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0.6V ADJUSTABLE PRECISION SHUNT REGULATOR

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 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/SOT353, thin SOT23 and very small DFN1520 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
 - <4 mV (0°C to 70°C)
 - <6 mV (-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)
- Lead Free by design/RoHS Compliant (Note 1)
- "Green"/Halogen free device (Note 2)

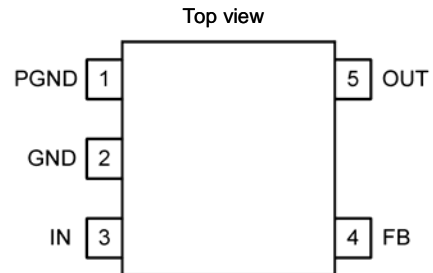
Applications

- Isolated DC-DC converters
- Core voltage POL
- Low Voltage Low-Dropout linear regulators
- Shunt regulators
- Adjustable voltage reference

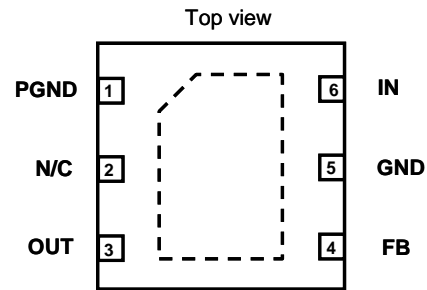
Notes: 1. No purposefully added lead.
2. Diodes Inc.'s "Green" policy can be found on our website at http://www.diodes.com/products/lead_free/index.php.

Pin Assignments

ZXRE060_H5 (SC70-5/SOT353) and ZXRE060_ET5 (TSOT23-5)

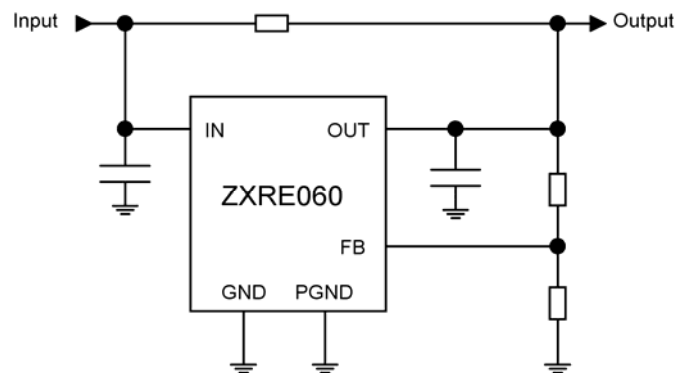


ZXRE060_FT4 (DFN1520H4-6)



Exposed flag floating or connect to GND

Typical Application Circuit

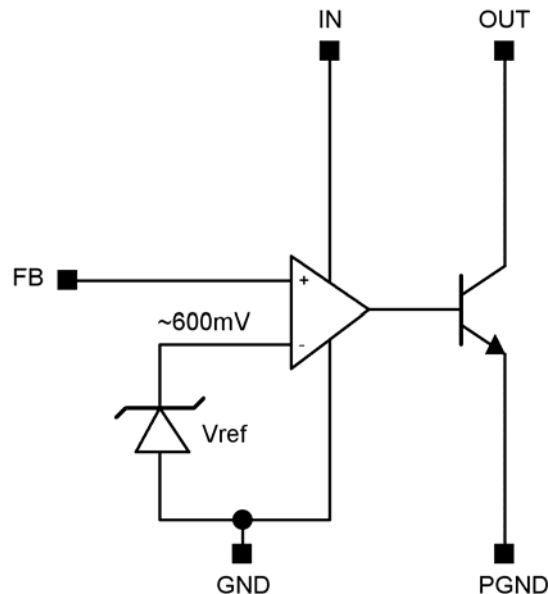


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Pin Description

| Pin (SC70-5 /SOT353, TSOT23-5) | Pin (DFN) | Name | Function |
|--------------------------------------|--------------|------|---|
| 1 | 1 | PGND | Power Ground: Ground return for emitter of output transistor: Connect PGND and GND together. |
| - | 2 | | No connection |
| 5 | 3 | OUT | Output. Connect a capacitor close to device between OUT and GND. See the <i>Applications Information</i> 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 optocouplers 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.

