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## Description

The ZXCT1107Q/09Q/10Q products are high-side unipolar current sense monitors. These devices eliminate the need to disrupt the ground plane when sensing a load current.

The wide common-mode input voltage range and low quiescent current, coupled with SOT23 and SOT25 packages, make them suitable for a range of automotive applications.

The device is line powered and as such doesn't need a separate supply rail.

Quiescent current is only 3µA, thereby minimizing current sensing error. One external gain setting resistor increases versatility by permitting wide gain ranges.

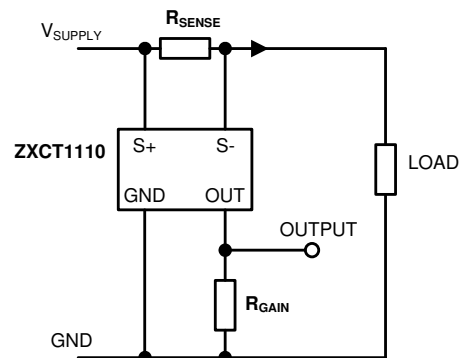
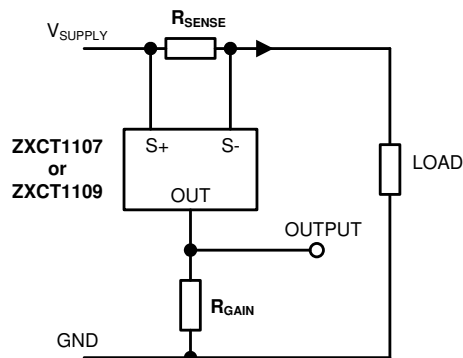
The ZXCT1107Q/09Q/10Q devices have been qualified to AEC-Q100 Grade 1 and are Automotive Compliant supporting PPAPs.

## Features

- Wide Supply and Common-Mode Voltage Range:
  - 2.5V to 36V
- SOT23 and SOT25 Packages
  - 3-Pin ZXCT1107Q/09Q
  - 5-Pin ZXCT1110Q
- Low Quiescent Current (3µA).
- Extended Industrial Temperature Range -40 to +125°C
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **Qualified to AEC-Q100 Standards for High Reliability**
- **PPAP Capable (Note 4)**

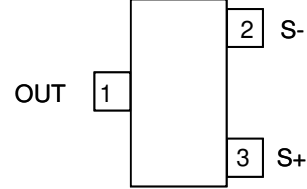
- Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
  2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
  3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
  4. Automotive products are AEC-Q100 qualified and are PPAP capable. Refer to [http://www.diodes.com/quality/product\\_compliance\\_definitions/](http://www.diodes.com/quality/product_compliance_definitions/).

## Typical Application Circuit

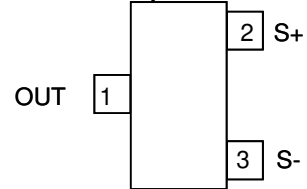


## Pin Assignments

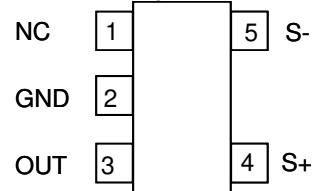
**ZXCT1107Q**  
Top View



**ZXCT1109Q**  
Top View



**ZXCT1110Q**  
Top View



## Applications

- Automotive Current Measurement
- Battery Management
- Over Current Monitor

## Pin Descriptions

Package Name	SOT23		SOT25	Description
	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 (ZXCT1107/9)	-0.3 to 40	V	
Voltage on S- and S+ relative to GND (ZXCT1110)	-0.3 to 40	V	
Voltage on OUT to GND (ZXCT1110)	-0.3 to $V_{S+}$	V	
Differential Sense Voltage, $V_{SENSE}$ (Notes 6 & 7)	-0.3 to +0.8	V	
Maximum Current into S+ and S- (Note 7)	$\pm 8.5$	mA	
Storage Temperature	-55 to +150	°C	
Maximum Junction Temperature	+150	°C	
Package Power Dissipation ( $T_A = +25^\circ\text{C}$ )			
SOT23	300 (Derate to Zero at +150°C)	mW	
SOT25	300 (Derate to Zero at +150°C)		
<b>ESD Ratings</b>			
<b>ZXCT1107Q/09Q</b>			
HBM	Human Body Model	1,500	V
MM	Machine Model	150	V
CDM	Charged Device Model	1,000	V
<b>ZXCT1110Q</b>			
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 <sub>S+</sub>	Common-Mode Input Range (Note 5)	ZXCT1110Q	2.5	36	V
		ZXCT1107Q/9Q	V <sub>OUT(MAX)</sub> + 2.5	36	
V <sub>SENSE</sub>	Differential Sense Input Voltage Range (V <sub>S+</sub> - V <sub>S-</sub> )	0	0.5	V	
V <sub>OUT</sub>	Output Voltage Range (0 ≤ V <sub>SENSE</sub> ≤ 100mV)	ZXCT1110Q	0	V <sub>S-</sub> - 1	V
		ZXCT1107Q/9Q	0	V <sub>S+</sub> - 2.5	
T <sub>A</sub>	Ambient Temperature Range	-40	+125	°C	

**Electrical Characteristics** (@T<sub>A</sub> = +25°C, V<sub>S+</sub> = 20V, V<sub>SENSE</sub> = 100mV, R<sub>GAIN</sub> = 0, unless otherwise stated) (Note 6)

