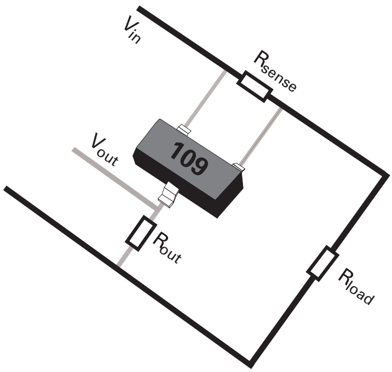
HIGH SIDE CURRENT MONITOR

The ZXCT series of devices are high side current sensing monitors that eliminate the need to disrupt the ground plane when sensing a load current.

Current measurement is a common requirement when dealing with applications such as battery chargers, power supply units, motor control and battery supervisory circuits. High side current sensing can be measured using an operational amplifier with an array of resistors, but as portable applications become smaller, dedicated devices in smaller packages are becoming more attractive.

To ensure usage of the device is optimised when high side current sensing with the ZXCT1009, it is important for the correct value of R_{SENSE} to be chosen.



Considerations for R_{SENSE}

Power Dissipation

The value of R_{SENSE} should be small enough such that the power dissipated from the device is acceptable. When higher values of R_{SENSE} are used the I^2R losses could become such that the value of V_{SENSE} may begin to drift, due to a rise in temperature, reducing the accuracy of the value measured.

This obvious power requirement must be balanced against accuracy:

Offset Voltage

The value of V_{SENSE} should be relatively large compared to the value of the device offset voltage. A higher value of R_{SENSE}, gives a higher value of V_{SENSE} enabling currents to be measured more accurately, since the offset voltages becomes less significant when compared to V_{SENSE}. The typical value of the offset voltage is smaller for the ZXCT1010, which has the addition of a ground pin.

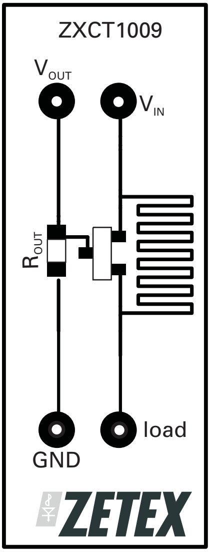
Inductance

The R_{SENSE} value must have a low inductance if the sense current has a high frequency component. This avoids the reactance of the inductive element creating an additional voltage, making the measured current appear to be larger than it actually is. Low-inductance metal film resistors are suitable for most applications. When considering a current with a high frequency, wirewound resistors are not recommended due to their large inductance.

Low Cost Solution for ZXCT1009/1010

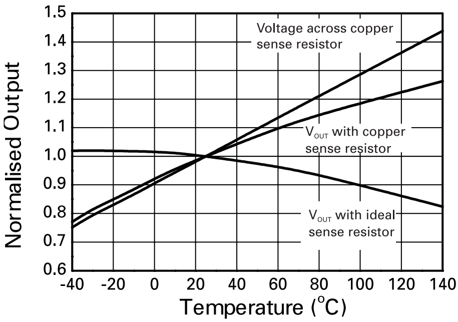
When cost is a critical factor in the solution, the copper trace of the PCB can be used for R_{SENSE} (figure 1.0a), instead of a conventional surface mount resistor.

PCB resistive trace used for RSENSE Figure 1.0a



Total circuit solution: 2 components. Shows area of 150mΩ sense resistor compared to SOT23 package. Practical tolerance of the PCB resistor will be around 5% depending on manufacturing methods. Temperature coefficient of the resistance of Copper is around +0.4% / °C. See ZXCT1009 datasheet for more details.

figure 1.0b Effect of Sense Resistor Material on temperature performance.



The graph, figure 1.0b above shows output characteristics of the device when using a PCB resistive trace for the low cost solution. The graph shows the linear rise in voltage across the resistor due to the PTC of the material and demonstrates how this rise in temperature compensates for the NTC of the device.

Extended Supply range for ZXCT1009

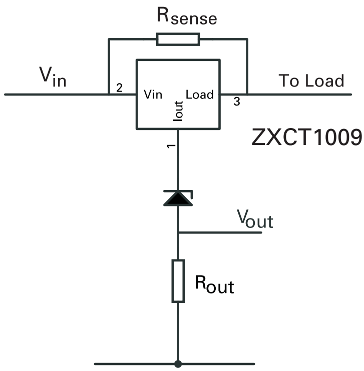
The ZXCT1009 has a maximum operating voltage of 20V. Where higher voltages are required, the following circuits can be considered.