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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 | Units |
|------------------|-------------------------------------|-----|-----|-------|
| 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 |

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Electrical Characteristics

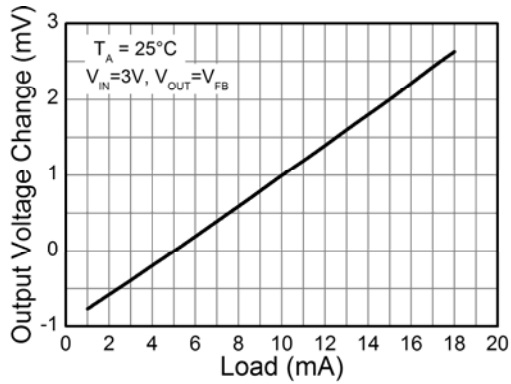
$T_A = 25^\circ\text{C}$, $V_{IN} = 3.3\text{V}$, $V_{OUT} = V_{FB}$, $I_{OUT} = 5\text{mA}$ unless otherwise stated (Note 3).

| Symbol | Parameter | Conditions | | Min | Typ | Max | Units | |
|---------------|--------------------------------|---|---|---|------|-------|---------------|-----|
| V_{FB} | Feedback voltage | $T_A = 0^\circ\text{C to } 85^\circ\text{C}$ | ZXRE060A | 0.597 | 0.6 | 0.603 | V | |
| | | | ZXRE060 | 0.594 | 0.6 | 0.606 | | |
| | | | 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 | |
| | | | | | | 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 | $V_{OUT} = 0.2\text{V to } 18\text{V}$, $I_{OUT} = 1\text{mA}$ (Ref. Figure 1) | | | | 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 | mA | |
| | | | | $T_A = -40 \text{ to } 125^\circ\text{C}$ | | | | |
| | | $V_{IN} = 2\text{V to } 18\text{V}$ | $I_{OUT} = 10\text{mA}$ | | | 0.48 | 1 | mA |
| | | | | $T_A = -40 \text{ to } 125^\circ\text{C}$ | | | | |
| $I_{OUT(LK)}$ | 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 | $I_{OUT} = 1 \text{ to } 15\text{mA}$ $f < 1\text{kHz}$ | | | 0.25 | 0.4 | Ω | |
| | | | $T_A = -40 \text{ to } 125^\circ\text{C}$ | | | | | 0.6 |
| PSRR | Power supply rejection ratio | $f = 300\text{kHz}$ $V_{AC} = 0.3\text{V}_{PP}$ | | | | >45 | dB | |
| BW | Amplifier Unity Gain Frequency | Ref: Fig 2 | | | 600 | | kHz | |
| G | Amplifier Transconductance | | | | 5000 | | mA/V | |

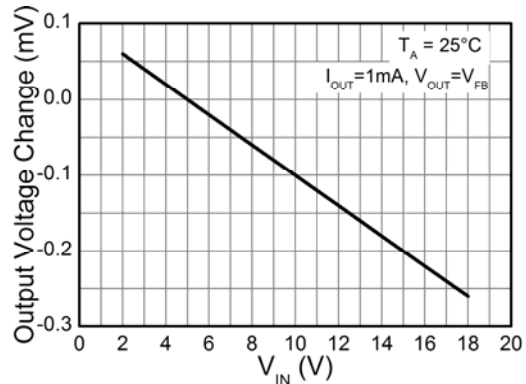
Note: 3. Production testing of the device is performed at 25 °C. Functional operation of the device and parameters specified over the operating temperature range are guaranteed by design, characterisation and process control.

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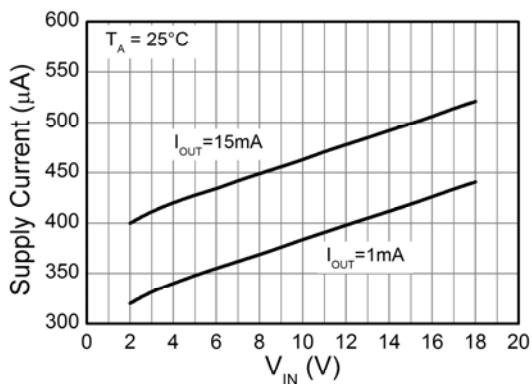
Typical Characteristics



