

Description

The ZXRE060 is a 5-terminal adjustable shunt regulator offering excellent temperature stability and output handling capability. The ZXRE060 simplifies the design of isolated low voltage DC-DC regulators. With its low 0.6V FB pin, it can control the regulation of rails as low as 0.6V. This makes it ideal for state of the art microprocessor/DSP and PLD core voltage POL converters.

The device open-collector output can operate from 0.2V to 18V and regulated output voltage can be set by selection of two external divider resistors.

Separating the input from the open collector output enables the ZXRE060 to be used to make low-cost low drop-out regulators operating at low input voltages.

The ZXRE060 is available in two grades with initial tolerances of 0.5% and 1% for the A and standard grades respectively. It is available in space saving low profile 5 pin SC70-5/SOT353, thin TSOT23-5 and very small DFN1520H4-6 packages.

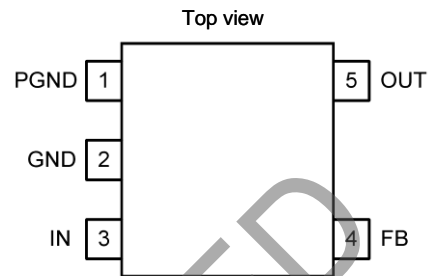
The ZXRE060 in TSOT23-5 has its OUT, GND and FB pins matching the Cathode, Anode and reference pins of the TL432 and TLV431 in SOT23-3, thereby facilitating simple upgrade paths.

Features

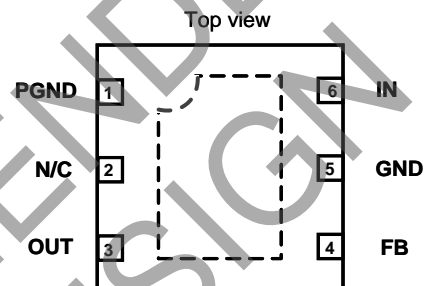
- Low Reference Voltage ($V_{FB} = 0.6V$)
- -40 to +125°C Temperature Range
- Reference Voltage Tolerance at +25°C
 - 0.5% ZXRE060A
 - 1% ZXRE060
- Typical Temperature Drift
 - <4mV (0°C to +70°C)
 - <6mV (-40°C to +85°C)
 - <12mV (-40°C to +125°C)
- 0.2V to 18V Open-collector Output
- High Power Supply Rejection
 - >45dB at 300kHz
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**

- Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
 2. See <https://www.diodes.com/quality/lead-free/> 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.

Pin Assignments



SC70-5/SOT353, TSOT23-5



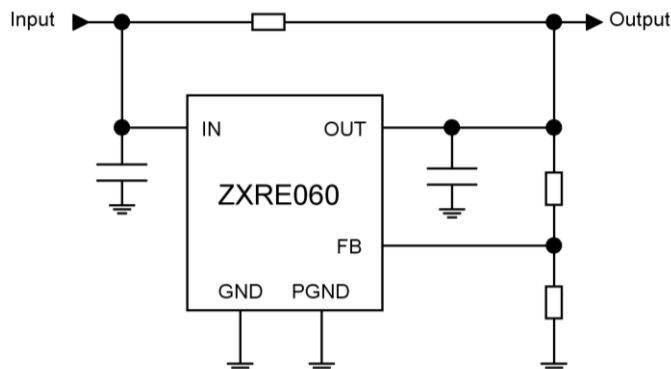
Exposed flag floating or connect to GND

DFN1520H4-6

Applications

- Isolated DC-DC Converters
- Core Voltage POL
- Low Voltage Low-Dropout Linear Regulators
- Shunt Regulators
- Adjustable Voltage Reference

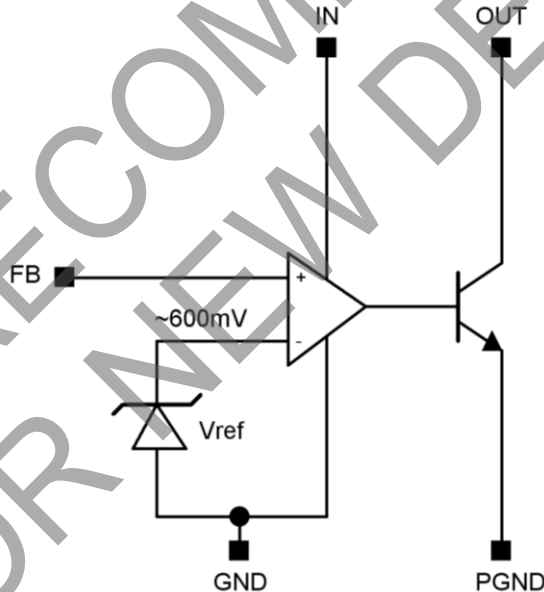
Typical Application Circuit



Pin Description

| Pin Number (SC70-5 /SOT353, TSOT23-5) | Pin Number (DFN1520H4-6) | Pin Name | Function |
|---------------------------------------|--------------------------|----------|--|
| 1 | 1 | PGND | Power Ground: Ground return for emitter of output transistor: Connect PGND and GND together. |
| — | 2 | N/C | No connection |
| 5 | 3 | OUT | Output. Connect a capacitor close to device between OUT and GND. See the Applications Information section. |
| 4 | 4 | FB | Feedback Input. Regulates to 600mV nominal. |
| 2 | 5 | GND | Analog Ground: Ground return for reference and amplifier: Connect GND and PGND together. |
| 3 | 6 | IN | Supply Input. Connect a 0.1µF ceramic capacitor close to the device from IN to GND. |
| — | Flag | — | Floating or connect to GND |

Function Block Diagram



The ZXRE060 differs from most other shunt regulators in that it has separate input and output pins and a low voltage reference. This enables it to regulate rails down to 600mV and makes the part ideal for isolated power supply applications that use opto-couplers in the feedback loop and where the open-collector output is required to operate down to voltages as low as 200mV.

