AN63
Designing with Shunt Regulators - ZXRE060 low voltage regulator

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Introduction

More and more there is a trend towards lower operating voltages for electronic circuits in order to both increase speed and keep power consumption down. This is especially the case with microprocessor applications.

Many applications are now required to operate at voltages as low as 1V and less. Until recently the lowest reference devices with a reference voltage of 1.2V will not do in these applications. The ZXRE060, a 0.6V reference, is designed to fill this gap.

With a normal reference, the power to drive its internal functions is normally derived from the voltage dropped across its cathode (K) and anode (A) terminals. Because the minimum 0.6V terminal voltage at which this device works is too low for this, provision is made for the device to be separately powered via two pins. This makes the 0.6V reference a 5-terminal device as illustrated in Figure 1 below.

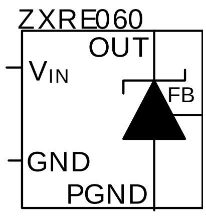


Figure 1 ZXRE060 - 0.6V reference

The extra two power pins are shown labelled V_{IN} and GND respectively. These pins require a minimum supply of 2.2V for the ZXRE060 to function correctly.

An interesting point is that V_{IN} can be connected to the OUT pin and GND connect to the PGND pin. This effectively turns the ZXRE060 into a 3-terminal device. The FB pins still controls at 0.6 but the regulated voltage across the device can not be less than 2.2V.

In its 3-terminal configuration, the ZXRE060 can technically be used in all the example circuits for a standard 3-terminal reference. However, using it for some of the circuits in the 5-terminal mode to take advantage of its 0.6V operation requires modified configurations. Primarily, this device is targeted at applications that need to operate below 1.24V and only this aspect is covered in this document.

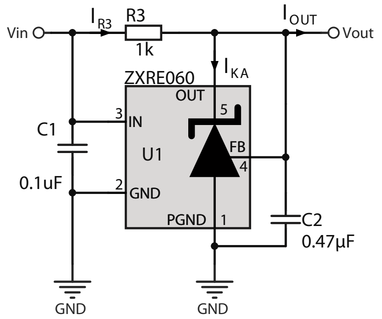


Figure 2
0.6V shunt regulator

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

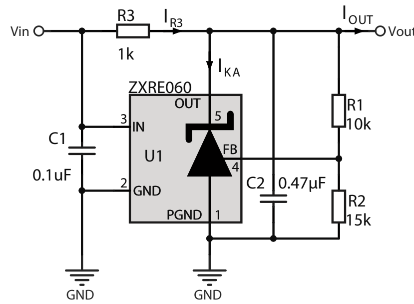


Figure 3
1.0V shunt regulator

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

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

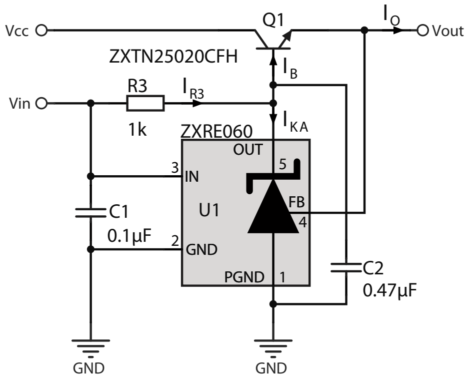


Figure 4
0.6V series LDO regulator

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

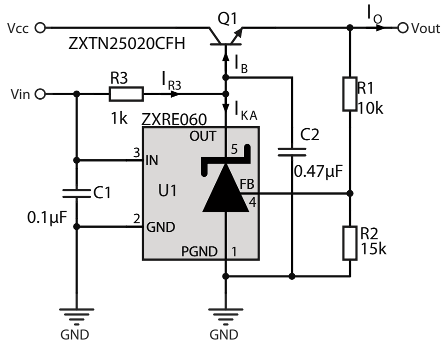


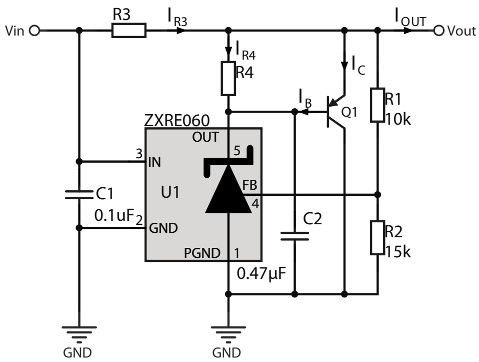
Figure 5
1.0V series LDO regulator

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

Design guides

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. $I_{KA(min)} \geq$ 10µA 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 $I_{R3} \leq$ 20 mA.