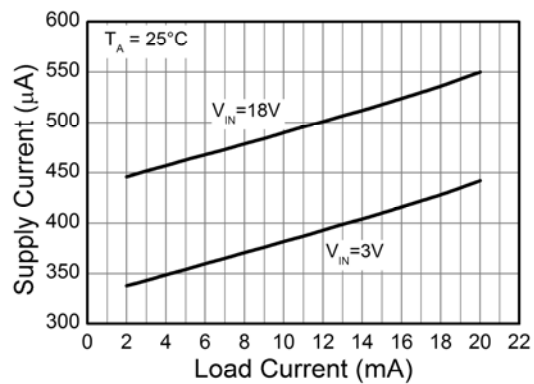
Load Regulation



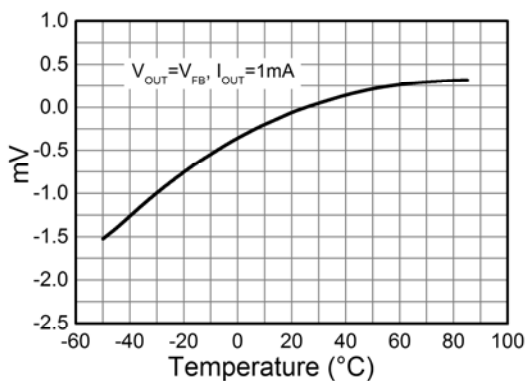
Line Regulation



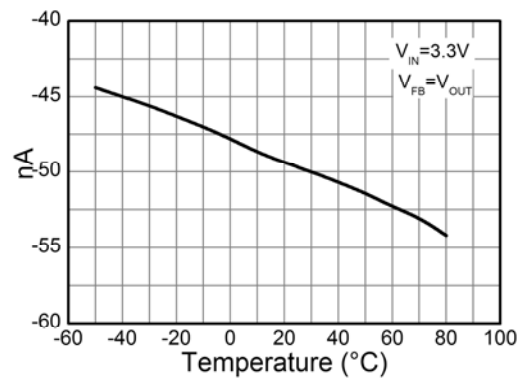
Supply Current vs Input Voltage



Supply Current vs Load Current



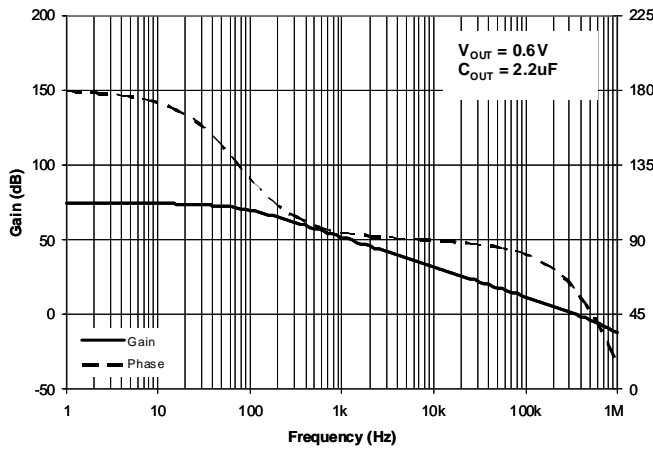
OUT Voltage Change with Temperature



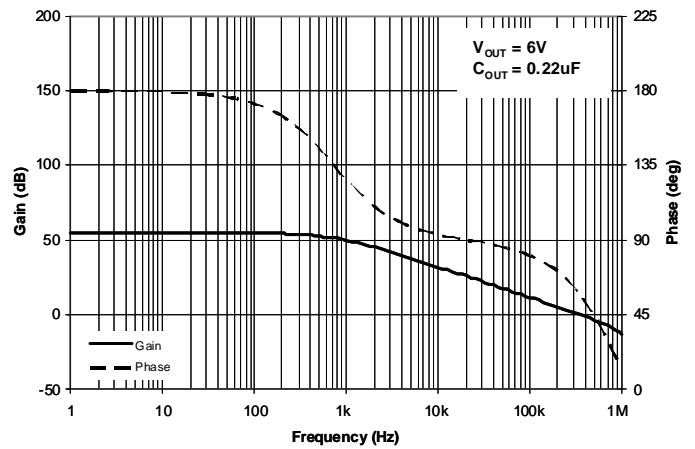
FB Bias Current vs Temperature

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Typical Operating Conditions (Cont.)