The wide input voltage range of 2V to 18V and output voltage range of 0.2V to 18V enables the ZXRE060 to be powered from an auxiliary rail, while controlling a master rail which is above the auxiliary rail voltage, or below the minimum V_{IN} voltage. This allows it to operate as a low-dropout voltage regulator for microprocessor/DSP/PLD cores.

As with other shunt regulators (and shunt references), the ZXRE060 compares its internal amplifier FB pin to a high accuracy internal reference; if FB is below the reference then OUT turns off, but if FB is above the reference then OUT sinks current – up to a maximum of 15mA.

Absolute Maximum Ratings (Voltages to GND Unless Otherwise Stated)

| Symbol | Parameter | Rating | Unit |
|------------------|--------------------------------|--------------|------|
| V _{IN} | IN Voltage relative to GND | 20 | V |
| V _{OUT} | OUT Voltage relative to GND | 20 | V |
| V _{FB} | FB Voltage relative to GND | 20 | V |
| P _{GND} | PGND Voltage relative to GND | -0.3 to +0.3 | V |
| I _{OUT} | OUT Pin Current | 20 | mA |
| T _J | Operating Junction Temperature | -40 to +150 | °C |
| T _{ST} | Storage Temperature | 55 to +150 | °C |

These are stress ratings only. Operation outside the absolute maximum ratings may cause device failure. Operation at the absolute maximum rating for extended periods may reduce device reliability.

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.

Package Thermal Data

| Package | θ_{JA} | P _{DIS} T _A = +25°C, T _J = +150°C |
|---------------|---------------|---|
| SC70-5/SOT353 | 400°C/W | 310mW |
| TSOT23-5 | 250°C/W | 500mW |
| DFN1520H4-6 | TBD | TBD |

Recommended Operating Conditions

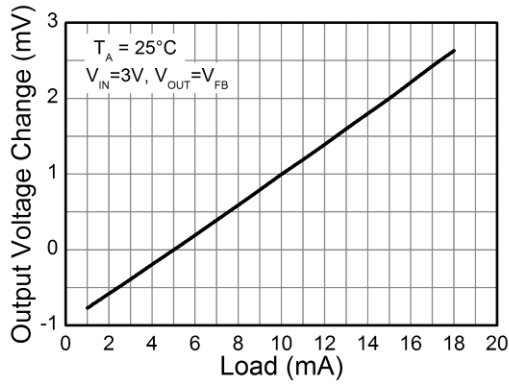
| Symbol | Parameter | Min | Max | Unit |
|------------------|-------------------------------------|-----|------|------|
| V _{IN} | IN Voltage Range (0 to +125°C) | 2 | 18 | V |
| V _{IN} | IN Voltage Range (-40 to 0°C) | 2.2 | 18 | |
| V _{OUT} | OUT Voltage Range | 0.2 | 18 | mA |
| I _{OUT} | OUT Pin Current | 0.3 | 15 | |
| T _A | Operating Ambient Temperature Range | -40 | +125 | °C |

Electrical Characteristics (@ $T_A = +25^\circ\text{C}$, $V_{IN} = 3.3\text{V}$, $V_{OUT} = V_{FB}$, $I_{OUT} = 5\text{mA}$, unless otherwise stated. (Note 4))

