

# Optimize Your System Design with the Right Window Voltage Supervisor

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## Abstract

Using a window voltage supervisor gives better regulation of the system power supply by preventing undervoltage and overvoltage scenarios. A stable system supply protects the systems or loads from potential malfunction or, worse, being damaged. Different window voltage supervisor architectures provide options for tolerance, undervoltage and overvoltage threshold setting, and output configuration, creating design flexibility depending on the application. This article aims to help engineers and system designers identify the most suitable window voltage supervisor for their application using different architecture examples.

## Introduction

Sudden fluctuations in voltages may cause severe problems in areas like automotive, industrial, or home appliances. This system power supply issue can be due to voltage spikes, poor or inconsistent flow of electricity, lightning strikes, flickering, etc.

Using a window voltage supervisor helps prevent malfunctions in the system as it detects a certain range of voltage regardless of whether it is under or over the range of voltage and provides an output signal that can be utilized in executing protective mechanisms. Window voltage supervisors are available with different architectures and features, and a better understanding of each type is necessary to arrive at an optimum system design. Options range from a resistor-programmable undervoltage (UV) and overvoltage (OV) trip, a fixed or factory-trimmed UV/OV threshold, multichannel for monitoring several voltages, or with single UV/OV or independent UV and OV output selection.

## Understanding Window Voltage Supervisors

A window voltage supervisor circuit is similar to the conventional window detector circuit that uses two comparators and each of the comparators detects a common input voltage against its reference voltages, which are the upper limit and the lower limit. The output shows the detection from the input in the form of a window between the two reference threshold voltages. Simply, it does not only detect under the threshold voltages but also over the threshold voltages. Figure 1 shows the conventional circuit and the waveform of a window detector circuit.

In this circuit, when  $V_{in}$  is greater than the lower limit, the output from U2 will be in a high state from a low state. In contrast with U1, when  $V_{in}$  becomes greater than the upper limit, the output will be in a low state from a high state. Therefore, if  $V_{in}$  is greater than the lower limit and lower than the upper limit, then both comparator's outputs will swing to the high state and turn on the AND gate output.

For a window voltage supervisor, each comparator shares a common reference voltage. It also provides a defined margin of supply tolerances, threshold hysteresis, and threshold accuracy specifications. The tolerance is a value often expressed in percentage used to determine the undervoltage and overvoltage threshold window with respect to the nominal voltage. Hysteresis ensures a reliable reset operation and prevents a false reset output even in the presence of supply noise or erroneous signals. The accuracy gives the allowable range of undervoltage and overvoltage thresholds.<sup>1</sup>

