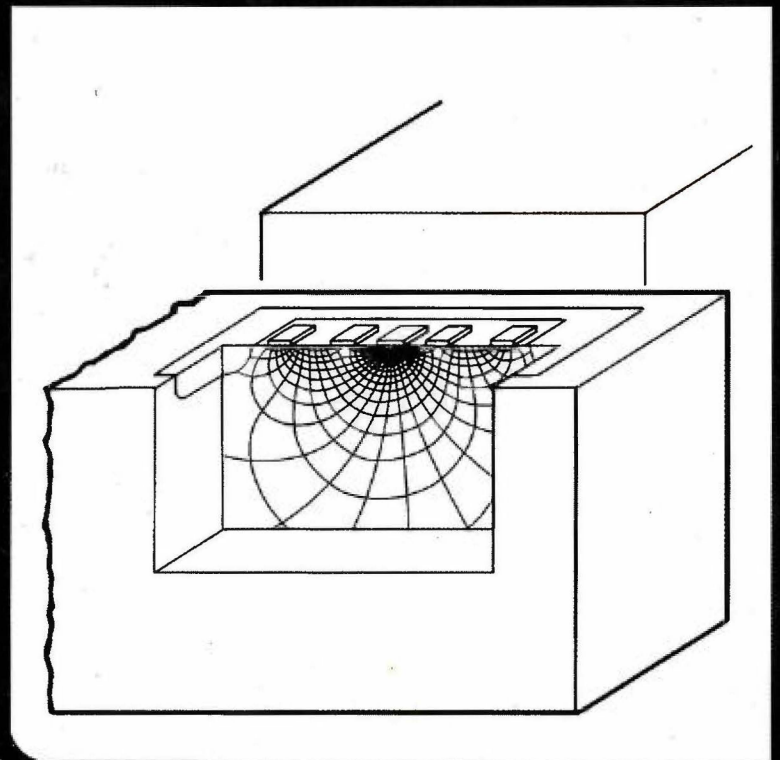




HALL EFFECT DEVICES

MAGNETIC SENSORS AND
CHARACTERIZATION OF
SEMICONDUCTORS

RS POPOVIĆ



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Magnetic Sensors and Characterization of Semiconductors

R S Popović

Landis & Gyr Corporation
Corporate Research and Development

I D E Williams



Adam Hilger
Bristol, Philadelphia and New York

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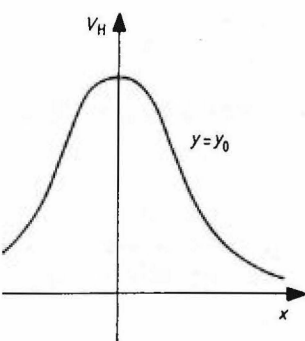
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(b)



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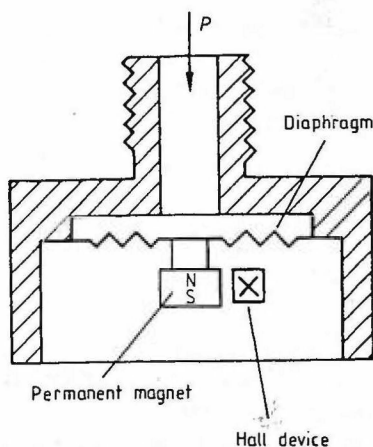


Figure 5.18 The displacement transducer based on a Hall device (see figure 5.17) applied in a pressure-measuring can. The permanent magnet is fixed on a diaphragm. The diaphragm deflexes under the pressure p and thus displaces the magnet relative to the Hall device.

finally converted into a Hall voltage. In such an application, the stability of the whole system is of paramount importance. A method has been devised for self-calibration which may help surmount the instability problem [50].

5.3.2 Measuring Electric Current, Power and Energy

A magnetic field and magnetic induction are inevitably associated with an electric current. Thus the measuring of the magnetic induction is equivalent to the measuring of the current itself. Moreover, the magnetic induction B can be made exactly proportional to the current i . Hence the measuring of the current in a conductor can be done without interrupting the conductor and without any galvanic contact between the current conductor and the sensor. Figure 5.19 schematically shows the basic arrangement for such a measurement: a current conductor, enclosed by a magnetic yoke, and a Hall magnetic sensor placed in the narrow air gap of the yoke. The yoke is made of a soft ferromagnetic material with a very high permeability. The Ampère law here attains the form

$$i = \oint_C \mathbf{H} \cdot d\mathbf{l} = H_0 l_0 + H_y l_y. \quad (5.40)$$

Here i denotes the current in the conductor, $\mathbf{H}$ the magnetic field, and the integration is done over the circular contour C ; H_0 and l_0 are the magnetic fields in the air gap and the gap width, respectively, and H_y and l_y are the

magnetic field and the contour length in the yoke, respectively. By substituting here $H = B/\mu_0\mu_r$, μ_0 being the permeability of free space and μ_r the relative permeability of a material, we have

$$B \simeq \frac{\mu_0}{l_0} i. \quad (5.41)$$

Here we assumed that $l_0 \gg l_y/\mu_r$. Substituting this equation into (5.7) yields

$$V_H = S_1 \frac{\mu_0}{l_0} I i. \quad (5.42)$$

Thus if the bias current of the Hall device I is held constant, the Hall voltage is proportional to the measured current i .