**ZXCT1107Q, ZXCT1109Q**

Symbol	Parameter	Conditions	T <sub>A</sub>	Min	Typ	Max	Units
I <sub>S-</sub>	S- Input Current	V <sub>SENSE</sub> = 0V (Note 6)	+25°C	—	19	100	nA
			-40°C	—	16	—	
			+125°C	—	35	—	
I <sub>OUT</sub>	Output Current (Note 8)	V <sub>SENSE</sub> = 0mV (Note 6)	+25°C	1	3	10	μA
			-40°C	—	2.2	—	
			+125°C	—	5.5	—	
		V <sub>SENSE</sub> = 10mV (Note 6)	+25°C	37	45	54	
			-40°C	—	42	—	
			+125°C	—	49	—	
		V <sub>SENSE</sub> = 30mV (Note 6)	+25°C	115	124	134	
			-40°C	—	119	—	
			+125°C	—	129	—	
		V <sub>SENSE</sub> = 100mV (Note 6)	+25°C	394	408	422	
			-40°C	—	396	—	
			+125°C	—	420	—	
		V <sub>SENSE</sub> = 200mV (Note 6)	+25°C	787	810	832	
			-40°C	—	785	—	
			+125°C	—	832	—	
V <sub>SENSE</sub> = 500mV (Note 6)	+25°C	1.965	2.015	2.064	mA		
	-40°C	—	1.965	—			
	+125°C	—	2.065	—			
I <sub>OUT-TC</sub>	Output Current Temperature Coefficient		Full Range	—	370	—	ppm/°C
CMSR	Common-Mode Sense Rejection	V <sub>S+</sub> = 2.5V to 36V	+25°C	—	0.1	0.4	μA/V
			-40°C	—	0.13	—	
			+125°C	—	0.05	—	
BW	-3dB Small Signal Bandwidth	V <sub>SENSE</sub> (AC) = 10mV <sub>PP</sub> (Note 6) R <sub>GAIN</sub> = 2.5kΩ	+25°C	—	0.65	—	MHz

Note: 8. Output current characteristic measured with low impedance ammeter connected to GND.

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

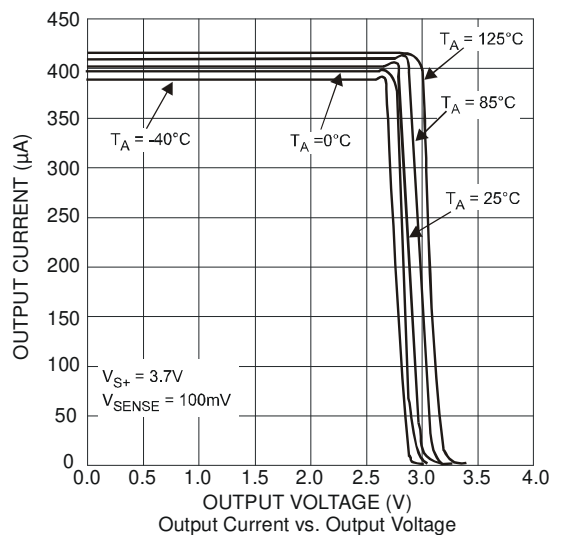
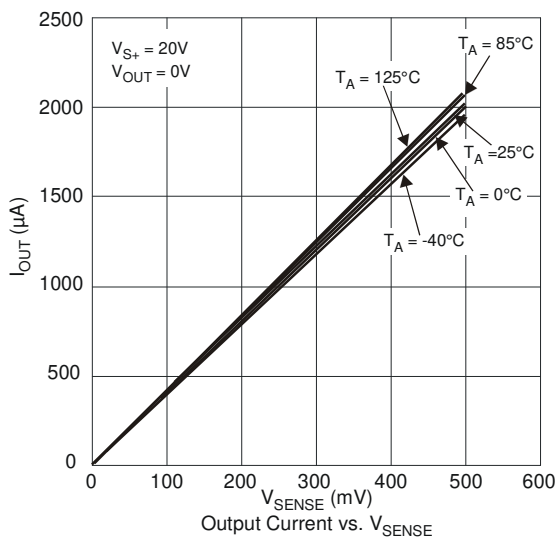
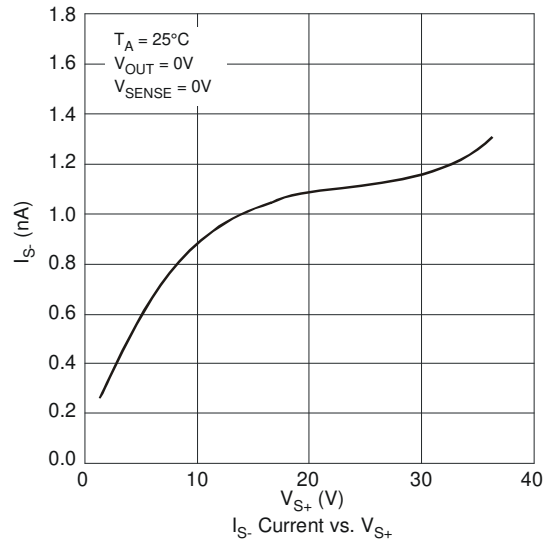
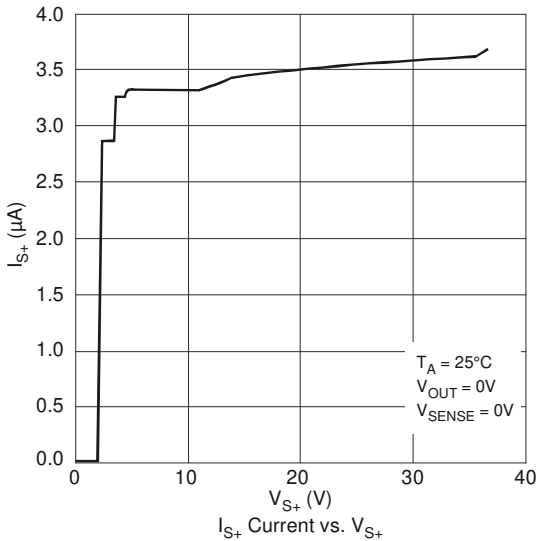
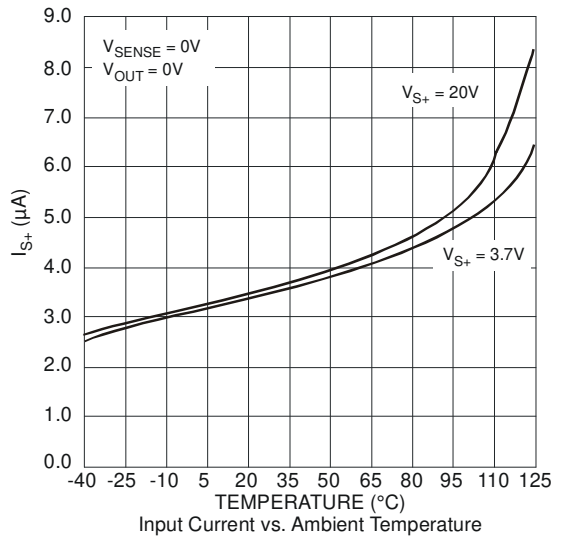
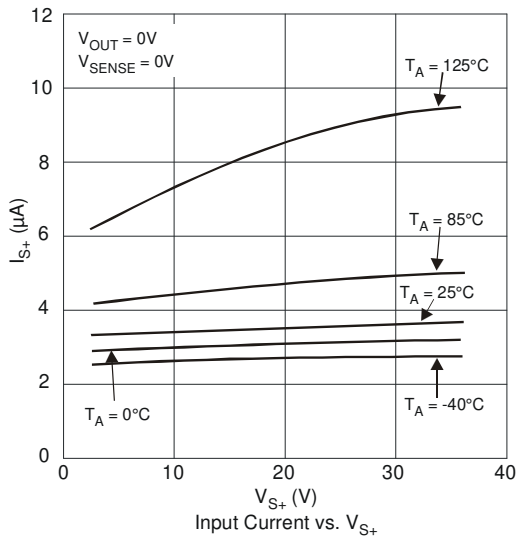
**ZXCT1110Q**

