TOSHIBA Semiconductor Application Note

Digital-Output Magnetic Sensor (Hall IC)

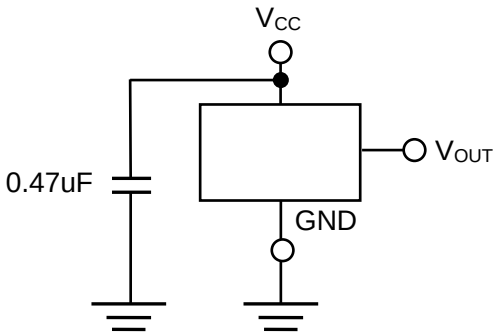
1. Introduction

The digital-output magnetic sensor is essentially a sensor which detects the magnetic flux density of a magnet and gives a digital signal at the output. The digital-output magnetic sensor is thus suitable for detecting the position of a magnet which is useful for open/close switch functions and slider functions in mobile phones, notebook PC, digital camera and digital video camera, etc. This application note will introduce the basic application circuit of the digital-output magnetic sensor and what to take note of during normal operation. We hope that you will find it useful.

2. Basic principles of magnetic sensor

・Basic operating circuit

The basic operating circuit is described in Fig.1.



V_{CC}: Supply Voltage Pin
GND: GND Pin
V_{OUT}: Output Pin

Fig.1 Basic operating circuit for Digital-output magnetic sensor

Please use a 0.47uF capacitor near the Supply Voltage Pin, Vcc, for stable operation of the device.

・Internal Circuit Block diagram

Toshiba's digital-output magnetic sensor TCS30/40xxx is a Silicon monolithic magnetic sensor (Hall IC) which detects magnetic flux using silicon hall elements. Please refer to Fig. 2 for the block diagram.

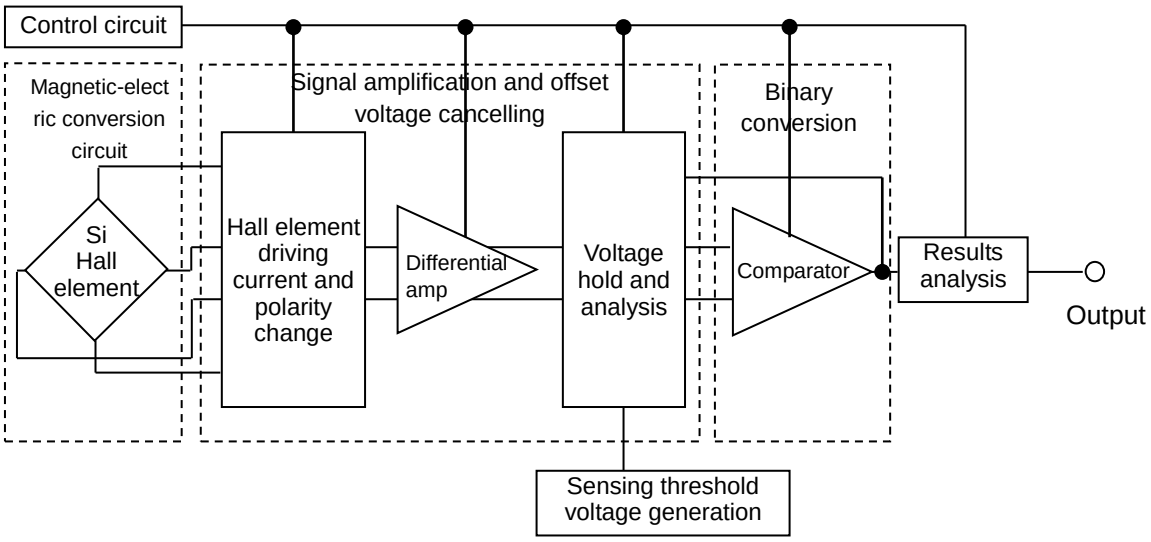


Fig.2 Digital-output magnetic sensor internal circuit block diagram

The internal circuit comprises of the following 8 circuits.

① Silicon hall element

② Switching circuit for drive current of hall elements and the difference between that and differential amp for offset cancelling used during polarity change.

③ Differential amp for the amplification of hall voltage VH in the silicon hall element.

④ Analysis circuit and voltage hold of amplified hall voltage from the silicon hall element, differential amp and comparator offset cancelling stages.

