CQ-2093

High-Speed Small-Sized Current Sensor

Overview

CQ-2093 is an open-type current sensor using a Hall sensor which outputs the analog voltage proportional to the AC/DC current. Quantum well ultra-thin film InAs (Indium Arsenide) is used as the Hall sensor, which enables the high-accuracy and high-speed current sensing. Simple AI-Shell® package with the Hall sensor, magnetic core, and primary conductor realizes the space-saving and high reliability.

Features

- Bidirectional type
- Electrical isolation between the primary conductor and the sensor signal
- 5V single supply operation
- Ratiometric output
- Low variation and low temperature drift of sensitivity and offset voltage
- Low noise output: 2.1mVrms (max.)
- Fast response time: 1μs (typ.)
- Small-sized surface mount package, halogen free

Functional Block Diagram

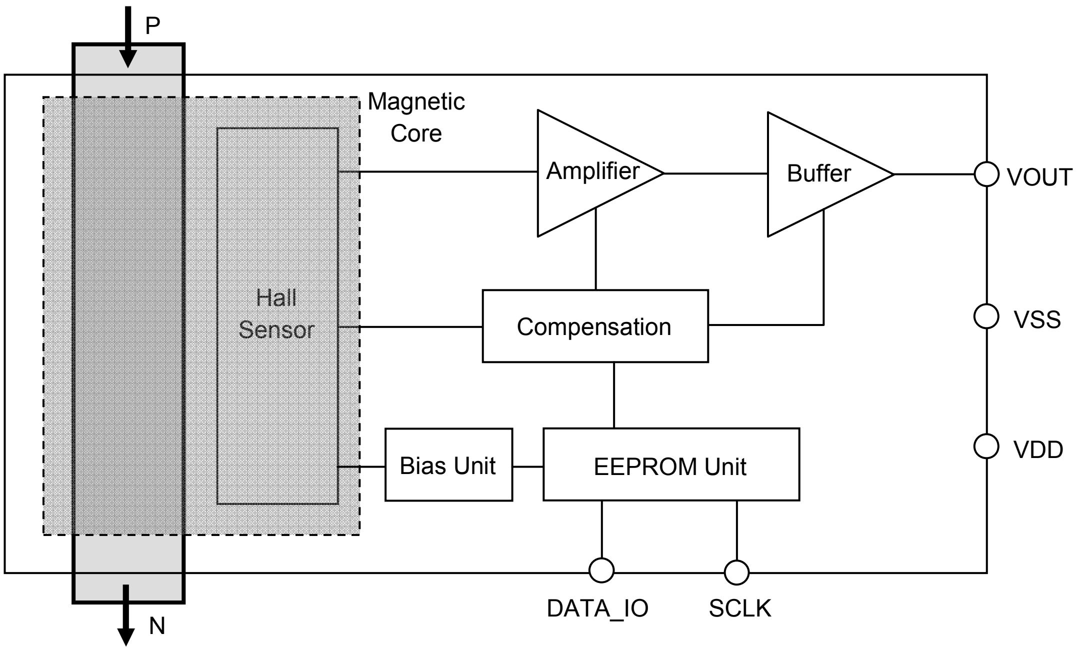


Figure 1. Functional block diagram of CQ-2093

Circuit Blocks

Table 1. Explanation of circuit blocks

Circuit Block	Function
Hall Sensor	Hall element which detects magnetic flux density generated from the measured current.
Amplifier	Amplifier of Hall element's output.
Buffer	Output buffer with gain. This block outputs the voltage (V_{OUT}) proportional to the current applied to the primary conductor.
Compensation	Compensation circuit which adjusts the temperature drifts of sensitivity and offset voltage.
Bias Unit	Drive circuit for Hall element.
EEPROM Unit	Non-volatile memory for setting adjustment parameters. The parameters are adjusted before the shipment.
Magnetic Core	Magnetic core which gathers the magnetic flux density to the Hall element.