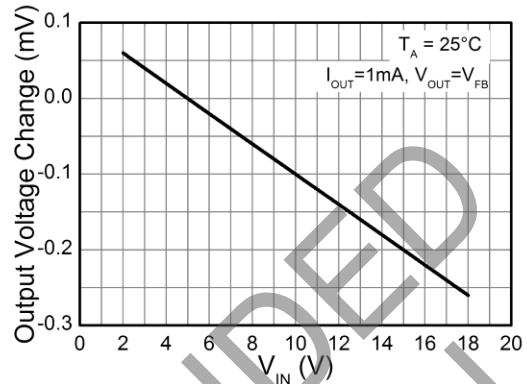
| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit | |
|---------------|--------------------------------|---|--------------------------|--|-------|------|---------------|-----|
| V_{FB} | Feedback Voltage | — | | ZXRE060A | 0.597 | 0.6 | 0.603 | V |
| | | — | | ZXRE060 | 0.594 | 0.6 | 0.606 | |
| | | $T_A = 0^\circ\text{C to } +85^\circ\text{C}$ | | ZXRE060A | 0.595 | — | 0.605 | |
| | | | | ZXRE060 | 0.592 | — | 0.608 | |
| | | $T_A = -40^\circ\text{C to } +85^\circ\text{C}$ | | ZXRE060A | 0.594 | — | 0.606 | |
| | | | | ZXRE060 | 0.591 | — | 0.609 | |
| | | $T_A = -40^\circ\text{C to } +125^\circ\text{C}$ | | ZXRE060A | 0.593 | — | 0.607 | |
| | | | | ZXRE060 | 0.590 | — | 0.610 | |
| FB_{LOAD} | Feedback Pin Load Regulation | $I_{OUT} = 1 \text{ to } 15\text{mA}$ | | — | 3.8 | 6 | mV | |
| | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | — | — | 10 | | |
| FB_{LINE} | Feedback Pin Line Regulation | $V_{IN} = 2\text{V to } 18\text{V}$ | | — | 0.1 | 1 | mV | |
| | | $V_{IN} = 2.2\text{V to } 18\text{V}$ | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | — | | 1.5 |
| FB_{OVR} | Output Voltage Regulation | $V_{OUT} = 0.2\text{V to } 18\text{V}$, $I_{OUT} = 1\text{mA}$ | | — | — | 1 | mV | |
| | | | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | — | | 1.5 |
| I_{FB} | FB Input Bias Current | $V_{IN} = 18\text{V}$ | | — | -45 | — | nA | |
| | | | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | -200 | | 0 |
| I_{IN} | Input Current | $V_{IN} = 2\text{V to } 18\text{V}$ | $I_{OUT} = 0.3\text{mA}$ | — | 0.35 | 0.7 | mA | |
| | | $V_{IN} = 2.2\text{V to } 18\text{V}$ | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | — | | 1 |
| | | $V_{IN} = 2\text{V to } 18\text{V}$ | $I_{OUT} = 10\text{mA}$ | — | 0.48 | 1 | mA | |
| | | $V_{IN} = 2.2\text{V to } 18\text{V}$ | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | — | | 1.5 |
| $I_{OUT(LK)}$ | OUT Leakage Current | $V_{IN} = 18\text{V}$, $V_{OUT} = 18\text{V}$, $V_{FB} = 0\text{V}$ | | — | — | 0.1 | μA | |
| | | | | $T_A = +125^\circ\text{C}$ | | — | | 1 |
| Z_{OUT} | Dynamic Output Impedance | $I_{OUT} = 1 \text{ to } 15\text{mA}$ | | — | 0.25 | 0.4 | Ω | |
| | | $f < 1\text{kHz}$ | | $T_A = -40 \text{ to } +125^\circ\text{C}$ | | — | | 0.6 |
| PSRR | Power Supply Rejection Ratio | $f = 300\text{kHz}$ $V_{AC} = 0.3V_{PP}$ | | — | >45 | — | dB | |
| BW | Amplifier Unity Gain Frequency | Ref: Figure 1 | | — | 600 | — | kHz | |
| G | Amplifier Transconductance | | | — | 5000 | — | mA/V | |

Note: 4. Production testing of the device is performed at $+25^\circ\text{C}$. Functional operation of the device and parameters specified over the operating temperature range are guaranteed by design, characterisation and process control.