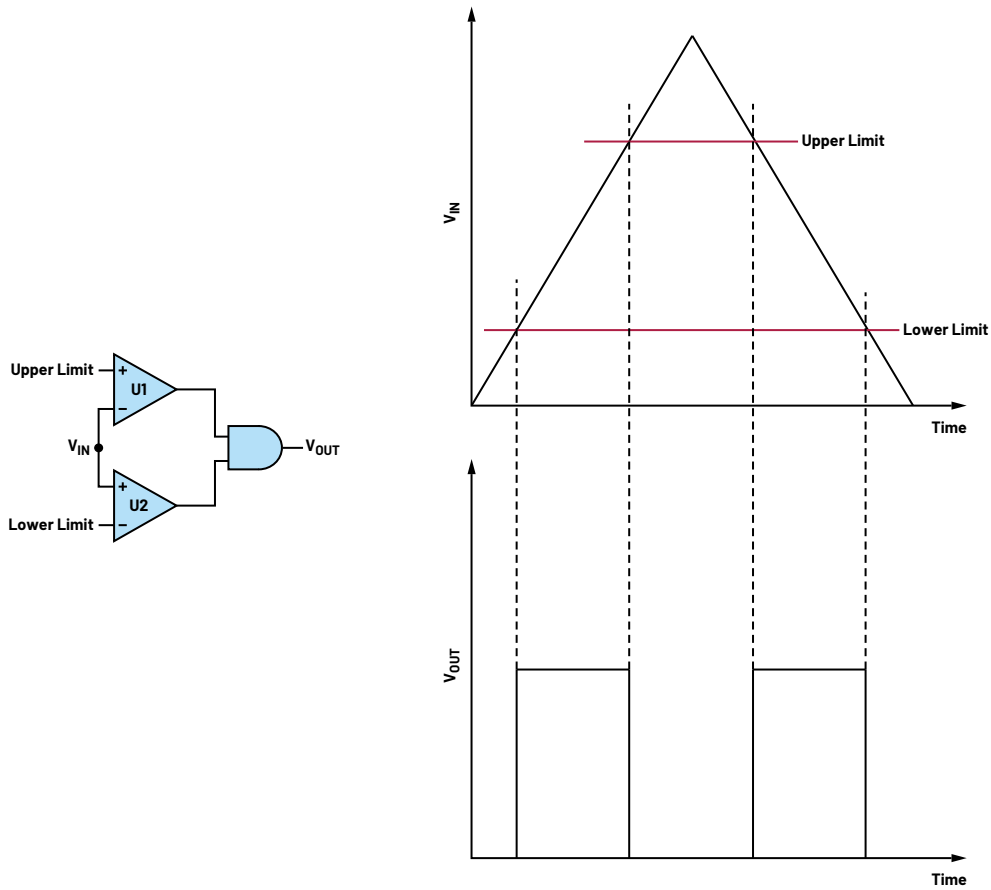


Figure 1. A conventional window detector circuit and waveform.

## Resistor-Programmable Voltage Thresholds with UV Output and OV Output

This type of architecture uses a three-resistor configuration externally wherein a resistive divider is connected to the comparator's negative and positive input in setting the threshold for monitoring UV and OV conditions on the system power supplies. It does not have a defined tolerance for the UV/OV threshold window, but the user can manually set it. Single and multiple channel variants are available on these types of supervisors, thus the supply voltage  $V_{CC}$  of these supervisors is separated with the input or monitoring pins.

Figure 2 illustrates the positive voltage monitoring block diagram with dedicated UV and OV outputs per channel and its input connection with three external resistors. In monitoring a positive supply ( $V_M$ ), the UV condition will trigger when the high-side voltage ( $V_H$ ) falls below the internal reference, and the OV condition will trigger when the low-side voltage ( $V_L$ ) exceeds the internal reference. The advantage of using a resistor-programmable window voltage supervisor is that it allows the user to set the desired UV and OV trip points, where R1 is chosen to set the desired trip point for the OV monitor, R2 for the UV monitor, and R3 is to complete the design. See the equations to determine the values of each resistor.

Given that the user has values for the monitored voltage ( $V_M$ ), and nominal current ( $I_M$ ) in the resistive divider,

$$\frac{V_M}{I_M} = R1 + R2 + R3 = R_{TOTAL} \quad (1)$$

For R1,

$$V_L = V_{OV\_TRIP} \times \frac{R1}{R_{TOTAL}} = REF \quad (2)$$

$$R1 = \frac{REF}{V_{OV\_TRIP}} \times \frac{V_M}{I_M} \quad (3)$$

For R2,

$$V_H = V_{UV\_TRIP} \times \frac{R1 + R2}{R_{TOTAL}} = REF \quad (4)$$

$$R2 = \frac{REF}{V_{UV\_TRIP}} \times \frac{V_M}{I_M} - R1 \quad (5)$$

One consideration in using external resistors is that they increase the power consumption of the system and may widen the overall accuracy. Minimizing power consumption can be achieved by using large-value resistors, while lower-value resistors can be used to maintain overall accuracy.

