AS5600

12-Bit Programmable Contactless Potentiometer

General Description

The AS5600 is an easy to program magnetic rotary position sensor with a high-resolution 12-bit analog or PWM output. This contactless system measures the absolute angle of a diametric magnetized on-axis magnet. This AS5600 is designed for contactless potentiometer applications and its robust design eliminates the influence of any homogenous external stray magnetic fields.

The industry-standard I^2C interface supports simple user programming of non-volatile parameters without requiring a dedicated programmer.

By default the output represents a range from 0 to 360 degrees. It is also possible to define a smaller range to the output by programming a zero angle (start position) and a maximum angle (stop position).

The AS5600 is also equipped with a smart low power mode feature to automatically reduce the power consumption.

An input pin (DIR) selects the polarity of the output with regard to rotation direction. If DIR is connected to ground, the output value increases with clockwise rotation. If DIR is connected to VDD, the output value increases with counterclockwise rotation.

Ordering Information and Content Guide appear at end of datasheet.

Key Benefits & Features

The benefits and features of AS5600, 12-bit Programmable Contactless Potentiometer are listed below:

Figure 1:
Added Value of Using AS5600

Benefits	Features
• Highest reliability and durability	• Contactless angle measurement
• Simple programming	• Simple user-programmable start and stop positions over the I^2C interface
• Great flexibility on angular excursion	• Maximum angle programmable from 18° up to 360°
• High-resolution output signal	• 12-bit DAC output resolution
• Selectable output	• Analog output ratiometric to VDD or PWM-encoded digital output

Benefits	Features
• Low-power consumption	• Automatic entry into low-power mode
• Easy setup	• Automatic magnet detection
• Small form factor	• SOIC-8 package
• Robust environmental tolerance	• Wide temperature range: -40°C to 125°C

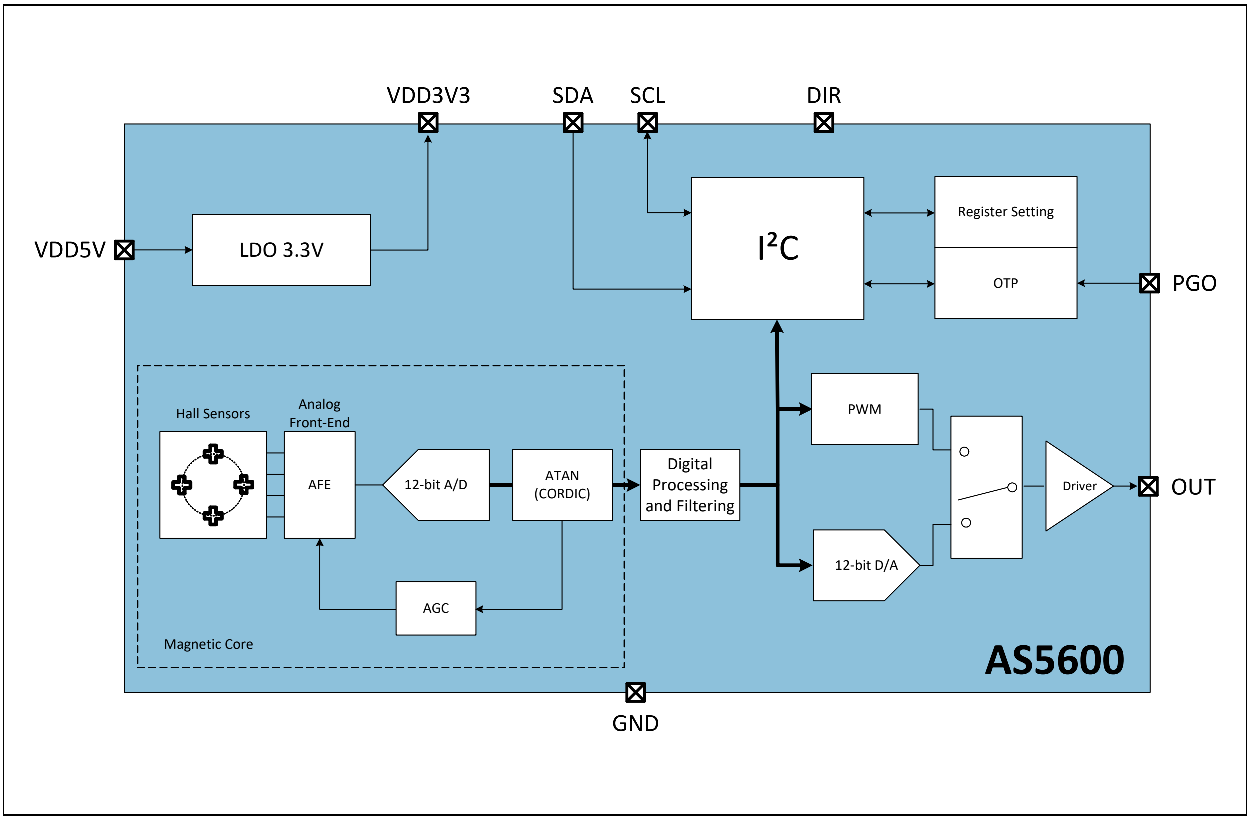
Applications

The AS5600 is ideally suited for contactless potentiometers, contactless knobs, pedals, RC servos and other angular position measurement solutions.

Block Diagram

The functional blocks of this device are shown below:

Figure 2:
Functional Blocks of AS5600



Pin Assignments

Figure 3:
SOIC-8 Pin-Out

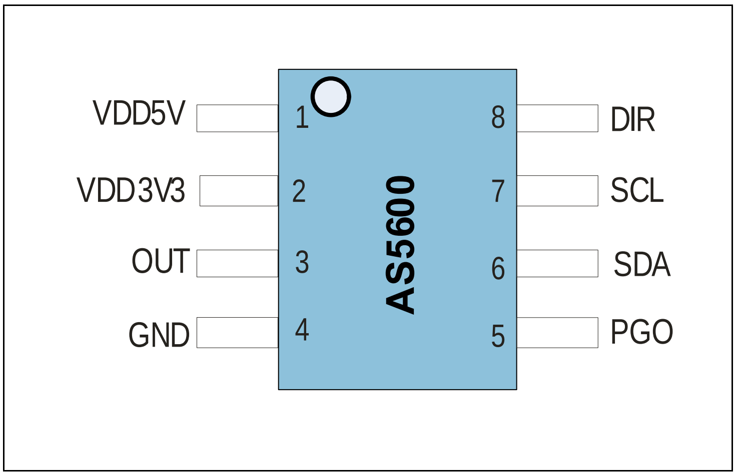


Figure 4:
Pin Description

Pin Number	Name	Type	Description
1	VDD5V	Supply	Positive voltage supply in 5V mode (requires 100nF decoupling capacitor)
2	VDD3V3	Supply	Positive voltage supply in 3.3V mode (requires an external 1-µF decoupling capacitor in 5V mode)
3	OUT	Analog/digital output	Analog/PWM output
4	GND	Supply	Ground
5	PGO	Digital input	Program option (internal pull-up, connected to GND = Programming Option B)
6	SDA	Digital input/output	I^2C Data (consider external pull-up)
7	SCL	Digital input	I^2C Clock (consider external pull-up)
8	DIR	Digital input	Direction polarity (GND = values increase clockwise, VDD = values increase counterclockwise)

Absolute Maximum Ratings

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under Operating Conditions is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Figure 5:
Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Units	Comments
Electrical Parameters					
VDD5V	DC Supply Voltage at VDD5V pin	-0.3	6.1	V	
VDD3V3	DC Supply Voltage at VDD3V3 pin	-0.3	4.0	V	
VIO	DC Supply Voltage at all digital or analog pins	-0.3	VDD+0.3	V	
I_{SCR}	Input current (latch-up immunity)	-100	100	mA	JESD78
Continuous Power Dissipation (T_A = 70°C)					
P_T	Continuous power dissipation		50	mW	
Electrostatic Discharge					
ESD_{HBM}	Electrostatic discharge HBM	±1		kV	MIL 883 E method 3015.7
Temperature Ranges and Storage Conditions					
T_{STRG}	Storage temperature range	-55	125	°C	
T_{BODY}	Package body temperature		260	°C	ICP/JEDEC J-STD-020 The reflow peak soldering temperature (body temperature) is specified according to IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices." The lead finish for Pb-free leaded packages is "Matte Tin" (100% Sn)
RH_{NC}	Relative humidity (non-condensing)	5	85	%	
MSL	Moisture sensitivity level	3			ICP/JEDEC J-STD-033

Electrical Characteristics

All limits are guaranteed. The parameters with minimum and maximum values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Operating Conditions

Figure 6:
System Electrical Characteristics and Temperature Range

Symbol	Parameter	Conditions	Min	Typ	Max	Units
VDD5V	Positive supply voltage in 5.0V mode	5.0V operation mode During OTP burn procedure (2)	4.5	5.0	5.5	V
VDD3V3	Positive supply voltage in 3.3V mode	3.3V operation mode	3.0	3.3	3.6	V
		During OTP burn procedure (2)	3.25	3.3	3.35	V
IDD	Supply current in NOM (1)	PM = 00 Always on			6.5	mA
IDD_LPM1	Supply current in LPM1 (1)	PM = 01 Polling time = 5ms			3.4	mA
IDD_ LPM2	Supply current in LPM2 (1)	PM = 10 Polling time = 20ms			1.8	mA
IDD_ LPM3	Supply current in LPM3 (1)	PM = 11 Polling time = 100ms			1.5	mA
IDD_BURN	Supply current per bit for burn procedure	Initial peak, 1 µs			100	mA
		Steady burning,<30 µs			40	mA
T_A	Operating temperature		-40		125	°C
T_P	Programming temperature		20		30	°C

Note(s):

1. For typical magnetic field (60mT) excluding current delivered to the external load and tolerance on polling times.
2. For OTP burn procedure the supply line source resistance should not exceed 1Ohm.