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



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

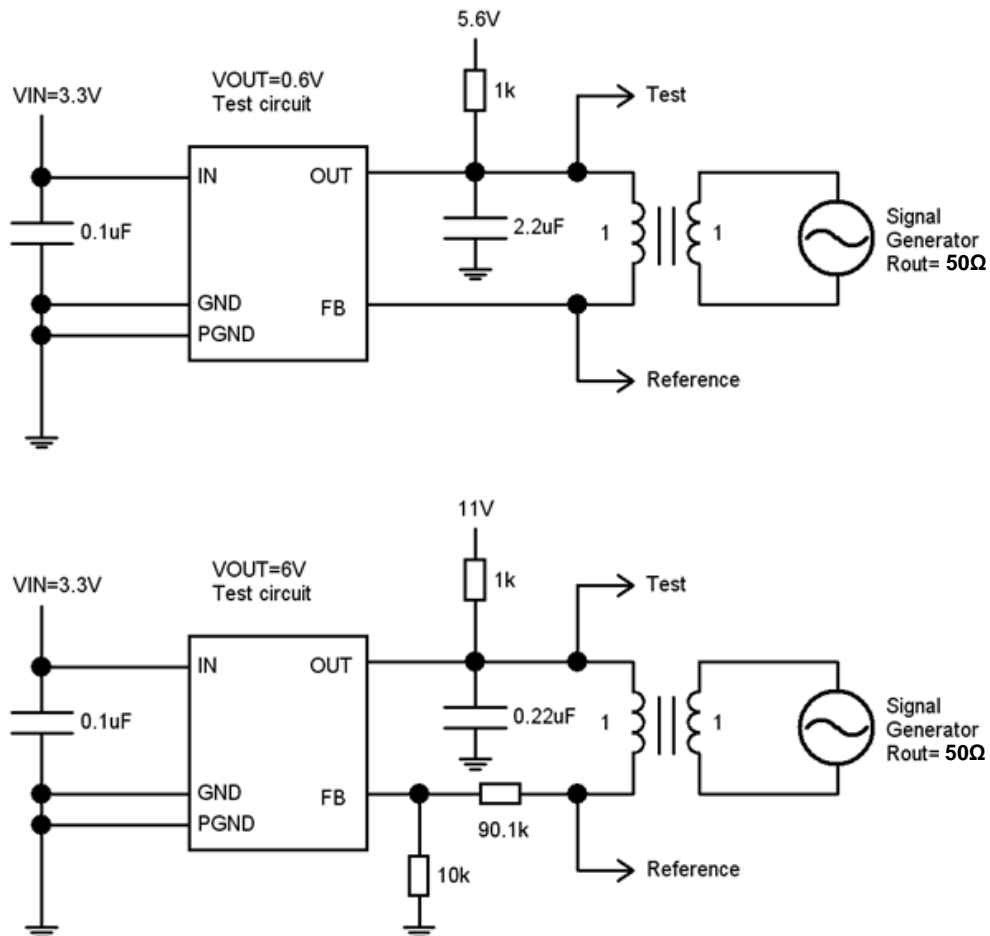


Figure 2. Test circuits for gain and phase plots

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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 fig 9 and fig10, it means the opto-coupler will have to be carefully positioned to enable this.

