



#### **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. makes ideal for state of PLD microprocessor/DSP and 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**

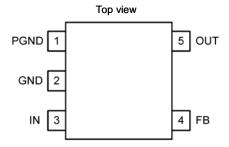
- Low reference voltage (V<sub>FB</sub> = 0.6V)
- -40 to 125°C temperature range
- Reference voltage tolerance at 25°C
  - o 0.5% ZXRE060A
  - 1% ZXRE060
- Typical temperature drift
  - o <4 mV (0°C to 70°C)
  - <6 mV (-40°C to 85°C)</p>
  - o <12mV (-40°C to 125°C)
- 0.2V to 18V open-collector output
- High power supply rejection
  - (>45dB at 300kHz)
- Lead Free by design/RoHS Compliant (Note 1)
- "Green"/Halogen free device (Note 2)

#### **Applications**

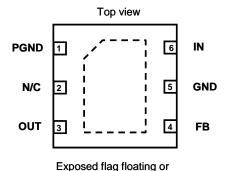
- Isolated DC-DC converters
- Core voltage POL
- Low Voltage Low-Dropout linear regulators
- Shunt regulators
- Adjustable voltage reference

#### **Pin Assignments**

ZXRE060\_H5 (SC70-5/SOT353) and ZXRE060\_ET5 (TSOT23-5)

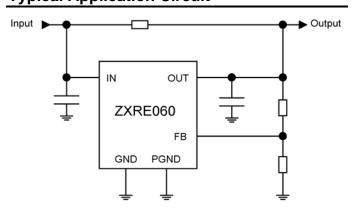


ZXRE060\_FT4 (DFN1520H4-6)



connect to GND

**Typical Application Circuit** 



Notes: 1. No purposefully added lead.

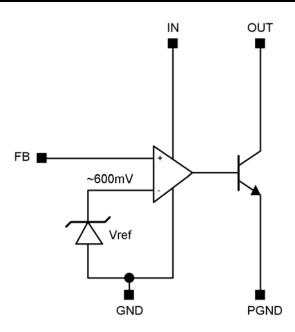
2. Diodes Inc.'s "Green" policy can be found on our website at http://www.diodes.com/products/lead\_free/index.php.



#### **Pin 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 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 $0.1\mu F$ 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 <sub>IN</sub>	IN Voltage relative to GND	20	V
V <sub>OUT</sub>	OUT Voltage relative to GND	20	V
$V_{FB}$	FB Voltage relative to GND	20	V
P <sub>GND</sub>	PGND Voltage relative to GND	-0.3 to +0.3	V
I <sub>OUT</sub>	OUT Pin Current	20	mA
TJ	Operating Junction Temperture	-40 to 150	°C
T <sub>ST</sub>	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.

## **Package Thermal Data**

Package	θ <sub>JA</sub>	P <sub>DIS</sub> T <sub>A</sub> = 25°C, T <sub>J</sub> = 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	
$V_{IN}$	IN Voltage Range (-40 to 0°C)	2.2	18	V
V <sub>OUT</sub>	OUT Voltage Range	0.2	18	
I <sub>OUT</sub>	OUT Pin Current	0.3	15	mA
$T_A$	Operating Ambient Temperature Range	-40	125	°C

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.



## **Electrical Characteristics**

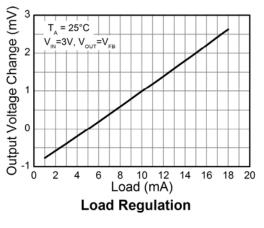
 $T_A = 25$ °C,  $V_{IN} = 3.3$ V,  $V_{OUT} = V_{FB}$ ,  $I_{OUT} = 5$ mA unless otherwise stated (Note 3).

