Application Report
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Using the TL431 as a Voltage Comparator

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ABSTRACT

This application report shows how engineers can use the TL431 in voltage comparator or window comparator applications.

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Trademarks

1 Introduction

An adjustable shunt regulator is used to take an input voltage and produce a regulated output voltage determined by the device characteristics. Engineers can connect the “REF” pin to the “CATHODE” pin in a closed-loop configuration to generate feedback and regulate the output of the device based on the input. Furthermore, engineers can also use a resistor gain network to increase the regulated output voltage in this configuration.

Engineers can break the closed loop from “REF” to “CATHODE” pins to use an adjustable shunt regulator as a simple voltage comparator or window comparator in the open-loop configuration. The TL431 is a shunt regulator commonly used for this application.

2 Voltage Comparator Application

Figure 1 shows the TL431 functional block diagram in the voltage comparator application. The input voltage is sent into the “REF” pin and is compared to the internal reference voltage. If the input voltage on the “REF” pin is less than the reference voltage, then the transistor in the block diagram remains off and acts as an open circuit that exists between the cathode and the anode. In this state, V_{sup} and V_{out} are equal and a logic “high” output is produced. Conversely, if the input voltage on the “REF” pin is greater than the reference voltage, then the transistor in the block diagram conducts and current flows between the cathode and the anode. In this state, the V_{ref} and V_{out} are equal and a logic “low” output is produced.

$$V_{out} = \begin{cases} V_{sup}, V_{IN} < V_{ref} \\ V_{ref}, V_{IN} > V_{ref} \end{cases} \quad (1)$$

Figure 2 shows the output of the voltage comparator in red with the input waveform in shown in blue. The V_{ref} voltage value should be as low as possible to provide ample to the “high” state. In this example, the TLV431 was chosen for its low V_{ref} value of 1.24 volts. A voltage divider network and logical inverter can also be used to further manipulate the output levels as necessary.

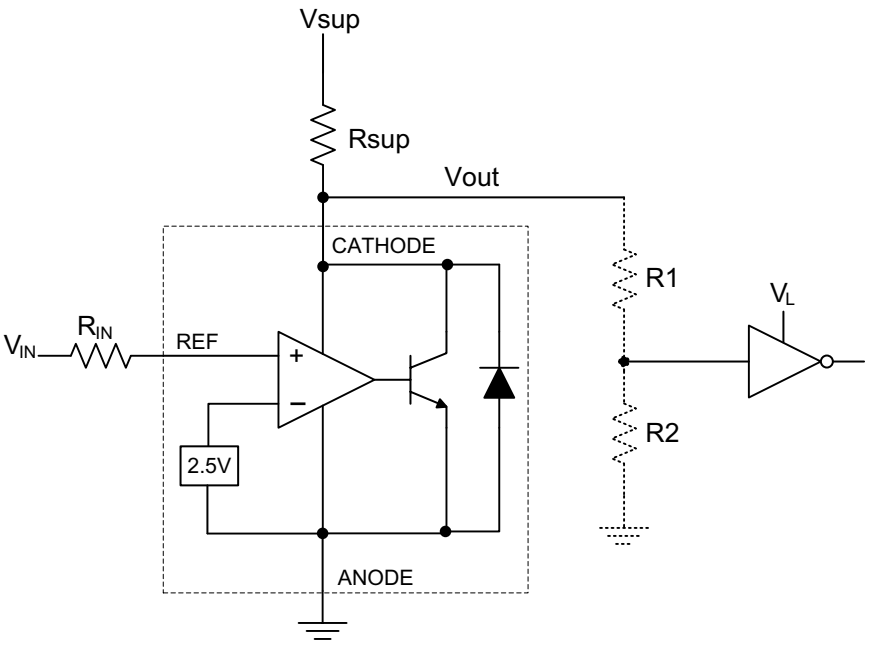

Figure 1. Voltage Comparator Application Functional Block Diagram

To design the voltage comparator, four parameters must be considered. The V_{sup} and R_{sup} must be designed to provide at least the minimum cathode current (I_{KA}), but they must not exceed the maximum cathode current value. The value set to V_{sup} will be the output value for the “high” state. The “low” state will be set by the characteristic value of V_{ref}. Also, the value for R_{IN} must be a large enough impedance value to minimize I_{REF}.

