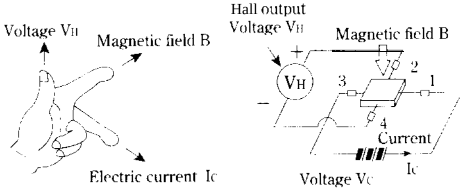
# General Description

## (1) Operating principles of the Hall device

The Hall device is an electro-magnetic conversion device which converts magnetic flux density into voltage, and is used as a magnetic sensor. When an electric current Ic is passed through a semiconductor chip and a perpendicular magnetic field (magnetic flux density B) is introduced, voltage $V_H$ is generated perpendicular to both electric current Ic and magnetic flux density B. This phenomenon is called the Hall effect. after the American researcher E.H. Hall, who discovered it in 1879.



Input terminals 1. 3
Output terminals : 2. 4

Fig. 1 Principles and structure of the Hall device

Voltage $V_H$ is called the Hall voltage, and is derived from the following equation :

$$V_H = K_H \cdot IC \cdot B \qquad (1)\ \text{(for constant-current operation)}$$
$$= K^* \cdot VC \cdot B \qquad (2)\ \text{(fur constant-voltage operation)}$$

Here $K_H$ is called the Hall sensitivity, which is determined according the semiconductor material used. It is usually expressed in units of mV/mA 100 mT. based on an input current of 1 mA and a magnetic flux density of 100 mT (milliteslas). K* is derived from the equation $K^* = K_H / Rd$ (where Rd is the internal resistance of the device).

## (2) Comparison of Hall device materials

The characteristics of Hall devices are determined by their material and shape, and vary according to two material constants: electron mobility $\mu$ and the energy band gap Eg. The larger the electron mobility $\mu$ is, the higher the sensitivity becomes. The larger the energy band gap is, the better the temperature characteristics of the Hall device are. Values for $\mu$ and Eg fur the main materials used are shown in Table 1 below.

Table 1: Comparison of materials used in Hall devices

| | Electron mobility (cm²/V sec) | Energy band gap (Eg) |
|---|---|---|
| Si | 1 900 | 1.12 |
| GaAs | 8 800 | 1.43 |
| InSb | 78 000 | 0.17 |
| InAs | 33 000 | 0.35 |

(Estimated values)

The characteristics of Hall devices made with each of the above materials is as follows.

Si: Although temperature characteristics are excellent, sensitivity is low and imbalance voltage $V_{HO}$ (voltage generated without application of a magnetic field) is large. Presently, silicon Hall devices are used mainly as Si Hall ICS with an amplifier or other devices integrated on a single, chip, rather than as simple Hall devices.

InSb This material features high sensitivity due to high electron mobility, but the small band gap causes considerable temperature drift.

InAs With less electron mobility than InSb, this material has lower sensitivity, but because the band gap is greater than that of InSb, temperature drift is smaller. This material is used in Hall probes for measuring magnetic fields due to its good linearity with respect to magnetic fields.

GaAs GaAs's large band gap produces the least temperature drift among all the materials shown in Table 1. While its electron mobility is smaller than that of InSb, lowering its sensitivity. GaAs's good control characteristics allow high sensitivity to be obtained through the same fine processing used in GaAs ICs.

## (3) Chip structure and the features of Sharp Hall devices

In Sharp Hall devices, the active layer is formed by direct ion injection into a semi-insulated GaAs substrate. This process has the same excellent control properties as the GaAs IC fabrication process, making fine processing easy. Sharp Hall devices therefore feature low dispersion of characteristics as well as high sensitivity

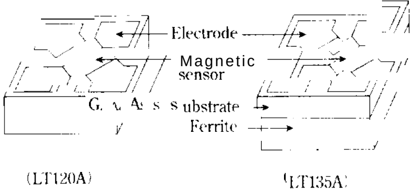


Fig. 2 Chip structure

## (4) Features of Sharp Hall devices

Temperature coefficient of the Hall voltage is small. (see Table 2-1)

Linearity of the Hall voltage is good. (see Table 2-2)

. Temperature coefficient of the input resistance is small. (see Table 2-3)

[dispersion of characteristics is low. (see Table 2-4).