Typical Output Characteristics

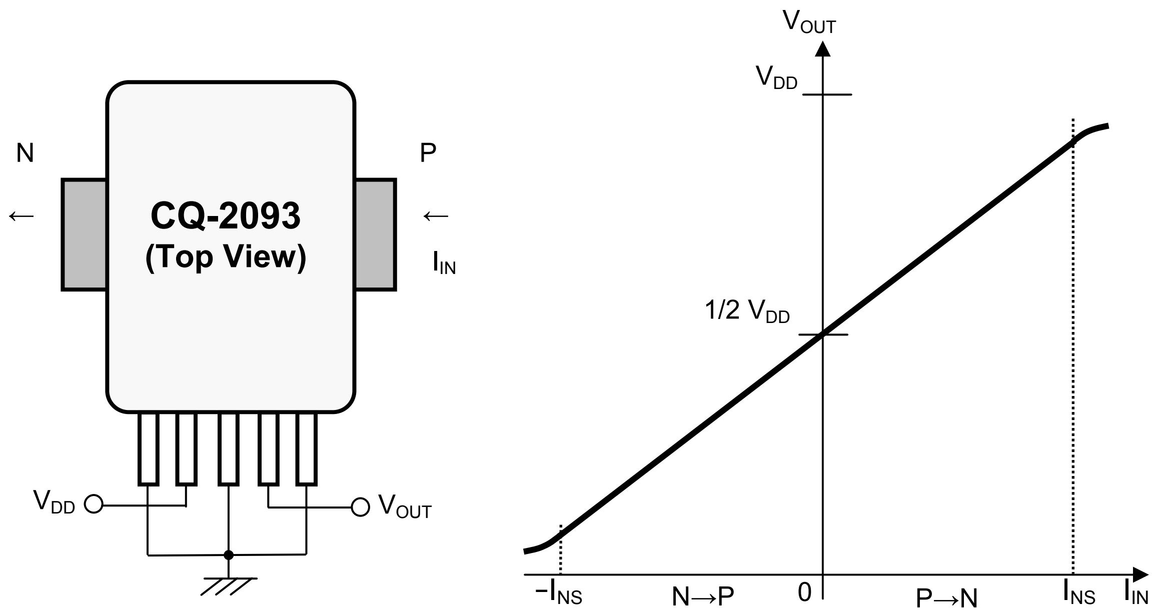


Figure 2. Typical output characteristics of CQ-2093

Pin/Function

Table 2. Pin-out description

No.	Name	I/O	Description
1	DATA_IO	-	Test pin (connect to ground)
2	VDD	-	Power supply pin (5V)
3	VSS	-	Ground pin (0V)
4	VOUT	O	Analog output pin
5	SCLK	-	Test pin (connect to ground)
6	P	I	Primary current pin (+)
7	N	I	Primary current pin (−)

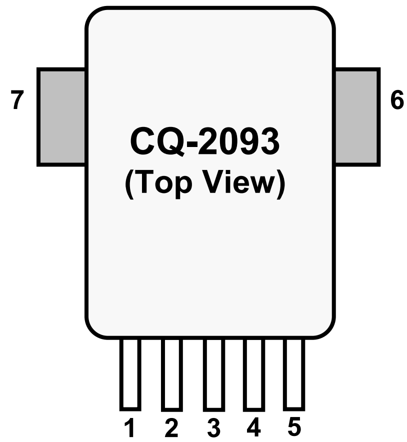


Figure 3. Pin-out diagram

Absolute Maximum Ratings

Table 3. Absolute maximum ratings

Parameter	Symbol	Min.	Max.	Units	Notes
Supply Voltage	V_{DD}	−0.3	6	V	VDD
Analog Output Current	I_{OUT}	−1	1	mA	VOUT
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.

Primary Current Derating Curve

Conditions: Mounted on the test board complying with the EIA/JEDEC Standards (EIA/JESD 51.)

