A Product Line of
Diodes Incorporated

ZETEX

ZXCT1107/1109/1110
LOW POWER HIGH-SIDE CURRENT MONITORS

Description

The ZXCT1107/09/10 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 packages make them suitable for a range of applications; including adapters, automotive and systems operating from industrial 24V rails.

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

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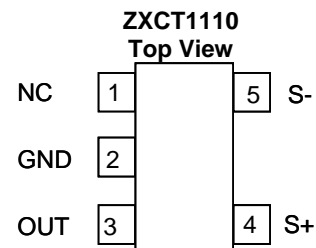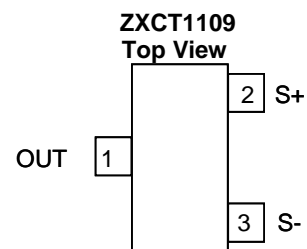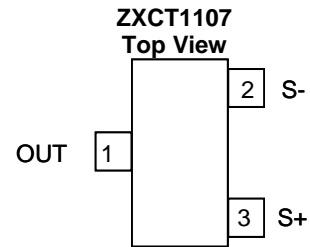
Features

- Wide supply and common-mode voltage range:
  2.5V to 36V
- SOT23 packages
  - 3-pin   ZXCT1107/09
  - 5-pin   ZXCT1110
- Low quiescent current (3µA).
- Extended industrial temperature range -40 to 125°C
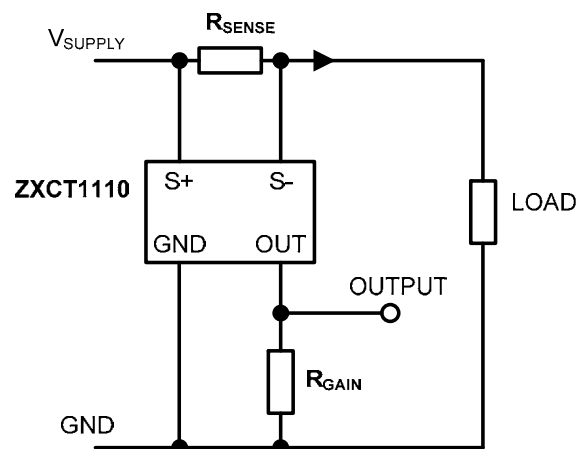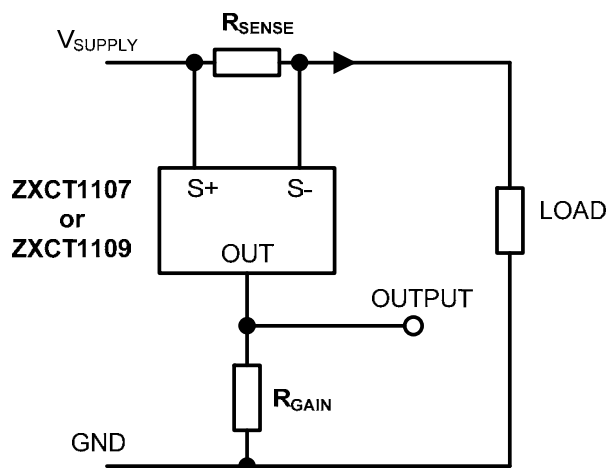- AEC-Q100 Grade1 Automotive qualified variants

Applications

- Automotive current measurement
- Industrial applications current measurement
- Battery management
- Over current monitor
- Power Management

Pin Assignments

ZXCT1107
Top View

OUT | 1

2 | S-

3 | S+

ZXCT1109
Top View

OUT | 1

2 | S+

3 | S-

ZXCT1110
Top View

NC | 1

GND | 2

OUT | 3

5 | S-

4 | S+

Typical Application Circuit

Pin Descriptions

Package	SOT23		SOT25	Description
Name	ZXCT1107	ZXCT1109	ZXCT1110	
OUT	1[1]	1[1]	3	Output pin. 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

Notes.   1. For the ZXCT1107 and ZXCT1109 pin 1 (OUT) acts as both the output pin and substrate connection. This means that for the ZXCT1107 and ZXCT1109 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}[2,3]	-0.3 to 0.8	V
Current into S+ and S-[3]	±8.5	mA
Storage Temperature	-55 to 150	°C
Maximum Junction Temperature	150	°C
Package Power Dissipation (T_A = 25°C) SOT23 SOT25	300 (De-rate to Zero at 150°C) 300 (De-rate to Zero at 150°C)	mW
ESD Ratings		
Human Body Model	1000	V
Machine Model	150	V

Operation above the absolute maximum rating may cause device failure. Operation at the absolute maximum ratings, for extended periods, may reduce device reliability.

Notes: 2. $V_{SENSE} = V_{S+} - V_{S-}$
          3. 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.

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

2 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Recommended Operating Conditions

Symbol	Parameter		Min	Max	Unit
V_{S+}	Common-mode input range[4]:	ZXCT1110	2.5	36	V
		ZXCT1107/9	$V_{OUT(MAX)}$ + 2.5	36	
V_{SENSE}	Differential Sense Input voltage range (V_{S+}-V_{S-})		0	0.5	V
V_{OUT}	Output voltage range ($0 \le V_{SENSE} \le 100mV$)	ZXCT1110	0	V_{S-} - 1	V
		ZXCT1107/9	0	V_{S+} - 2.5	
T_A	Ambient temperature range		-40	125	°C

Notes.   4. For the ZXCT1107 and ZXCT1109 pin 1 (OUT) acts as both the output pin and substrate connection. This means that for the ZXCT1107 and ZXCT1109 the minimum rail voltage that can be used is 2.5V + V_{OUT} (see applications section for more details).

