Ver 1-6

Close Position Sensing

ASAHI KASEI EMD Corporation

Close Position Sensing CPS

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Close Position Sensing
CPS

Basic Principles about Hall element

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What is Hall element?

- What is Hall element?
  - A magneto-electric transducer which utilizes the Hall effect.
- What is Hall element made of?
  - AKE's Hall element is made of thin semiconductor film.

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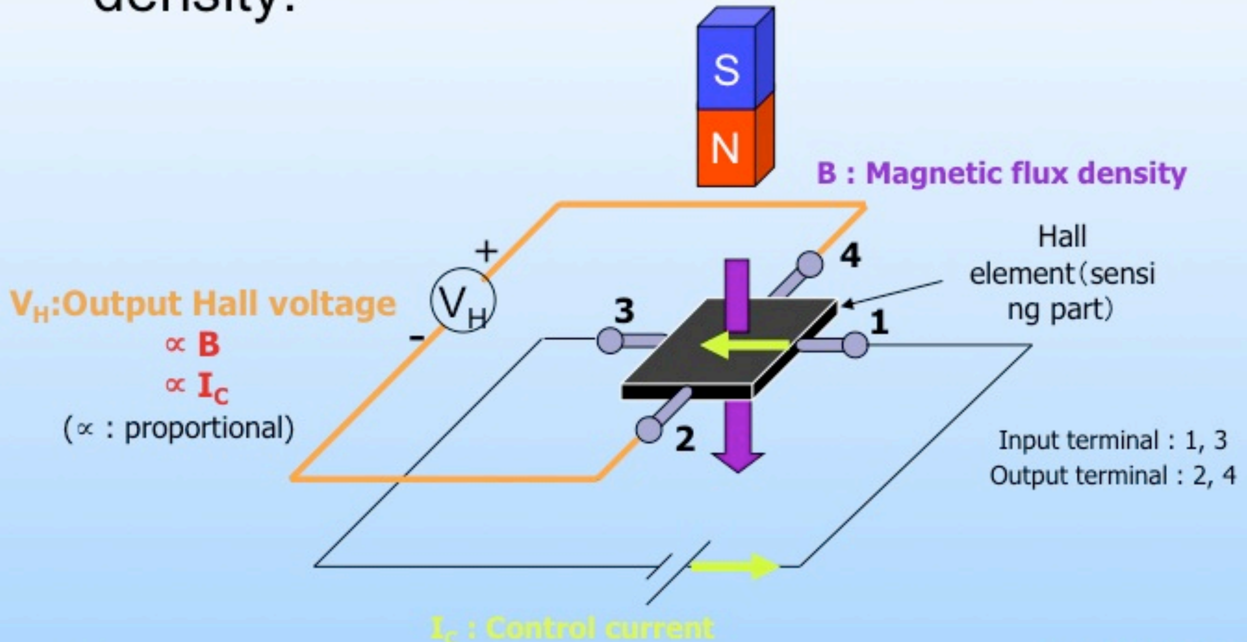
Basic Principles about Hall element

Principle of Hall effect

Output of the Hall element is proportional to the control current and the magnetic flux density.



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Specific characteristics of Hall element

- Output Voltage is proportional to Input current/ voltage.

$$V_H \propto I_C$$

$$V_H \propto V_C$$

- Output voltage is proportional to the magnetic flux density perpendicular to the film.

$$V_H \propto B$$

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Configurations for CPS

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Configurations for CPS

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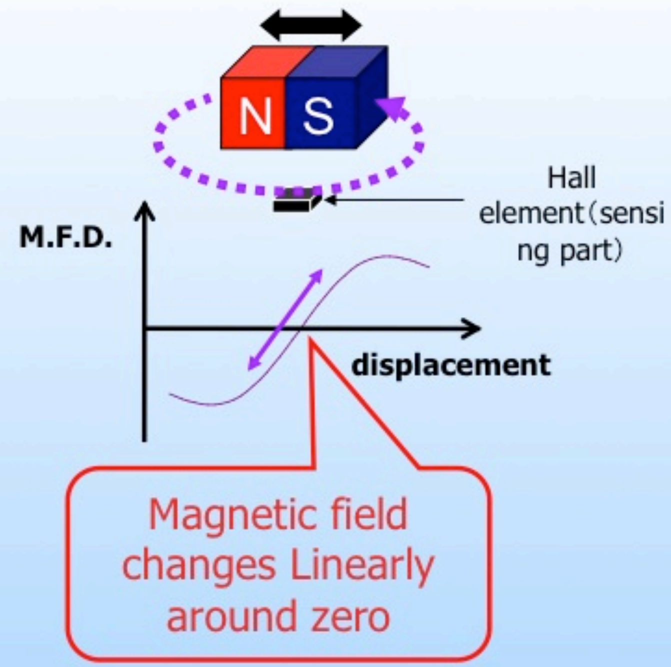
< Type 1 > configuration

- Use one magnet and one Hall element.
- Detect the boundary of N-pole and S-pole.



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< Type 1 > features

- Simple configuration consist of one magnet and one Hall element.
- Magnet is relatively small.
- Best applied for shorter displacement (~1mm).

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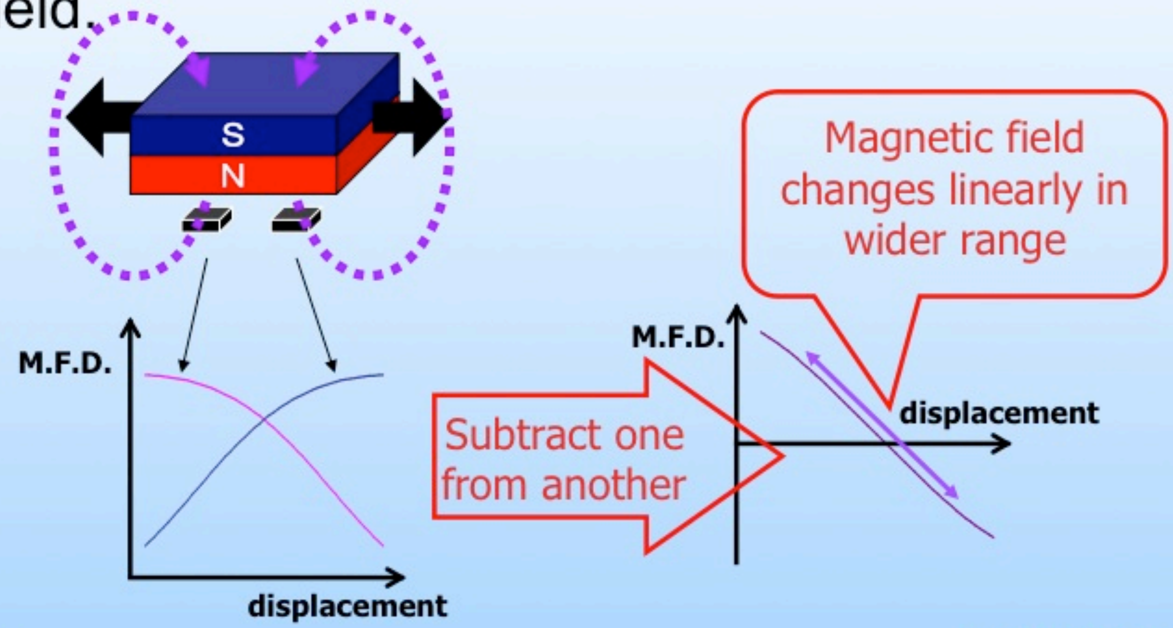
< Type 2 > configuration

- Use the symmetrical distribution of magnetic field.



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Configurations for CPS

Close Position Sensing CPS

< Type 2 > features

- Use one magnet and two Hall elements.
- Best applied for long displacement (~5.5mm).
- Applied for two dimensional detection by using four Hall elements and one magnet. (See the drawing on the right.)
- Temperature dependence of Hall sensors and magnet can be canceled by operating two outputs.

