EQ-950L

Programmable Linear Hall IC with Fast Response Time

Features

- Analog output voltage proportional to the magnetic flux density
- Ratiometric output from supply voltage
- 5V single supply operation
- EEPROM (2-wire serial I/F)
- Adjustable magnetic sensitivity and zero field output voltage
- Small temperature drifts of magnetic sensitivity and zero field output voltage
- Fast response time: 1μs to step input magnetic flux density
- Low noise output: 2.1mVrms
- Selectable unipolar/bipolar operation

Functional Block Diagram

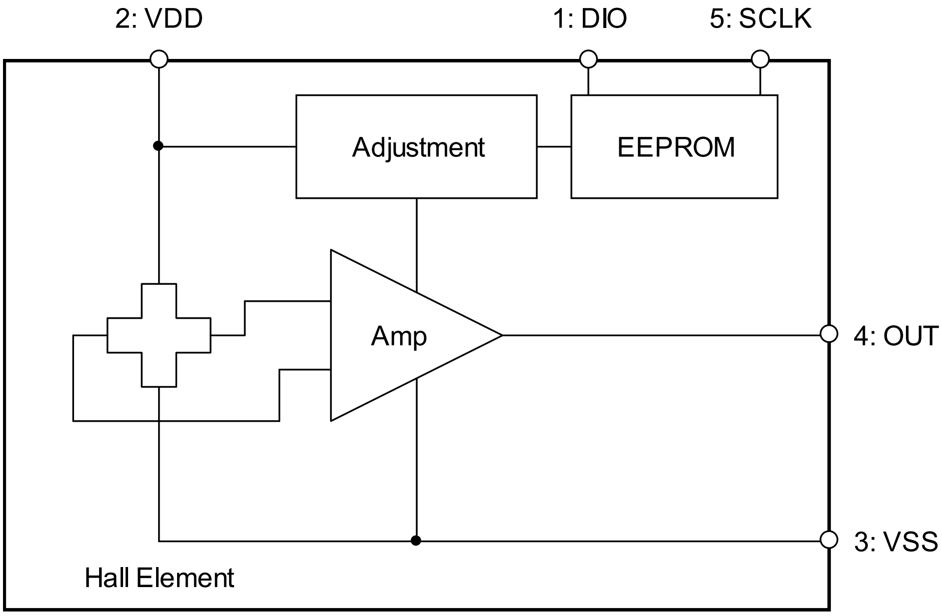


Figure 1. Functional block diagram of EEQ-950L

Circuit Blocks

Table 1. Explanation of circuit blocks

Circuit Block	Function
Hall Element	High-sensitive Hall element which generates output voltage proportional to the input magnetic flux density.
Amp	Gain-adjustable amplifier which amplifies the output from Hall element. Maximum load current is ±0.5mA, and maximum load capacitance is 100pF.
Adjustment	Adjusts the sensitivity and zero field output voltage of the Hall element.
EEPROM	Non-volatile memory for setting adjustment parameters.

Typical Output Characteristics

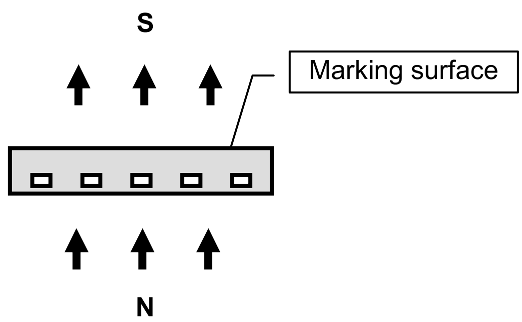


Figure 2. Definition of sensitivity direction

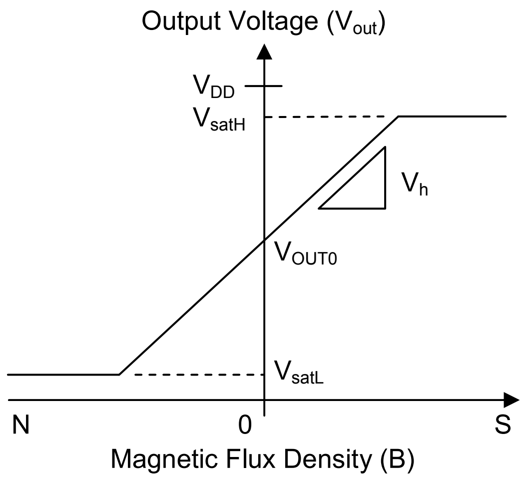


Figure 3. Output Characteristics of EQ-950L

NOTE:
- Sensitivity (V_h) means the slope of B-V_{out} curve.
- Sensitivity (V_h) and zero field output voltage (V_{OUT0}) can be selected using programming function.

Pin/Function

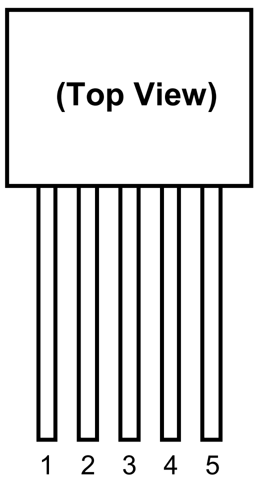


Figure 4. Pin-out diagram

Table 2. Pin-out Description

No.	Pin Name	I/O	Type	Description
1	DIO	I/O	Digital	Serial data input/output pin*
2	VDD	-	Power	Power supply pin (5V)
3	VSS	-	Power	Ground pin (GND)
4	OUT	O	Analog	Analog output pin
5	SCLK	I	Digital	Serial clock input pin*

*All digital I/O pins are recommended to be connected to VSS, unless using programmable functions.