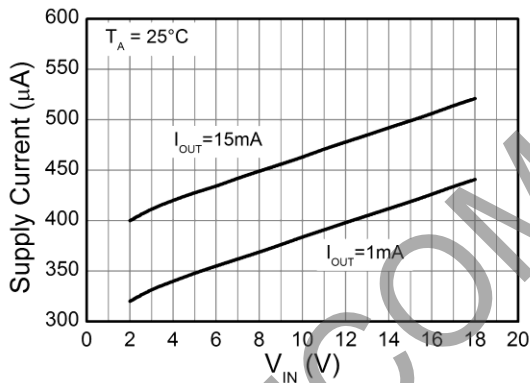
Typical Characteristics



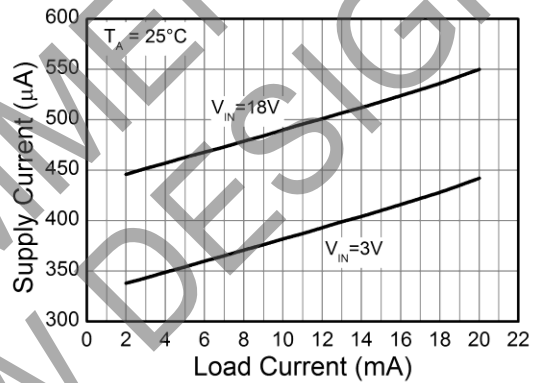
Load Regulation



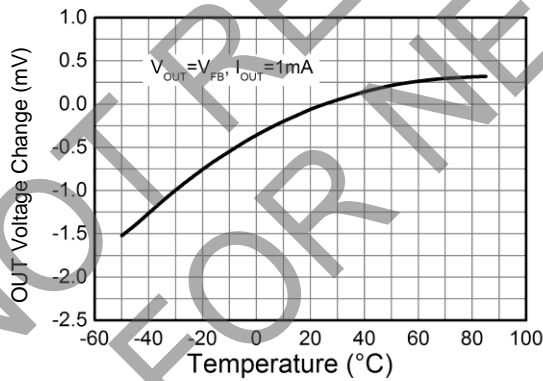
Line Regulation



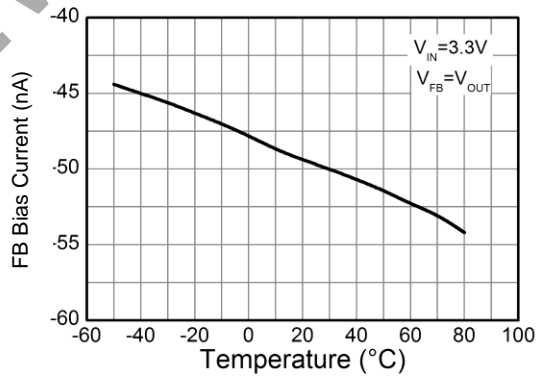
Supply Current vs Input Voltage



Supply Current vs Load Current

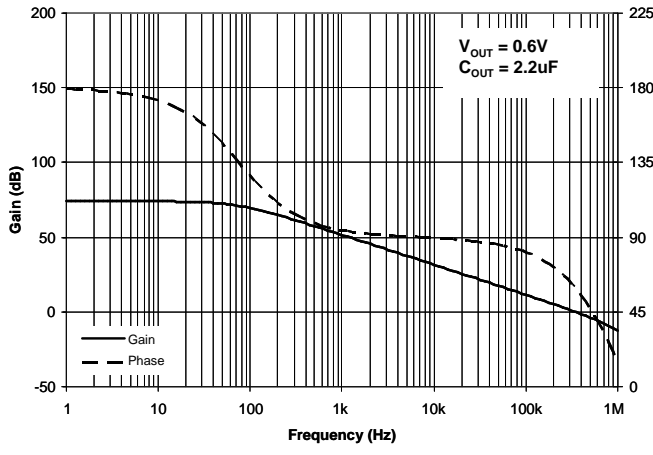


OUT Voltage Change with Temperature

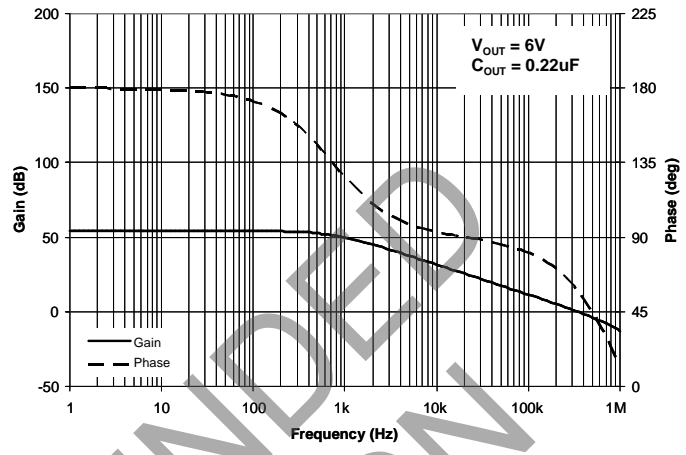


FB Bias Current vs Temperature

Typical Operating Conditions (Cont.)



