

Pin Descriptions

Package	SOT23		SOT25	Description
Name	ZXCT1107Q	ZXCT1109Q	ZXCT1110Q	
OUT	1	1	3	Output pin (Note 5). Current output.
S+	3	2	4	This is the positive input of the current monitor and has a wide common-mode input range. This also acts as the analog supply and provides power to internal circuitry. The current through this pin varies with differential sense voltage.
S-	2	3	5	This is the negative input of the current monitor and has a wide common-mode input range.
GND	—	—	2	Ground pin and substrate connection.
NC	—	—	1	No connection.

Note: 5. For the ZXCT1107Q and ZXCT1109Q pin 1 (OUT) acts as both the output pin and substrate connection. This means that for the ZXCT1107Q and ZXCT1109Q the minimum rail voltage that can be used is $2.5V + V_{OUT}$ (see applications section for more details).

Absolute Maximum Ratings

Description		Rating	Unit
Voltage on S- and S+ relative to OUT (ZXCT1107Q/09Q)		-0.3 to 40	V
Voltage on S- and S+ relative to GND (ZXCT1110Q)		-0.3 to 40	V
Voltage on OUT to GND (ZXCT1110Q)		-0.3 to V _{S+}	V
Differential Sense Voltage, V _{SENSE} (Notes 6 and 7)		-0.3 to +0.8	V
Maximum Current into S+ and S- (Note 7)		±8.5	mA
Storage Temperature		-55 to +150	°C
Maximum Junction Temperature		+150	°C
Package Power Dissipation (T _A = +25°C) SOT23 SOT25		300 (Derate to Zero at +150°C) 300 (Derate to Zero at +150°C)	mW
ESD Ratings			
ZXCT1107Q/09Q			
HBM	Human Body Model	1,500	V
MM	Machine Model	150	V
CDM	Charged Device Model	1,000	V
ZXCT1110Q			
HBM	Human Body Model	1,000	V
MM	Machine Model	150	V
CDM	Charged Device Model	1,000	V

Notes: 6. $V_{SENSE} = V_{S+} - V_{S-}$.

7. The differential input voltage limit, $V_{S+} - V_{S-}$, may be exceeded provided that the input current limit into S+ or S- is not exceeded.
Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at conditions between maximum recommended operating conditions and absolute maximum ratings is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.
Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.)

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{S+}	Common-Mode Input Range (Note 5)	ZXCT1110Q	2.5	V
		ZXCT1107Q/09Q	$V_{OUT(MAX)} + 2.5$	
V_{SENSE}	Differential Sense Input Voltage Range ($V_{S+} - V_{S-}$) (Note 8)	0	0.5	V
V_{OUT}	Output Voltage Range ($0 \leq V_{SENSE} \leq 100mV$)	ZXCT1110Q	0	V
		ZXCT1107Q/09Q	0	
T_A	Ambient Temperature Range	-40	+125	°C

- Notes: 5. For the ZXCT1107Q and ZXCT1109Q pin 1 (OUT) acts as both the output pin and substrate connection. This means that for the ZXCT1107Q and ZXCT1109Q the minimum rail voltage that can be used is $2.5V + V_{OUT}$ (see applications section for more details).
8. The device operates linearly over the range $10mV \leq V_{SENSE} \leq 500mV$, however at $0V < V_{SENSE} < 10mV$ the output current due V_{SENSE} is not guaranteed to remain linear and may fall to 0.

Electrical Characteristics (@ $T_A = +25^\circ C$, $V_{S+} = 20V$, $V_{SENSE} = 100mV$, $R_{GAIN} = 0$, unless otherwise stated) (Note 6)

ZXCT1107Q, ZXCT1109Q

Symbol	Parameter	Conditions	T_A	Min	Typ	Max	Unit
I_{S-}	S- Input Current	$V_{SENSE} = 0V$	+25°C	—	19	100	nA
			-40°C	—	16	—	
			+125°C	—	35	—	
I_{OUT}	Output Current (Note 9)	$V_{SENSE} = 0mV$	+25°C	1	3	10	μA
			-40°C	—	2.2	—	
			+125°C	—	5.5	—	
		$V_{SENSE} = 10mV$	+25°C	37	45	54	
			-40°C	—	42	—	
			+125°C	—	49	—	
		$V_{SENSE} = 30mV$	+25°C	115	124	134	
			-40°C	—	119	—	
			+125°C	—	129	—	
		$V_{SENSE} = 100mV$	+25°C	394	408	422	μA
			-40°C	—	396	—	
			+125°C	—	420	—	
		$V_{SENSE} = 200mV$	+25°C	787	810	832	
			-40°C	—	785	—	
			+125°C	—	832	—	
		$V_{SENSE} = 500mV$	+25°C	1.965	2.015	2.064	mA
			-40°C	—	1.965	—	
			+125°C	—	2.065	—	
I_{OUT-TC}	Output Current Temperature Coefficient	—	Full Range	—	370	—	ppm/°C
CMSR	Common-Mode Sense Rejection	$V_{S+} = 2.5V$ to 36V	+25°C	—	0.1	0.4	$\mu A/V$
			-40°C	—	0.13	—	
			+125°C	—	0.05	—	
BW	-3dB Small Signal Bandwidth	$V_{SENSE(AC)} = 10mV_{PP}$ (Note 6) $R_{GAIN} = 2.5k\Omega$	+25°C	—	0.65	—	MHz

- Notes: 6. $V_{SENSE} = V_{S+} - V_{S-}$.
9. Output current characteristic measured with low impedance ammeter connected to GND.
- The device operates linearly over the range $10mV \leq V_{SENSE} \leq 500mV$. At $0 < V_{SENSE} < 10mV$ the output current due V_{SENSE} is not guaranteed to remain linear and may fall to 0.

Electrical Characteristics (Cont.) (@ $T_A = +25^\circ\text{C}$, $V_{S+} = 20\text{V}$, $V_{\text{SENSE}} = 100\text{mV}$, $R_{\text{GAIN}} = 0$, unless otherwise stated) (Note 6)