Electrical Characteristics (T_A = 25°C, V_{S+} = 20V, V_{SENSE}[5] = 100mV, R_{GAIN} = 0 unless otherwise stated)

ZXCT1107, ZXCT1109

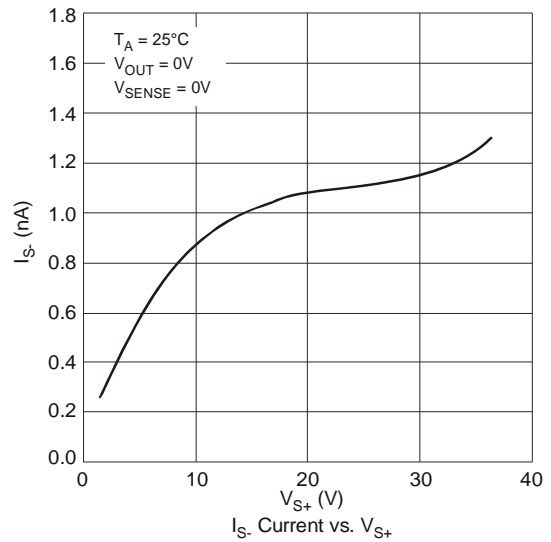| Symbol	Parameter	Conditions	T_A	Min	Typ	Max	Units
I_{S-}	S- input current	V_{SENSE}[5] = 0V	25°C		19	100	nA
			-40°C		16		
			125°C		35		
I_{OUT}	Output current[6]	V_{SENSE}[5] = 0mV	25°C	1	3	10	µA
			-40°C		2.2		
			125°C		5.5		
		V_{SENSE}[5] = 10mV	25°C	37	45	54	
			-40°C		42		
			125°C		49		
		V_{SENSE}[5] = 30mV	25°C	115	124	134	
			-40°C		119		
			125°C		129		
		V_{SENSE}[5] = 100mV	25°C	394	408	422	
			-40°C		396		
			125°C		420		
		V_{SENSE}[5] = 200mV	25°C	787	810	832	
			-40°C		785		
			125°C		832		
		V_{SENSE}[5] = 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	µA/V
			-40°C		0.13		
			125°C		0.05		
BW	-3dB Small Signal Bandwidth	V_{SENSE}[5] (AC) = 10mV$_{PP}$ R_{GAIN} = 2.5kΩ	25°C		0.65		MHz

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

3 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Electrical Characteristics (T_A = 25°C, V_{S+} = 20V, V_{SENSE}[5] = 100mV, R_{GAIN} = 0 unless otherwise stated) (cont.)

ZXCT1110

Symbol	Parameter	Conditions	T_A	Min	Typ	Max	Units
I_Q	GND pin current	V_{SENSE}[5] = 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[6,7]	V_{SENSE}[5] = 10mV	25°C		0	±4	µA
			-40°C		-1.8		
			125°C		+2.5		
G_T	Transconductance	V_{SENSE}[5] = 10mV to 150mV	25°C	3.928	4	4.072	mA/V
			-40°C		3.9		
			125°C		4.08		
GE	Transconductance error	V_{SENSE}[5] = 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}[5] (AC) = 10mV$_{PP}$, R_{GAIN} = 2.5kΩ	25°C		0.65		MHz

Notes.
5. V_{SENSE} = "V_{SENSE+}" − "V_{SENSE-}"
6. Output current characteristic measured with low impedance ammeter connected to GND
7. Defined as difference between actual output current and 40µA; measured at V_{SENSE} =10mV. This will include an error due to bias currents of the device.
8. For V_{SENSE} > 10mV, the internal voltage-current converter is fully linear. This enables a true offset to be defined and used.