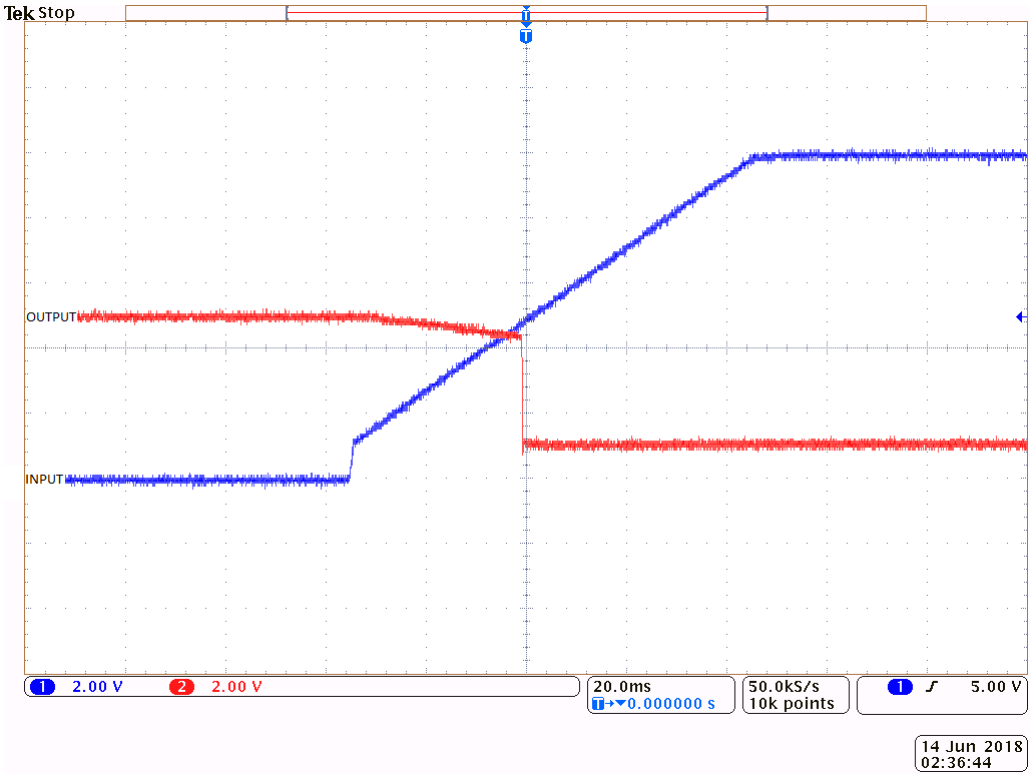

Figure 2. Voltage Comparator Output

3 Window Comparator Application

Figure 3 shows how two shunt regulators can be applied as a window comparator. In this configuration, one shunt regulator is configured in the closed-loop configuration with a pair of resistor divider networks. The first pair of resistors sets the upper threshold voltage (V_H). The second pair of resistors sets the lower threshold voltage (V_L).

$$V_H = \left(1 + \frac{R_2}{R_1}\right) V_{REF} \tag{2}$$

$$V_L = \left(1 + \frac{R_3}{R_4}\right) V_{REF} \tag{3}$$

The window comparator will go “high” until the lower threshold voltage is reached, then go “low” until the upper threshold voltage is reached again. Once the upper threshold voltage is reached, the window comparator output goes “high” again. The logic “high” output voltage is set by V_{PULLUP}. The logic “low” output voltage set by V_{ref} should be as low as possible. Figure 4 shows the output of this circuit. The input is shown in blue as a ramp from 0 to 20 volts. The output in red is shown with a high state of 5 volts and a low state approximately equal to V_{ref}. In this example, the lower threshold was set to 5 volts and the upper threshold was set to 13 volts.

$$V_{out} = \begin{cases} V_{PULLUP}, V_{IN} < V_L \\ V_{ref}, V_L < V_{IN} < V_H \\ V_{PULLUP}, V_H < V_{IN} \end{cases} \tag{4}$$