Digital Inputs and Outputs

Figure 7:
Digital Input and Output Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_IH	High-level input voltage		0.7 × VDD			V
V_IL	Low-level input voltage				0.3 × VDD	V
V_OH	High-level output voltage		VDD - 0.5			V
V_OL	Low-level output voltage				0.4	V
I_LKG	Leakage current				±1	µA

Analog Output

Figure 8:
Analog Output Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
INL_DAC	DAC integral-non-linearity electrical specification				±5	LSB
DNL_DAC	DAC differential-non-linearity electrical specification				±1	LSB
ROUT_FD	Output resistive load	0 to VDD output	100			kΩ
ROUT_PD	Output resistive load	10% to 90% output	10			kΩ
COUT	Output capacitive load				1	nF

PWM Output

Figure 9:
PWM Output Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Units
PWMf1	PWM frequency [1]	PWMF = 00		115		Hz
PWMf2	PWM frequency [1]	PWMF = 01		230		Hz
PWMf3	PWM frequency [1]	PWMF = 10		460		Hz
PWMf4	PWM frequency [1]	PWMF = 11		920		Hz
PWM_DC	PWM duty cycle		2.9		97.1	%
PWM_SR	PWM slew rate	Cload = 1nF	0.5		2	V/µs
I_O	Output current for PWM output		±0.5			mA
C_L	Capacitive load for PWM output				1	nF

Note(s):

1. Frequency is given as typical values, tolerance is ±5%

Timing Characteristics

Figure 10:
Timing Conditions

Symbol	Parameter	Conditions	Min	Typ	Max	Units
T_DETWD	Watchdog detection time [1]	WD = 1		1		minute
T_PU	Power-up time				10	ms
F_S	Sampling rate				150	µs
T_SETTL1	Settling time	SF = 00			2.2	ms
T_SETTL2	Settling time	SF = 01			1.1	ms
T_SETTL3	Settling time	SF = 10			0.55	ms
T_SETTL4	Settling time	SF = 11			0.286	ms

Note(s):

1. Given as typical values, tolerance is ±5%

Magnetic Characteristics

Figure 11:
Magnetic Characteristics

Symbol	Parameter	Conditions	Min	Max	Units
Bz	Orthogonal magnetic field strength, regular output noise ON_SLOW and ON_FAST	Required orthogonal component of the magnetic field strength measured at the die's surface along a circle of 1mm	30	90	mT
Bz_ERROR	Minimum required orthogonal magnetic field strength, Magnet detection level			8	mT

System Characteristics

Figure 12:
System Specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Units
RES	Resolution			12		bit
INL_BL	System INL	Deviation from best line fit; 360° maximum angle, no magnet displacement, no zero-programming performed (PWM, I^2C)			±1	degree
ON_SLOW	RMS output noise (1 sigma)	Orthogonal component for the magnetic field within the specified range (Bz), after 2.2 ms; SF = 00			0.015	degree
ON_FAST	RMS output noise (1 sigma)	Orthogonal component for the magnetic field within the specified range (Bz), after 286 µs, SF=11			0.043	degree

Detailed Description

The AS5600 is a Hall-based rotary magnetic position sensor using planar sensors that convert the magnetic field component perpendicular to the surface of the chip into a voltage.

The signals coming from the Hall sensors are first amplified and filtered before being converted by the analog-to-digital converter (ADC). The output of the ADC is processed by the hardwired CORDIC block (Coordinate Rotation Digital Computer) to compute the angle and magnitude of the magnetic field vector. The intensity of the magnetic field is used by the automatic gain control (AGC) to adjust the amplification level to compensate for temperature and magnetic field variations.

The angle value provided by the CORDIC algorithm is used by the output stage. The user can choose between an analog output and a PWM-encoded digital output. The former provides an output voltage which represents the angle as a ratiometric linear absolute value. The latter provides a digital output which represents the angle as the pulse width.

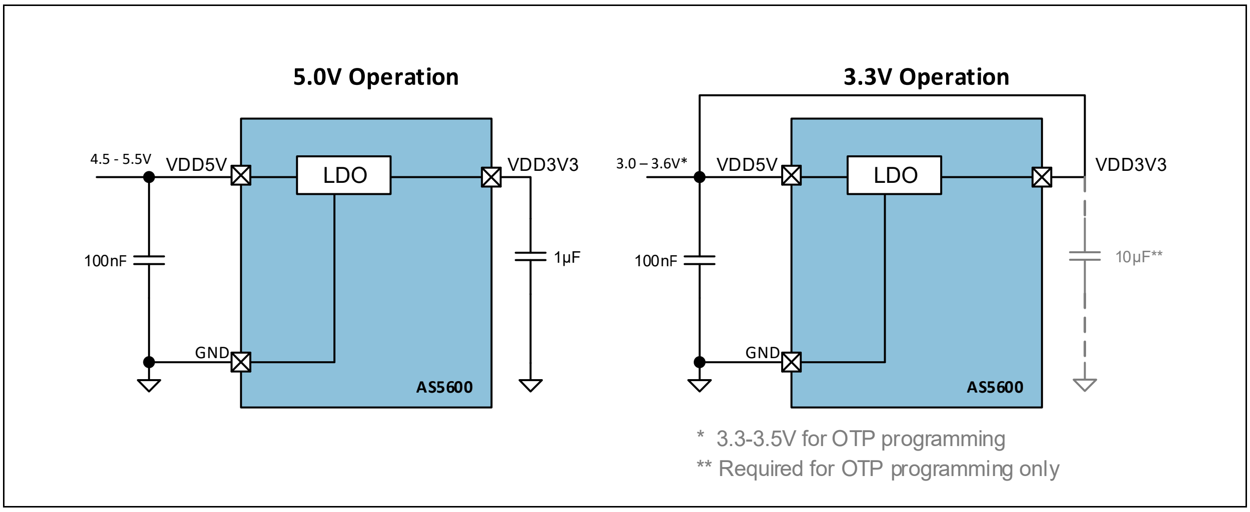
The AS5600 is programmed through an industry-standard I²C interface to write an on-chip non-volatile memory. This interface can be used to program a zero angle (start position) and a maximum angle (stop position) which maps the full resolution of the output to a subset of the entire 0 to 360 degree range.

IC Power Management

The AS5600 be powered from a 5.0V supply using the on-chip LDO regulator, or it can be powered directly from a 3.3V supply. The internal LDO is not intended to power other external ICs and needs a 1 µF capacitor to ground, as shown in Figure 13.

In 3.3V operation, the VDD5V and VDD3V3 pins must be tied together. VDD is the voltage level present at the VDD5V pin.

Figure 13:
5.0V and 3.3V Power Supply Options



I²C Interface

The AS5600 supports the 2-wire Fast-mode Plus I²C-slave protocol in device mode, in compliance with the NXP Semiconductors (formerly Philips Semiconductors) specification UM10204. A device that sends data onto the bus is a transmitter and a device receiving data is a receiver. The device that controls the message is called a master. The devices that are controlled by the master are called slaves. A master device generates the serial clock (SCL), controls the bus access, and generates the START and STOP conditions that control the bus. The AS5600 always operates as a slave on the I²C bus. Connections to the bus are made through the open-drain I/O lines SDA and the input SCL. Clock stretching is not included.

The host MCU (master) initiates data transfers. The 7-bit slave address of the AS5600 is 0x36 (0110110 in binary).

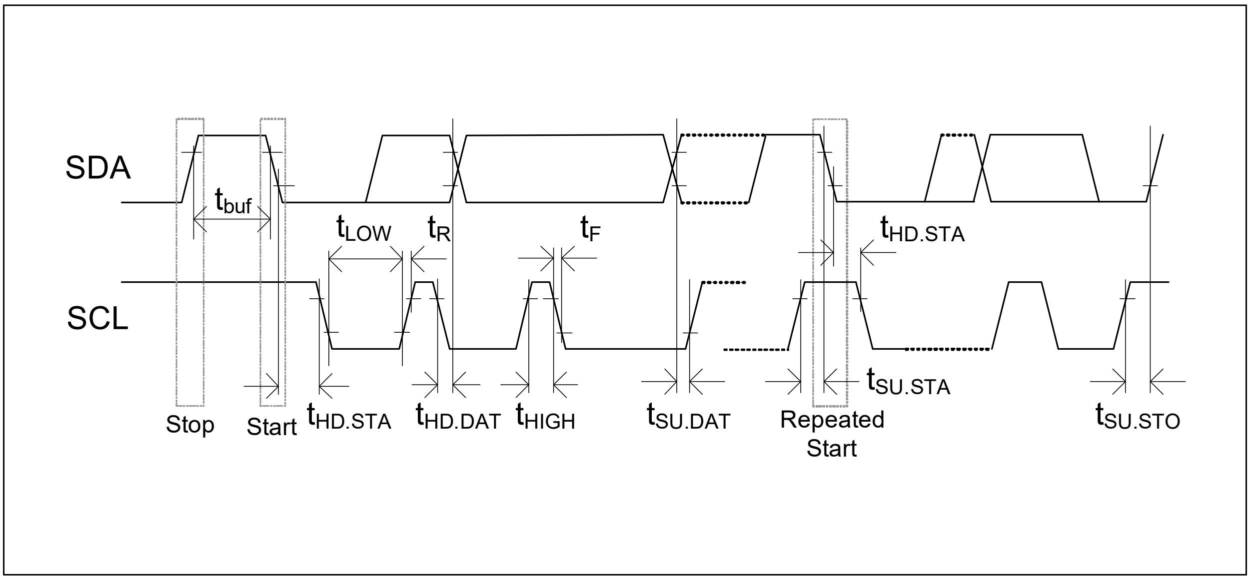
Supported Modes

- Random/Sequential read
- Byte/Page write
- Automatic increment (ANGLE register)
- Standard-mode
- Fast-mode
- Fast–mode plus

The SDA signal is the bidirectional data line. The SCL signal is the clock generated by the I²C bus master to synchronize sampling data from SDA. The maximum SCL frequency is 1 MHz. Data is sampled on the rising edge of SCL.

I²C Interface Operation

Figure 14:
I²C Timing Diagram



I^2C Electrical Specification

Figure 15:
I^2C Electrical Specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
VIL	Logic low input voltage		-0.3		0.3 x VDD	V
VIH	Logic high input voltage		0.7 x VDD		VDD + 0.3	V
VHYS	Hysteresis of Schmitt trigger inputs	VDD > 2.5V	0.05 x VDD			V
VOL	Logic low output voltage (open-drain or open-collector) at 3 mA sink current	VDD > 2.5V			0.4	V
IOL	Logic low output current	VOL = 0.4V	20			mA
t_{OF}	Output fall time from VIHmax to VILmax		10		120 (1)	ns
t_{SP}	Pulse width of spikes that must be suppressed by the input filter				50 (2)	ns
I_I	Input current at each I/O Pin	Input Voltage between 0.1 x VDD and 0.9 x VDD	-10		+10 (3)	µA
C_B	Total capacitive load for each bus line				550	pF
$C_{I/O}$	I/O capacitance (SDA, SCL) (4)				10	pF

Note(s):

1. In Fast-mode Plus, fall time is specified the same for both output stage and bus timing. If series resistors are used this has to be considered for bus timing.
2. Input filters on the SDA and SCL inputs suppress noise spikes of less than 50 ns.
3. I/O pins of Fast-mode and Fast-mode Plus devices must not load or drive the SDA and SCL lines if VDD is switched OFF.
4. Special-purpose devices such as multiplexers and switches may exceed this capacitance because they connect multiple paths together.

I^2C Timing

Figure 16:
I^2C Timing

Symbol	Parameter	Min	Max	Unit
f_{SCLK}	SCL clock frequency		1.0	MHz
t_{BUF}	Bus free time (time between the STOP and START conditions)	0.5		µs
$t_{HD;STA}$	Hold time; (Repeated) START condition (1)	0.26		µs
t_{LOW}	Low phase of SCL clock	0.5		µs
t_{HIGH}	High phase of SCL clock	0.26		µs
$t_{SU;STA}$	Setup time for a Repeated START condition	0.26		µs
$t_{HD;DAT}$	Data hold time (2)		0.45	µs
$t_{SU;DAT}$	Data setup time (3)	50		ns
t_R	Rise time of SDA and SCL signals		120	ns
t_F	Fall time of SDA and SCL signals	10	120 (4)	ns
$t_{SU;STO}$	Setup time for STOP condition	0.26		µs

Note(s):

1. After this time, the first clock is generated.
2. A device must internally provide a minimum hold time of 120 ns (Fast-mode Plus) for the SDA signal (referred to the V_{IHmin} of SCL) to bridge the undefined region of the falling edge of SCL.
3. A Fast-mode device can be used in a standard-mode system, but the requirement $t_{SU;DAT}$ = 250 ns must be met. This is automatically if the device does not stretch the low phase of SCL. If such a device does stretch the low phase of SCL, it must drive the next data bit on SDA (t_{Rmax} + $t_{SU;DAT}$ = 1000 + 250 = 1250 ns) before SCL is released.
4. In Fast-mode Plus, fall time is specified the same for both output stage and bus timing. If series resistors are used, this has to be considered for bus timing.