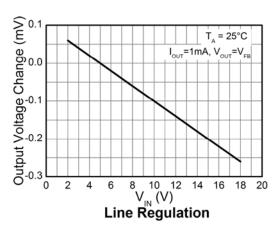
Symbol	Parameter	Conditions		Min	Тур	Max	Units
			ZXRE060A	0.597	0.6	0.603	
			ZXRE060	0.594	0.6	0.606	
		$T_A = 0$ °C to 85°C	ZXRE060A	0.595		0.605	
		1 A = 0 C to 85 C	ZXRE060	0.592		0.608	
$V_{FB}$	Feedback voltage	$T_A = -40^{\circ}\text{C to } 85^{\circ}\text{C}$	ZXRE060A	0.594		0.606	V
		1A = -40 C to 65 C	ZXRE060	0.591		0.609	
		$T_A = -40^{\circ}\text{C to } 125^{\circ}\text{C}$	ZXRE060A	0.593		0.607	
		1 <sub>A</sub> = -40 C to 125 C	ZXRE060	0.590		0.610	
$FB_{LOAD}$	Feedback pin load	I <sub>OUT</sub> = 1 to 15mA			3.8	6	mV
LPLOAD	regulation	IOUT = 1 to ISINA	$T_A = -40 \text{ to } 125^{\circ}\text{C}$			10	
FB <sub>LINE</sub>	Feedback pin line	$V_{IN} = 2V$ to 18V			0.1	1	mV
I DLINE	regulation	$V_{IN} = 2.2V \text{ to } 18V$	$T_A = -40 \text{ to } 125^{\circ}\text{C}$			1.5	IIIV
$FB_OVR$	Output voltage regulation	$V_{OUT} = 0.2V \text{ to } 18V,$				1	mV
		I <sub>OUT</sub> =1mA (Ref. Figure 1)	$T_A = -40 \text{ to } 125^{\circ}\text{C}$			1.5	
	FB input bias	V <sub>IN</sub> = 18V			-45		nA
I <sub>FB</sub>	current		$T_A = -40 \text{ to } 125^{\circ}\text{C}$	-200		0	
	Input current	V <sub>IN</sub> = 2V to 18V			0.35	0.7	1
		$V_{IN} = 2.2V \text{ to } 18V$ $I_{OUT} = 0.3\text{mA}$	$T_A = -40 \text{ to } 125^{\circ}\text{C}$			1	mA
I <sub>IN</sub>		V <sub>IN</sub> = 2V to 18V			0.48	1	^
		$V_{IN} = 2.2V \text{ to } 18V$ $I_{OUT} = 10\text{mA}$	$T_A = -40 \text{ to } 125^{\circ}\text{C}$			1.5	mA
	OUT leakage	$V_{IN} = 18V$ ,				0.1	
$I_{OUT(LK)}$	current	$V_{OUT} = 18V,$ $V_{FB} = 0V$	T <sub>A</sub> = 125°C			1	μΑ
_	Dynamic Output	$I_{OUT} = 1 \text{ to } 15\text{mA}$			0.25	0.4	
$Z_{OUT}$	Impedance	f < 1kHz	$T_A = -40 \text{ to} 125^{\circ}\text{C}$		-	0.6	Ω
PSRR	Power supply	f=300kHz			>45		dB
	rejection ratio	$V_{AC} = 0.3V_{PP}$					
BW	Amplifier Unity Gain Frequency	Ref: Fig 2			600		kHz
G	Amplifier Transconductance			_	5000		mA/V

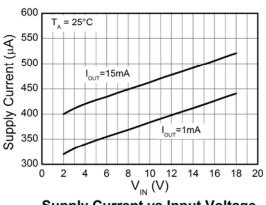
Note: 3. Production testing of the device is performed at 25 °C. Functional operation of the device and parameters specified over the operating temperature range are guaranteed by design, characterisation and process control.