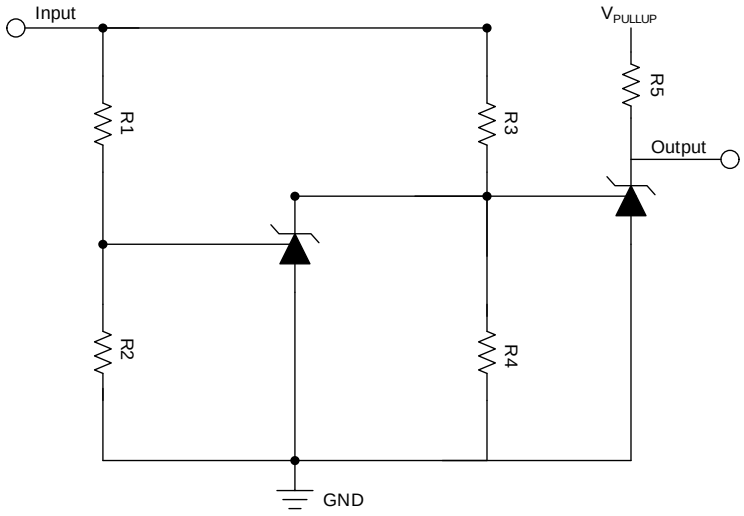

Figure 3. Window Comparator Application Schematic

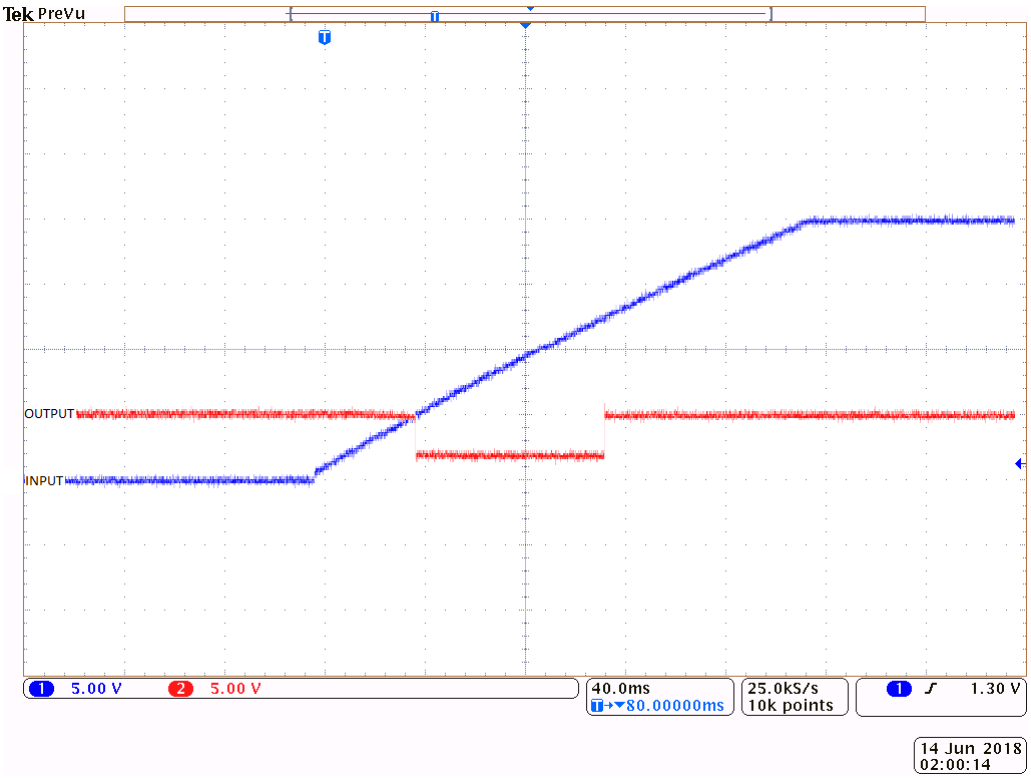

Figure 4. Window Comparator Output

For the window comparator application design, the engineer must use Equation 2 and Equation 3 to determine the upper and lower thresholds, respectively. As with the voltage comparator configuration, take care when designing this circuit to ensure the maximum current ratings for both the "REF" and "CATHODE" pins are not exceeded while ensuring minimum operating conditions.

4 Alternative Device Recommendations

There are important performance metrics to consider when choosing a shunt regulator for a comparator application. Two important parameters to consider are the bandgap reference voltage and the minimum cathode current. A lower bandgap reference voltage as seen in the TLV431, allows for a lower logic "low" output voltage without the need for external hardware. The lower cathode current of the ATL431 is designed for low power applications. Finally, the TL431 provides an effective, optimized solution, as well.

Table 1. Alternative Device Recommendations

Device	Bandgap Reference	Minimum Cathode Current	Price at 1ku
TL431	V_{ref} = 2.5 V	I_{min} = 0.4 mA	$0.07
TLV431	V_{ref} = 1.24 V	I_{min} = 55 µA	$0.21
ATL431	V_{ref} = 2.5 V	I_{min} = 20 µA	$0.16

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