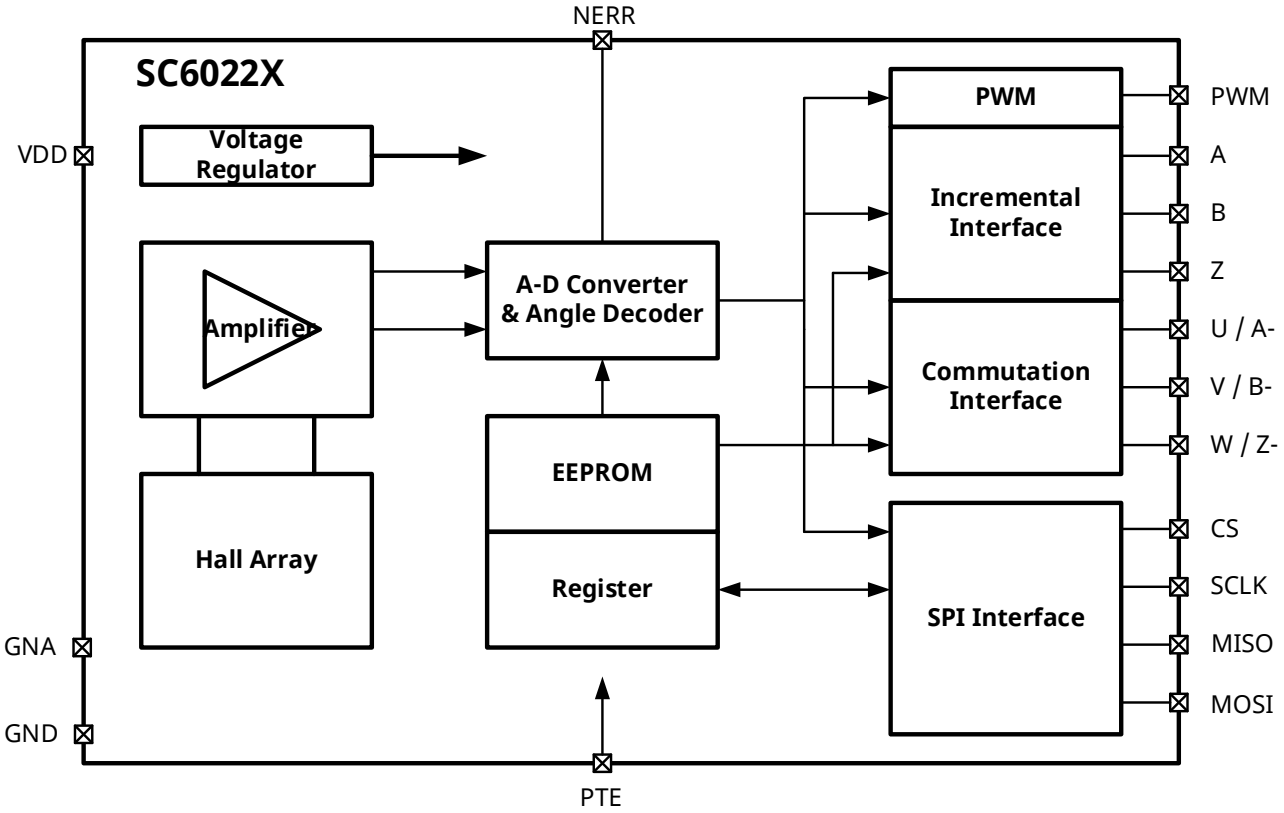


Fig.5 Block Diagram

10. Function Description

10.1. Position of the Hall Sensors

The Hall sensors are placed in the center of the package at a 90° angle to one another and arranged in a circle.

The zero-angle position of the magnet is reached when the value of V_{PCOS}-V_{NCOS} is at a maximum. This is the case when the South Pole of the magnet is exactly above the PCOS sensor and the North Pole is above sensor NCOS. When the magnet is rotated counterclockwise, the angle is increasing, as shown in the Fig.6.

