

## 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  $\mu\text{A}$  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  $\pm 0.9\%$  buffered reference voltage over line, load, and temperature.

### EVALUATION BOARD PHOTOGRAPH

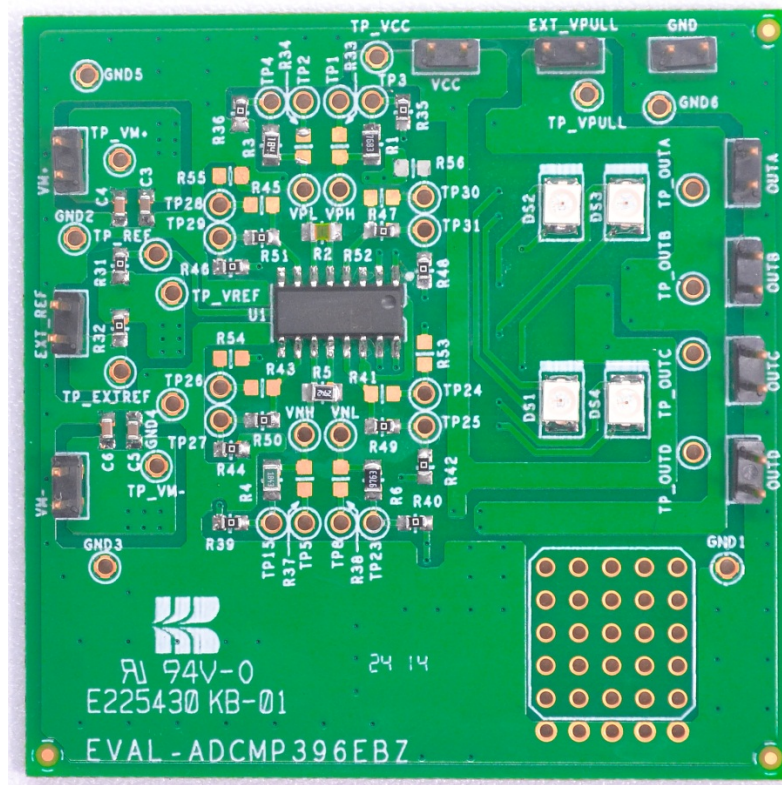


Figure 1.

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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, R1, R2, and R3, divide the positive voltage for monitoring,  $V_{M+}$ , into high-side voltage,  $V_{PH}$ , and low-side voltage,  $V_{PL}$ .

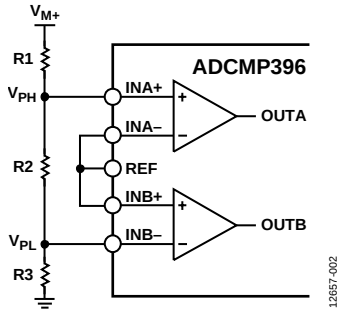


Figure 2. Positive Undervoltage/Overvoltage Monitoring Configuration

To trigger an overvoltage condition, the low-side voltage (in this case,  $V_{PL}$ ) must exceed the  $V_{REF}$  threshold. The low-side voltage,  $V_{PL}$ , is given by Equation 1:

$$V_{PL} = V_{REF} = V_{OV+} \left( \frac{R3}{R1 + R2 + R3} \right) \quad (1)$$

where  $R1 + R2 + R3 = \frac{V_{M+}}{I_{M+}}$

Therefore, R3, which sets the desired trip point for the over-voltage monitor, is calculated using Equation 2:

$$R3 = \frac{(V_{REF})(V_{M+})}{(V_{OV+})(I_{M+})} \quad (2)$$

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:

$$V_{PH} = V_{REF} = V_{UV+} \left( \frac{R2 + R3}{R1 + R2 + R3} \right) \quad (3)$$

Because R3 is already known, R2 can be expressed as follows:

$$R2 = \frac{(V_{REF})(V_{M+})}{(V_{UV+})(I_{M+})} - R3 \quad (4)$$

When R2 and R3 are known, R1 is calculated using Equation 5:

$$R1 = \frac{V_{M+}}{I_{M+}} - R2 - R3 \quad (5)$$

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 REF.

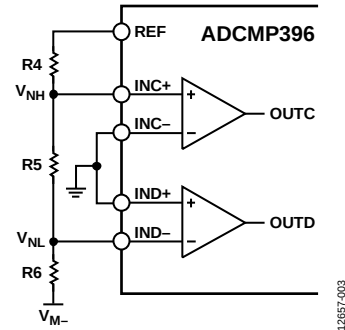


Figure 3. Negative Undervoltage/Overvoltage Monitoring Configuration

Equation 2, Equation 4, and Equation 5 need some minor modifications for use with negative voltage monitoring. The reference voltage,  $V_{REF}$ , is added to the overall voltage drop; it must therefore be subtracted from  $V_{M-}$ ,  $V_{UV-}$ , and  $V_{OV-}$  before using each in negative voltage monitoring.

Three external resistors, R4, R5, and R6, divide the positive voltage for monitoring,  $V_{M-}$ , into the high-side voltage,  $V_{NH}$ , and low-side voltage,  $V_{NL}$ .

