
High Speed 12-Bit Magnetic Rotary Encoder

FEATURES

- Contactless 12-bit resolution rotary encoder
- Programmable resolution, pole-pairs and zero position
- 12-bit absolute outputs
 - SPI interface
 - PWM interface
- Incremental outputs
 - A/B/Z interface (Up to 500 wires)
 - U/V/W interface (Up to 16 pairs of pole)
 - A+/B+/Z+ and A-/B-/Z- differential output
- Angle linearity error $< \pm 0.5^\circ$
- Maximum tracking speed: 10krpm
- Wide temperature range: -40°C to 125°C
- SSOP16 package

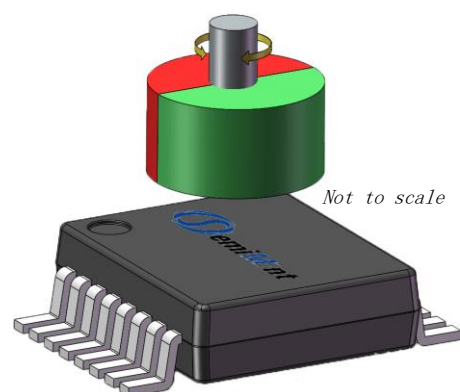
APPLICATIONS

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

DESCRIPTION

SC60221 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. SC60221 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 10k RPM.

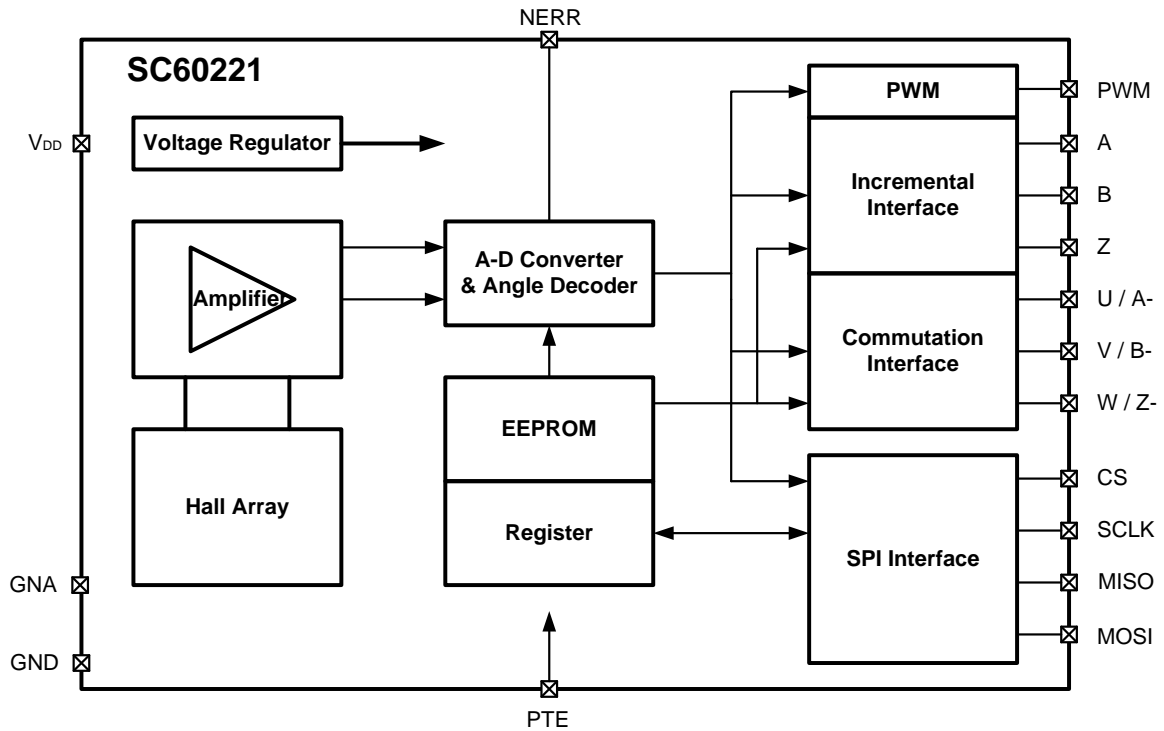
SC60221 is available in a 16-pin SSOP package, which is lead (Pb) free, with 100% matte tin lead frame plating.