<Features of the high-sensitivity LT135A>

The Sharp high-sensitivity LT135A Hall device incorporates ferrite for magnetic flux convergence and optimizes active layer carrier density to achieve a Hall device with especially high sensitivity and precision even for a GaAs device(for details see data pages 16 and 17).

. No-load Hall voltage TYP. 240 mV (6 V, 100 mT)

. Controls temperature drift of the imbalance voltage $V_{HO}$ over a wide range.
Max. temperature drift +/–5 mV
(−20°C to +25°C, +25°C to +125°C)
[It is not specified for commercially available GaAs Hall devices. ]

Linearity range (recommended operating temperature range) is increased for easier use.
Within the ranges of −20°C to +25°C and +25°C to +125°C (compared with the range for previous Sharp products of 0 to 80°C)
Temperature coefficient of Hall voltage TYP. –0.03%/°C.
Temperature coefficient of input resistance TYP. 0.2%/°C.
[The temperature range for commercially available GaAs Hall devices is unknown.]

## (5) Hall ICs

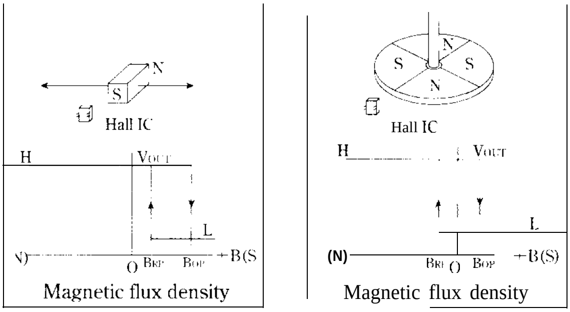
In addition to the GaAs Hall devices described above, Sharp manufactures two types of "Hall IC," which combine a GaAs Hall device and a silicon IC within a single device.

One of these devices can convert amplifier output to a digital signal via a Schmidt circuit and connects directly to a TTL or CMOS IC. It is therefore used in noncontact switches (LT230A/253A/251A/260A/261A/262A), The other device, the fan motor Hall IC (LT202A), is commonly used to drive the brushless DC fan motors of cooling systems for office automation equipment such as personal computers, and consumer electronics products,

There are two types of Hall ICs for noncontact switch, classified according to their method of utilizing the magnetic field :

(a) Those which utilize changes in the strength of a unidirectional magnetic field (south pole) to drive the IC (unidirectional field type)

(b) Those which create an alternating magnetic field by rotating a disc magnet with alternating contacts between north and south poles (alternating field type)



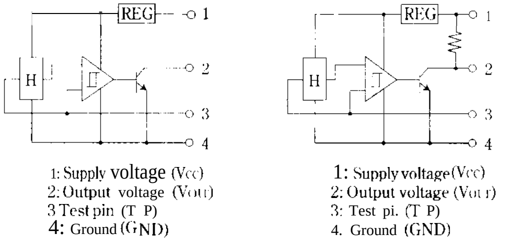
⟨[Unidirectional field type] (Alternating field type)

Fig. 3 Contactless switch Hall ICs
($B_{RP}$: release point, $B_{OP}$ : operating point)

Electrical output is as shown in Fig.3. Output is produced in response to variations in magnetic flux density. The unidirectional field type and the alternating field type are each available in an open corrector type and a direct-coupled (built-in pull-up resistance) type TTL.

Using its proprietary process and assembly technology, Sharp manufactures compact-size Hall ICS (2.9 x 1.56 x 1,1 mm), with high sensitivity (operating point: 30 mT max.) and wide temperature characteristics (−20°C to +125-C), In particular, to conform to Electrical Industry Association of Japan (EIAJ) standards for chip component dimensions, the chip has a compact design and can be mounted automatically.

