AsahiKASEI
MICRODEVICES

CQ-361x
Σ-Δ Digital Coreless Current Sensor

1. General Description

CQ-361x is an open-type current sensor using Hall sensors. It has a Sigma Delta modulator producing a 1-bit data stream whose density is proportional to an AC current / a DC current. Ultra-low noise property is realized by III-V compound semiconductor Hall elements. Coreless ultra-small surface mount package realizes the space-saving. In addition, the low primary conductor resistance suppresses heat generation to achieve the $60A_{rms}$ continuous current. These features contribute to miniaturize your substrate and system size.

The CQ-361x series also has isolation performance as defined by safety standard of UL 61800-5-1, which is an excellent fit for robotics, AC servo motors, and so on.

2. Features

- Σ-Δ modulator 20MHz(Output Clock)
- Ultra-low noise(Effective number of bits:12.0~14.5 bits)
- Small-sized surface mount package (12.7mm×10.9mm×2.25mm)
- Maximum primary current : $60A_{rms}$
- Quite small primary conductor resistance : 0.27mΩ Typ.
- No need of isolated power supply
- Stray magnetic field reduction function
- Isolation performance as defined by safety standard of UL61800-5-1
- Certified with safety standard of UL-1577 and IEC/UL62368-1.
- Isolation Voltage:5.0kV (AC50Hz, 60s)

3. Applications

- Robotics
- AC Servo motors

CQ-361x is suitable for other applications which are required isolation with small size and suppressing the heating. (For example, Shunt + Isolated ADC replacement)

4. Table of Contents

5. CQ-36xx Series

Table 1. CQ-36xx Series

AVDD (V)	DVDD (V)	Ratio / Non-ratio	Output Voltage (V)	Maximum Primary Current (Arms)	Clock Type	Clock Frequency (MHz)	Series
5.0	3.3	Non-Ratio	3.3	60	Input	20	CQ-360x
					Output	20	CQ-361x
					Input	10	CQ-362x
					Output	10	CQ-363x

Table 2. Sensitivity and Linear Sensing Range

Part Number	I_{NS} (A)	Sensitivity (%/A)
CQ-36x1	±10.5	4.00
CQ-36x2	±21	2.00
CQ-36x3	±42	1.00
CQ-36x4	±60	0.700
CQ-36x5	±84	0.500
CQ-36x6	±168	0.250

6. Block Diagram and Functions

6.1. Block Diagram

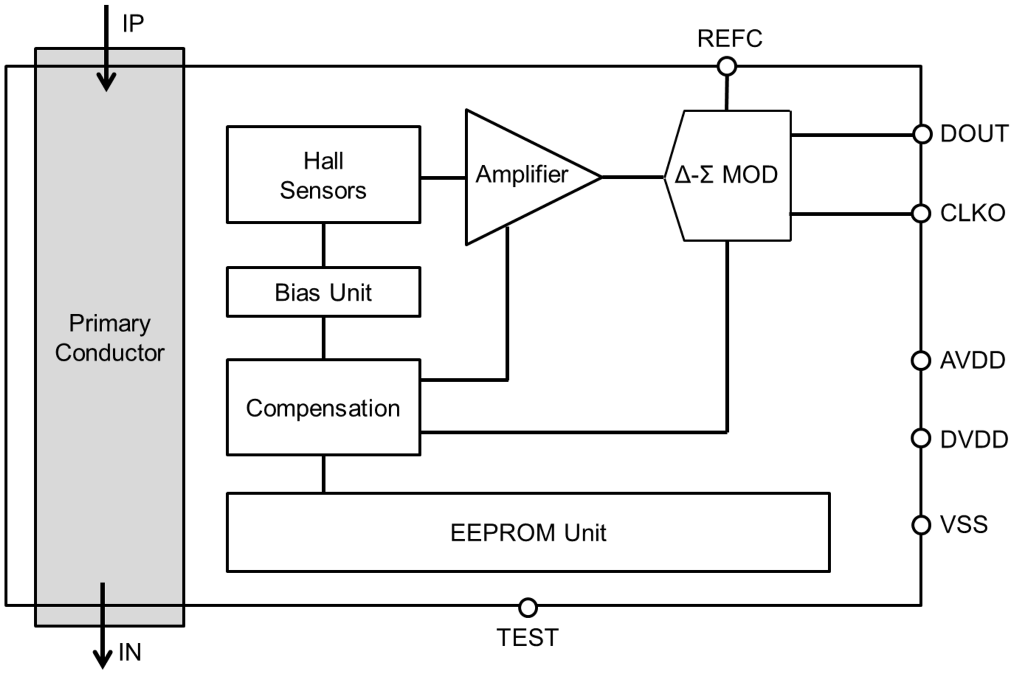


Figure 1. Block diagram of CQ-361x

6.2. Functions

Table 3. Explanation of circuit blocks

Circuit Block	Function
Primary Conductor	A device has the primary conductor built-in.
Hall Sensors	Hall elements which detect magnetic flux density generated from the measured current.
Amplifier	Amplifier of Hall elements' output.
Σ-Δ MOD	Σ-Δ modulator. C-MOS data output type. Operated by output clock.
Compensation	Compensation circuit which adjusts the temperature drifts of sensitivity and zero-current output.
Bias Unit	Drive circuit for Hall elements.
EEPROM Unit	Non-volatile memory for setting adjustment parameters.