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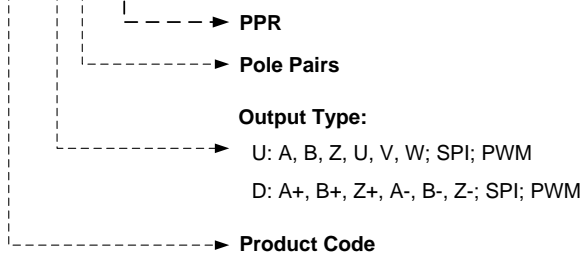
BLOCK DIAGRAM



ORDERING INFORMATION

Part Number	Packing	Mounting	Output Type	Marking
SC60221-U	80 pcs Tube	16-pin SSOP	A, B, Z, U, V, W; SPI; PWM	60221
SC60221-D	80 pcs Tube	16-pin SSOP	A+, B+, Z+, A-, B-, Z-; SPI; PWM	60221-D

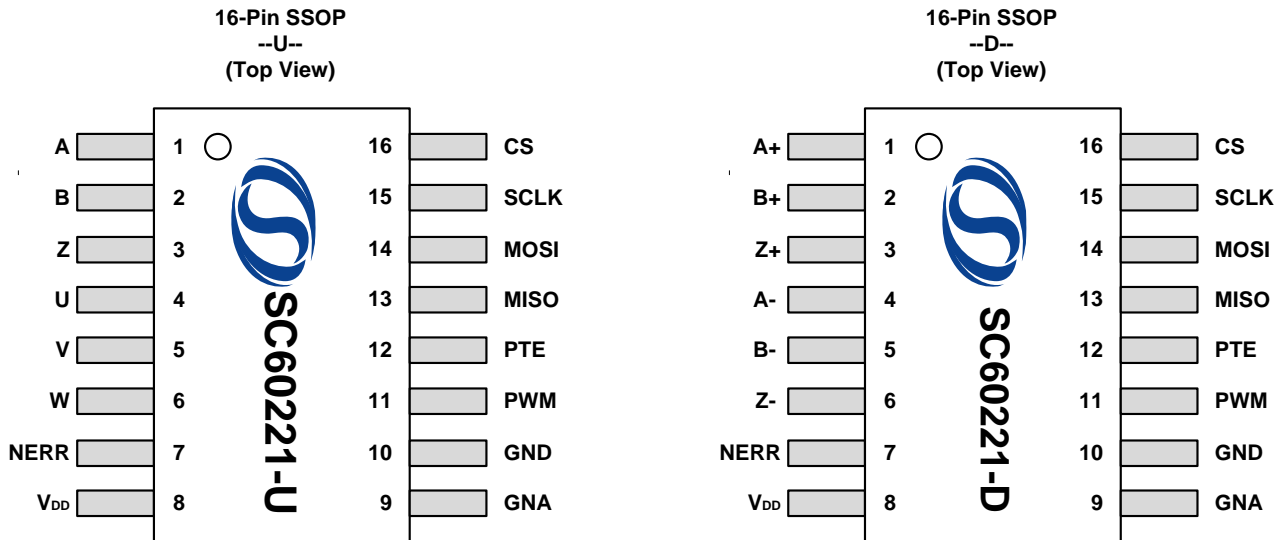
SC60221-D-P4-1000



Eg: SC60221-U-P4-1024:

1024 PPR, 4 pole pairs and with A, B, Z, U, V, W and SPI, PWM outputs.

TERMINAL CONFIGURATION



No.	Pin Name		I/O	Type	Description
	SC60221-U	SC60221-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	V _{DD}	V _{DD}	-	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

ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Min.	Max.	Unit
Voltage at V _{DD} A, B, Z, U, V, W, MOSI, MISO, SCLK, CS, NERR	V ₀		-0.3	6	V
Current in V _{DD}	I ₀		-10	20	mA
Current at A, B, Z, U, V, W, MISO, NERR	I ₀		-100	100	mA
Current at SCLK, CS, MOSI, PTE	I ₀		-10	10	mA
EEPROM Write Cycles			--	100	cycle
Operating ambient temperature	T _A		-40	125	°C
Storage temperature	T _{STG}		-65	165	°C
Operating junction temperature	T _{J(max)}		--	165	°C

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.