Note 1. Simplest circuit for Vin > 20V:

In the case where the maximum to minimum supply voltage variation is less than the operating range of the ZXCT1009 (20V - 2.5V => 17.5V), 1 zener diode can be added in series with Rout. (Figure 2.0).

The zener voltage is chosen to make Vin – $V_{IOUT} \leqslant 20V$, at the max input voltage.

Figure 2.0 Extended supply range using a Zener Diode



E.g. Supply voltage range = 15V to 30V, Vout between 0V and 1V.

Choose a 10V zener diode.

Consider Iout as the device's ground connection, the ZXCT1009 will be supplied with:

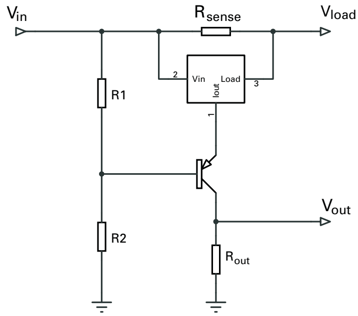
15V - 10V – 1V => 4V minimum - ok

30V – 10V – 0V => 20V maximum - ok

Note 2. For V_{in} > 20V with larger input voltage supply range.

This circuit (figure 3.0) can be used for correct operation during transients or high input voltages and is only dependent on the

Figure 3.0 Extended Supply range using additional transistor



voltage rating of the chosen transistor; V_{CEO}. TR1 is used in common base configuration and is used to drop most of the supply voltage between collector and emitter. When the current gain is reasonably high (>100), $I_C \approx I_E$ and I_{out} still flows through R_{out} and hence Vout can be calculated in the normal way.

R1 must be chosen to preserve the ZXCT1009's normal supply range, large enough in value to provide the minimum operating voltage to the device at the lowest supply voltage but not too large that the maximum device operating voltage is exceeded at the highest input voltage.

E.g.

V_{IN} = 20 to 100V V_{OUT} >2V

Choose the R_1/R_2 current to be 0.5mA to keep the power dissipation in R_2 low. At V_{IN} = 100V, choose R_1 to supply the device with 20V.

V_{R1} is then 20V (ignore the V_{BE} of T_{R1}).

$$R_1 = \frac{20}{0.5 \times 10^{-3}} = 40K\Omega$$

Choose NPV 39kΩ.

V_{R2} is 100V – ($39x10^{-3}$ x $0.5x10^{-3}$) => 80.5V

$$R_2 = \frac{80.5}{0.5 \times 10^{-3}} => 161K\Omega$$

Choose NPV 180kΩ.

Now check for minimum device voltage:

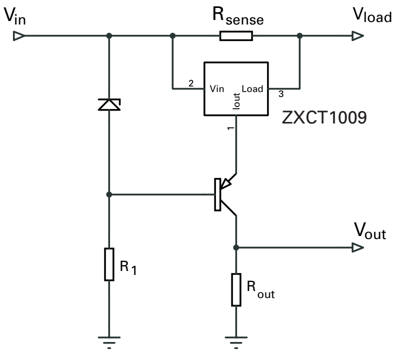
$$\left[20 \times \frac{R_1}{R_1 + R_2}\right] - 1V_{BE} = 3.56V - 0.6V => 2.96V — ok$$

And maximum device voltage:

$$\left[100 \times \frac{R_1}{R_1 + R_2}\right] - 1V_{BE} = 17.8V - 0.6V => 17.2V — ok$$

If a larger supply voltage range is needed a zener diode can be used to sustain a suitable operating voltage for the ZXCT1009, e.g. 4V7.

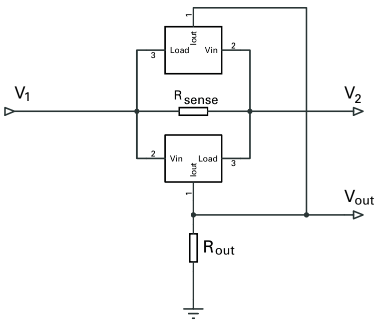
Figure 4.0 Extended Supply Range using additional transistor and Zener



Bi-directional Current Sensing for ZXCT1009/1010

The ZXCT1009 / 1010 can be used to measure current bi-directionally, if two devices are connected as shown in figure 5.0.