ZXCT1107/1109/1110
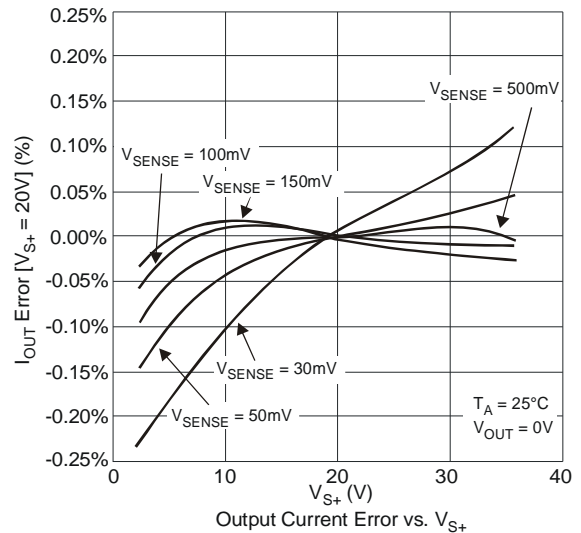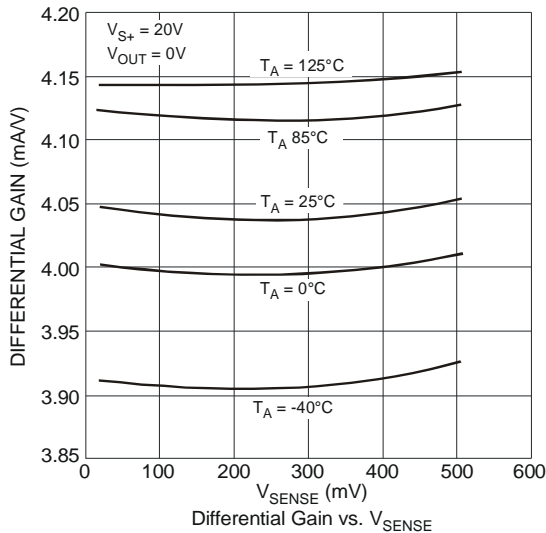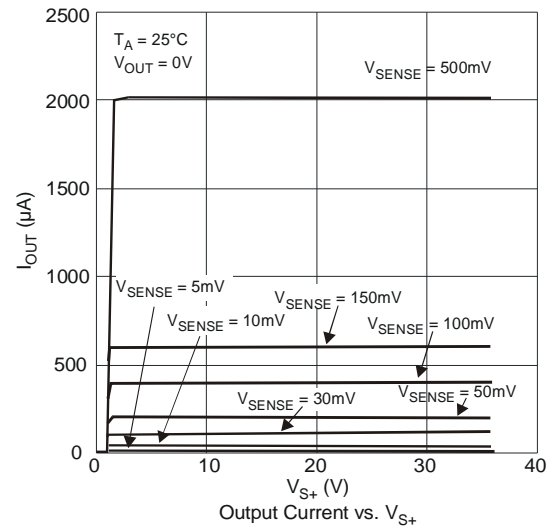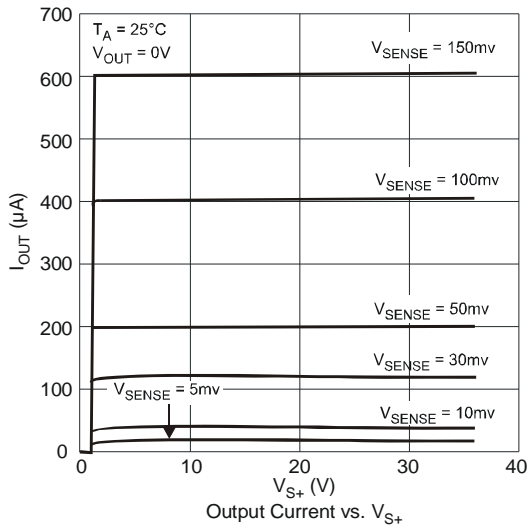Document number: DS35033 Rev. 3 - 2
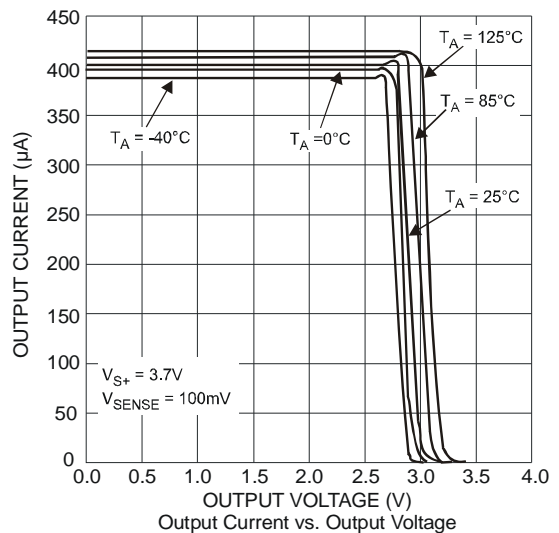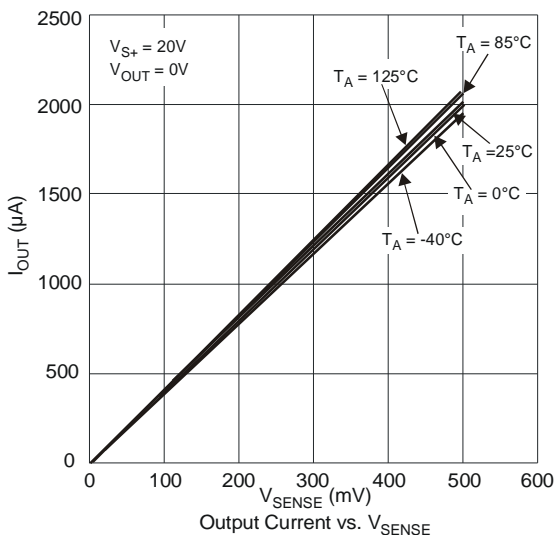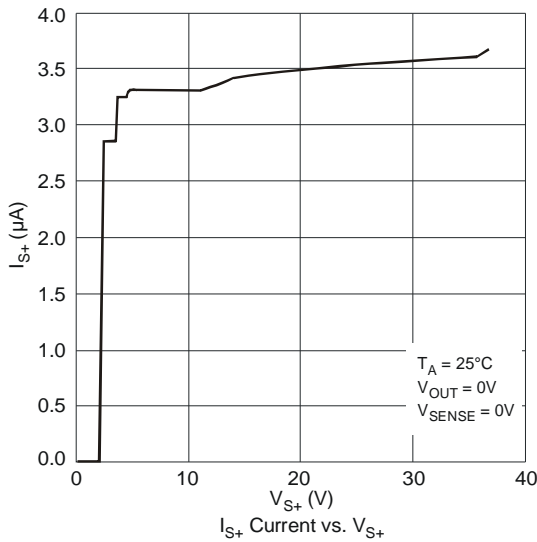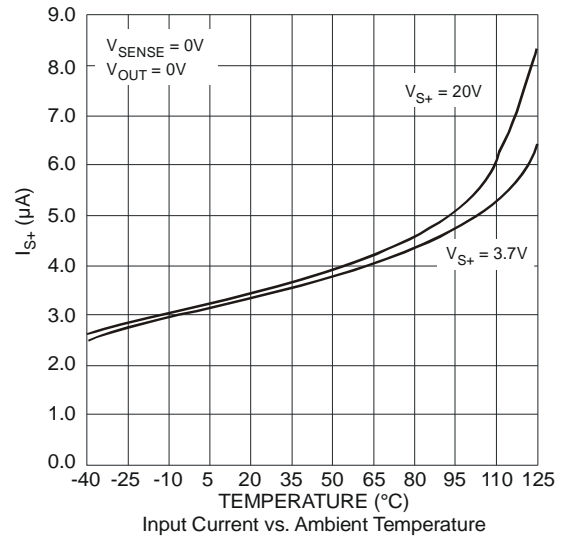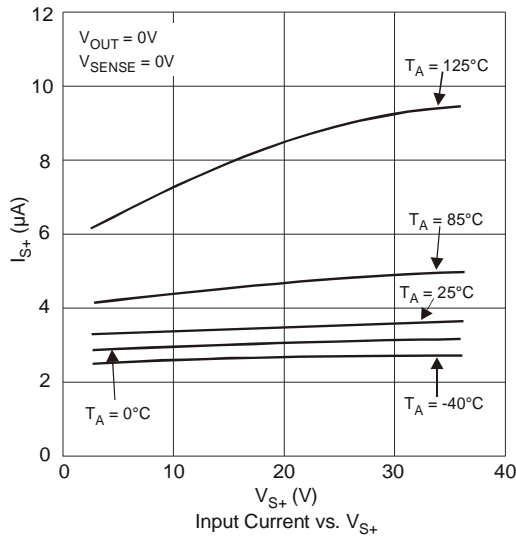
4 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Typical Characteristics

