# ZXCT1012
# Reduced height micro-power current monitor

## Description

The ZXCT1012 is a high side current sense monitor. Using this type of device eliminates the need to disrupt the ground plane when sensing a load current.

The ZXCT1012 takes the voltage developed across a small value resistor and translates it into a proportional output current. A user defined output resistor scales the output current into a ground referenced voltage.

The ZXCT1012 has the accuracy specification of the ZXCT1010 but in TSOT23-5, and TDFN3x3-5.

A minimum operating current of just 3.5µA, combined with its TSOT23-5 package make it suitable for portable battery equipment where size and current consumption are critical.

The wide input voltage range down to as low as 2.5V make it suitable for a wide range of applications requiring direct operation from a battery.

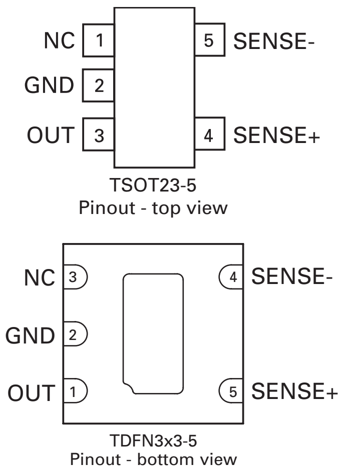
## Features

- 2.5V to 20V supply range
- 3.5µA quiescent current
- Current output - user set gain
- Thin package - TSOT23-5 and TDFN3x3-5
- Temperature range -40 to 85°C

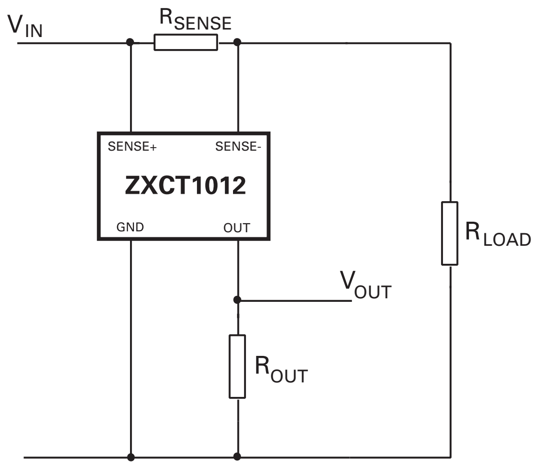
## Applications

- Battery fuel gauge
- Battery chargers
- Overcurrent monitor
- Power management

## Pin connections




## Applications circuit




## Ordering information

| Device | Package | Status | Device marking | Reel size (inches) | Tape width (mm) | Quantity per reel |
|---|---|---|---|---|---|---|
| ZXCT1012DAATA | TDFN-5 (3mm x 3mm) | Active | 1012 | 7 | 8 | 3000 |
| ZXCT1012ET5TA | TSOT23-5 | Active | 1012 | 7 | 8 | 3000 |

## Pin information

| Pin | | Name | Description |
|---|---|---|---|
| TDFN5 | TSOT23-5 | | |
| 3 | 1 | N/C | No connection |
| 2 | 2 | GND | Ground connection |
| 1 | 3 | OUT | Output current pin. Current generated due to a difference voltage between $V_{SENSE+}$ and $V_{SENSE-}$ flows out of this pin. A suitable value resistor connected to ground creates an output voltage. The maximum voltage out of this pin will be $V_{SENSE-}$ - 1.5V. |
| 5 | 4 | SENSE+ | This pin should be connected to the rail whose current is being measured and also provides power to internal circuitry. It is the positive input of the current monitor and has an input range from 20V down to 2.5V. The current through this pin varies with differential sense voltage. |
| 4 | 5 | SENSE- | This is the negative input of the current monitor and has an input range from 20V down to 2.5V. |