< Open-corrector type> < Direct-coupled type TTL>



(Notice. LT262A does not have a built-in REG)

Fig. 4 Block diagram of Hall ICs for contactless switches

Table 2: Comparison of Sharp GaAs Hall devices and commercially available InSb Hall devices

| | | Sharp GaAs Hall device (model No. LT120A) | Commercially available InSb Hall devices |
|---|---|---|---|
| 1 | Temperature coefficient of Hall voltage | MAX. −0.04%/°C | MAX. −2%/°C |
| 2 | Hall voltage linearity | MAX.0.3% | MAX.5% |
| 3 | Temperature coefficient of input resistance | MAX, 0.2%/°C | MAX. −2%/°C |
| 4 | Input resistance | 650 to 950 Ω | 240~550 Ω |

## (6) Application fields for Hall devices

Because of their excellent temperature characteristics and Hall voltage linearity, these GaAs Hall devices can be applied not only in brushless DC motors using pulse output, but also in high-precision, low-rotation-speed brushless DC motors using linear (sine wave) output, and in ammeters and displacement gages.

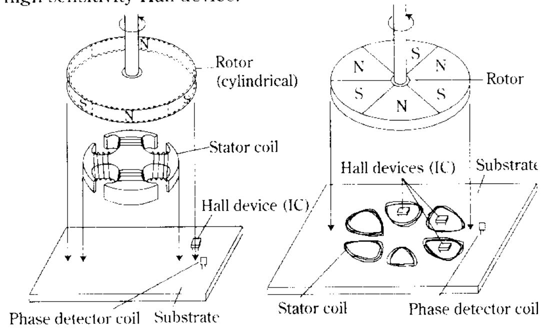
Table 3: The Hall device market

| Field of Application | Equipment | Application |
|---|---|---|
| A/V equipment | VCRs, Camcorders, DAT, Video Disc players, Cassette recorders | Brushless DC motors, FG detections, reel-rotation detections |
| OA equipment | FDD, CD-ROM drives, printers, laser scanners | Brushless DC motors, index detections, paper-feed quantify detections |
| Measuring equipment | Water supply meters, ammeters, wattmeters, fluxmeters, displacement gages | Rotation detections, electric current detectors, magnetic flux density detections |
| Consumer electronics | Inverter air-conditioners | Rotation detections |
| Other | Automobiles, sewing machines | Engine rotation detections, position detections, displacement detections |

1 Brushless DC motors

Brushless DC motors require no contact point because they use a Hall device tu detect the rotor position. “Ibis reduces noise and extends the operating life of the equipment. Also, by synchronizing with an external control signal, the rotation speed can be accurately controlled.

Brushless DC motors are available in two types: axial [Fig. 5 (b) ] and radial [Fig. 5(a) 1. The Hall device in the axial type can be placed inside the magnetic circuit, enabling the use of low-sensitivity Hall devices. In the radial type, however. the Hall device is placed outside the magnetic circuit, requiring a high-sensitivity Hall device.

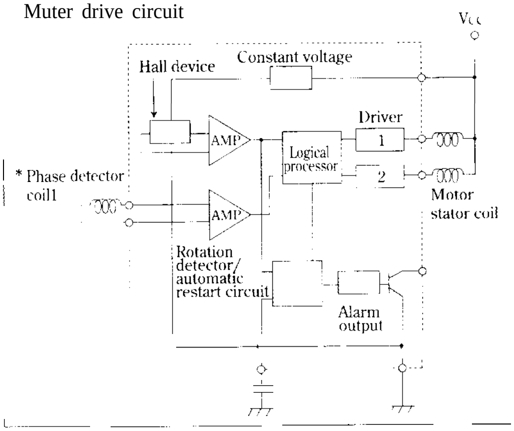


(a) Radial type
(Hall device (IC) is placed outside the stator coil)

(b) Axial type
(Hall device (1[) i. placed within the stator coil)

Fig. 5 Structure of brushless DC motors

Muter drive circuit



*1 Phase detector coil

This coil detects the phase of the magnetic pule and cuts any electric current which is not contributing to rotation This increases tbe efficiency of motor rotation.