  (B1-B2)/(B1+B2)

Two dimensional detection

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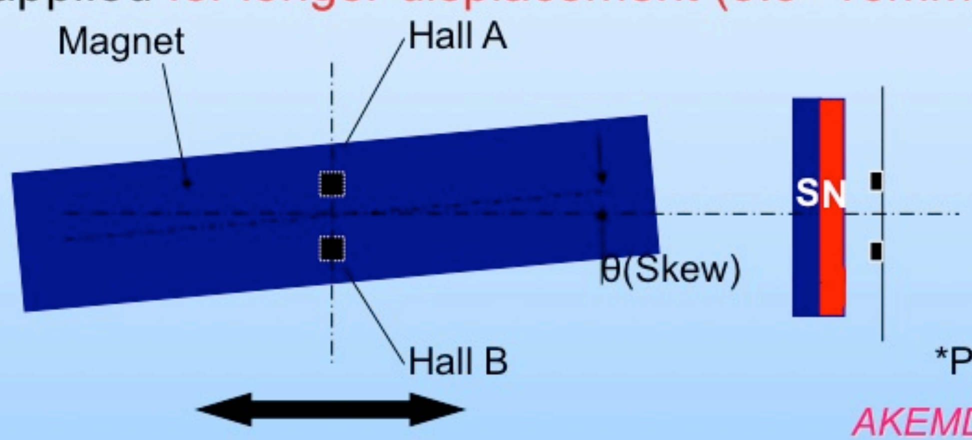
< Type 3 > Skewed magnet

- An extended configuration of Type 2.
- Magnet is skewed along traveling axis.
- Use two Hall elements and subtract outputs from one another. (B_A-B_B)
- Best applied for longer displacement (5.5~10mm).



*Pat. Pending

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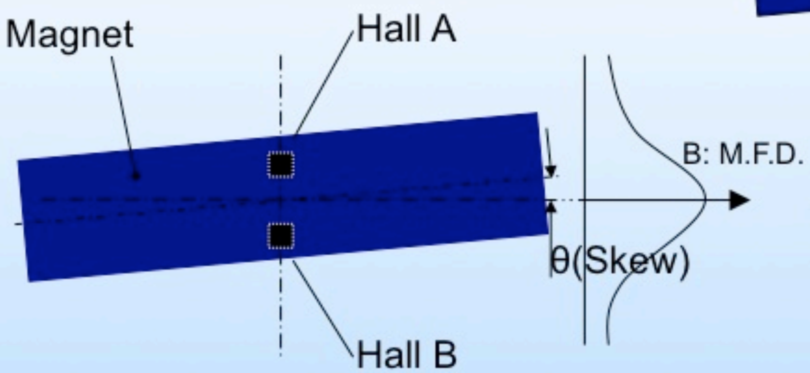
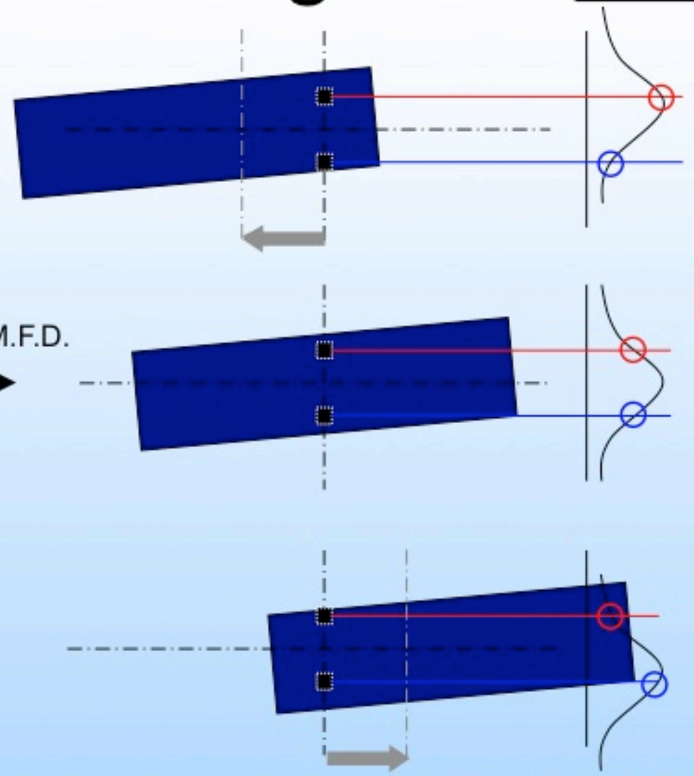
< Type 3 > Skewed magnet





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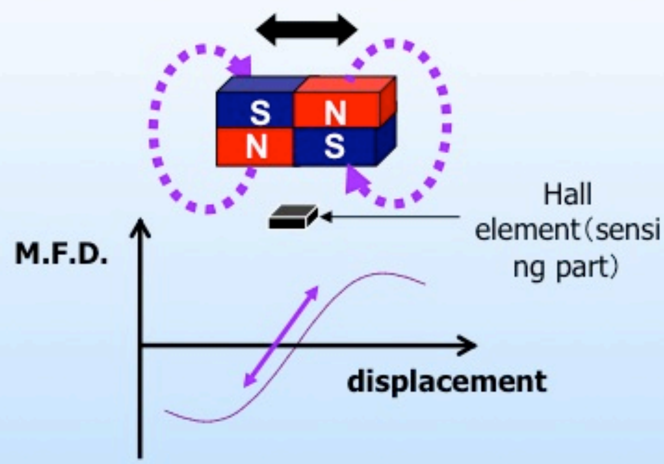
< Type4 > multipolar magnet

- An extended configuration of Type 1.
- Magnet is magnetized in two directions.
- If the magnet is too small, it can't be magnetized well.
- M.F.D. is comparatively larger than Type 1.



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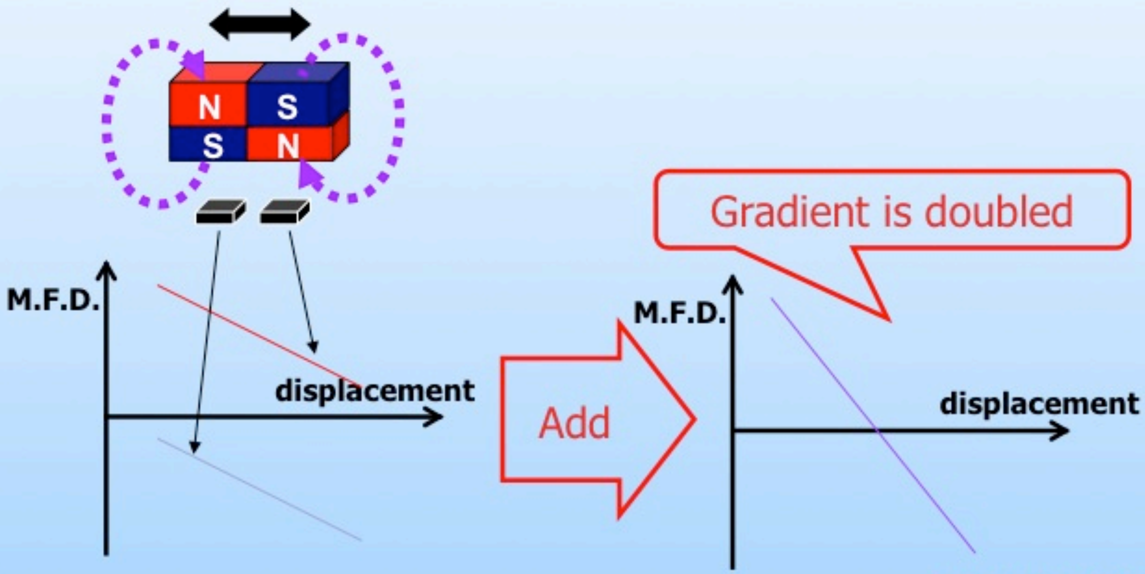
Configurations for CPS

< Type 5 > multipolar magnet 2

- Optimized for the use in which larger signal is needed.



