Evaluation Board for **ADCMP396 Quad Comparator**
with Accurate Reference Output

**FEATURES**
- Positive and negative voltage monitoring
- LED indicated voltage output status
- Test points for easy probing

**PACKAGE CONTENTS**
- EVAL-ADCMP396EBZ evaluation board

**EVALUATION BOARD DESCRIPTION**
The EVAL-ADCMP396EBZ features accurate positive and negative voltage monitoring with 0.9% accuracy. The evaluation board uses LEDs to indicate an overvoltage or undervoltage event in both positive and negative voltage being monitored.

**DEVICE DESCRIPTION**
The ADCMP396 is a quad rail-to-rail input low power comparator suitable for general-purpose applications. The ADCMP396 consumes only 41.61 µA of supply current making it ideal for battery-powered systems.

The ADCMP396 has a common-mode input range of 200 mV beyond rails, a typical offset voltage of 1 mV across the full common-mode range, and an undervoltage lockout (UVLO) monitor. In addition, the design of the comparator allows a defined output state upon power-up, it generates a logic low output while the supply is still below the UVLO threshold.

The ADCMP396 incorporates a 1 V ± 0.9% buffered reference voltage over line, load, and temperature.

![Evaluation Board Photograph](image)

*Figure 1.*
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## REVISION HISTORY

12/14—Revision 0: Initial Version
EVALUATION BOARD HARDWARE
POSITIVE AND NEGATIVE VOLTAGE MONITORING

When monitoring a positive supply, the desired nominal operating voltage for monitoring is denoted by \( V_{M+} \), \( I_M \) is the nominal current through the resistor divider, \( V_{OV} \) is the overvoltage trip point, and \( V_{UV} \) is the undervoltage trip point.

Figure 2 illustrates the positive voltage monitoring input connection. Three external resistors, \( R_1, R_2, \) and \( R_3 \), divide the positive voltage for monitoring, \( V_{M+} \), into high-side voltage, \( V_{PH} \), and low-side voltage, \( V_{PL} \).

\[
V_{PL} = V_{REF} = V_{OV+} \left( \frac{R_3}{R_1 + R_2 + R_3} \right)
\]

where \( R_1 + R_2 + R_3 = \frac{V_{M+}}{I_M} \).

Therefore, \( R_3 \), which sets the desired trip point for the over-voltage monitor, is calculated using Equation 2:

\[
R_3 = \frac{V_{REF} \left( V_{M+} \right)}{V_{OV+} \left( I_M \right)}
\]

To trigger the undervoltage condition, the high-side voltage, \( V_{PH} \), must be less than the \( V_{REF} \) threshold. The high-side voltage, \( V_{PH} \), is given by Equation 3:

\[
V_{PH} = V_{REF} = V_{UV-} \left( \frac{R_2 + R_3}{R_1 + R_2 + R_3} \right)
\]

Because \( R_3 \) is already known, \( R_2 \) can be expressed as follows:

\[
R_2 = \frac{V_{REF} \left( V_{M+} \right)}{V_{UV-} \left( I_M \right)} - R_3
\]

When \( R_2 \) and \( R_3 \) are known, \( R_1 \) is calculated using Equation 5:

\[
R_1 = \frac{V_{M+}}{I_M} - R_2 - R_3
\]

If \( V_{M+}, I_M, V_{OV+}, \) or \( V_{UV-} \) change, each step must be recalculated.

Figure 3 shows the circuit configuration for the negative supply voltage monitoring. To monitor a negative voltage, a reference voltage is required to connect to the end node of the voltage divider circuit, in this case \( \text{REF} \).

\[
V_{NH} = \text{GND} = \left( \frac{V_{REF} - V_{OV-}}{R_4 + R_5 + R_6} \right) + V_{UV-}
\]

where \( R_4 + R_5 + R_6 = \frac{V_{M-} - V_{REF}}{I_M} \).

Therefore, \( R_4 \), which sets the desired trip point for the over-voltage monitor, is calculated using Equation 7:

\[
R_4 = \frac{V_{REF} \left( V_{M-} - V_{REF} \right)}{V_{UV-} \left( I_M \right)} - \frac{V_{REF} - V_{REF}}{I_M}
\]

To trigger an undervoltage condition, the monitored voltage must be more positive than the nominal voltage, the high-side voltage (in this case, \( V_{NH} \)) must be more positive than ground. Equation 8 gives the low-side voltage, \( V_{NL} \):

\[
V_{NL} = \text{GND} = \left( \frac{V_{REF} - V_{UV-}}{R_5 + R_6} \right) + V_{UV-}
\]

Because \( R_4 \) is already known, \( R_5 \) can be expressed as follows:

\[
R_5 = \frac{V_{REF} \left( V_{M-} - V_{REF} \right)}{I_M \left( V_{REF} - V_{UV-} \right)} - R_4
\]

When \( R_4 \) and \( R_5 \) are known, \( R_6 \) is calculated using the following formula:

\[
R_6 = \frac{V_{M-} - V_{REF}}{I_M} - R_5 - R_6
\]
**POSITIVE AND NEGATIVE VOLTAGE MONITORING EXAMPLE**

The EVAL-ADCMP396EBZ is designed to monitor 3.3 V ± 10% both in positive and negative polarities.