Input Current vs. V_S+

Input Current vs. Ambient Temperature

I_S+ Current vs. V_S+

I_S- Current vs. V_S+

Output Current vs. V_SENSE

Output Current vs. Output Voltage

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

5 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Typical Characteristics (cont.)

Output Current vs. Ambient Temperature

Output Current vs. Ambient Temperature

Output Current vs. V_{S+}

Output Current vs. V_{S+}

Differential Gain vs. V_{SENSE}

Output Current Error vs. V_{S+}

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

6 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Typical Characteristics (cont.)

Output Current Error vs. V_{S+}

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

7 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Typical AC Characteristics

Small Signal Pulse Response

Large Signal Pulse Response

Large Signal Pulse Response

Small Signal Pulse Response

Small Signal Pulse Response

Small Signal Pulse Response

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

8 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated
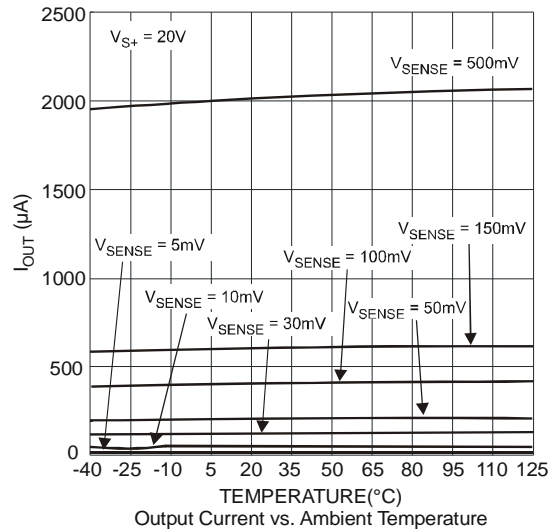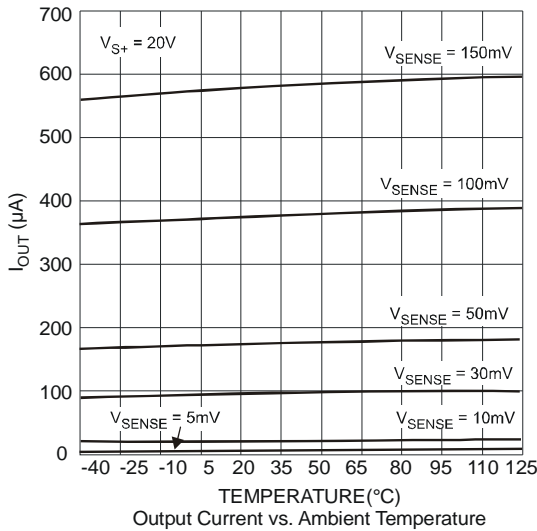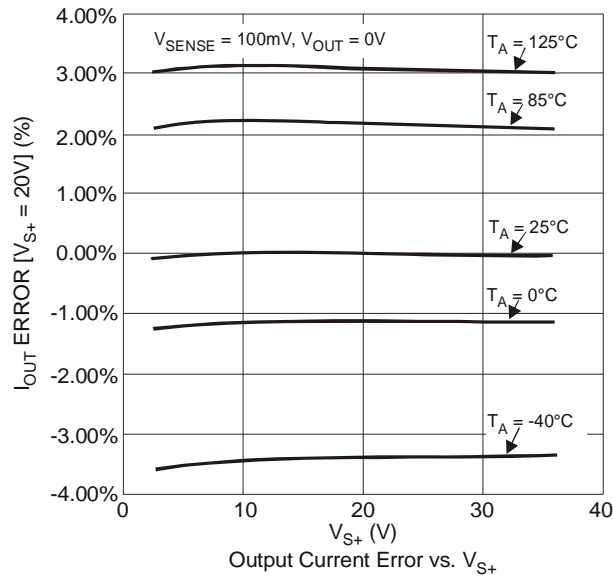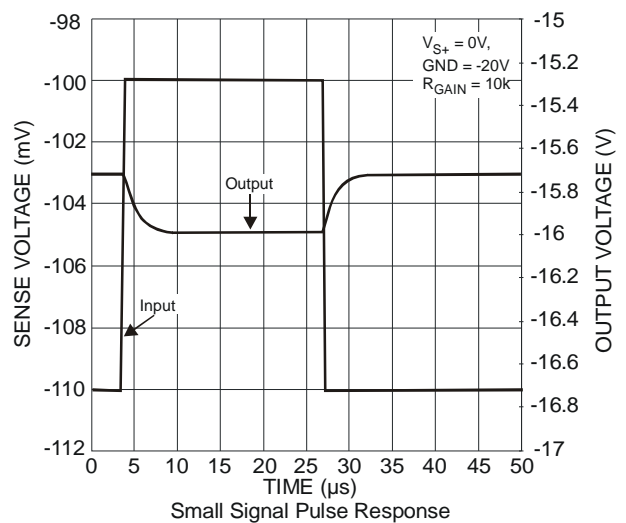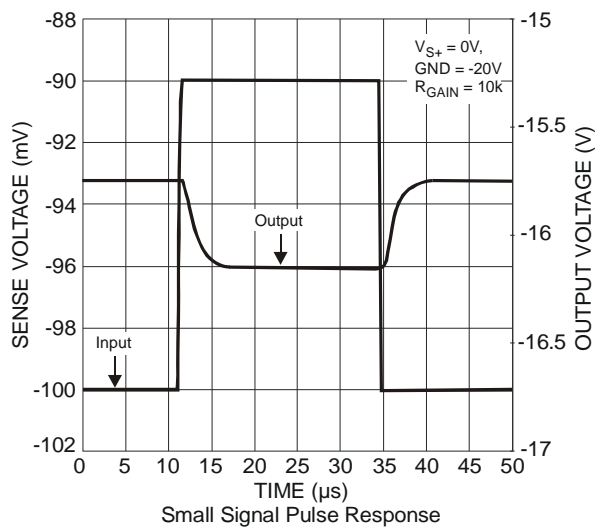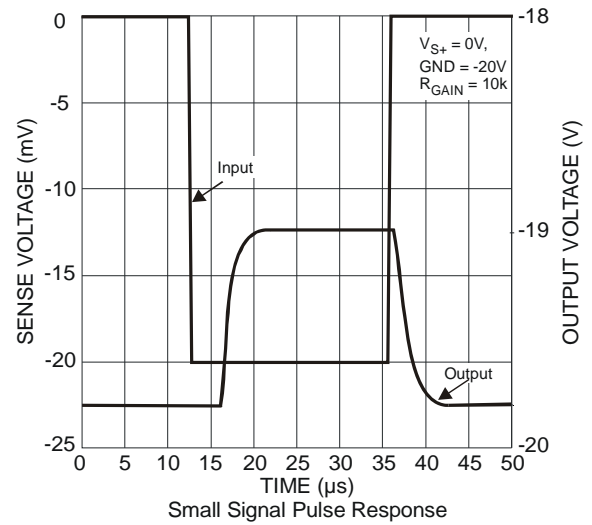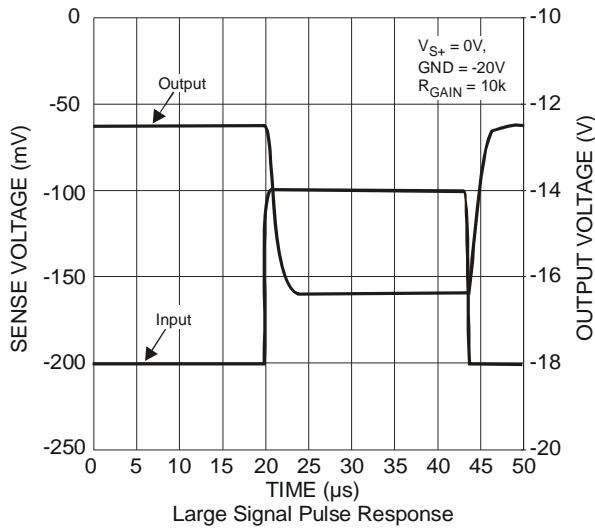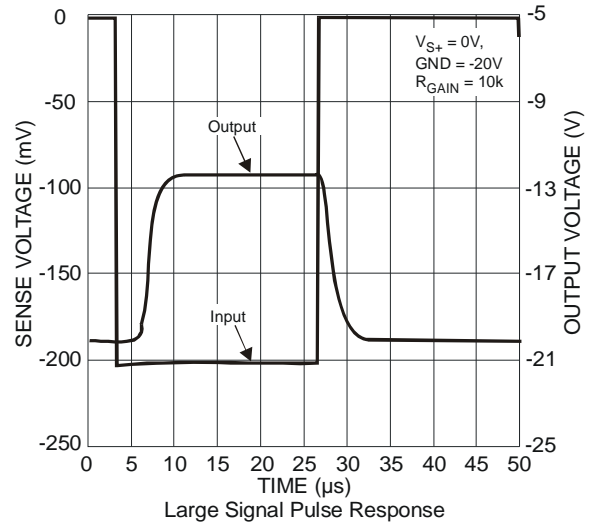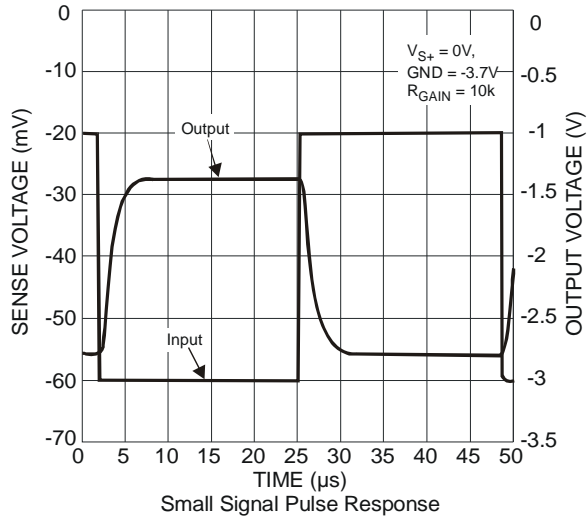
Typical AC Characteristics (cont.)
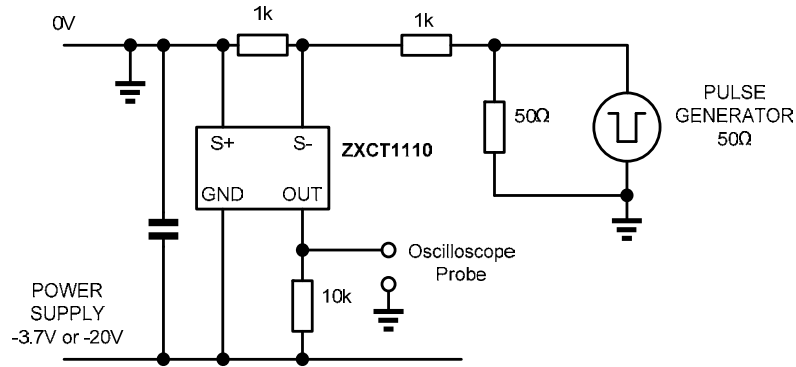
Test Circuit for Pulse Response