Refer to the Appendix in AN57 for information on calculating output error.



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

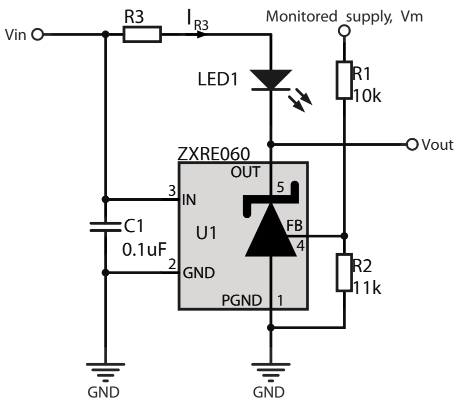
$$(V_{OUT} \geq 0.2V + V_{BE})$$

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

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 $I_B = \frac{I_{OUT(\max)}}{(h_{FE(\min)}+1)}$
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 15mA and 20mA for this current, I_{R4}. Calculate R4 from $R4 = \frac{V_{BE}}{I_{R4}}$



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

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

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

$$I_{F(\max)} \geq I_{R3} \leq 20mA$$

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

Figure 7
1.15V over-voltage indicator

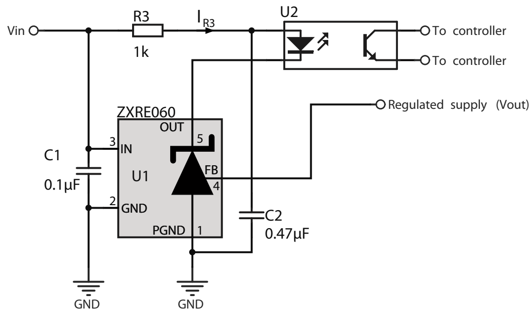


Figure 8
Opto-isolated 0.6V shunt regulator

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

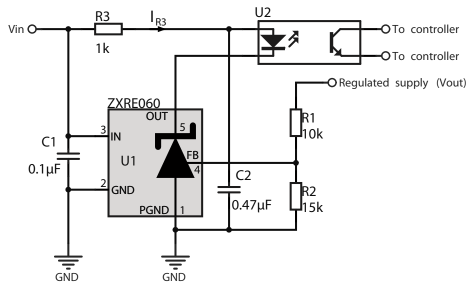


Figure 9
Opto-isolated 1.0V shunt regulator

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

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

$$20mA \geq I_{R3} \leq I_{F(MAX)}$$

V_F and I_F are forward voltage drop and current for the opto-coupler LED respectively.

Stability considerations

The physical position of C2 and its value is critical to maintaining good stability. C2 should be located in close physical proximity to the ZXRE060 and connected to its pins with the shorted and widest possible copper track. The value of C2 required to ensure stability generally ranges from about 0.1µF up to 10 µF depending on application and environment with higher gain applications generally requiring smaller values.

Conclusion

The above circuits are only representative of what could be done with the ZXRE060 and are by no means exhaustive. They provide examples of basic considerations and calculations that are needed by the designer. These calculations can either be applied to, or be adapted for, use in similar designs.

Recommended further reading

AN58 - Designing with Shunt Regulators - *Shunt Regulation*

AN59- Designing with Shunt Regulators - *Series Regulation*

AN60 - Designing with Shunt Regulators - *Fixed Regulators and Opto-Isolation*

AN61- Designing with Shunt Regulators - *Extending the operating voltage range*

AN62 - Designing with Shunt Regulators - *Other Applications*

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