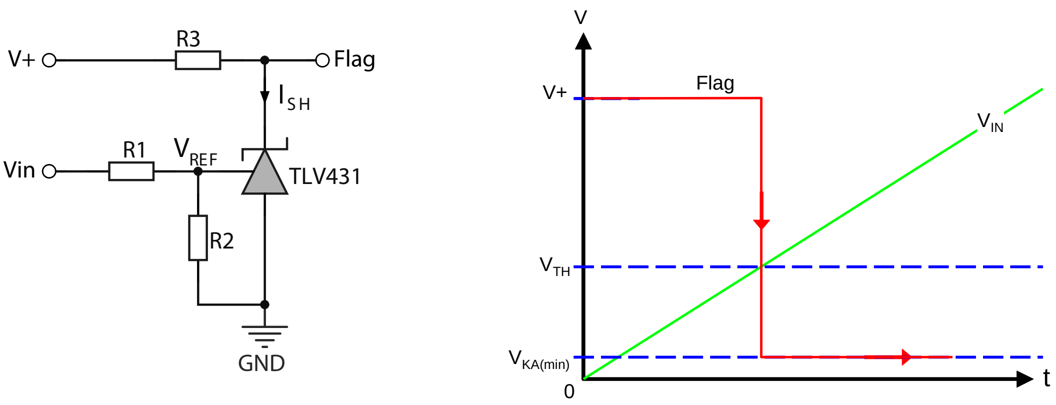
AN62
Designing with Shunt Regulators - Other applications

Peter Abiodun A. Bode, Snr. Applications Engineer, Diodes Zetex Ltd

Introduction

Shunt regulators or voltage references can be applied to other applications beyond the obvious PSU ones. Some of these are shown below.

A simple voltage comparator



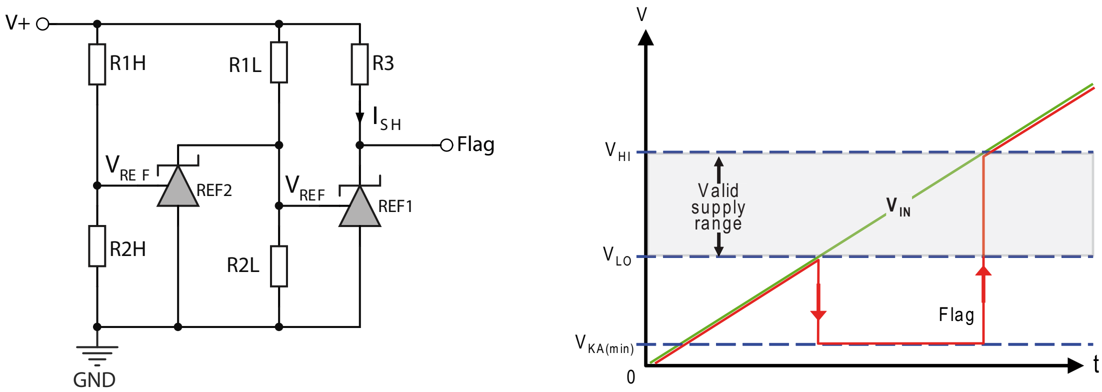
$$V_{TH} = V_{REF}\left(1 + \frac{R1}{R2}\right) \qquad R3 = \frac{V^{+} - V_{KA(min)}}{I_{SH}} \qquad 0.1mA \le I_{SH} \le 15mA$$

Figure 1 Using the TLV431 as a level detector

In its open loop state, the 3-terminal reference is analogous to a line-powered comparator with its non-inverting input internally connected to a reference voltage. This means the remaining inverting input can be used for comparator functions.

Figure 1 above shows the TLV431 being used as a level comparator. Its output (Flag) is normally high and goes low when the input reaches or exceeds the threshold (VTH) determined by R1 and R2.