Common Mode Rejection Ratio CMRR

$T_A = 25°C$
$V_{S+} = 20V$
$V_{SENSE} = 100mV$
$V_{S+\ AC} = V_{S-\ AC}$ 10mV
$R_{GAIN} = 2.5K$

Test circuit for CMRR

Small Signal Bandwidth

$T_A = 25°C$
$V_{S+} = 20V$
$V_{SENSE\ DC} = 100mV$
$V_{SENSE\ AC} = 10mVpp$
$R_{GAIN} = 2.5K$
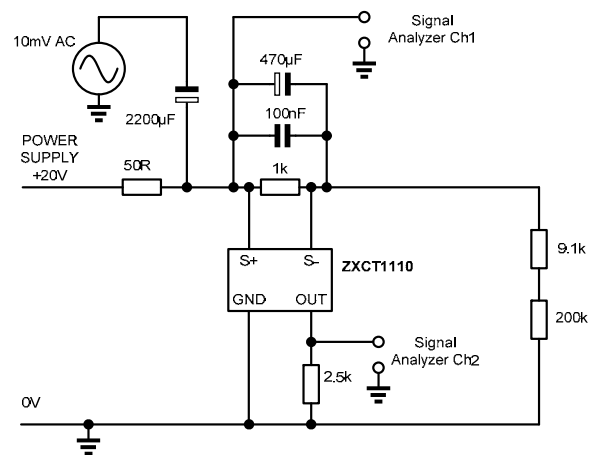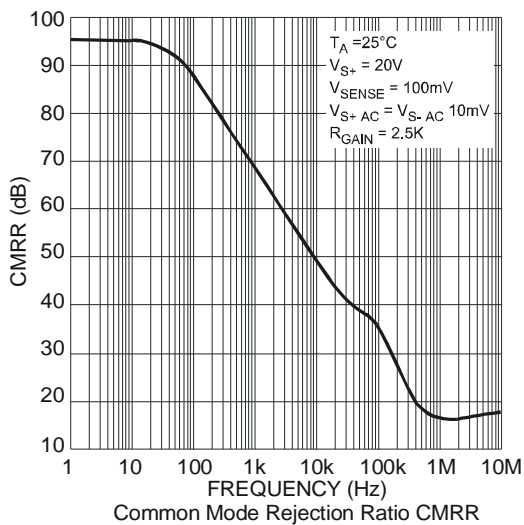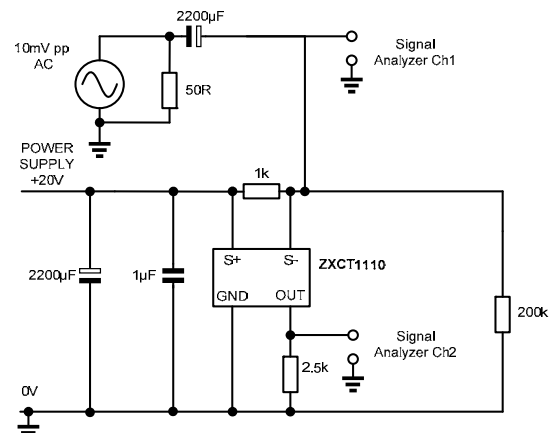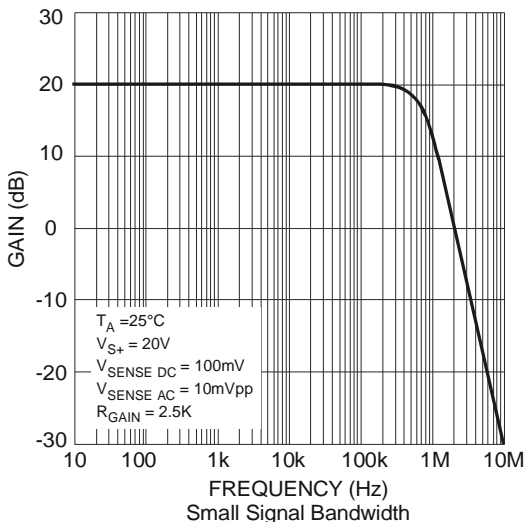
Test circuit for Small signal bandwidth

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

9 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Application Information

Description

The current monitor ICs ZXCT1107, ZXCT1109 and ZXCT1110 all use a similar application circuit topology for high-side current sensing, with small differences. The ZXCT1110 has a separate ground pin whereas the ZXCT1107 and ZXCT1109 do not. The use of ZXCT1110 allows reduction of the absolute current measurement error in some applications by providing a reduced output offset current. The ZXCT1107 provides a mirror image pin assignment of the ZXCT1109 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.