ESD Protection

Human Body Model (HBM) tests according to: standard EIA/JESD22-A114-B HBM

Parameter	Symbol	Limit Values		Units
		Min.	Max.	
ESD-Protection	V _{ESD}	-4	4	kV

OPERATING CHARACTERISTICS

valid through the full operate temperature range, VDD=5V, CBY=0.1 uF, unless otherwise specified

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Electrical Characteristics						
Supply Voltage	V _{DD}		3.0	5.0	5.5	V
Supply Current	I _{DD}	No load, f _{mag} =0 rpm	10	16	22	mA
Bandgap Reference	V _{bg}		1.18	1.25	1.32	V
Reference voltage	V _{ref}		45	50	55	%VDD
Turn-on Threshold	V _{th(on)}	Increasing voltage	2.6	2.75	2.9	V
Turn-off Threshold	V _{th(off)}	Decreasing voltage	2.4	2.6	2.8	V
Hysteresis	V _{th(Hys)}		0.15	--	--	V
Reference Voltage Offset	V _{R(offset)}		470	500	530	mV
Sine/Digital Converter						
Sine/Digital Converter Resolution	RES _(sdc)		--	12	--	bit
Integral non-linearity	INL _{opt}	V _{DD} =5V, Temp=25°C, D _{in} =1.0mm	-0.9	--	0.9	Deg
Integral non-linearity	INL _{temp}	Maximum error with respect to the best line fit, T _{amb} =-40 to 125°C	1.5	--	1.5	Deg
Relative Angular Accuracy	AA(rel)	With reference to an output period at A, B	-20	0	+20	%
Angle Output Delay Time	T _D	at ABZ hysteresis = "1LSB"	--	18.0	45.0	μS
Signal Level Control						
Differential Peak-to-Peak Output Amplitude	V _{pp}		3.2	4.0	4.8	V
Controller Setting Time	t _(on)	to ± 10% of final amplitude	--	--	300	μS
Min. Amplitude error	V _{t(lo)}		1.0	--	2.8	V
Max. Amplitude error	V _{t(hi)}		4.8	--	5.8	V
PWM Output						
PWM frequency (default)	F _(pwm)	V _{DD} =5V, Temp=25°C	927	976	1024	Hz
PWM frequency (optional)	F _(pwm)	V _{DD} =5V, Temp=25°C	232	244	256	Hz

OPERATING CHARACTERISTICS (continued)

valid through the full operate temperature range, VDD=5V, CBY=0.1uF, unless otherwise specified