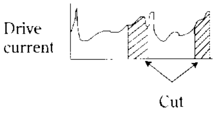
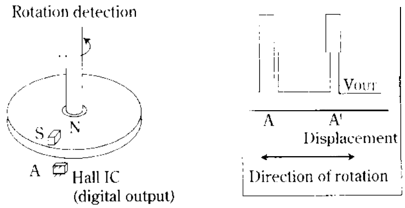


Fig 6 High-efficiency motor drive method (the area within the dotted line represents the Sharp LT202A)

2 Rotation detection

The Hall device detects rotation by detecting the changes in magnetic flux occurring during rotation of a multipolar magnet. Using the LT253A, magnets polarized to as little as 0.5 mm can be detected



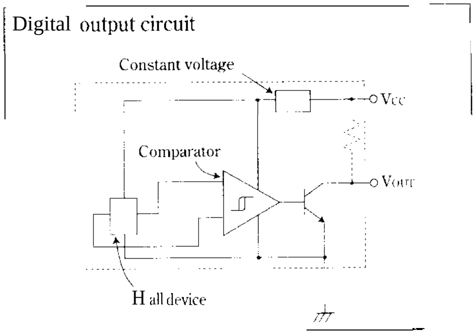
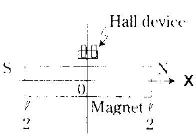


Fig. 7 Method of detecting rotation (the area within the dotted line represents the Sharp contactless switch Hall IC)

) Displacement detection

As Fig. 8 shows, when a Hall device is placed on a bar magnet, the shift in the magnet causes the output voltage shown in Fig. 9 to occur in the Hall device. The displacement can be detected by using magnet displacement and the linear area of Hall voltage.



Fig, 8
Displacement detection

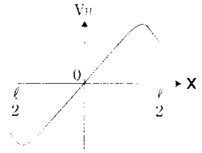
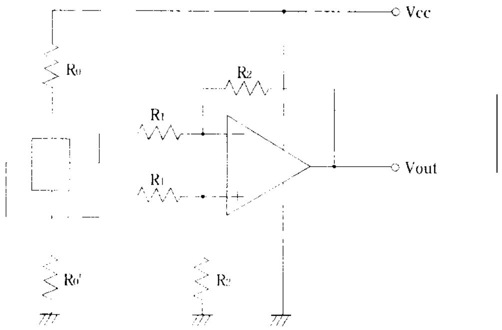


Fig. 9
Example of output of displacement detection

## (7) Application circuit for the Hall device

Hall devices (LT120A, LT135A, LT140A)    Amplifiers (IR3F01, IR3702)

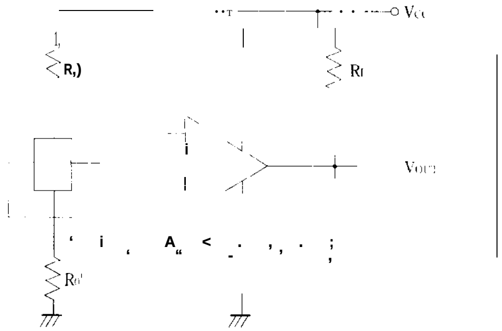


$V_{OUT} = \frac{R_2}{R_1} V_H (V_H = \text{Hall voltage})$

Resistors $R_0$ and $R_0'$ are used to adjust the impressed current or voltage of the Hall device. If the impressed current or voltage is below the rated voltage, they are not required,

Fig 10 Diagram of circuit with linear-amplified Hall device

Hall devices (LT120A, LT135A, LT140A)    Comparator (IR9393)



$R_I$:Pull-up resistor

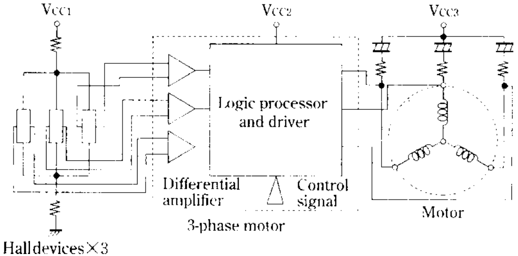
$$V_{TH} = \frac{R_0' + R_1}{R_0' + R_1 + R_2} \cdot V_{CC}$$