7. Pin Configurations and Functions

7.1. Pin Configurations

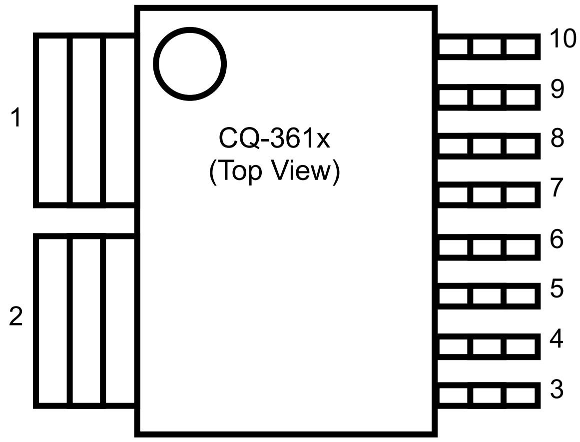


Figure 2. Pin configurations of CQ-361x

7.2. Functions

Table 4. Pin configuration and functions of CQ-361x

Pin No.	Pin Name	I/O	Type	Function
1	IP	I	-	Primary conductor pin (+)
2	IN	I	-	Primary conductor pin (-)
3	VSS	GND	-	Ground pin (GND)
4	REFC	—	-	External capacitor pin for Σ-Δ MOD
5	TEST	—	-	Test pin(Recommended external connection: GND)
6	DOUT	O	Digital	Data output pin(3.3V)
7	CLKO	O	Digital	Output clock pin (3.3V, 20MHz)
8	DVDD	PWR	Power	Digital power supply pin (3.3V)
9	AVDD	PWR	Power	Analog power supply pin (5V)
10	VSS	GND	-	Ground pin (GND)

An input current of 0A to the primary conductor ideally produces a data stream of 50% zeros of the time and 50% ones of the time. An input current of $+I_{NS}$(IP to IN) to the primary conductor produces a data stream of 8% zeros of the time and 92% ones of the time. An input current of $-I_{NS}$(IP to IN) to the primary conductor produces a data stream of 92% zeros of the time and 8% ones of the time. Full scale (F.S.) of output density is defined as 84%, which is the value between 8% and 92%($-I_{NS}$ to $+I_{NS}$) .

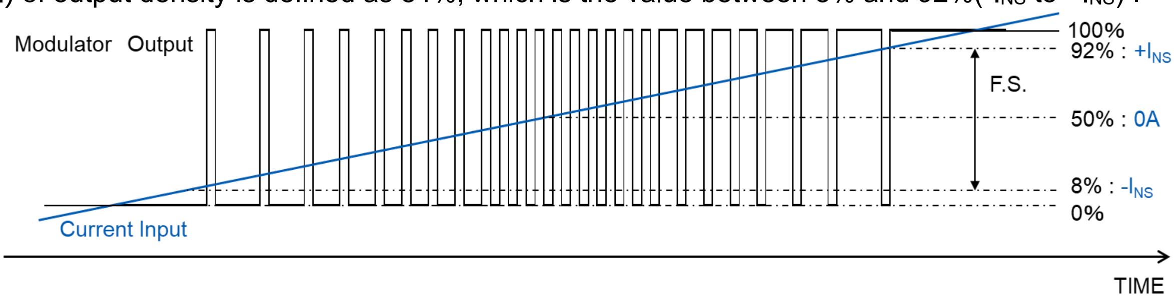


Figure 3. Typical output characteristics of CQ-361x

8. Absolute Maximum Ratings

Table 5. Absolute maximum ratings

Parameter	Symbol	Min.	Max.	Units	Notes
Analog Supply Voltage	AVDD	-0.3	6.5	V	AVDD pin
Digital Supply Voltage	DVDD	-0.3	6.5	V	DVDD pin
Digital Output Current	I_{OUT}	-10	10	mA	DOUT pin and CLKO pin
Junction Temperature	T_j	-40	150	°C	
Storage Temperature	T_{STG}	-55	150	°C	

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

9. Recommended Operating Conditions

Table 6. Recommended operating conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Analog Supply Voltage	AVDD	4.5	5.0	5.5	V	AVDD pin
Digital Supply Voltage	DVDD	3.0	3.3	3.6	V	DVDD pin
Sensor Output Load Capacitance	C_{LDOUT}			30	pF	Between DOUT pin and VSS pin
Clock Output Load Capacitance	C_{LCLKO}			30	pF	Between CLKO pin and VSS pin
Sensor Output Load Resistance	R_{LDOUT}	18			kΩ	Between DOUT pin and VSS pin
Clock Output Load Resistance	R_{LCLKO}	18			kΩ	Between CLKO pin and VDD pin
Operating Ambient Temperature	T_a	-40		125	°C	
Case Temperature Note 1)	T_c	-40		130	°C	Under the condition of safety standard of UL61800-5-1
Maximum Primary Current (RMS)	I_{RMSmax}			60	A_{rms}	Continuous DC value or RMS value which can be applied to the primary conductor

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

Note1) Continuous 60A_{rms} current can be flowed through this IC, and even a larger current can be flowed transiently. Using as your system under the condition of safety standard of UL61800-5-1, the case temperature of this IC should be less than 130°C.