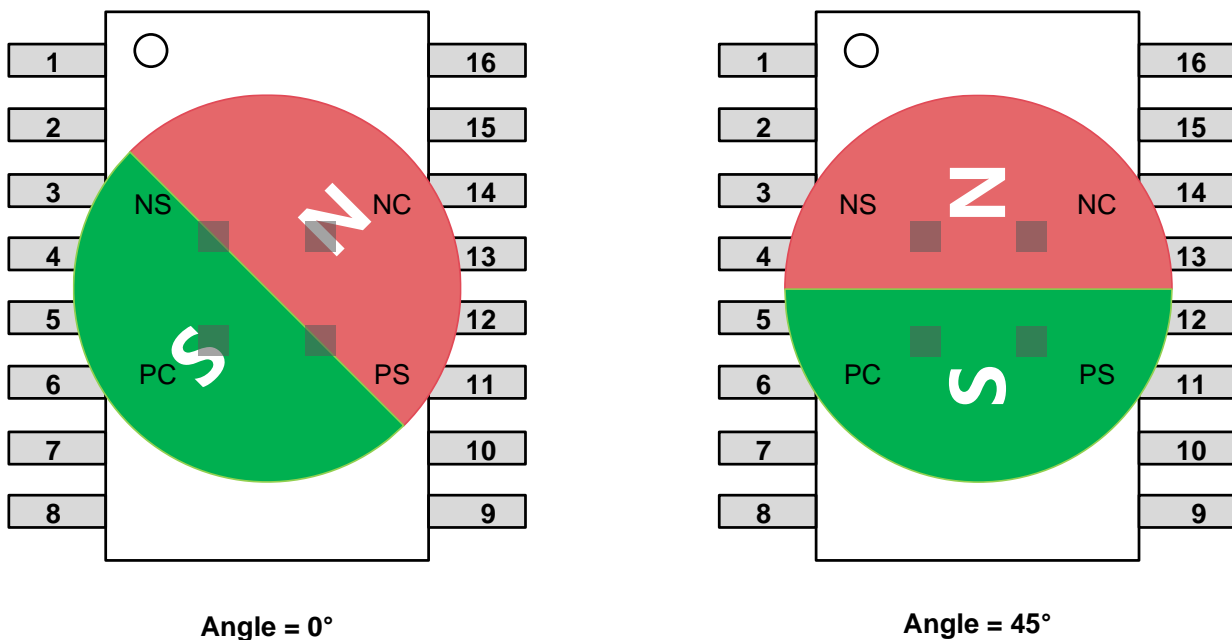
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Magnetic Input Specification						
Diameter	d_{mag}	ϕ 6mm x 2.5mm for cylindrical Magnets	4.0	6.0	10.0	mm
Thickness	t_{mag}		--	2.5	--	mm
Installation Distance	D_{in}	Recommended magnets	--	1.0	2.0	mm
Field Amplitude	H_{ext}	At chip surface	25	--	125	mT
Rotation Frequency	$f_{(mag)}$		--	--	333	Hz
Rotating Speed of Magnet	rpm		--	--	10	krpm
Lateral Displacement of Magnet Axis to Center of Hall Sensors	X_{dis}		--	--	0.2	mm
Displacement Chip Center to Package Center	X_{pac}		-0.15	--	0.15	mm
Angular Alignment of Chip vs. Package	ϕ_{pac}		-3	--	3	Deg
Displacement of Chip Surface to Package Surface	h_{pac}		--	0.4	--	mm
Digital Inputs:CS,SCLK,MOSI						
Threshold Voltage hi	$V_{t(hi)}$		--	--	2	V
Threshold Voltage lo	$V_{t(lo)}$		0.8	--	--	V
Pull-down Current MOSI	$I_{pd()}$	$V_{()}=1V...V_{PD}$	6	38	60	μA
Pull-up Current Source at CS,SCLK	$I_{pu()}$	$V_{()}=0...V_{PD}-1V$	-80	-140	-200	μA
Digital Inputs:PTE						
Drop-down current PTE	$I_{pd()}$	$V_{()}=1V...V_{PD}$	1	4	10	μA
Open the threshold	PTE_{on}		--	6.5	--	V
Close the threshold	PTE_{off}		--	5.5	--	V
Digital OUTPUTS:A,B,Z,U,V,W,PWM,MISO,NERR						
Saturation Voltage hi	$V_{S()hi}$	$I_{()hi}=-4mA$, with reference to V_{DD}	--	--	200	mV
Saturation Voltage lo	$V_{S()lo}$	$I_{()lo}=4mA$, with reference to GND	--	--	200	mV
Short-Circuit Current hi	$I_{short()hi}$	$V_{()}=GND$;	10	--	20	mA
Short-Circuit Current lo	$I_{short()lo}$	$V_{()}=V_{DD}$;	5	--	15	mA
Rise-Time lo to hi	t_{Rise}	$R_L=100\Omega$ to GND;	5	--	30	nS
Fall-Time high to lo	t_{Fall}	$R_L=100\Omega$ to V_{DD} ;	5	--	30	nS

FUNCTIONAL DESCRIPTION

Position of the Hall Sensors

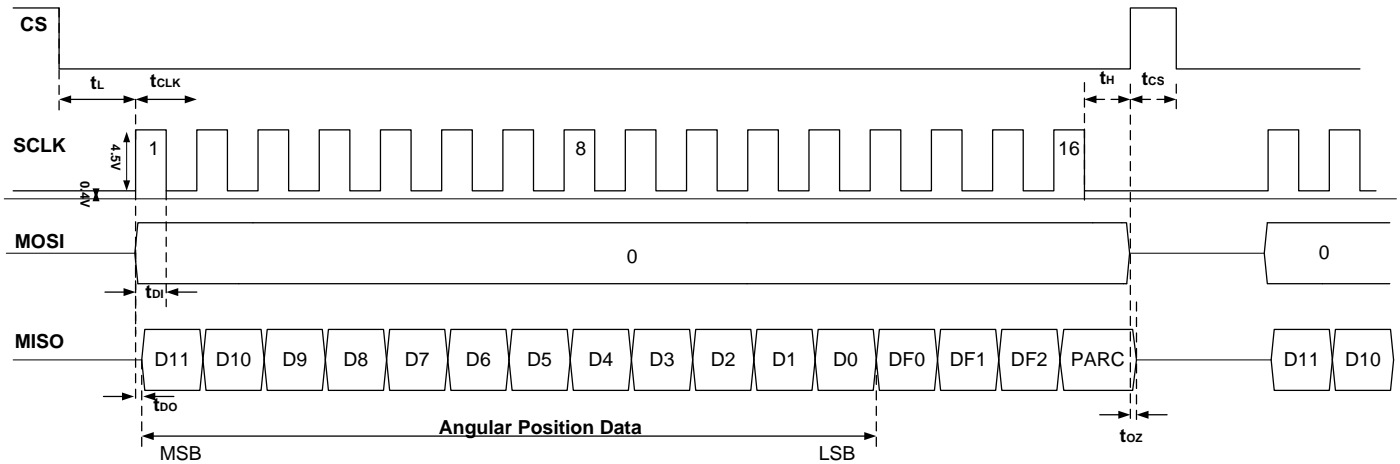
The Hall sensors are placed in the center of the package at a 90° angle to one another and arranged in a circle.

