# High Speed 12-Bit Magnetic Rotary Encoder

## FEATURES

- Contactless 12 bit resolution angular encoder
- 360° angle measurement with revolution counter and angle speed measurement
- 12 bit absolute outputs
  - SPI interface
  - PWM interface
- Angle linearity error < ±0.35°
- Output pins can be configured as push-pull or open-drain
- Maximum tracking speed : 20,000 rpm
- 0.18 um CMOS technology
- ESD > 4kV (HBM)
- Wide temperature range: -40℃ to 125℃
- SOP8 package

## APPLICATIONS

- Contactless angle measurements
- Robotics
- Rotary switches
- General angular sensing
- Angular encoder

## DESCRIPTION

The SC60228 is a 360° angle sensor IC with a built-in Hall element, and easily achieve a non-contact rotation angle sensor in combination with diametrically magnetized two pole magnets. By detecting the magnetic field parallel vector to the IC package surface, the signal conditioning unit generates constant-amplitude sine and cosine voltages that can be used for angle calculation. The resolution can be programmed up to a maximum of 4096 angular and it is suitable to various angle measurement applications and an encoder application.

Data communications are accomplished with a bi-directional SPI interface that is SSI-compatible. The sensor configuration is stored in registers, which are accessible by the SPI interface. The device also provides the 12-bit PWM interface.

The device is packaged in an 8-pin SOP. It is lead (Pb) free, with 100% matte tin-plated lead frame.

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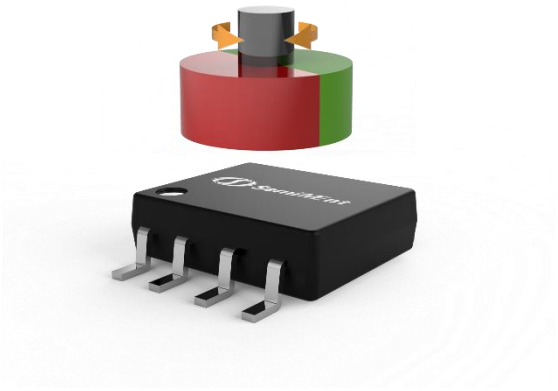

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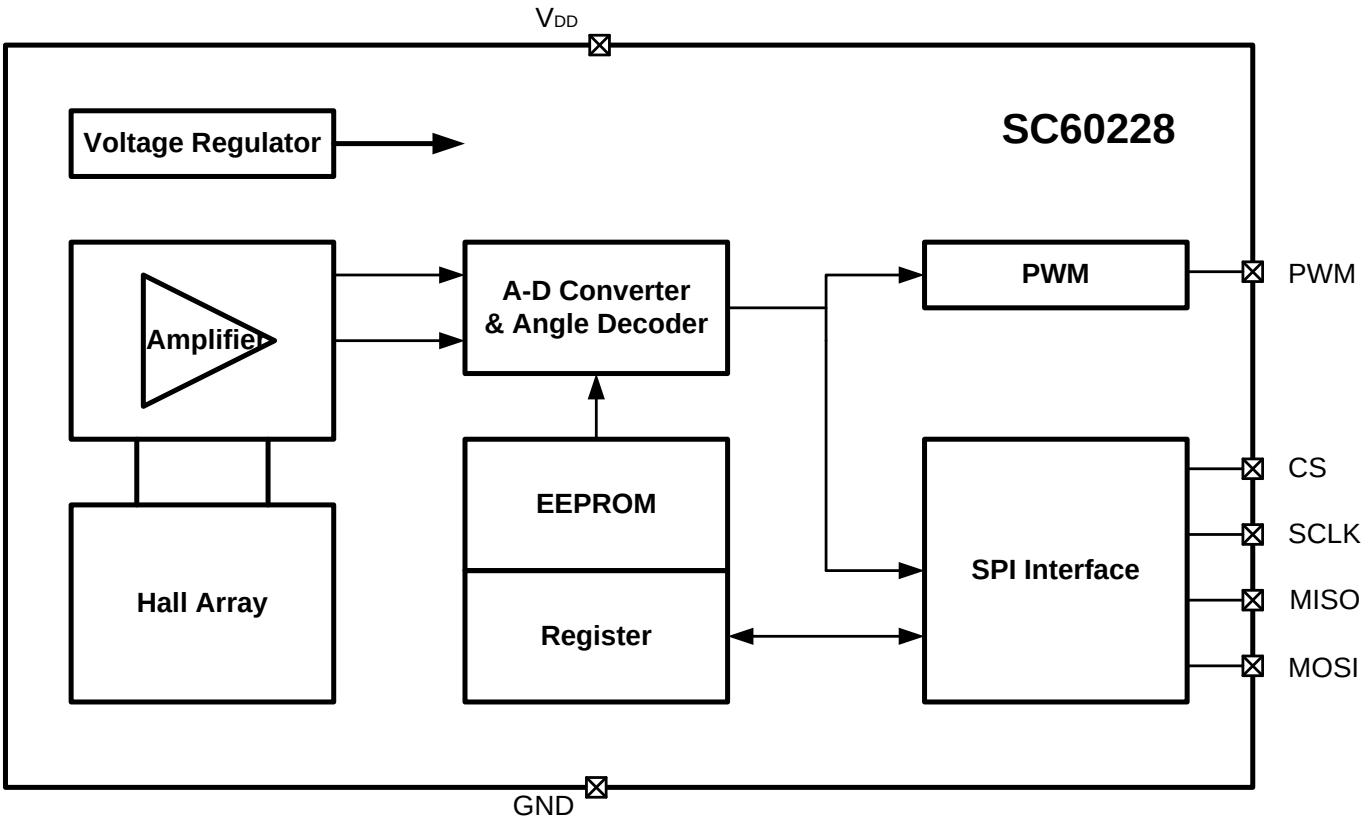
## BLOCK DIAGRAM