Absolute Maximum Ratings

Table 3. Absolute maximum ratings

Conditions (unless otherwise specified): T_a=25°C

Parameter	Symbol	Min.	Max.	Units	Notes
Supply Voltage	V_{DD}	−0.3	6.5	V	VDD
Analog Output Current	I_{OUT}	−10	10	mA	OUT
Digital Input/Output Voltage	V_{Dig}	−0.3	V_{DD}+0.3	V	DIO, SCLK V_{Dig}≦6.5V
Digital Input/Output Current	I_{Dig}	−10	10	mA	DIO, SCLK
Storage Temperature	T_{stg}	−40	125	°C	

WARNING: Operation at or beyond these limits may result in permanent damage to the device. Normal operation is not guaranteed at these extremes.

Recommended Operating Conditions

Table 4. Recommended operating conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Supply Voltage	V_{DD}	4.5	5	5.5	V	
Output Current	I_{OUT}	−0.5		0.5	mA	OUT
Output Load Capacitance	C_L			100	pF	OUT
Operating Ambient Temperature	T_a	−40		105	°C	

NOTE: Electrical and magnetic characteristics are not guaranteed when operated at or beyond these conditions.

Electrical and Magnetic Characteristics

Table 5. Electrical and magnetic characteristics

Conditions (unless otherwise specified): T_a=35°C, V_{DD}=5V, initial EEPROM settings

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Current Consumption	I_{DD}	B=0mT, No Loads		6.6	9	mA
Sensitivity *1)	V_h	See Figure 5		60		mV/mT
Zero Field Output Voltage *1)	V_{OUT0}	B=0mT		2.50		V
Range of Input Magnetic Flux Density *2) *3)	B_{IN}	VO0DIG=00h, GAIN1=00h	−35.9		35.9	mT
Bandwidth	f_T	at −3dB C_L=100pF		400		kHz
Rise/Fall Response Time	t_r, t_r	See Figure 8 C_L=100pF		1		μs
Output Saturation Voltage (H)	V_{satH}	I_{OUT}=−0.5mA	4.7			V
Output Saturation Voltage (L)	V_{satL}	I_{OUT}=0.5mA			0.3	V
Linearity Error *2) *4)	ρ	See Figure 5 F.S.=V_{satH}−V_{satL}	−0.5		0.5	%F.S.
Sensitivity Drift through High Temperature Range *3)	$V_{h\text{-}dH}$	See Figure 6 T_a=35~105°C	−2		2	%
Absolute Value of Maximum Sensitivity Drift through Low Temperature Range *5)	$V_{h\text{-}dLmax}$	See Figure 6 T_a=−40~35°C		2		%
Zero Field Output Voltage Drift through High Temperature Range *2) *3)	$V_{OUT0\text{-}dH}$	See Figure 7 T_a=35~105°C B=0mT	−19		19	mV
Absolute Value of Maximum Zero Field Output Voltage Drift through Low Temperature Range *2) *5)	$V_{OUT0\text{-}dLmax}$	See Figure 7 T_a=−40~35°C B=0mT		9.5		mV
Power-On Time	t_{on}	See Figure 9 C_L=100pF, B=0mT			1	ms
Output Noise	V_{nrms}	100Hz~4MHz			2.1	mVrms
Ratiometric Error of Sensitivity	$V_{h\text{-}R}$	V_{DD}=4.5V~5.5V	−1		1	%
Ratiometric Error of Zero Field Output Voltage	$V_{OUT0\text{-}R}$	V_{DD}=4.5V~5.5V B=0mT	−1		1	%

1mT=10Gauss

*1) These parameters can be changed by using internal EEPROM. Please see ‘Programmable Functions’ section for details.
*2) These parameters will be changed with changing sensitivity or zero field output voltage by using internal EEPROM. Please see ‘Programmable Functions’ section for details.
*3) These parameters are guaranteed by design.
*4) ‘%F.S’ means the ratio of error to the full scale (F.S.)
*5) These parameters are for reference only.
*6) These parameters can drift by the values in ‘Reliability Tests’ section over the lifetime of this product.

Characteristics Definitions

(1) Sensitivity V_h [mV/mT]

Sensitivity is defined as the slope of the approximate straight line calculated by the least square method, using the data of OUT voltage (V_{OUT}) when the magnetic flux density (B) is swept within the range of input magnetic flux density (B_{IN}).

(2) Linearity error ρ [%F.S.]

Linearity error is defined as the ratio of the maximum error voltage (V_d) to the full scale (F.S.), where V_d is the maximum difference between the OUT voltage (V_{OUT}) and the approximate straight line calculated in the sensitivity definition. Definition formula is shown in below:

$$\rho = Vd / F.S. \times 100$$

NOTE) Full scale (F.S.) is defined by the multiplication of the range of input magnetic flux density and sensitivity (See Figure 5).