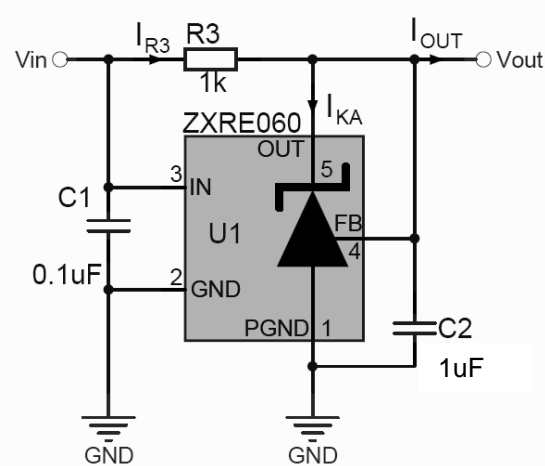


Figure 3. 0.6V Shunt Regulator

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

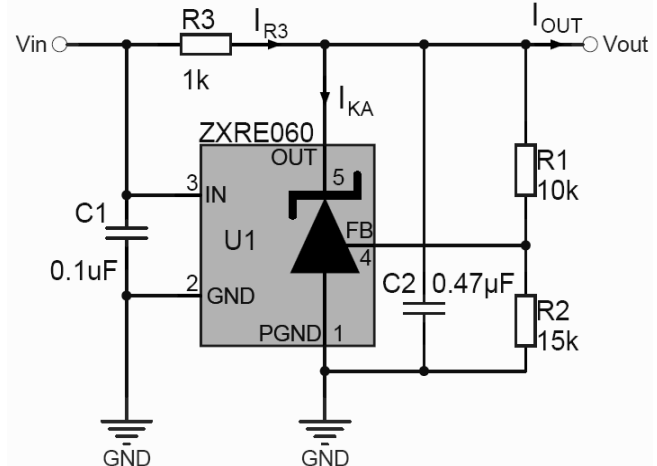


Figure 4. 1.0V Shunt Regulator

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

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

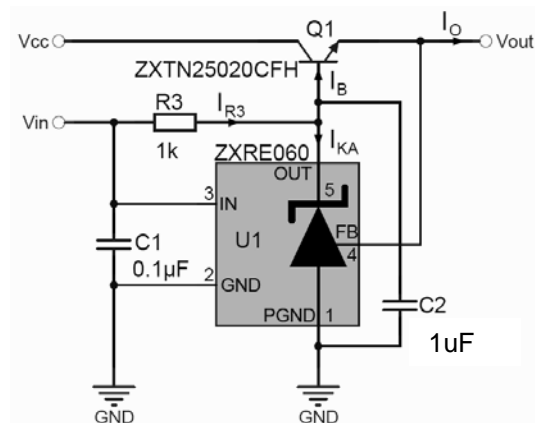


Figure 5. 0.6V series LDO regulator

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

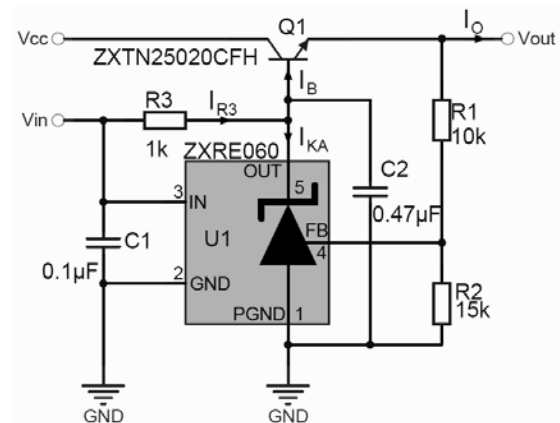


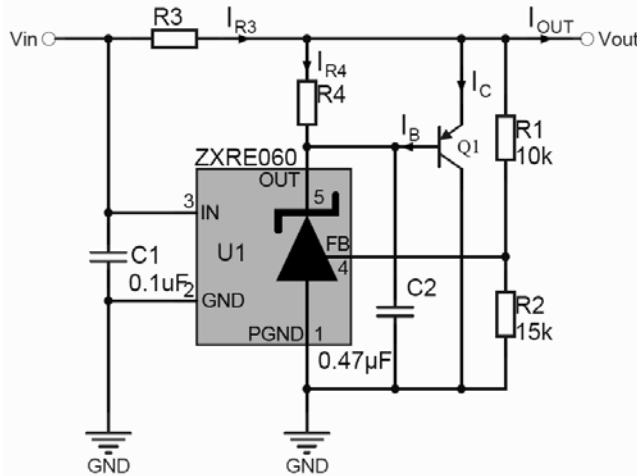
Figure 6. 1.0V series LDO regulator

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

Design guides

1. Determine I_{OUT} and choose a suitable transistor taking power dissipation into consideration.
2. Determine I_B from $I_B = \frac{I_{OUT(max)}}{(h_{FE(min)} + 1)}$
3. 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.
4. Determine R3 from $R3 = \frac{V_{IN} - (V_{OUT} + V_{BE})}{I_{R3}}$.
5. Although unlikely to be a problem, ensure that $I_{R3} \leq 15$ mA.