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

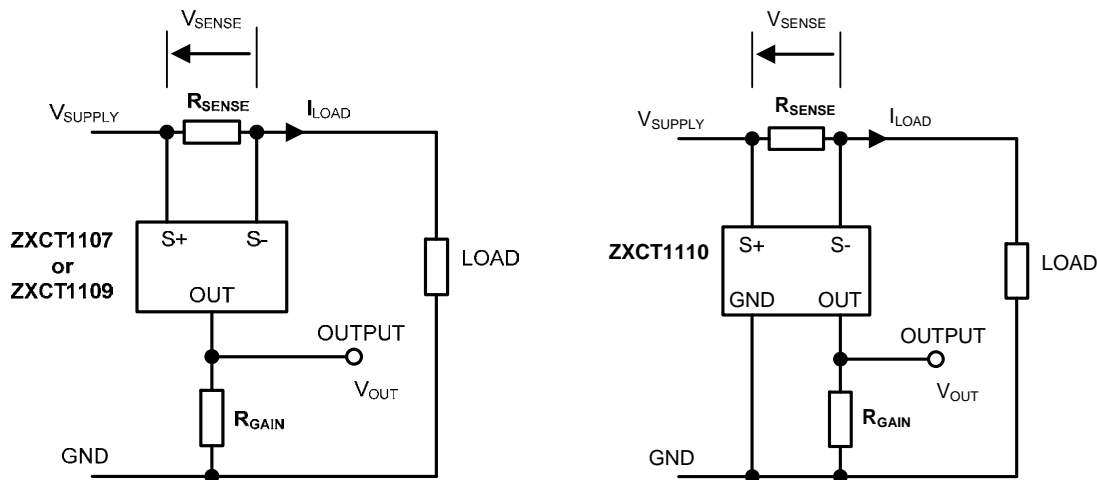Then the resistors determine the output voltage as described below.

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 ZXCT1107/1109/1110 device and the tolerances of the two resistors R_{SENSE} and R_{GAIN}. The ZXCT1107/ZXCT1109 absolute error is shown in Table 1 with error limits drawn from the table of Electrical Characteristics above. This error varies with V_{SENSE}.

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

10 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Application Information (cont.)

The ZXCT1110 is highly linear and has a transconductance of 4mA/V ±1.8% and an output of 40µA ±4µA at V_{SENSE}=10mV. The output current can therefore be calculated (Standard International Units) as:

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

The worst-case current error is then

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

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

The percentage error is

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

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

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

This shows that the error is reduced with increasing V_{SENSE}. Then the minimum V_{SENSE} required to give the error ±ε % is

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

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

Table 1: ZXCT1107/ZXCT1109 Error

V_{SENSE}	Mean I_{OUT}	Error Band	Percent Error
10mV	45.5 µA	±8.5µA	±18.7%
30mV	124.5 µA	±9.5µA	±7.6%
100mV	408 µA	±14µA	±3.4%
200mV	809.5 µA	±22.5µA	±2.8%

Table 2: ZXCT1110 Error

V_{SENSE}	Mean I_{OUT}	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%

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

11 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Application Information (cont.)

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} = 100mV, 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}.

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

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

$$I_{OUTT} = 0.004 * V_{SENSET}$$ Equation 1a

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

or $$R_{GAIN} = \frac{V_{OUTT}}{0.004 * V_{SENSET}}$$ Equation 5

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

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

Equation 5 gives

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

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.
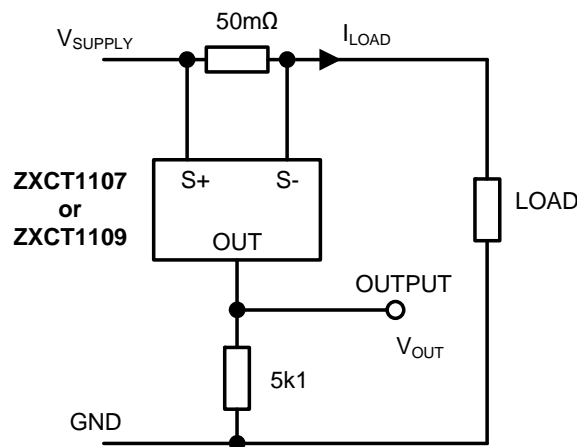

Figure 2. Example Circuit using ZXCT1107/ZXCT1109

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

12 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Application Information (cont.)

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

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

Equation 4 gives

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

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.

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%.
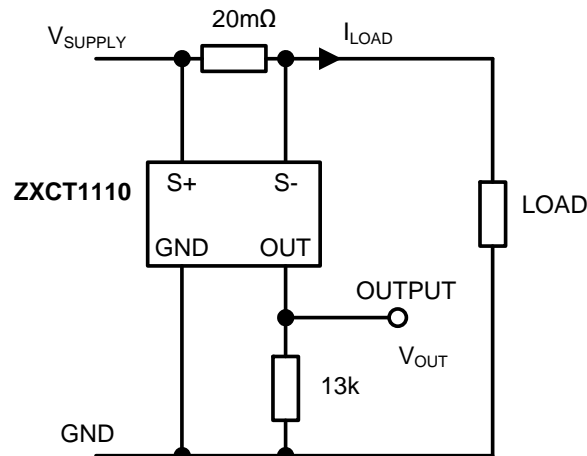
Figure 3. Example Circuit using ZXCT1110

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_{PROT} limits the current and therefore protects the current monitor device against load short circuit without introducing significant current measurement error.