Symbol	Parameter	Conditions	$T_A$	Min	Typ	Max	Units
$I_Q$	GND Pin Current	$V_{\text{SENSE}} = 0\text{V}$ (Note 6)	+25°C	—	3	5	$\mu\text{A}$
			-40°C	—	2.2	—	
			+125°C	—	5.8	—	
$I_{S-}$	S- Input Current	$V_{\text{SENSE}} = 0\text{V}$ (Note 6)	+25°C	—	19	100	nA
			-40°C	—	16	—	
			+125°C	—	35	—	
CMSR	Common-Mode Sense Rejection	$V_{S+} = 2.5\text{V}$ to 36V	+25°C	—	0.1	0.4	$\mu\text{A/V}$
			-40°C	—	0.13	—	
			+125°C	—	0.05	—	
$I_{OO}$	Output Offset Current (Notes 8 & 9)	$V_{\text{SENSE}} = 10\text{mV}$ (Note 6)	+25°C	—	0	$\pm 4$	$\mu\text{A}$
			-40°C	—	-1.8	—	
			+125°C	—	+2.5	—	
$G_T$	Transconductance	$V_{\text{SENSE}} = 10\text{mV}$ to 150mV (Note 6)	+25°C	3.928	4	4.072	mA/V
			-40°C	—	3.9	—	
			+125°C	—	4.08	—	
GE	Transconductance Error (Note 10)	$V_{\text{SENSE}} = 10\text{mV}$ to 150mV (Note 6)	+25°C	-1.8	—	1.8	%
$I_{\text{OUT GT-TC}}$	Transconductance Temp. Co.	—	+25°C	—	265	—	ppm/°C
$V_{\text{OUTH}}$	Output Relative to $V_{S-}$	—	+25°C	-1	-0.78	—	V
			-40°C	—	-0.88	—	
			+125°C	—	-0.63	—	
BW	-3dB Small Signal Bandwidth	$V_{\text{SENSE}}(\text{AC}) = 10\text{mV}_{\text{PP}}$ , (Note 6) $R_{\text{GAIN}} = 2.5\text{k}\Omega$	+25°C	—	0.65	—	MHz