I²C Modes

Invalid Addresses

There are two addresses used to access an AS5600 register. The first is the slave address used to select the AS5600. All I²C bus transactions include a slave address. The slave address of the AS5600 is 0x36 (0110110 in binary) The second address is a word address sent in the first byte transferred in a write transaction. The word address selects a register on the AS5600. The word address is loaded into the address pointer on the AS5600. During subsequent read transactions and subsequent bytes in the write transaction, the address pointer provides the address of the selected register. The address pointer is incremented after each byte is transferred, except for certain read transactions to special registers.

If the user sets the address pointer to an invalid word address, the address byte is not acknowledged (the A bit is high). Nevertheless, a read or write cycle is possible. The address pointer is increased after each byte.

Reading

When reading from an invalid address, the AS5600 returns all zeros in the data bytes. The address pointer is incremented after each byte. Sequential reads over the whole address range are possible including address overflow.

Automatic Increment of the Address Pointer for ANGLE, RAW ANGLE and MAGNITUDE Registers

These are special registers which suppress the automatic increment of the address pointer on reads, so a re-read of these registers requires no I²C write command to reload the address pointer. This special treatment of the pointer is effective only if the address pointer is set to the high byte of the register.

Writing

A write to an invalid address is not acknowledged by the AS5600, although the address pointer is incremented. When the address pointer points to a valid address again, a successful write accessed is acknowledged. Page write over the whole address range is possible including address overflow.

Supported Bus Protocol

Data transfer may be initiated only when the bus is not busy.

During data transfer, the data line must remain stable whenever SCL is high. Changes in the data line while SCL is high are interpreted as START or STOP conditions.

Accordingly, the following bus conditions have been defined:

Bus Not Busy

Both SDA and SCL remain high.

Start Data Transfer

A change in the state of SDA from high to low while SCL is high defines the START condition.

Stop Data Transfer

A change in the state of SDA from low to high while SCL is high defines the STOP condition.

Data Valid

The state of the data line represents valid data when, after a START condition, SDA is stable for the duration of the high phase of SCL. The data on SDA must be changed during the low phase of SCL. There is one clock period per bit of data.

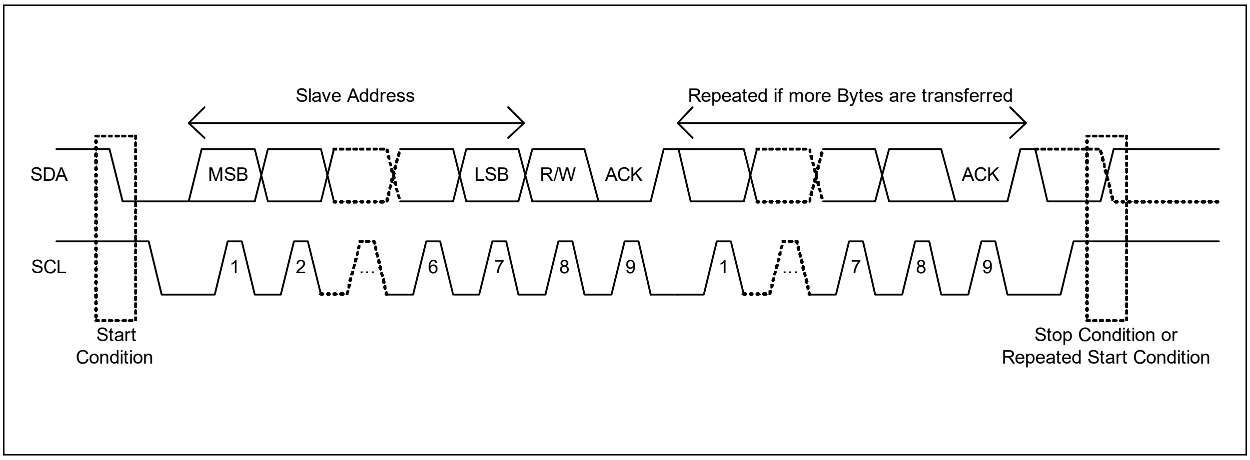
Each I^2C bus transaction is initiated with a START condition and terminated with a STOP condition. The number of data bytes transferred between START and STOP conditions is not limited, and is determined by the I^2C bus master. The information is transferred byte-wise and each receiver acknowledges with a ninth bit.

Acknowledge

Each I^2C slave device, when addressed, is obliged to generate an acknowledge after the reception of each byte. The I^2C bus master device must generate an extra clock period for this acknowledge bit.

A slave that acknowledges must pull down SDA during the acknowledge clock period in such a way that SDA is stable low during the high phase of the acknowledge clock period. Of course, setup and hold times must be taken into account. A master must signal an end of a read transaction by not generating an acknowledge bit on the last byte that has been clocked out of the slave. In this case, the slave must leave SDA high to enable the master to generate the STOP condition.

Figure 17:
Data Read



Depending on the state of the R/W bit, two types of data transfer are possible:

Data Transfer from a Master Transmitter to a Slave Receiver

The first byte transmitted by the master is the slave address, followed by R/W = 0. Next follows a number of data bytes. The slave returns an acknowledge bit after each received byte. If the slave does not understand the command or data it sends a not acknowledge (NACK). Data is transferred with the most significant bit (MSB) first.

Data Transfer from a Slave Transmitter to a Master Receiver

The master transmits the first byte (the slave address). The slave then returns an acknowledge bit, followed by the slave transmitting a number of data bytes. The master returns an acknowledge bit after all received bytes other than the last byte. At the end of the last received byte, a NACK is returned. The master generates all of the SCL clock periods and the START and STOP conditions. A transfer is ended with a STOP condition or with a repeated START condition. Because a repeated START condition is also the beginning of the next serial transfer, the bus is not released. Data is transferred with the most significant bit (MSB) first.

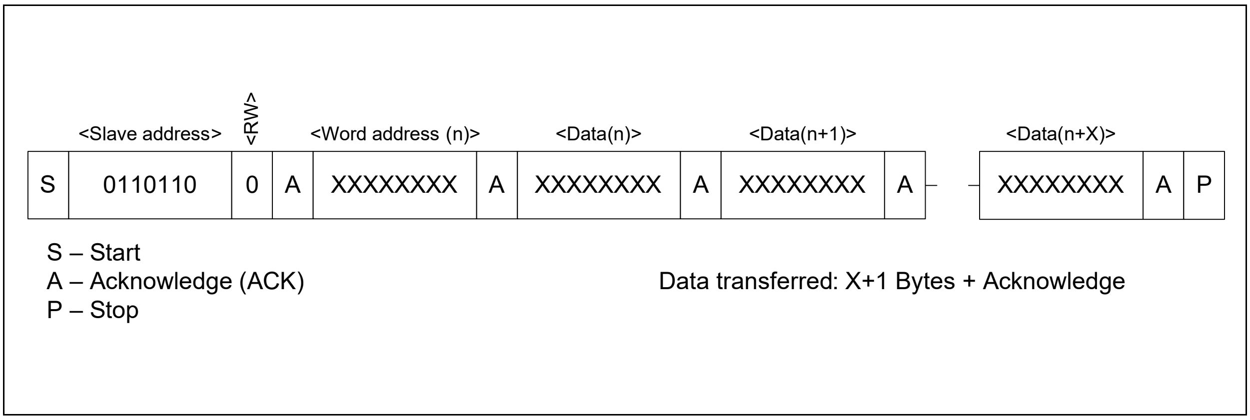
AS5600 Slave Modes

Slave Receiver Mode (Write Mode)

Serial data and clock are received through SDA and SCL. Each byte is followed by an acknowledge bit or by a not acknowledge depending on whether the address-pointer selects a valid address. START and STOP conditions are recognized as the beginning and end of a bus transaction. The slave address byte is the first byte received after the START condition. The 7-bit AS5600 address is 0x36 (0110110 in binary).

The 7-bit slave address is followed by the direction bit (R/W), which, for a write, is 0 (low). After receiving and decoding the slave address byte the slave device drives an acknowledge on SDA. After the AS5600 acknowledges the slave address and write bit, the master transmits a register address (word address) to the AS5600. This is loaded into the address pointer on the AS5600. If the address is a valid readable address, the AS5600 answers by sending an acknowledge (A bit low). If the address pointer selects an invalid address, a not acknowledge is sent (A bit high). The master may then transmit zero or more bytes of data. If the address pointer selects an invalid address, the received data are not stored. The address pointer will increment after each byte transferred whether or not the address is valid. If the address-pointer reaches a valid position again, the AS5600 answers with an acknowledge and stores the data. The master generates a STOP condition to terminate the write transaction.

Figure 18:
Data Write (Slave Receiver Mode)



Slave Transmitter Mode (Read Mode)

The first byte is received and handled as in the slave receiver mode. However, in this mode, the direction bit indicates that the AS5600 will drive data on SDA. START and STOP conditions are recognized as the beginning and end of a bus transaction. The slave address byte is the first byte received after the master generates a START condition. The slave address byte contains the 7-bit AS5600 address. The 7-bit slave address is followed by the direction bit (R/W), which, for a read, is 1 (high). After receiving and decoding the slave address byte, the slave device drives an acknowledge on the SDA line. The AS5600 then begins to transmit data starting with the register address pointed to by the address pointer. If the address pointer is not written before the initiation of a read transaction, the first address that is read is the last one stored in the address pointer. The AS5600 must receive a not acknowledge (NACK) to end a read transaction.

Figure 19:
Data Read (Slave Transmitter Mode)