Gain and Phase vs Frequency, $V_{OUT}=0.6V$



Gain and Phase vs Frequency, $V_{OUT}=6V$

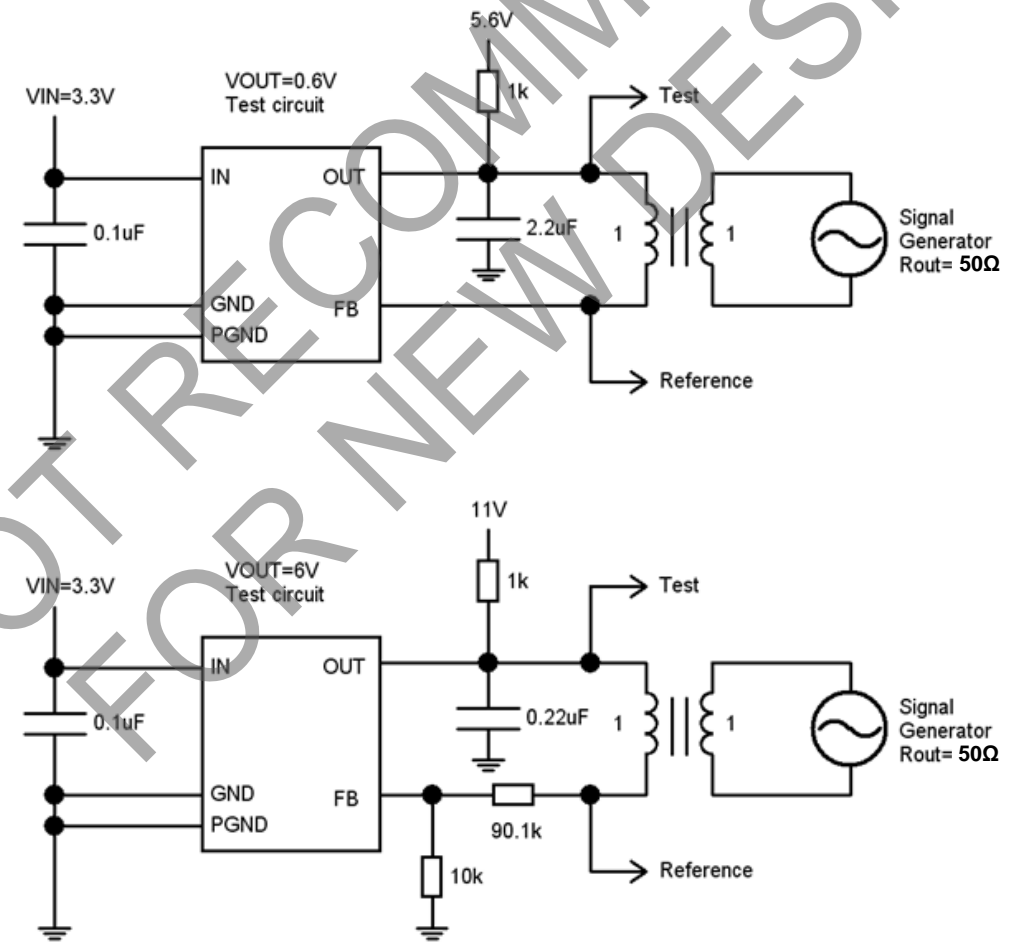


Figure 1. Test Circuits for Gain and Phase Plots

Application Information

The following show some typical application examples for the ZXRE060. It is recommended to include the compensation capacitor C2 to guarantee stability. C2 may range in value from 0.1µF to 10µF depending on the application. The time constant formed by C2 and R3 should be greater than 1ms multiplied by the feedback factor $R2/(R1 + R2)$.

Both C1 and C2 should be as close to the ZXRE060 as possible and connected to it with the shortest possible track. In the case of Figure 8 and Figure 9, it means the opto-coupler will have to be carefully positioned to enable this.

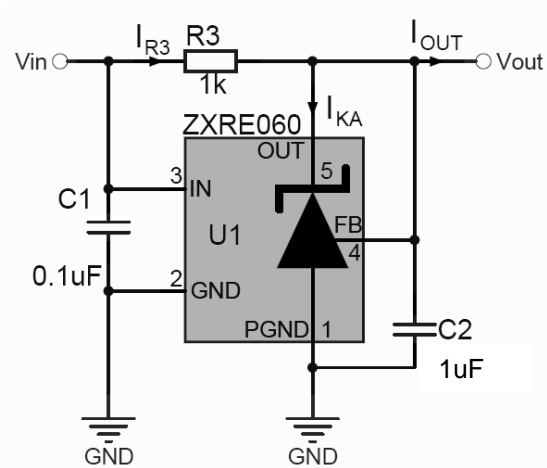


Figure 2. 0.6V Shunt Regulator
 $V_{OUT} = V_{REF}$

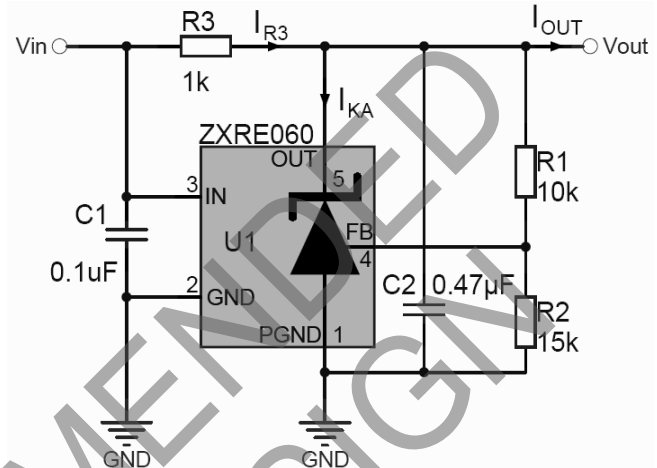


Figure 3. 1.0V Shunt Regulator
 $V_{OUT} = V_{REF} \left(1 + \frac{R1}{R2}\right)$