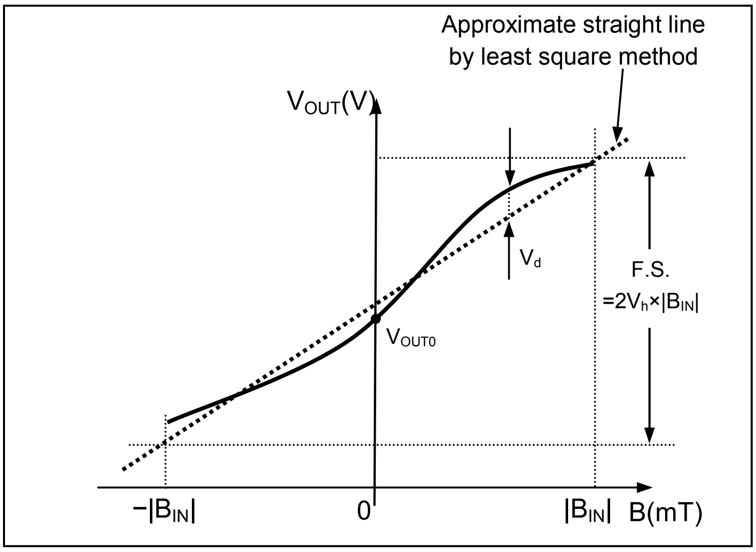


Figure 5. Output characteristics of EQ-950L

(3) Ratiometric error of sensitivity $V_{h\text{-}R}$ [%] and ratiometric error of zero field offset voltage $V_{OUT0\text{-}R}$ [%]

Output of EQ-950L is ratiometric, which means the values of sensitivity (V_h) and zero field offset voltage (V_{OUT0}) are proportional to the supply voltage (V_{DD}). Ratiometric error is defined as the difference between the V_h (or V_{OUT0}) and ideal V_h (or V_{OUT0}) when the V_{DD} is changed from 5.0V to V_{DD1} ($4.5V<V_{DD1}<5.5V$). Definition formula is shown in below:

$$V_{h\text{-}R} = 100 \times \{(V_h(V_{DD} = V_{DD1}) / V_h(V_{DD} = 5V)) - (V_{DD1} / 5)\} / (V_{DD1} / 5)$$
$$V_{OUT0\text{-}R} = 100 \times \{(V_{OUT0}(V_{DD} = V_{DD1}) / V_{OUT0}(V_{DD} = 5V)) - (V_{DD1} / 5)\} / (V_{DD1} / 5)$$

(4) Sensitivity drift $V_{h\text{-}d}$ [%]

Sensitivity drift is defined as the drift ratio of the sensitivity (V_h) at $T_a=T_{a1}$ ($-40°C<T_{a1}<105°C$) to the V_h at T_a=35°C, and calculated from the formula below:

$$V_{h\text{-}d} = 100 \times (V_h(T_{a1}) / V_h(35°C) - 1)$$

Sensitivity drift through high temperature range ($V_{h\text{-}dH}$) is defined as the $V_{h\text{-}d}$ at an arbitrary T_{a1} ($35°C<T_{a1}<105°C$) and absolute value of maximum sensitivity drift through low temperature range ($V_{h\text{-}dLmax}$) is defined as the maximum value of $|V_{h\text{-}d}|$ through $-40°C<T_{a1}<35°C$. *(continued)*

Reference data of the sensitivity drift of EQ-950L is shown in Figure 6.

(5) Zero field offset voltage drift $V_{OUT0\text{-}d}$ [mV]

Zero field offset voltage drift is defined as the drift value between the zero field offset voltage (V_{OUT0}) at T_a=T_{a1} (−40°C<T_{a1}<105°C) and the V_{OUT0} at T_a=35°C, and calculated from the formula below:

$$V_{OUT0\text{-}d} = V_{OUT0}(T_a = T_{a1}) - V_{OUT0}(T_a = 35°C)$$

Zero field offset voltage drift through high temperature range ($V_{OUT0\text{-}dH}$) is defined as the $V_{OUT0\text{-}d}$ at an arbitrary T_{a1} (35°C<T_{a1}<105°C) and absolute value of maximum zero field offset voltage drift through low temperature range ($V_{OUT0\text{-}dLmax}$) is defined as the maximum value of $|V_{h\text{-}d}|$ through −40°C<T_{a1}<35°C. Reference data of the zero field offset voltage drift of EQ-950L is shown in Figure 7.