⑤ Detection threshold voltage producing circuit, which produces a reference voltage used for the threshold limit for the detection of magnetic field.

⑥ Comparator which provides a binary output after comparing the value from the hall element with the threshold value, to determine if there is a significant magnetic field.

⑦ Maintain output voltage from the comparator, circuit for maintaining the detection results.

⑧ Control element for operation control of all circuits.

3. Application example of Magnetic sensor (South-pole detection type : TCS30SPU)

Using the South-pole detection digital-output magnetic sensor TCS30SPU as an example、Fig.3 shows the sensor and the corresponding field. In Fig.4, as the magnet is brought close to the sensor, magnetic field flows from North-pole to the South-pole as detected by the sensor.

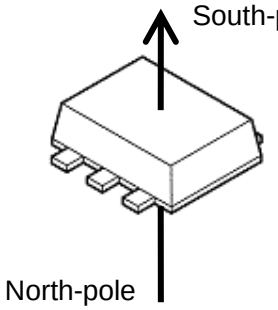


Fig.3 Package and magnetic field direction (TCS30SPU example)

Caution:

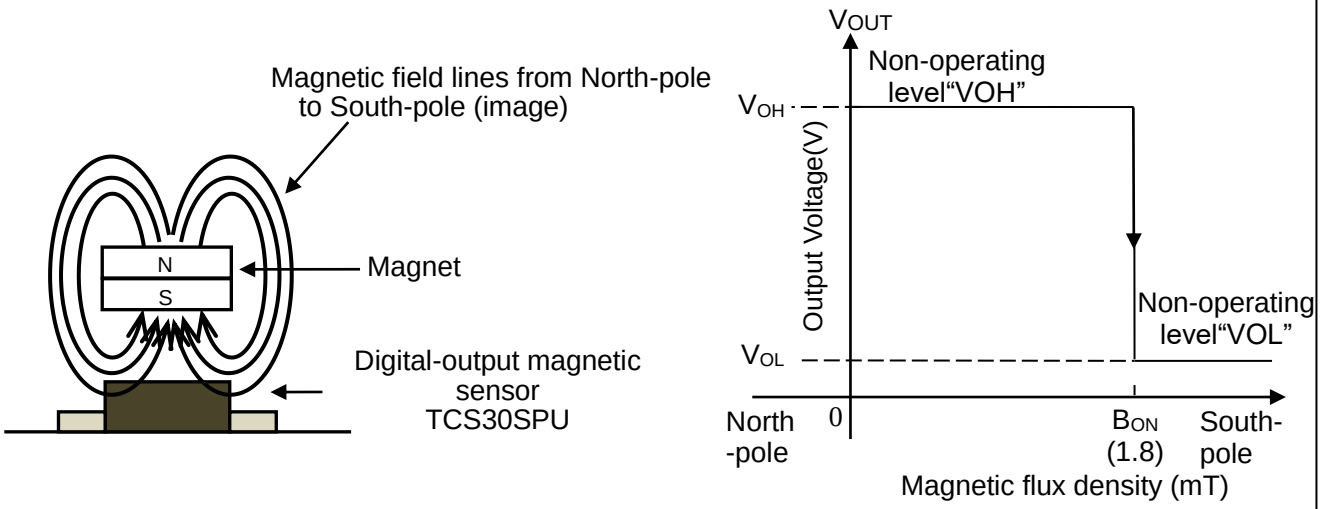
The sensor will sense the magnetic field as shown in Fig.3. As such, if similar to brining a South-pole to the top, bringing a North-pole close to the bottom will also result in positive output. To prevent this:

- Consider carefully magnetic sensor and magnet location
- Placing a magnetic shield on the bottom of sensor

The required magnetic field for the operation of magnetic sensor is determined by the magnetic flux density. For TCS30SPU, as the magnet is moved towards the sensor, the value required is 1.8mT(typ) and above for operating point (B_{ON}) and output voltage is switched to L level (Fig.4). As the magnet is moved away from the device and the threshold magnetic flux density is 0.8mT(typ) and below, the releasing point (B_{OFF}) and output voltage will be H level (Fig.5). As such, the hysteresis (BH) or difference between operating and releasing point flux density | BON-BOFF | is 1.0mT(typ) (Fig.6).

Please refer to the datasheet for the operating, releasing point and hysteresis magnetic flux density for each product.