Application Information (Continued)



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

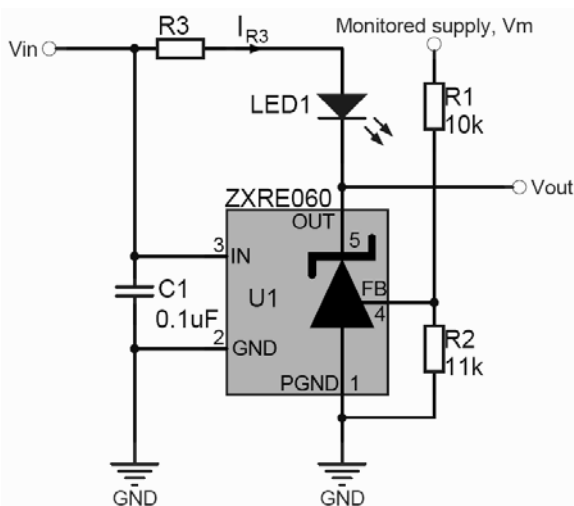
$$(V_{OUT} \geq 0.2V + V_{BE})$$

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

Figure 7. 1V Current-biased 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 8. 1.15V over-voltage indicator

Application Information (Continued)

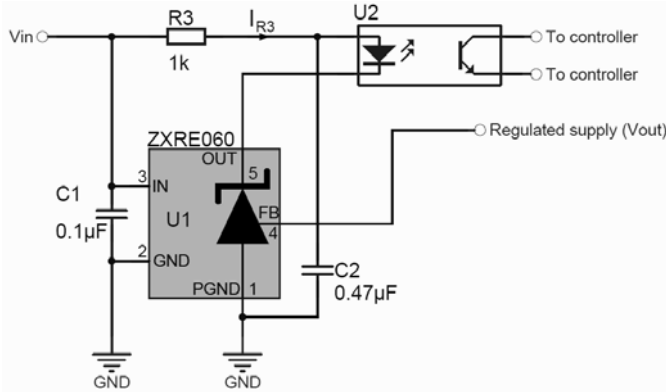


Figure 9. Opto-isolated 0.6V shunt regulator

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

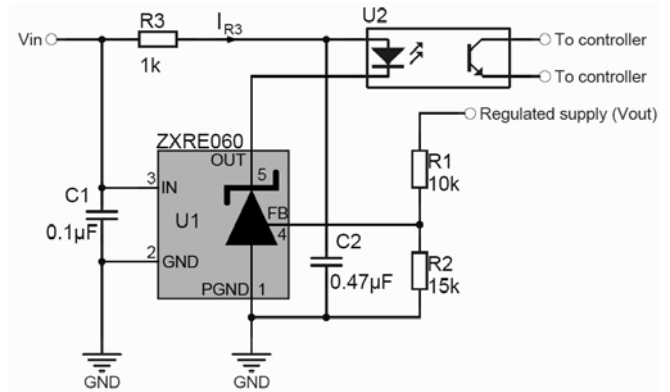


Figure 10. Opto-isolated 1.0V shunt regulator

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

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

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

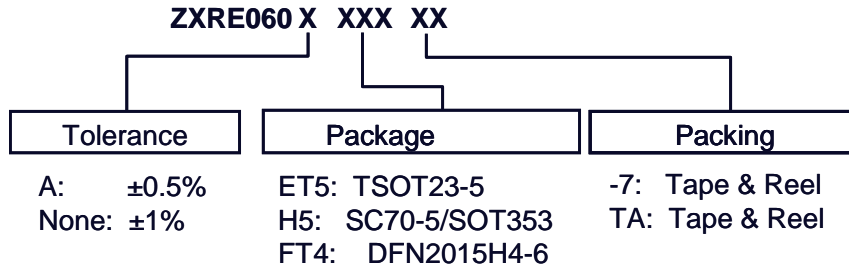
V_F and I_F are forward voltage drop and forward current respectively for the optocoupler LED.