## Absolute maximum ratings

| | |
|---|---|
| $V_{SENSE+}$ max. | 20V |
| Voltage on any pin (relative to GND pin) | -0.6 and $V_{SENSE+}$ +0.5V |
| $V_{SENSE}$(‡) | -0.15V to +3V |
| Ambient operating temperature range | -40 to 85°C |
| Storage temperature | -55 to 150°C |
| Maximimum junction temperature | 150°C |
| Package power dissipation | 300mW at $T_{amb}$= 25°C (De-rate to zero at 150°C) |

| Package | $R_{\Theta JA}$ | $P_{DISS}$ at 25°C |
|---|---|---|
| TSOT23-5 (*) | 250°C/W | 500mW |
| TDFN3x3 5 pin(*) (†) | 232°C/W | 540mW |

**NOTES**:
(*) Mounted on 30mm x 16mm x1.1mm FR4 board with 1oz copper.

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

**NOTES**:
(‡) $V_{SENSE}$ is defined as the differential voltage between the SENSE+ and SENSE- pins.

$$V_{SENSE} = V_{SENSE+} - V_{SENSE-}$$

(†) Exposed lead not connected to thermal plane

## Recommended operating conditions

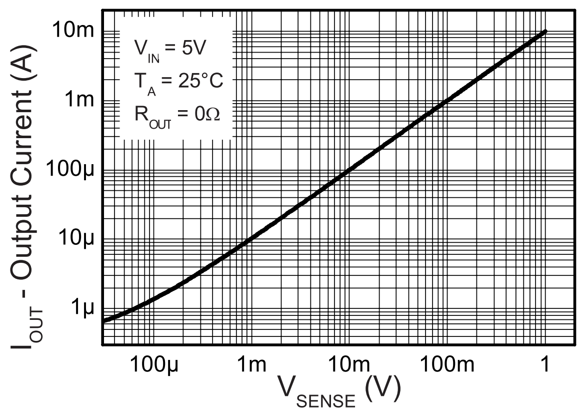
| Symbol | Recommended parameter | Limits Min. | Limits Max. | Units |
|---|---|---|---|---|
| $V_{IN}$ | Sense+ range | 2.5 | 20 | V |
| $T_A$ | Ambient temperature range differential | -40 | 85 | °C |
| $V_{SENSE}$ | Sense voltage | 10 | 2500 | mV |
| $V_{OUT}$ | Output voltage swing | 0 | $V_{SENSE-}$ -1.5 | V |

## Electrical characteristics
## Test conditions $T_{amb}$ = 25°C, $V_{IN} = V_{SENSE+}$ = 5V, unless otherwise stated

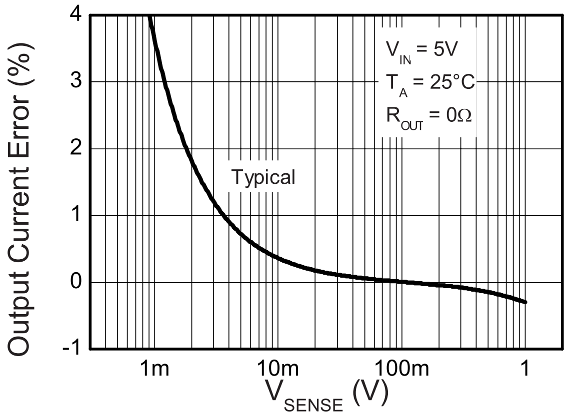
| Symbol | Parameter | Conditions | | Limits Min. | Limits Typ. | Limits Max. | Unit |
|---|---|---|---|---|---|---|---|
| $I_{OUT}$ | Output current | $V_{SENSE}$ = 0V | | 0 | 0.3 | 15 | µA |
| | | $V_{SENSE}$ = 10mV | | 85 | 100 | 115 | µA |
| | | $V_{SENSE}$ = 40mV | | 380 | 400 | 420 | µA |
| | | $V_{SENSE}$ = 100mV | | 0.975 | 1.00 | 1.025 | mA |
| | | $V_{SENSE}$ = 200mV | | 1.95 | 2.00 | 2.05 | mA |
| $I_Q$ | Ground pin current | $V_{SENSE}$ = 0V | | | 3.5 | 8 | µA |
| $I_{SENSE-}$ | SENSE- pin input current | | | | | 100 | nA |
| Acc | Accuracy | $R_{SENSE}$ = 0.1V<br>$V_{SENSE}$ = 200mV | | -2.5 | | 2.5 | % |
| Gm | Transconductance, $I_{OUT}/V_{SENSE}$ (*) | | | | 10 | | mA/V |
| Tc | Temperature coefficient | $V_{SENSE}$ = 200mV<br>$T_{amb}$ = 0 to 50°C (*) | | | 500 | | ppm/°C |
| BW | Bandwidth | $C_L$ = 5pF,<br>$R_{OUT}$ = 1kΩ | $V_{SENSE}$ = 10mV<br>$V_{SENSE}$ = 100mV | | 300<br>2 | | kHz<br>MHz |
| CMRR(‡) | Common mode rejection ratio | $V_{SENSE}$ = 100mV, $R_{OUT}$ = 1kΩ<br>$V_{IN}$ = 2.5V to 20V | | | 80 | | dB |