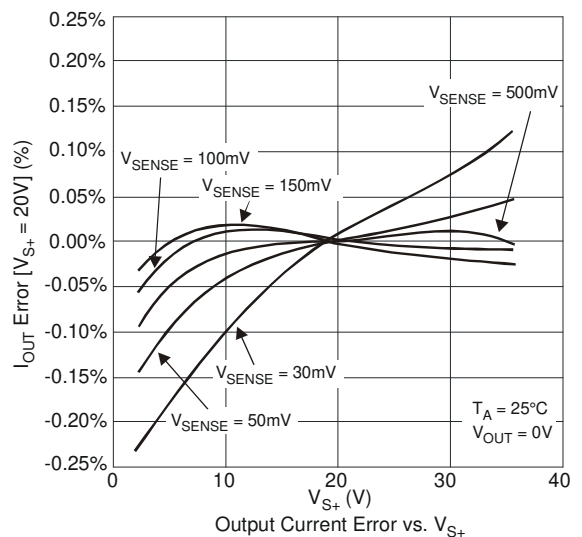
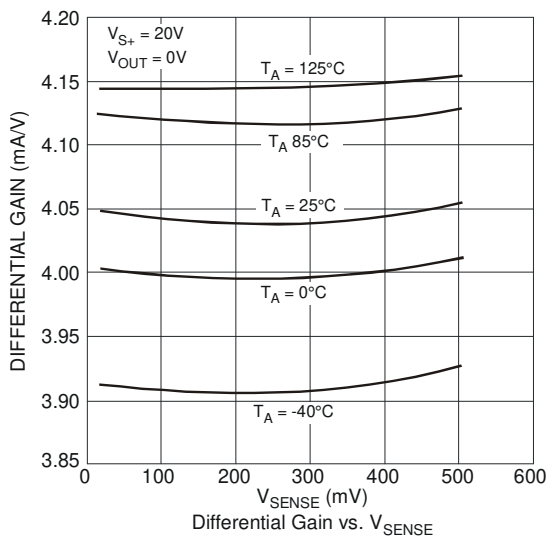
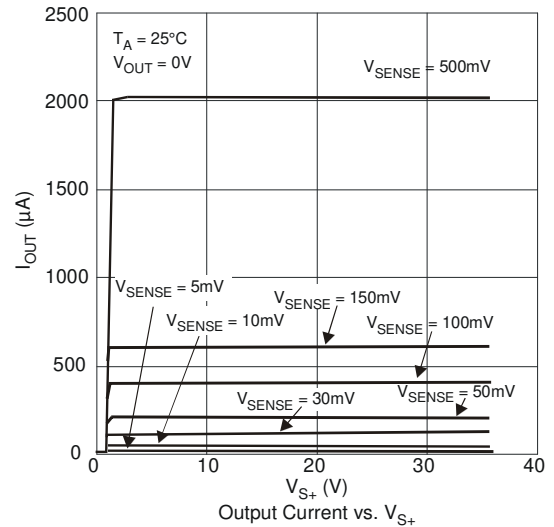
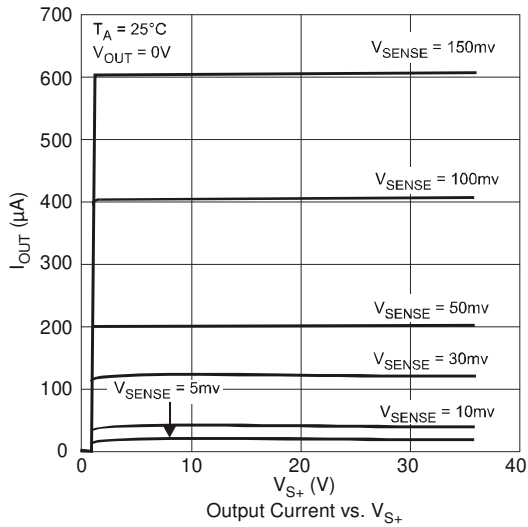
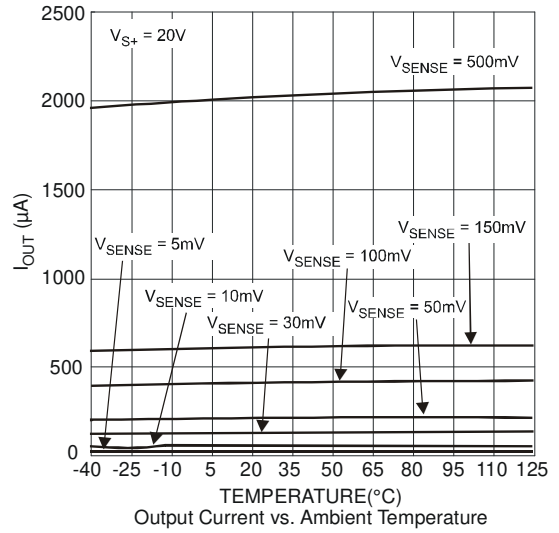
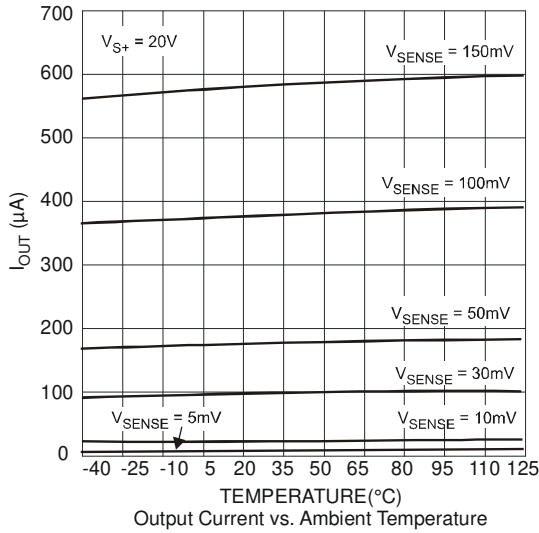
Notes: 9. Output Offset Current is defined as difference between actual output current and 40 $\mu\text{A}$ ; measured at  $V_{\text{SENSE}} = 10\text{mV}$ . This will include an error due to bias currents of the device.

10. 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.