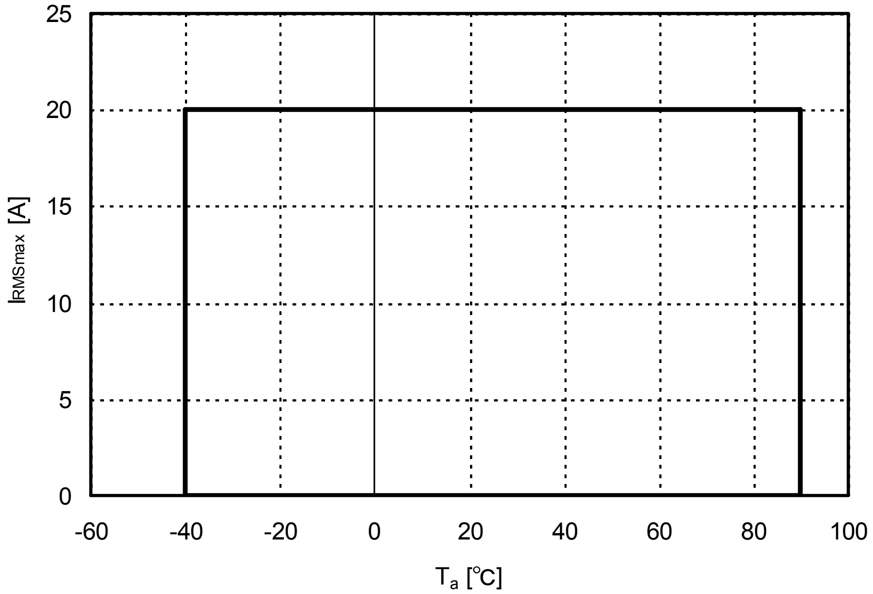


Figure 4. Primary current derating curve of CQ-2093

Recommended Operating Conditions

Table 4. Recommended operating conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Supply Voltage	V_{DD}	4.5	5.0	5.5	V	
Output Current	I_{OUT}	−0.5		0.5	mA	VOUT
Output Load Capacitance	C_L			100	pF	VOUT
Operating Ambient Temperature	T_a	−40		90	°C	

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

Electrical Characteristics

Table 5. Electrical characteristics

Conditions (unless otherwise specified): T_a=25°C, V_{DD}=5V

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Maximum Primary Current (RMS)	I_{RMSmax}	T_a=−40~90°C	−20		20	A
Current Consumption	I_{DD}	No Loads			9	mA
Sensitivity*	V_h		58.8	60.0	61.2	mV/A
Offset Voltage*	V_{of}	I_{IN}=0A	2.423	2.500	2.577	V
Linear Sensing Range	I_{NS}		−35		35	A
Linearity Error*	ρ		−1		1	%F.S.
Rise Response Time	t_r	I_{IN} 90% → V_{OUT} 90% C_L=100pF		1		μs
Fall Response Time	t_f	I_{IN} 10% → V_{OUT} 10% C_L=100pF		1		μs
Bandwidth	f_T	−3dB, C_L=100pF		400		kHz
Output Noise**	V_{Nrms}				2.1	mVrms
Temperature Drift of Sensitivity at High Temperature**	$V_{h\text{-}dH}$	Variation ratio to V_h(T_a=35°C) T_a=35~90°C	−2		2	%
Maximum Temperature Drift of Sensitivity at Low Temperature	$V_{h\text{-}dLmax}$	Variation ratio to V_h(T_a=35°C) T_a=−40~35°C		±2		%
Maximum Temperature Drift of Offset voltage	$V_{of\text{-}dmax}$	Variation from V_{of}(T_a=35°C) T_a=−40~90°C, I_{IN}=0A		±17.5		mV
Ratiometricity Error of Sensitivity**	$V_{h\text{-}R}$	V_{DD}=4.5V~5.5V	−1		1	%
Ratiometricity Error of Offset Voltage**	$V_{of\text{-}R}$	V_{DD}=4.5V~5.5V I_{IN}=0A	−1		1	%
Primary Conductor Resistance	R_1			340		μΩ
Isolation Voltage**	V_{INS}	AC 50/60Hz, 60s	2.5			kV
Isolation Resistance**	R_{INS}	DC 1kV	500			MΩ

* These parameters can drift by the values described in ‘Reliability Tests’ section over the lifetime of the product.
** These characteristics are guaranteed by design.

Characteristics Definitions

(1) Sensitivity V_h [mV/mT], offset voltage V_{of} [V]

Sensitivity is defined as the slope of the approximate straight line calculated by the least square method, using the data of VOUT voltage (V_{OUT}) when the primary current (I_{IN}) is swept within the range of linear sensing range (I_{NS}). Offset voltage is defined as the intercept of the approximate straight line above.