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Application Examples

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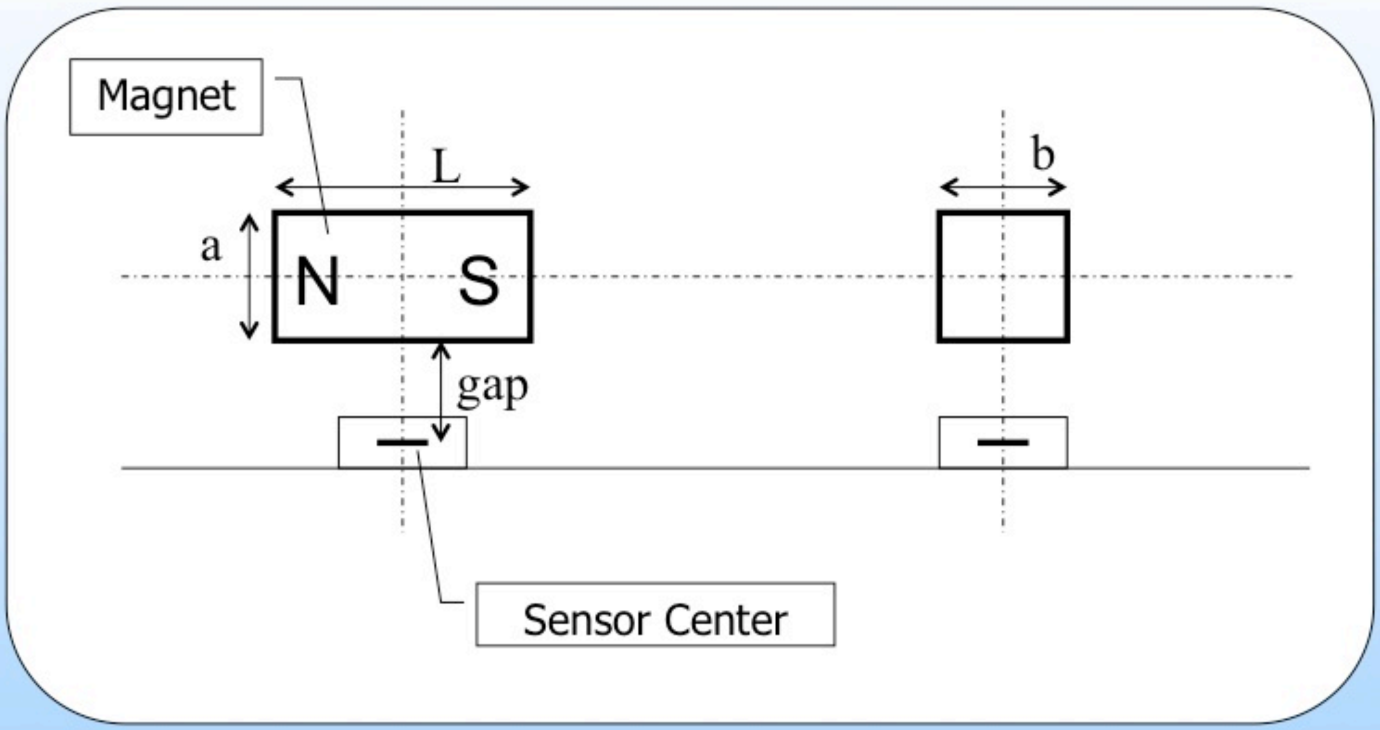
Application Examples

Close Position Sensing CPS

< Type 1 > Dimension



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< Type 1 > Dimension

- Magnet size: a*b*L (magnetized along L)
- Residual magnetic flux density is defined as “Br”.
- Distance from the surface of the magnet to the sensor center is defined as “gap”.
- The magnet moves in L direction.

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Application Examples

< Type 1 > Parameters

item	value	unit
a	1	mm
b	1	mm
L	2	mm
Br	1300	mT
gap	0.75	mm

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< Type 1 > M.F.D. Distribution

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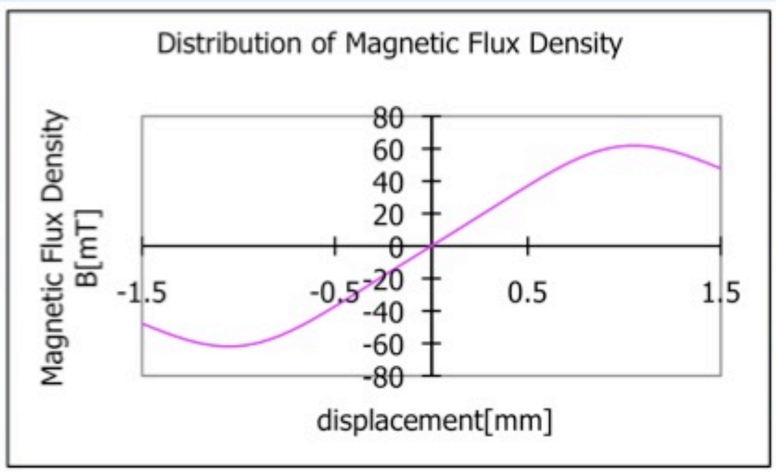
- The distribution of M.F.D. at the sensor center when the magnet displacement is 3mm (±1.5mm) is calculated and shown below.
- Around zero flux, M.F.D. changes linearly with displacement.



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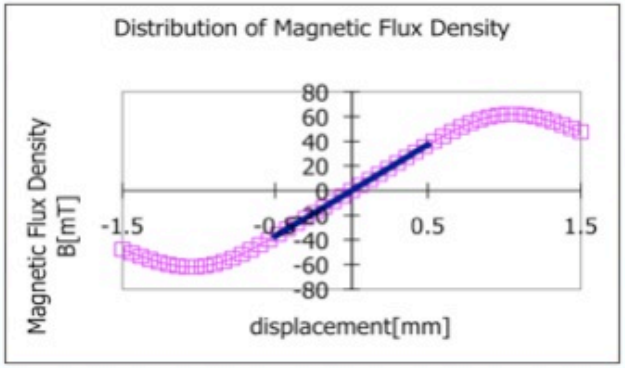
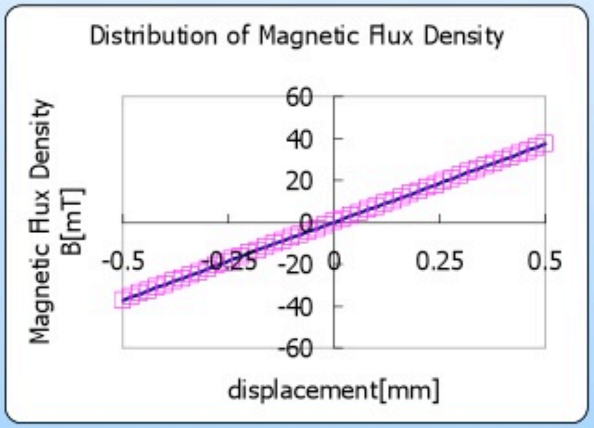
Application Examples

Close Position Sensing CPS

< Type 1 > Linearity





- The approximate linear line is added on the graph. Lower one is zoomed.
- The approximate linear line is defined as the straight line which connect two ends (end-end line). ±0.5mm for example.
- The linearity is defined as the difference between M.F.D. curve and the end-end line. The error is expressed as δB in M.F.D., δd in displacement, δ in ratio to whole travel.

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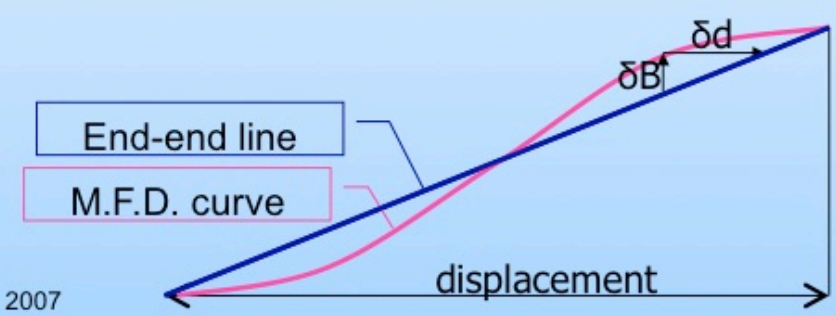
Application Examples

Close Position Sensing CPS

< Type 1 > Linearity

- Error is defined as the difference between M.F.D. curve and end-end line.
  - δB = B(M.F.D. curve) – B(end-end line)
- Error is also expressed as the displacement transformed formula δd.
- Ratio between error and full M.F.D. change or displacement is defined as δ.
- Error here is calculated only from M.F.D. distribution. It have nothing to do with characteristics of Hall element.