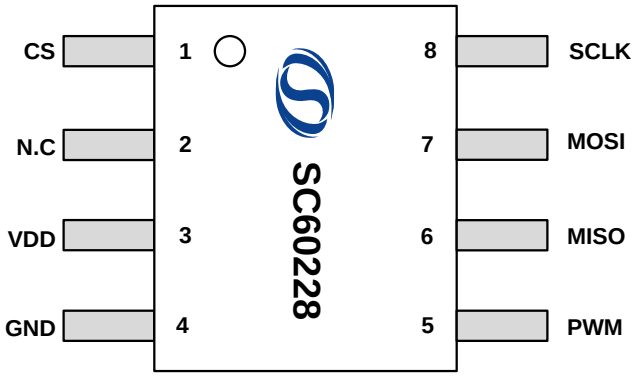



## ORDERING INFORMATION

| Part Number | Packing | Mounting | Output Type | Marking |
|---|---|---|---|---|
| SC60228DC | Reel, 3000 pieces/reel | 8-pin SOP | SPI; PWM | 60228 |

# TERMINAL CONFIGURATION

**8-Pin SOP8**
**DC Package**
**(Top View)**




| No. | Pin Name | I/O | Type | Description |
|---|---|---|---|---|
| 1 | CS | Input | Digital | SPI Chip Select Signal |
| 2 | N.C. | | | No Connected |
| 3 | $V_{DD}$ | - | Power | Power Supply PIN |
| 4 | GND | - | GND | Ground PIN |
| 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 |

# ABSOLUTE MAXIMUM RATINGS

| Characteristic | Symbol | Notes | Min. | Max. | Unit |
|---|---|---|---|---|---|
| Voltage at $V_{DD}$, MOSI, MISO, SCLK, CS, PWM | $V_{()}$ | | -0.3 | **6** | V |
| Current in $V_{DD}$ | $I_{()}$ | | -10 | 20 | mA |
| Current at MISO | $I_{()}$ | | -100 | 100 | mA |
| Current at SCLK, CS, MOSI | $I_{()}$ | | -10 | 10 | mA |
| EEPROM Write Cycles | | | | 100 | cycle |
| Operating Ambient Temperature | $T_A$ | | -40 | 125 | ℃ |
| Storage Temperature | $T_{STG}$ | | -65 | 165 | ℃ |
| Maximum Junction Temperature | $T_{J(max)}$ | | | 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.*