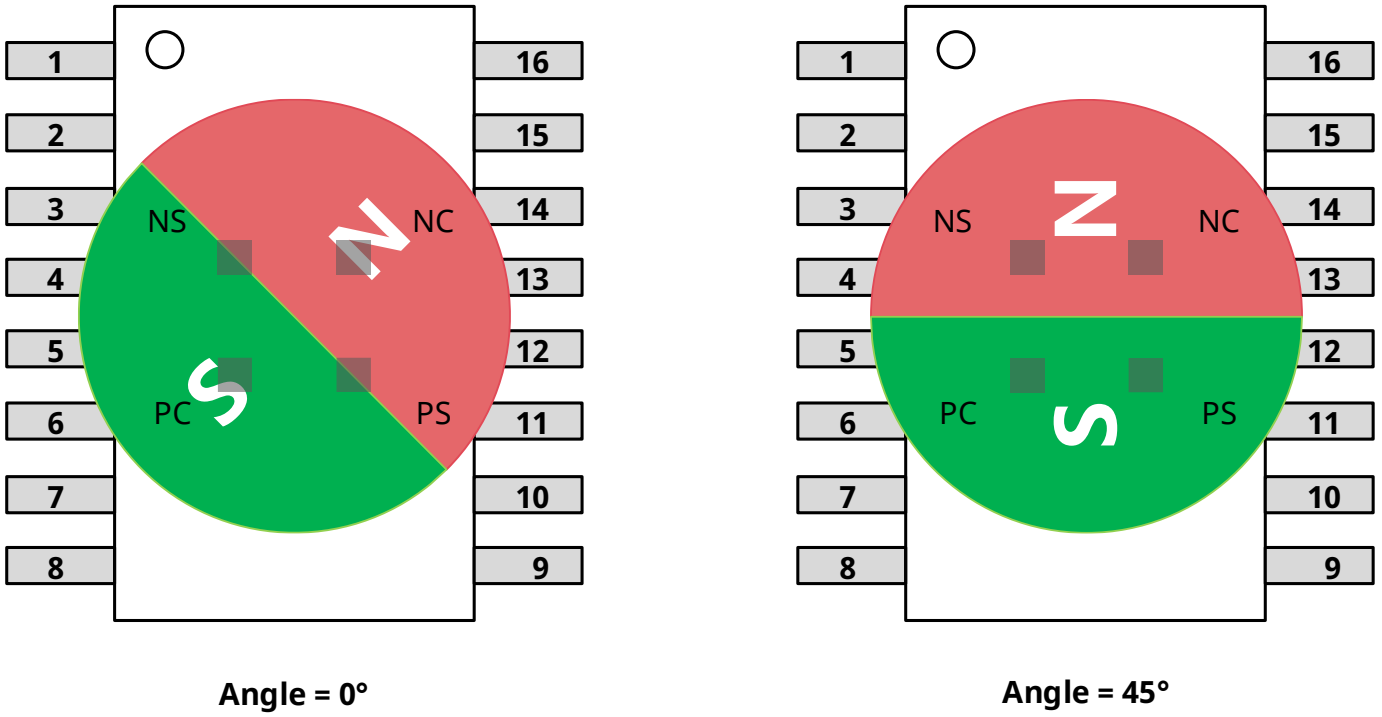


Fig.6 Schematic diagram of angular position

10.2. SPI Interface

Serial Peripheral Interface Timing Diagram with Absolute Angular Position Data

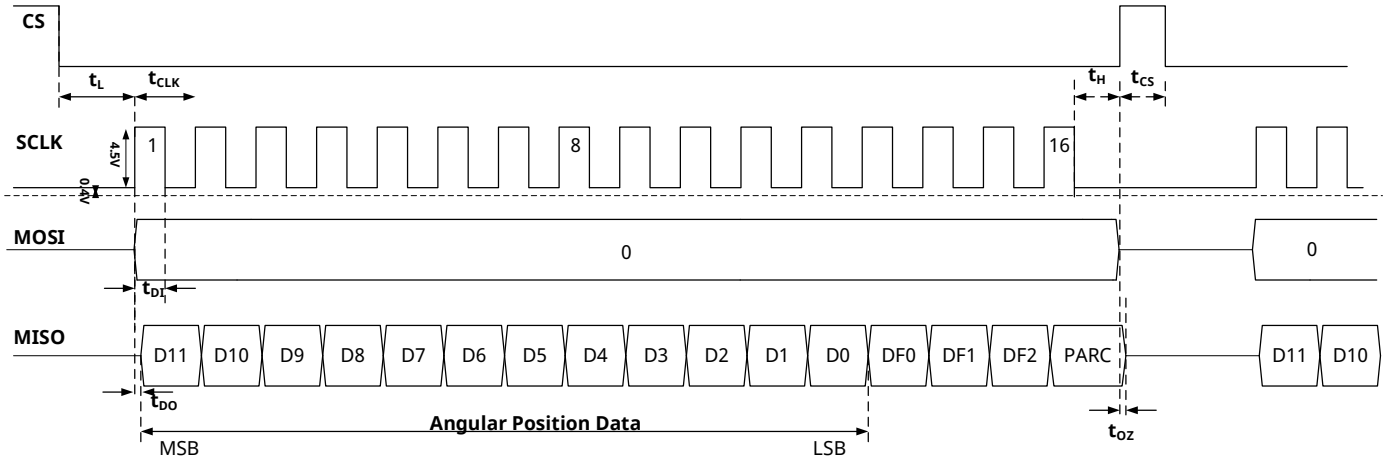


Fig.7 SPI timing diagram

SPI Timing Definition

Parameter	Description	Min.	Max.	Unit
t_L	Time between CS falling edge and SCLK rising edge	250	-	ns
t_{CLK}	Serial clk period	100	-	ns
t_H	Time between last falling edge of SCLK and rising edge of CS	tCLK/2	-	ns
t_{CS}	High time of CS between two transmissions	250	-	ns
t_{DO}	SCLK edge to data output valid	-	50	ns
t_{DI}	Data input valid to falling clock edge	20	-	ns
t_{OZ}	Release bus time after CS rising edge	-	10	ns

SPI Read Data Frame

Bit	Name	Description
15	PARC	Parity bit (odd) calculated on the lower 15 bits of data frame
14	DF2	Data fixed; logic High
13	DF1	Data fixed; logic High
12	ERR	Becomes logic High, when the fault occurs
11:0	DATA	Absolute angular position data (MSB is clocked out first)

10.3. Incremental Outputs

The SC60221/4 provides the ABZ incremental output via A, B, Z pin. These outputs are encoded from the angle output data. When the magnet is rotating in counter-clockwise at default settings, the B-phase leads the A-phase.