10. Electrical Characteristics

Table 7. Electrical Characteristics

Conditions (unless otherwise specified) :
T_a = 35°C, AVDD = 5.0V, DVDD = 3.3V, CLKO=20MHz,16bit, and Sinc3 filter with OSR =256

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units
Analog Current Consumption	I_{AVDD}	I_{IN}=0A, C_L=30pF			48.1	58.1	mA
Digital Current Consumption	I_{DVDD}	I_{IN}=0A, C_L=30pF			3.8	4.1	mA
Sensitivity Note 2)	D_h		CQ-3611	3.96	4.00	4.04	%/A
			CQ-3612	1.98	2.00	2.02	
			CQ-3613	0.990	1.00	1.01	
			CQ-3614	0.693	0.700	0.707	
			CQ-3615	0.495	0.500	0.505	
			CQ-3616	0.247	0.250	0.253	
Zero-Current Output Note 2)	D_{of}	I_{IN}=0A		49.58	50	50.42	%
Output Saturation Density H	D_{satH}	I_{IN}=+I_{NS}		92			%
Output Saturation Density L	D_{satL}	I_{IN}=-I_{NS}				8	%
Linear Sensing Range Note 3)	I_{NS}		CQ-3611	-10.5		10.5	A
			CQ-3612	-21		21	
			CQ-3613	-42		42	
			CQ-3614	-60		60	
			CQ-3615	-84		84	
			CQ-3616	-168		168	
Linearity Error Note 2) Note 3)	ρ		CQ-3611	-0.35	±0.26	0.35	%F.S.
			CQ-3612	-0.35	±0.26	0.35	
			CQ-3613	-0.35	±0.26	0.35	
			CQ-3614	-0.35	±0.26	0.35	
			CQ-3615	-0.35	±0.26	0.35	
			CQ-3616	-0.45	±0.35	0.45	
Response Time Note 4)	t_r	ΔI_{IN} 90% to ΔD_{out} 90%, Sinc3 filter with OSR=64			13		μs
Bandwidth Note 4)	f_T	Sinc3 filter with OSR=64			80		kHz
Signal-to-Noise Ratio	S_{NR}	I_{IN}=0A	CQ-3611		74.6		dB
			CQ-3612		79.4		
			CQ-3613		84.8		
			CQ-3614		86.6		
			CQ-3615		87.8		
			CQ-3616		89.0		
Effective Number of Bits	E_{NOB}	I_{IN} =0A	CQ-3611		12.0		bits
			CQ-3612		12.9		
			CQ-3613		13.8		
			CQ-3614		14.1		
			CQ-3615		14.3		
			CQ-3616		14.5		

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
PSRR	P_{srr}	200mVpp sine wave on AVDD, frequency=1MHz		-110		dB
Stray Magnetic Field Reduction	E_{bc}	Equivalent to zero-current output drift -10mT < stray Magnetic field <10mT		±0.01		A/mT
Primary Conductor Resistance Note 3)	R_P	T_c = 35°C		0.27		mΩ
Thermal Resistance Junction to Ambient	θ_{ja}	Board Layout is Figure 8. $\Delta T=R_p\times I_{IN}^2\times\theta_{ja}/1000$		29		°C/W
Isolation Voltage Note 6)	V_{INS}	AC50Hz, 60s	5.0			kV_{rms}
Isolation Resistance Note 3)	R_{INS}	DC1kV	500			MΩ
Retention Time of EEPROM data	EEP_{RT}	T_j = 105°C	10			Year
		T_j = 100°C	15			

Table 8. Temperature drift characteristics

Conditions (unless otherwise specified) :
AVDD = 5.0V, DVDD = 3.3V, CLKO=20MHz,16bit, and Sinc3 filter with OSR =256