# 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 operating temperature range, $V_{DD}$=3.3V, $C_{BYPASS}$=0.1uF; unless otherwise specified

| Characteristics | Symbol | Test Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Electrical Characteristics** | | | | | | |
| Supply Voltage | $V_{DD}$ | | 3.0 | 3.3 | 5.5 | V |
| Supply Current | $I_{DD}$ | $V_{DD}$=5.0V,no load, mag=0 | 10.0 | 14.5 | 19.0 | mA |
| | | $V_{DD}$=3.3V,no load, mag=0 | 8 | 12 | 15 | |
| Bandgap Reference | $V_{bg}$ | | 1.18 | 1.25 | 1.32 | V |
| Reference Voltage | $V_{ref}$ | | 45 | 50 | 55 | %$V_{DD}$ |
| 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 | $INL_{opt}$ | | -0.35 | -- | 0.35 | Deg |
| Power on time | $t_{(on)}$ | | -- | -- | 5 | mS |
| **PWM Output** | | | | | | |
| PWM Frequency (Default) | $f_{(pwm)}$ | $V_{DD}$=3.3V，Temp=25℃ | 927 | 976 | 1024 | V |
| PWM Frequency (Optional) | $f_{(pwm)}$ | $V_{DD}$=3.3V，Temp=25℃ | 232 | 244 | 256 | V |
| **Magnetic Input Specification** | | | | | | |
| Diameter | $d_{mag}$ | ϕ6mm x 2.5mm for cylindrica Magnets | 4.0 | 6.0 | -- | mm |
| Thickness | $t_{mag}$ | | 2.5 | -- | -- | mm |
| Installation Distance | $D_{in}$ | Recommended magnets | 0.5 | -- | 2 | mm |
| Field Amplitude | $H_{ext}$ | At chip surface | 25 | -- | 125 | mT |
| Rotating Speed of Magnet | rpm | | -- | -- | 20,000 | rpm |

## OPERATING CHARACTERISTICS (continued)

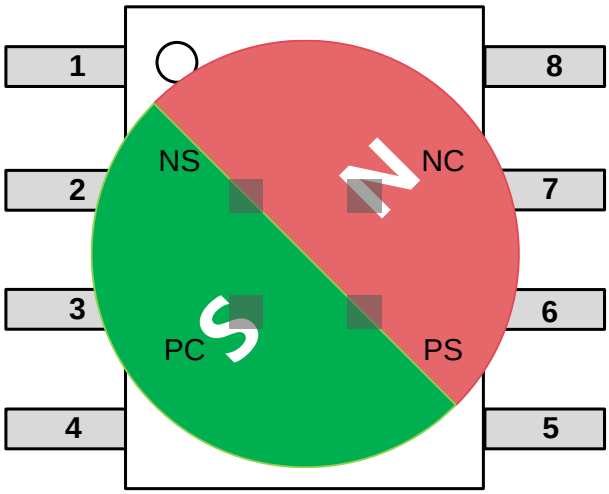
| Characteristics | Symbol | Test Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Digital INPUTS:CS,SCLK,MOSI** | | | | | | |
| Threshold Voltage hi | $V_{t()hi}$ | | -- | -- | 2 | V |
| Threshold Voltage lo | $V_{t()lo}$ | | 0.8 | -- | -- | V |
| Pull-down Current MOSI | $I_{pd()}$ | $V_{()}$ = 1 V...$V_{PD}$ | 6 | 38 | 60 | µA |
| Pull-up Current Source at CS,SCLK | $I_{pu()}$ | $V_{()}$ = 0...$V_{PD}$ – 1 V | -80 | -140 | -200 | µA |
| **Digital OUTPUTS:PWM,MISO** | | | | | | |
| Saturation Voltage hi | $V_{s()hi}$ | $I_{()hi}$ = -4 mA, with reference to $V_{DD}$ | -- | -- | 200 | mV |
| Saturation Voltage lo | $V_{s()lo}$ | $I_{()lo}$ = 4 mA, with reference to GND | --- | -- | 200 | mV |
| Short-Circuit Current hi | $I_{short()hi}$ | $V_{()}$ = GND; | 10 | -- | 20 | mA |
| Short-Circuit Current lo | $I_{short()lo}$ | $V_{()}$ = VDD; | 5 | -- | 15 | mA |
| Rise-Time lo to hi | $t_{Rise}$ | $R_L$ = 100 Ω to GND; | 5 | -- | 30 | nS |
| Fall-Time high to lo | $t_{Fall}$ | $R_L$ = 100 Ω to VDD; | 5 | -- | 30 | nS |