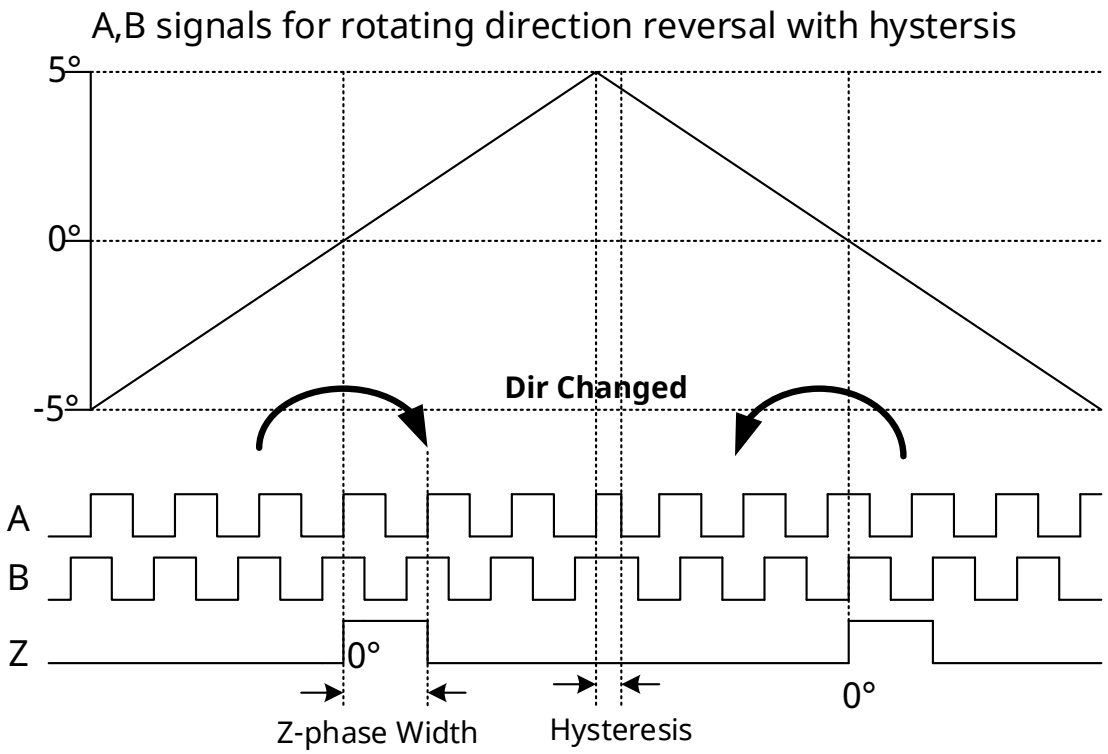


Fig.8 Pulse waveform diagram

The Z-phase width is programmable between 1LSB, 2LSB, 4LSB (default) and 8LSB.

The Z-signal position is programmable.

The ABZ Hysteresis is programmable between 0LSB, 2LSB, 4LSB (default) and 8LSB.

ABZ Resolution Setting			
No.	**Type**	**Pulses per Round**	**Counts per Revolution**
1	Binary	1024	4096
2		512	2048
3		256	1024
4		128	512
5		64	256
6	Decimal	1000	4000
7		800	3200
8		600	2400
9		500	2000
10		400	1600
11		360	1440
12		300	1200
13		200	800
14		100	400
15		50	200

10.4. UVW Commutation Mode

The SC60221/4 provides UVW commutation output necessary for detecting the magnetic pole of the DC brushless motor via U, V, and W pin. The phase of each output is shifted by electric angle phase 120°. The output resolution is programmable from 1 to 16 pole pairs.