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Units
Temperature Drift of Sensitivity Note 5) Note 7) Note 8)	$D_{h\text{-}d}$	T_a =-10~85°C		-0.9	0.8	1.3	%
		T_a =-10~125°C		-0.9	0.8	1.3	
		T_a =-40~125°C		-0.9	2.2	3.3	
Temperature Drift of Zero-current Output Note 5) Note 7) Note 8)	D_{of_d}	T_a = -10~85°C I_{IN}=0A	CQ-3611	-0.09	±0.04	0.08	%F.S.
			CQ-3612	-0.04	±0.02	0.04	
			CQ-3613	-0.03	±0.01	0.03	
			CQ-3614	-0.02	±0.01	0.02	
			CQ-3615	-0.02	±0.01	0.02	
			CQ-3616	-0.02	±0.01	0.02	
		T_a = -10~125°C I_{IN}=0A	CQ-3611	-0.11	±0.04	0.11	%F.S.
			CQ-3612	-0.05	±0.03	0.06	
			CQ-3613	-0.03	±0.02	0.04	
			CQ-3614	-0.02	±0.01	0.03	
			CQ-3615	-0.02	±0.01	0.03	
			CQ-3616	-0.02	±0.01	0.02	
		T_a = -40~125°C I_{IN}=0A	CQ-3611	-0.13	±0.05	0.12	%F.S.
			CQ-3612	-0.07	±0.03	0.07	
			CQ-3613	-0.03	±0.02	0.04	
			CQ-3614	-0.03	±0.01	0.03	
			CQ-3615	-0.03	±0.01	0.03	
			CQ-3616	-0.02	±0.01	0.02	
Total Accuracy Note 5) Note 8)	E_{total}	T_a = -10~85°C	CQ-3611	-1.3	0.9	1.5	%F.S.
			CQ-3612	-1.3	0.8	1.4	
			CQ-3613	-1.2	0.8	1.4	
			CQ-3614	-1.2	0.8	1.4	
			CQ-3615	-1.2	0.8	1.4	
			CQ-3616	-1.3	0.9	1.5	
		T_a = -10~125°C	CQ-3611	-1.3	0.9	1.5	
			CQ-3612	-1.3	0.8	1.4	
			CQ-3613	-1.2	0.8	1.4	
			CQ-3614	-1.2	0.8	1.4	
			CQ-3615	-1.2	0.8	1.4	
			CQ-3616	-1.3	0.9	1.5	
		T_a = -40~125°C	CQ-3611	-1.3	1.5	2.5	
			CQ-3612	-1.3	1.5	2.5	
			CQ-3613	-1.2	1.4	2.4	
			CQ-3614	-1.2	1.4	2.4	
			CQ-3615	-1.2	1.3	2.3	
			CQ-3616	-1.5	1.4	2.5	

Table 9. Digital characteristics

Conditions (unless otherwise specified) : T_a =35°C, AVDD =5.0V, DVDD = 3.3V

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
CLKO period	t_{CLKO}		45.45	50	55.56	ns
CLKO Frequency	t_{CLKOF}		18	20	22	MHz
CLKO High Pulse Width	t_{CLKOH}		0.45× t_{CLKO}	0.5× t_{CLKO}	0.55× t_{CLKO}	ns
CLKO Low Pulse Width	t_{CLKOL}		0.45× t_{CLKO}	0.5× t_{CLKO}	0.55× t_{CLKO}	ns
CLKO " ↑ " to DOUT data Delay	t_d			0	5	ns
CLKO High-Level Output Voltage	V_{CLKOH}	with 18kΩ(R_{LCLKO})	DVDD-0.2			V
CLKO Low-Level Output Voltage	V_{CLKOL}	with 18kΩ(R_{LCLKO})			0.2	V
DOUT High-Level Output Voltage	V_{OH}	with 18kΩ(R_{LDOUT})	DVDD-0.2			V
DOUT Low-Level Output Voltage	V_{OL}	with 18kΩ(R_{LDOUT})			0.2	V

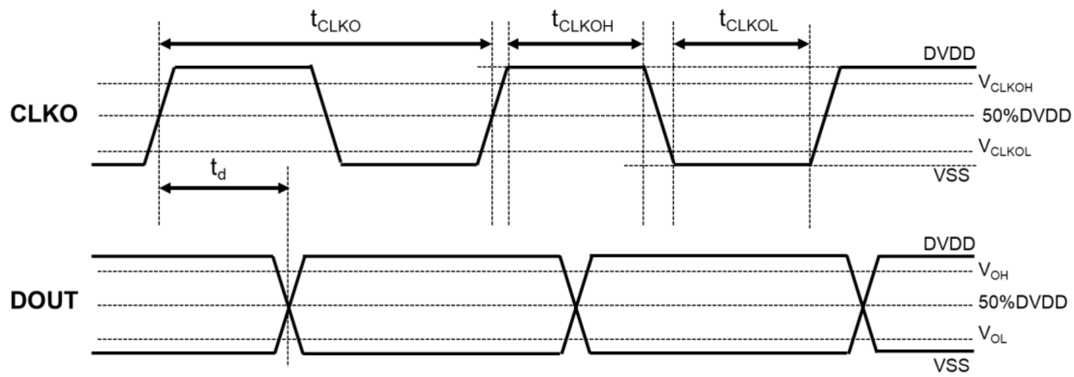


Figure 4. Data Output Timing

Note 2) These values can be drifted by long-term use or reflow process. Please check '15.Reliability Tests' for the reference of drift values.

Note 3) These parameters are guaranteed by design.

Note 4) These parameters are tested to input the equivalent current signal into IC in wafer condition. These characteristics after assembly are guaranteed by design.

Note 5) These values can be drifted by long-term use or reflow process.

Note 6) This parameter is tested for 1second at 6kV_{rms} in mass-production line for all devices.

Note 7) These parameters are defined as the drift from the values at T_a=35°C.

Note 8) The typical value is defined as the "average value ± 1σ" of the actual measurement result in a certain lot.