A Hall device is a natural four-quadrant multiplier. An elegant method for measuring electric power is based on this property: if the bias current of the Hall device in figure 5.19 is made proportional to the line voltage v , that is $I \sim v$, then according to (5.42) $V_H \sim vi$. Suppose the line voltage is given by $v = V_m \cos \omega t$ and the current in the thick conductor by $i = I_m \cos(\omega t + \varphi)$. The Hall voltage is then given by

$$V_H = C_m V_m I_m \cos \varphi + C_m V_m I_m \cos(2\omega t + \varphi) \quad (5.43)$$

where C_m is the meter transduction constant. The first term on the right-hand side of this equation is a DC voltage proportional to active power, and the second term is an AC voltage which can be filtered out.

Figure 5.20 shows a simple single-phase electricity meter (watt-hour meter) based on this principle. The bias current of the Hall device is directly derived from the line voltage using a high-value resistor R . Thus $I = v/(R + R_{in})$, R_{in}

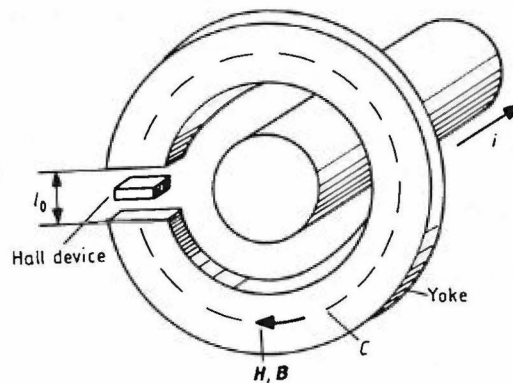


Figure 5.19 A basic arrangement for the electrical measurements using a Hall device. The Hall device lies in the air gap of the magnetic yoke, which encloses a current-carrying conductor. Then $V_H \sim B \sim i$.

ke, respectively. By substituting the permeability of free space and μ_r the

$$(5.41)$$

his equation into (5.7) yields

$$(5.42)$$

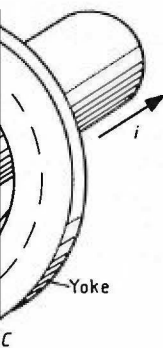
field constant, the Hall voltage

multiplier. An elegant method for measuring the Hall voltage is: if the bias current of the Hall device is proportional to the line voltage v , that is $i = I_m \cos(\omega t + \varphi)$.

$$\cos(2\omega t + \varphi) \quad (5.43)$$

The first term on the right-hand side is proportional to active power, and the second term is filtered out.

Electricity meter (watt-hour meter) based on a Hall device is directly derived from (5.43). Thus $I = v/(R + R_{in})$, R_{in}



ical measurements using a gap of the magnetic yoke, Then $V_H \sim B \sim i$.

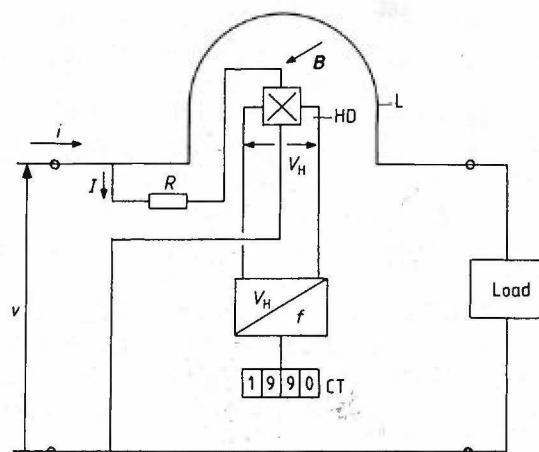


Figure 5.20 Schematic diagram of a single-phase electricity meter (watt-hour meter) based on a Hall device. L denotes a current-carrying conductor which produces a magnetic induction B around it. A Hall device HD yields the output voltage V_H which is proportional to the product IB , and thus also $V_H \sim iv$. A voltage-frequency converter (V_H/f) converts the Hall voltage V_H into a frequency f ; and a counter CT counts the energy pulses and displays the energy being consumed.

being the input resistance of the Hall device. Substituting this into (5.42), we obtain the watt-meter transduction constant in the form

$$C_m \simeq \frac{S_1 \mu_0}{R l_0} \quad (5.44)$$

where we have assumed $R \gg R_{in}$.

The block V_H/f in figure 5.20 denotes a voltage-frequency converter, and CT a counter. In fact, the counter integrates the output signal of the Hall device (5.43). It also works as a low-pass filter. Thus the state of the counter indicates the electric energy used up by the load.

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