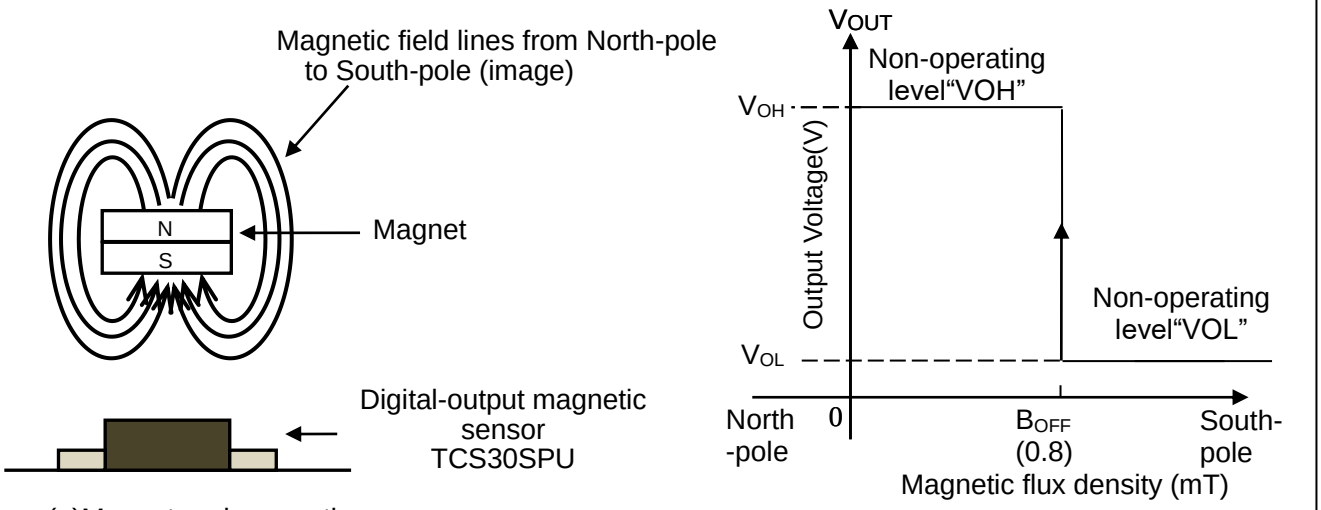
Fig.4 Operation characteristics as the magnet is bought towards the magnetic sensor. (South-pole detection type TCS30SPU example)



(a)Magnet and magnetic sensor diagram

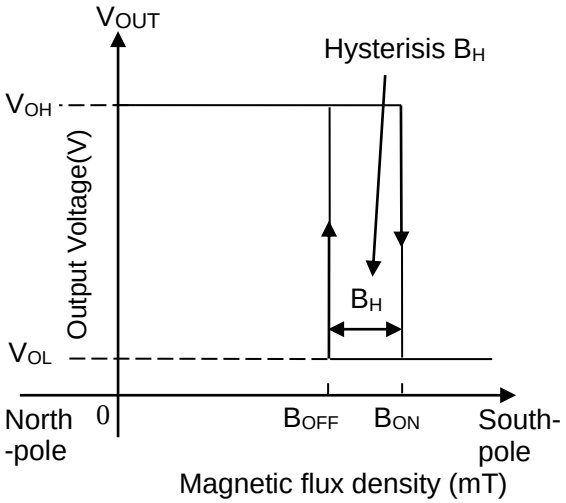
(b)Operating Characteristics : (B_{ON}) operation

Fig.5 Operation characteristics as the magnet is bought away from the magnetic sensor. (South-pole detection type TCS30SPU example)



(a)Magnet and magnetic sensor diagram

(b)Operating Characteristics : (B_{OFF}) operation



(b) Operating Characteristics

Magnetic flux density	Output
B_{ON}	V_{OL}
B_{OFF}	V_{OH}

(a) Magnetic Flux density and output voltage table

Fig.6 Magnetic flux density and output voltage relationship (South-pole detection type: TCS30SPU)

・Pulse operation to lower power consumption

Our digital-output magnetic sensor implements pulse operation (Fig.7). The operating frequency (f_{opr}) for magnet sensing is 25Hz(typ), and the power is cut-off during rest phases to reduce power consumption.