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 figure below.



SPI Interface

Serial Peripheral Interface Timing Diagram with Absolute Angular Position Data



SPI Timing Definition

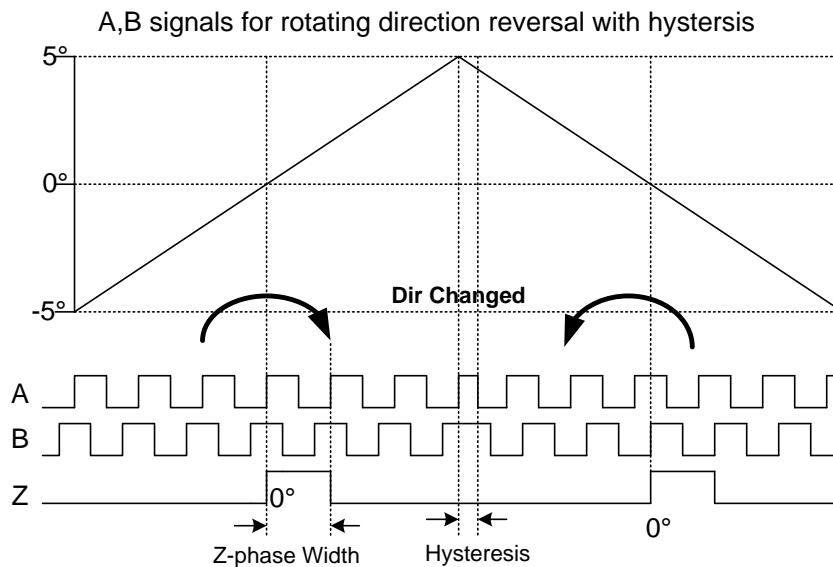
Parameter	Description	Min.	Max.	Units
t_L	Time between CS falling edge and SCLK rising edge	250	--	ns
t_{CLK}	Serial clk period	100	--	ns
t_H	Time between last falling edge of SCLK and rising edge of CS	$t_{CLK}/2$	--	ns
t_{CS}	High time of CS between two transmissions	250	--	ns
t_{DO}	SCLK edge to data 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)

Incremental Outputs

The SC60221 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.



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

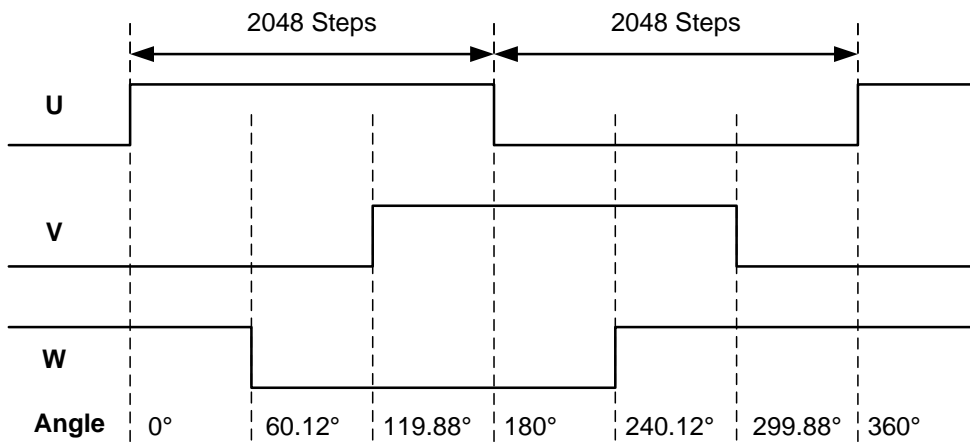
ABZ Resolution Setting			
No.	Type	Pulses per Round	Counts per Revolution
1	Binary	1024	4096
2		512	2048
3		256	1024
4		128	512
5		64	256
6	Decimal	1000	4000
7		800	3200
8		600	2400
9		500	2000
10		400	1600
11		360	1440
12		300	1200
13		200	800
14		100	400
15		50	200