$$R3 = \frac{V_{IN} - V_{OUT}}{I_{R3}}$$

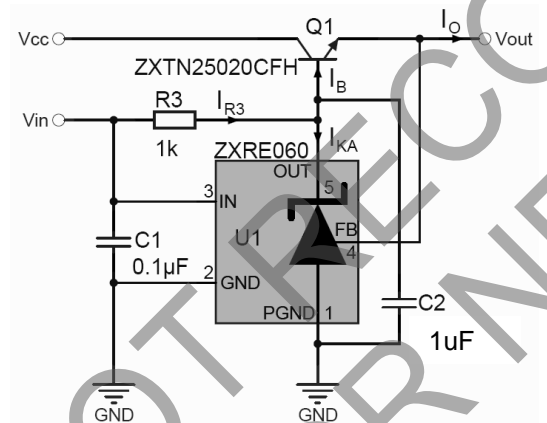


Figure 4. 0.6V series LDO regulator
 $V_{OUT} = V_{REF}$

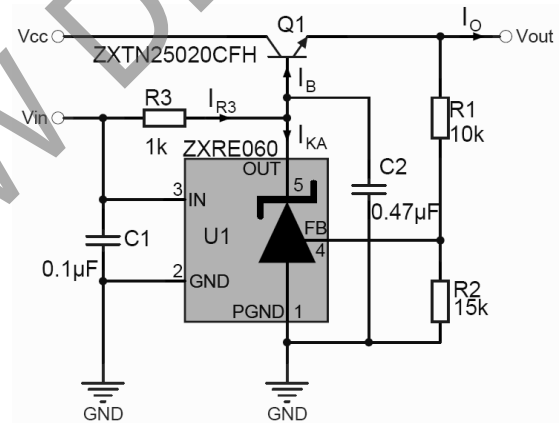
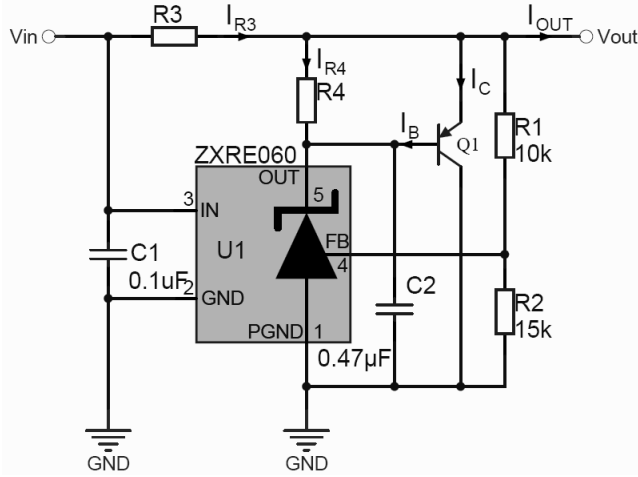


Figure 5. 1.0V series LDO regulator
 $V_{OUT} = V_{REF} \left(1 + \frac{R1}{R2}\right)$

Design Guides

- Determine I_{OUT} and choose a suitable transistor taking power dissipation into consideration.
- Determine I_B from $I_B = \frac{I_{OUT(max)}}{(hFE(min) + 1)}$
- Determine I_{R3} from $I_{R3} \geq I_B + I_{KA(min)}$. The design of the ZXRE060 effectively means there is no $I_{KA(min)}$ limitation as in conventional references. There is only an output leakage current which is a maximum of 1µA. Nevertheless, it is necessary to determine an $I_{KA(min)}$ to ensure that the device operates within its linear range at all times. $I_{KA(min)} \geq 10\mu A$ should be adequate for this.
- Determine R3 from $R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_{R3}}$.
- Although unlikely to be a problem, ensure that $I_{R3} \leq 15mA$.

Application Information (Cont.)



$$V_{OUT} = V_{REF} \left(1 + \frac{R1}{R2} \right)$$

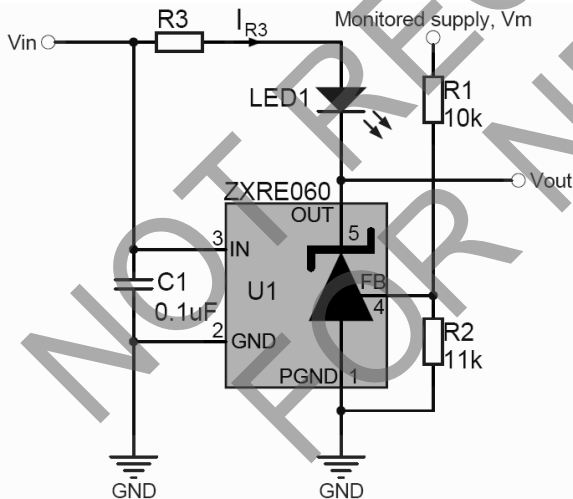
$$(V_{OUT} \geq 0.2V + V_{BE})$$

$$R3 = \frac{V_{IN} - V_{OUT}}{I_{R3}}$$

Figure 6. 1V Current-boosted Shunt Regulator

Design Guides

1. Determine I_{OUT} and choose a suitable transistor taking power dissipation into consideration.
2. Determine I_B from $I_B = \frac{I_{OUT(max)}}{(hFE(min) + 1)}$
3. Determine I_{R3} from $I_{R3} = I_{OUT(max)}$
4. Determine $R3$ from $R3 = \frac{V_{IN} - V_{OUT}}{I_{R3}}$
5. It is best to let the ZXRE060 supply as much current as it can before bringing Q1 into conduction. Not only does this minimise the strain on Q1, it also guarantees the most stable operation. Choose a nominal value between 10mA and <15mA for this current, I_{R4} .
6. Calculate $R4$ from $R4 = \frac{V_{BE}}{I_{R4}}$



V_{OUT} goes low and LED is lit when monitored supply

$$V_M > V_{REF} \left(1 + \frac{R1}{R2} \right)$$

$$R3 = \frac{V_{IN} - (V_F + 0.2)}{I_{R3}}$$

$$15mA \geq I_{R3} \leq I_{F(MAX)}$$

V_F and I_F are forward voltage drop and current of LED1.

Figure 7. 1.15V Over-voltage Indicator

Application Information (Cont.)