11. Characteristic Descriptions

11.1. Sensitivity (D_h), Zero-Current Output (D_{of}), and Linearity Error (ρ) are defined as below:

Sensitivity (D_h) is defined as the slope of the approximate straight line calculated by the least square method, using the data of output (D_{out}) when the primary current (I_{IN}) is swept within the range of linear sensing range (I_{NS}).
The output (D_{out}) when the primary current (I_{IN}) is 0A is the Zero-Current output (D_{of}).
Linearity error (ρ) is defined as the ratio of the maximum error (D_d) to the full scale (F.S. = 84%), where D_d is the maximum difference between the output (D_{out}) and the approximate straight line. Definition formula is shown as below:

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

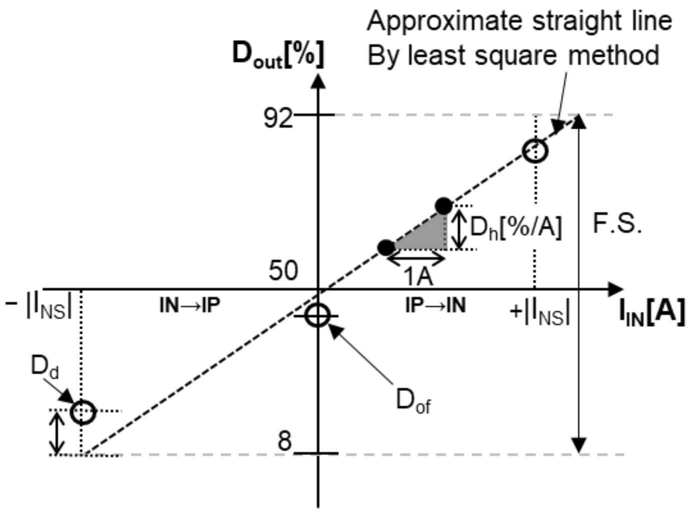


Figure 5. Characteristic definitions of CQ-361x

11.2. Total Accuracy E_{total} [%F.S.] is defined as below:

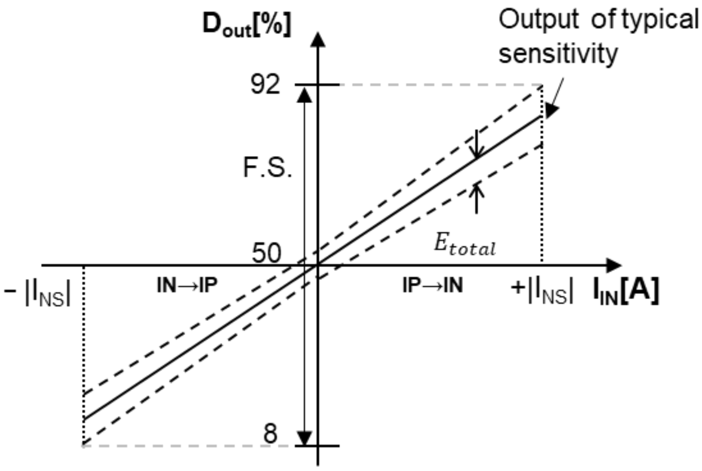


Figure 6. Total Accuracy definitions of CQ-361x

$$E_{total} = \frac{(D_{h-meas} - D_h) \times I_{NS}}{F.S.} + \frac{D_{of-d}}{F.S.} + \rho_{meas}$$

D_{h-meas} : Measured Sensitivity value [%/A]
D_h : Sensitivity (Typ.) [%/A]
D_{of-d} : Measured Temperature Drift of Zero-Current Output [%]
ρ_{meas} : Measured Linearity Error [%F.S.]

11.3. Signal-to-Noise Ratio S_{NR} [dB] is defined as below:

$$S_{NR} = 20 \times \log_{10}\left(\frac{\frac{|I_{NS}|}{\sqrt{2}}}{N_{rms}}\right) \text{[dB]}$$

N_{rms}: Noise [A_{rms}]

(with digital filter Sinc3, OSR=256, DC~10kHz, I_{IN}=0A)

