Low Voltage Sensor with Optical Indicator

Harshitha Thimmapuram
Electrical Engineering Department
California Polytechnic State University, San Luis Obispo
San Luis Obispo, United States of America

***Abstract*— This experiment implemented a low-supply voltage sensor using a Zener reference, a linear voltage divider, and a comparator driving an LED indicator. The circuit activates an LED when the supply voltage falls below a designed threshold of approximately 8.0 V. A 4.3 V Zener diode with a 2.2 kΩ bias resistor was used to generate a stable reference voltage, while a 50 kΩ trimmer was adjusted to establish the desired divider ratio. Measurements showed that the comparator switched at approximately 7.3–7.4 V, slightly lower than the theoretical 8.0 V trip point. The results demonstrate stable Zener operation, predictable comparator behavior, and effective LED indication of undervoltage conditions.**

***Index Terms*—Low-supply voltage sensor, Zener diode, comparator, voltage divider, LED indicator.**

I. INTRODUCTION

A. Low-Supply Voltage Sensing

A low-supply voltage sensor is a circuit that identifies when the supply voltage drops below a defined threshold. In this experiment, a comparator was used to detect this condition by comparing the supply voltage V_{DD} to a fixed reference generated by a Zener diode. When V_{DD} is above the threshold, the comparator output remains high and the LED stays off. Once V_{DD} falls below this level, the comparator switches low and activates the LED to indicate the undervoltage condition. A schematic of the circuit is shown in Fig. 1.

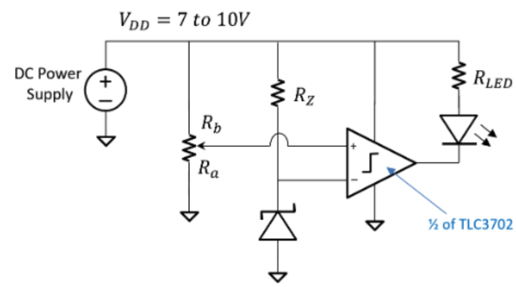

Fig. 1: Schematic of Low-Supply Voltage Sensor-Indicator Circuit

B. Optical Indicator

In this experiment, the Red Light Emitting Diode (WP7113ID) provides the undervoltage indication. When the supply falls below the comparator trip threshold, the comparator output drives the LED through a current-limiting resistor. Above the threshold, the LED remains off.

C. Comparator With Zener and Linear Dividers

The sensing circuit uses a Zener diode to generate a fixed 4.3 V reference and a linear voltage divider to produce a voltage proportional to V_{DD} The comparator evaluates these two voltages to determine whether the supply has fallen too low. When the divider output exceeds the Zener reference, the comparator output remains high and the LED is off; when the divider output drops below the reference, the comparator switches low and turns on the LED.

To set the desired trip point, a 50 kΩ multi-turn potentiometer was used for the divider. The potentiometer was adjusted so that the divider output matched the Zener reference when the supply was at the intended trip voltage of 8.0 V. Assuming the potentiometer resistance was exactly 50 kΩ, the effective values of the upper and lower resistances, R_a and R_b were calculated based on the condition that the divider output equals the Zener voltage at the switching point. Using the voltage-divider relationship, the divider output is given by expression 1.

$$V_+ = \frac{R_a}{R_a + R_b} V_{DD} \tag{1}$$

And setting $V_+ = V_z = 4.3$ V at $V_{DD} = 8$V gives

$$\frac{R_a}{R_a + R_b} = \frac{4.3}{8} = 0.5375$$

Since the potentiometer total resistance satisfies expression 2.

$$R_a + R_b = 50\ \text{k}\Omega \tag{2}$$

The effective resistance values become

$$R_a = 0.5375 \times 50\ \text{k}\Omega \approx 26.9\ \text{k}\Omega$$
$$R_b = 50\ \text{k}\Omega - 26.9\ \text{k}\Omega \approx 23.1\ \text{k}\Omega.$$

These calculated values were used to predict the theoretical trip voltage of the comparator, which was designed to be approximately 8.0 V. A schematic of the complete sensing circuit is shown in Fig. 1.

II. TEST RESULTS/DATA

The final network shown in Figure 1 was built in three separate stages (as seen in Figure 2, Figure 3, and Figure 4) to allow for verification at each step and data collection.

A. Zener-Based Voltage Limiter

The first network required the assembly of the zener-based voltage limiter with the power supply, as shown in Fig. 2. The step verified that the diode was biased correctly and that the voltage drop across the diode matched. The supply voltage was increased incrementally by 0.5V from 7V to 10V, with the voltage drop across the zener diode being measured at each V_{DD}. Table 1 summarizes the measured values.

TABLE I: Output Voltage of Zener Regulator vs. Supply Voltage

V_{DD}, V	7	7.5	8	8.5	9	9.5	10
V_z, V	3.425	3.477	3.523	3.57	3.608	3.65	3.682

The Zener voltage increased slightly as the supply voltage rose, confirming proper breakdown operation and providing a stable reference for the comparator threshold.