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

13 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Application Information (cont.)
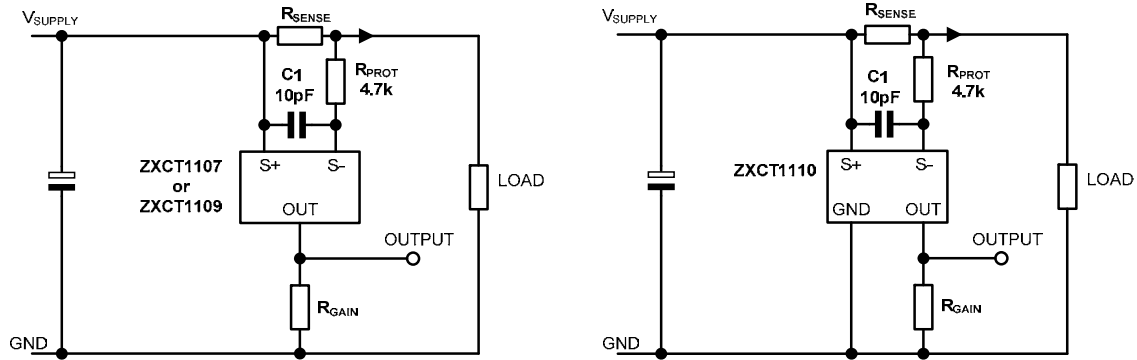
Figure 4. Protection and EMC Filtering

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 a TV LED backlight 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 kΩ, 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.
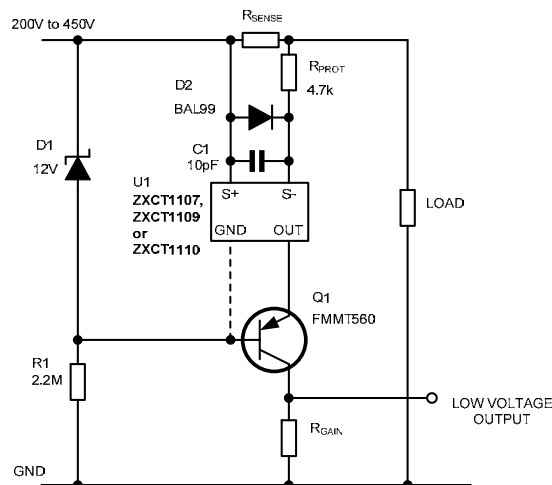
Figure 5. 450V Current Monitor

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

14 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Ordering Information

| Order Reference	Package	Device Marking	Reel Size	Quantity Per Reel	Tape Width (mm)
ZXCT1107SA-7	SOT23	1107	7", 180mm	3000	8
ZXCT1109SA-7	SOT23	1109	7", 180mm	3000	8
ZXCT1110W5-7	SOT25	1110	7", 180mm	3000	8

Package Outline Dimensions (All Dimensions in mm)

Package type: SOT23
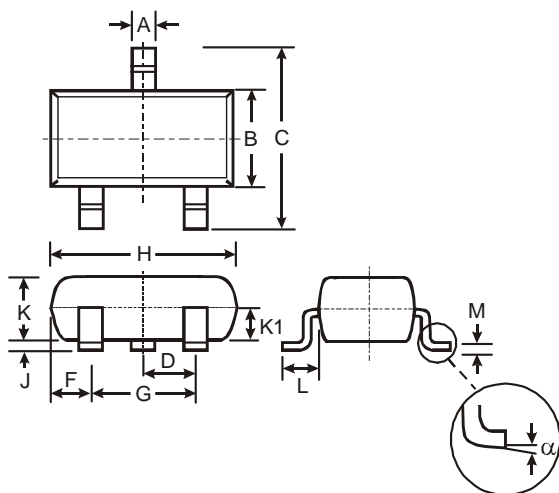
SOT23			
Dim	Min	Max	Typ
A	0.37	0.51	0.40
B	1.20	1.40	1.30
C	2.30	2.50	2.40
D	0.89	1.03	0.915
F	0.45	0.60	0.535
G	1.78	2.05	1.83
H	2.80	3.00	2.90
J	0.013	0.10	0.05
K	0.903	1.10	1.00
K1	-	-	0.400
L	0.45	0.61	0.55
M	0.085	0.18	0.11
α	0°	8°	-
All Dimensions in mm			

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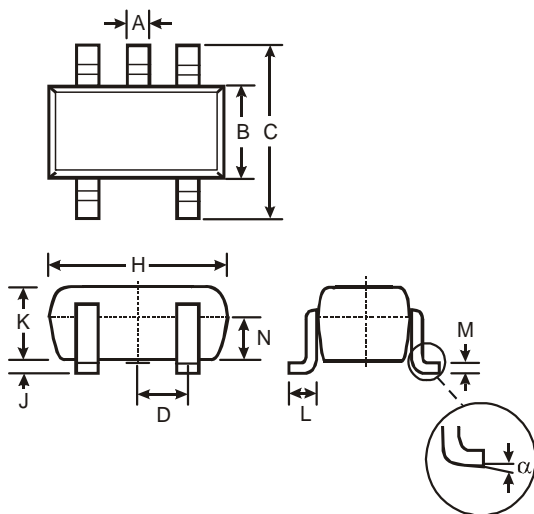
SOT25			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	—	—	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	—
All Dimensions in mm			

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

15 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

ZXCT1107/1109/1110
Document number: DS35033 Rev. 3 - 2

16 of 16
www.diodes.com

JULY 2011
© Diodes Incorporated

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

[Diodes Incorporated](#):
  [ZXCT1110W5-7](#) [ZXCT1107SA-7](#) [ZXCT1109SA-7](#)