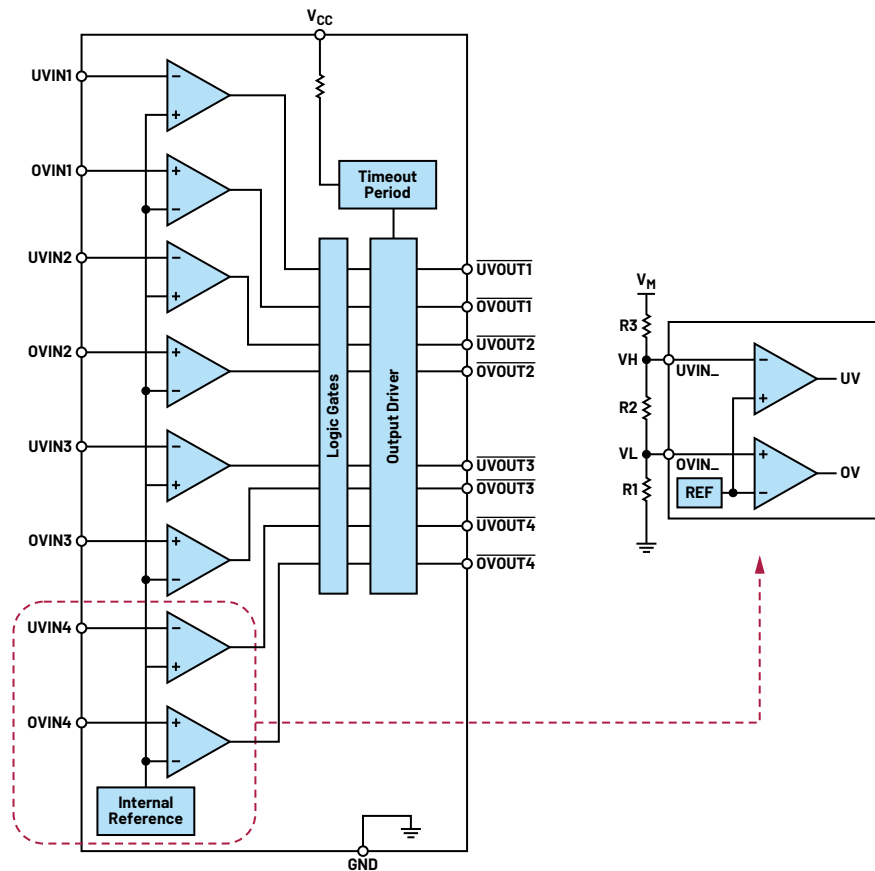


Figure 2. A resistor-programmable UV/OV threshold internal block diagram and configuration.

The **MAX16009**, a low voltage, high accuracy, quad window voltage supervisor, has this type of architecture. This product offers flexibility in the design such as in setting the UV and OV thresholds that can be as low as 0.4 V in multiple channels. Figure 3 is an example using the MAX16009. This device is used in the scope section of the endoscope, which has a long tube with a light and camera that is inserted into the human body to look inside a cavity or organ. This system operates with multiple voltage rails at low voltage levels. This voltage supervisor

increases the reliability and robustness of the system by monitoring the core supply and the input/output supply of the field programmable gate arrays (FPGAs) to ensure voltage hazards do not occur.

The **ADM12914**, which is a  $\pm 0.8\%$  accurate quad UV/OV positive/negative voltage supervisor, also has resistor-programmable UV/OV thresholds. It features a three-state pin to determine the polarity of the third and fourth inputs, which allows the device to monitor positive or negative supplies. Its high accuracy monitoring