11.4. Effective Number of Bits E_{NOB} [bits] is defined as below:

$$E_{NOB} = \frac{S_{NR} - 1.76}{6.02} \text{ [bits]}$$

12. Recommended External Circuits

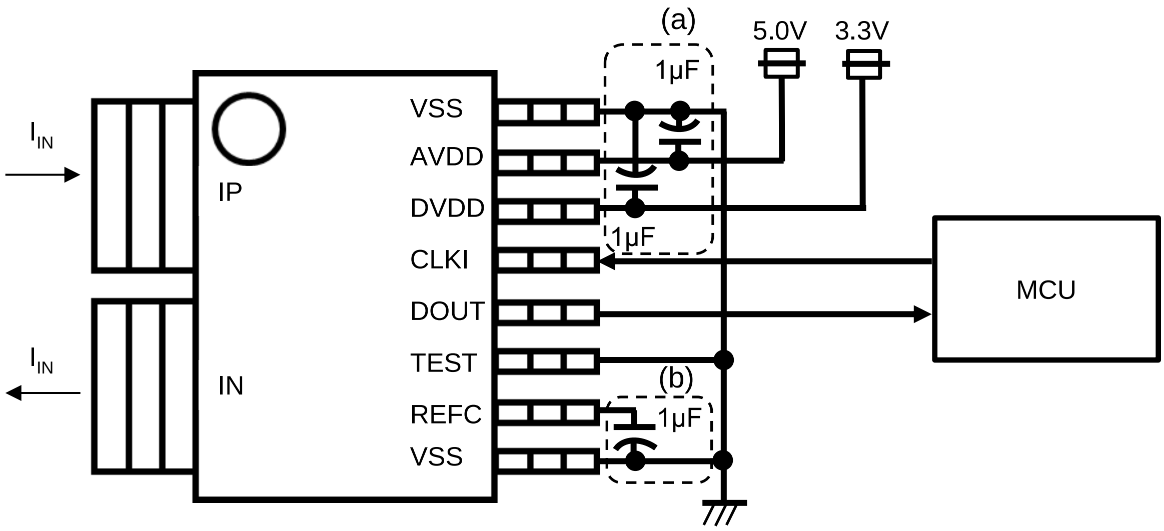


Figure 7. Recommend External Circuit of CQ-361x

(a) Please place a 1μF bypass capacitor as close as possible to the AVDD, DVDD, and VSS pins of the CQ-361x.
(b) Insert a 1μF capacitor between the REFC pin and VSS for output stabilization.

13. Board Layout for Measuring Thermal Resistance

Table 10. Board information

Board Size	68.6mm×68.6mm
Layer number	4
Copper layer thickness	70μm
Board Thickness	1.6mm

・Top pattern(1st) ・Inner pattern(2nd/3rd VSS) ・Bottom pattern(4th)

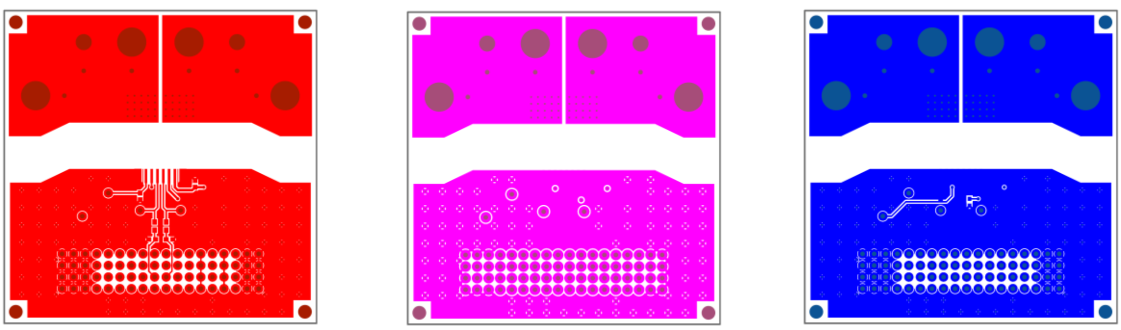
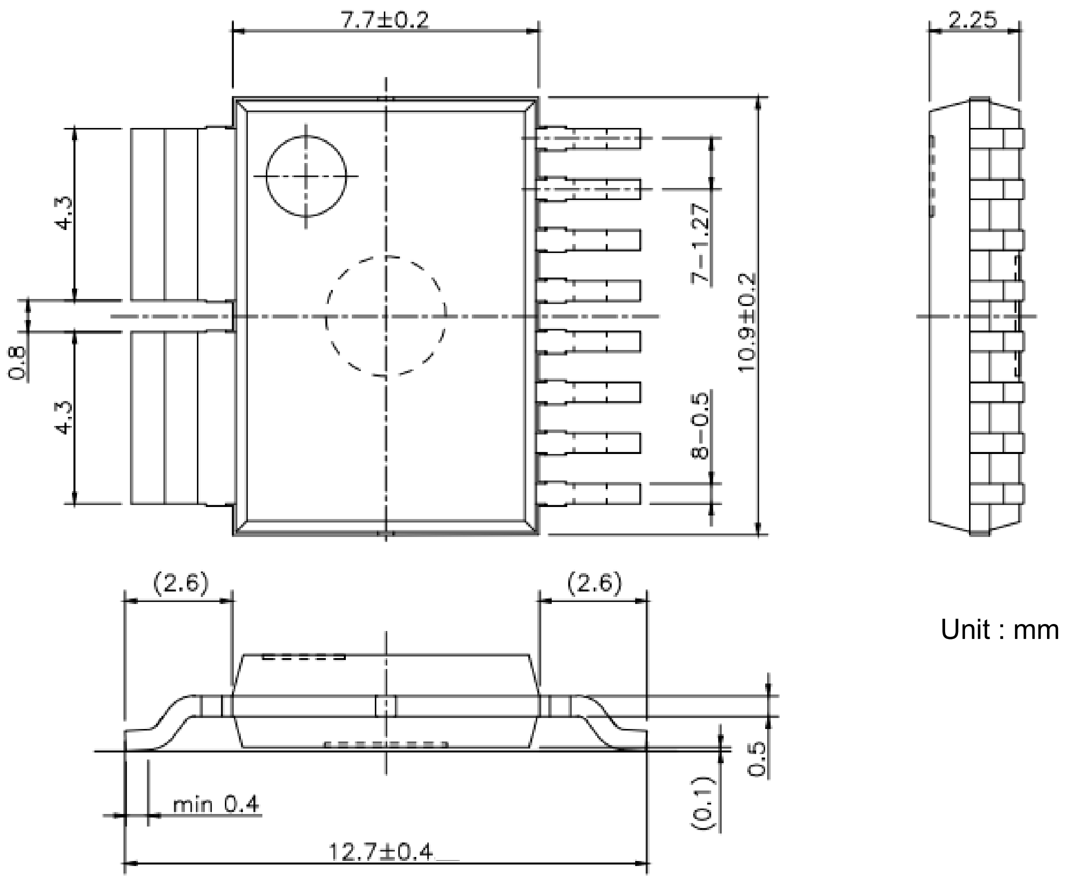