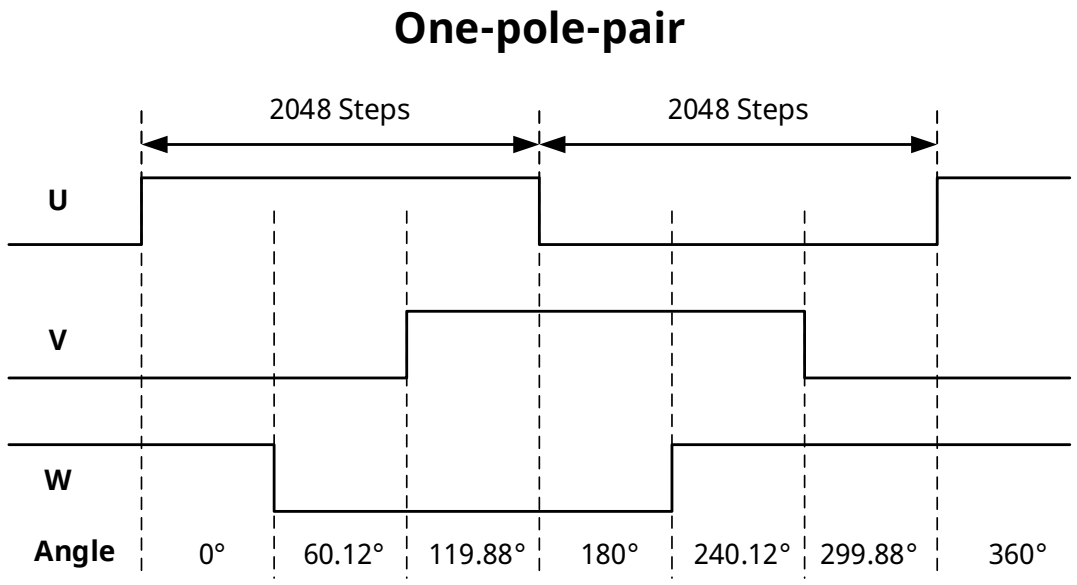


Fig.9 1 pair of polar UVW waveforms

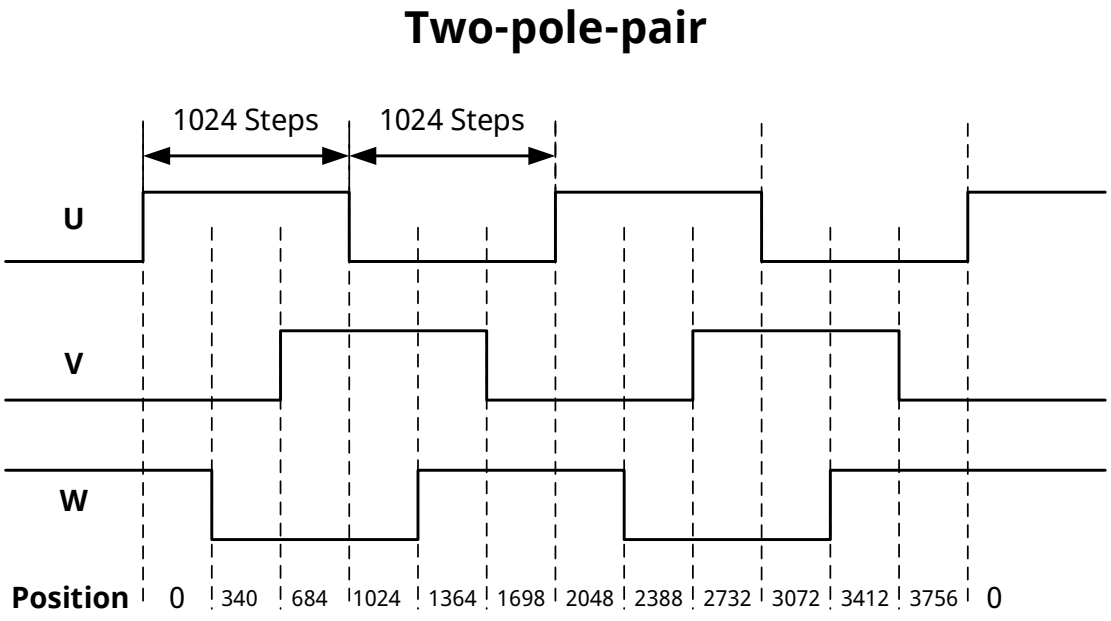


Fig.10 2 pair of polar UVW waveforms

10.5. Pulse Width Modulation Output

The SC60221/4/8 provides a pulse width modulated output (PWM), whose duty cycle is proportional to the measured angle.

$$Position = t_{on} \text{ X } 4098 / (t_{on} + t_{off}) - 1$$

The PWM frequency is internally trimmed to an accuracy of ±5% (±10% over full temperature range). This tolerance can be canceled by measuring the complete duty cycle as shown below:

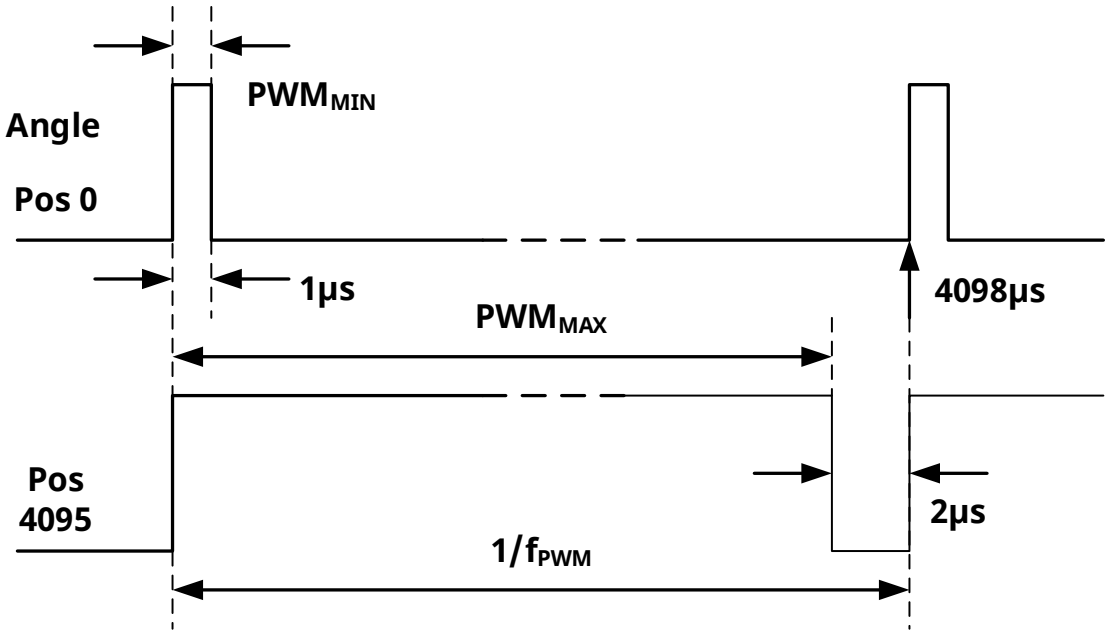


Fig.11 Schematic diagram of waveform with PWM frequency of 244Hz

PWM default frequency(976Hz)

Parameter	Symbol	Typ.	Unit	Note
PWM frequency	f_{PWM}	976	kHz	Signal period: 4098
MIN pulse width	PW_{MIN}	0.25	us	Position 0d； Angle 0 deg
Max pulse width	PW_{MAX}	1024	us	Position 4095d； Angle 359.91 deg

PWM optional frequency(244Hz)

Parameter	Symbol	Typ.	Unit	Note
PWM frequency	f_{PWM}	244	kHz	Signal period: 4098
MIN pulse width	PW_{MIN}	1	us	Position 0d； Angle 0 deg
Max pulse width	PW_{MAX}	4096	us	Position 4095d； Angle 359.91 deg