(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 VOUT voltage (V_{OUT}) and the approximate straight line calculated in the sensitivity and offset voltage 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 linear sensing range and sensitivity (See Figure 5).

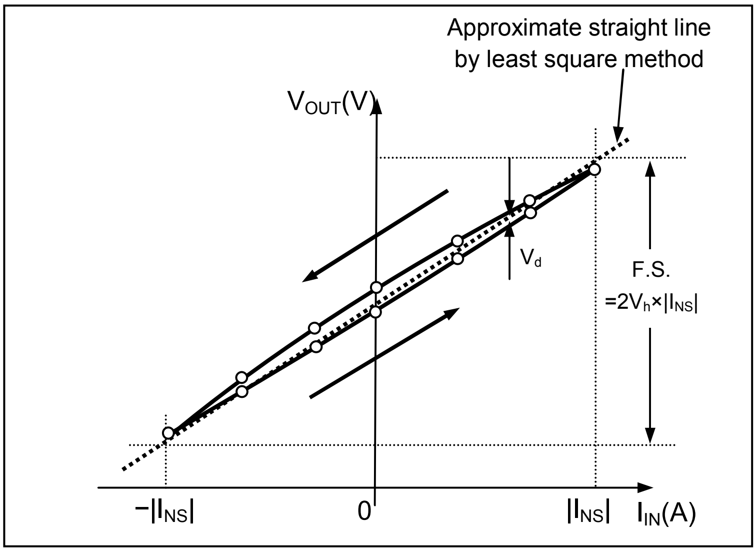


Figure 5. Output characteristics of CQ-2093

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

Output of CQ-2093 is ratiometric, which means the values of sensitivity (V_h) and offset voltage (V_{of}) are proportional to the supply voltage (V_{DD}). Ratiometric error is defined as the difference between the V_h (or V_{of}) and ideal V_h (or V_{of}) when the V_{DD} is changed from 5.0V to V_{DD1} ($4.5V<V_{DD1}<5.5V$). Definition formula is shown in below:

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

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

Temperature drift of sensitivity is defined as the drift ratio of the sensitivity (V_h) at $T_a=T_{a1}$ ($-40°C<T_{a1}<90°C$) to the V_h at T_a=35°C, and calculated from the formula below:

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

Temperature drift of sensitivity at high temperature ($V_{h\text{-}dH}$) is defined as the $V_{h\text{-}d}$ at an arbitrary T_{a1} ($35°C<T_{a1}<90°C$) and maximum temperature drift of at 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 temperature drift of sensitivity of CQ-2093 is shown in Figure 6.

(5) Temperature drift of offset voltage $V_{of\text{-}d}$ [mV]

Temperature drift of offset voltage is defined as the drift value between the offset voltage (V_{of}) at T_a=T_{a1} (−40°C<T_{a1}<90°C) and the V_{of} at T_a=35°C, and calculated from the formula below:

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

Maximum temperature drift of offset voltage ($V_{of\text{-}dmax}$) is defined as the maximum value of $|V_{h\text{-}d}|$ through −40°C<T_{a1}<90°C.
Reference data of the temperature drift of offset voltage of CQ-2093 is shown in Figure 7.

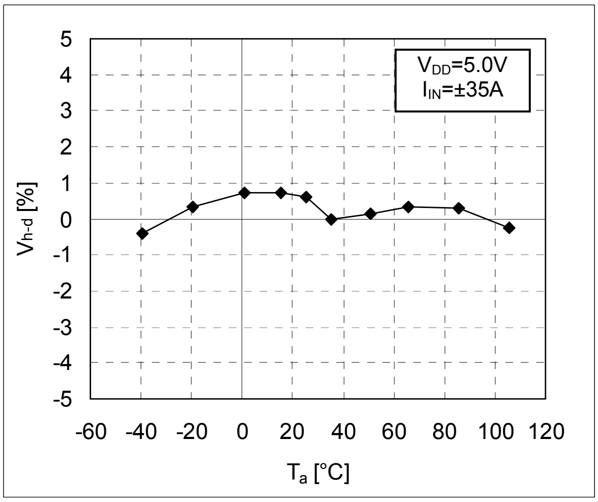


Figure 6. Temperature drift of sensitivity of CQ-2093 (for reference, n=1)