ZXCT1110Q

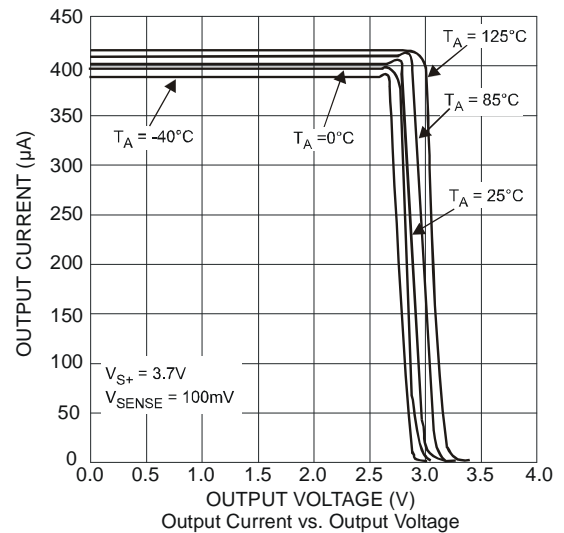
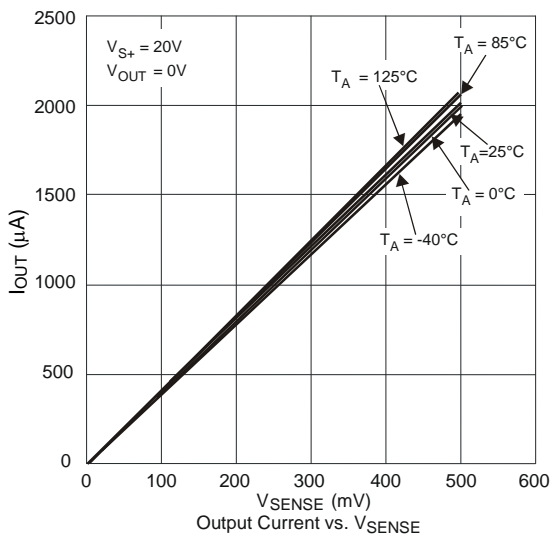
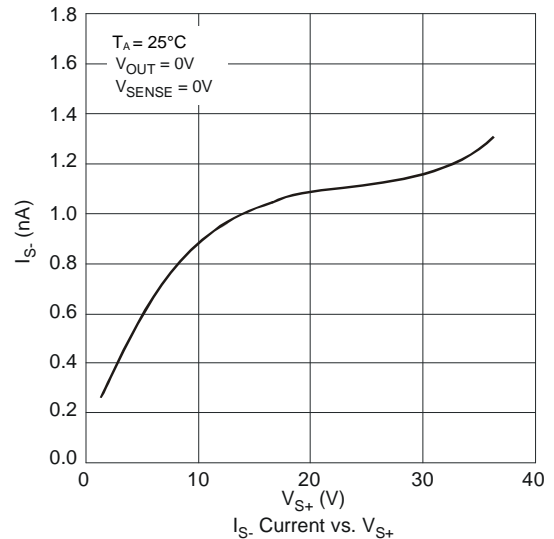
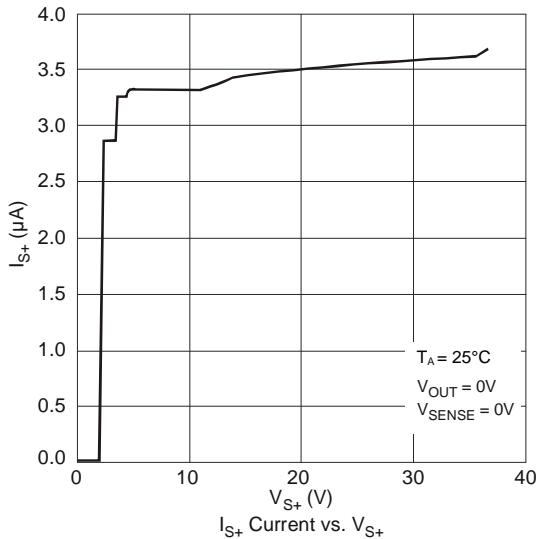
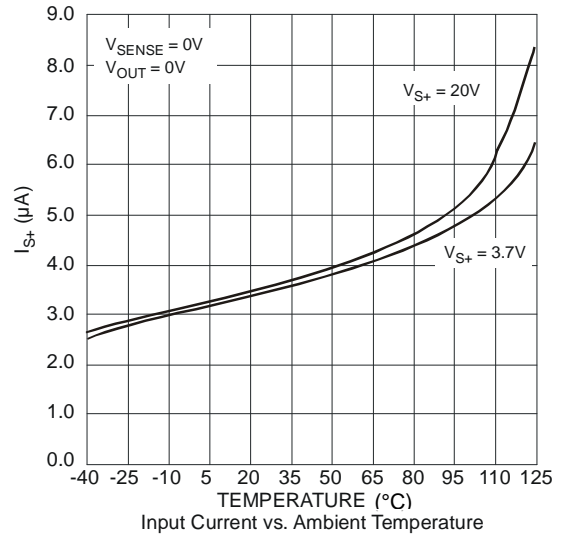
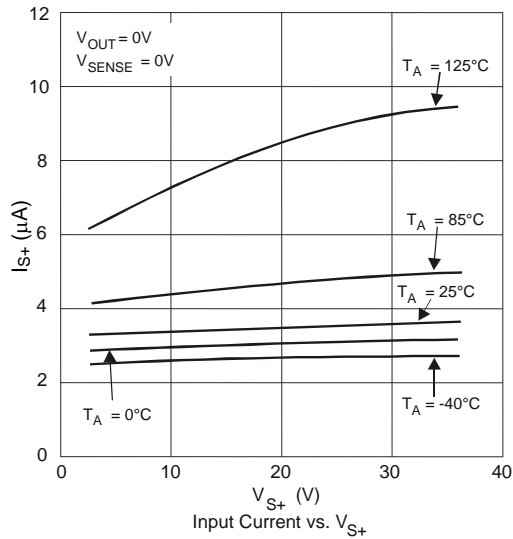
Symbol	Parameter	Conditions	T _A	Min	Typ	Max	Unit
I _Q	GND Pin Current	V _{SENSE} = 0V	+25°C	—	3	5	μA
			-40°C	—	2.2	—	
			+125°C	—	5.8	—	
I _{S-}	S- Input Current		+25°C	—	19	100	nA
			-40°C	—	16	—	
			+125°C	—	35	—	
CMSR	Common-Mode Sense Rejection	V _{S+} = 2.5V to 36V	+25°C	—	0.1	0.4	μA/V
			-40°C	—	0.13	—	
			+125°C	—	0.05	—	
I _{OO}	Output Offset Current (Notes 10 and 11)	V _{SENSE} = 10mV	+25°C	—	0	±4	μA
			-40°C	—	-1.8	—	
			+125°C	—	+2.5	—	
G _T	Transconductance	V _{SENSE} = 10mV to 150mV	+25°C	3.928	4	4.072	mA/V
			-40°C	—	3.9	—	
			+125°C	—	4.08	—	
GE	Transconductance Error (Note 11)	V _{SENSE} = 10mV to 150mV	+25°C	-1.8	—	1.8	%
I _{OUT} G _T -TC	Transconductance Temp. Co.	—	+25°C	—	265	—	ppm/°C
V _{OUTH}	Output Relative to V _{S-}	—	+25°C	-1	-0.78	—	V
			-40°C	—	-0.88	—	
			+125°C	—	-0.63	—	
BW	-3dB Small Signal Bandwidth	V _{SENSE} (AC) = 10mV _{PP} , R _{GAIN} = 2.5kΩ	+25°C	—	0.65	—	MHz

Notes: 6. $V_{\text{SENSE}} = V_{S+} - V_{S-}$.