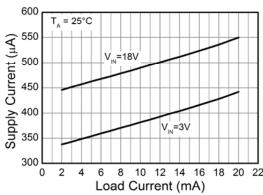


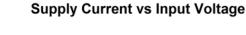
# **Typical Characteristics**

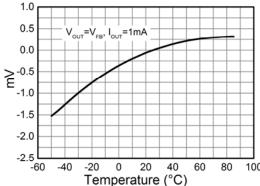




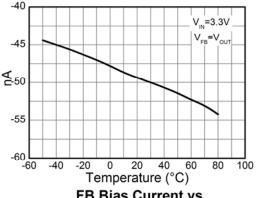








**Supply Current vs Load Current** 

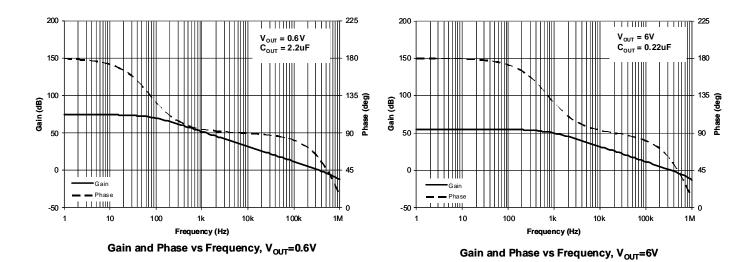


OUT Voltage Change with Temperature

FB Bias Current vs Temperature



# **Typical Operating Conditions (Cont.)**



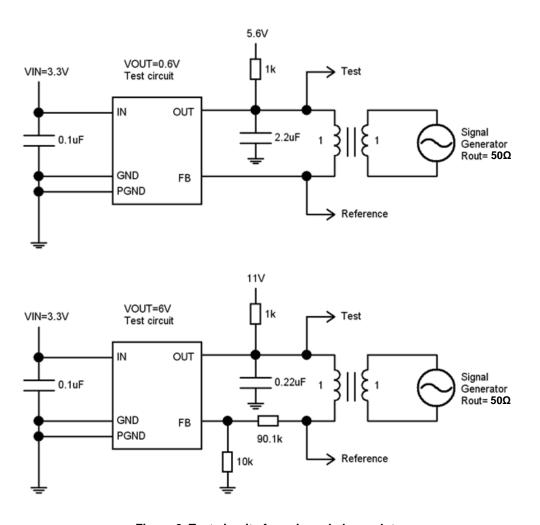


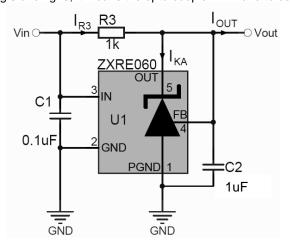
Figure 2. Test circuits for gain and phase plots



#### **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  $0.1\mu\text{F}$  to  $10\mu\text{F}$  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.



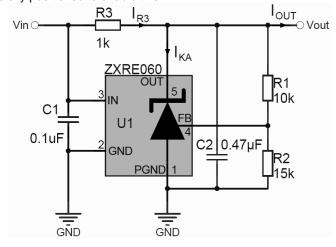
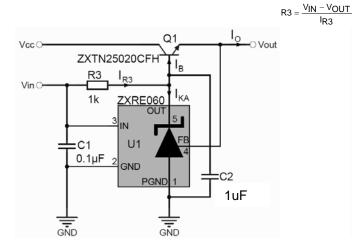


Figure 3. 0.6V Shunt Regulator

 $V_{OUT} = V_{REF}$ 

Figure 4. 1.0V Shunt Regulator

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



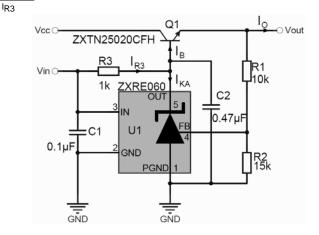


Figure 5. 0.6V series LDO regulator

 $V_{OUT} = V_{REF}$ 

Figure 6. 1.0V series LDO regulator

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

#### Design guides

- 1. Determine  $I_{\text{OUT}}$  and choose a suitable transistor taking power dissipation into consideration.
- 2. Determine  $I_B$  from  $I_B = \frac{IOUT(max)}{(h_{FE(min)} + 1)}$
- 3. Determine  $I_{R3}$  from  $I_{R3} \ge I_{B} + I_{KA(min)}$ . 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.  $I_{KA(min)} \ge 10$ µA should be adequate for this.
- 4. Determine R3 from  $_{R3} = \frac{V_{IN} (V_{OUT} + V_{BE})}{|I_{Da}|}$ .
- 5. Although unlikely to be a problem, ensure that  $I_{R3} \le 15$  mA.



## **Application Information (Continued)**

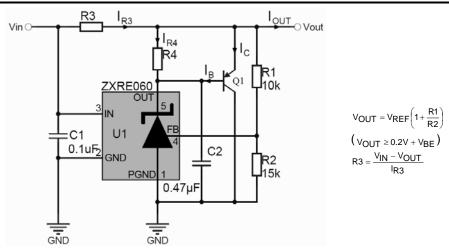


Figure 7. 1V Current-boosted shunt regulator

#### Design guides

- 1. Determine I<sub>OUT</sub> and choose a suitable transistor taking power dissipation into consideration.
- $2. \quad \ \ Determine \ I_{B} \ from \ \ _{I_{B}} = \frac{I_{OUT(max)}}{(h_{FE(min)} + 1)}$
- 3. Determine  $I_{R3}$  from  $I_{R3} = I_{OUT(max)}$
- 4. Determine R3 from  $_{R3} = \frac{V_{IN} V_{OUT}}{l_{P2}}$
- 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<sub>R4</sub>.
- 6. Calculate R4 from  $_{R4} = \frac{V_{BE}}{I_{R4}}$

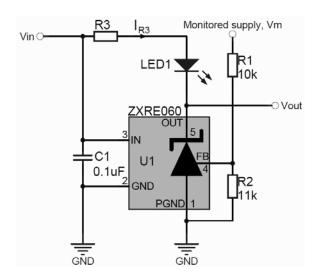


Figure 8. 1.15V over-voltage indicator

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

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

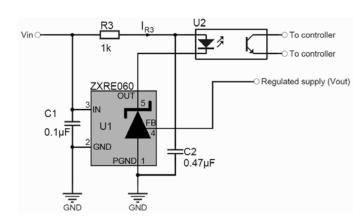
$$R3 = \frac{V_{IN} - (V_F + 0.2)}{I_{R3}}$$

$$15mA \ge I_{R3} \le I_{F(MAX)}$$

V<sub>F</sub> and I<sub>F</sub> are forward voltage drop and current of LED1.