**NOTES:**
(*) Temperature dependent measurements are extracted from characterisation and simulation results.
(‡) With the ZXCT1012 using SENSE+ as its power supply pin, common mode rejection cannot be distinguished from power supply rejection.

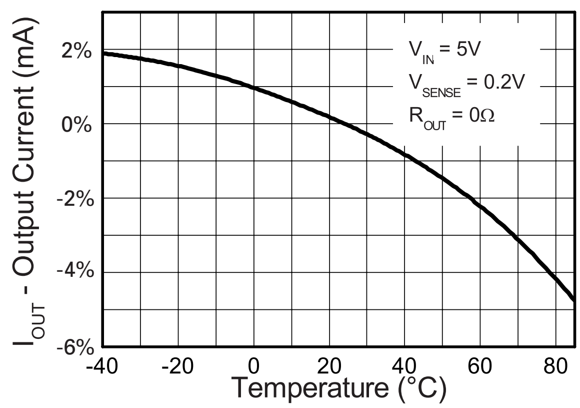
## Typical characteristics



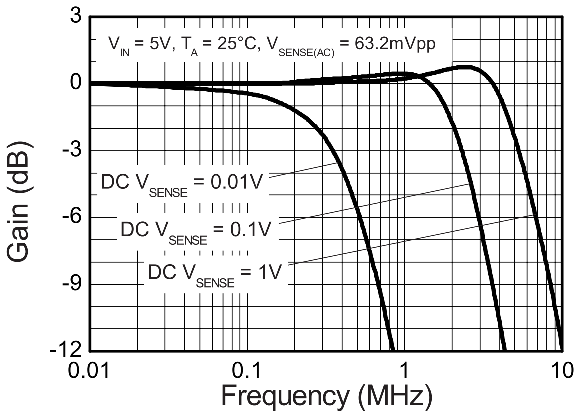

**Typical Output v Sense Voltage**



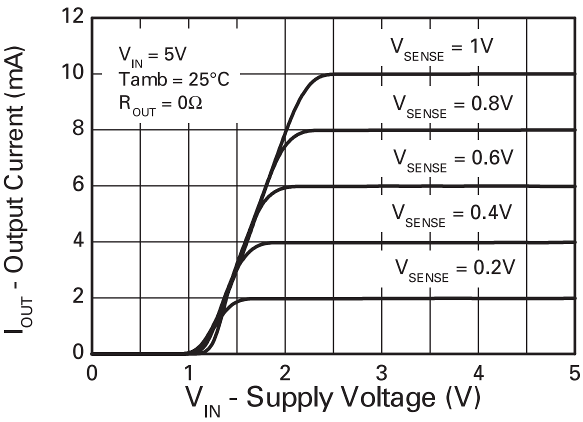

**Error v Sense Voltage**



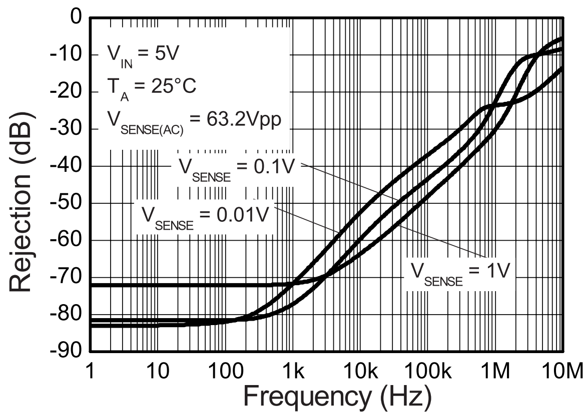

**Output Current v Temperature**




**Frequency Response**




**Transfer Characteristic**




**Common Mode Rejection**

## Applications information

The ZXCT1012 current monitor works by converting the voltage developed across a small sense resistor into a current on the out pin. In reality it is a voltage to current converter. This output current can be converted into a voltage simply by passing it through a resistor ($R_{OUT}$) to ground.