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

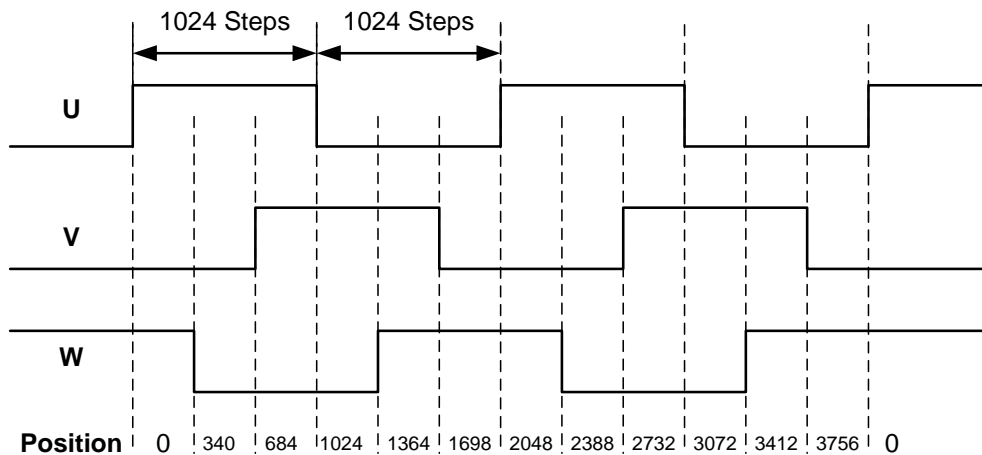
UVW Commutation Mode (SC60221-U)

The SC60221 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.