10. Output Offset Current is defined as difference between actual output current and $40\mu\text{A}$; measured at $V_{\text{SENSE}} = 10\text{mV}$. This will include an error due to bias currents of the device.

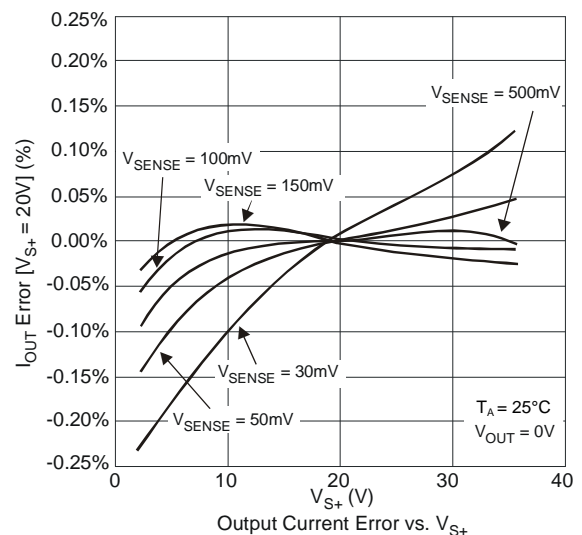
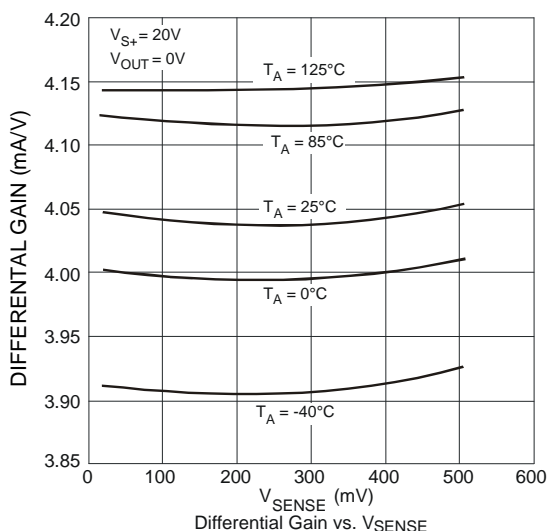
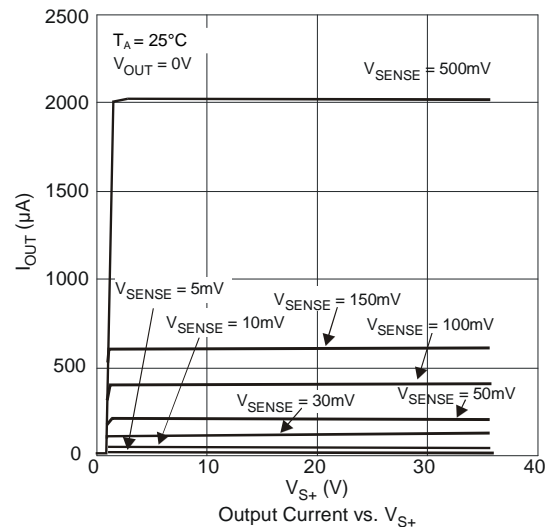
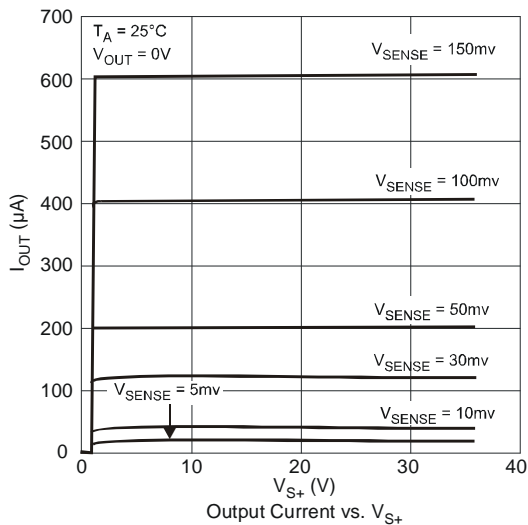
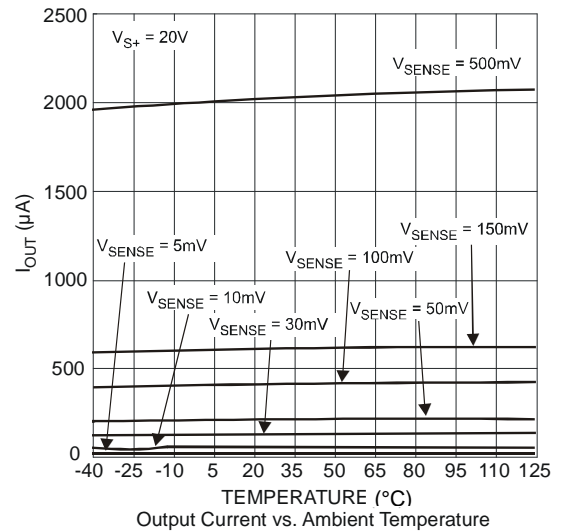
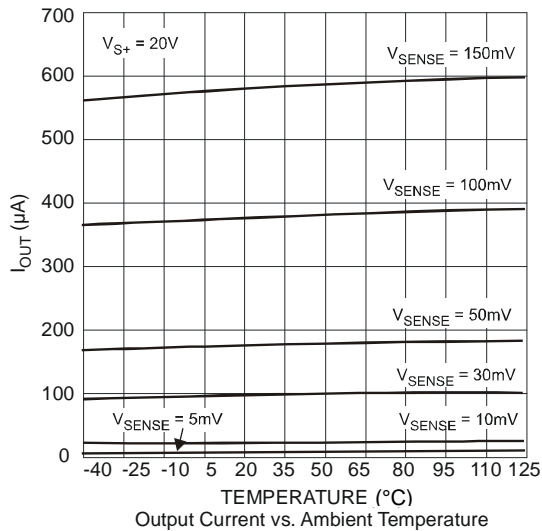
11. For $V_{\text{SENSE}} > 10\text{mV}$, the internal voltage-current converter is fully linear. This enables a true offset to be defined and used. At $V_{\text{SENSE}} < 10\text{mV}$ the output current due V_{SENSE} is not guaranteed to remain linear and may fall to 0.