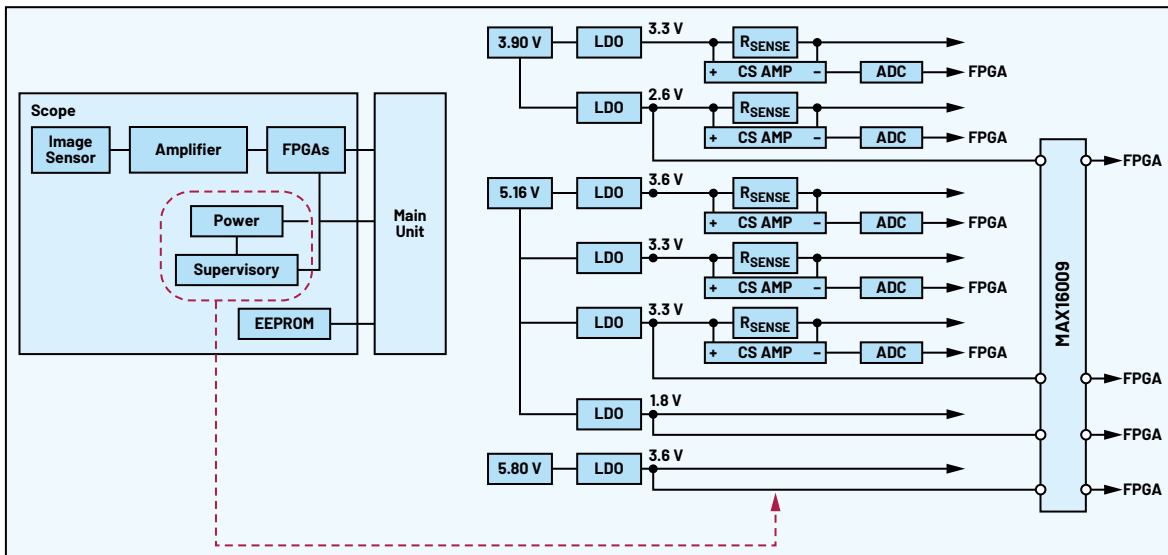


Figure 3. An endoscope high level block diagram.

is valuable for instrument applications such as impulse winding testers, which discover potential defects in coil products such as transformers, motors, etc. It detects units with low insulation between layers, which is often difficult to find in the early phase of production. The tester is used to apply an impulse voltage across a winding's terminals and compare the test waveforms with a reference from a known-good winding resulting in detecting defects.<sup>2</sup> This application uses high speed sampling analog-to-digital converter (ADC) products to sample and display the waveform and compare it to the standard waveform for detection. The flexibility in setting the threshold and the high threshold accuracy of the ADM12914 is beneficial in precise monitoring of the voltage bias of different circuit blocks of the impulse winding tester such as the ADC driver, high speed amplifier, and microprocessor, thus is critical in producing high quality coil products that, in the end, will be used in industrial, automotive, and consumer products.

Table 1 lists examples of ADI window voltage supervisors with resistor-programmable UV and OV thresholds based on the number of channels.

**Table 1. Window Voltage Supervisors with Resistor-Programmable UV and OV Thresholds**

Part Number	No. of Channels	Dedicated UV and OV Outputs per Channel
MAX6763	1	Yes
MAX6764		
MAX6459		
LTC2912	2	No (Common UV and OV outputs for all channels)
LTC2913		
LTC2914		
ADM12914	4	No (Common UV and OV outputs for all channels)
ADM2914		
MAX16008		
MAX16009		
MAX16063	Yes	

### Factory-Trimmed Voltage Thresholds with a Selectable Window

This type of window voltage supervisor architecture provides factory-trimmed voltage thresholds with a selectable window for UV/OV thresholds. Some of these types offer options for a single or independent undervoltage and overvoltage output.

The MAX6762 has this type of architecture. It offers fixed factory-trimmed voltage thresholds for monitoring system voltages from 0.9 V to 5 V with a selectable  $\pm 5\%$ ,  $\pm 10\%$ , or  $\pm 15\%$  window for the defined UV/OV thresholds, which eliminates the need for external components and their variabilities. The window can be selected through the state of the SET pin, which provides flexibility to system engineers in optimizing their design. Unlike the first type of architecture we discussed, the  $V_{CS}$ s of these window voltage supervisors are the monitored voltages. Thus, there are

no separate monitoring pins. Figure 4 shows the functional block diagram of the MAX6762, showing the UV/OV threshold window options and output configuration.

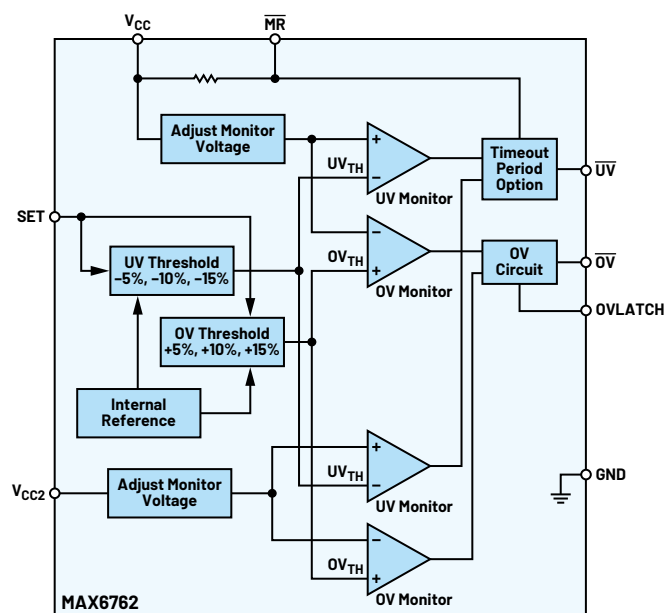


Figure 4. A functional block diagram of the MAX6762, an example of a window voltage supervisor with factory-trimmed thresholds.