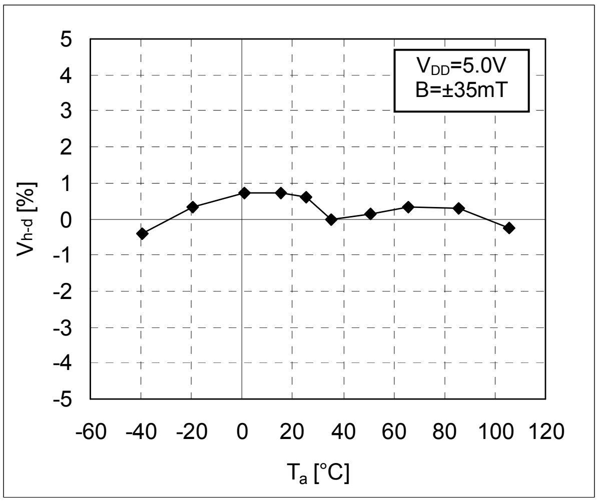


Figure 6. Sensitivity drift of EQ-950L (for reference, n=1)

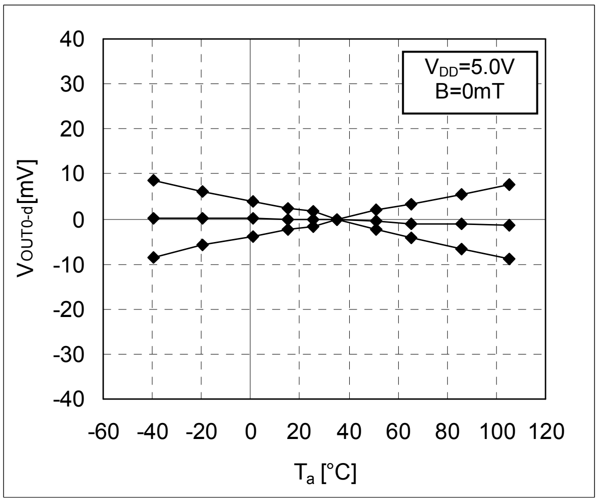


Figure 7. Zero field offset voltage drift of EQ-950L (for reference, n=3)

(6) Rise response time t_r [μs] and fall response time t_f [μs]

Rise response time (or fall response time) is defined as the time delay from the 90% (or 10%) of input magnetic field (B) to the 90% (or 10%) of the OUT voltage (V_{OUT}) under the pulse input of magnetic flux density (see Figure 8.)

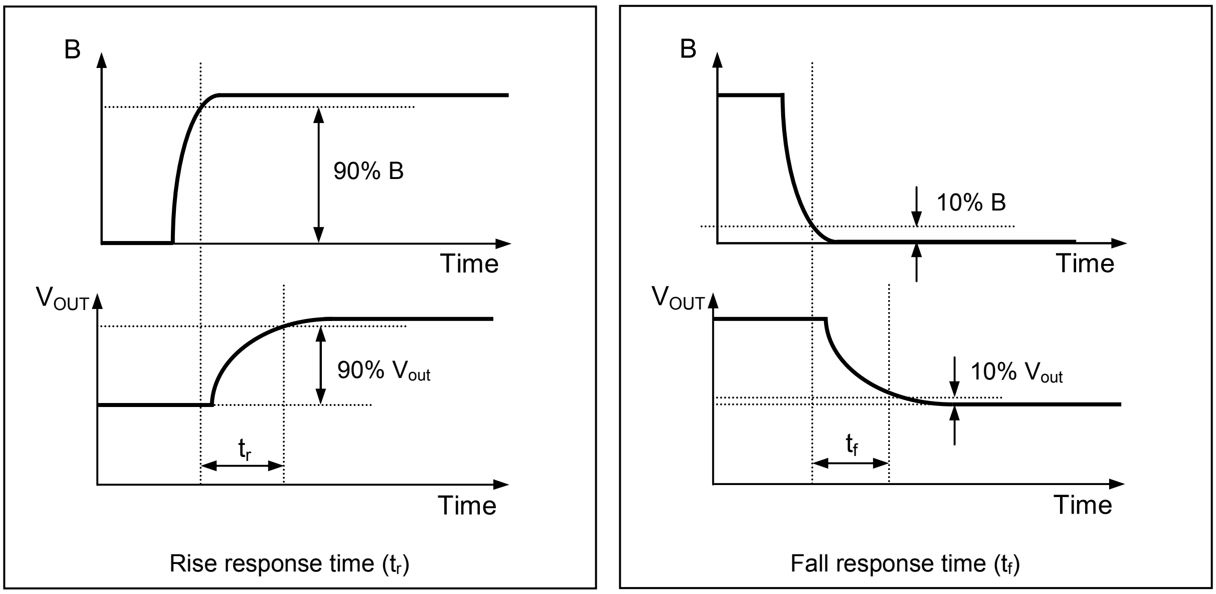


Figure 8. Definition of response time

(7) Power-on time t_{on} [ms]

Power-on time is defined as the time delay from the 90% of supply voltage (V_{DD}) to the 90% of the OUT voltage (V_{OUT}) when apply the power supply (see Figure 9.)

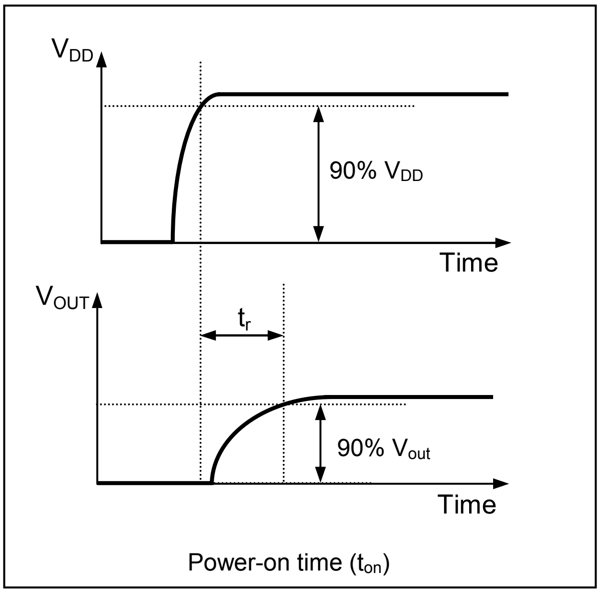


Figure 9. Definition of power-on time

EEPROM Characteristics

Table 6. EEPROM characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
EEPROM Endurance*1)	EEN				1000	Cycles
EEPROM Data Retention	ERE	T_j=105°C	10			Years

*1) Data retention are not guaranteed after rewritten over 1000 cycles.