Typical Characteristics (Note 12)



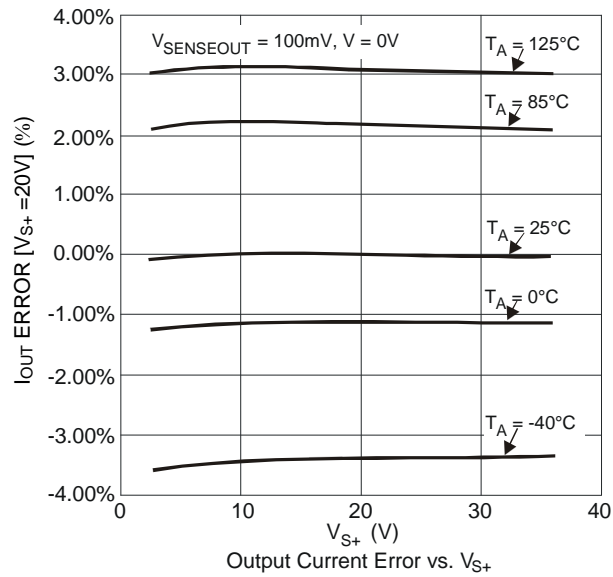
Note: 12. Typical characteristic only and not guaranteed performance.

Typical Characteristics (Cont.) (Note 12)



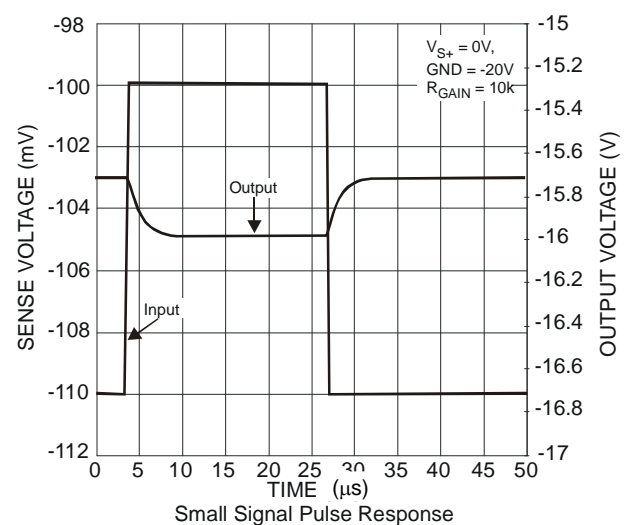
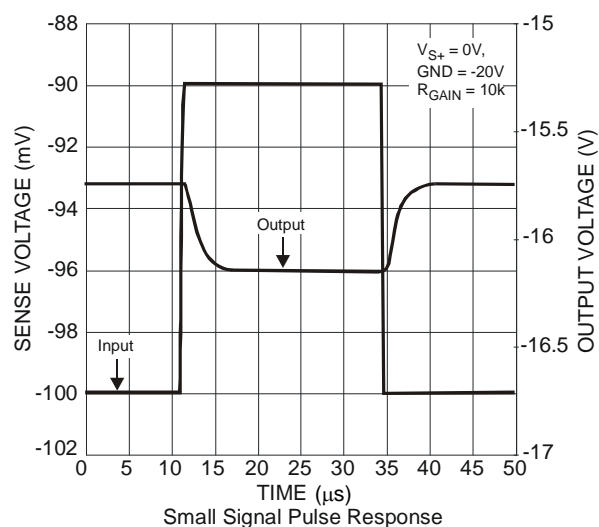
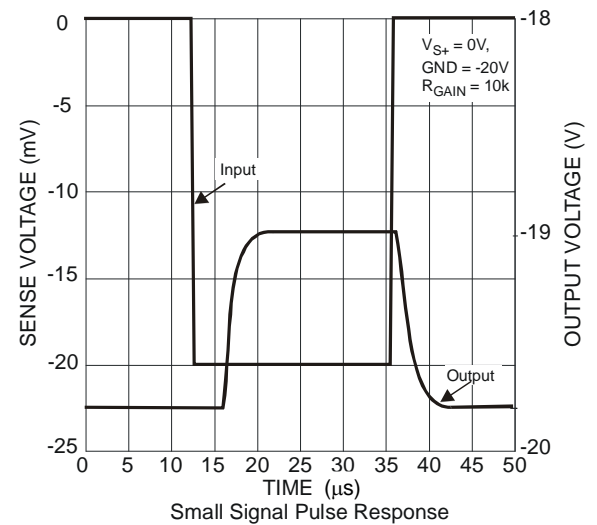
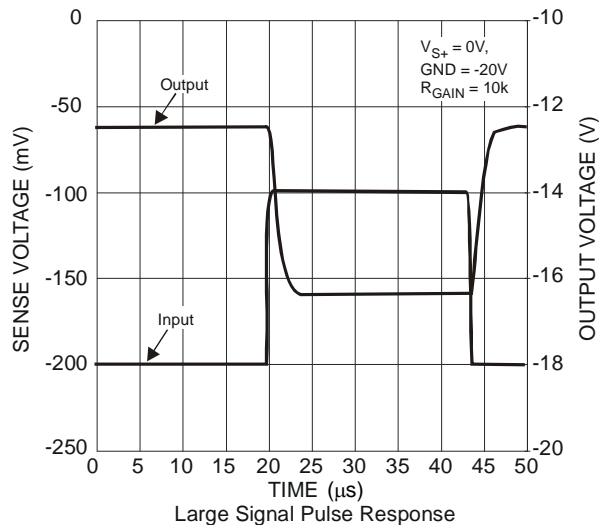
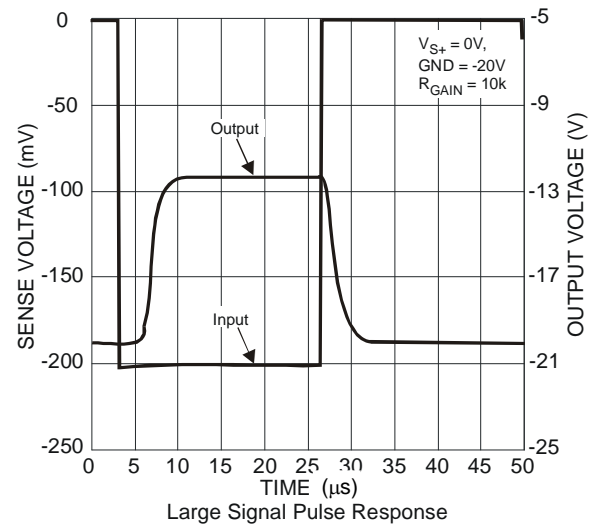
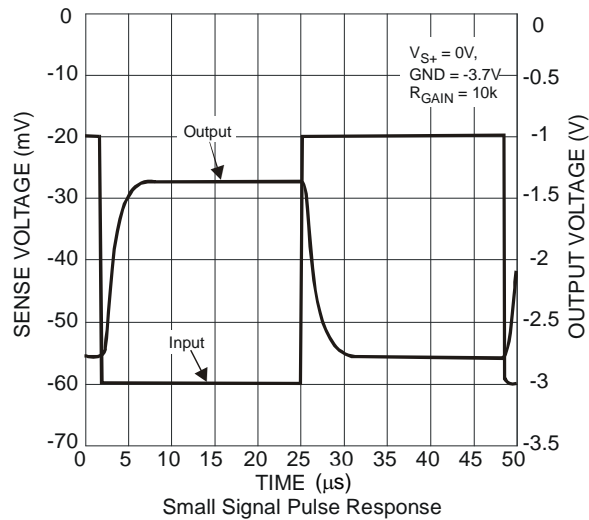
Note: 12. Typical characteristic only and not guaranteed performance.

