AN62
Designing with Shunt Regulators - Other applications
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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

\[ V_{SN} = V_{REF} \left(1 + \frac{R_1}{R_2}\right) \]

\[ R_3 = \frac{V^+ - V_{KA(min)}}{I_{SN}} \]

0.1mA ≤ ISN ≤ 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**

![Diagram of a window comparator](image)

\[ V_{LO} = V_{REF} \left(1 + \frac{R_{1L}}{R_{2L}}\right) \]

\[ V_{HI} = V_{REF} \left(1 + \frac{R_{1H}}{R_{2H}}\right) \]

\[ R_3 = \frac{V^+ - V_{REF}}{I_{SH}} \quad 0.1\text{mA} \leq I_{SH} \leq 15\text{mA} \]

**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 \(I_{R1} \ll \frac{V_{REF}}{R_s}\) and \(h_{FE} > 100\)

\[ I_{OUT} = \frac{V_{REF}}{R_s} \]

\[ R_1 = \frac{V_{(V_{REF} + V_{BE})}}{I_{R1(min)} + I_B} \]

**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 $I_{KA\text{(min)}}$ 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.

![Figure 4 Constant current sink](image)

**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 Regulation*

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

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

AN63 - Designing with Shunt Regulators - *ZXRE060 Low Voltage Regulator*
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**Issue 1 - September 2008**

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