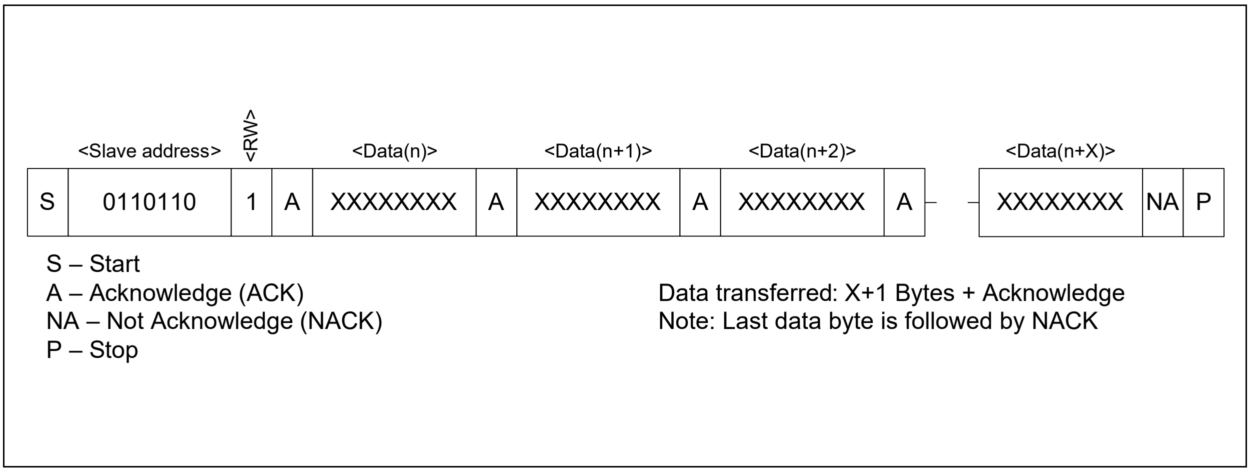
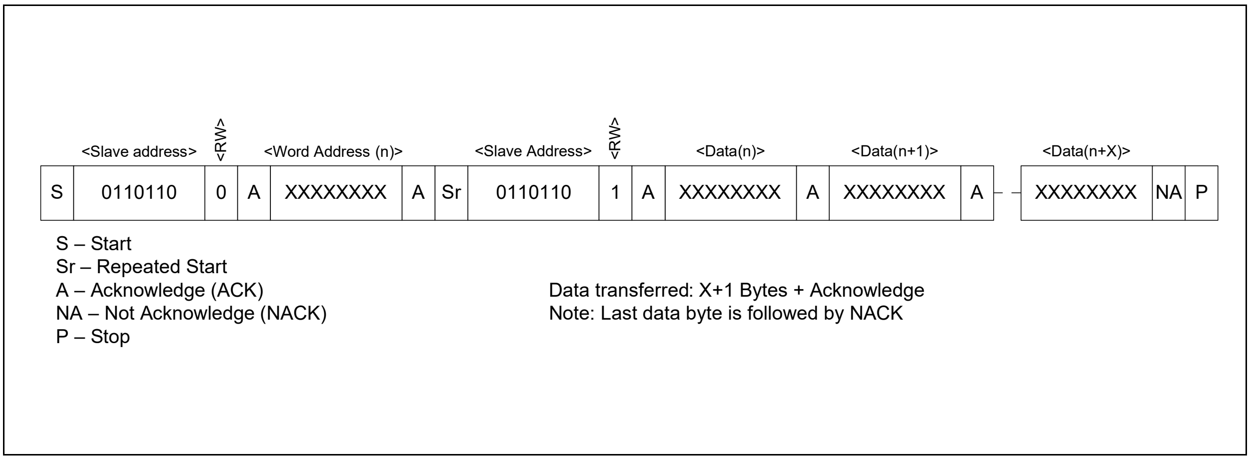


Figure 20:
Data Read with Address Pointer Reload (Slave Transmitter Mode)



SDA and SCL Input Filters

Input filters for SDA and SCL inputs are included to suppress noise spikes of less than 50 ns.

寄存器描述

以下寄存器可以通过串行I²C接口访问。从机的7位设备地址为0x36(0110110二进制)。为了对配置进行永久编程，提供了一个非易失性存储器(OTP)。

Figure 21:
Register Map

Address	Name	R/W	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Configuration Registers [(1), (2)]										
0x00	ZMCO	R							ZMCO(1:0)	
0x01	ZPOS	R/W/P					ZPOS(11:8)			
0x02			ZPOS(7:0)							
0x03	MPOS	R/W/P					MPOS(11:8)			
0x04			MPOS(7:0)							
0x05	MANG	R/W/P					MANG(11:8)			
0x06			MANG(7:0)							
0x07	CONF	R/W/P			WD	FTH(2:0)			SF(1:0)	
0x08			PWMF(1:0)		OUTS(1:0)		HYST(1:0)		PM(1:0)	
Output Registers										
0x0C	RAW ANGLE	R					RAW ANGLE(11:8)			
0x0D		R	RAW ANGLE(7:0)							
0x0E	ANGLE	R					ANGLE(11:8)			
0x0F		R	ANGLE(7:0)							
Status Registers										
0x0B	STATUS	R			MD	ML	MH			
0x1A	AGC	R	AGC(7:0)							
0x1B	MAGNITUDE	R					MAGNITUDE (11:8)			
0x1C		R	MAGNITUDE(7:0)							
Burn Commands										
0xFF	BURN	W	Burn_Angle = 0x80; Burn_Setting = 0x40							

Note(s):
1. 要更改配置，请读出寄存器，只修改所需的位，然后写入新的配置。空白字段可能包含出厂设置。
2. 在上电期间，配置寄存器被重置为永久编程值。未编程位为零。

ZPOS/MPOS/MANG Registers

这些寄存器用于配置起始位置 (ZPOS) 和停止位置 (MPOS) 或更窄角度范围的最大角度 (MANG) 角度范围必须大于18度。在角范围变窄的情况下，分辨率不会缩放到变窄的范围 (e.g. 0° to
360°(full-turn) → 4096dec; 0° to180°→2048dec). 要配置角度范围，请参见 Angle Programming.

CONF Register

CONF 寄存器支持自定义AS5600。 Figure 22 显示了CONF寄存器的映射。

Figure 22:
CONF Register

Name	Bit Position	Description
PM(1:0)	1:0	Power Mode 00 = NOM, 01 = LPM1, 10 = LPM2, 11 = LPM3
HYST(1:0)	3:2	Hysteresis 00 = OFF, 01 = 1 LSB, 10 = 2 LSBs, 11 = 3 LSBs
OUTS(1:0)	5:4	Output Stage 00 = analog (full range from 0% to 100% between GND and VDD, 01 = analog (reduced range from 10% to 90% between GND and VDD, 10 = digital PWM
PWMF (1:0)	7:6	PWM Frequency 00 = 115 Hz; 01 = 230 Hz; 10 = 460 Hz; 11 = 920 Hz
SF(1:0)	9:8	Slow Filter 00 = 16x [(1)]; 01 = 8x; 10 = 4x; 11 = 2x
FTH(2:0)	12:10	Fast Filter Threshold 000 = slow filter only, 001 = 6 LSBs, 010 = 7 LSBs, 011 = 9 LSBs,100 = 18 LSBs, 101 = 21 LSBs, 110 = 24 LSBs, 111 = 10 LSBs
WD	13	Watchdog 0 = OFF, 1 = ON

Note(s):

1. 强制低功耗模式(LPM)

ANGLE/RAW ANGLE Register

RAW角度寄存器包含未缩放和未修改的角度。缩放后的输出值在ANGLE寄存器中可用。

Note(s): 角度寄存器在360度范围的极限处有一个10 lsb的迟滞，以避免在一次旋转内的不连续点或输出切换。

STATUS Register

状态寄存器提供指示AS5600当前状态的位。

Figure 23:
STATUS Register

Name	State When Bit Is High
MH	AGC 最小增益溢出，磁铁太强
ML	AGC 最大增益溢出，磁体太弱
MD	检测到磁铁

AGC Register

AS5600在闭环中使用自动增益控制来补偿由于温度变化，IC和磁铁之间的气隙以及磁铁退化而引起的磁场强度变化。AGC寄存器表示增益。为了获得最稳健的性能，增益值应该位于其范围的中心。物理系统的气隙可通过调节来达到此值。

在5V工作时，AGC范围为0-255个计数。AGC范围在3.3V模式下减少到0-128个计数。

MAGNITUDE Register

幅度寄存器表示内部CORDIC的幅度值。

Non-Volatile Memory (OTP)

非易失性存储器用于对配置进行永久编程。为了对非易失性存储器进行编程，使用I²C接口 (Option A, Option C) 。或者，可以通过输出引脚对启动和停止位置进行编程 (Option B) 。编程可以在5V供电模式或3.3V工作模式下进行，但使用3.3V的最小供电电压和VDD3V3引脚到地的10 µF电容。这个10 µF的电容仅在器件编程时才需要。两个不同的命令用于对设备进行永久编程:

Burn_Angle Command (ZPOS, MPOS)

主微控制器可以用BURN_ANGLE命令对ZPOS和MPOS进行永久编程。要执行BURN_ANGLE命令，请将值0x80写入寄存器0xFF。BURN_ANGLE命令最多可以执行3次。ZMCO显示了ZPOS和MPOS被永久写入的次数。

该命令只能在检测到磁铁存在的情况下执行(MD = 1)。

Burn_Setting Command (MANG, CONFIG)

主机微控制器可以使用BURN_SETTING命令执行MANG和CONFIG的永久写入。要执行BURN_SETTING命令，将值0x40写入寄存器0xFF。

只有当ZPOS和MPOS从未被永久写入(ZMCO = 00)时，才可以写入MANG。BURN_ SETTING命令只能执行一次。

Angle Programming

对于不使用完整的0到360度角范围的应用程序，可以通过编程实际使用的范围来增强输出分辨率。在这种情况下，输出的全分辨率自动缩放到编程的角度范围。角度范围必须大于18度。

范围是通过编程一个开始位置(ZPOS)和一个停止位置(MPOS)或角度范围的大小(MANG)来指定的。

The BURN_ANGLE命令最多可以执行3次。

有三种推荐的方法来编程角度范围:

- **Option A:** 通过I²C接口进行角度编程
- **Option B:** 通过OUT引脚进行角度编程
- **Option C:** 通过I²C接口编程最大角度范围

Figure 24:
Option A: Angle Programming Through the I²C Interface

Use the correct hardware configuration shown in Figure 37 and Figure 38.	
Step 1	上电AS5600。
Step 2	将磁铁转到开始位置。
Step 3	读取RAW角度寄存器。 将RAW角度值写入ZPOS寄存器。 至少等待1ms。
Step 4	按照DIR引脚上的电平(GND为顺时针方向，VDD为逆时针方向)所定义的方向旋转磁铁至停止位置。旋转的量必须大于18度。
Step 5	读取RAW角度寄存器。 将RAW角度值写入MPOS寄存器。 至少等待1ms。
继续执行步骤6，对配置进行永久编程。	
Step 6	执行BURN_ANGLE命令对设备进行永久编程。至少等待1ms。
Step 7	验证BURN_ANGLE命令: 将命令0x01、0x11和0x10依次写入寄存器0xFF，以加载实际的OTP内容。 读取ZPOS和MPOS寄存器以验证BURN_ANGLE命令是否成功。
Step 8	在新的上电周期后再次读取并验证ZPOS和MPOS寄存器。

Note(s):
1. 每次执行register命令后，新设置至少在1 ms后的输出中生效。
2. 强烈建议在此过程之后执行功能测试。

Figure 25:
Option B: Angle Programming Through the OUT Pin

使用如 Figure 37 和 Figure 38 所示的正确硬件配置。PGO引脚连接到GND, OUT引脚被内部电阻拉高，直到编程过程完成。	
Step 1	上电AS5600。
Step 2	把磁铁定位在起始位置。
Step 3	将OUT引脚拉到GND上至少100毫秒，然后让引脚浮动。
Step 4	按照DIR引脚上的电平(GND为顺时针，VDD为逆时针)所定义的方向旋转磁铁至停止位置。旋转的角度必须大于18度。
Step 5	将OUT引脚拉到GND上至少100毫秒，然后让引脚浮动。
Step 6	检查OUT引脚是否永久驱动到GND。这表示在编程过程中发生了错误。如果驱动在OUT引脚上的电压对应于磁铁位置，则该过程执行成功。

Note(s):

1. 在第5步之后，新的设置对输出有效。
2. I如果步骤3之后没有步骤5，则不会执行永久写入操作。
3. 强烈建议在此过程之后执行功能测试。
4. 这个过程只能执行一次;零点位置和最大角度只能通过I^2C (Option A) 重新编程。
5. 只有在检测到磁铁存在的情况下(MD = 1)，才能执行此过程。

Figure 26:
Option C: Programming a Maximum Angular Range Through the I²C Interface