Typical Characteristics (Cont.) (Note 12)



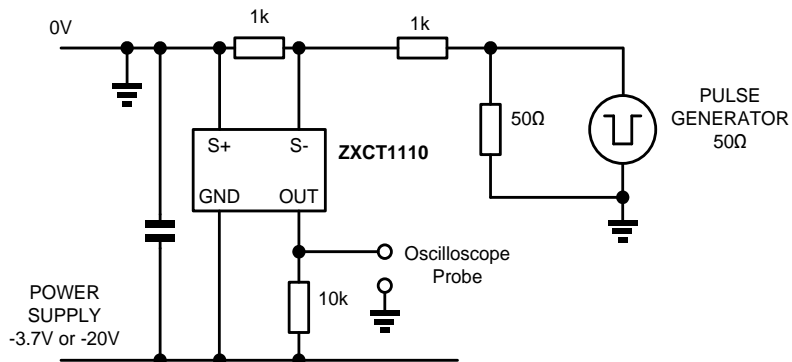
Note: 12. Typical characteristic only and not guaranteed performance.

Typical AC Characteristics (Note 12)

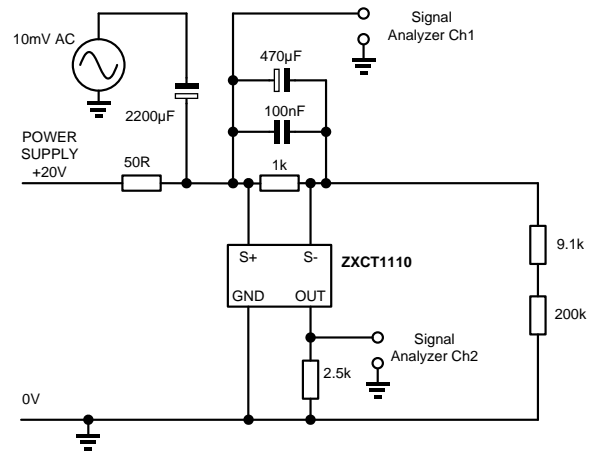
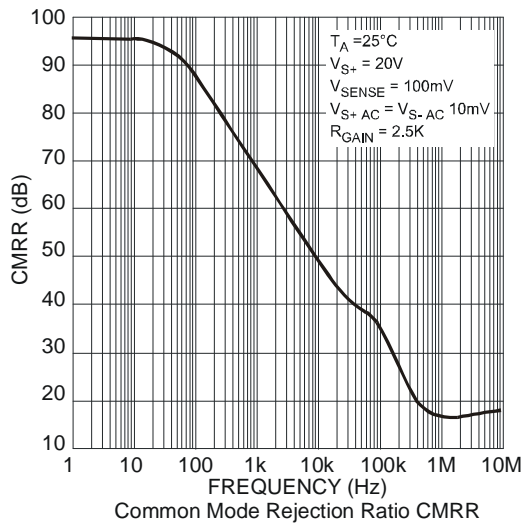


Note: 12. Typical characteristic only and not guaranteed performance.

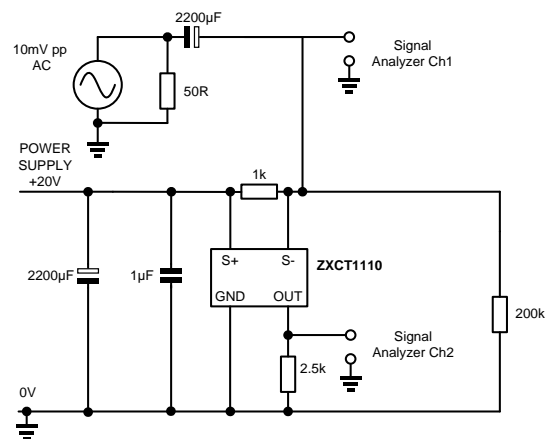
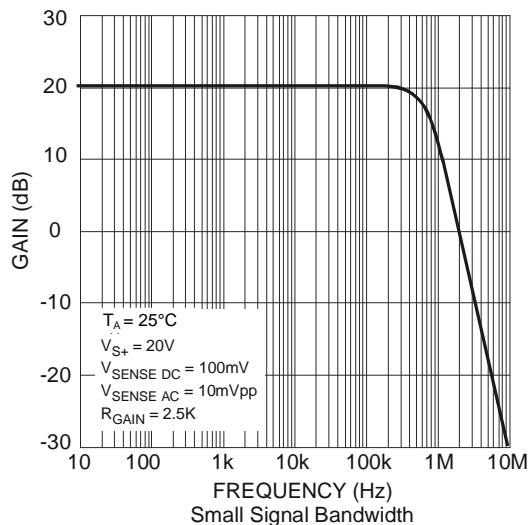
Typical AC Characteristics (Cont.) (Note 12)



Test Circuit for Pulse Response



Test circuit for CMRR



Test circuit for Small signal bandwidth

Note: 12. Typical characteristic only and not guaranteed performance.

Application Information

Description

The current monitor ICs ZXCT1107Q, ZXCT1109Q and ZXCT1110Q all use a similar application circuit topology for high-side current sensing, with small differences. The ZXCT1110Q has a separate ground pin whereas the ZXCT1107Q and ZXCT1109Q do not. The use of ZXCT1110Q allows reduction of the absolute current measurement error in some applications by providing a reduced output offset current. The ZXCT1107Q provides a mirror image pin assignment of the ZXCT1109Q to ease PCB layout in very small equipment designs.

The basic application circuit for each device is shown in Figure 1. Two external resistors are required. The resistor R_{SENSE} is connected in the path of the current to be monitored. The resistor R_{GAIN} converts the device output current to a voltage for convenient processing by a further device, such as a comparator, amplifier or analog-to-digital converter within a microcontroller system.