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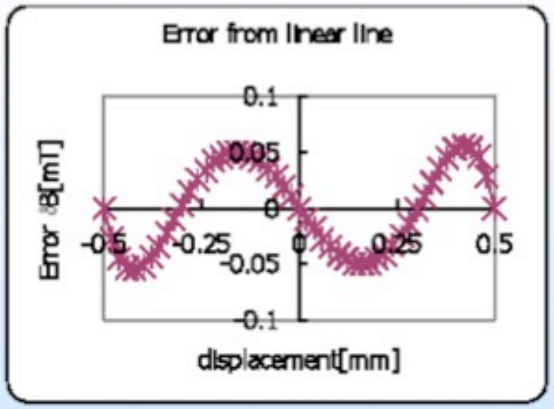
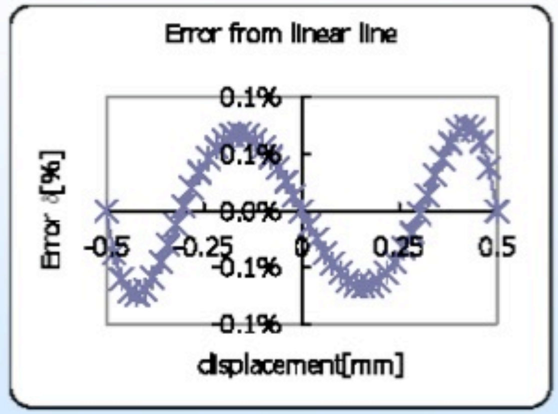
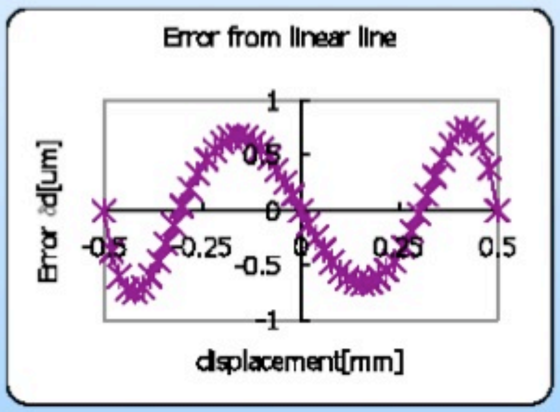
Application Examples

< Type 1 > Linearity







- The error is calculated from M.F.D. curve and shown in various unit.
- In this case, the error is calculated as ±1um.

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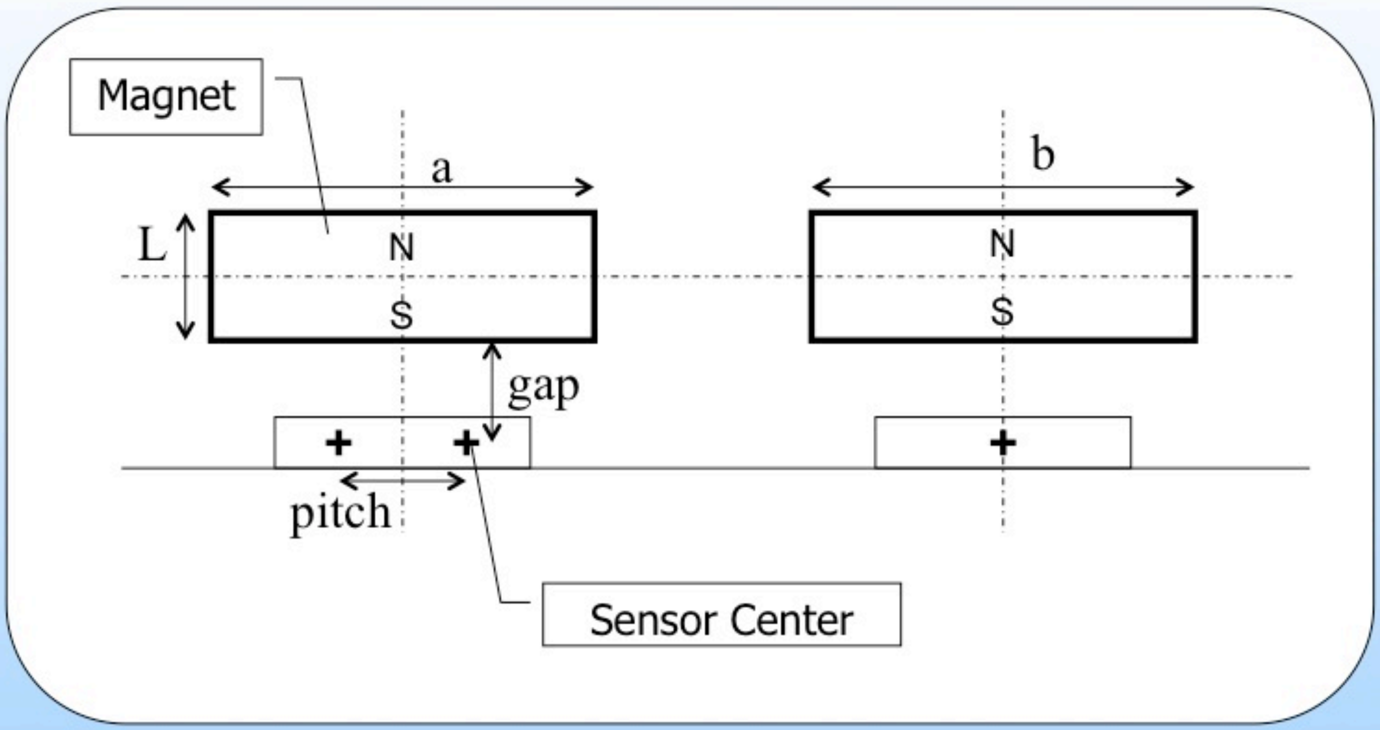
< Type 2 > Dimension



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Application Examples

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< Type 2 > Dimension

- Magnet size: a*b*L (magnetized along L)
- Residual magnetic flux density is defined as “Br”.
- Distance from the surface of the magnet to the sensor center is defined as “gap”.
- Distance between two sensor centers is defined as “pitch”.
- The magnet moves in “a” direction.

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Application Examples

< Type 2 > Parameters

item	value	unit
a	4.9	mm
b	3.3	mm
L	3.2	mm
Br	1300	mT
gap	2.5	mm
pitch	3.1*	mm

*@using HQ-8220

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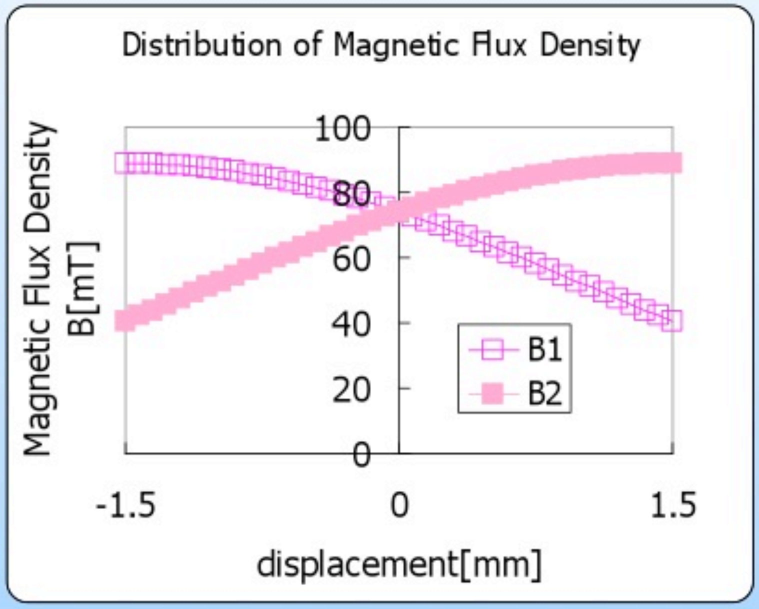
Close Position Sensing CPS

< Type 2 > M.F.D. Distribution

- The distribution of M.F.D. at sensor centers HE1 and HE2 when the magnet displacement is 3mm (±1.5mm) is calculated and shown below.



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Application Examples

< Type 2 > M.F.D. Distribution

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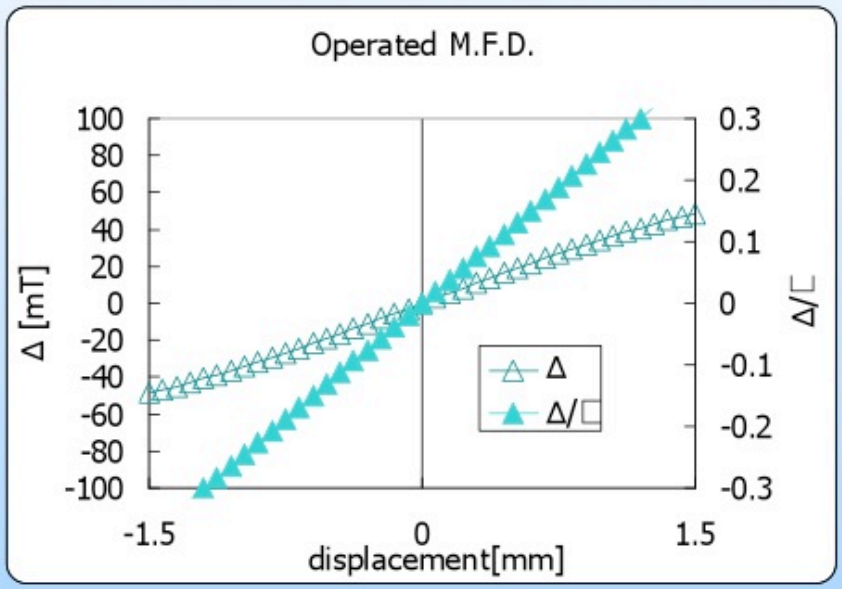
- Operated M.F.D. changes linearly with displacement.
  - ☐ Δ = B2-B1
  - ☐ Δ/Σ = (B2-B1)/(B2+B1)



