8.1 What is Hall element?

The Hall element is a flux conversion element which can convert the magnetic flux density directly into the voltage (Hall voltage), functioning as a magnetic sensor. As shown in Fig. 1, application of a magnetic field in a direction to the current I_C flow direction in the Hall element causes the force to act on the electron in a direction to both the current I_C and magnetic field. As a result, the potential difference called the Hall voltage V_H to occurs on both ends of Hall element.

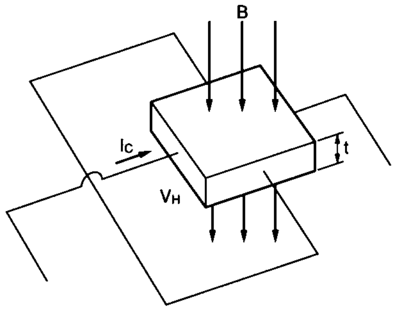


Fig. 1 Principle of Hall element

This phenomenon is called the Hall effect because it was first discovered by E.H. Hall in 1879.
Assuming that the sample thickness as "t" and the carrier density as "n", the Hall voltage V_H is determined as follows:

$$V_H = \frac{BI_C}{ent} = R_H \frac{BI_C}{t} \quad \cdots\cdots (1)$$

In this equation, "e" is a carrier charge and $R_H = 1/en$ is called the Hall coefficient. Assuming that the sample width as "ω", length "l", specific resistance as "ρ", and the carrier mobility as "μ", the input resistance R_{IN} is expressed as follows:

$$R_{IN} = \rho \frac{l}{\omega t} = \frac{1}{en\mu} \cdot \frac{l}{\omega t} \quad \cdots\cdots (2)$$

The equation (1) can also be rewritten as follows:

$$V_H = \mu BV_C \frac{\omega}{l} \quad \cdots\cdots (3)$$

V_C indicates the control voltage (current $I_C \times$ input resistance R_{IN}).
The Hall effect occurs in every substance. To obtain the high Hall voltage V_H, it is necessary to select the material with low carrier density and high mobility and to reduce the thickness "t".

Table 1 shows characteristics of typical semiconductor materials used in Hall element.

Table 1 Semiconductor materials used in Hall element

Material	Electron mobility $\left[\frac{cm^2}{V \cdot s}\right]$	Band gap (eV)
Ge	3000	0.70
Si	1900	1.10
GaAs	8000	1.43
InAs	20000	0.36
InSb	70000	0.18

Temperature characteristic of the Hall element depends on the temperature characteristic of carrier mobility and density. GaAs is favorable because of large band gap (1.43eV) and less change in the carrier density depending on the temperature.

8.2 Characteristics of Hall element

During constant-current driving, V_H of the Hall element is determined as follows:

$$V_H = K_H \cdot I_C \cdot B \quad \left(K_I = \frac{1}{net}\right) \quad \cdots\cdots (4)$$

In this equation, K_H is called a cumulative sensitivity which is determined from characteristics of semiconductor materials used. Normally, this is expressed by $mV/mA \cdot T$ and refers to the sensitivity for the input current of 1mA and the magnetic field of 0.1T. During constant-voltage driving, this is determined as follows:

$$V_H = K_I \cdot V_C \cdot B \quad \left(K_I = \frac{G_H \omega}{l}\right) \quad \cdots\cdots (5)$$

(G_H to be geometrical factor)

V_H depends greatly on the element design and material, but is correlated with the control current or control voltage and magnetic flux density.
The temperature characteristic of Hall voltage is related to change in the carrier density depending on the temperature in the case of constant-current drive as is known from the equation (4). As is known from the equation (5), the temperature dependence of carrier mobility is related to this in the case of constant-voltage drive.
Around the room temperature, the temperature dependence of carrier is greater than the mobility in GaAs. The use of GaAs for constant-current drive causes improvement of the temperature characteristics. For your reference, the V_H temperature characteristic for OH009 is shown in Fig. 2.

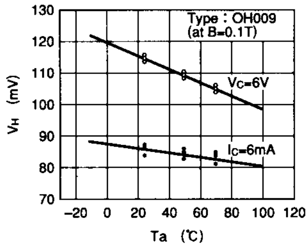


Fig. 2 V_H—Ta characteristic (OH009)

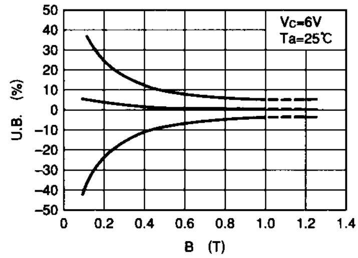


Fig. 3 U.B.—B

8.3 Cautions for the use of Hall element

8.3.1 Unequilibrium voltage V_{HO}

The Hall element should have zero output voltage when there is no magnetic field. Practically, however, the current distribution in crystal is not necessary even or the output pins are not always symmetrical. Resulting in more or less potential difference at output pin.

This is called the unequilibrium voltage V_{HO} and should be considered as an offset of a circuit when the analog signal is to be handled.

Panasonic offers two ranks. The one is based on unequilibrium voltage V_{HO} under certain conditions and the other rank (or the unequilibrium U.B.) based on the ratio of the unequilibrium voltage to the Hall voltage.