使用如使用如Figure 37 和 Figure 38 所示的正确硬件配置。	
Step 1	上电AS5600。
Step 2	使用i2c接口将最大角度范围写入MANG寄存器。例如，如果最大角度范围是90度，那么用0x400写入MANG寄存器。 通过写入CONFIG寄存器来配置其他配置设置。 至少等待1ms。
继续执行步骤3，对配置进行永久编程。	
Step 3	执行BURN_SETTINGS命令对设备进行永久编程。至少等待1ms。
Step 4	验证BURN_SETTINGS命令: 将命令0x01、0x11和0x10依次写入寄存器0xFF，以加载实际的OTP内容。 读取并验证MANG和CONF寄存器，以验证BURN_SETTINGS命令是否成功。
继续步骤5永久编程零位置。如果OUT引脚用于此选项，则PGO引脚必须连接到GND。	
Step 5	将磁铁定位在起始位置(零角度)。
Step 6	将OUT引脚拉到GND上至少100毫秒，然后让引脚浮动。或者，通过I²C接口编程零点位置(Option A) 。 至少等待1ms。
Step 7	通过I²C验证永久编程 (Option A) 或检查OUT是否永久驱动到GND (Option B) 。
Step 8	在一个新的上电周期后，再次读取和验证永久编程寄存器。

Note(s):

1. 在执行每个register命令后，新的配置至少在1ms后才会在输出中生效。
2. 建议在该操作完成后进行功能测试。

输出级

CONF寄存器中的out位用于在模拟比率输出(默认)和数字PWM输出之间进行选择。如果选择PWM，则DAC断电。

不管哪个输出是启用的，外部单元可以随时通过I²C接口从角度寄存器读取角度。

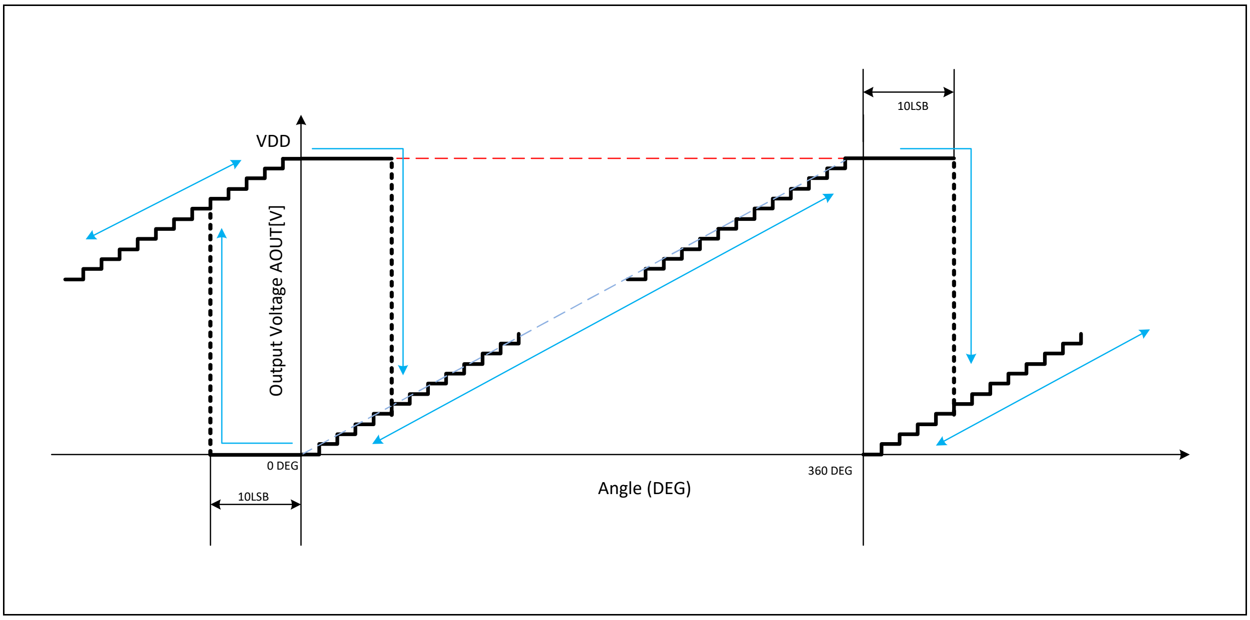
模拟输出模式

默认情况下，AS5600输出级配置为模拟比率输出。数模转换器(DAC)具有12位分辨率。在默认模式下，DAC的下参考电压为GND，上参考电压为VDD。OUT引脚上的输出电压在GND和VDD之间呈比例关系。

最大角度范围可编程从18度到360度。默认范围是360度。

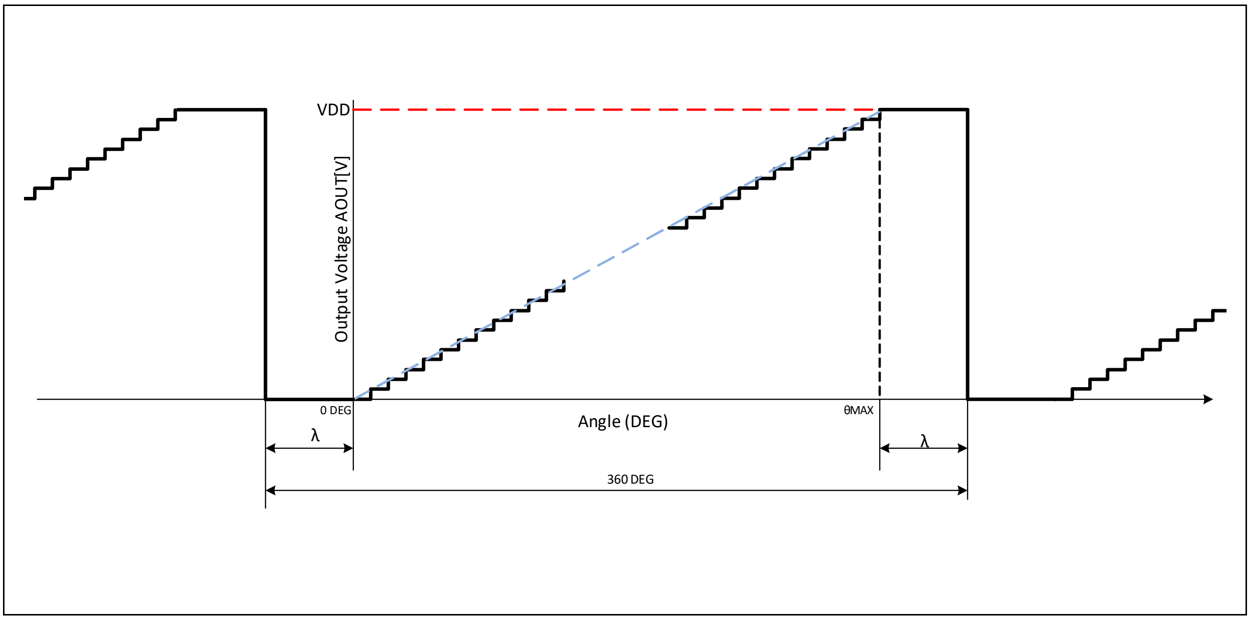
如下图所示，如果范围是360度，为了避免不连续点恰好在范围的极限处，施加10-LSB的迟滞。当磁体接近零或360度时，这种迟滞抑制了切换OUT引脚。

Figure 27:
Output Characteristic Over a 360° Full-Turn Revolution



AS5600既支持零角度编程，也支持最大角度范围编程。如Figure 28 所示，减小最大角度范围将非间断点推到边缘，使其远离0和θmax(其中θmax是最大角度)，其中λ= (360 - θmax)/2。

Figure 28:
Output Characteristic Over a Range Smaller Than 360°

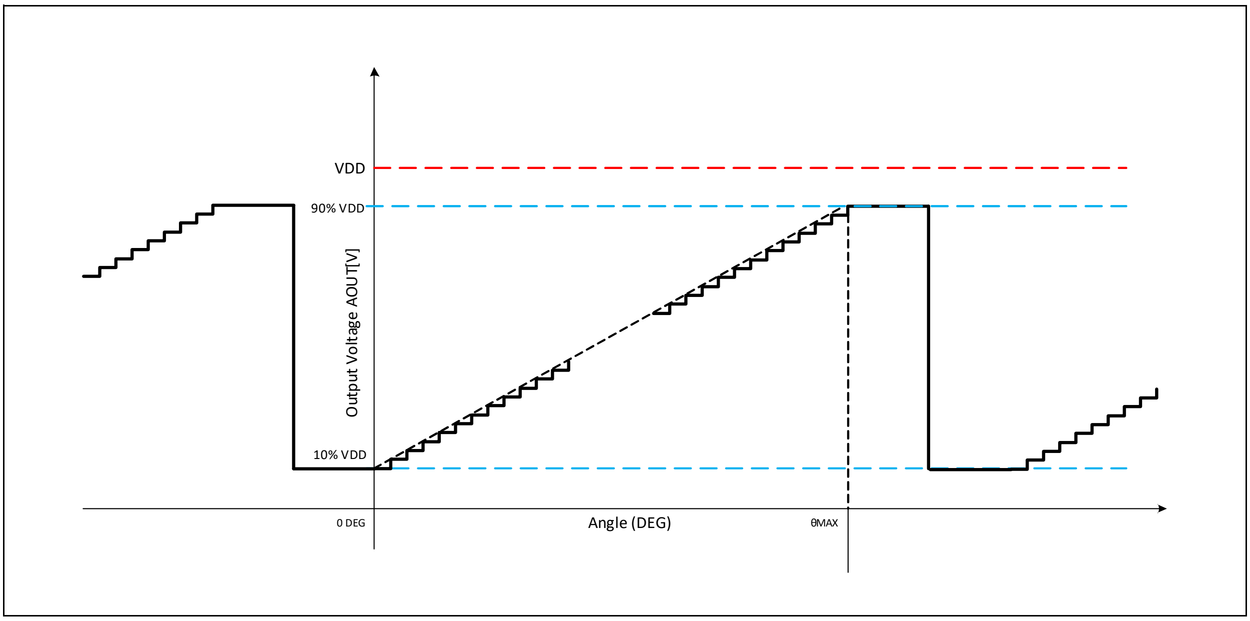


如果最大角度范围小于360度，则DAC分辨率自动降低。若θ max为最大角度，则输出信号OUT的步数N为:

$$N = (\theta_{max}/360) \times 4096$$

AS5600还允许使用CONF寄存器中的OUTS位选择OUT信号的输出动态特性。在默认情况下(OUTS = 00)，输出可以覆盖整个电压范围(0V到VDD)，但可以编程在GND和VDD之间减小10%到90%的范围(OUTS = 01)。

Figure 29:
Output Characteristics with Reduced Output Range (10%-90%)