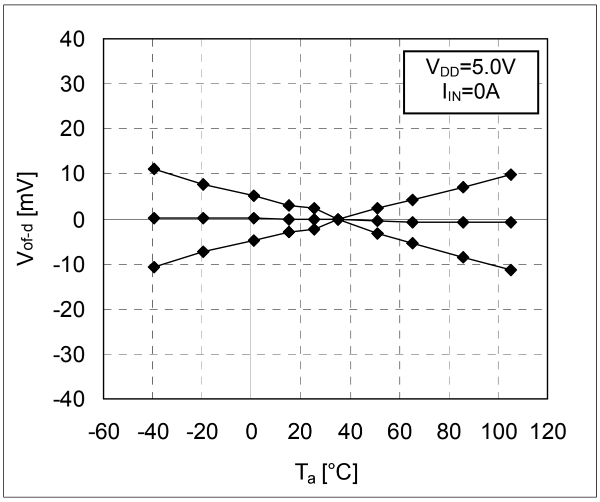


Figure 7. Temperature drift of offset voltage of CQ-2093 (for reference, n=3)

(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 primary current (I_{IN}) to the 90% (or 10%) of the VOUT voltage (V_{OUT}) under the pulse input of primary current (see Figure 8.)

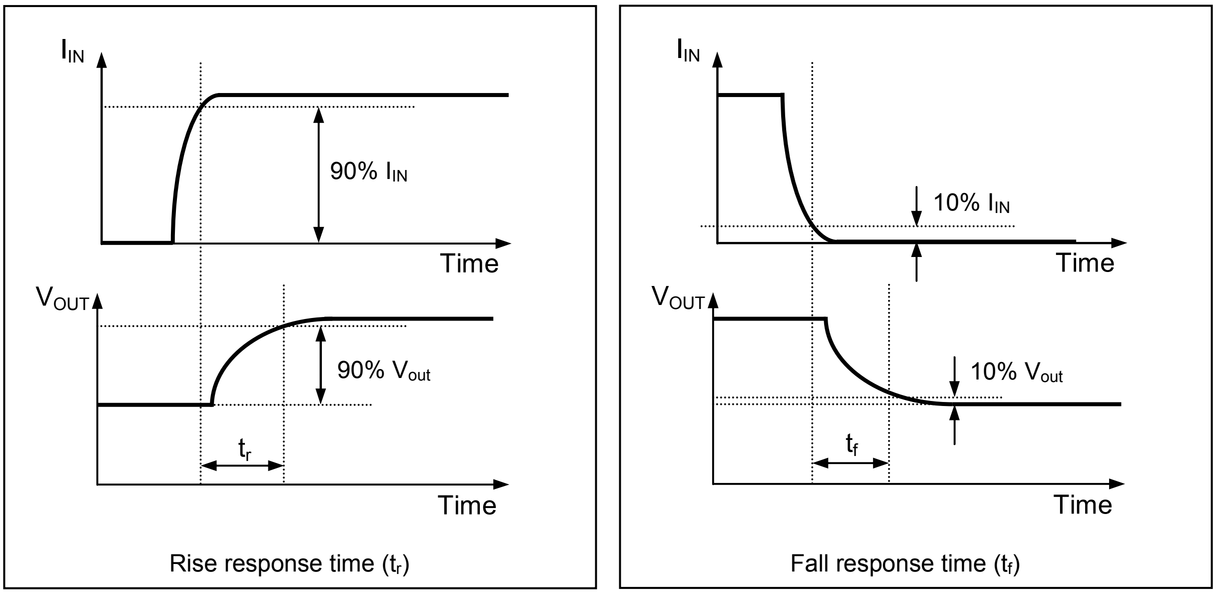
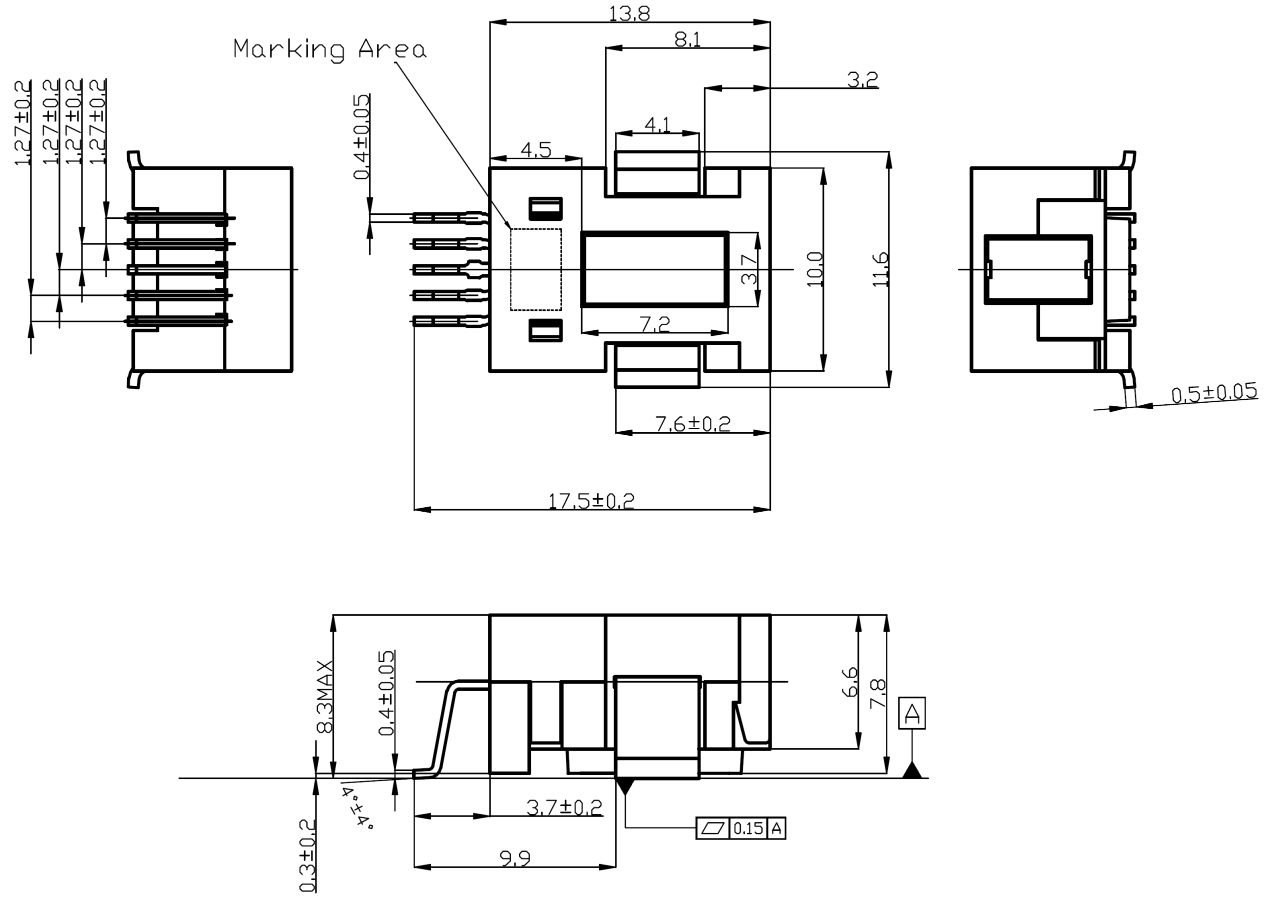