A window comparator



$$V_{LO} = V_{REF}\left(1+\frac{R1L}{R2L}\right) \qquad V_{HI} = V_{REF}\left(1+\frac{R1H}{R2H}\right) \qquad R3 = \frac{V^{+} - K_{A(min)}}{I_{SH}} \qquad 0.1mA \le I_{SH} \le 15mA$$

Figure 2 Window comparator for PSU supervision or Power-On Reset

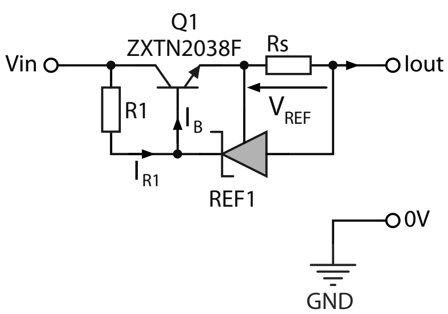
An extended variation of Figure 1 is the use of two references to implement a window comparator. It is effectively two level comparators in series. It is a circuit that gives an output only when the input is within a window defined by a lower (V_{LO}) and a higher (V_{HI}) limit. The window comparator is used either in general PSU supervision, status indicator or as a power-on reset (POR) in many types of applications.

Circuit explanation

The graph shows how it works. At input voltages below V_{LO}, both devices are off and so the output (Flag) simply follows the input. At input voltages above V_{LO}, REF1 switches on taking Flag low. The circuit remains in this state until the input voltage reaches or exceeds V_{HI}. At this point, REF2 switches on, inhibiting the input to REF1 which therefore switches off causing Flag to go high again.

Thus the flag represents an indication of the input voltage lying in the range of an acceptable window.

Simple current sources



$$I_{OUT} = \frac{V_{REF}}{R_S}\left(\frac{h_{FE}}{h_{FE}+1}\right) + I_{R1}$$

By making $I_{R1} << \frac{V_{REF}}{R_S}$ and $h_{FE} > 100$

$$I_{OUT} \approx \frac{V_{REF}}{R_S}$$

$$R1 = \frac{V_{IN(min)} - (V_{OUT(max)} + V_{REF} + V_{BE})}{I_{KA(min)} + I_B}$$

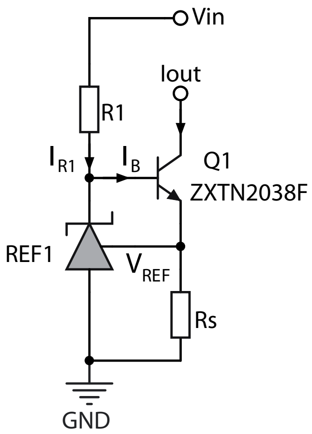
Figure 3 Constant current source

Constant current circuits are used in many applications, e.g. relaxation oscillators, biasing circuits, active loads, battery chargers, test and measurement, etc.

Figure 3 above shows a very simple constant current source. The output current expression includes two sources of error, one of which is the effect of the finite current gain, h_{FE}, of transistor Q1. This error can be minimised by using a transistor with the highest possible gain. If necessary a Darlington pair may be used which will practically remove this error.

A far more dominant error source is the I_{R1} term in the expression. This is largely influenced by the requirement of the reference device that is used. A reference with very small $I_{KA(min)}$ such as the TLV431 will help in keeping this error current down to a minimum. Ultimately, this error term cannot be got rid of and it puts a lower limit on how effectively the circuit can be used as a constant current source for very small currents. Significant errors can be expected for currents below 10mA.

A constant current source that does not have this problem is shown in Figure 4 below. It is more appropriately a constant "current sink" and has eliminated the I_{R1} error altogether. I_{R1} still flows and has same requirements but it is not seen by the load which is connected between V_{IN} and Q1's collector. The circuit is good enough down to at least 10µA or less depending on the transistor used.



$$I_{OUT} = \frac{V_{REF}}{R_S}\left(\frac{h_{FE}}{h_{FE}+1}\right)$$

By making

$$I_{OUT} \approx \frac{V_{REF}}{R_S}$$

$$\frac{V_{IN(\max)} - (V_{OUT(\min)} + V_{REF} + V_{BE})}{I_{KA(\max)} + I_B} \le R1 \le \frac{V_{IN(\min)} - (V_{OUT(\max)} + V_{REF} + V_{BE})}{I_{KA(\min)} + I_B}$$

Figure 4 Constant current sink

Conclusion

The preceding examples illustrate the flexibility of 3-terminal voltage references beyond the obvious and intended applications. These examples can either be used on their own or as building blocks for more complex applications.

Recommended further reading

AN58 - Designing with Shunt Regulators - *Shunt Regulation*

AN59 - Designing with Shunt Regulators - *Series Regulatio*n

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

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

AN63 - Designing with Shunt Regulators - *ZXRE060 Low Voltage Regulator*

Definitions

Product change

Diodes Incorporated reserves the right to alter, without notice, specifications, design, price or conditions of supply of any product or service. Customers are solely responsible for obtaining the latest relevant information before placing orders.