Applications that require tight regulation of the voltage supply and are noise-sensitive can easily select the option of tight tolerance. On the other hand, applications that are more tolerant to power supply noise and do not require tight regulation can choose to set a wider tolerance to maximize the usable power supply window avoiding oversensitivity and system oscillation. This architecture allows the designer to balance flexibility with complexity by solution. Factory-trimmed voltage simplifies the solution by eliminating the need for external resistors while allowing flexibility in choosing the appropriate window through the SET pin.

Figure 5 shows an example of a simplified power tree of a wireless transceiver. Aside from needing optimum noise performance, this application requires tight regulation of the power rails. Postlinear regulators such as low dropout (LDO) regulators are often used to suppress the noise brought by switching noises and the harmonics components of switching regulators in the upstream supply, yet sometimes high performing switchers are enough. However, using a window voltage supervisor improves the overall reliability by ensuring that the analog and digital supplies are operating within the tight regulation requirement. In the example, the supply rails are monitored by the MAX6762 with a defined threshold window. Tighter tolerance can be chosen since regulators with optimum noise performance are used. The UV outputs are configured into a logic OR to put the microprocessor into reset mode, and the OV outputs as an input to a nonmaskable interrupt (NMI) of the microprocessor.

Table 2 lists examples of window voltage supervisors that have factory-trimmed voltage thresholds with a selectable window. Single-channel and dual-channel variants are available with choices of independent UV and OV outputs or a single UV/OV output.

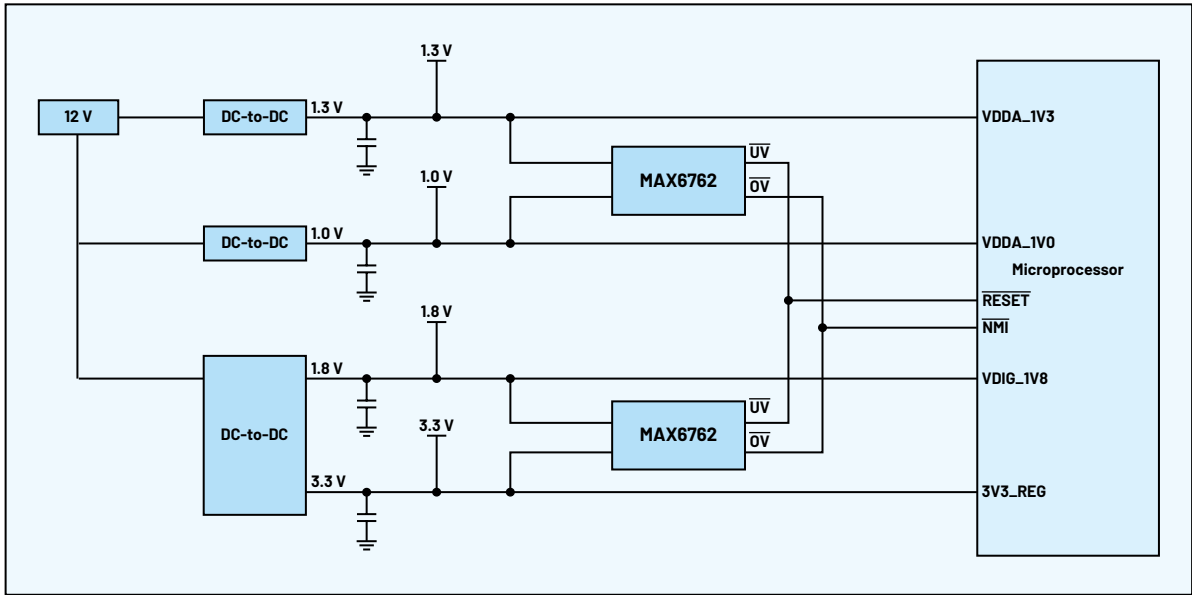


Figure 5. An example of a power tree for a transceiver microprocessor.