One-pole-pair



Two-pole-pair

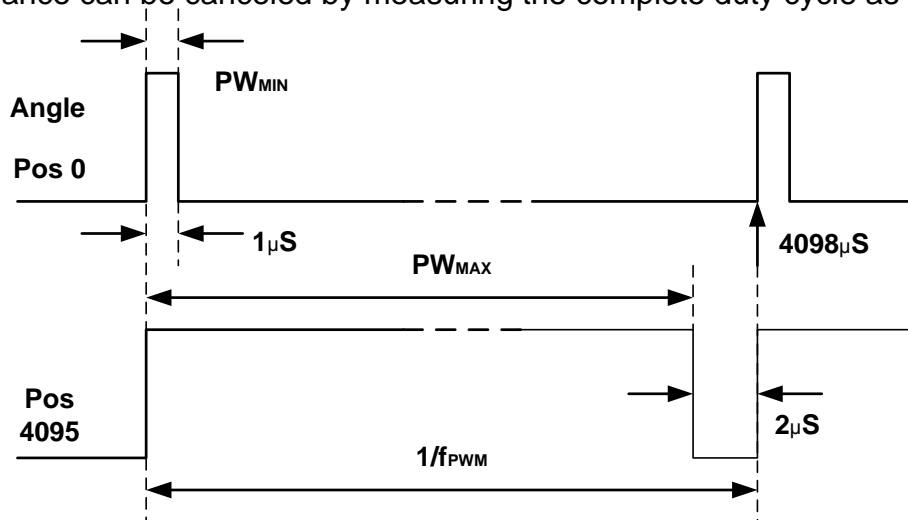


Pulse Width Modulation Output

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

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

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



Schematic diagram of waveform with PWM frequency of 244Hz

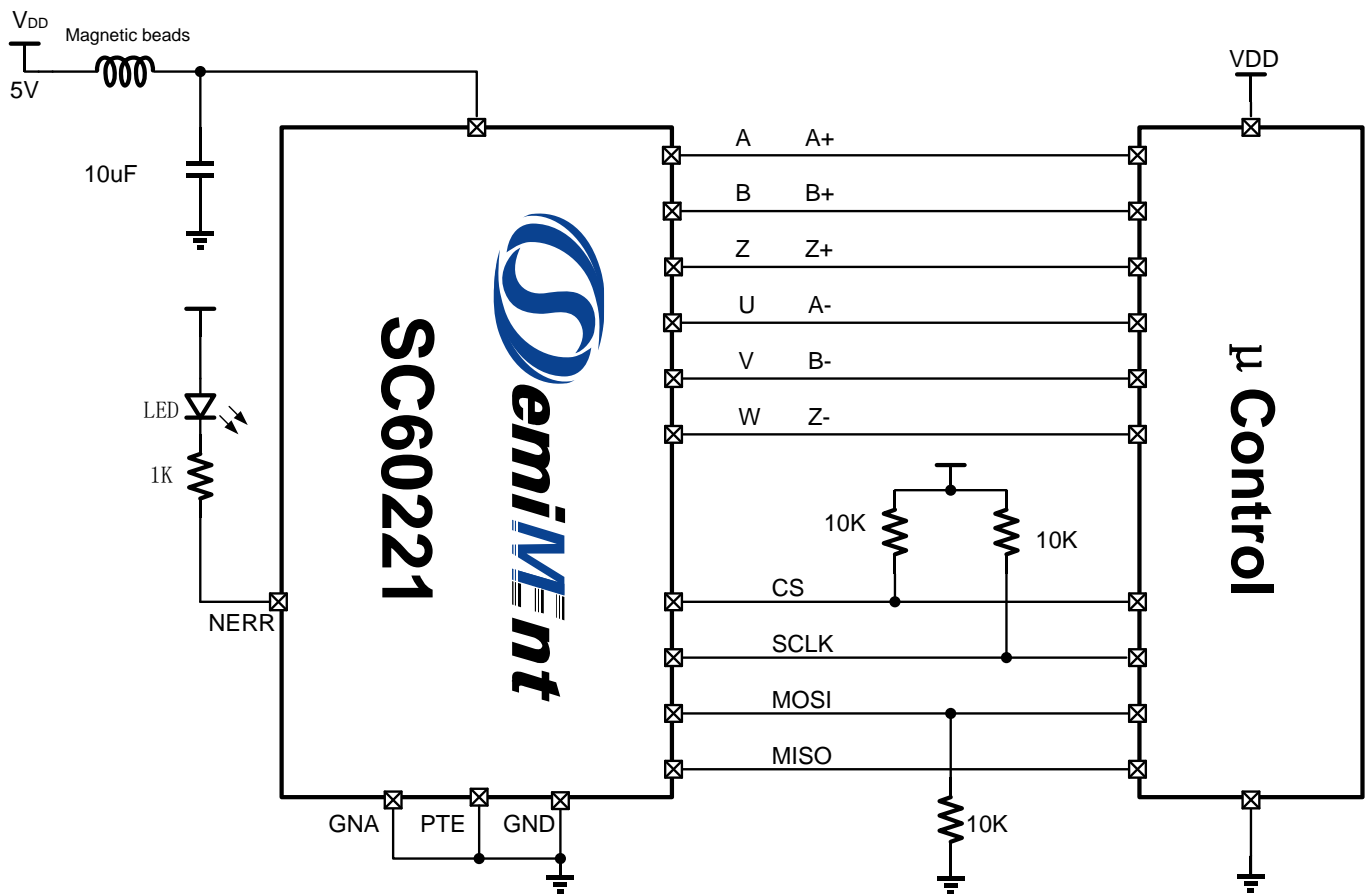
PWM default frequency (976Hz)

Parameter	Symbol	Typ	Unit	Note
PWM frequency	f_{PWM}	976	kHz	Signal period: 4098 μ S
MIN pulse width	PW_{MIN}	0.25	μ S	Position 0d
Max pulse width	PW_{MAX}	1024	μ S	Position 4095d

PWM optional frequency (976Hz)

Parameter	Symbol	Typ	Unit	Note
PWM frequency	f_{PWM}	244	kHz	Signal period: 4098 μ S
MIN pulse width	PW_{MIN}	1	μ S	Position 0d
Max pulse width	PW_{MAX}	4096	μ S	Position 4095d