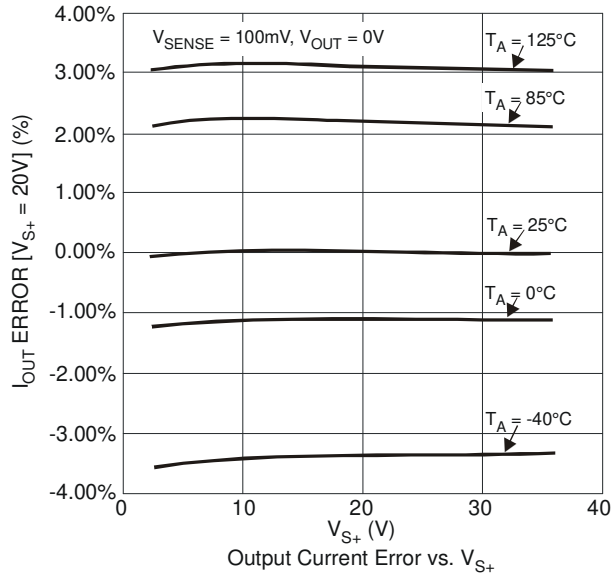
**Typical Characteristics**



**Typical Characteristics** (Continued)

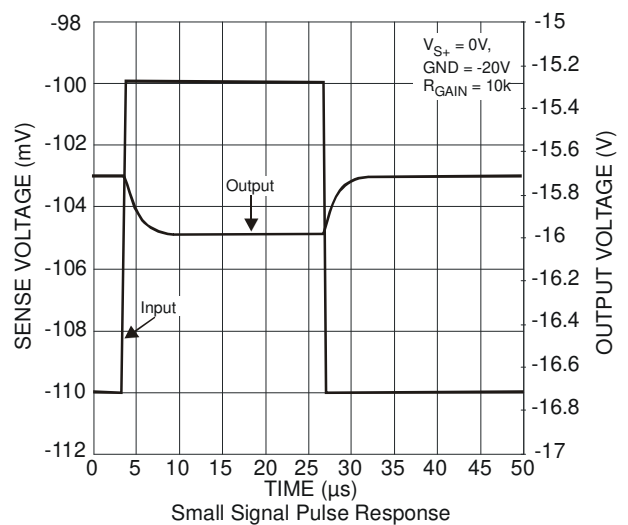
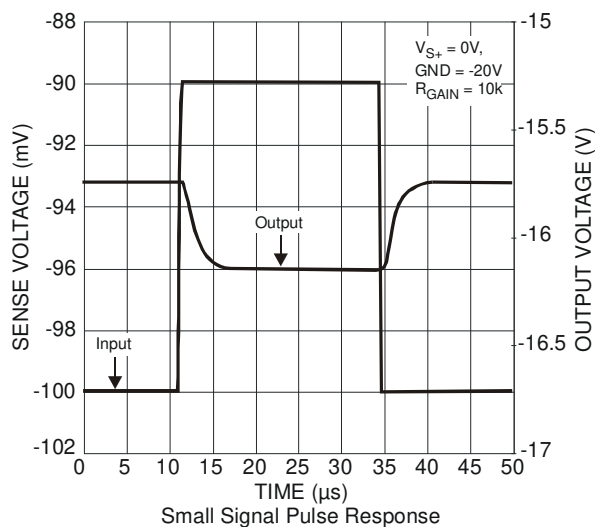
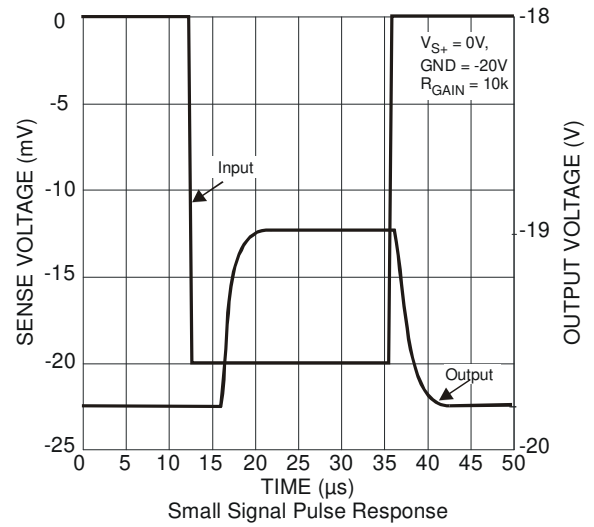
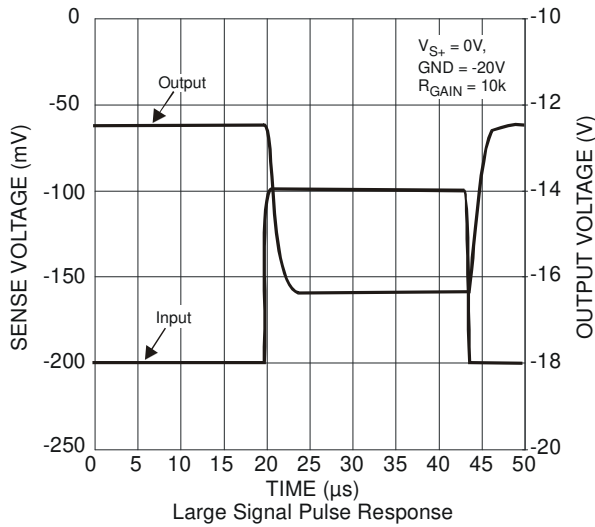
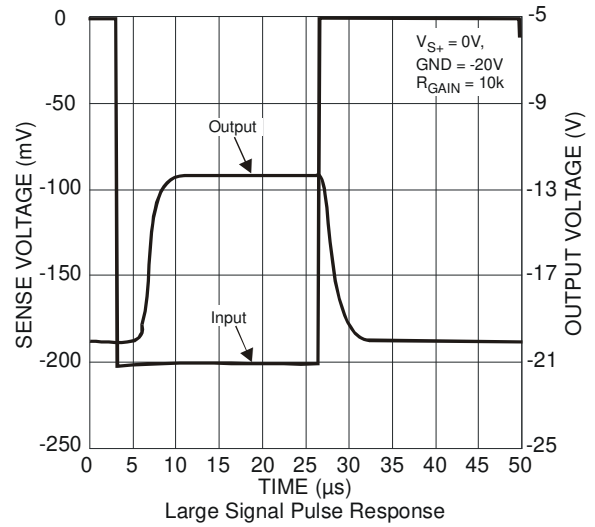
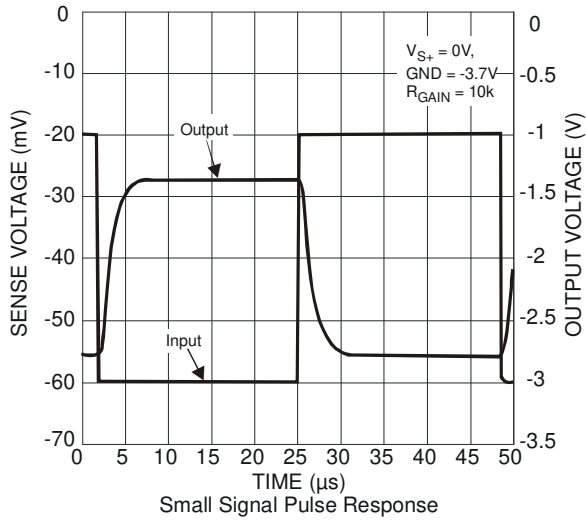


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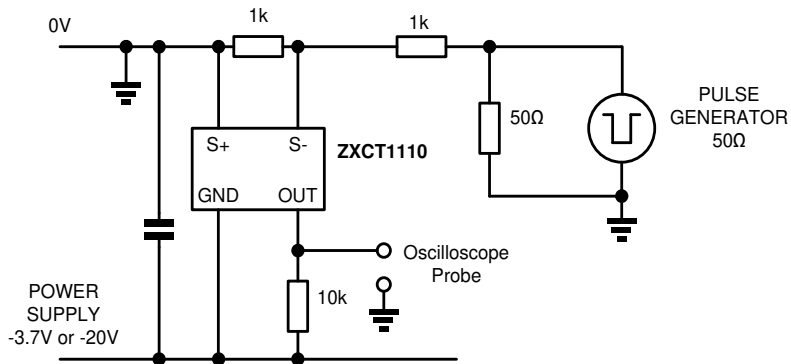