Figure 5.0 Bi-directional Current Sensing using ZXCT1009s



If the voltage V_1 is positive with respect to the voltage V_2 the lower device will be active, delivering a proportional output current to R_{out}. Due to the polarity of the voltage across R_{sense}, the upper device will be inactive and will not contribute to the current delivered to R_{out}. When V_2 is more positive than V_1, current will be flowing in the opposite direction, causing the upper device to be active instead.

Non-linearity will be apparent at small values of V_{sense} due to offset current contribution. Devices can use separate output resistors if the current direction is to be monitored independently.

ZETEX

Short circuit / over-current applications Circuit Figure 6.0

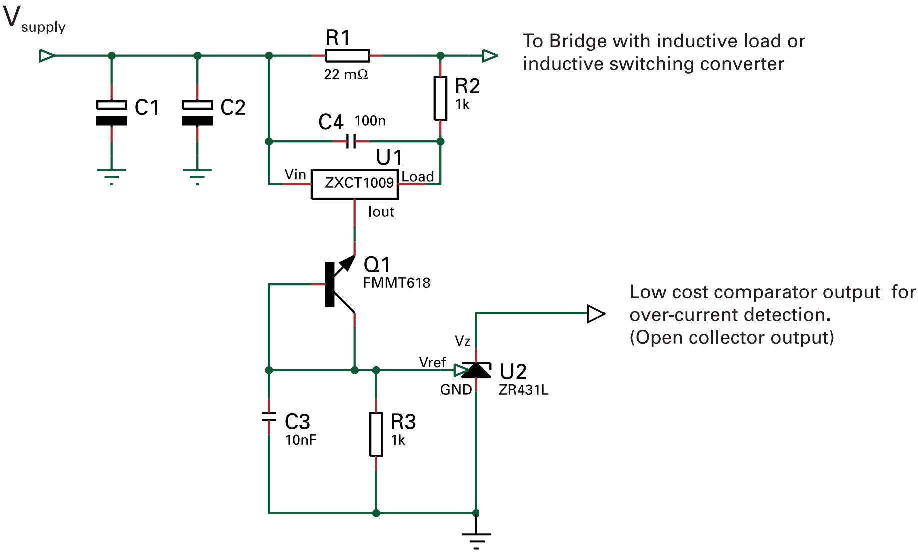


Figure 6.0 above shows a solution for short circuit or over-current protection.

It senses the current in a small resistor (R1 - 22 milli-ohm) which is fitted between optional reservoir capacitors (C1 & C2) and the load in question. The small voltage developed across R1 is converted by the ZXCT1009 into a proportional current in resistance R3.

When monitoring an inductive load where voltage transients may be present, R2 and C4 provide filtering to ensure correct operation. If the load is purely resistive these components can be omitted.

Transistor Q1 serves to reduce the voltage seen by U1 and operates as a zener diode in its reverse Vbe breakdown mode. Q1 is not needed when operating with supplies below 20 volts.

The voltage developed across R3 is then fed to U2 (ZR431L) which is actually a programmable voltage reference used as a comparator. When the voltage on the Vref pin exceeds 1.24 volts, the device conducts, pulling the open collector output low. The required pull-up resistor can be connected to any supply rail of choice up to 20V. The advantage of using the ZR431L as a level detector in preference to a transistor Vbe or a FET V_T is that the voltage sense level is virtually independent of temperature.

The sensitivity of the current limit can be increased or reduced by adjusting the value of R3 to develop the required 1.24 volts at different currents. C3 provides a time delay to prevent false triggering.

Value of current that causes the output to switch can be calculated by rearranging the datasheet formula:

$$V_{OUT} = V_{REF} = 0.01 \times V_{SENSE} \times R_{OUT}$$

(Vref = 1.24V, Rout = R3 and Vsense = ILOAD x R1)

So the trip current will be:

$$Itrip = \frac{1.24}{0.01 \times R1 \times R3} \text{ (A)}$$

(Notes)

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