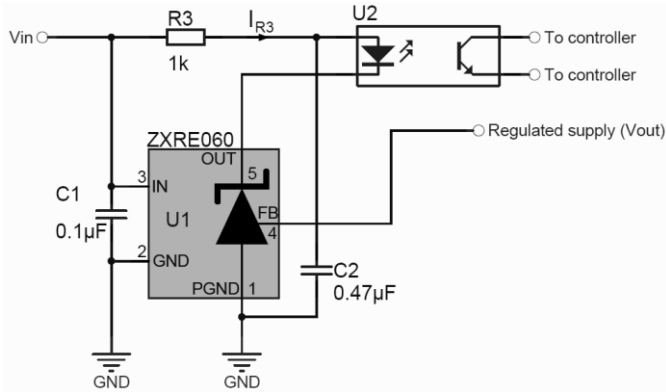


Figure 8. Opto-isolated 0.6V Shunt Regulator

$$V_{OUT} = V_{REF}$$

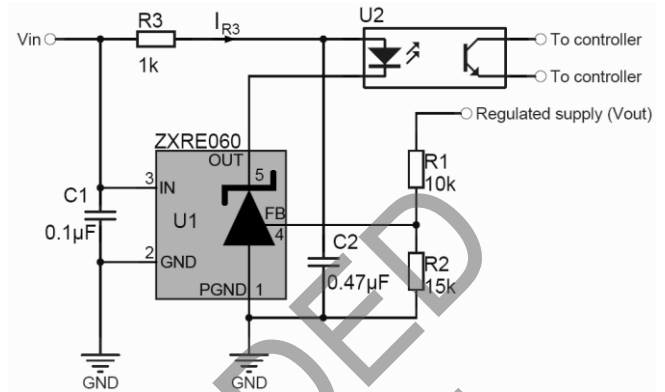


Figure 9. Opto-isolated 1.0V Shunt Regulator

$$V_{OUT} = V_{REF} \left(1 + \frac{R1}{R2} \right)$$

$$R3 = \frac{V_{IN} - (V_F + 0.2)}{I_{R3}}$$

$$15\text{mA} \geq I_{R3} \leq I_F(\text{MAX})$$

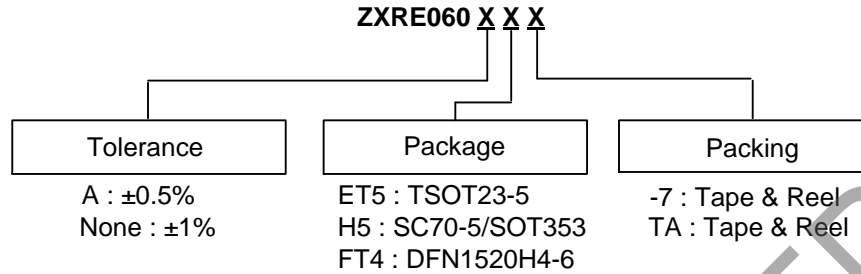
V_F and I_F are forward voltage drop and forward current respectively for the optocoupler LED.

More applications information is available in the following publications which can be found on Diodes Incorporated's web site.

- AN58 - Designing with Diodes Incorporated's References – *Shunt Regulation*
- AN59 - Designing with Diodes Incorporated's References – *Series Regulation*
- AN60 - Designing with Diodes Incorporated's References – *Fixed Regulators and Opto-Isolation*
- AN61 - Designing with Diodes Incorporated's References – *Extending the operating voltage range*
- AN62 - Designing with Diodes Incorporated's References – *Other Applications*
- AN63 - Designing with Diodes Incorporated's References – *ZXRE060 Low Voltage Regulator*

NOT RECOMMENDED FOR NEW DESIGN

Ordering Information

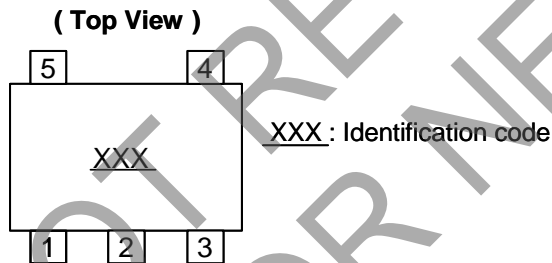


| Tol. | Order Code | Package | Identification Code | Reel Size | Tape Width | Quantity/Reel |
|------|---------------|---------------|---------------------|-----------|------------|---------------|
| 0.5% | ZXRE060AET5TA | TSOT23-5 | S6A | 7", 180mm | 8mm | 3000 |
| | ZXRE060AH5TA | SC70-5/SOT353 | S6A | 7", 180mm | 8mm | 3000 |
| | ZXRE060AFT4-7 | DFN1520H4-6 | S6A | 7", 180mm | 8mm | 3000 |
| 1% | ZXRE060ET5TA | TSOT23-5 | S06 | 7", 180mm | 8mm | 3000 |
| | ZXRE060H5TA | SC70-5/SOT353 | S06 | 7", 180mm | 8mm | 3000 |
| | ZXRE060FT4-7 | DFN1520H4-6 | S06 | 7", 180mm | 8mm | 3000 |

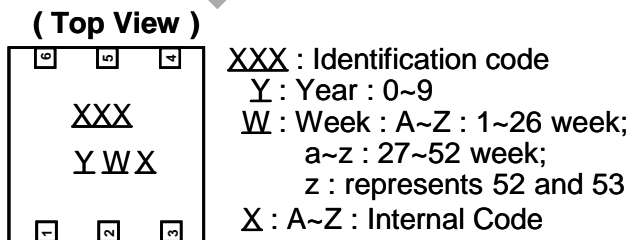
Note: 5. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.