$V_{IH}$:Hysteresis width

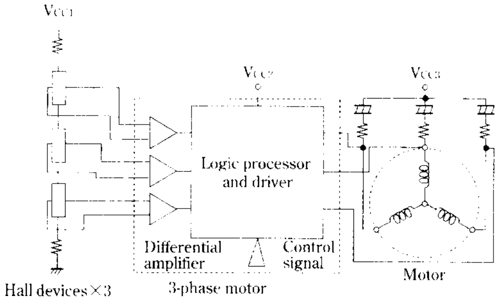
$R_I$: Resistance between terminals 3 and 4 of the Hall devices

Resistors $R_0$ and $R_0'$ are used to adjust the impressed current or impressed voltage of the Hall device. If the impressed current or voltage is below the rated voltage, they are not necessary.

Fig. 11 Diagram of circuit receiving switching output from the Hall device



( Parallel type)

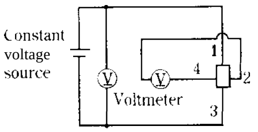


(Serial type)

Fig. 12 Examples of Hall motor circuit applications

## (8) Measurement circuits

### (a) Imbalance voltage $V_{HO}$. no-load Hall voltage $V_H$



Terminal connections

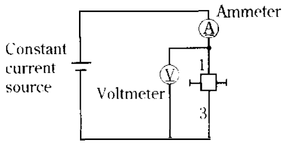
1: Input + 3: Input −
2: Output t 4 Output

$V_H = V_M - V_{HO}$

$V_M$ : Output voltage measurement value from specified magnetic field

$V_{HO}$ : Voltage measurement value when no magnetic field is present

### (b) Input resistance

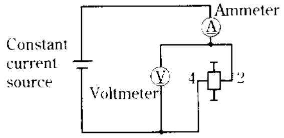


$R_{IN} = V_M / I_M$

$V_M$ : Voltage measurement value

$I_M$ Specified current

### (c) Output resistance



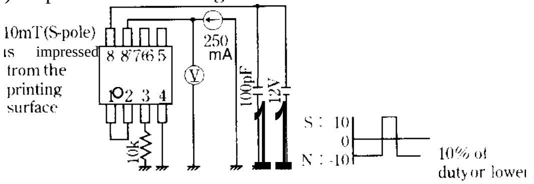
$R_{OUT} = V_M / I_M$

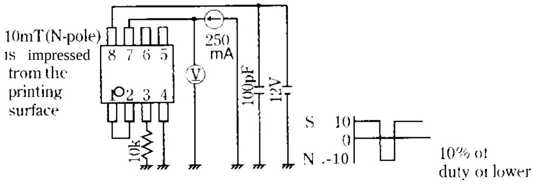
$V_M$ : Voltage measurement value

$I_M$ : Specified current

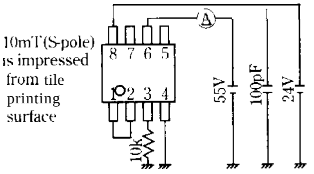
## Hall IC fur fan motor (LT202A)

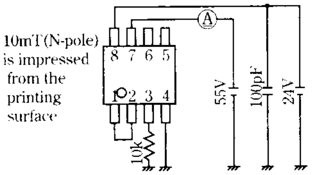
### (a) output saturation voltage



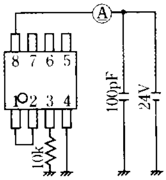


### (b) Output cutoff current

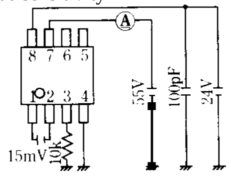


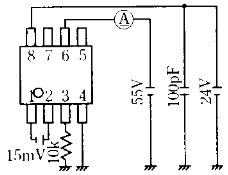


### (c) Power supply current



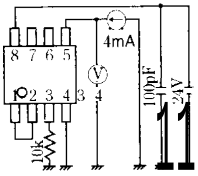
### (d) Coil input sensitivity



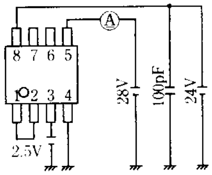


The Hall device measures coil input sensitivity by impressing the coil input current and verifying the output current condition