**Table 2. Window Voltage Supervisors with Factory-Trimmed Voltage Thresholds and a Selectable Window**

Part Number	No. of Channels	UV/OV Output
MAX6754	1	Single UV/OV output
MAX6755		
MAX6756		
MAX6757		
MAX6759	2	Independent UV and OV outputs
MAX6760		
MAX6762		

### Factory-Trimmed Voltages and Window with Single UV/OV Output

This architecture detects a UV or an OV fault in a factory-set threshold window. Its difference from the second type discussed is that the tolerance for the UV/OV thresholds is factory-trimmed. Common supervisors with this architecture provide a single reset output. Multichannel options that can monitor multiple voltage rails in a single chip are also available with a variety of thresholds to accommodate different supply voltages and tolerances.

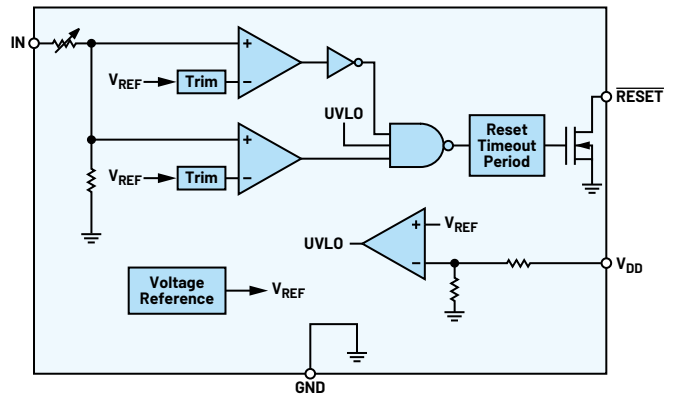


Figure 6. A functional block diagram of a factory-trimmed threshold and tolerance.

In Figure 6, this type of window voltage supervisor uses internal comparators to determine the input conditions from the input voltage (IN) and input supply voltage ( $V_{DD}$ ). The  $V_{DD}$  level is monitored for the UVLO level and, separately, the monitored voltage's OV and UV through the IN pin. If the IN falls outside the preprogrammed UV/OV window, then a reset output will be asserted. The voltage reference determines the variety of factory-trimmed nominal input voltage and a wide range of options for input tolerance within the given threshold accuracy specification. The tolerance sets the UV/OV threshold levels with respect to the programmed nominal input voltage. This voltage supervisor also has internal hysteresis at the window thresholds to help avoid noise-caused multiple fault conditions.

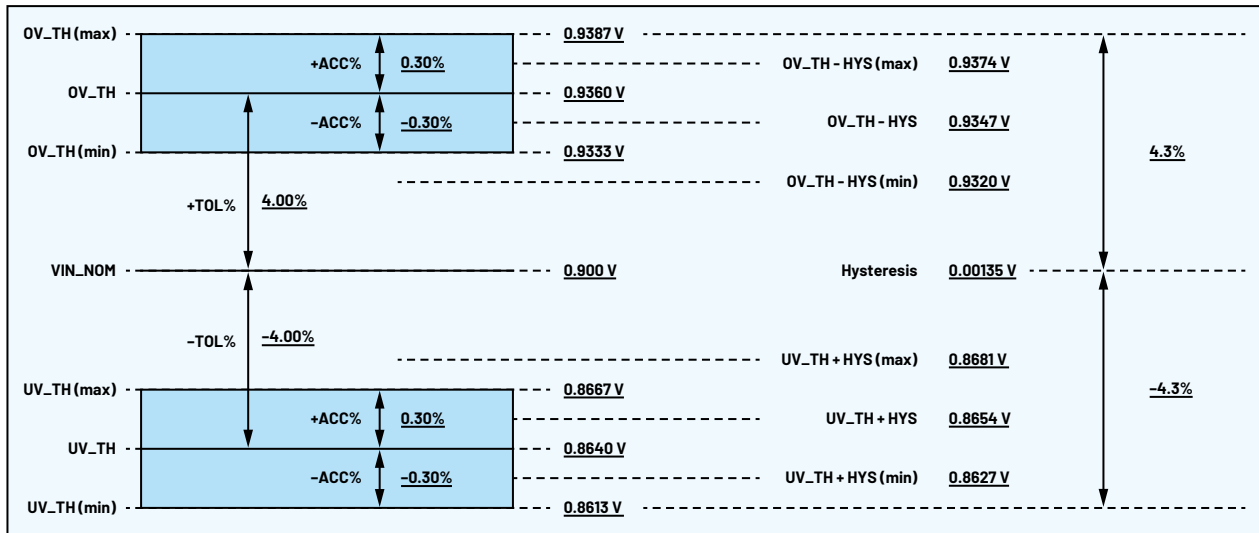


Figure 7. A window voltage calculator sample computation result for the MAX16193.