V_{HO} and UB are expressed as follows;

$$UB=\frac{|V_H^+|-|V_H^-|}{|V_H^+|+|V_H^-|}$$

wherein

$$|V_H^+|=aBV+V_{HO}$$
$$|V_H^-|=aBV-V_{HO}$$

a : Proportion constant

B : Magnetic flux density

V : Applied voltage

V_{HO} : Unequilibrium voltage

Therefore;

$$U.B.=\frac{V_{HO}}{aBV}=\frac{V_{HO}}{V_H}\quad (V_H=aBV)$$

V_{HO} is also expressed as follows:

$$V_{HO}=bV \quad \text{(b: proportion constant)}$$

Accordingly,

$$U.B.=\frac{b}{aB}\propto a\frac{1}{B} \quad \text{(in reverse proportion to B)}$$

8.3.2 Various characteristics

i) Magnetic flux density (B) and unequilibrium ratio (U.B.)

ii) Applied voltage (V) and Unequilibrium ratio (UB) and unequilibirum voltage (V_{HO})

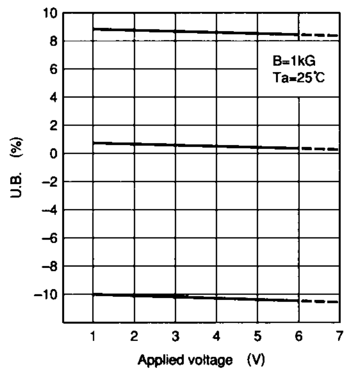


Fig. 4 U.B.—V

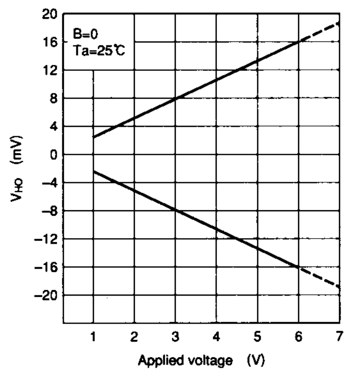


Fig. 5 V_{HO}—V

iii) Temperature dependence

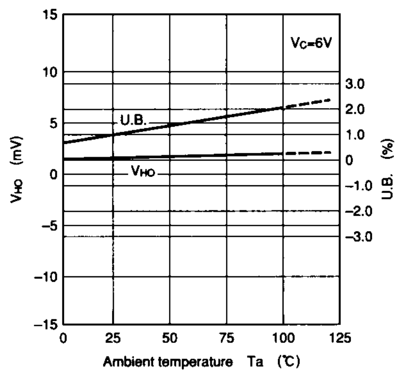


Fig. 6 U.B., B_{HO}—Ta

8.3.3 Typical drive circuit

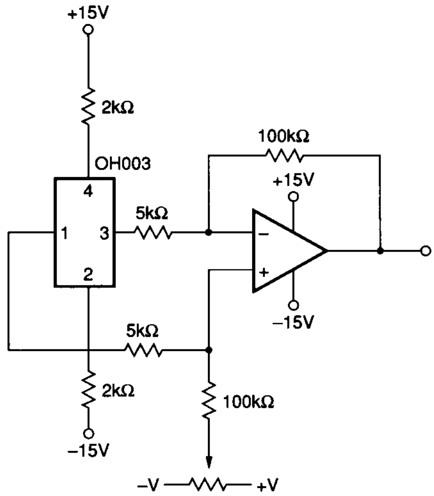
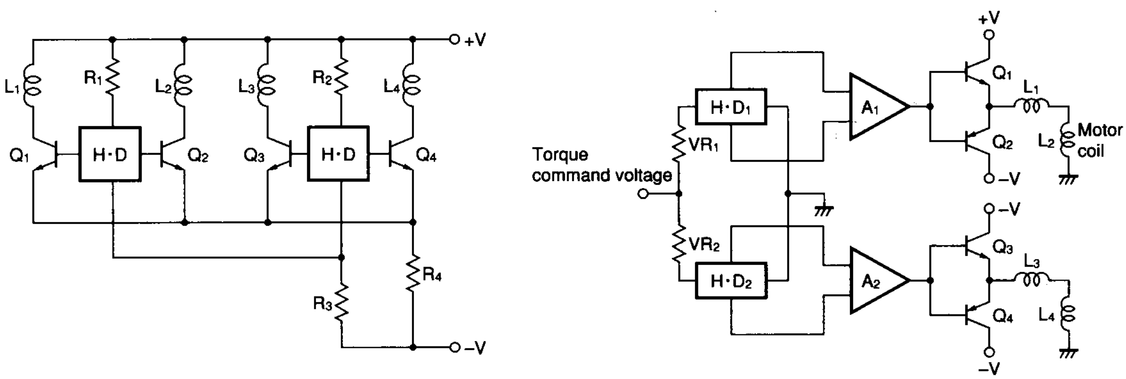


Fig. 7 Typical drive circuits



(a) Differential drive method

(b) Sine wave drive method

Fig. 8 Hall motor drive methods

8.4 InSb Hall element

InSb Hall element is similar to the GaAs Hall element and consists of two input electrodes and two output electrodes. When compared with the GaAs Hall element, this element has similarities and differences as described below:

Similarities Since the Hall effect is used as an operation principle, the output characteristics for the applied magnetic field and applied voltage is the same as for the GaAs Hall element.

Differences Due to difference in physical properties of band gap, the InSb Hall element has poor temperature dependence than the GaAs Hall element. On the other hand, the InSb element has higher sensitivity than the GaAs element.

In terms of application, the InSb element is more suitable for the small motor with small magnetic field while the GaAs element is more suitable for the purpose requiring operation at high temperature.

Due attention must be paid on the applied voltage during use. InSb develops avalanche withstand at lower voltage than GaAs element. In this sense, only 2V maximum can be applied to the InSb element as compared to 6V maximum in the case of GaAs element.

Since both elements show no difference in terms of impedance, both elements can be used equally in the same drive circuit.