Programmable Functions

Sensitivity and zero field offset voltage of EQ-950L can be changed by rewriting the internal EEPROM. Programming kit (EQD-950L) for accessing EEPROM is available. Please contact us for details.

All parameters in this section are guaranteed by design, unless otherwise specified.

(1) Sensitivity

EEPROM of EQ-950L has two addresses for sensitivity.

One is the sensitivity selection (GAIN1), which is used for selecting sensitivity from the 13 target sensitivity from 15mV/mT to 130mV/mT. Table 7 shows the list of target sensitivity. This function affects the specification of the range of input magnetic flux density (B_{IN}) and zero field offset voltage drift (V_{OUT0-d}).

The other is the sensitivity adjustment (GAIN2), which is used for adjusting sensitivity within the ±1% of target sensitivity selected by GAIN1. GAIN2 has 128 adjustment steps, which realizes the adjustment range of −24.9~25.3% and adjustment resolution of 0.39%. (T_a=35°C, V_{DD}=5.0V, typ.)

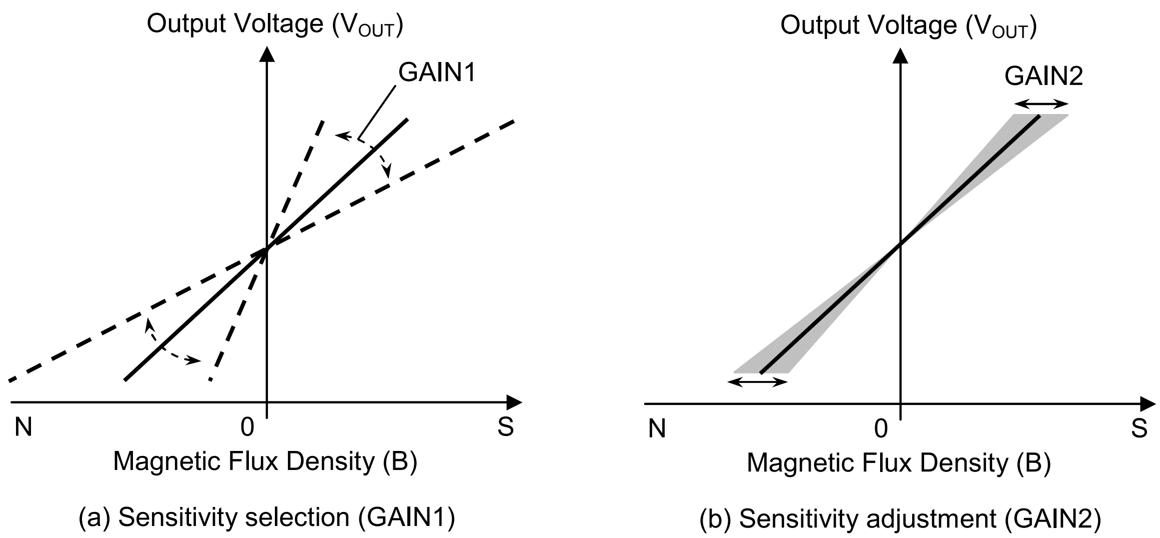


Figure 10. Adjustment sequence of sensitivity

Table 7. List of target sensitivity

Conditions: T_a=35°C, V_{DD}=5V

GAIN1(hex)	Target Sensitivity V_h [mV/mT]	Sensitivity Error after Adjusted GAIN2 V_{h-e} [%]	Range of Input Magnetic Flux Density B_{IN} [mT]	Zero Field Offset Voltage through High Temperature Range $V_{OUT0-dH}$ [mV]	Absolute Value of Maximum Zero Field Offset Voltage through High Temperature Range (typ.) $V_{OUT0-dLmax}$ [mV]
0x00	15	−1 ~ 1	−143.8 ~ 143.8	−5 ~ 5	±2.5
0x01	18		−119.9 ~ 119.9	−6 ~ 6	±3.0
0x02	21		−102.7 ~ 102.7	−7 ~ 7	±3.5
0x03	26		−83.0 ~ 83.0	−9 ~ 9	±4.5
0x04	35		−61.6 ~ 61.6	−11 ~ 11	±5.5
0x05	42		−51.3 ~ 51.3	−14 ~ 14	±7.0
0x06	47		−45.9 ~ 45.9	−15 ~ 15	±7.5
0x07	53		−40.7 ~ 40.7	−17 ~ 17	±8.5
0x08(default)	60		−35.9 ~ 35.9	−19 ~ 19	±9.5
0x09	70		−30.8 ~ 30.8	−22 ~ 22	±11.0
0x0A	84		−25.6 ~ 25.6	−27 ~ 27	±13.5
0x0B	105		−20.5 ~ 20.5	−33 ~ 33	±16.5
0x0C	130		−16.6 ~ 16.6	−42 ~ 42	±21.0