# **Application Information (Continued)**



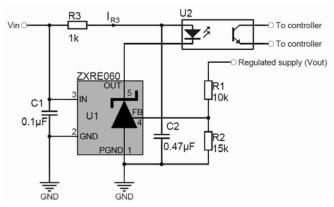


Figure 9. Opto-isolated 0.6V shunt regulator

Figure 10. Opto-isolated 1.0V shunt regulator

$$V_{OUT} = V_{REF}$$
 
$$V_{OUT} = V_{f}$$
 
$$R3 = \frac{V_{IN} - (V_{F} + 0.2)}{I_{R3}}$$
 
$$15mA \ge I_{R3} \le I_{F(MAX)}$$

 $V_F$  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



### **Ordering Information**



FT4: DFN2015H4-6



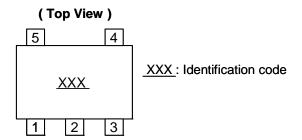
	Tol.	Order Code	Part	Code	Reel Size	Tape Width	Quantity/Reel
		ZXRE060AET5TA	TSOT23-5	S6A	7", 180mm	8mm	3000
,	0.5%	ZXRE060AH5TA	SC70-5/SOT353	S6A	7", 180mm	8mm	3000
		ZXRE060AFT4-7	DFN1520H4-6	S6A	7", 180mm	8mm	3000
		ZXRE060ET5TA	TSOT23-5	S06	7", 180mm	8mm	3000
,	1%	ZXRE060H5TA	SC70-5/SOT353	S06	7",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

Identification

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

# (Top View)

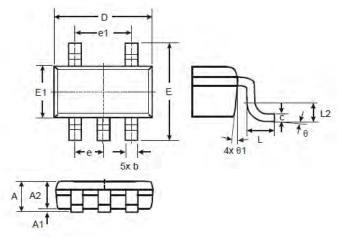
2

3

XXX: Identification code 5 4 Y: Year: 0~9 XXXW: Week: A~Z: 1~26 week; a~z: 27~52 week; YWXz: represents 52 and 53 X: A~Z: Internal Code

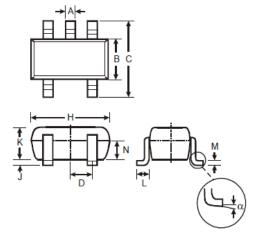
# Package Outline Dimensions (All Dimensions in mm)

#### 1. TSOT23-5



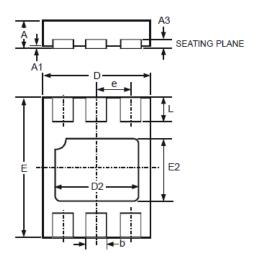
	TSOT23-5					
Dim	Min	Max	Тур			
Α	ı	1.00	_			
A1	0.01	0.10	-			
A2	0.84	0.90	_			
D	_	-	2.90			
E	_	-	2.80			
E1	ı	_	1.60			
b	0.30	0.45	_			
С	0.12	0.20	_			
е	-	_	0.95			
e1	-	_	1.90			
L	0.30	0.50				
L2	_	_	0.25			
θ	0°	8°	4°			
θ1	4°	12°	_			
All Dimensions in mm						

#### 2. SC70-7/SOT353



	SOT-353				
Dim	Min	Max			
Α	0.10	0.30			
В	1.15	1.35			
С	2.00	2.20			
D	0.65	Тур			
F	0.40	0.45			
Н	1.80	2.20			
J	0	0.10			
K	0.90	1.00			
L	0.25	0.40			
M	0.10	0.22			
α	0°	8°			
All Dimensions in mm					

#### 3. DFN1520H4-6



DFN1520H4-6					
Dim	Min	Max	Тур		
Α	_	0.40	_		
A1	0	0.05	-		
A3	_	_	0.13		
b	0.20	0.30	-		
D	1.45	1.575	_		
D2	1.00	1.20	_		
е	_	_	0.50		
E	1.95	2.075	_		
E2	0.70	0.90	1		
L	0.25	0.35	_		
All Dimensions in mm					





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