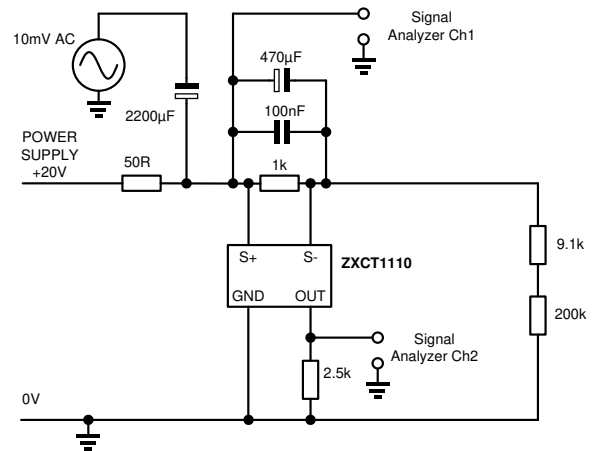
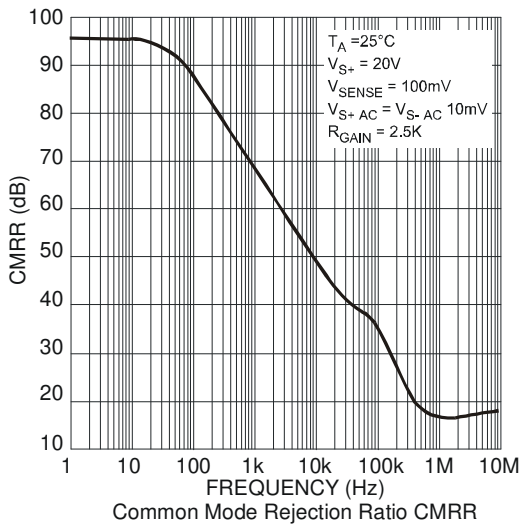
**Typical AC Characteristics**



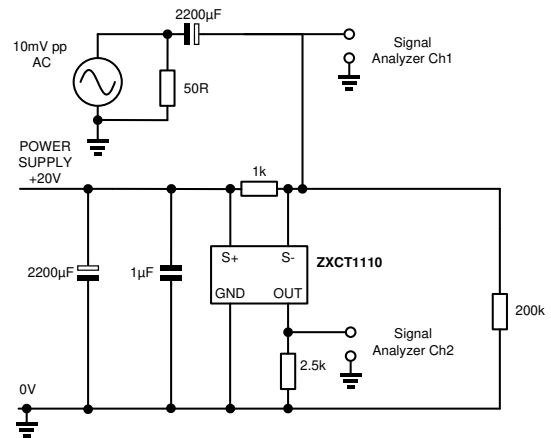
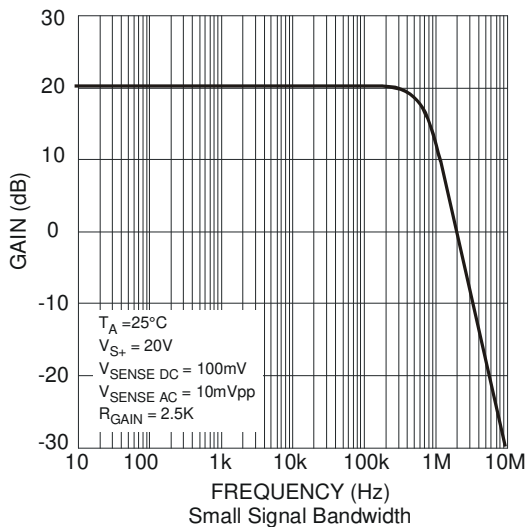
**Typical AC Characteristics** (Continued)



**Test Circuit for Pulse Response**



**Test circuit for CMRR**



**Test circuit for Small signal bandwidth**

## 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.

The current monitor output current is defined through the nominal transconductance of 4mA/V.

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

Then the resistors determine the output voltage as described below.

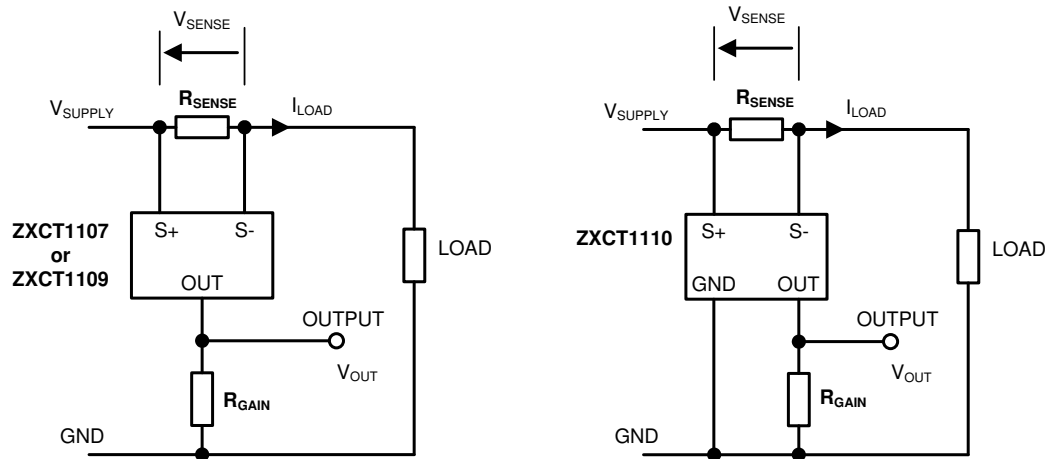


Figure 1 Basic Application Circuit

### 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/1109Q/1110Q 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  $V_{SENSE}$ .