Marking Information

(1) TSOT23-5, SC70-5/SOT353

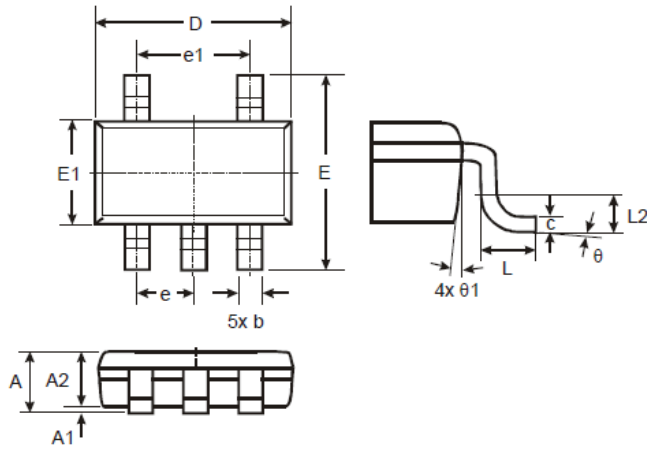


(2) DFN1520H4-6



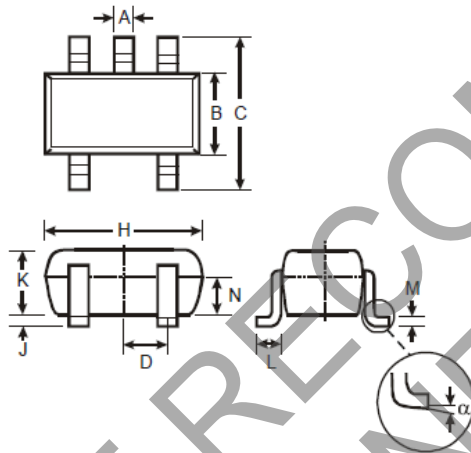
Package Outline Dimensions

(1) TSOT23-5



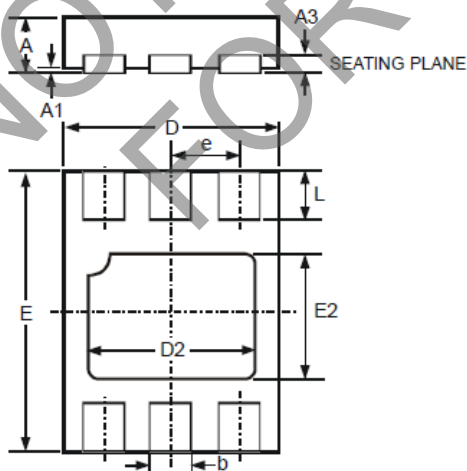
| TSOT23-5 | | | |
|----------------------|------|------|------|
| Dim | Min | Max | Typ |
| A | - | 1.00 | - |
| A1 | 0.01 | 0.10 | - |
| A2 | 0.84 | 0.90 | - |
| D | - | - | 2.90 |
| E | - | - | 2.80 |
| E1 | - | - | 1.60 |
| b | 0.30 | 0.45 | - |
| c | 0.12 | 0.20 | - |
| e | - | - | 0.95 |
| e1 | - | - | 1.90 |
| L | 0.30 | 0.50 | - |
| L2 | - | - | 0.25 |
| theta | 0° | 8° | 4° |
| theta1 | 4° | 12° | - |
| All Dimensions in mm | | | |

(2) SC70-5/SOT353



| SOT-353 | | |
|----------------------|----------|------|
| Dim | Min | Max |
| A | 0.10 | 0.30 |
| B | 1.15 | 1.35 |
| C | 2.00 | 2.20 |
| D | 0.65 Typ | |
| F | 0.40 | 0.45 |
| H | 1.80 | 2.20 |
| J | 0 | 0.10 |
| K | 0.90 | 1.00 |
| L | 0.25 | 0.40 |
| M | 0.10 | 0.22 |
| alpha | 0° | 8° |
| All Dimensions in mm | | |

(3) DFN1520H4-6



| DFN1520H4-6 | | | |
|----------------------|------|-------|------|
| Dim | Min | Max | Typ |
| A | - | 0.40 | - |
| A1 | 0 | 0.05 | - |
| A3 | - | - | 0.13 |
| b | 0.20 | 0.30 | - |
| D | 1.45 | 1.575 | - |
| D2 | 1.00 | 1.20 | - |
| e | - | - | 0.50 |
| E | 1.95 | 2.075 | - |
| E2 | 0.70 | 0.90 | - |
| L | 0.25 | 0.35 | - |
| All Dimensions in mm | | | |

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A. Life support devices or systems are devices or systems which:

1. are intended to implant into the body, or
2. support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in significant injury to the user.

B. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or to affect its safety or effectiveness.

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