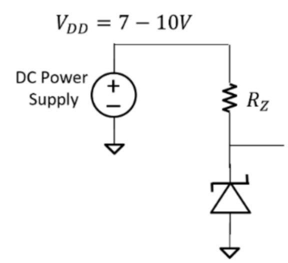

Fig. 2: Zener-Based Voltage Limiter

B. Voltage-difference generation and trimming

The second stage required adding the potentiometer to the Zener circuit from Fig. 2, forming the linear divider network shown in Fig. 3. After it is connected, the potentiometer must be adjusted in order to achieve near zero difference between the voltage produced by the two branches when the supply voltage is 8V. The near zero value is seen in the multimeter in Figure 4.

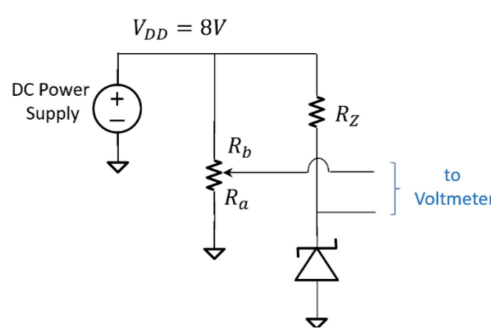

Fig. 3: Addition of Linear Voltage Divider

Fig. 4: Near Zero Voltage Difference

C. Comparator Assembly and Test

In this stage of the experiment, the TLC3702 voltage comparator was added to the circuit, with the non-inverting input connected to the linear voltage divider and the inverting input connected to the Zener-based reference, as shown in Fig. 5. To determine the comparator's trip point, the supply voltage was slowly varied from 7 V to 10 V while monitoring the comparator output. The specific value of V_{DD} at which the output transitioned was recorded, and the results are presented in Table II. A photo of the assembled comparator stage used during this measurement is shown in Fig. 6.

TABLE II: Comparator Trip Voltage Measurements

V_{DD}, V	7.0	7.2	7.3	7.5	7.8
Output V	0.000075 V	0.000071 V	7.3 V	7.5 V	7.8 V

The comparator output transitioned at approximately 7.3–7.4 V, which is slightly below the theoretical value of 8.0 V from Section I.

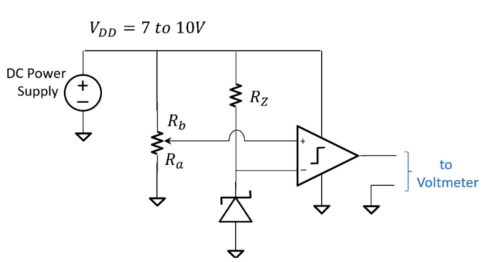

Fig. 5: Schematic with Comparator

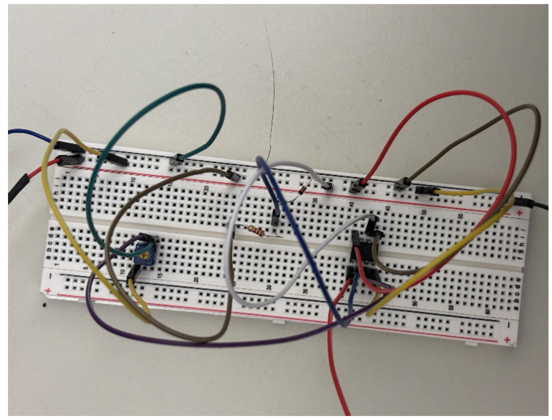

Fig. 6: Addition of Comparator on Breadboard

D. Adding the LED

Finally, the LED and a 1 kΩ series resistor were added to the comparator output as shown in Fig. 1. The LED remained off when V_{DD} was above the trip point and illuminated once the comparator switched low. (shown in Fig. 7. where the output of the comparator is at ground)

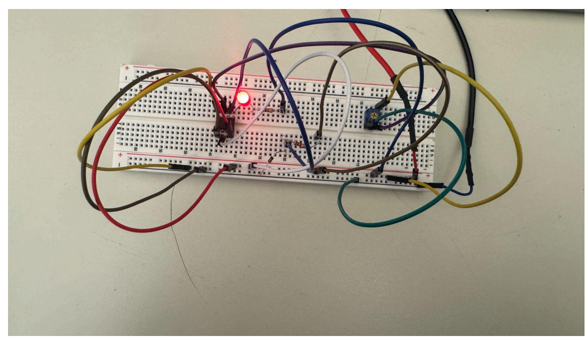

Fig. 7: LED ON with Comparator Output to GND

III. CONCLUSION

The purpose of this experiment was to design and evaluate a low-supply voltage sensor using a Zener reference, a linear divider, and a comparator driving an LED indicator. The circuit successfully detected when the supply voltage fell below a specified threshold and provided a clear visual indication through the LED. The Zener diode produced a stable reference voltage across the tested supply range, consistent with expected Zener breakdown characteristics, and the divider was adjusted so that its output matched the Zener voltage near the intended trip point.

The comparator transitioned at approximately 7.3–7.4 V, which is slightly below the theoretical trip voltage of 8.0 V derived in Section I. This deviation can be attributed to several factors, including tolerances in the Zener voltage, variations in the potentiometer's effective resistance, and the input offset voltage of the comparator. These sources of error are typical in circuits and lead to small differences between theoretical and measured behavior. Despite these effects, the measured trip point was close to the calculated value, indicating that the theoretical analysis accurately predicted the circuit's behavior.

When the LED was added to the comparator output, the indicator operated as expected: the LED remained off when the supply was above the trip point and illuminated once the supply voltage dropped below the threshold. This confirmed correct interaction between the comparator output stage and the LED load.

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