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

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

The worst-case current error is then:

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

or

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

The percentage error,  $\epsilon$ , is:

$$\epsilon = \frac{I_{OUTERROR}}{I_{OUTIDEAL}} * 100\% = \frac{I_{OUTERROR}}{V_{SENSE} * 0.004} * 100\%$$

**Application Information** (Continued)

**Calculation of Resistor Values** (Continued)

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

or 
$$\varepsilon = \pm \frac{0.082}{V_{SENSE}} \pm 1.8\% \qquad \text{Equation 2}$$

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

$$V_{SENSE} = \frac{0.082}{\varepsilon - 1.8} \text{ V} \quad [\text{only for ZXCT1110}] \qquad \text{Equation 3}$$

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

**Table 1: ZXCT1107Q/ZXCT1109Q Error**

V <sub>SENSE</sub>	Mean I <sub>OUT</sub>	Error Band	Percent Error
10mV	45.5μA	±8.5μA	±18.7%
30mV	124.5μA	±9.5μA	±7.6%
100mV	408μA	±14μA	±3.4%
200mV	809.5μA	±22.5μA	±2.8%

**Table 2: ZXCT1110Q Error**

V <sub>SENSE</sub>	Mean I <sub>OUT</sub>	Error Band	Percent Error
10mV	40μA	±4μA	±10%
30mV	120μA	±5.44μA	±4.53%
100mV	400μA	±10.48μA	±2.62%
200mV	800μA	±17.68μA	±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  $V_{SENSE} = 100\text{mV}$ , 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,  $I_{LOADT}$ .

$$R_{SENSE} = \frac{V_{SENSET}}{I_{LOADT}} \qquad \text{Equation 4}$$

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

$$I_{OUTT} = 0.004 \cdot V_{SENSET} \qquad \text{Equation 1a}$$

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

or 
$$R_{GAIN} = \frac{V_{OUTT}}{0.004 \cdot V_{SENSET}} \qquad \text{Equation 5}$$

## Application Information (Cont.)

### Design Example

A current monitor is required to provide an output voltage of 2V ±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 ZXCT11xx error must not exceed 4%. From Table 1, the error of ZXCT1107/1109 will be 3.4% if the sense voltage is 100mV. This satisfies the total error requirement of 6%.

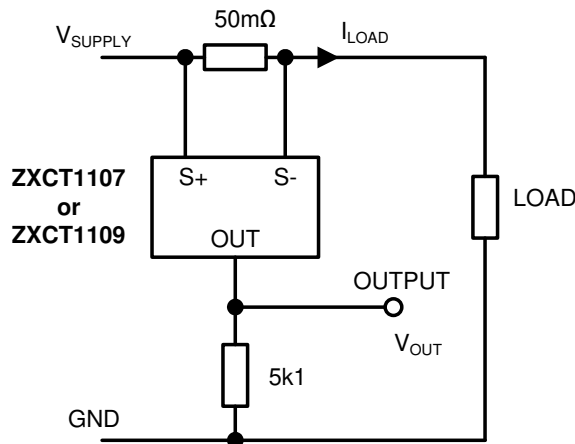
Equation 4 gives:

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

Equation 5 gives:

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

A suitable preferred value is 5.1kΩ. 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 ZXCT1107/ZXCT1109**

Alternatively, the ZXCT1110 may be used with a reduced sense voltage if desired. From Equation 3, with ε=4%,

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

Equation 4 gives:

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

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

Equation 5 gives:

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

A suitable preferred value is 13kΩ.

**Application Information** (Cont.)

The alternative example circuit using the ZXCT1110 with a sense voltage of 40mV is shown in Figure 3, giving the required overall accuracy of ±6%.

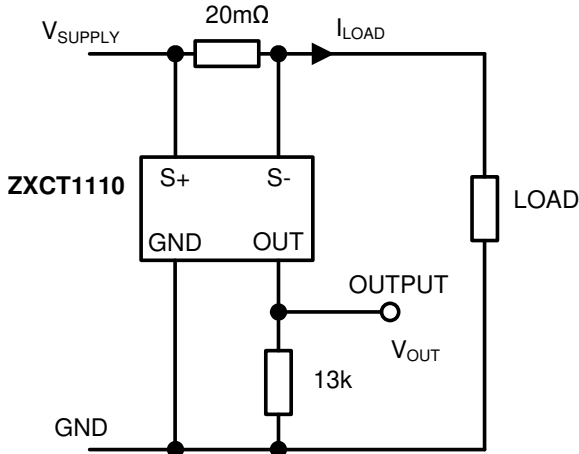


Figure 3 Example Circuit using ZXCT1110

**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 ZXCT11xx is rated for a maximum sense voltage of +0.8V, but is safe if the input current is limited to ±8.5mA. In Figure 4, the resistor R<sub>PROT</sub> limits the current and therefore protects the current monitor device against load short circuit without introducing significant current measurement error.

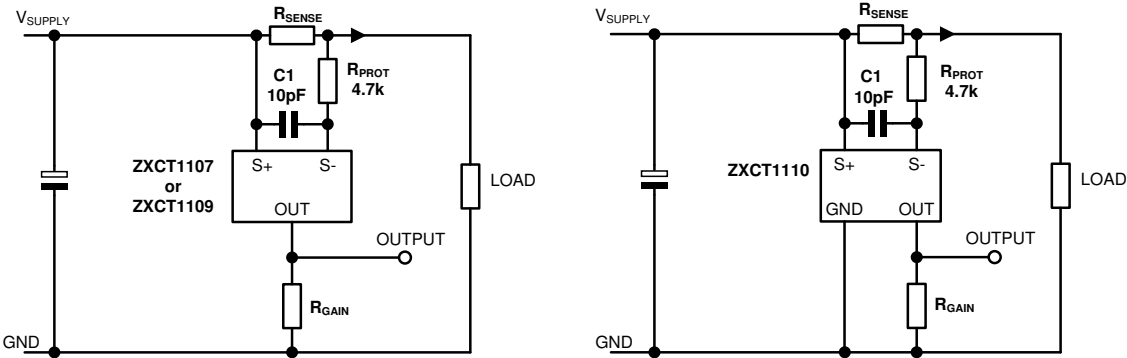


Figure 4 Protection and EMC Filtering

**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<sub>PROT</sub> 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.