The current monitor has a transconductance of 10mA/V. But the overall amplifying conversion is affected by both the $R_{SENSE}$ and $R_{OUT}$.

The gain equation of the ZXCT1012 is:

$$V_{OUT} = I_L \times R_{SENSE} \frac{R_{OUT}}{100}$$

For best performance $R_{SENSE}$ should be connected as close to the SENSE+ (and SENSE-) pins; which minimizes any series resistance with $R_{SENSE}$ and potential for interference pickup.

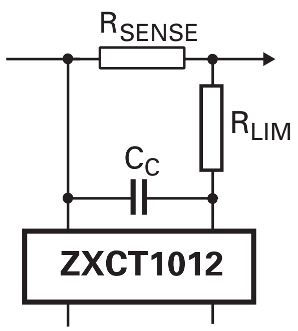
When choosing appropriate values for $R_{SENSE}$ a compromise must be reached between in-line signal loss (including potential power dissipation effects) and small signal accuracy.

Higher values for $R_{SENSE}$ gives better accuracy at low load currents by reducing the inaccuracies due to internal offsets. For best operation the ZXCT1012 has been designed to provide best performance with $V_{SENSE}$ of the order of 40mV to 200mV.

Current monitors are single supply devices which means they tend to saturate at very low sense voltages. However it does mean the output can never go negative. Also the output can never change direction (monotonic). This is important if the current monitor is used in a control loop.

As the sense voltage is reduced the output will tend to saturate as the input offset voltage starts to have greater effect. It is recommended to have a minimum sense voltage of 10mV to minimize linearity errors. Zetex has specified the output voltage at $V_{SENSE}$ of 10mV, 40mV, 100mV and 200mV; which is the recommended sense voltage range.

The maximum differential input voltage, $V_{SENSE}$, is 2.5V; however this will cause large output currents to flow increasing power dissipation in the chip. The sense voltage can be increased further, without damaging the ZXCT1012, by the inclusion of a resistor, $R_{LIM}$, between SENSE- pin and the load. Typical values around 10kΩ. See figure below.




If large reverse currents are expected then the resistor, $R_{LIM}$, will provide protection from exceeding absolute maximum ratings.

A suitable value for $R_{LIM}$ can be determined from:

$$R_{LIM} \approx \frac{V_{SENSE(REF)}}{5mA}$$

Where $V_{SENSE(REV)}$ is the maximum expected reverse sense voltage generated.

The following lines describe how to scale a load current to an output voltage.

$V_{SENSE}$ = $R_{SENSE}$ * $I_{LOAD}$ equation (1)

$I_{OUT}$ = 10mA/V x $V_{SENSE}$ equation (2)

$V_{OUT}$ = $I_{OUT}$ x $R_{OUT}$ equation (3)

## Design example

In the circuit below a 1A current is to be represented by a 100mV output voltage ($V_{OUT}$):

A) To be within recommended values choose the value of $R_{SENSE}$ to give:

50mV > $V_{SENSE}$ > 200mV at full load.

For example set $V_{SENSE}$ = 100mV at 1.0A.

From equation (1)

$R_{SENSE}$ = 0.1V/1.0A = 0.1Ω

B) Now choose $R_{OUT}$ to give:

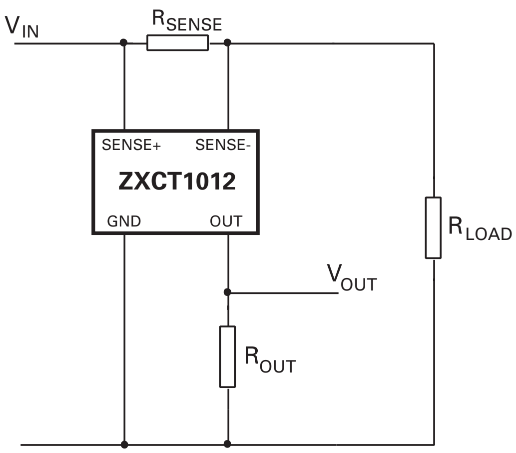
$V_{OUT}$ = 100mV, when $V_{SENSE}$ = 100mV.