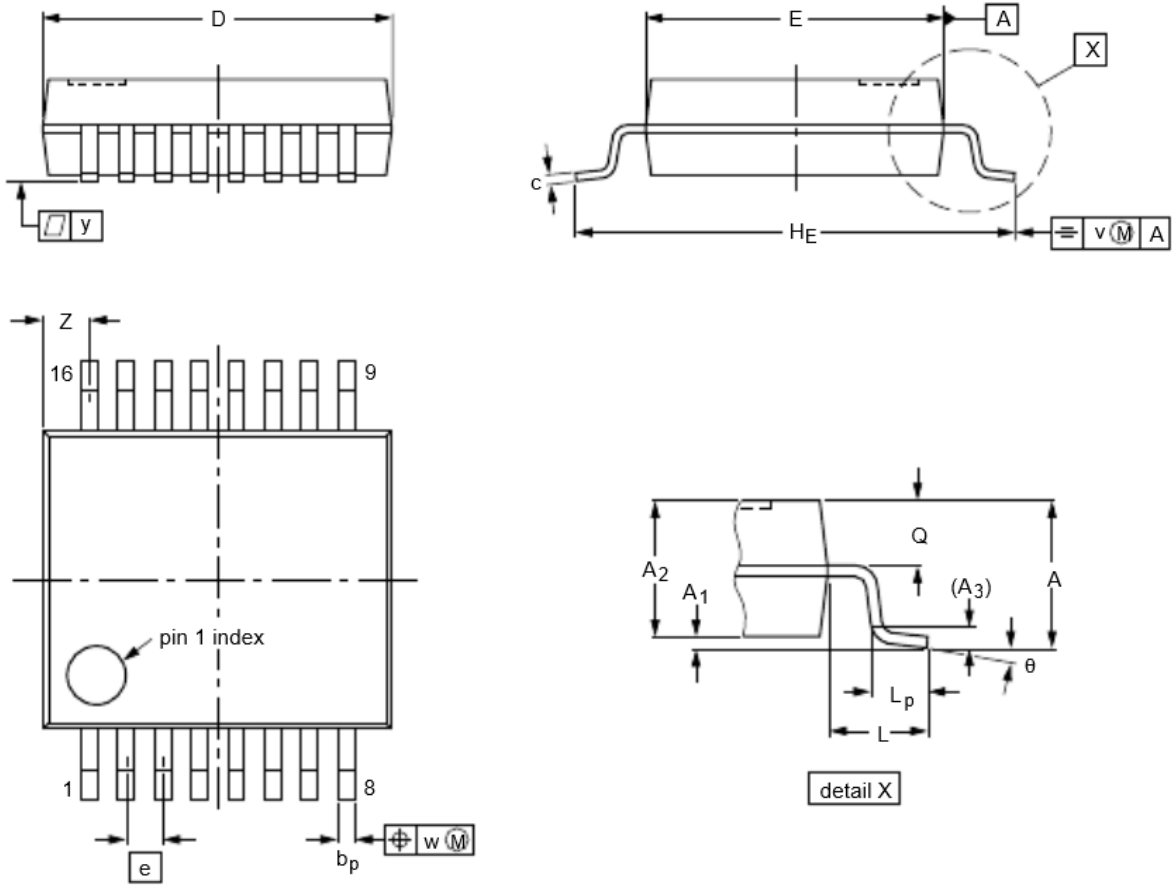
TYPICAL APPLICATION



Remark:

1. Add SMD inductor (magnetic bead) and 10 μ F 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.

PACKAGE INFORMATION



DIMENSIONS (mm are the original dimensions)

UNIT	A	A ₁	A ₂	A ₃	b _p	c	D ⁽¹⁾	E ⁽¹⁾	e	H _E	L	L _P	Q	v	w	y	Z ⁽¹⁾	θ
mm	2	0.21	1.85	0.25	0.38	0.25	6.5	5.6	0.65	8.2	1.25	0.95	0.9	0.2	0.13	0.1	1.00	8°
		0.05	1.65		0.22	0.09	5.9	5.0		7.4		0.55	0.7					0.55

Note:

1. Plastic or metal protrusions of 0.25mm maximum per side are not included.

Revision History

Revision	Date	Description
Rev0.1	2018-09-05	Initial release
Rev1.1	2019-01-04	Update typical application circuit
Rev2.3	2020-04-06	Add version history
RevA/1.0	2020-12-29	Update format