**Application Information (Cont.)**

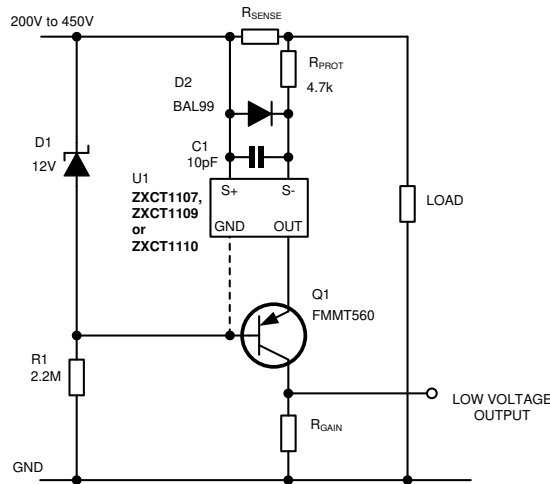
**PCB Layout Considerations**

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-.

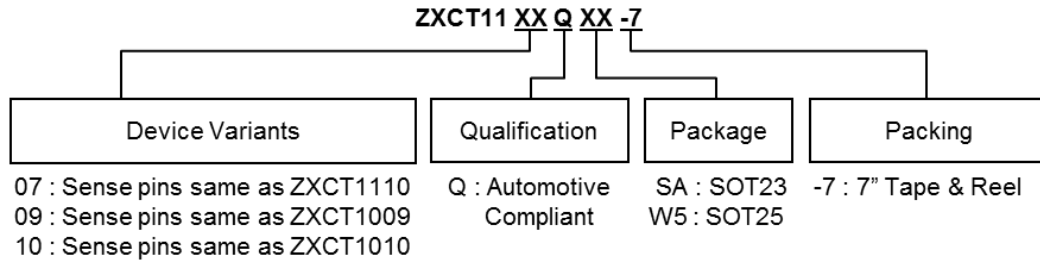
**Application: High Voltage Current Monitor**

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 $\Omega$ , 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 11)	Package Code	Identification Code	Reel Size	Quantity per Reel	Tape Width (mm)	Qualification Grade (Note 12)
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: 11. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at <http://www.diodes.com/datasheets/ap02001.pdf>.  
 12. Automotive products are AEC-Q100 qualified and are PPAP capable. Refer to [http://www.diodes.com/quality/product\\_compliance\\_definitions/](http://www.diodes.com/quality/product_compliance_definitions/). See ZXCT1107/09/10 datasheet for commercial qualified versions.

## Marking Information

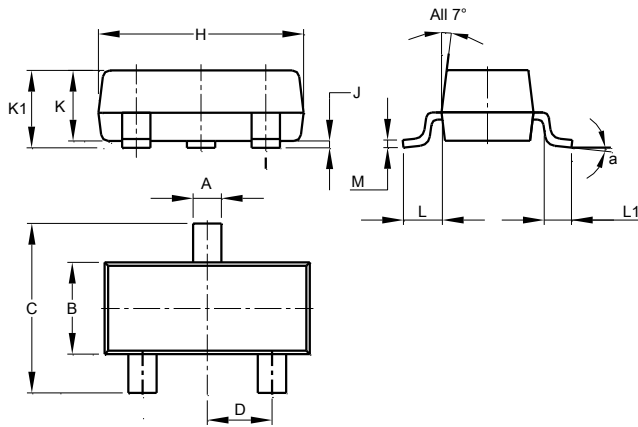




**Package Outline Dimensions**

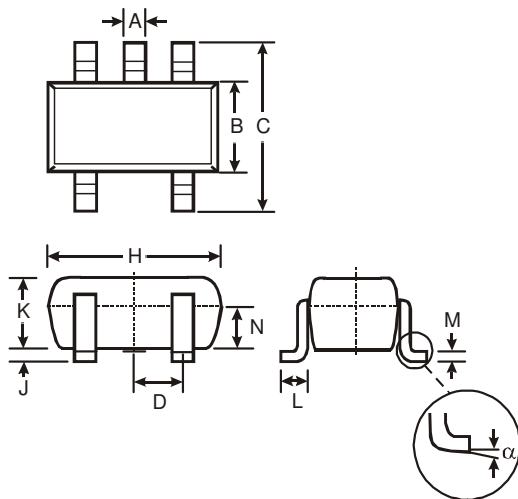
Please see AP02002 at <http://www.diodes.com/datasheets/ap02002.pdf> for the latest version.

**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**

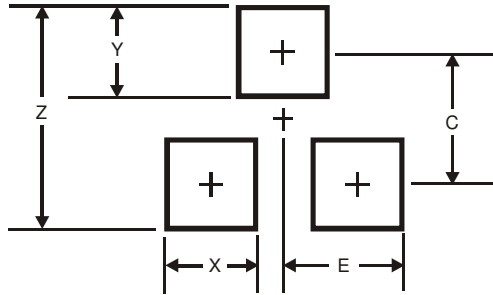


SOT25			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	—	—	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
alpha	0°	8°	—
All Dimensions in mm			

**Suggested Pad Layout**

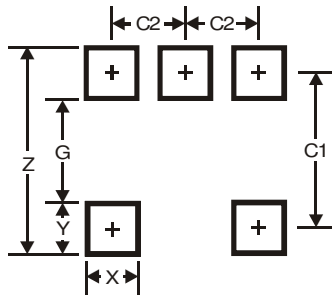
Please see AP02001 at <http://www.diodes.com/datasheets/ap02001.pdf> for the latest version.

**SOT23**



Dimensions	Value (in mm)
Z	2.9
X	0.8
Y	0.9
C	2.0
E	1.35

**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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