The nominal voltage for the EVAL-ADCMP396EBZ is 3.3 V and the nominal current through the resistor divider is 5 µA for positive voltage monitoring and −5 µA for negative voltage monitoring.

For the positive voltage monitoring, threshold $V_{OV+}$ and $V_{UV+}$ are 3.63 V and 2.97 V, respectively. The $V_{REF}$ used is the 1 V reference of the ADCMP396. Use Equation 2 for $R_3$.

\[
R_3 = \frac{V_{REF}(V_{M+})}{V_{OV+}(I_{M+})}
\]

\[
R_3 = \frac{(1 \text{ V})(3.3 \text{ V})}{(3.63 \text{ V})(5 \mu\text{A})}
\]

$R_3 = 181.8 \text{ kΩ}$

Because $R_3$ is already known, compute for $R_2$ using Equation 4,

\[
R_2 = \frac{V_{REF}(V_{M+})}{V_{UV+}(I_{M+})} - R_3
\]

\[
R_2 = \frac{(1 \text{ V})(3.3 \text{ V})}{(2.97 \text{ V})(5 \mu\text{A})} - 181.8 \text{ kΩ}
\]

$R_2 = 40.4 \text{ kΩ}$

When both $R_2$ and $R_3$ are known, compute for $R_1$ using Equation 5,

\[
R_1 = \frac{V_{M+}}{I_{M+}} - R_2 - R_3
\]

\[
R_1 = \frac{3.3 \text{ V}}{5 \mu\text{A}} - 181.8 \text{ kΩ} - 40.4 \text{ kΩ}
\]

$R_1 = 437.78 \text{ kΩ}$

For the negative voltage monitoring, thresholds for $V_{OV-}$ and $V_{UV-}$ are −3.63 V and −2.97 V, respectively. Negative voltage monitoring also uses the 1 V reference of the ADCMP396 as $V_{REF}$. Compute for $R_4$ using Equation 7:

\[
R_4 = \frac{V_{REF}(V_{M-} - V_{REF})}{I_{M-}(V_{REF} - V_{OV-})}
\]

\[
R_4 = \frac{1 \text{ V}(−3.3 \text{ V}−1 \text{ V})}{−5 \mu\text{A}(1 \text{ V}+3.63 \text{ V})}
\]

$R_4 = 185.8 \text{ kΩ}$

Because $R_4$ is already known, compute for $R_5$ using Equation 9,

\[
R_5 = \frac{V_{REF}(V_{M-} - V_{REF})}{I_{M-}(V_{REF} - V_{UV-})} - R_4
\]

\[
R_5 = \frac{1 \text{ V}(−3.3 \text{ V}−1 \text{ V})}{−5 \mu\text{A}(1 \text{ V}+2.97 \text{ V})} - 185.8 \text{ kΩ}
\]

$R_5 = 30.9 \text{ kΩ}$

When both $R_4$ and $R_5$ are known, compute for $R_6$ using Equation 10,

\[
R_6 = \frac{(V_{M-} - V_{REF})}{I_{M-}} - R_5 - R_6
\]

\[
R_6 = \frac{−(3.3 \text{ V}−1 \text{ V})}{−5 \mu\text{A}} - 185.8 \text{ kΩ} - 30.9 \text{ kΩ}
\]

$R_6 = 643.3 \text{ kΩ}$

Calculated resistor values are replaced with the following standard values:

$R_1 = 432 \text{ kΩ}$

$R_2 = 40.2 \text{ kΩ}$

$R_3 = 180 \text{ kΩ}$

$R_4 = 184 \text{ kΩ}$

$R_5 = 29.4 \text{ kΩ}$

$R_6 = 634 \text{ kΩ}$

Because the resistor values were changed, the actual overvoltage and undervoltage trip points are changed. The actual $V_{OV}$ and $V_{UV}$ thresholds can be computed by the following formulas:

\[
RT_+ = R_1 + R_2 + R_3
\]

\[
RT_- = R_4 + R_5 + R_6
\]

\[
V_{OV+} = \frac{V_{REF}(R_{T+})}{R_3}
\]

\[
V_{UV+} = \frac{V_{REF}(R_{T+})}{(R_2 + R_3)}
\]

\[
V_{OV-} = \frac{−V_{REF}(R_5 + R_6)}{R_4}
\]

\[
V_{UV-} = \frac{−V_{REF}(R_6)}{R_4 + R_5}
\]

\[
V_{OV-} = −3.605 \text{ V}
\]

\[
V_{UV-} = −2.971 \text{ V}
\]

The demo board uses LEDs to indicate if an overvoltage or an undervoltage scenario happened. Table 1 the truth table of the demo board light indication.