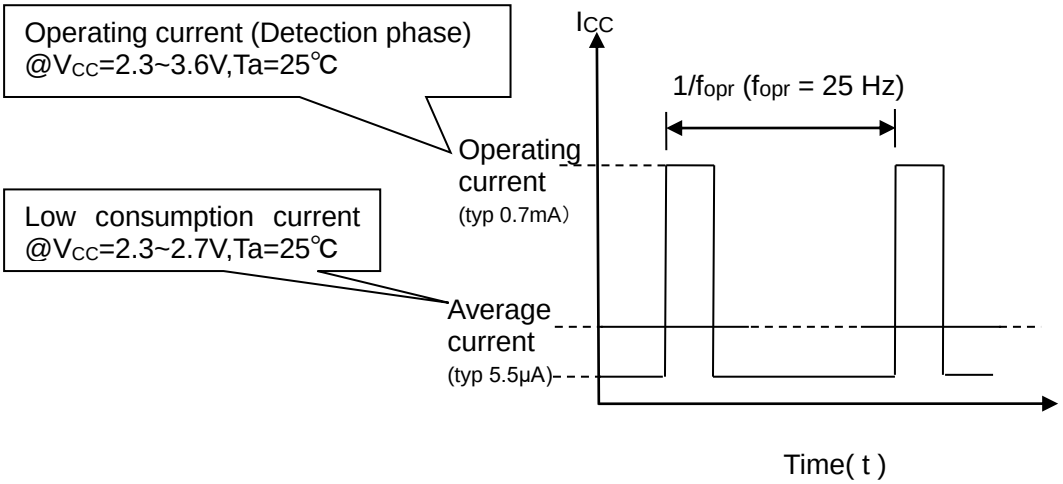


Fig.7 Pulse operation and consumption current (S-pole detection type: TCS30SPU)

・Positioning of magnet sensing element

The position of the magnet sensing element is shown in Fig.8. Please align the magnet with the magnet sensing element.

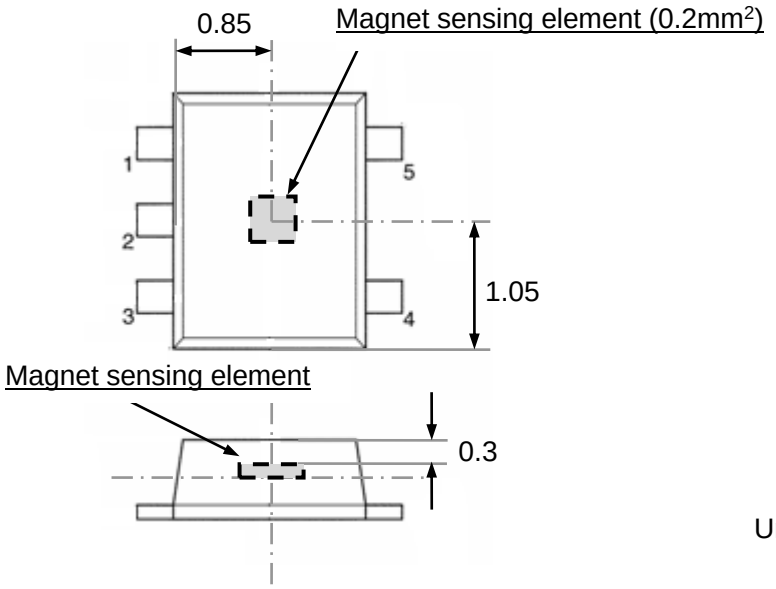


Fig.8 Magnet sensing element (South-pole detection type: TCS30SPU) : typical values

4. Toshiba magnetic sensor lineup

・Different pole detection types

There are 3 types:

① South-pole detection type (Fig.6 shows the magnetic operating characteristics)

② North-pole detection type (Fig.9 shows the magnetic operating characteristics)

③ South-pole and North-pole, dual detection type (Fig.10 shows the magnetic operating characteristics)

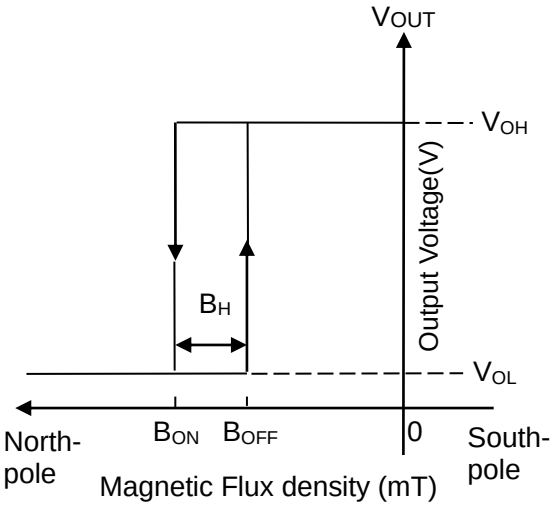


Fig.9 Magnetic operating characteristics
(North-pole detection type: TCS30NPU)