11. Typical Application

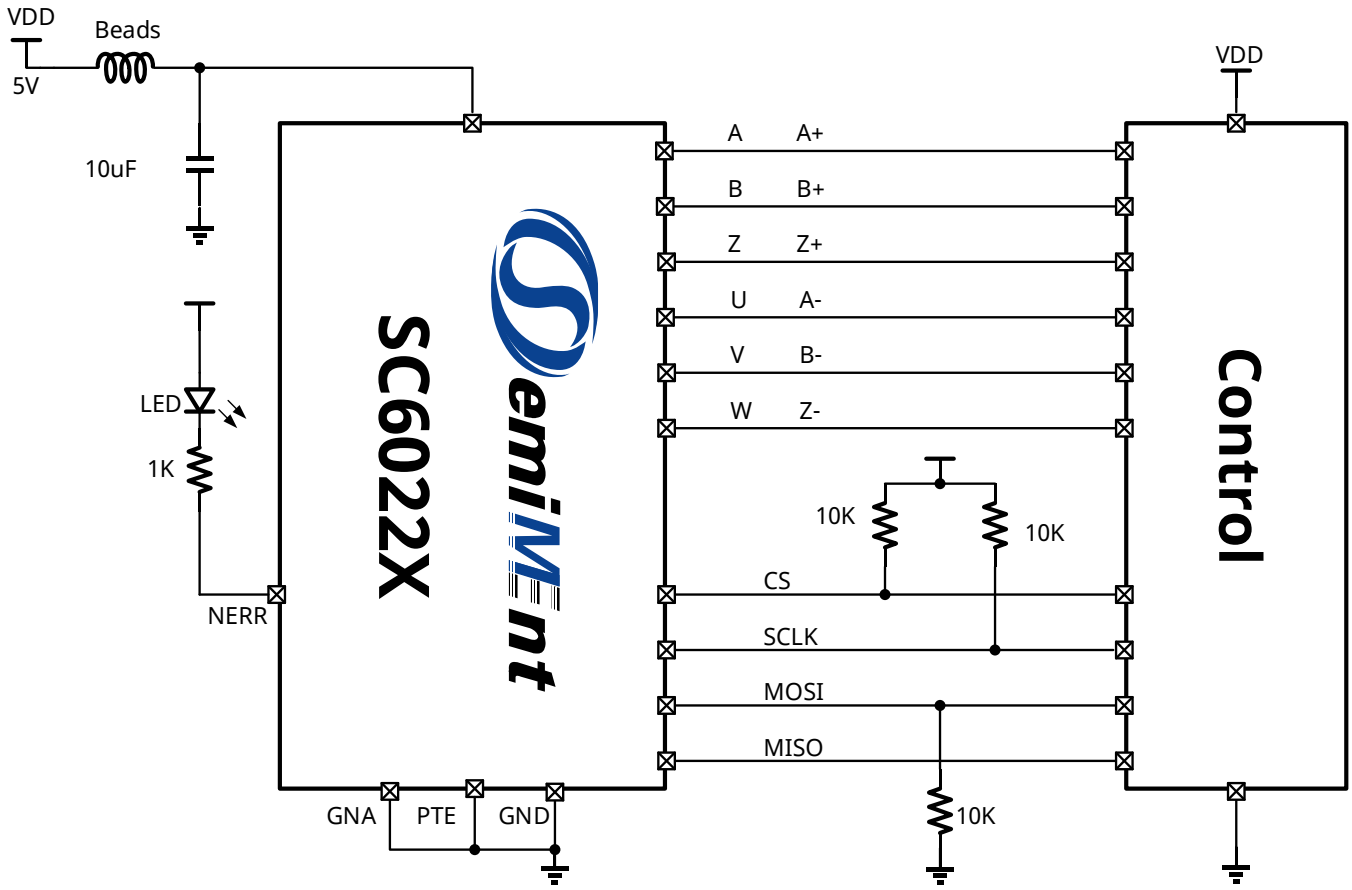


Fig.12 Typical Application

Note:

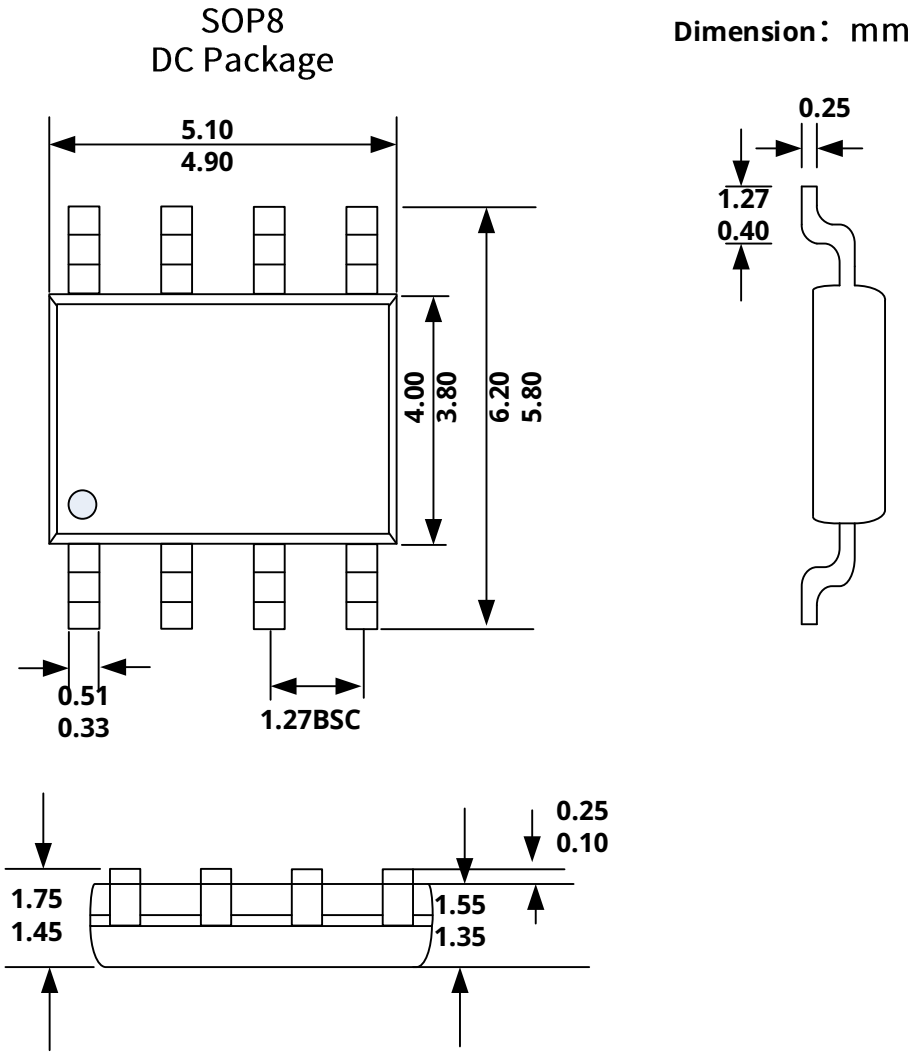
(1) Add SMD inductor (magnetic bead) and 10uF decoupling capacitor to power end of magnetic encoder chip.