Figure 8. Definition of response time

Package Dimensions



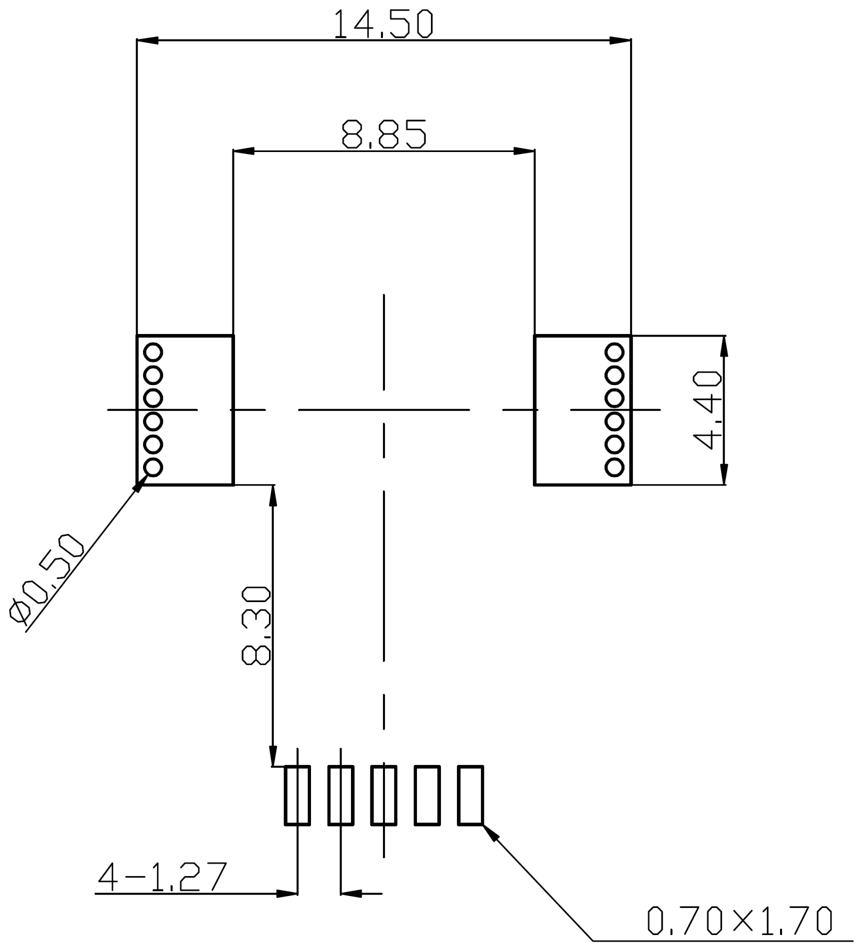
Unit:mm

Note1) The tolerances of dimensions without any mention are ±0.1mm.
Note2) Package contains some adhesive materials (RoHS compliant, halogen free) to hold the magnetic core.

Terminals: Cu
Plating for Terminals: Sn (100%)
RoHS compliant, halogen free

Figure 9. Package outline

Recommended Land Pattern (Reference Only)



Unit:mm

Figure 10. Recommended land pattern of CQ-2093

Note) If 2 or more trace layers are used as the current path, please make enough number of through-holes to flow current between the trace layers.