PWM输出方式

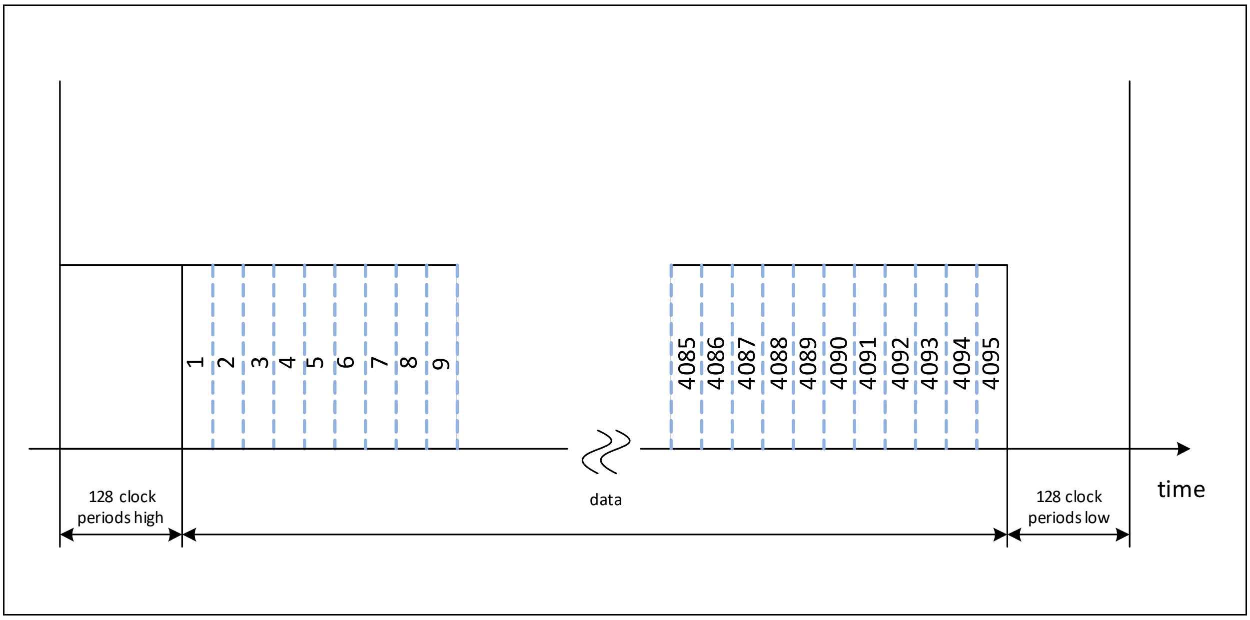
AS5600输出级可以在CONF寄存器的OUTS位中编程，用于pwm编码的数字输出(OUTS = 10)。在这种模式下，OUT引脚提供数字PWM信号。每个脉冲的占空比与旋转磁体的绝对角度成正比。

如 Figure 30 所示，PWM信号由4351个PWM时钟周期的帧组成。该PWM帧由以下部分组成:

- 128 PWM 时钟周期高
- 4095 PWM 时钟周期数据
- 128 PWM 时钟周期低

角度用帧的数据部分表示，1PWM时钟周期代表整个角范围的4096分之一。PWM频率是用CONF寄存器中的PWM位来编程的。

Figure 30:
Output Characteristics in Pulse Width Modulation Mode



0度角由128个时钟周期高和4223个时钟周期低表示，而最大角度由4223个时钟周期高和128个时钟周期低表示。

步骤响应和过滤器设置

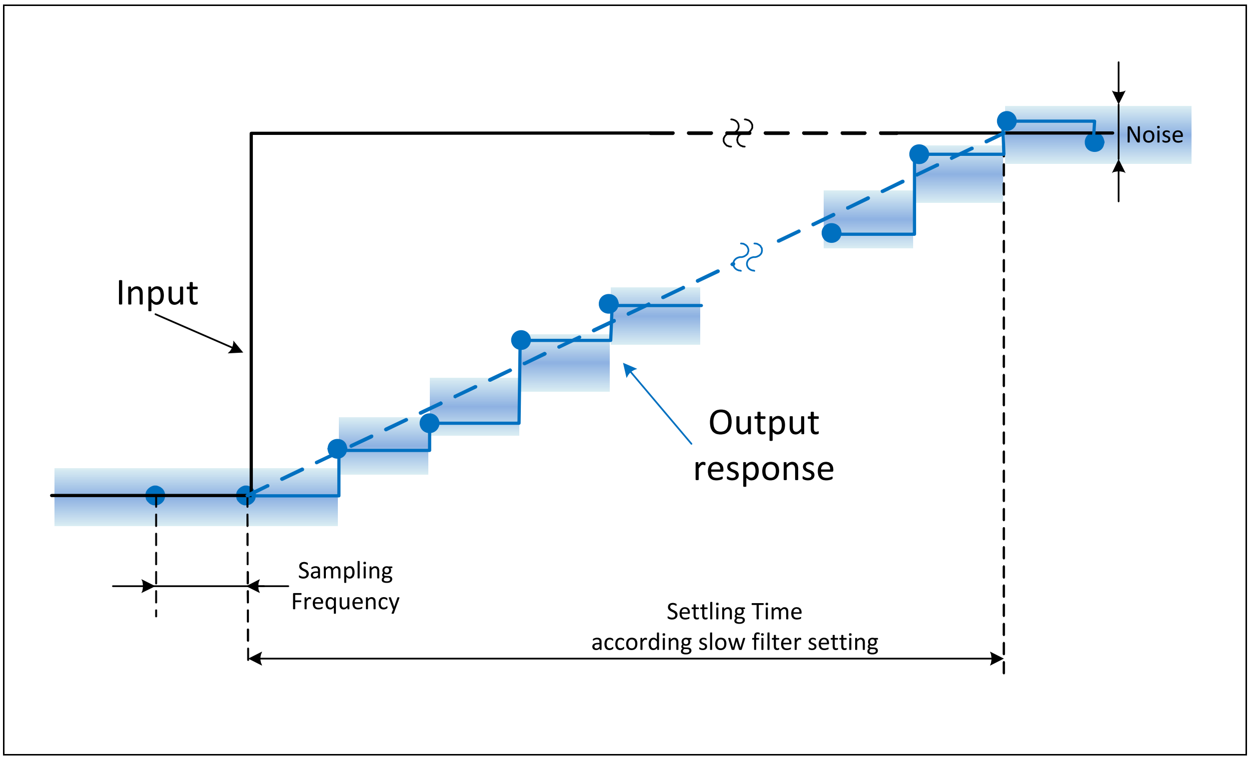
AS5600具有数字后处理可编程滤波器，可在快速或慢速模式下设置。通过在CONF寄存器的FTH位设置快速过滤阈值，可以使能快速过滤模式。

如果快速滤波器为OFF，则阶跃输出响应由慢速线性滤波器控制。慢速滤波器的阶跃响应是用CONF寄存器中的SF位可编程的。 Figure 32 显示了不同SF位设置下延迟和噪声之间的权衡。

Figure 31:
Step Response Delay vs. Noise Band

SF	Step Response Delay (ms)	Max. RMS Output Noise (1 Sigma) (Degree)
00	2.2	0.015
01	1.1	0.021
10	0.55	0.030
11	0.286	0.043

Figure 32:
Step Response (fast filter OFF)

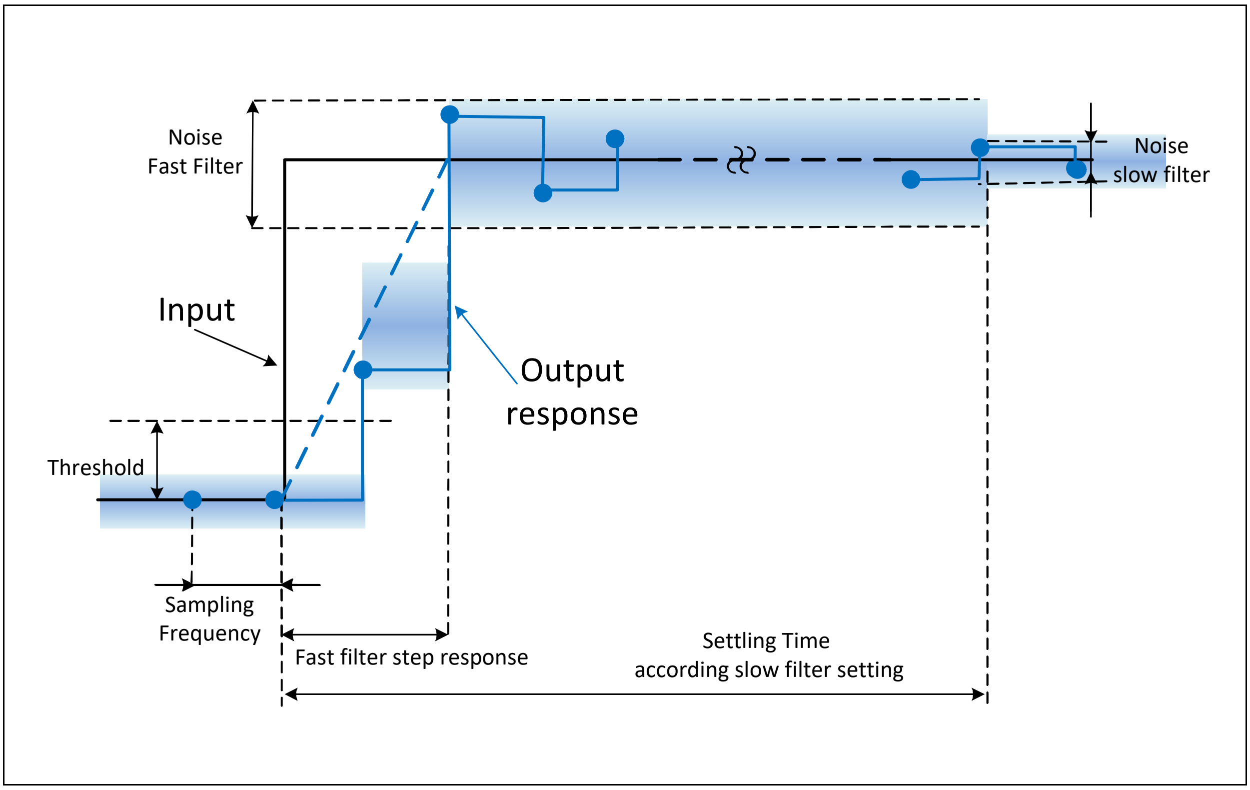


对于快速阶跃响应和低噪声后，可以启用快速滤波器。只有当输入变化大于快速滤波器阈值时，快速滤波器才能工作，否则输出响应仅由慢速滤波器决定。快速滤波阈值是用 FTH bits 在 CONF Register 编程的。如 Figure 34 所示，在两个完整的采样周期后，阶跃响应保持在一个误差带内，以稳定到由慢速滤波器确定的最终值。

Figure 33:
Fast Filter Threshold

FTH	Fast Filter Threshold (LSB)	
	Slow-to-fast filter	Fast-to-slow filter
000	Slow filter only	
001	6	1
010	7	1
011	9	1
100	18	2
101	21	2
110	24	2
111	10	4

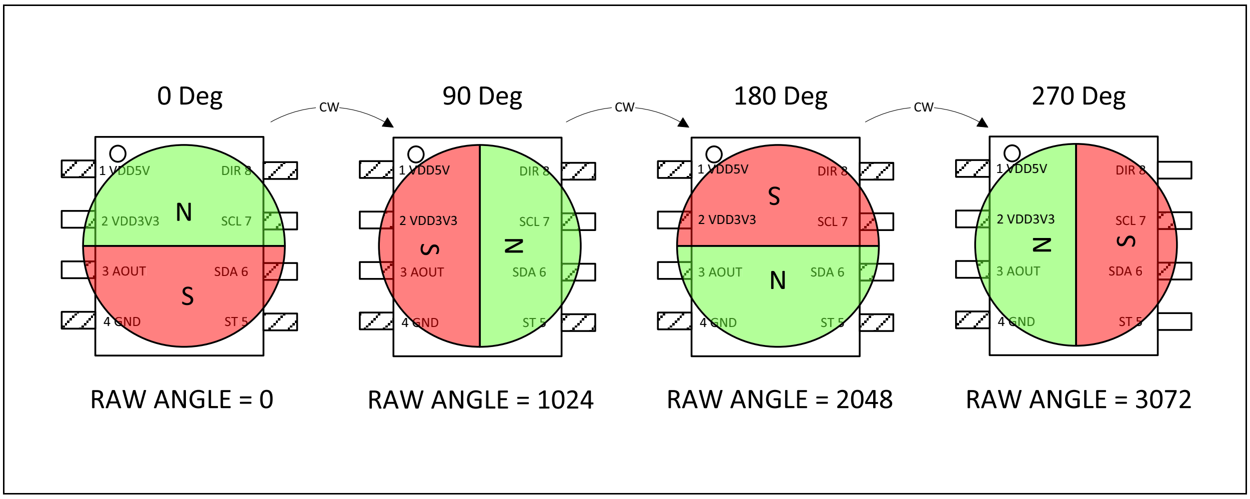
Figure 34:
Step Response (fast filter ON)