# FUNCTIONAL DESCRIPTION

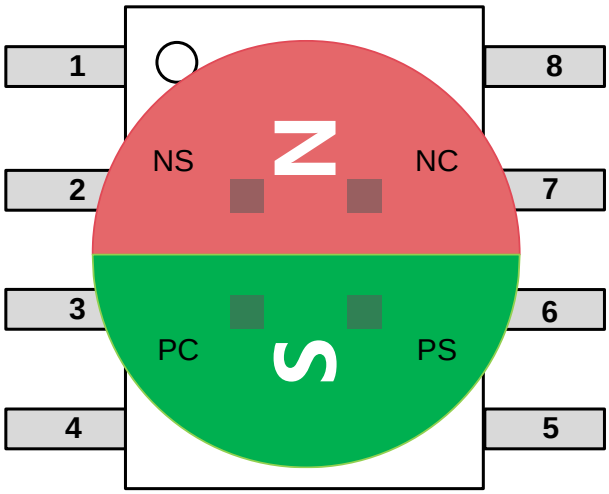
## Position of the Hall Sensors

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.



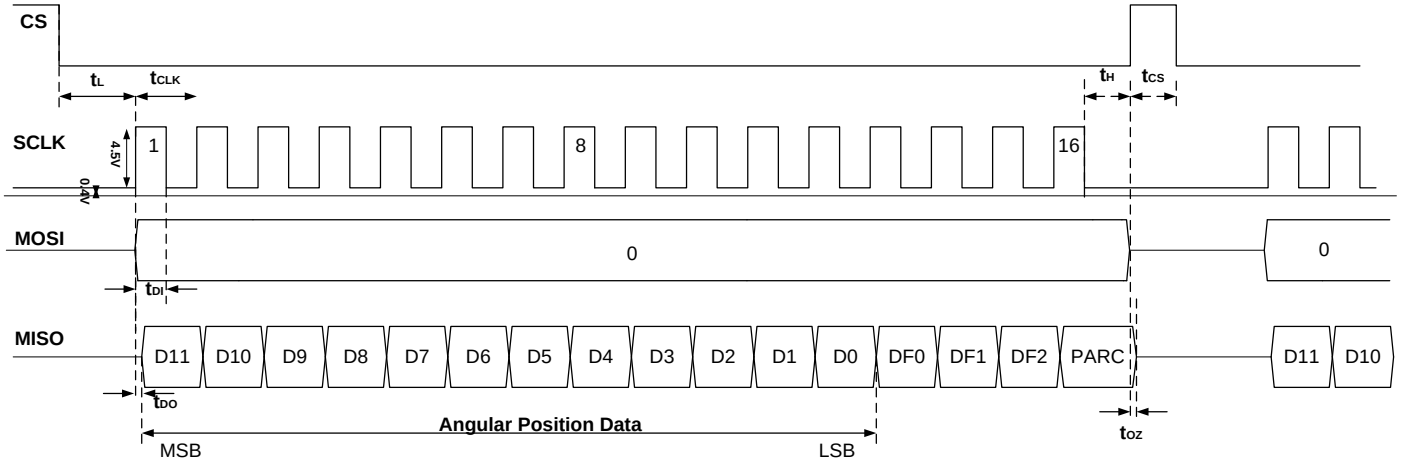

**Angle = 0°**




**Angle = 45°**

# 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

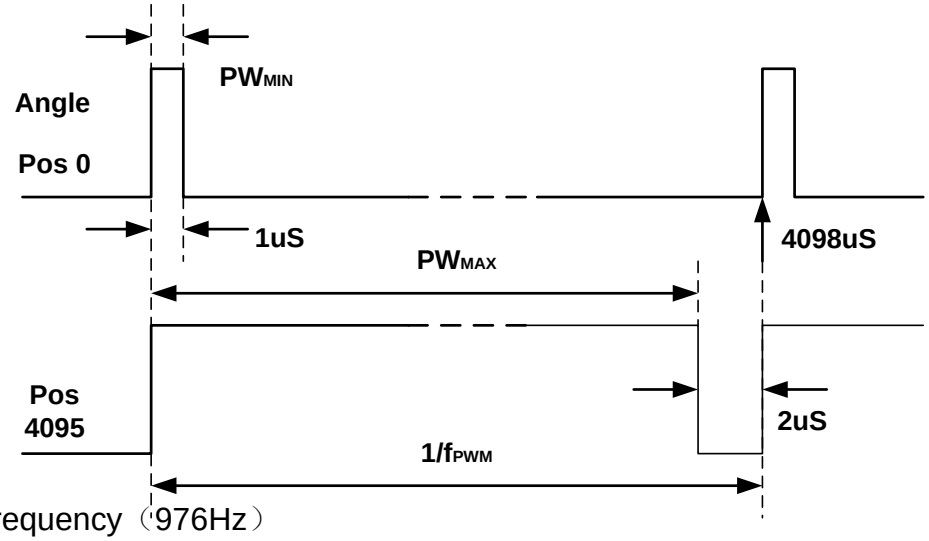
| Bit | Name | Description |
|---|---|---|
| 15 | PARC | Parity bit (odd) calculated on the lower 15 bits of data frame |
| 14 | DF2 | Data fixed; logic High |
| 13 | DF1 | Data fixed; logic High |
| 12 | ERR | Becomes logic High, when the fault occurs |
| 11:0 | DATA | Absolute angular position data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

## Pulse Width Modulation Output

The SC60228 provides a pulse width modulated output (PWM), whose duty cycle is proportional to the measured angle.

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

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:



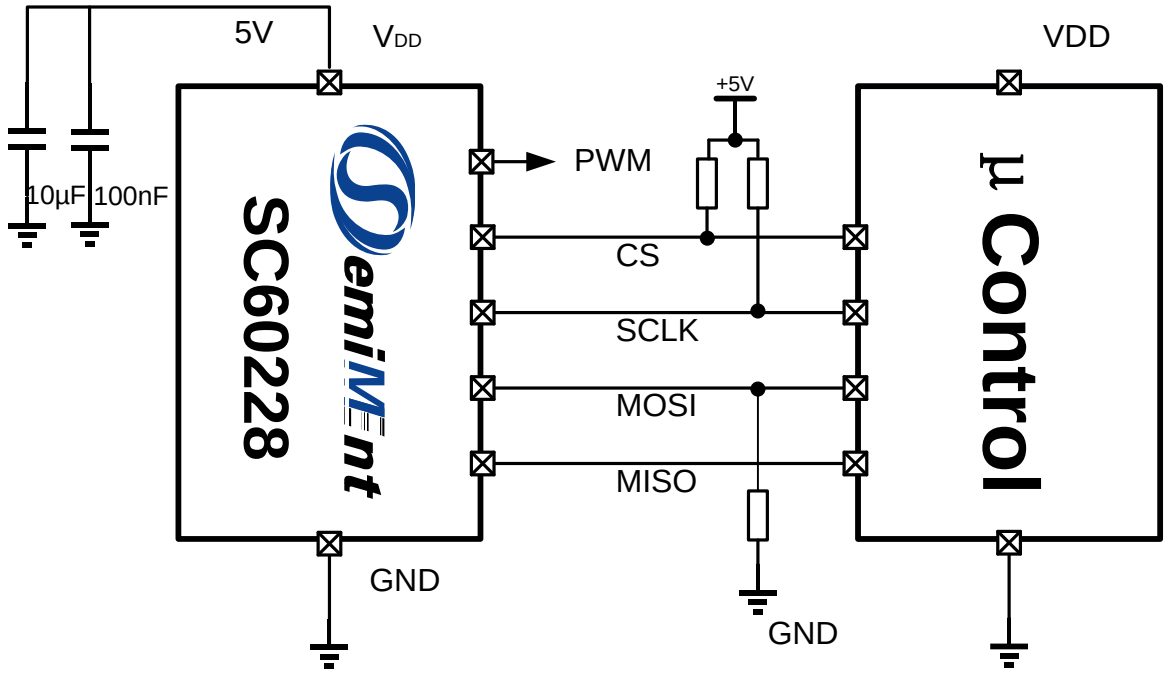

PWM default frequency（976Hz）

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

PWM optional frequency（244Hz）

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

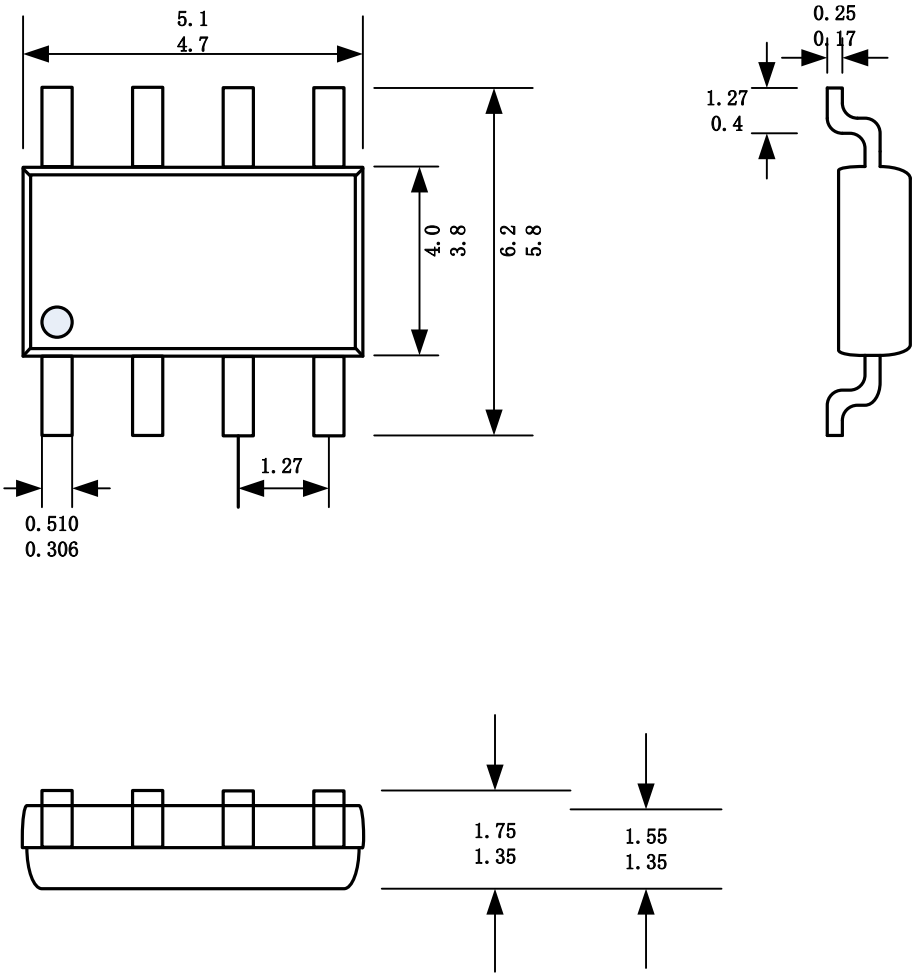
# TYPICAL APPLICATION




Remark:

Decoupling capacitors of 100nF and 10uF are recommended in $V_{DD}$ pin.

# PACKAGE INFORMATION




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.

# Revision History

| Revision | Date | Description |
|---|---|---|
| Rev0.1 | 2018-06-08 | Initial release |
| Rev1.1 | 2019-08-11 | Update typical application circuit |
| Rev1.2 | 2020-01-19 | Add version history |
| RevA/1.0 | 2020-12-28 | Update format |