Application Brief

Voltage Supervision with a Comparator

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Why Monitoring Voltages Matter

The ability to supervise voltages is a must for any system regardless of the simplicity or complexity of the design. In the analog world, voltages are the decoders to our system. The information we get from monitoring voltages is used to protect our system and troubleshoot failures. There are a myriad of ways to implement voltage monitoring but a cost-effective option is to use a comparator.

Comparator Introduction

For a quick introduction to comparators, see An Overview on Comparators. In short, a comparator is a device that compares an input voltage to a reference voltage and sets the output voltage based on the input levels, as shown in Figure 1.

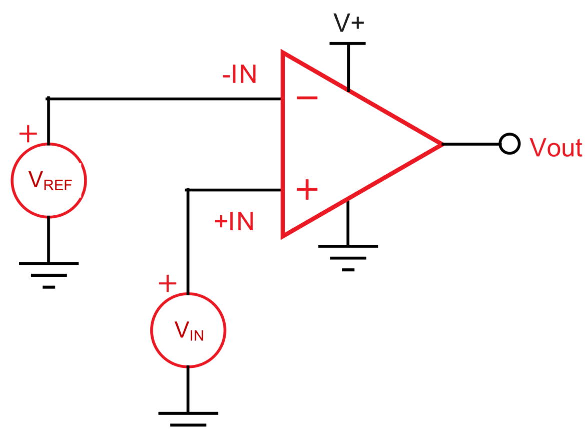

Figure 1. Non-inverting Comparator Configuration

For a non-inverting configuration, if the input voltage is greater than the reference voltage, then the comparator output is high or logic 1. When the input voltage is less than the reference voltage, then the comparato output is low or logic 0. Table 1 shows how the output is reversed for an inverting configuration. Because of their simplicity, comparators can often be found in the building blocks of integrated solutions such as voltage supervisors and reset ICs. As a result, many of the basic features of integrated solutions like multi-channel monitoring and built-in hysteresis can also be found in a standard comparator design. Examples of features that are available in comparators and supervisors are shown in Table 2.

Table 1. Comparator Output Levels

Input	Output	
	Non-inverting	**Inverting**
V_{IN} => V_{REF}	HIGH (1)	LOW (0)
V_{IN} < V_{REF}	LOW (0)	HIGH (1)
V_{IN} = V_{REF}	UNDEFINED (Determined by Vos)	UNDEFINED (Determined by Vos)

Comparator vs. Voltage Supervisor

What determines if a comparator or voltage supervisor is better for voltage monitoring? If there is a timing element that requires the output to be delayed before the device is triggered, then a voltage supervisor is the simplest way to implement this feature. Although possible to implement RC timing delay with a comparator, the ease that comes with integrating these elements makes a voltage supervisor a more attractive option.

For other voltage monitoring applications, comparators can add a level of flexibility to the design. Voltage supervisors forces the designer to work with whatever the pre-existing reference configuration is set to. This means that if the system needs a 1.8 V reference but the supervisor being used has a fixed 1.2 V reference then another supervisor with a 1.8 V internal reference must be added to the BOM. The more the system needs begin to vary, the bigger the BOM count grows. With a standard comparator, the reference voltage can be adjusted to whatever voltage is desired. This allows the BOM to be manageable as the same device can be used for multiple use cases and instances as well as less time spent requalifying new devices, which enables faster iterations to the designs.

Table 2. Comparator vs. Voltage Supervisor Functionalities

Features	Voltage Supervisor	Comparator
Configurations		
Single-channel monitoring	Yes	Yes
Multi-channel monitoring	Yes	Yes
Window voltage monitoring	Yes	Yes
Output Topologies		
Open-drain / Open-collector	Yes	Yes
Push-Pull	Yes	Yes
LVDS	-	Yes
Standard small packages	Yes	Yes
Reference Options		
External reference	-	Yes
Adjustable integrated reference	Yes	Yes
Fixed Integrated reference	Yes	Yes
Built-in Features		
Ability to reset or turn off another device	Yes	Yes
Programmable reset delay	Yes	-
Built-in hysteresis	Yes	Yes
Adjustable hysteresis	Yes	Yes
Known Start-up	Yes	Yes
Fail-Safe	Yes	Yes

Comparator Classifications for Voltage Monitoring Applications

From the standard SOT-23 to leadless nanometer packages, comparators come in all different specs and sizes. For high-speed applications, use a comparator with a small propagation delay. For power-sensitive designs, consider using a comparator with low quiescent current such as the TLV70xx family of devices. The 36 V capable Dual commercial grade standard comparator (LM393B)/ Dual industrial grade standard comparator (LM2903B) and 40 V capable TLV18xx devices are used for high voltage battery monitoring applications. Likewise, for low voltage ≤ 5 V needs, the 5.5-V, low-voltage standard quad-channel comparator with 1-µs delay (LM339LV)/ '1.65-V to 5.5-V, low-voltage dual commodity comparator (LM393LV) and TLV90xx devices are most appropriate. For space constraint systems that call for more precision, use a comparator with an integrated reference. These features are filtered on the Comparators Product Selection Page to help you find a device that fits your design needs.