Applications disclaimer

The circuits in this design/application note are offered as design ideas. It is the responsibility of the user to ensure that the circuit is fit for the user's application and meets with the user's requirements. No representation or warranty is given and no liability whatsoever is assumed by Diodes Inc. with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Diodes Inc. does not assume any legal responsibility or will not be held legally liable (whether in contract, tort (including negligence), breach of statutory duty, restriction or otherwise) for any damages, loss of profit, business, contract, opportunity or consequential loss in the use of these circuit applications, under any circumstances.

Life support

Diodes Zetex products are specifically not authorized for use as critical components in life support devices or systems without the express written approval of the Chief Executive Officer of Diodes Incorporated. As used herein:

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.

Reproduction

The product specifications contained in this publication are issued to provide outline information only which (unless agreed by the company in writing) may not be used, applied or reproduced for any purpose or form part of any order or contract or be regarded as a representation relating to the products or services concerned.

Terms and Conditions

All products are sold subjects to Diodes Inc. terms and conditions of sale, and this disclaimer (save in the event of a conflict between the two when the terms of the contract shall prevail) according to region, supplied at the time of order acknowledgement.

For the latest information on technology, delivery terms and conditions and prices, please contact your nearest Diodes Zetex sales office.

Quality of product

Diodes Zetex Semconductors Limited is an ISO 9001 and TS16949 certified semiconductor manufacturer.

To ensure quality of service and products we strongly advise the purchase of parts directly from Diodes Inc. or one of our regionally authorized distributors. For a complete listing of authorized distributors please visit: **www.zetex.com or www.diodes.com**

Diodes Inc. does not warrant or accept any liability whatsoever in respect of any parts purchased through unauthorized sales channels.

ESD (Electrostatic discharge)

Semiconductor devices are susceptible to damage by ESD. Suitable precautions should be taken when handling and transporting devices. The possible damage to devices depends on the circumstances of the handling and transporting, and the nature of the device. The extent of damage can vary from immediate functional or parametric malfunction to degradation of function or performance in use over time. Devices suspected of being affected should be replaced.

Green compliance

Diodes Inc. is committed to environmental excellence in all aspects of its operations which includes meeting or exceeding regulatory requirements with respect to the use of hazardous substances. Numerous successful programs have been implemented to reduce the use of hazardous substances and/or emissions.

All Diodes Zetex components are compliant with the RoHS directive, and through this it is supporting its customers in their compliance with WEEE and ELV directives.

Product status key:

"Preview"	Future device intended for production at some point. Samples may be available
"Active"	Product status recommended for new designs
"Last time buy (LTB)"	Device will be discontinued and last time buy period and delivery is in effect
"Not recommended for new designs"	Device is still in production to support existing designs and production
"Obsolete"	Production has been discontinued

Datasheet status key:

"Draft version"	This term denotes a very early datasheet version and contains highly provisional information, which may change in any manner without notice.
"Provisional version"	This term denotes a pre-release datasheet. It provides a clear indication of anticipated performance. However, changes to the test conditions and specifications may occur, at any time and without notice.
"Issue"	This term denotes an issued datasheet containing finalized specifications. However, changes to specifications may occur, at any time and without notice.

Diodes Zetex sales offices

Europe	Americas	Asia Pacific	Corporate Headquarters
Diodes Zetex GmbH Kustermann-park Balanstraße 59 D-81541 München Germany	Zetex Inc 700 Veterans Memorial Highway Hauppauge, NY 11788 USA	Diodes Zetex (Asia) Ltd 3701-04 Metroplaza Tower 1 Hing Fong Road, Kwai Fong Hong Kong	Diodes Incorporated 15660 N Dallas Parkway Suite 850, Dallas TX75248, USA
Telefon: (49) 89 45 49 49 0 Fax: (49) 89 45 49 49 49 europe.sales@zetex.com	Telephone: (1) 631 360 2222 Fax: (1) 631 360 8222 usa.sales@zetex.com	Telephone: (852) 26100 611 Fax: (852) 24250 494 asia.sales@zetex.com	Telephone: (1) 972 385 2810 www.diodes.com