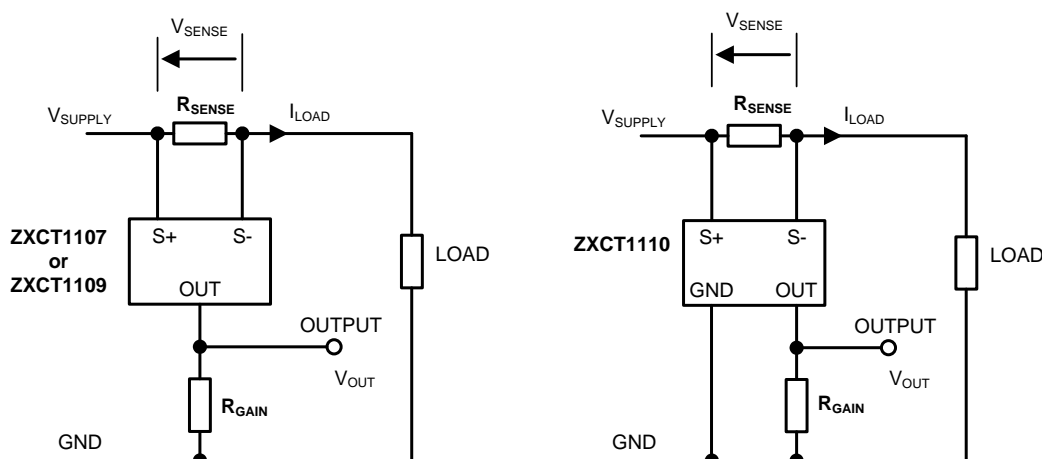


Figure 1 Basic Application Circuit

The current monitor output current is defined through the nominal transconductance of 4mA/V over a $10\text{mV} \leq V_{SENSE} \leq 500\text{mV}$.

$$I_{OUT} = 0.004 * V_{SENSE} \quad \text{Amp} \quad \text{Equation 1}$$

The external resistors, R_{SENSE} and R_{GAIN} , determine the output voltage as described below.

$$V_{OUT} = I_{LOAD} * R_{SENSE} * 0.004 * R_{GAIN} \quad \text{Equation 2}$$

Measuring currents that result in a $V_{SENSE} < 10\text{mV}$ is not recommended because below 10mV the offsets within the ZXCT11xxQ may cause its output current to fall to zero (ZXCT1107Q/09Q's $V_{SENSE}=0$ I_{OUT} level). This could result in the output current measured not being distinguishable from the no-load current.

Calculation of Resistor Values

In order to select R_{SENSE} , a choice of sense voltage is required. This often involves a compromise between power efficiency and accuracy for the given temperature range. The resistor must be small enough to avoid excessive volt drop between the power supply and the load.

However, the resistor must be large enough to avoid excessive current measurement error, particularly random errors.

In a typical application, a digital system, perhaps a microcontroller, is set up to monitor the current. At a certain threshold current level, I_{LOADT} , the system is required to disconnect the load or report a fault. At this current level, the current measurement error must be limited to a known value. The total percentage error comprises the inherent error in the ZXCT1107Q/09Q/10Q devices and the tolerances of the two resistors R_{SENSE} and R_{GAIN} . The ZXCT1107Q/09Q absolute error is shown in Table 1 with error limits drawn from the table of Electrical Characteristics above. This error varies with V_{SENSE} .

Table 1: ZXCT1107Q/ZXCT1109Q Error

V_{SENSE}	Mean I_{OUT}	Error Band	Percent Error
10mV	45.5 μ A	$\pm 8.5\mu$ A	$\pm 18.7\%$
30mV	124.5 μ A	$\pm 9.5\mu$ A	$\pm 7.6\%$
100mV	408 μ A	$\pm 14\mu$ A	$\pm 3.4\%$
200mV	809.5 μ A	$\pm 22.5\mu$ A	$\pm 2.8\%$

Application Information (Cont.)

The ZXCT1110Q is highly linear and has a transconductance of 4mA/V $\pm 1.8\%$ and an output of 40 μ A $\pm 4\mu$ A at $V_{SENSE}=10$ mV. The output current can therefore be calculated (Standard International Units) as:

$$I_{OUT} = (40 \pm 4) \times 10^{-6} + (V_{SENSE} - 0.01) \times (0.004 \pm 0.000072) \text{ A}$$

The worst-case current error is then:

$$I_{OUTERROR} = I_{OUT} - I_{OUTIDEAL} = \pm \{ 4 \times 10^{-6} + (V_{SENSE} - 0.01) \times 0.000072 \} \text{ A}$$

or $I_{OUTERROR} = \pm \{ 3.28 \times 10^{-6} + V_{SENSE} \times 0.000072 \} \text{ A}$

The percentage error, ε , is:

$$\varepsilon = \frac{I_{OUTERROR}}{I_{OUTIDEAL}} \times 100\% = \frac{I_{OUTERROR}}{V_{SENSE} \times 0.004} \times 100\%$$

Calculation of Resistor Values (Cont.)

$$\text{Then } \varepsilon = \pm \frac{3.28 \times 10^{-4} + V_{SENSE} \times 0.0072}{V_{SENSE} \times 0.004} \%$$

$$\text{or } \varepsilon = \pm \frac{0.082}{V_{SENSE}} \pm 1.8\% \quad \text{Equation 3}$$

This shows that the error is reduced with increasing V_{SENSE} . Then the minimum V_{SENSE} required to give the error $\pm \varepsilon$ % is:

$$V_{SENSE} = \frac{0.082}{\varepsilon - 1.8} \text{ V} \quad [\text{only for ZXCT1110Q}] \quad \text{Equation 4}$$

In the application, the effect of the external resistor tolerances must also be taken into account.

Table 2: ZXCT1110Q Error

V_{SENSE}	Mean I_{OUT}	Error Band	Percent Error
10mV	40 μ A	$\pm 4\mu$ A	$\pm 10\%$
30mV	120 μ A	$\pm 5.44\mu$ A	$\pm 4.53\%$
100mV	400 μ A	$\pm 10.48\mu$ A	$\pm 2.62\%$
200mV	800 μ A	$\pm 17.68\mu$ A	$\pm 2.21\%$

Note that in order to avoid additional error, V_{SUPPLY} must be at least 1.5V greater than V_{OUT} . This margin depends on the value of V_{SENSE} . For $V_{SENSE} = 100$ mV, this margin can be reduced to 1.0V.

R_{SENSE} is chosen based on the threshold V_{SENSET} of sense voltage selected as above, for the chosen threshold load current, I_{LOADT} .

$$R_{SENSE} = \frac{V_{SENSET}}{I_{LOADT}} \quad \text{Equation 5}$$

R_{GAIN} is chosen to give the required threshold output voltage, V_{OUTT} . From Equation 1, the threshold output current is:

$$I_{OUTT} = 0.004 \times V_{SENSET} \quad \text{Equation 1a}$$

$$R_{GAIN} = \frac{V_{OUTT}}{I_{OUTT}}$$

$$\text{or } R_{GAIN} = \frac{V_{OUTT}}{0.004 \times V_{SENSET}} \quad \text{Equation 6}$$

Application Information (Cont.)