Voltage Monitoring using a Comparator with an External Reference

The biggest advantage of using a comparator to monitor voltages and power rails is the ability to dictate your own trip point. The comparator trip point is set with an external reference device such as Adjustable precision shunt regulator (TL431) or with a voltage divider consisting of two resistors in series. In the inverting configuration depicted in Figure 2, resistors R1 and R2 are used to set the comparator's voltage reference. By manipulating the magnitudes of R1 and R2, you are able to customize the comparator threshold to your desired trip point. Depending on the voltage of the signal, additional resistors are used to divide down the input voltage signal.

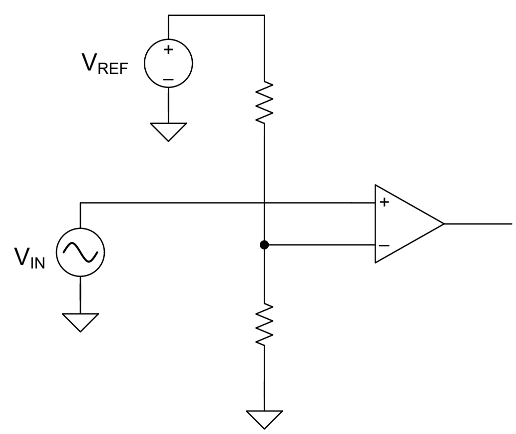

Figure 2. Using Resistors to Create an External Reference

Since resistors are relatively low cost and easy to procure, the comparator is repurposed for different voltage monitoring needs such as overvoltage, undervoltage, and reverse voltage monitoring and protection. See Overvoltage protection with comparator circuit, Undervoltage protection with comparator circuit, and Using comparators in reverse current applications for additional comparator voltage supervision applications.

Creating a Window Comparator

To determine if a voltage signal is between two reference voltages, place two open-drain comparators in parallel as show in Figure 3. Notice that this configuration still utilizes eternal resistors to set the upper and lower limits of the comparator and can be accomplished using two single channel comparators or one dual channel comparator. For a more detailed explanation on how to make a window voltage detector using a comparator, check out the Window Comparator Circuit document.

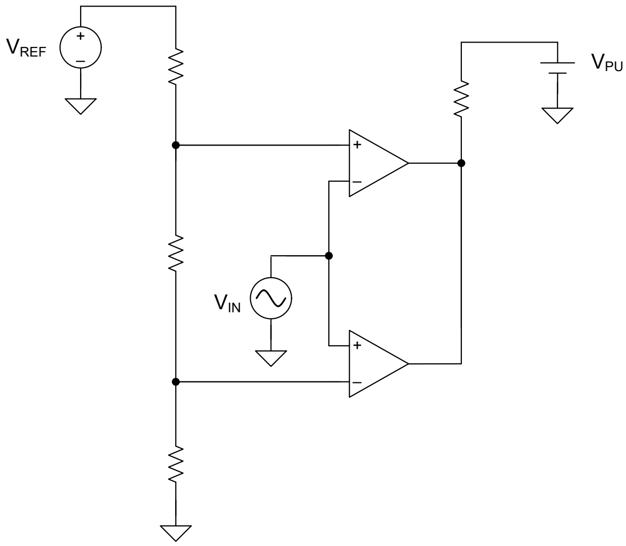

Figure 3. Window Comparator Configuration

Creating a Multi-stage Voltage Detection Circuit with a Comparator

Voltages are monitored at multiple trip points by placing three series resistors parallel to two comparators in the early warning detection configuration shown in Figure 4. When the input voltage crosses the set threshold of comparator one and two, the outputs of the comparators is used to first turn on a warning light or alarm before a force shutdown occurs.