From equation (2)

$I_{OUT}$ = 10mA/V x 0.1 = 1mA

Rearranging equation (3) for $R_{OUT}$ gives:

$R_{OUT} = V_{OUT}/I_{OUT}$ = 0.1/0.001 = 100Ω




= 0.1 / (0.1 x 0.01) = 100Ω

## Typical circuit application

Where $R_{LOAD}$ represents any load including DC motors, a charging battery or further circuitry that requires monitoring, Rsense can be selected on specific requirements of accuracy, size and power rating.

## Power dissipation

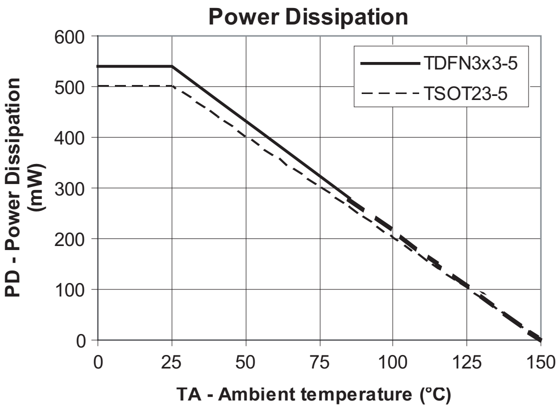
The maximum allowable power dissipation of the device for normal operation ($P_{MAX}$), is a function of the package junction to ambient thermal resistance ($\Theta_{JA}$), maximum junction temperature ($T_{JMAX}$), and ambient temperature ($T_{amb}$), according to the expression:

$$P_{MAX} = (T_{JMAX} - T_{amb}) / \Theta_{JA}$$

The device power dissipation, $P_D$ is given by the expression:

$$P_D = I_{OUT} \cdot (V_{IN} - V_{OUT}) \text{ watts}$$

Care must be taken when using this device at large input voltages and large sense voltages to prevent too much power dissipation.