The MAX16193, which is a 0.3% accurate dual-channel supervisory circuit, with a selected nominal input voltage (VIN\_NOM) of 0.9 V and input tolerance level (TOL) of 4%, uses this architecture. The following formulas are used to determine the UV and OV threshold levels (UV\_TH and OV\_TH):

$$UV\_TH = VIN\_NOM \times (1 - TOL) = 0.9V \times (1 - 4\%) = 0.8640V \quad (6)$$

$$OV\_TH = VIN\_NOM \times (1 + TOL) = 0.9V \times (1 + 4\%) = 0.9360V \quad (7)$$

And with 0.3% threshold accuracy (ACC) over the supply range is shown as:

$$UV\_TH(max) = VIN\_NOM \times (1 - TOL + ACC) = 0.9V \times (1 - 4\% + 0.3\%) = 0.8667V \quad (8)$$

$$UV\_TH(min) = VIN\_NOM \times (1 - TOL - ACC) = 0.9V \times (1 - 4\% - 0.3\%) = 0.8613V \quad (9)$$

$$OV\_TH(max) = VIN\_NOM \times (1 + TOL + ACC) = 0.9V \times (1 + 4\% + 0.3\%) = 0.9387V \quad (10)$$

$$OV\_TH(min) = VIN\_NOM \times (1 + TOL - ACC) = 0.9V \times (1 + 4\% - 0.3\%) = 0.9333V \quad (11)$$

To help us visualize these values, Figure 7 shows an illustration of the computed parameters. The calculations were obtained simply by using the [Window Voltage Monitor Calculator](#), a tool to help system designers ensure that the device specifications fit the design requirements such as the power supply operating window. Figure 7 shows that using this device with a nominal voltage of 0.9 V, tolerance of 4%, and threshold accuracy of 0.3%, the power supply operating window will be ±3.7%. This example is suitable for applications that have low core voltages and require tight regulation.

This tool is available for download from the product pages of the following: [MAX16138](#), [MAX16191](#), [MAX16193](#), [MAX16132 through MAX16135](#), [MAX16137](#).

Other products using the same architecture are the MAX16132 through MAX1635, a family of low voltage, high precision single-/dual-/triple-/quad-voltage supervisors that feature an independent reset output for the MAX16132/MAX16133/MAX16134 and a dual reset output for the MAX16135. They have ±1% threshold accuracy over temperature and window threshold monitoring and are ideal for automotive advanced driver assistance systems (ADAS) applications. They have several nominal voltage options that can be chosen to support the application requirements. ADAS solutions contain cameras, long-range radar, ultrasound, and light detecting and ranging (LIDAR) sensing technologies. An example of an ADAS block diagram is shown in Figure 8, where the window voltage supervisor is under the supervisory category in the power management system block. The sensing circuits require several different voltage rails to be monitored for devices such as amplifiers, ADCs, radar transceivers, and microcontrollers, which may range from 1.8 V to 5 V. When the power supply voltage in the system fails to provide enough voltage levels, it will negatively impact the system's ability to accurately sense the environment. In effect, the sensors may have difficulty detecting and tracking objects accurately, leading to false alarms or missed warnings.<sup>3</sup> The MAX16132 through MAX1635 have several trimmed voltage threshold options to choose from that can support the ADAS requirements with high accuracy to address the tight regulation requirement. They offer a nominal input voltage that is factory programmable from 1 V to 5 V with a wide range of options for input tolerance from ±4% to ±11% and a hysteresis of 0.25% and 0.5%.