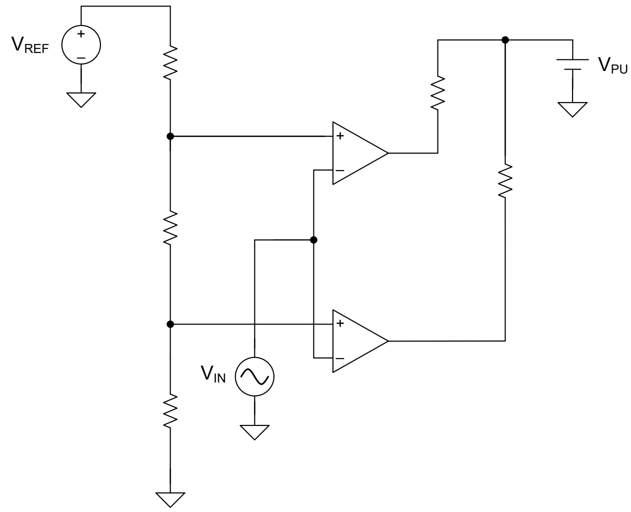

Figure 4. Multi-stage Voltage Detection Circuit

Alternatively, if time is not an important factor then such a configuration is used for a two-phase voltage application where the first comparator serves as the trigger for an event that concludes when the threshold of the second comparator has been crossed.

Voltage Monitoring using the Comparator's Supply Voltage as the Reference

Another way to create the comparator threshold is to use a regulated power supply as the voltage reference. This allows you to take advantage of already existing components in your system without any extra expenditures on cost and space. Figure 5 shows an undervoltage detection circuit using the 4-pin Nanopower micropackage low-voltage comparator (TLV7081) with an internal configuration that ties the inverting input pin of the comparator to the positive supply pin. This layout is replicated by comparators with standard pinouts simply by connecting an input pin to the power supply in a similar fashion as Figure 5.

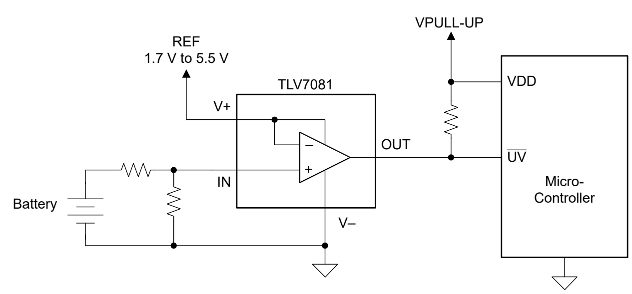

Figure 5. Voltage Monitoring using the TLV7081

The power supply can only be used as the reference if the power supply does not violate the comparator's input common mode range. Since most comparator inputs can handle up to 5V, this is mainly a concern at higher voltages. For these higher voltage rails, consider using TI's TLV18xx 40V comparator family. The TLV185x and TLV186x comparators are not only 40 V capable but are also fail-safe and have internal reverse battery/polarity protection circuitry. Because the TLV185x/6x devices are fail-safe, the devices can handle voltage spikes independent of the supply, up to 40 V. The internal reverse battery protection also means that the TLV185x/6x is directly connected to the battery and if the polarity of the battery voltages changes for any reason, the input pins of the comparator remain undamaged. These two features make it possible to connect TLV185x/6x directly to a ≤ 40 V supply and use the supply as the reference voltage.