方向(顺时针vs逆时针)

AS5600允许用DIR引脚控制磁铁旋转的方向。如果DIR连接到GND (DIR = 0)，从顶部顺时针旋转将产生计算角度的增量。如果DIR引脚连接到VDD (DIR = 1)，则计算角度的增量将逆时针旋转。

Figure 35:
Raw Angle in Clockwise Direction



磁滞

为了避免磁铁不移动时输出的任何切换，可以使用 HYST 位在 CONF 寄存器启用12位分辨率的1到3 LSB滞后。

磁铁检测

作为安全和诊断功能，AS5600指示没有磁铁。如果测量的磁场强度低于最小指定水平 (Bz_ERROR)，则输出被驱动为低电平，而不管选择了哪种输出模式(模拟或PWM)，并且 MD 位在 STATUS 寄存器中为0。

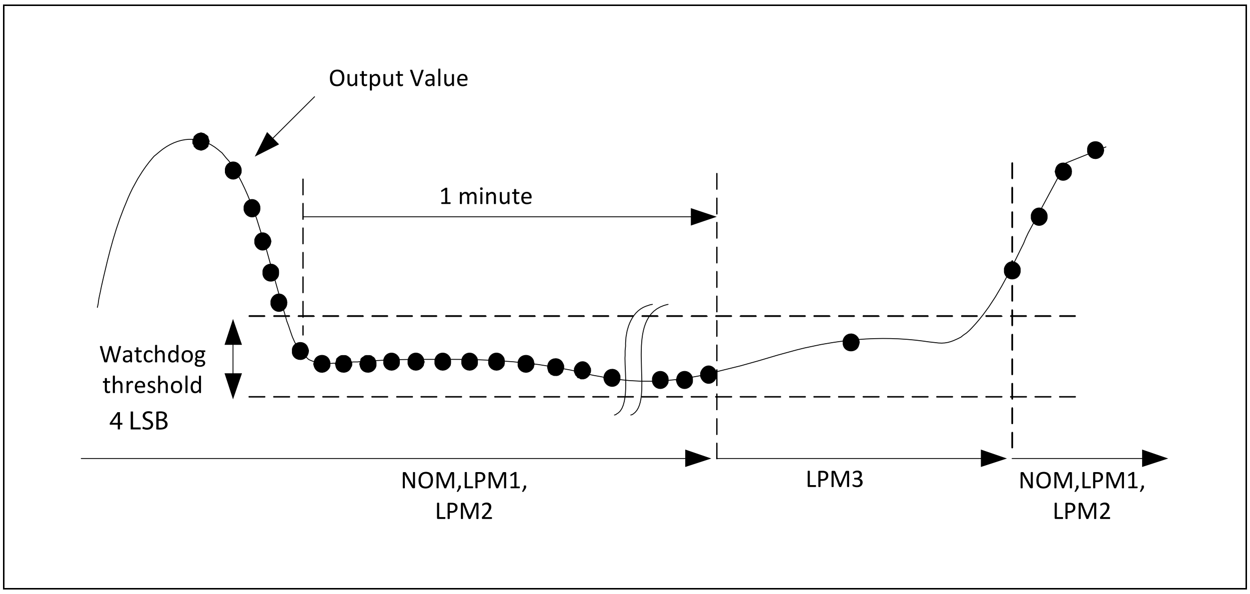
低功耗模式

数字状态机自动管理低功耗模式，以降低平均电流消耗。三种低功耗模式是可用的，可以启用 PM 位在 CONF 寄存器中。当前消耗和轮询时间如 Figure 6 所示。

看门狗定时器

看门狗定时器允许通过切换到LMP3来节省电源，如果角度保持在看门狗阈值4 LSB内至少一分钟，如 Figure 36 所示。看门狗功能可以通过WD 位在 CONF 寄存器中开启。

Figure 36:
Watchdog Timer Function

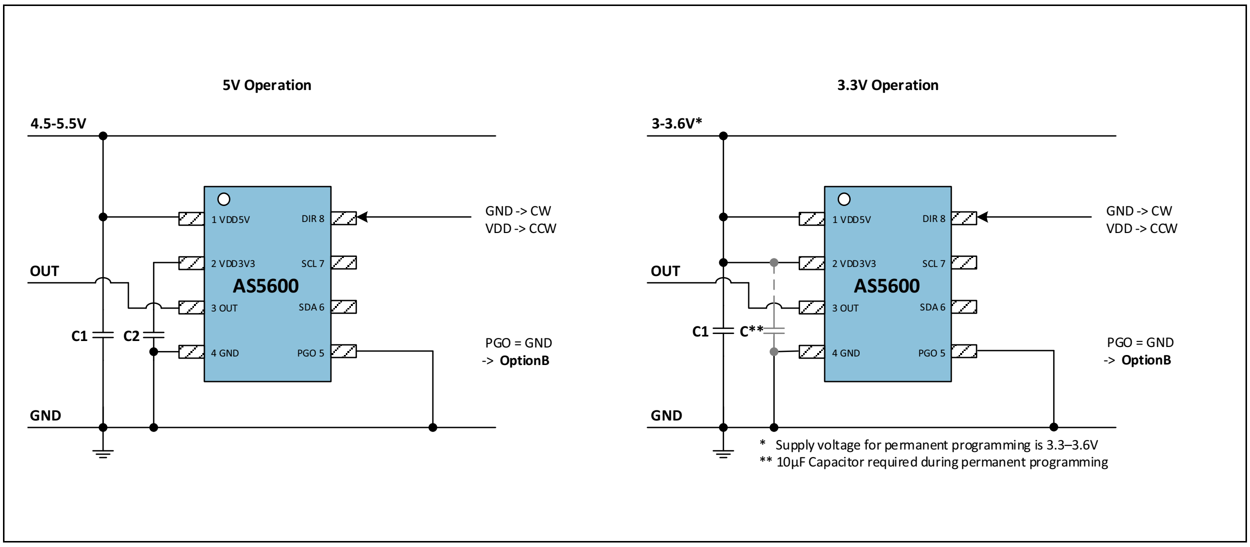


Application Information

示意图

所有必需的外部组件都显示在下面的参考应用程序图中。为了改善EMC和远程应用，请考虑额外的保护电路。

Figure 37:
Application Diagram for Angle Readout and Programming Through OUT Pin (Option B)



Note(s):

1. 考虑在通过OUT引脚编程期间，由内部上拉电阻驱动输出高电平。在编程过程中断开额外的外部负载。

Figure 38:
Application Diagram for Angle Readout and Programming with I²C (Option A and Option C)

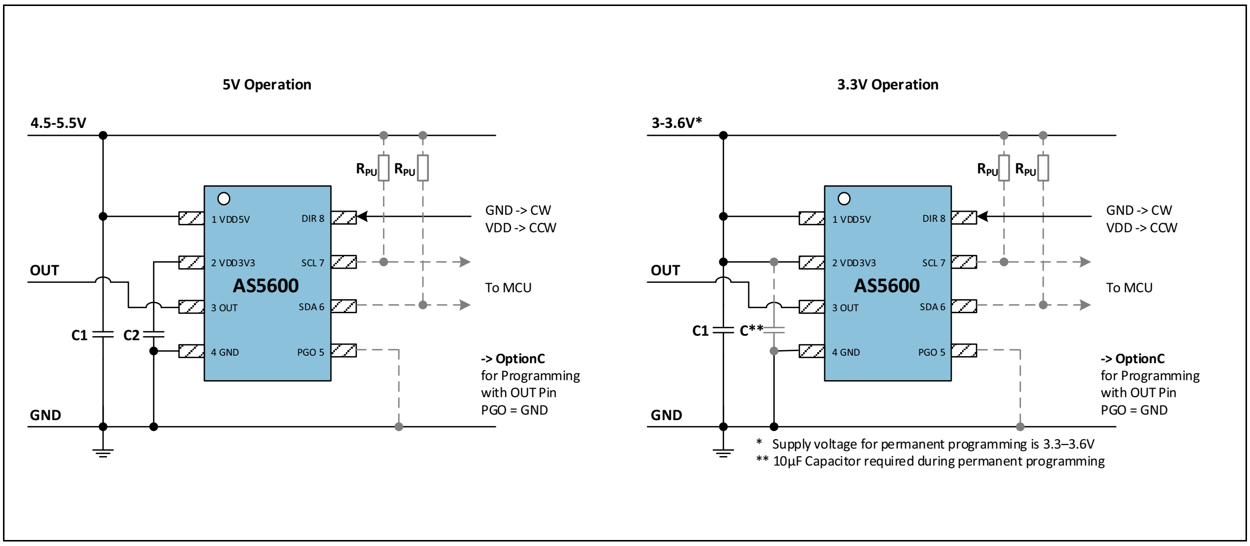


Figure 39:
Recommended External Components

Component	Symbol	Value	Units	Notes
VDD5V buffer capacitor	C1	100	nF	20%
LDO regulator capacitor	C2	1	µF	20%; < 100 mΩ; Low ESR ceramic capacitor
Optional pull-up for I²C bus	RPU	4.7	KΩ	Refer to UM10204 for RPU sizing

Note(s):