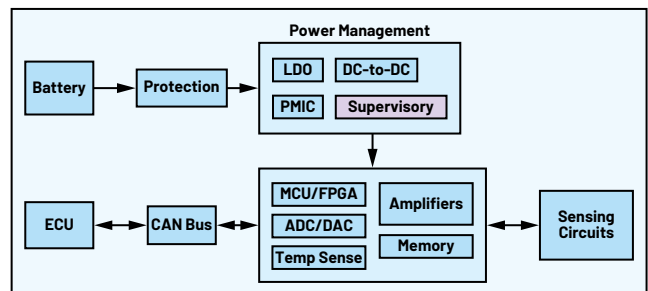


Figure 8. An ADAS high level block diagram.

This window voltage supervisor is often used in an industrial application such as collaborative robots or cobots. A cobot is an autonomous robot worker responsible for repetitive and hazardous tasks, working alongside human workers in a shared workspace. It is equipped with a variety of sensors for safety features that automatically stop when they detect a nearby human or get in contact with a human worker, then resume working once the human worker has left the area. Real-time control of robotic systems can be achieved through an FPGA's fast processing capability.<sup>4</sup> Critical functions like fine-tuned motor control and stable feedback loops need highly accurate power system monitors, which the MAX16134 can provide.

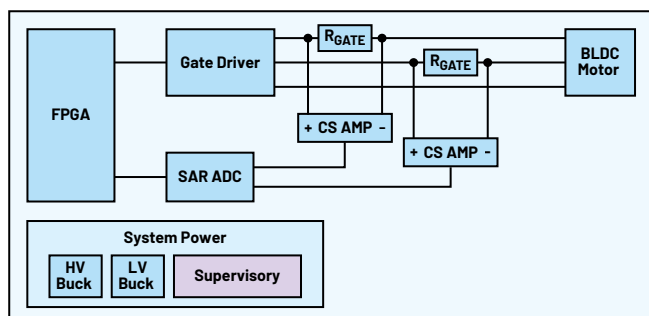


Figure 9. A cobot high level block diagram.

Table 3 shows different generics that have factory-trimmed threshold voltage and tolerance options with a given accuracy available with a different number of channels.

**Table 3. Window Voltage Supervisors with Factory-Trimmed Voltage Thresholds and Tolerance**

Part Number	No. of Channels	Voltage Thresholds	Tolerance
MAX16193	2	IN1: 0.6 V to 0.9 V IN2: 0.9 V to 3.3 V	±2% to ±5%
MAX16132	1	1.0 V to 5.0 V	±4% to ±11%
MAX16133	2		
MAX16134	3		
MAX16135	4		

## Conclusion

Window voltage supervisors add reliability and system robustness by monitoring not only the undervoltage but also the overvoltage to decrease the chance of a power supply fault. ADI offers a wide variety of window voltage supervisors to choose from to support different applications. Different architectures in setting voltage thresholds and tolerances are designed and made available to help system architects arrive at the optimum design.

## References

- <sup>1</sup>Noel Tenorio. "How Voltage Supervisors Address Power Supply Noise and Glitches." *Analog Dialogue*, Vol. 57, November 2023.
- <sup>2</sup>Yuki Maita. "High-Precision Winding Testing with a New Type of Impulse Winding Tester." *EE Power*, December 2019.
- <sup>3</sup>Bonnie Baker. "Gatekeeping Soldiers Protect ADAS Power Supply Voltage Integrity." Analog Devices Inc., July 2020.
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### About the Author

Camille Bianca Gomez is a product applications engineer at Multimarket Power—East. She joined Analog Devices in March 2022 and obtained her bachelor's degree in electronics engineering from De La Salle University—Laguna Campus. She previously worked as a design engineer in an automotive manufacturing company for 3.5 years and is now focusing on support and product development of high performance supervisory products.



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Noel Tenorio is a product applications manager under multimarket power handling high performance supervisory products at Analog Devices Philippines. He joined ADI in August 2016. Prior to ADI, he worked as a design engineer in a switch-mode power supply research and development company for six years. He has a bachelor's degree of electronics and communications engineering from Batangas State University, and a postgraduate degree in electrical engineering major in power electronics, and a Master of Science degree in electronics engineering from Mapua University. He also had a significant role in applications support for thermoelectric cooler controller products prior to handling supervisory products.