Voltage Monitoring using a Comparator with an Integrated Reference

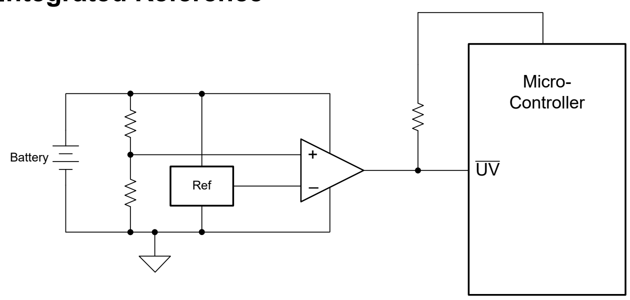

Figure 6. Undervoltage Detection using a Comparator + External Reference

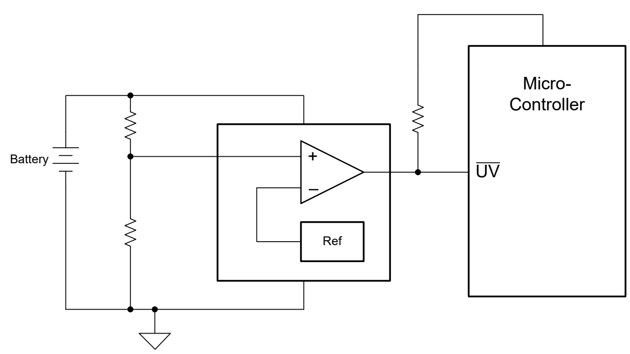

Figure 7. Undervoltage Detection using an Integrated Reference Comparator

TI has quite a selection of integrated reference comparators, from the 36 V comparator with integrated reference (TLV6713) high voltage 36 V comparators with integrated references to our TLV301xB family with an externally available reference pin. For designs that are limited in space or sensitive to power dissipation, the use of external resistors to set the voltage threshold are not the best option. For such systems, a small size comparator with an integrated reference such as the 0.73 mm x 0.73 mm DSBGA Low-power comparator with reference (TLV4041R5YKAR) can work. The undervoltage detection circuit in Figure 6 becomes simpler and more compact when the comparator + voltage reference is replaced with an integrated reference comparator as shown Figure 7. Table 3 shows that by using an integrated reference comparator, you are able to decrease the amount of space your voltage detection circuit takes up by about a factor of ten and consume 90% less energy.

Table 3. Comparator + External Reference vs. Integrated Reference Comparator

Comparator + External Reference vs. Integrated Reference Comparator Solution				
	Comparator + External Reference			Integrated Reference Comparator
	TLV7031	**ATL431**	**Total**	**TLV4041R5YKAR**
Smallest package (mm)	X2SON	SOT-23	5.28mm²	DSBGA
	0.8 x 0.8	2.9 x 1.6		0.73mm x 0.73mm
I_Q (typ)	0.315 µA	20 µA	20.3 µA	2 µA

Another benefit of using an integrated reference comparator for voltage supervision is the precision. Most of TI's integrated reference comparators have a reference accuracy of 1% across temperature allowing for accurate monitoring of your voltage rails. As more and more international standards for functional safety (such as IEC 61508) are established, the need for more precision in voltage monitoring grows. Adding external components to your design can introduce additional noise that have already been accounted for in an internal reference comparator design. This additional noise can become a concern as you work with higher voltages in your system.

Window Comparator and Multi-stage Voltage Detection with an Integrated Reference

The window comparator and multi-level voltage detection circuit also becomes simpler with an integrated reference comparator. TI's Low power window comparator with integrated reference (TLV6700) and Low power, high voltage window comparator with integrated reference (TLV6710) comparator are 18 V and 36 V dual comparators designed with a window comparator configuration as depicted by the functional block diagram in Figure 8.

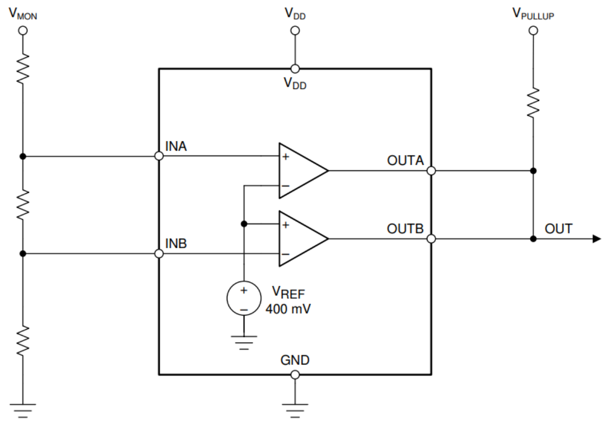

Figure 8. Voltage Monitoring using Window Comparators TLV6700/6710

As shown in Figure 9, Dual comparator with integrated reference push-pull (TLV4062) and Dual comparator with integrated reference (TLV4082) are a pair of dual channel comparators with an internal configuration similar to Figure 4, which allows for a simpler multi-stage voltage detection circuit to be built.

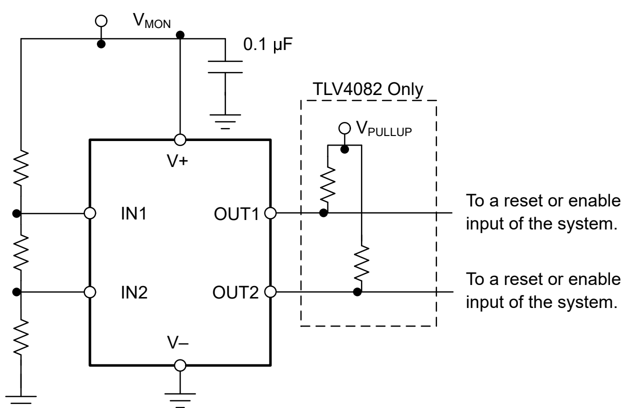

Figure 9. Multi-Level Voltage Detection using TLV4062 and TLV4082