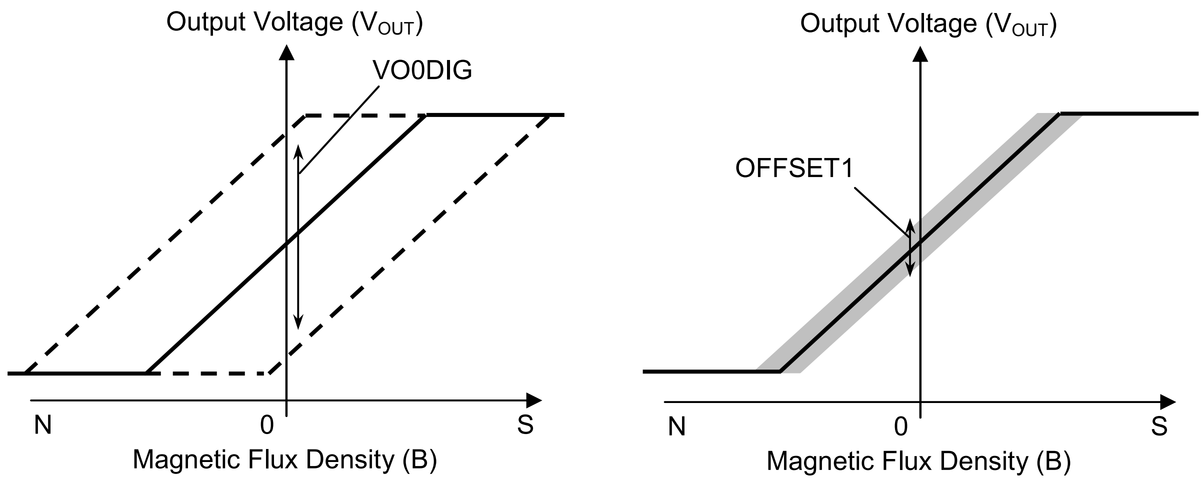
NOTE) Adjustment of sensitivity to an arbitrary value other than the target sensitivities on the above list is not guaranteed.

(2) Zero field offset voltage

EEPROM of EQ-950L has two addresses for zero field offset voltage.

One is the zero field offset voltage selection (VO0DIG), which is used for selecting zero field offset voltage from the 3 target zero field offset voltage. Table 8 shows the list of target zero field offset voltage. This function affects the specification of the range of input magnetic flux density (B_{IN}) and linearity error (ρ).

The other is the zero field offset voltage adjustment (OFFSET1), which is used for adjusting zero field offset voltage within the ±20mV of target zero field offset voltage selected by VO0DIG. OFFSET1 has 32 adjustment steps, which realizes the adjustment range of −312.0~292.5mV and adjustment resolution of 19.5mV. (T_a=35°C, V_{DD}=5.0V, GAIN2=0x3F, typ.) Adjustment range and resolution will change with the GAIN2.



(a) Zero field offset voltage selection (VO0DIG) (b) Zero field offset voltage adjustment (OFFSET1)