**Table 1. Demo Board Light Indication Truth Table**

<table>
<thead>
<tr>
<th>Monitored Voltage</th>
<th>Fault</th>
<th>DS1</th>
<th>DS2</th>
<th>DS3</th>
<th>DS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{M+}$</td>
<td>$V_{OV}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{M-}$</td>
<td>$V_{OV}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{M+}$</td>
<td>$V_{UV}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{M-}$</td>
<td>$V_{UV}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When both $R_4$ and $R_5$ are known, compute for $R_6$ using Equation 10,
### SWITCH, JUMPER, LED, AND CONNECTOR FUNCTIONS

#### Table 2. Pin Header Functions

<table>
<thead>
<tr>
<th>Connector</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCC</td>
<td>Supply connector. Connect 2.3 V to 5.5 V.</td>
</tr>
<tr>
<td>EXT_VPULL</td>
<td>Input pin for the pull-up voltage.</td>
</tr>
<tr>
<td>EXT_VREF</td>
<td>Input pin for an external reference voltage.</td>
</tr>
<tr>
<td>VM+</td>
<td>Input pin for the positive voltage being monitored.</td>
</tr>
<tr>
<td>VM−</td>
<td>Input pin for the negative voltage being monitored.</td>
</tr>
<tr>
<td>OUTA</td>
<td>Output pin of Channel A.</td>
</tr>
<tr>
<td>OUTB</td>
<td>Output pin of Channel B.</td>
</tr>
<tr>
<td>OUTC</td>
<td>Output pin of Channel C.</td>
</tr>
<tr>
<td>OUTD</td>
<td>Output pin of Channel D.</td>
</tr>
</tbody>
</table>

#### Table 3. LED Functions

<table>
<thead>
<tr>
<th>LED</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS1</td>
<td>This LED used to indicate an undervoltage event in the positive voltage.</td>
</tr>
<tr>
<td>DS2</td>
<td>This LED used to indicate an overvoltage event in the positive voltage.</td>
</tr>
<tr>
<td>DS3</td>
<td>This LED used to indicate an overvoltage event in the negative voltage.</td>
</tr>
<tr>
<td>DS4</td>
<td>This LED used to indicate an undervoltage event in the negative voltage.</td>
</tr>
</tbody>
</table>

#### Table 4. Test Points

<table>
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<tr>
<th>Test Point</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPH</td>
<td>Positive high-side voltage.</td>
</tr>
<tr>
<td>VPL</td>
<td>Positive low-side voltage.</td>
</tr>
<tr>
<td>VNH</td>
<td>Negative high-side voltage.</td>
</tr>
<tr>
<td>VNL</td>
<td>Negative low-side voltage.</td>
</tr>
<tr>
<td>TP_REF</td>
<td>ADCMP396 reference test point.</td>
</tr>
<tr>
<td>TP_VREF</td>
<td>Reference voltage used for the resistor dividers.</td>
</tr>
<tr>
<td>TP_VPULL</td>
<td>External pull-up voltage.</td>
</tr>
<tr>
<td>TP_VCC</td>
<td>Supply voltage.</td>
</tr>
<tr>
<td>TP_VM+</td>
<td>Positive voltage.</td>
</tr>
<tr>
<td>TP_VM−</td>
<td>Negative voltage.</td>
</tr>
<tr>
<td>GND1</td>
<td>Ground.</td>
</tr>
<tr>
<td>GND2</td>
<td>Ground.</td>
</tr>
<tr>
<td>GND3</td>
<td>Ground.</td>
</tr>
<tr>
<td>GND4</td>
<td>Ground.</td>
</tr>
<tr>
<td>GND5</td>
<td>Ground.</td>
</tr>
<tr>
<td>GND6</td>
<td>Ground.</td>
</tr>
<tr>
<td>TP_OUTA</td>
<td>OUTA.</td>
</tr>
<tr>
<td>TP_OUTB</td>
<td>OUTB.</td>
</tr>
<tr>
<td>TP_OUTC</td>
<td>OUTC.</td>
</tr>
<tr>
<td>TP_OUTD</td>
<td>OUTD.</td>
</tr>
</tbody>
</table>
EVALUATION BOARD OVERVIEW

Figure 4. Evaluation Board Simplified Schematic
Figure 5. Evaluation Board Schematic
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