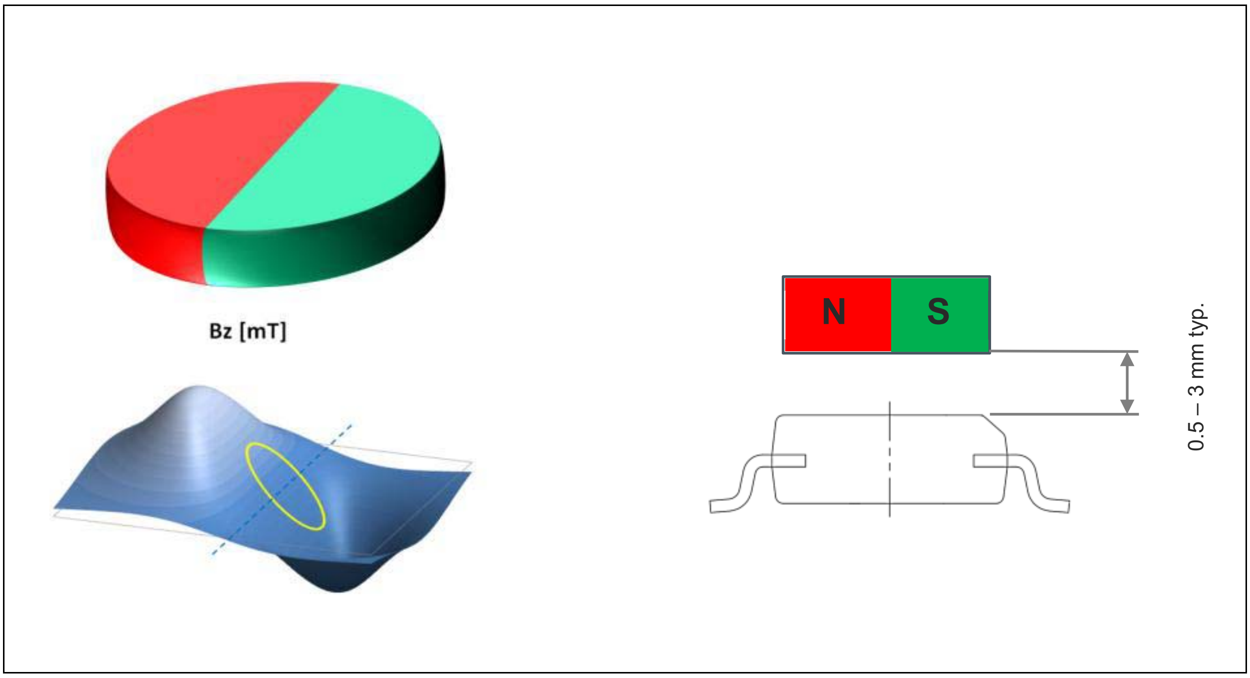
1. Given parameter characteristics have to be fulfilled over operation temperature and product lifetime

磁要求

AS5600要求磁场分量Bz垂直于芯片上的敏感区域。

沿着霍尔元件圆的圆周，磁场Bz应为正弦形状。利用差分测量原理消除位移误差，Bz沿圆半径的磁场梯度应在磁体的线性范围内。

Figure 40:
Magnetic Field Bz and Typical Airgap

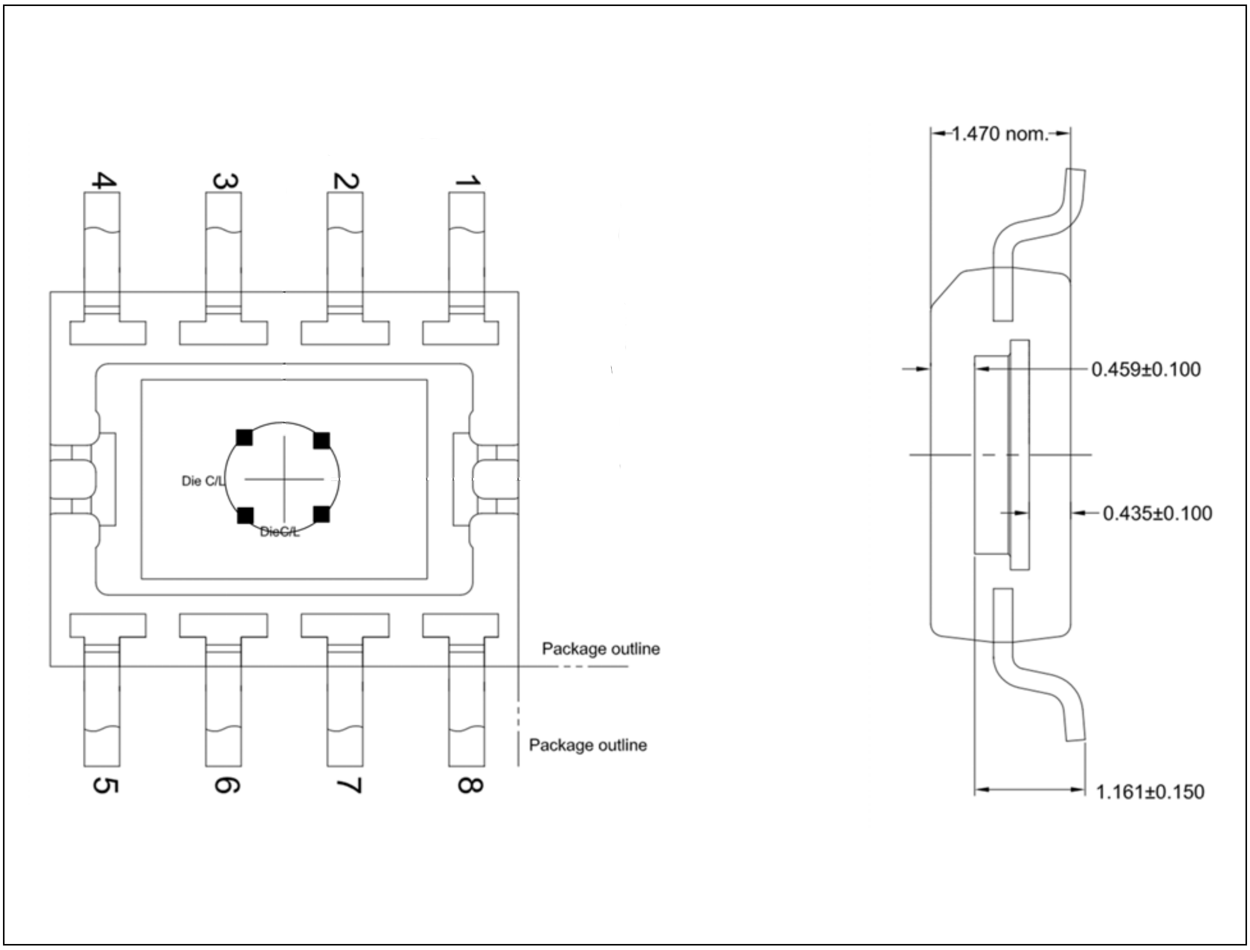


典型的气隙在0.5 mm到3mm之间，它取决于所选择的磁铁。更大更强的磁铁可以产生更大的气隙。以AGC值为导向，通过调整磁铁与AS5600之间的距离，使AGC值处于其范围的中心，即可找到最佳气隙。当使用直径为6mm的磁铁时，参考磁铁的旋转轴从封装中心的最大允许位移为0.25 mm。

机械数据

内部霍尔元件被放置在一个半径为1毫米的圆区域的中心。

Figure 41:
Hall Element Positions

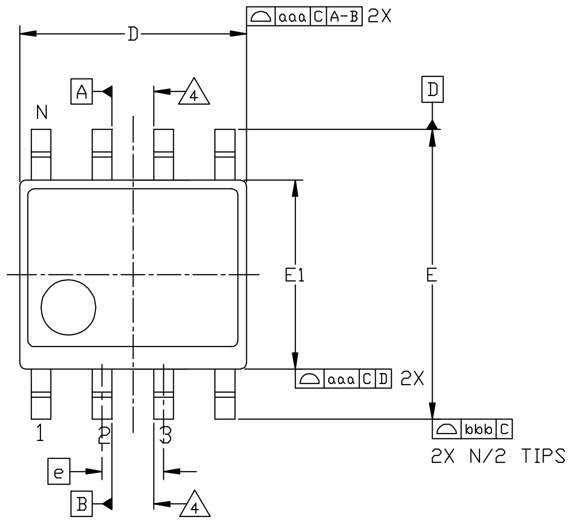


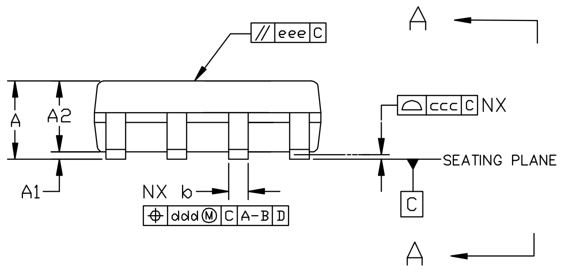
Note(s):

1. All dimensions in mm.
2. Die thickness 356µm nom.

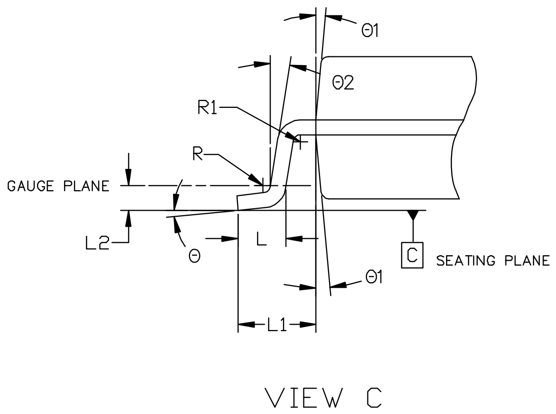
封装图纸和标记

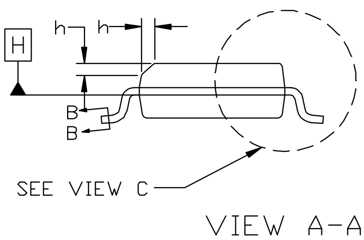
Figure 42:
SOIC8 Package Outline Drawing

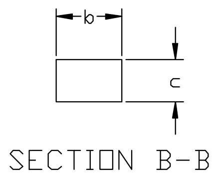




Symbol	Min	Nom	Max
A	-	-	1.75
A1	0.10	-	0.25
A2	1.25	-	-
b	0.31	-	0.51
c	0.17	-	0.25
D	-	4.90 BSC	-
E	-	6.00 BSC	-
E1	-	3.90 BSC	-
e	-	1.27 BSC	-
L	0.40	-	1.27
L1	-	1.04 REF	-
L2	-	0.25 BSC	-
R	0.07	-	-
R1	0.07	-	-
h	0.25	-	0.50
Θ	0º	-	8º
Θ1	5º	-	15º
Θ2	0º	-	-
aaa	-	0.10	-
bbb	-	0.20	-
ccc	-	0.10	-
ddd	-	0.25	-
eee	-	0.10	-
fff	-	0.15	-
ggg	-	0.15	-
N		8	







RoHS

Green

Note(s):

1. Dimensioning & tolerancing conform to ASME Y14.5M-1994.
2. All dimensions are in millimeters. Angles are in degrees.
3. N is the total number of terminals.
4. DATUMS A & B to be determined at DATUM H.

Figure 43:
Package Marking

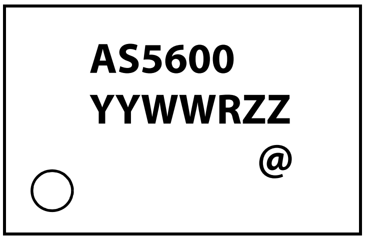


Figure 44:
Packaging Code

YY	WW	R	ZZ	@
Last two digits of the manufacturing year	Manufacturing week	Plant identifier	Free choice/ traceability code	Sublot identifier

Ordering & Contact Information

Figure 45:
Ordering Information

Ordering Code	Package	Marking	Delivery Form	Delivery Quantity
AS5600-ASOT	SOIC-8	AS5600	13" Tape&Reel in dry pack	2500 pcs
AS5600-ASOM	SOIC-8	AS5600	7" Tape&Reel in dry pack	500 pcs

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Document Status

Document Status	Product Status	Definition
Product Preview	Pre-Development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice
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Datasheet	Production	Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade
Datasheet (discontinued)	Discontinued	Information in this datasheet is based on products which conform to specifications in accordance with the terms of ams AG standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs

Revision Information

Changes from 1-05 (2018-May-18) to current revision 1-06 (2018-Jun-20)	Page
Updated Figure 6	5
Updated text under ZPOS/MPOS/MANG Registers	19

Note(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

Content Guide