Figure 11. Adjustment sequence of zero field offset voltage

Table 8. List of target zero field offset voltage

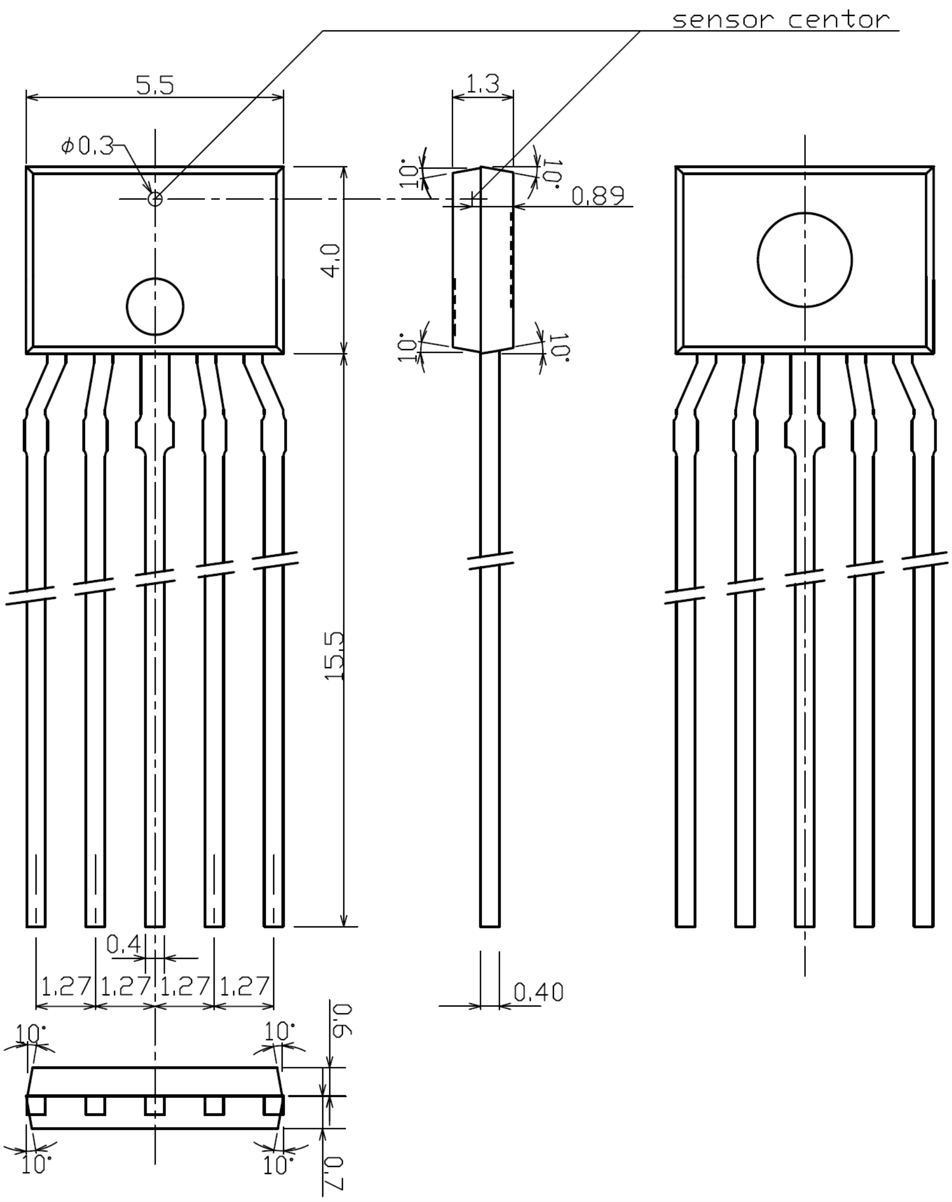
条件：T_a=35°C, V_{DD}=5V

VO0DIG(hex)	Target Zero Field Offset Voltage V_{OUT0} [V]	Zero Field Offset Voltage Error after Adjusting VO0DIG V_{OUT0-e} [mV]	GAIN1(hex)	Range of Input Magnetic Flux Density B_{IN} [mT]	Linearity Error *1) ρ [%F.S.]
0x00(default)	2.50	−20 ~ 20	0x00	−143.8 ~ 143.8	−0.5 ~ 0.5
			0x01	−119.9 ~ 119.9	
			0x02	−102.7 ~ 102.7	
			0x03	−83.0 ~ 83.0	
			0x04	−61.6 ~ 61.6	
			0x05	−51.3 ~ 51.3	
			0x06	−45.9 ~ 45.9	
			0x07	−40.7 ~ 40.7	
			0x08	−35.9 ~ 35.9	
			0x09	−30.8 ~ 30.8	
			0x0A	−25.6 ~ 25.6	
			0x0B	−20.5 ~ 20.5	
			0x0C	−16.6 ~ 16.6	
0x01	0.45	−20 ~ 20	0x00	0 ~ 279.2	−1.0 ~ 1.0
			0x01	0 ~ 232.6	
			0x02	0 ~ 199.4	
			0x03	0 ~ 161.0	
			0x04	0 ~ 119.6	
			0x05	0 ~ 99.7	
			0x06	0 ~ 89.1	
			0x07	0 ~ 79.0	
			0x08	0 ~ 69.8	
			0x09	0 ~ 59.8	
			0x0A	0 ~ 49.8	
			0x0B	0 ~ 39.8	
			0x0C	0 ~ 32.2	
0x02	4.55	−20 ~ 20	0x00	−279.2 ~ 0	−1.0 ~ 1.0
			0x01	−232.6 ~ 0	
			0x02	−199.4 ~ 0	
			0x03	−161.0 ~ 0	
			0x04	−119.6 ~ 0	
			0x05	−99.7 ~ 0	
			0x06	−89.1 ~ 0	
			0x07	−79.0 ~ 0	
			0x08	−69.8 ~ 0	
			0x09	−59.8 ~ 0	
			0x0A	−49.8 ~ 0	
			0x0B	−39.8 ~ 0	
			0x0C	−32.2 ~ 0	

*1) Linearity error will increase when input magnetic flux density exceeds the range of −145mT < B < 145mT.

NOTE) Adjustment of zero field offset voltage to an arbitrary value other than the target zero field offset voltage on the above list is not guaranteed.

Package Dimensions



NOTE 1: The center of the sensor is located within the Φ0.3mm circle.
NOTE 2: The tolerances of dimensions are ±0.1mm unless otherwise specified.

Package type	: SIP
Material of Terminals	: Cu
Material of Plating for Terminals	: Sn (100%)
Plating Thickness	: 10μm (typ.)