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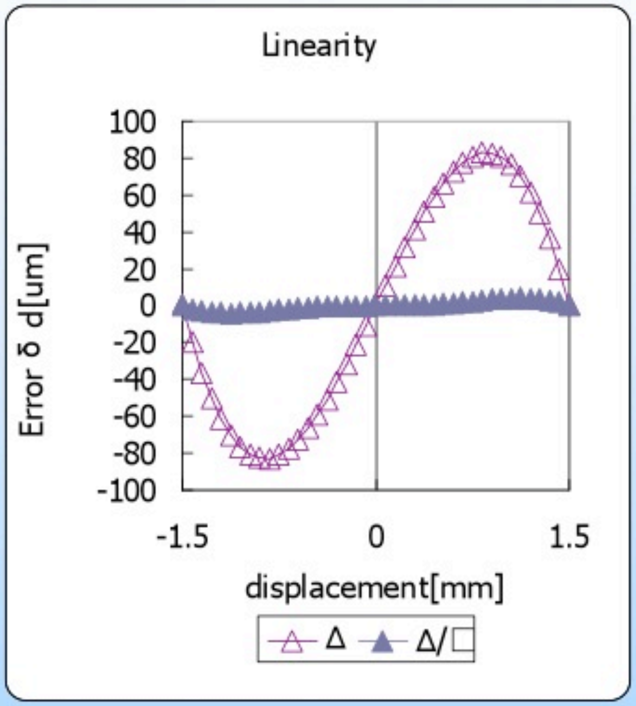
Application Examples

< Type 2 > Linearity

- The linearity is defined as the difference between M.F.D. curve and the end-end line.
- The error is transformed to displacement
  - □ Δ: ±80um
  - □ Δ/Σ: ±2um
- In this case, error of Δ/Σ is smaller than that of Δ. In other cases, error of Δ may be smaller than that of Δ/Σ.



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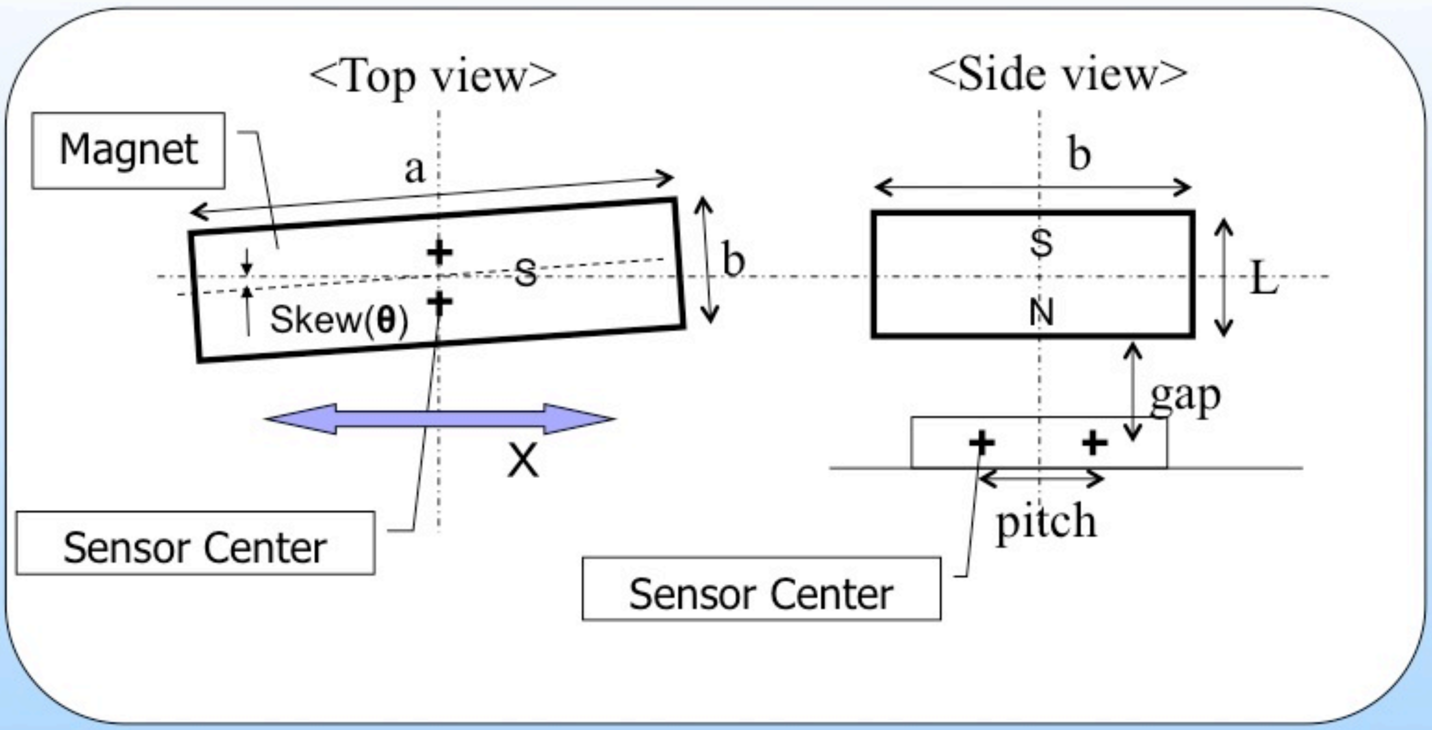
Application Examples

< Type 3 > Dimension



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< Type 3 > Dimension

- Magnet size: a*b*L (magnetized along L)
- Residual magnetic flux density is defined as “Br”.
- Distance from the surface of the magnet to the sensor center is defined as “gap”.
- Distance between two sensor centers is defined as “pitch”.
- Angle between “a” direction and “x”direction is defined Skew angle(θ).
- The magnet moves in “x” direction.

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Close Position Sensing

< Type 3 > Parameters

item	value	unit
a	13.2	mm
b	1.6	mm
L	2.0	mm
Br	1300	mT
gap	0.8	mm
Skew(θ)	4	°
pitch	0.8*	mm

*@using HQ-0221

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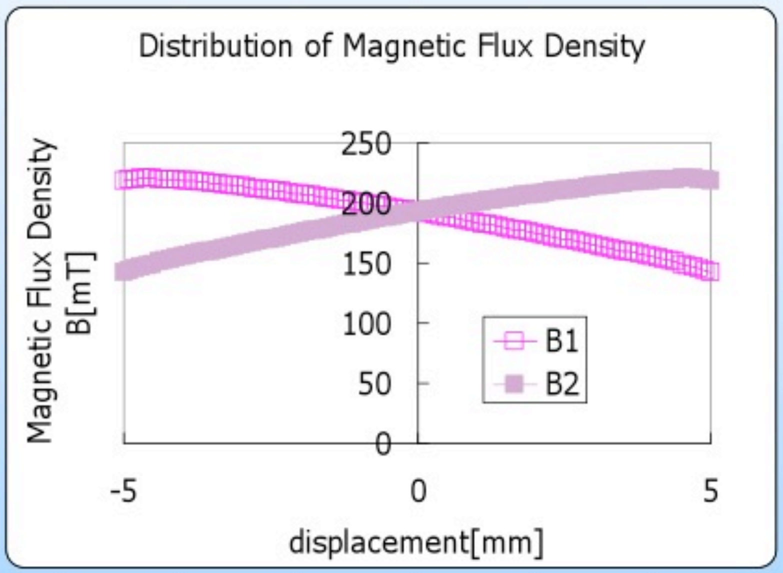
Application Examples

< Type 3 > M.F.D. Distribution

- The distribution of M.F.D. at sensor centers HE1 and HE2 when the magnet displacement is 10mm (±5mm) is calculated and shown below.