(2) CS and SCLK end plus 10K pull-up resistor, MOSI plus 10K pull-down resistor.

(3) Since SPI communication is a board-level communication protocol, it is recommended that the length of the connection line should not exceed 30cm if communication is required via wire connection.

(4) If ABZUVW is connected to the controller end, please use RS422 differential communication chip 26C31 for differential signal transmission in long line communication.

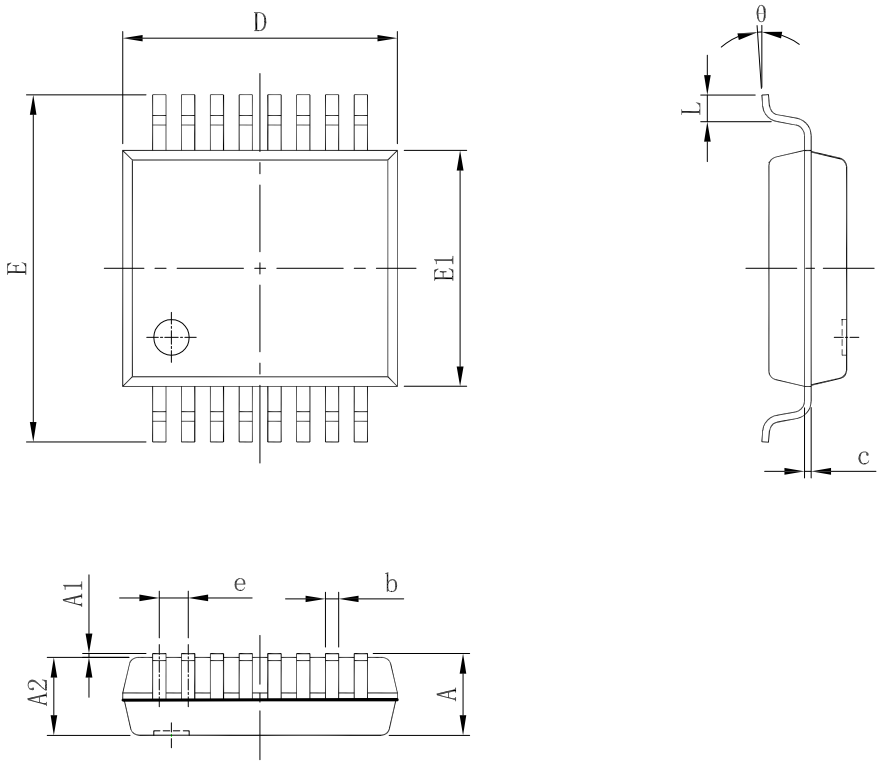
12. Package Information DC



Notes:
(1) Exact body and lead configuration at vendor's option within limits shown.
(2) Height does not include mold gate flash.
Where no tolerance is specified, dimension is nominal.

Fig.13 SOP8 Package Dimension Drawing

13. Package Information SS



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	**Max.**	**Min.**	**Max.**
A	—	2.000	—	0.079
A1	0.050	—	0.002	—
A2	1.650	1.850	0.065	0.073
b	0.220	0.380	0.009	0.015
c	0.090	0.250	0.004	0.010
D	5.900	6.500	0.232	0.256
E	7.400	8.200	0.291	0.323
E1	5.000	5.600	0.197	0.220
e	0.650(BSC)		0.026(BSC)	
L	0.550	0.950	0.022	0.037
θ	0°	8°	0°	8°

Fig.14 SSOP16 Package Dimension Drawing

14. Revision History

Revision	Date	Description
Rev.E0.1	2019-04-05	Initial release
Rev.A1.0	2019-07-16	Update typical application circuit
Rev.A1.1	2020-05-31	Add version history
Rev.A1.2	2025-02-17	Modify the order information