Design Example

A current monitor is required to provide an output voltage of 2V \pm 6% when the load current of a 12V supply is 2A. Resistors are available with 1% tolerance.

The sense and output resistors will contribute a total possible error of 2%, so the ZXCT11xxQ error must not exceed 4%. From Table 1, the error of ZXCT1107Q/09Q will be 3.4% if the sense voltage is 100mV. This satisfies the total error requirement of 6%.

Equation 5 gives:

$$R_{\text{SENSE}} = 100\text{mV}/2\text{A} = 50\text{m}\Omega$$

Equation 6 gives:

$$R_{\text{GAIN}} = \frac{2}{0.004 * 0.1} = 5\text{k}\Omega$$

A suitable preferred value is 5.1k Ω . This gives a systematic error of +2%, which can be compensated elsewhere in the system if desired.

Figure 2 shows the resulting schematic.

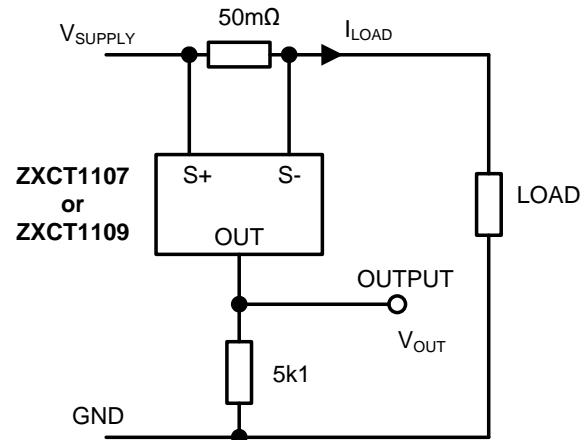


Figure 2 Example Circuit using ZXCT1107Q/09Q

Alternatively, the ZXCT1110Q may be used with a reduced sense voltage if desired. From Equation 4, with $\epsilon=4\%$,

$$V_{\text{SENSE}} = \frac{0.082}{\epsilon - 1.8} = 0.082/(4 - 1.8) = 37.2\text{mV}$$

Equation 5 gives:

$$R_{\text{SENSE}} = 37.2\text{mV}/2\text{A} = 18.6\text{m}\Omega$$

A suitable preferred value is 20m Ω . Then the sense voltage will be 2A * 20m Ω = 40mV.

Equation 6 gives:

$$R_{\text{GAIN}} = \frac{2}{0.004 * 0.04} = 12500\Omega$$

A suitable preferred value is 13k Ω .

The alternative example circuit using the ZXCT1110Q with a sense voltage of 40mV is shown in Figure 3, giving the required overall accuracy of \pm 6%.

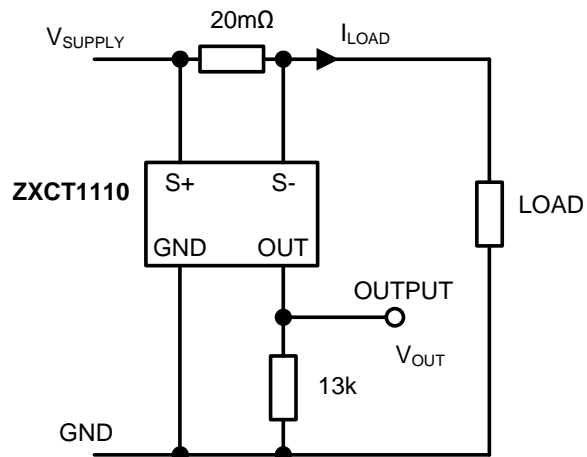


Figure 3 Example Circuit using ZXCT1110Q

Application Information (Cont.)

Protection against Load Short Circuit

In the event of a load short circuit or overload, a large proportion of the supply voltage may appear between the sense terminals. The supply may be current limited, but there is normally a large reservoir capacitor which can deliver enough energy to damage the ZXCT11xx before the supply voltage falls to a safe level due to current limit activation.

The ZXCT11xxQ is rated for a maximum sense voltage of +0.8V, but is safe if the input current is limited to $\pm 8.5\text{mA}$. In Figure 4, the resistor R_{PROT} limits the current and therefore protects the current monitor device against load short circuit without introducing significant current measurement error.

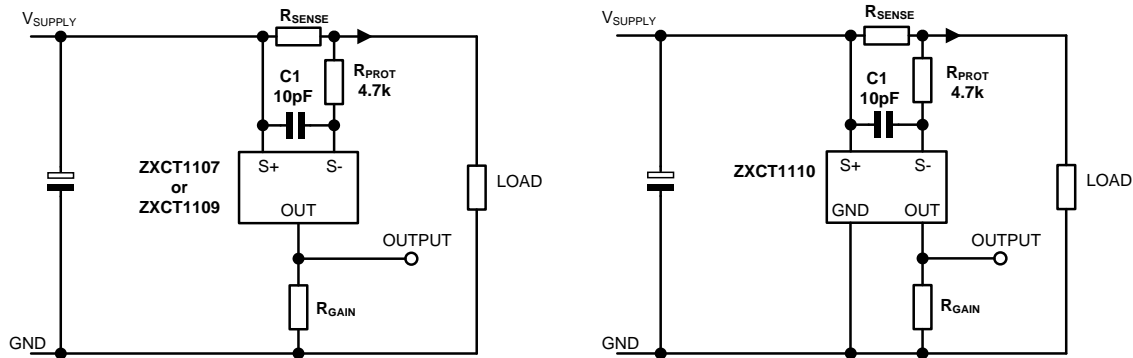


Figure 4 Protection and EMC Filtering

EMC Susceptibility

In many applications, the circuit is required to operate in the presence of RF radiation. This radiation is coupled into the circuit via the supply or load connections and will often cause significant bias shift due to rectification within the integrated circuit. The bias shift may lead to erroneous operation of the integrated circuit. In Figure 4, a low pass filter, R_{PROT} and C1 , provides significant attenuation in the VHF and UHF regions. The value of C1 is recommended to be in the range of 10pF to 47pF, leadless ceramic type.

PCB Layout Considerations

It is necessary to take into account a small volt drop in the PCB copper and solder joints to R_{SENSE} . Such volt drops can create noticeable error at currents of the order of 1A and greater. The PCB must be designed to provide the maximum possible copper carrying current via the sense resistor, and the traces from the S+ and S- pins must be connected only to the resistor pads. In this way, the effect of the copper is minimized.

If used, the capacitor C1 should be placed very close the input pins S+ and S- .