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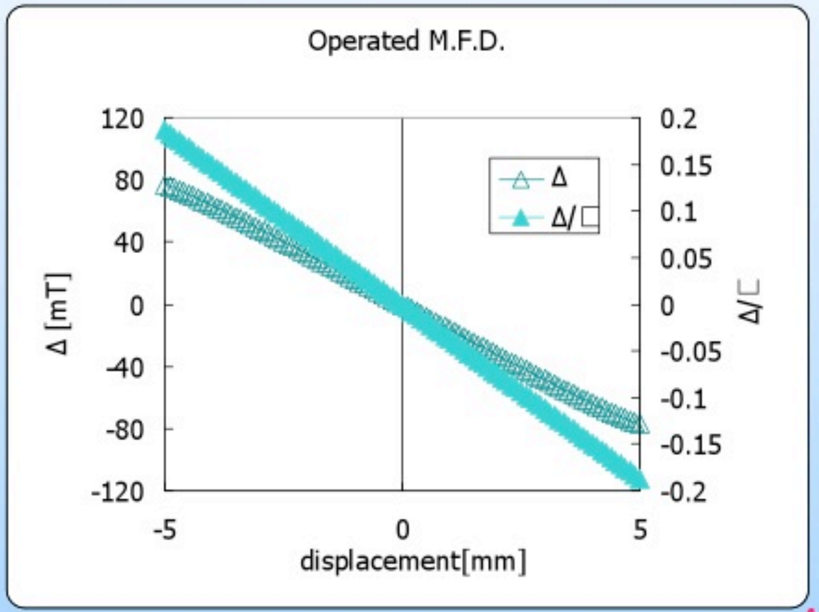
< Type 3 > M.F.D. Distribution

- Operated M.F.D. changes linearly with displacement.
  - Δ = B2-B1
  - Δ/Σ = (B2-B1)/(B2+B1)



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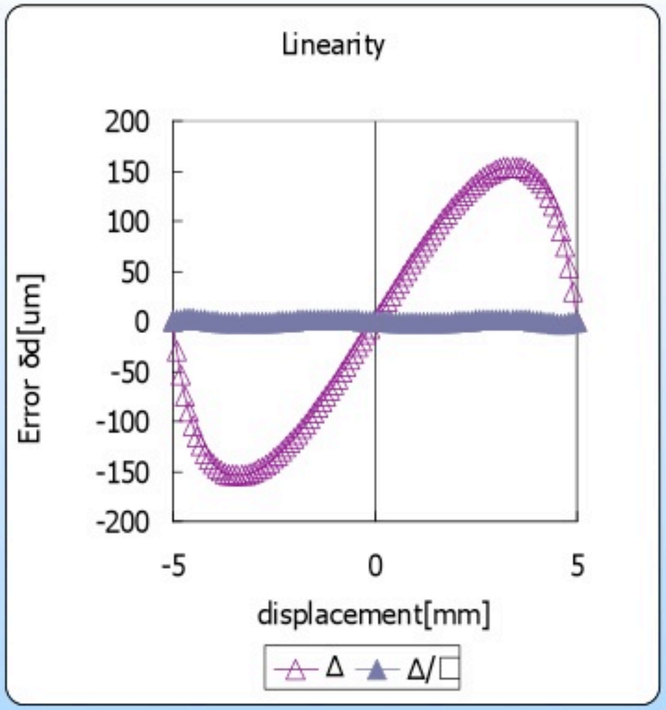
Application Examples

< Type 3 > Linearity

- The linearity is defined as the difference between M.F.D. curve and the end-end line.
- The error is transformed to displacement
  - ☐ Δ: ±150um
  - ☐ Δ/Σ: ±4um
- In this case, error of Δ/Σ is smaller than that of Δ. In other cases, error of Δ may be smaller than that of Δ/Σ.



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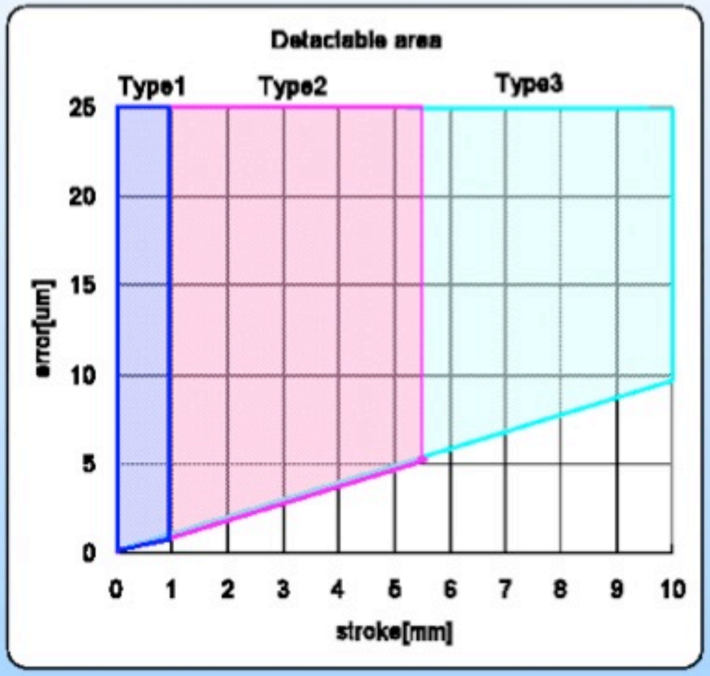
Application Examples

Detectable area

- Detectable area is calculated as follows:

  About 0.1% resolution / Full stroke



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Note

- All the discussion in this chapter is based on the magnetic field only and have nothing to do with characteristics of Hall element.
- M.F.D. is calculated by integral method. Calculated value and measured value might have slight misfit. At real use, actual measurement is recommended.

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Adopted Examples

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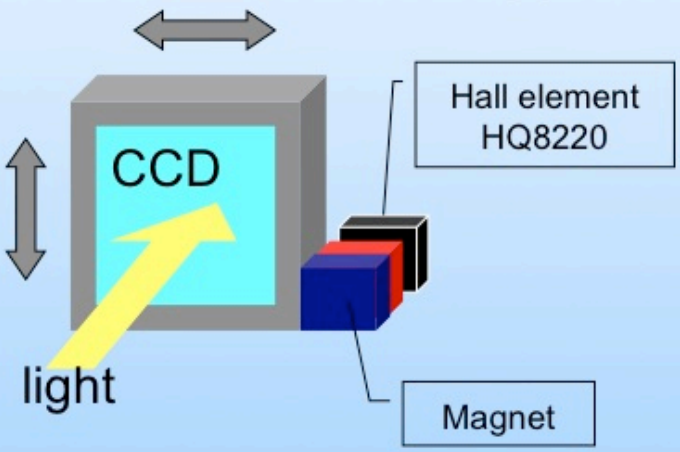
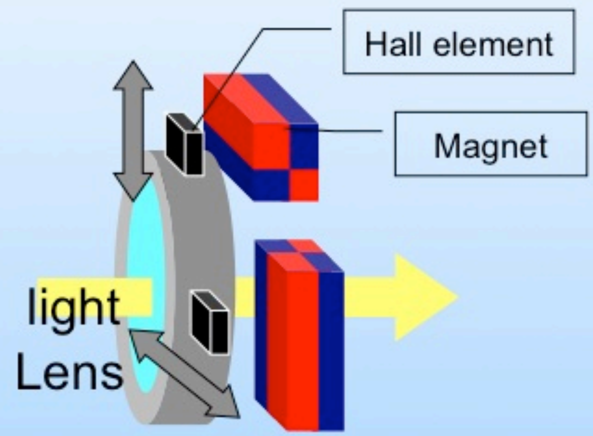
Adopted

DSC/DVC

- Position Sensing for Anti-Shake/OIS/VR
  - CCD shift : Type 2
  - Lens shift : Type 1





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Adopted

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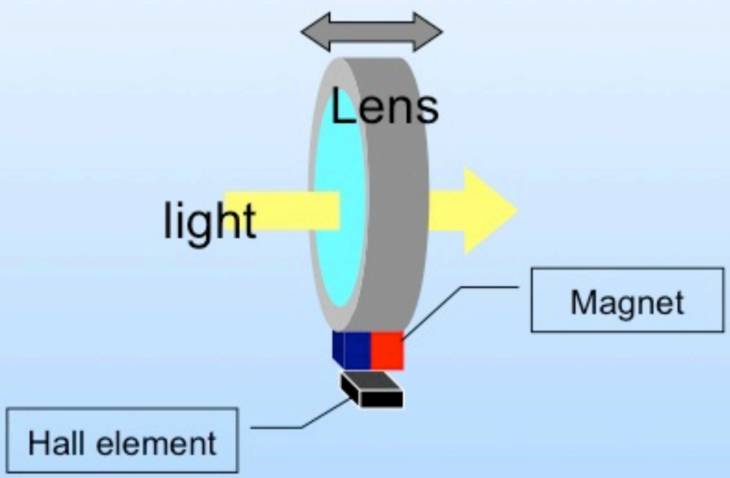
Camera Module