Figure 8. Board layout for measuring thermal resistance of CQ-361x

14. Package

14.1. Outline Dimensions



The tolerances of dimensions without any mention are ±0.1mm.
(   ) is a reference values.

Figure 9. Outline dimensions of CQ-361x

Terminals : Cu
Plating for Terminals : Sn-Bi
Package material : RoHS compliant, halogen-free

Table 11. Isolation characteristics of CQ-361x

Parameter	Symbol	Min.	Typ.	Max.	Units
Creepage distance	Cr	8.0			mm
Clearance distance	Cl	8.0			mm

*Flammability standard is V0. (According to UL94)
*Comparative tracking index (CTI) is 400V. Material Group is II.

14.2. Standards

・IEC/UL 62368-1 Audio/video, information and communication technology equipment Part 1: Safety requirements Edition 2. (File No. E359197)
・CSA C22.2 No.62368-1-14 Audio/video, information and communication technology equipment Part 1: Safety requirements Edition 2. (File No. E359197)
・UL1577-Non-optical Isolators-Edition 5.(File No. E499004)
・CSA Component Acceptance Service No. 5A - Component Acceptance Service for Optocouplers and Related Devices (File No. E499004)

14.3. Recommended Pad Dimensions

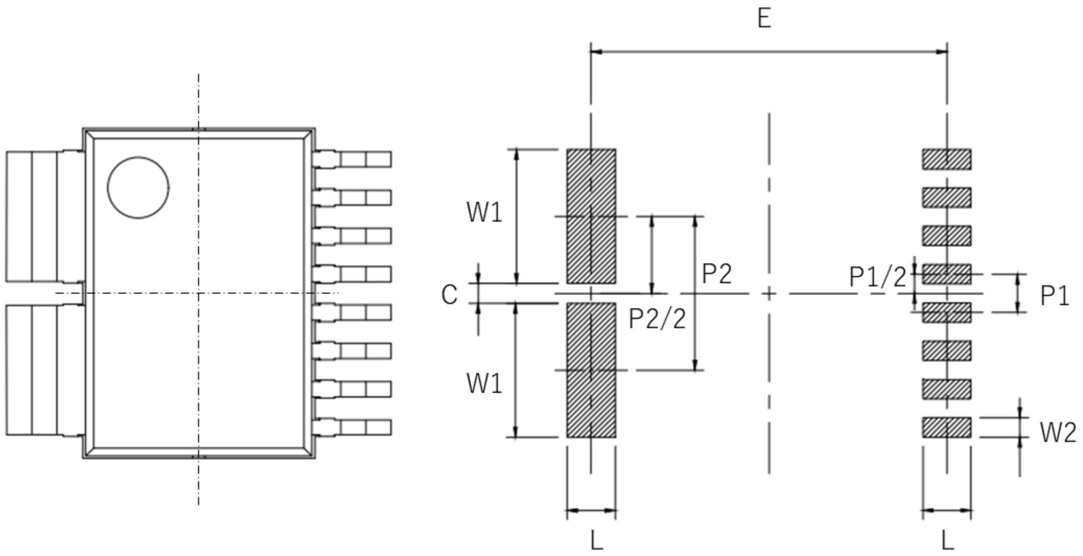


Figure 10. Recommended pad pattern

Table 12. Recommended pad dimensions

L	1.59
E	11.79
W1	4.44
W2	0.64
C	0.66
P1	1.27
P2	5.10

Unit:mm

If two or more trace layers are used as the current paths, please make enough number of through-holes to flow current between the trace layers. In order to make heat dissipation better, it is recommended that Pad on Via should be provided on the pad of the primary conductor.

14.4. Marking

Production information is printed on the package surface by laser marking. Markings consist of 11 characters excluding Asahi Kasei logo.