### (e) Alarm output saturation voltage



### (f) **Alarm** output leak current



③ Noncontact switch Hall ICS

< Unidirectional magnetic field-type: LT230A/253A/251A/280A >

(a) Operating magnetic flux densities $B_{OP}$ and $B_{RP}$ and hysteresis breadth $B_H$

◎ $B_{OP}$

Minimum magnetic flux density when measurement circuit (c) sweeps the magnetic flux density from 10 mT to 30 mT and $V_{OUT}$ becomes low level

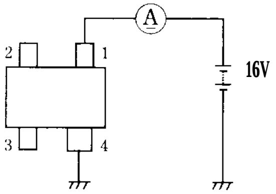
◎ $B_{RP}$

Maximum magnetic flux density when measurement circuit (c) sweeps the magnetic flux density from 30 mT to 10 mT and $V_{OUT}$ becomes high level.

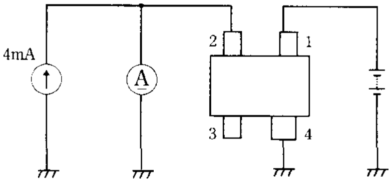
◎ $B_H$

$B_H = B_{OP} - B_{RP}$

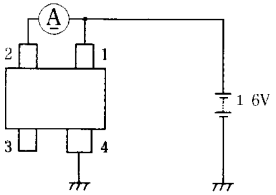
(b) Supply current Icc ($V_{CC}$=16V*1, B≧10mT)



(c) L-level output voltage $V_{OL}$ ($V_{CC}$=16V*1, B≦30mT)



(d) output leak current $I_{OH}$ ($V_{CC}$=16V*1, B≦10mT)



Vcc=3V for LT280A

Notice: For all of the above circuits, the direction of the magnetic field is indicated as follows;When B is plus (+) value, the south pole (S) is impressed on the marking printed surface When B is minus (–) value, the north pole (N) is impressed on the marking printed surface

< Alternating magnetic field-type: LT260A/261A/262A >

(a) Operating magnetic flux densities $B_{OP}$ and $B_{RP}$ and hysteresis breadth $B_H$

◎ $B_{OP}$

Minimum magnetic flux density when measurement circuit (c) sweeps magnetic flux density from — 10 mT to 10 mT and $V_{OUT}$ becomes low level.

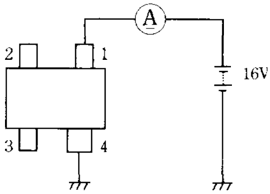
◎ $B_{RP}$

Maximum magnetic flux density when measurement circuit (c) sweeps magnetic flux density from 10 mT to – 10 mT and $V_{OUT}$ becomes high level,

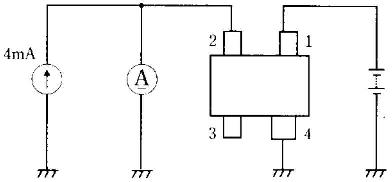
◎ $B_H$

$B_H = B_{OP} — B_{RP}$

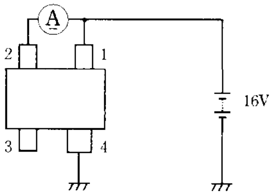
(b) Supply current Icc ($V_{CC}$=16V*2, B≦– 10mT)



(c) L-level output voltage $V_{OL}$ ($V_{CC}$=16V*2, B= 10mT)



(d) Output leak current $I_{OH}$ ($V_{CC}$= 16V*2, B> – 10mT)



*2 Vcc = 5V for LT262A

Notice For all of the above circuits, the direction of the magnetic field is indicated as follows;When B is plus (+) value, the south pole (s) is impressed on the marking printed surface. When B is minus (–) value, the north pole (N) is impressed on the marking printed surface.