Application: High Voltage Current Monitor

The schematic of Figure 5 shows how the current monitor may be used in a high voltage application such as an Electric Vehicle system. In this configuration the 500V PNP transistor Q1 drops a large proportion of the supply voltage. Diode D2 limits the differential input voltage to a safe level under overload conditions. The voltage across U1 is limited by the zener diode D1 . The output current of U1 is limited to about 3mA by the D2 . As R_{GAIN} is typically a few k Ω the output voltage is therefore limited to a few volts. An additional output clamping diode may be required for higher gains. R1 is chosen to give a suitable bias current in D1 for the given supply voltage range.

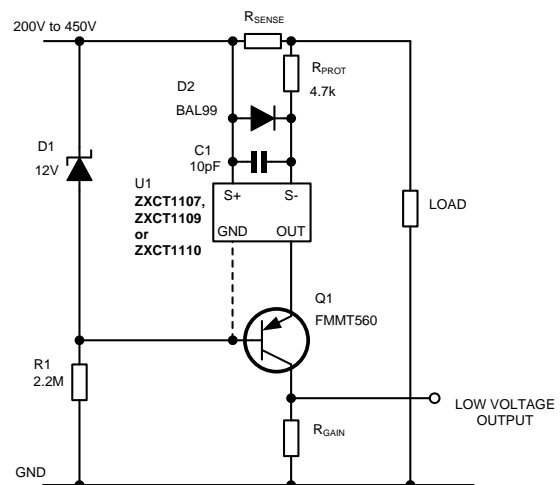
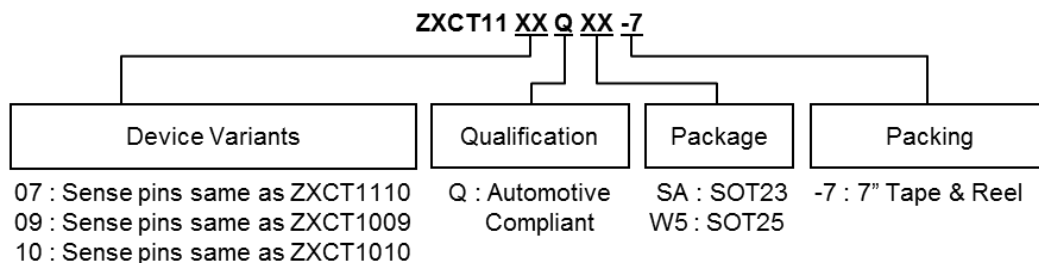


Figure 5 400V Current Monitor

Ordering Information



Order Reference	Package (Note 13)	Package Code	Identification Code	Reel Size	Quantity per Reel	Tape Width (mm)	Qualification Grade (Note 14)
ZXCT1107QSA-7	SOT23	SA	1107	7", 180mm	3,000	8	Automotive Compliant
ZXCT1109QSA-7	SOT23	SA	1109	7", 180mm	3,000	8	Automotive Compliant
ZXCT1110QW5-7	SOT25	W5	1110	7", 180mm	3,000	8	Automotive Compliant

Notes: 13. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.

14. Automotive Compliant products are AEC-Q100 qualified and are PPAP capable. Refer to <https://www.diodes.com/quality/>. See ZXCT1107/09/10 datasheet for commercial qualified versions.

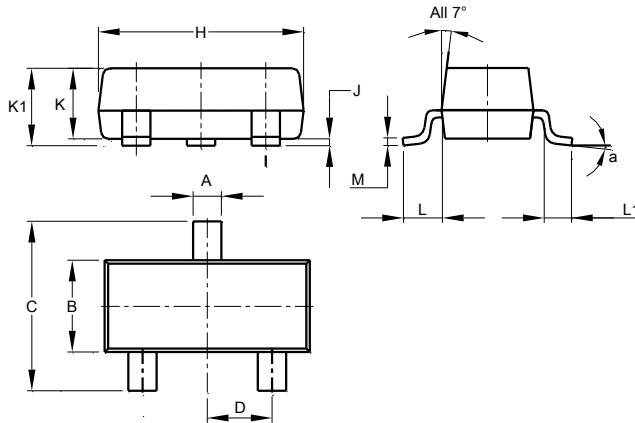
Marking Information



Package Outline Dimensions

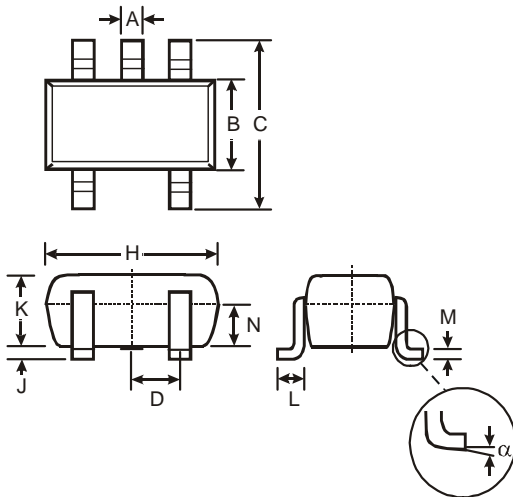
Please see <http://www.diodes.com/package-outlines.html> for the latest version.

SOT23



SOT23			
Dim	Min	Max	Typ
A	0.37	0.51	0.40
B	1.20	1.40	1.30
C	2.30	2.50	2.40
D	0.89	1.03	0.915
F	0.45	0.60	0.535
G	1.78	2.05	1.83
H	2.80	3.00	2.90
J	0.013	0.10	0.05
K	0.890	1.00	0.975
K1	0.903	1.10	1.025
L	0.45	0.61	0.55
L1	0.25	0.55	0.40
M	0.085	0.150	0.110
a	8°		
All Dimensions in mm			

SOT25

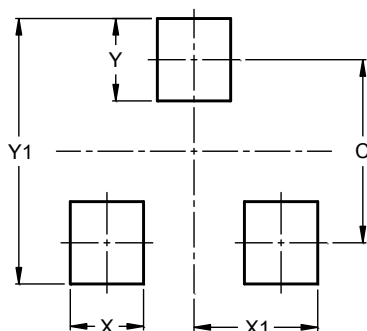


SOT25			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	—	—	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	—
All Dimensions in mm			

Suggested Pad Layout

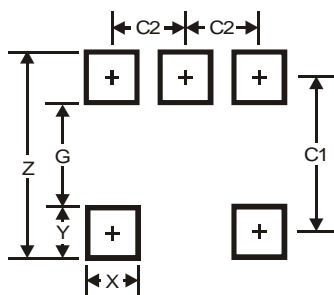
Please see <http://www.diodes.com/package-outlines.html> for the latest version.

SOT23



Dimensions	Value (in mm)
C	2.0
X	0.8
X1	1.35
Y	0.9
Y1	2.9

SOT25



Dimensions	Value (in mm)
Z	3.20
G	1.60
X	0.55
Y	0.80
C1	2.40
C2	0.95

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