Application Circuits

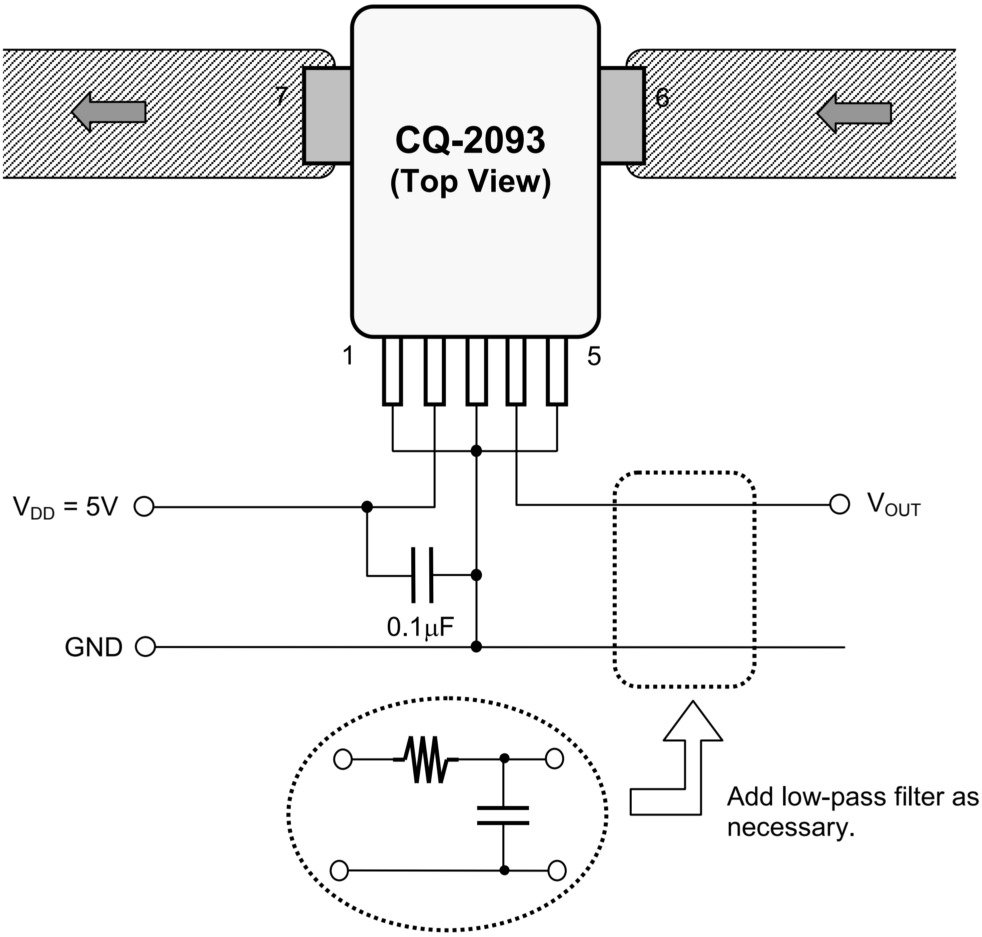


Figure 11. Application Circuits of CQ-2093

Markings

Production information is printed on the package surface by laser marking. Markings consist of 12 characters (6 characters × 2 lines).

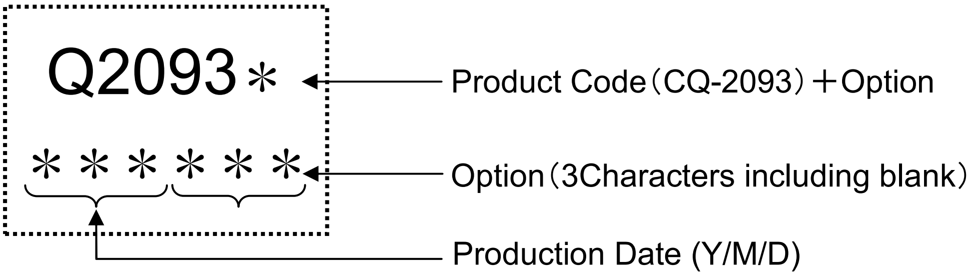


Figure 12. Markings of CQ-2093

Table 6. Production date code table

Last Number of Year		Month		Day	
Character	Number	Character	Month	Character	Day
0	0	C	Jan.	1	1
1	1	D	Feb.	2	2
2	2	E	Mar.	3	3
3	3	F	Apr.	4	4
4	4	G	May.	5	5
5	5	H	Jun.	6	6
6	6	J	Jul.	7	7
7	7	K	Aug.	8	8
8	8	L	Sep.	9	9
9	9	M	Oct.	0	10
		N	Nov.	A	11
		P	Dec.	B	12
				C	13
				D	14
				E	15
				F	16
				G	17
				H	18
				J	19
				K	20
				L	21
				N	22
				P	23
				R	24
				S	25
				T	26
				U	27
				V	28
				W	29
				X	30
				Y	31

Reliability Tests

Table 7. Test parameters and conditions of reliability test

No.	Test Parameter	Test Conditions	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	Heat Cycle Test	【JEITA EIAJ ED-4701 105】 −40°C ↔ 25°C ↔125°C 30min. ↔ 5min. ↔30min. Tested in vapor phase	22	100 cycles
6	Vibration Test	【JEITA EIAJ ED-4701 403】 Vibration frequency: 10~55Hz (1min.) Vibration amplitude: 1.5mm (x, y, z directions)	5	2h for each direction

Tested samples are pretreated as below before each reliability test:

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

Criteria：

Products whose drifts before and after the reliability tests do not exceed the values below are considered to be in spec.

Sensitivity V_h (T_a=25°C) : Within ±1.5%
Offset Voltage V_{of} (T_a=25°C) : Within ±100mV
Linearity ρ (T_a=25°C) : Within ±1%