Figure 12. Package outline

Application Circuits

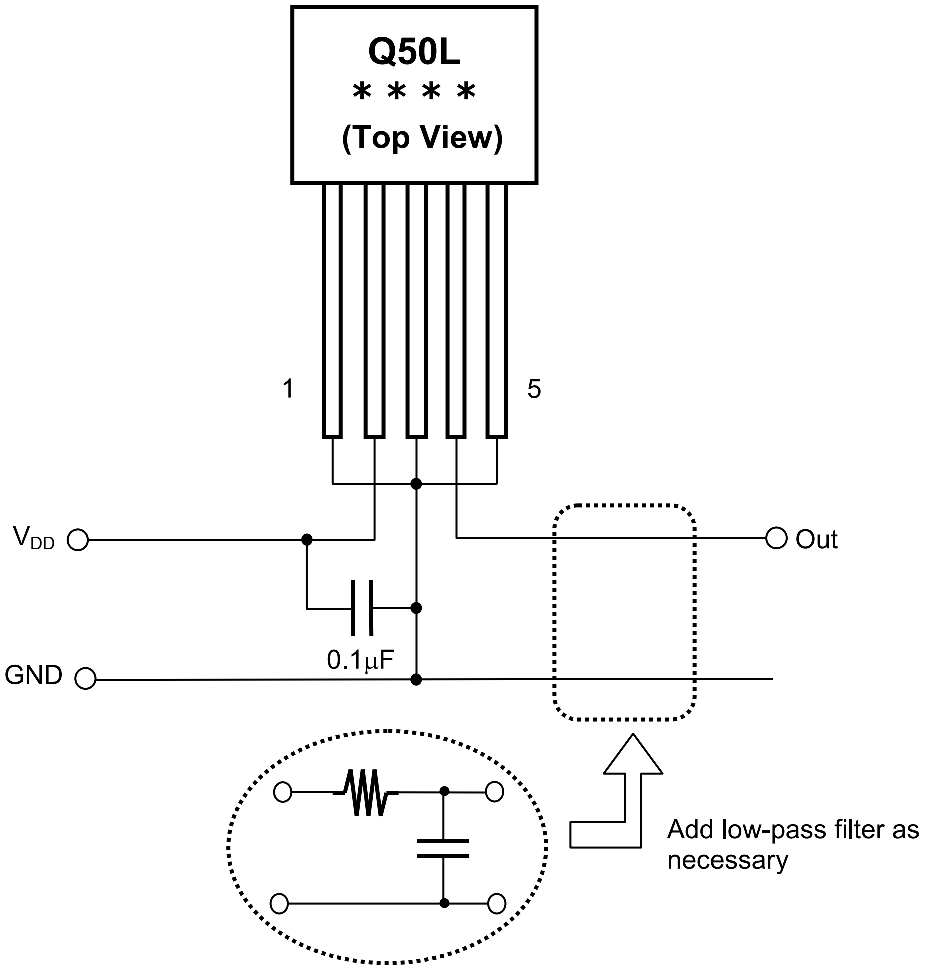


Figure 13. Application circuits of EQ-950L

Markings

Production information is printed on the package surface by laser marking.

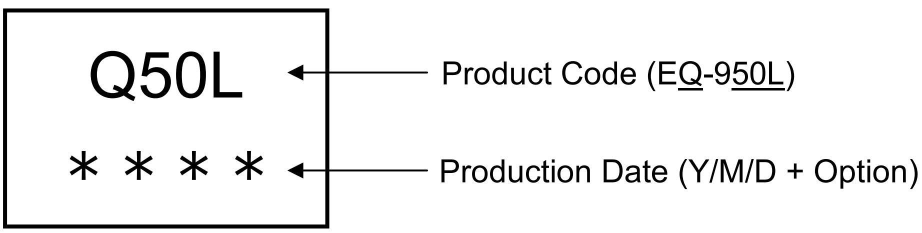


Figure 14. Marking example of EQ-950L

Reliability Tests

Table 9. Test parameters and conditions of reliability test

No.	Test Parameter	Test Conditions [JEITA Standards]	n	Test Time
1	High Humidity Storage Test	[JEITA EIAJ ED-4701 102] T_a=85°C, 85%RH, continuous operation	22	1000h
2	High Temperature Bias Test	[JEITA EIAJ ED-4701 101] T_a=125°C, continuous operation	22	1000h
3	High Temperature Storage Test	[JEITA EIAJ ED-4701 201] T_a=150°C	22	1000h
4	Low Temperature Storage Test	[JEITA EIAJ ED-4701 202] T_a= −55°C	22	1000h
5	Thermal Shock Test	[JEITA EIAJ ED-4701 307] −40°C ↔ +110°C 5min. ↔ 5min. Tested in liquid phase	22	100 cycles
6	Heat Cycle Test	[JEITA EIAJ ED-4701 105] −40°C ↔ +125°C 30min. ↔ 30min. Tested in vapor phase	22	100 cycles

Tested samples are pretreated as below before each reliability test:

Pretreating Conditions

Desiccation: 125°C / 24h → Moisture Absorption: 85°C/85%RH/168h → Reflow: 3 times (JEDEC Level1)

Criteria:

Sensitivity and zero field output voltage of EQ-950L are adjusted after pretreating. Variations of characteristics between the value after adjustment and the value after the reliability tests are as below:

Sensitivity V_h (T_a=35°C)	: Within ±1.5%
Zero Field Output Voltage V_{OUT0} (T_a=35°C)	: Within ±100mV
Linearity Error ρ (T_a=35°C)	: Within ±1%
Output Noise V_{nrms} (T_a=35°C)	: Within ±1mVrms
EEPROM Data	: No Change