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

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

ZXRE060
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Ordering Information



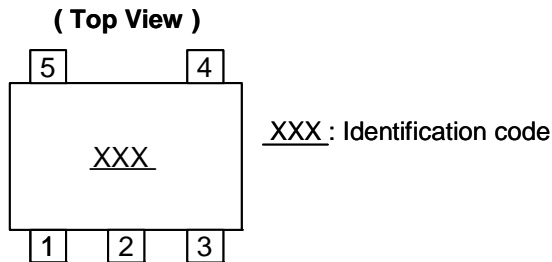
| Tol. | Order Code | Part | Identification Code | Reel Size | Tape Width | Quantity/Reel |
|------|---------------|---------------|---------------------|-----------|------------|---------------|
| 0.5% | ZXRE060AET5TA | TSOT23-5 | S6A | 7", 180mm | 8mm | 3000 |
| | ZXRE060AH5TA | SC70-5/SOT353 | S6A | 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 |



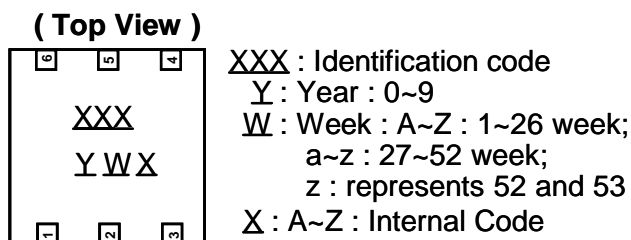
Notes: 4. For packaging details, go to our website at <http://www.diodes.com/datasheets/ap02007.pdf>

Marking Information

1. TSOT23-5, SC70-7/SOT353



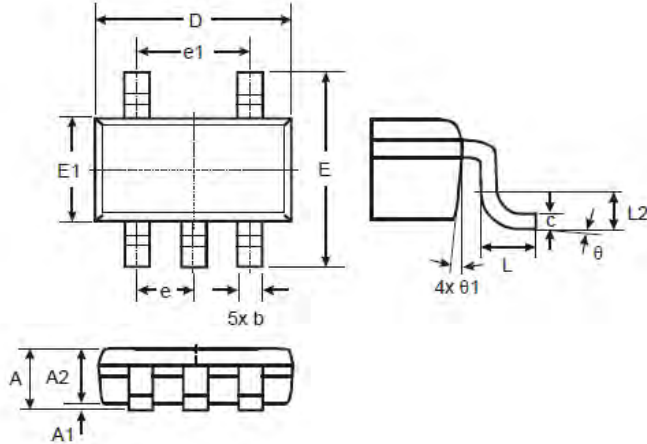
2. DFN1520H4-6



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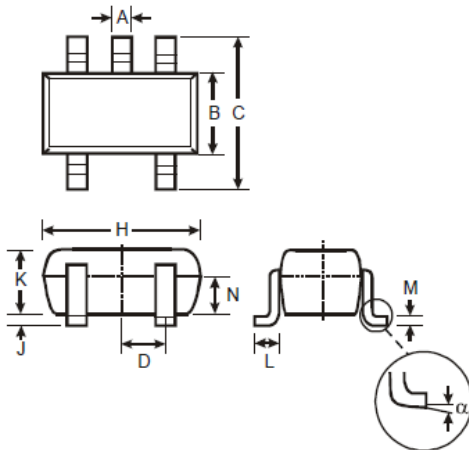
Package Outline Dimensions (All Dimensions in mm)

1. TSOT23-5



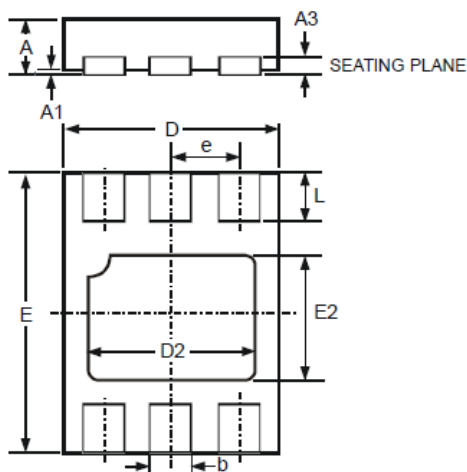
| TSOT23-5 | | | |
|----------------------|------|------|------|
| Dim | Min | Max | Typ |
| A | - | 1.00 | - |
| A1 | 0.01 | 0.10 | - |
| A2 | 0.84 | 0.90 | - |
| D | - | - | 2.90 |
| E | - | - | 2.80 |
| E1 | - | - | 1.60 |
| b | 0.30 | 0.45 | - |
| c | 0.12 | 0.20 | - |
| e | - | - | 0.95 |
| e1 |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

2. SC70-7/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 | | | |

0.6V ADJUSTABLE PRECISION SHUNT REGULATOR

IMPORTANT NOTICE

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