$V_{IN}$ = 20V $V_{SENSE}$ = 2.5V

$R_{OUT}$ = 100Ω

$I_{OUT}$ = 2.5 x 0.01

= 25mA

$V_{OUT}$ = $I_{OUT}$ x $R_{OUT}$

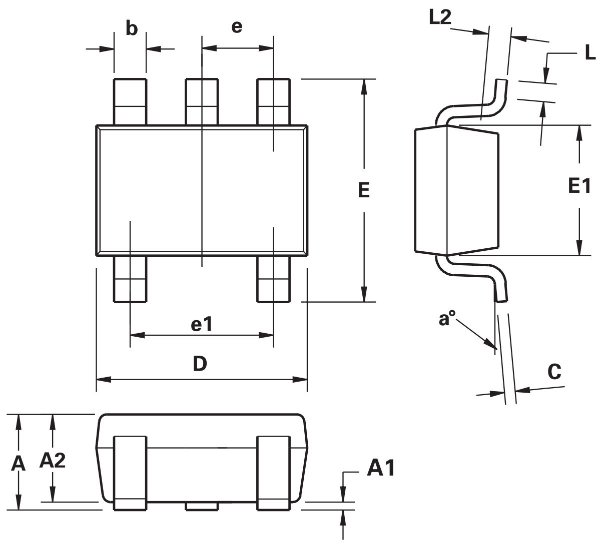
= 25mA x 100Ω

= 2.5V

$\therefore P_D$ = 25mA (20 - 2.5)V

= 438mW

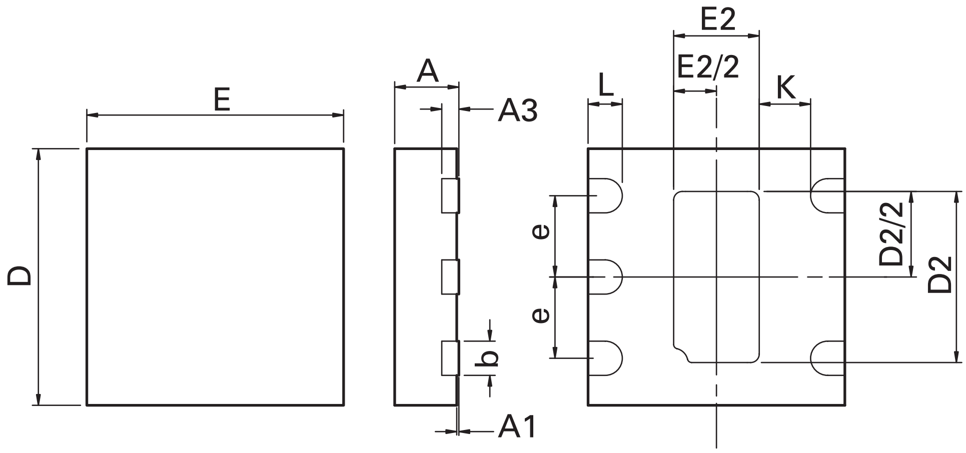
## Package outline - TSOT23-5




| DIM | Millimeters | | Inches | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| A | - | 1.00 | - | 0.0393 |
| A1 | 0.01 | 0.10 | 0.0003 | 0.0039 |
| A2 | 0.84 | 0.90 | 0.0330 | 0.0354 |
| b | 0.30 | 0.45 | 0.0118 | 0.0177 |
| c | 0.12 | 0.20 | 0.0047 | 0.0078 |
| D | 2.90 BSC | | 0.114 BSC | |
| E | 2.80 BSC | | 0.110 BSC | |
| E1 | 1.60 BSC | | 0.062 BSC | |
| e | 0.95 BSC | | 0.0374 BSC | |
| e1 | 1.90 BSC | | 0.0748 BSC | |
| L | 0.30 | 0.50 | 0.0118 | 0.0196 |
| L2 | 0.25 BSC | | 0.010 BSC | |
| a° | 4° | 12° | 4° | 12° |

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

## DAA package outline - TDFN3x3-5




| Dim. | Millimeters | | Inches | | Dim. | Millimeters | | Inches | |
|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | | Min. | Max. | Max. | Max. |
| A | 0.70 | 0.80 | 0.0276 | 0.0315 | e | 0.95REF | | 0.0374REF | |
| A1 | 0.00 | 0.05 | 0.00 | 0.002 | E | 3.00BSC | | 0.1181BSC | |
| A3 | 0.20REF | | 0.0079REF | | E2 | 0.85 | 1.10 | 0.0335 | 0.0433 |
| b | 0.30 | 0.45 | 0.0118 | 0.0177 | L | 0.30 | 0.50 | 0.0118 | 0.0197 |
| D | 3.00BSC | | 0.1181BSC | | K | 0.20 | - | 0.0079 | - |
| D2 | 1.85 | 2.10 | 0.0728 | 0.0827 | - | - | - | - | - |

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

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| Zetex GmbH<br>Kustermann-park<br>Balanstraße 59<br>D-81541 München<br>Germany<br>Telefon: (49) 89 45 49 49 0<br>Fax: (49) 89 45 49 49 49<br>europe.sales@zetex.com | Zetex Inc<br>700 Veterans Memorial Highway<br>Hauppauge, NY 11788<br>USA<br><br>Telephone: (1) 631 360 2222<br>Fax: (1) 631 360 8222<br>usa.sales@zetex.com | Zetex (Asia Ltd)<br>3701-04 Metroplaza Tower 1<br>Hing Fong Road, Kwai Fong<br>Hong Kong<br><br>Telephone: (852) 26100 611<br>Fax: (852) 24250 494<br>asia.sales@zetex.com | Zetex Semiconductors plc<br>Zetex Technology Park, Chadderton<br>Oldham, OL9 9LL<br>United Kingdom<br><br>Telephone: (44) 161 622 4444<br>Fax: (44) 161 622 4446<br>hq@zetex.com |