- Auto Focus/Zoom lens position sensing



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Reference

Close Position Sensing CPS

Material Lineup

	HQ Series	HG Series
Material	InAs	GaAs
Sensitivity	High	Standard
Temp. coef.	Proportional	Stable
Input	const. voltage	const. current
Applied	Type 2&3	Type 1

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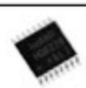
Reference

Package Lineup

	features	type	pin#	dimension
HQ Series				
HQ-0111 		SON	4	1.6*0.8*0.6
HQ-0221 	2 sensors in 1 package	SON	6	2*1.25*0.6
HQ-8220 	4 sensors in 1 package	TSOP	16	5.0*4.4*0.95 (5.0*6.2*1.0)
HQ-0441 	4 sensors in 1 package	SON	20	4.0*4.0*0.55
HG Series				
HG-1*6* 		TSOP	4	1.5*1.5*0.6 (1.5*2.5*0.65)
HG-011* 		SON	4	1.6*0.8*0.45

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Close Position Sensing CPS

Specification

Item	Rin[Ω]	Rout[Ω]	Vh[mV]	αVh[%/°C]
Condition	Ic=0.1mm	Ic=0.1mm	Vc=3V(HQ), 6V(HG) B=50mT	Ta=25~125 °C HQ(CV),HG(CC)
HQ Series	750~1150	750~1150	90~130	-0.2
HG-				
106C, 0111	650~850	650~850	55~ 75	-0.03
106A, 0112	450~750	1000~2000	75~95	-0.03
166A, 0113	1000~1500	1800~3000	78~102	-0.04
176A, 0114	1600~2400	3200~4800	78~102	-0.06
186A, 0115	2200~3200	4400~6400	80~110	-0.07

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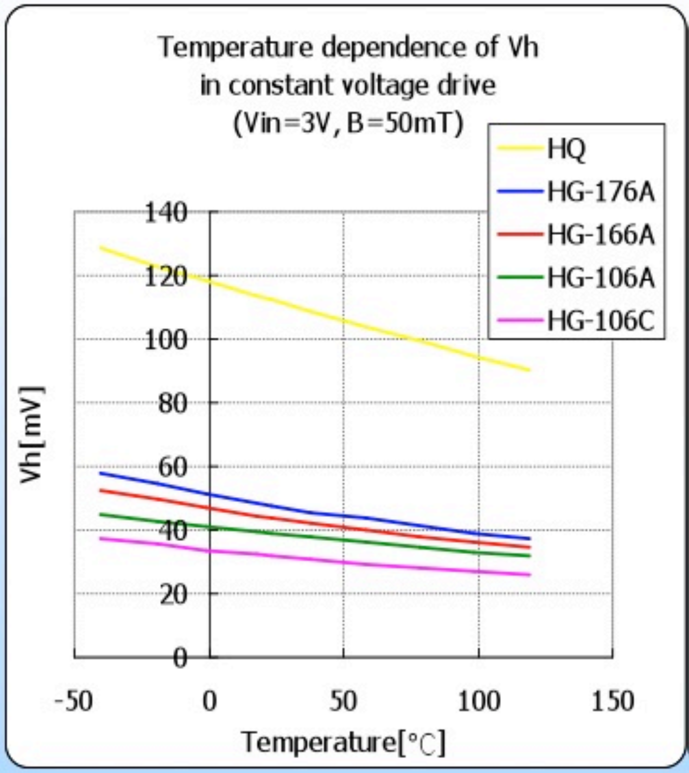
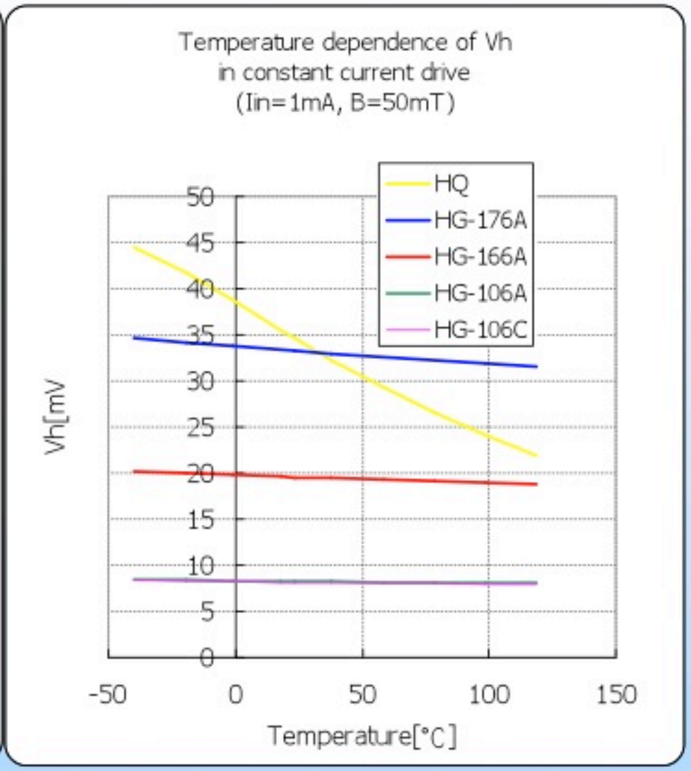
Featured characteristic





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Output Voltage

- Output Voltage is calculated as follows:
  - Vh: Output Hall Voltage [mV] (sensitivity)
  - Vin: Input Voltage [V]
  - Vo: Output Voltage [mV]
  - B: Magnetic Flux Density [mT]
  - x: 3V@HQ, 6V@HG

$$Vo = B \times \frac{Vh}{50} \times \frac{Vin}{x}$$

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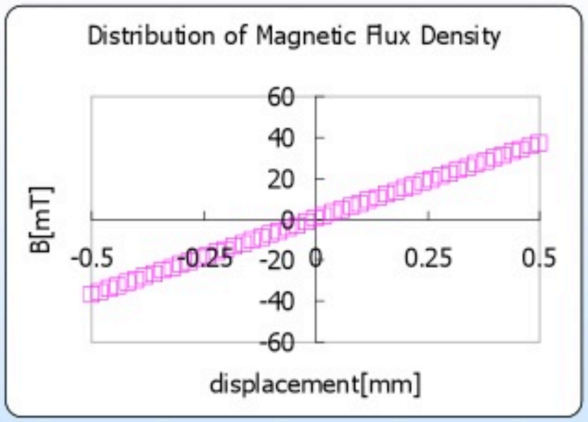
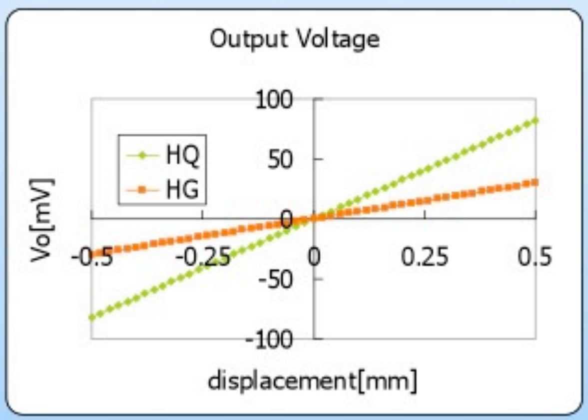
Output Voltage





- For example, output voltage is calculated in case Type 1.
  - HQ-0111
    - Vin=3V (constant)
    - Vh=110mV (Vin=3V,B=50mT)
  - HG-106C
    - Iin=5mA (constant)
    - Vh=40mV (Iin=5mA,B=50mT)