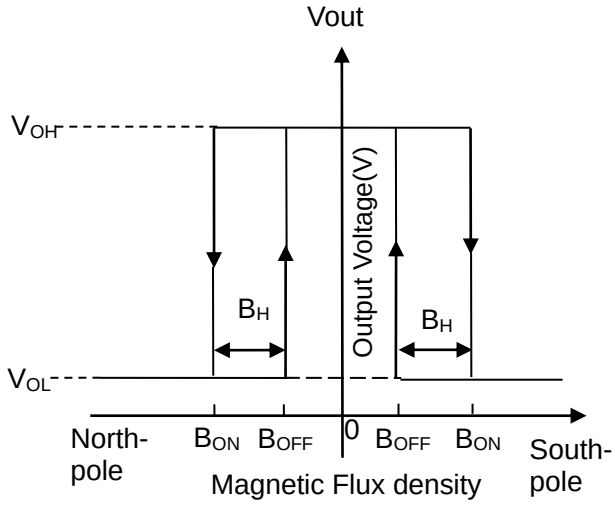


Fig.10 Magnetic operating characteristics
(South/North-pole detection type: TCS30DPU)

・Different output circuit types

There are 3 output circuit types

① Push-pull output

② Open-drain output

③ Open-drain output with Inverted logic

①Push-pull output

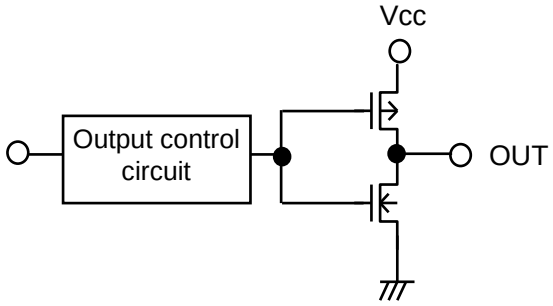


Fig.11 Push-pull output circuit

Push-pull output characteristics

・"H" output level close to V_{CC} level

・Low consumption current

Magnetic Flux density	Output logic
Above B_{ON}	L level
Below B_{OFF}	H level

②Open-drain output

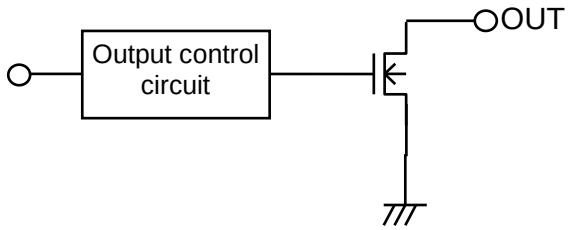


Fig.12 Open-drain output circuit

Open-drain output characteristics

・Output can be pulled-up to 5V

(Variable output voltage)

：During high impedance output

Magnetic Flux density	Output logic
Above B_{ON}	L level
Below B_{OFF}	Z (high impedance)

③Open-drain output with Inverted logic

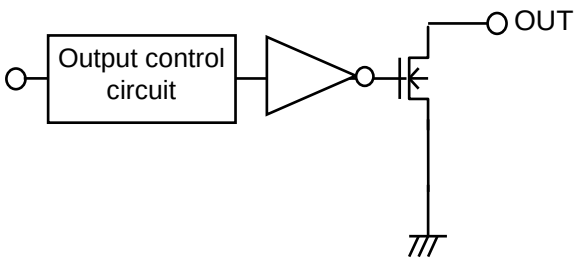


Fig.13 Open-drain with Inverted logic output circuit

Open-drain output characteristics

・For long standby time, consumption current can be reduced

・Output can be pulled-up to 5V

(Variable output voltage)

：During high impedance output

Magnetic Flux density	Output logic
Above B_{ON}	Z (high impedance)
Below B_{OFF}	L level

5. Other precautions

1. Please take into consideration the possible variation in the sensor characteristics and magnet, allowing some margin in your design.
2. The sensitivity of the sensor might be affected by stress on the package.
   Please do not apply excessive stress on the package during soldering.

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