Asahi Kasei
C Q 3 6 X_a X_b ← Production Code (CQ-36X_aX_b)
Y M D L_2 L_1 ← Production Date (Y/M/D/L_2/L_1)

Figure 11. Markings of CQ-361x

Table 13. Production date code table

CLK frequency /Type (X_a)		Sensitivity (X_b)		Year (Y)		Month (M)		Day (D)		Lot number (L_2, L_1)	
Char-acter	CLK frequency /Type	Char-acter	Sensitivity (%/A)	Char-acter	Year	Char-acter	Month	Char-acter	Day	Character	
0	20MHz/ Input	1	4.00	D	2023	C	January	1	1	0	1
1	20MHz /Output	2	2.00	E	2024	D	February	2	2	1	2
2	10MHz /Input	3	1.00	F	2025	E	March	3	3	2	3
3	10MHz /Output	4	0.700	G	2026	F	April	4	4	3	4
		5	0.500	H	2027	G	May	5	5	4	5
		6	0.250	J	2028	H	June	6	6	5	6
				K	2029	J	July	7	7	6	7
				L	2030	K	August	8	8	7	8
				N	2031	L	September	9	9	8	9
				P	2032	M	October	0	10	9	0
				R	2033	N	November	A	11	A	A
				S	2034	P	December	B	12	B	B
				T	2035			C	13	C	C
				U	2036			D	14	D	D
				V	2037			E	15	E	E
				W	2038			F	16	F	F
				X	2039			G	17	G	G
				0	2040			H	18	H	H
				1	2041			J	19	J	J
				2	2042			K	20	K	K
				3	2043			L	21	L	L
				4	2044			N	22	N	N
				5	2045			P	23	P	P
				6	2046			R	24	R	R
				7	2047			S	25	S	S
				8	2048			T	26	T	T
				9	2049			U	27	U	U
				A	2050			V	28	V	V
				B	2051			W	29	W	W
				C	2052			X	30	X	X
								Y	31	Y	Y

15. Reliability Tests

No.	Test Parameter	Test Conditions【Reference】	n	Test Time
1	Temperature Humidity Bias Test	【JEITA EIAJ ED-4701 102】 T_a=85°C, 85%RH, continuous operation	66	1000h
2	High Temperature Operating Life Test	【JEITA EIAJ ED-4701 101】 T_a =150°C, continuous operation	88	1000h
3	High Temperature Storage Test	【JEITA EIAJ ED-4701 201】 T_a=150°C	40	1000h
4	Low Temperature Operating Life Test	【JEITA EIAJ ED-4701 101】 T_a=−40°C, continuous operation	44	1000h
5	Temperature Cycle Test	【JEITA EIAJ ED-4701 105】 −65°C ↔ +150°C 30min. ↔ 30min. Tested in vapor phase	100	500cycle

Tested samples are pretreated as below before each reliability test:
Desiccation: 125°C/24h → Moisture Absorption: 60°C/60%RH/168h
→ Reflow: 3 times (JEDEC Level 2a)

Criteria:

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

Sensitivity D_h (T_a=35°C) : Within ±2.5%
Linearity Error ρ (T_a=35°C) : Within ±0.24%F.S.
CLK period fluctuation (T_a=35°C) : Within ±2.0%
EEPROM data : Unchanged
Zero-Current Output D_{of} (T_a=35°C) : As shown in the table below

Part number	Zero-Current Output D_{of} (T_a=35°C)
CQ-3611	Within ±0.60%F.S.
CQ-3612	Within ±0.27%F.S.
CQ-3613	Within ±0.18%F.S.
CQ-3614	Within ±0.13%F.S.
CQ-3615	Within ±0.13%F.S.
CQ-3616	Within ±0.13%F.S.

16. Precautions

<Storage Environment>

Products should be stored at an appropriate temperature, and at as low humidity as possible by using desiccator (5 to 35°C). It is recommended to use the products within 4 weeks since packing was opened. Keep products away from chlorine and corrosive gas. When stored in an inappropriate environment, it can affect the product properties.

<Long-term Storage>

Long-term storage may result in poor lead solderability and degraded electrical performance even under proper conditions. For those parts, which stored long-term should be checked as for solderability before it is used.
For storage longer than 1 year, it is recommended to store in nitrogen atmosphere. Oxygen of atmosphere oxidizes leads of products, and lead solderability get worse.

<Other Precautions>

1) This product should not be used under the environment with corrosive gas including chlorine or sulfur.
2) This product is lead (Pb) free. All leads are plated with Sn-Bi. Do not store this product alone in high temperature and high humidity environment. Moreover, this product should be mounted on substrate within six months after delivery.
3) This product is damaged when it is used on the following conditions:
- Supply voltage is applied in the opposite way.
- Overvoltage which is larger than the value indicated in the specification.
4) This product will be damaged if it is used for a long time with the current (effective current) which exceeds the current rating. Careful attention must be paid so that maximum effective current is smaller than current rating.
5) The characteristics can be changed by the influences of nearby current and magnetic field and electric field. Please make sure of the mounting position.

As this product contains gallium arsenide, observe the following procedures for safety.
1) Do not alter the form of this product into a gas, powder, liquid, through burning, crushing, or chemical processing.
2) Observe laws and company regulations when discarding this product.

17. Revision History

Date (Y/M)	Revision	Page	Contents
25/01	00	19	
25/09	01	4	Revised the Compensation section
		7	Revised the notes Corrected the Linearity Error values Revised the Response time condition
		12	Corrected the units for Noise and ENOB

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