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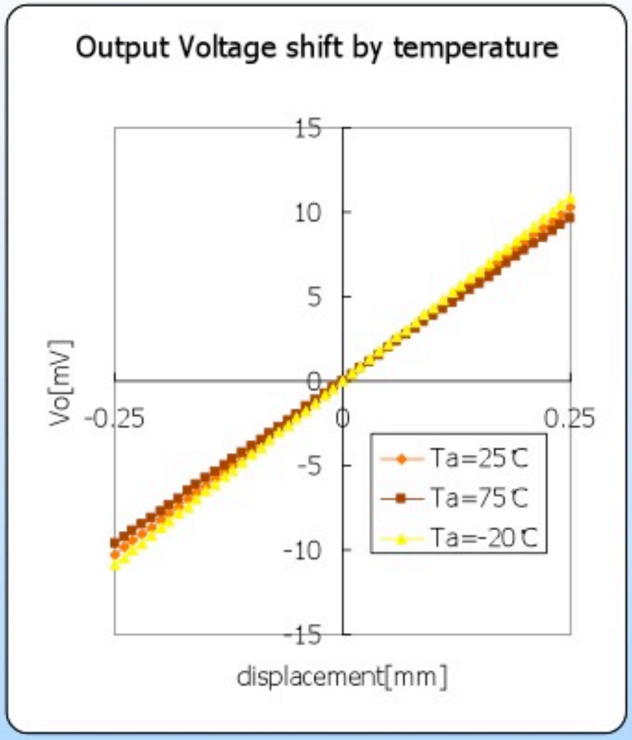
Output Voltage

<Temperature dependence>

- Assume Vh and B has temperature coefficient:
  - Vh: -0.03 [%/˚C]
  - B: -0.1 [%/˚C]

    (assumimg HG-106C and Nd-Fe-B magnet)
- Condition:
  - Ta = 25˚C (original)
  - Ta = 75˚C
  - Ta = -20˚C



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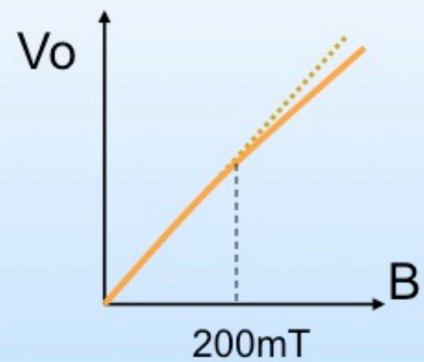
Reference

Magneto Resistive Effect

- Magneto Resistive effect (MR effect) is effect that electrical resistance increases when an external magnetic field (B) is applied.
- Both Hall effect and MR effect are caused by Lorentz force, so that Hall element also has MR effect.
- Usually MR effect of Hall element is too small to detect. But when a Hall element is driven in constant voltage and B is large enough, output voltage of Hall element decreases comparing to the case B is not so large.
- In case of HQ, when it is driven in 3V, it shows MR effect under condition B > 200mT.



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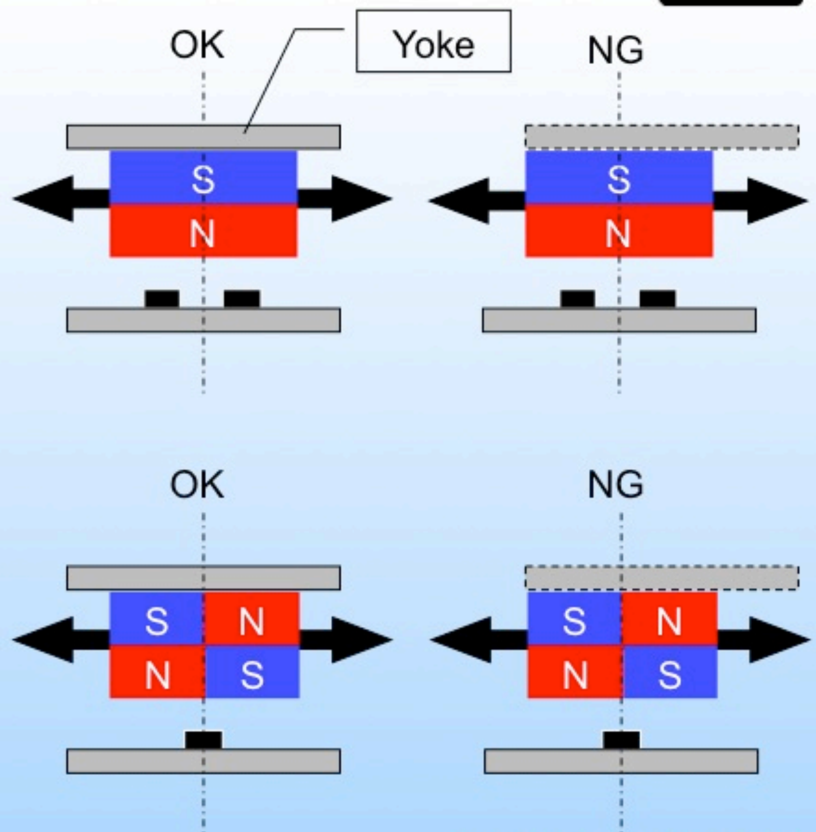
Reference

Yoke

- When ferromagnetic material is placed around magnet as a yoke, be sure that layout is symmetrical about the plane which is perpendicular to the traveling axis.



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955 Industrial Road, San Carlos, CA 94070 tel: (650) 204-9071 fax: (650) 585-4606 email: eric@gmw.com web: www.gmw.com

Reference

Close Position Sensing

Noise -1

- Hall element has noise on its output voltage. The noise voltage varies according to the kind of Hall element.

  - ☐HQ series: 0.015mV (@Vin=1.5V, 3σ)
  - ☐HG106C/0111: 0.012mV (@Iin=1mA, 3σ)
  - ☐HG106A/0112: 0.016mV
  - ☐HG166A/0113: 0.055mV
  - ☐HG176A/0114: 0.126mV
  - ☐HG186A/0115: 0.286mV

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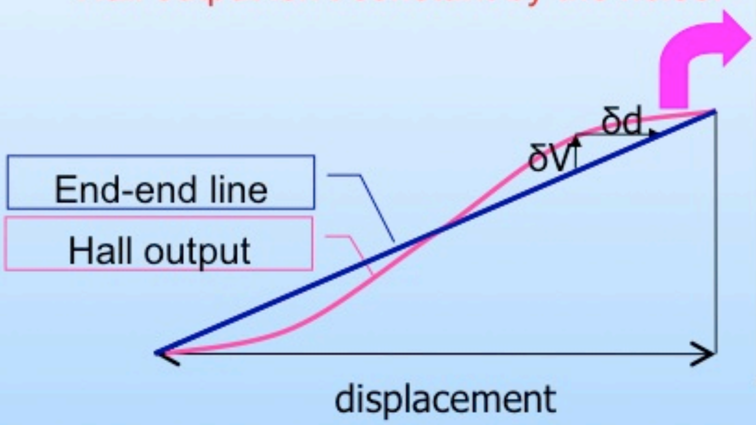
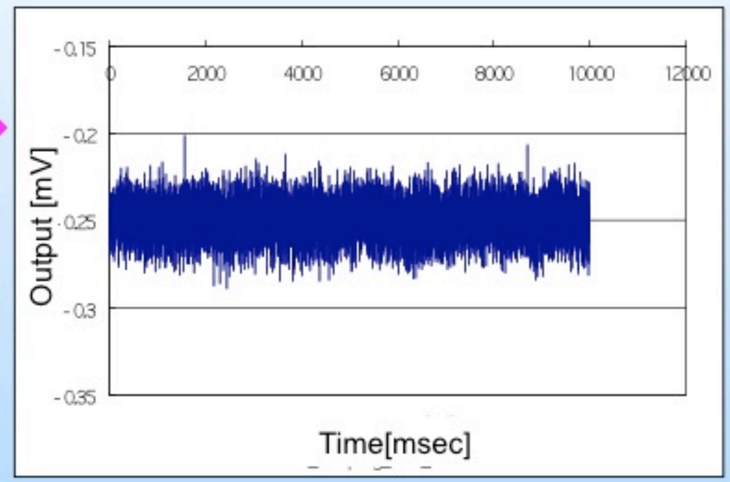
Noise -2

- In CPS, Hall element noise might effect accuracy/resolution.

Hall output isn't constant by the noise.





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Reference Website Links

Asahi:

Main Page & Latest Product Release News: http://www.asahi-kasei.co.jp/ake/en/

Top Product Index: http://www.asahi-kasei.co.jp/ake/en/product/index.html

Hall Effect Elements: http://www.asahi-kasei.co.jp/ake/en/product/hall/index.html

Hall Effect IC's: http://www.asahi-kasei.co.jp/ake/en/product/ic/index.html

GMW:

Main: http://www.gmw.com

Hall Effect Elements: http://www.gmw.com/magnetic_sensors/asahi/hall-element.html

Hall Effect IC's: http://www.gmw.com/magnetic_sensors/asahi/hall-effect-ic.html