To trigger an overvoltage condition, the monitored voltage must be more negative than the nominal voltage, the high-side voltage (in this case,  $V_{NH}$ ) must be more negative than ground. The high-side voltage,  $V_{NH}$ , is given by Equation 6:

$$V_{NH} = GND = \left[ (V_{REF} - V_{OV-}) \left( \frac{R5 + R6}{R4 + R5 + R6} \right) \right] + V_{OV-} \quad (6)$$

where  $R4 + R5 + R6 = \frac{(V_{M-} - V_{REF})}{I_{M-}}$

Therefore, R4, which sets the desired trip point for the over-voltage monitor, is calculated using Equation 7:

$$R4 = \frac{V_{REF}(V_{M-} - V_{REF})}{I_{M-}(V_{REF} - V_{OV-})} \quad (7)$$

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

$$V_{NL} = GND = \left[ (V_{REF} - V_{UV-}) \left( \frac{R6}{R4 + R5 + R6} \right) \right] + V_{UV-} \quad (8)$$

Because R4 is already known, R5 can be expressed as follows:

$$R5 = \frac{V_{REF}(V_{M-} - V_{REF})}{I_{M-}(V_{REF} - V_{UV-})} - R4 \quad (9)$$

When R4 and R5 are known, R6 is calculated using the following formula:

$$R6 = \frac{(V_{M-} - V_{REF})}{I_{M-}} - R5 - R4 \quad (10)$$

## POSITIVE AND NEGATIVE VOLTAGE MONITORING EXAMPLE

The EVAL-ADCMP396EBZ is designed to monitor  $3.3 \text{ V} \pm 10\%$  both in positive and negative polarities.

The nominal voltage for the EVAL-ADCMP396EBZ is  $3.3 \text{ V}$  and the nominal current through the resistor divider is  $5 \mu\text{A}$  for positive voltage monitoring and  $-5 \mu\text{A}$  for negative voltage monitoring.

For the positive voltage monitoring, threshold  $V_{OV+}$  and  $V_{UV+}$  are  $3.63 \text{ V}$  and  $2.97 \text{ V}$ , respectively. The  $V_{REF}$  used is the  $1 \text{ V}$  reference of the ADCMP396. Use Equation 2 for  $R3$ .

$$R3 = \frac{(V_{REF})(V_{M+})}{(V_{OV+})(I_{M+})}$$

$$R3 = \frac{(1 \text{ V})(3.3 \text{ V})}{(3.63 \text{ V})(5 \mu\text{A})}$$

$$R3 = 181.8 \text{ k}\Omega$$

Because  $R3$  is already known, compute for  $R2$  using Equation 4,

$$R2 = \frac{(V_{REF})(V_{M+})}{(V_{UV+})(I_{M+})} - R3$$

$$R2 = \frac{(1 \text{ V})(3.3 \text{ V})}{(2.97 \text{ V})(5 \mu\text{A})} - 181.8 \text{ k}\Omega$$

$$R2 = 40.4 \text{ k}\Omega$$

When both  $R2$  and  $R3$  are known, compute for  $R1$  using Equation 5,

$$R1 = \frac{V_{M+}}{I_{M+}} - R2 - R3$$

$$R1 = \frac{3.3 \text{ V}}{5 \mu\text{A}} - 181.8 \text{ k}\Omega - 40.4 \text{ k}\Omega$$

$$R1 = 437.78 \text{ k}\Omega$$

For the negative voltage monitoring, thresholds for  $V_{OV-}$  and  $V_{UV-}$  are  $-3.63 \text{ V}$  and  $-2.97 \text{ V}$ , respectively. Negative voltage monitoring also uses the  $1 \text{ V}$  reference of the ADCMP396 as  $V_{REF}$ . Compute for  $R4$  using Equation 7:

$$R4 = \frac{V_{REF}(V_{M-} - V_{REF})}{I_{M-}(V_{REF} - V_{OV-})}$$

$$R4 = \frac{1 \text{ V}(-3.3 \text{ V} - 1 \text{ V})}{-5 \mu\text{A}(1 \text{ V} + 3.63 \text{ V})}$$

$$R4 = 185.8 \text{ k}\Omega$$

Because  $R4$  is already known, compute for  $R5$  using Equation 9,

$$R5 = \frac{V_{REF}(V_{M-} - V_{REF})}{I_{M-}(V_{REF} - V_{UV-})} - R4$$

$$R5 = \frac{1 \text{ V}(-3.3 \text{ V} - 1 \text{ V})}{-5 \mu\text{A}(1 \text{ V} + 2.97 \text{ V})} - 185.8 \text{ k}\Omega$$

$$R5 = 30.9 \text{ k}\Omega$$

When both  $R4$  and  $R5$  are known, compute for  $R6$  using Equation 10,

$$R6 = \frac{(V_{M-} - V_{REF})}{I_{M-}} - R5 - R4$$

$$R6 = \frac{(-3.3 \text{ V} - 1 \text{ V})}{-5 \mu\text{A}} - 185.8 \text{ k}\Omega - 30.9 \text{ k}\Omega$$

$$R6 = 643.3 \text{ k}\Omega$$

Calculated resistor values are replaced with the following standard values:

$$R1 = 432 \text{ k}\Omega$$

$$R2 = 40.2 \text{ k}\Omega$$

$$R3 = 180 \text{ k}\Omega$$

$$R4 = 184 \text{ k}\Omega$$

$$R5 = 29.4 \text{ k}\Omega$$

$$R6 = 634 \text{ k}\Omega$$

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:

$$R_{T+} = R1 + R2 + R3 \quad (11)$$

$$R_{T-} = R4 + R5 + R6 \quad (12)$$

$$V_{OV+} = \frac{V_{REF}(R_{T+})}{R3} \quad (13)$$

$$V_{OV+} = 3.623 \text{ V}$$

$$V_{UV+} = \frac{V_{REF}(R_{T+})}{(R2 + R3)} \quad (14)$$

$$V_{UV+} = 2.962 \text{ V}$$

$$V_{OV-} = \frac{-V_{REF}(R5 + R6)}{R4} \quad (15)$$

$$V_{OV-} = -3.605 \text{ V}$$

$$V_{UV-} = \frac{-V_{REF}(R6)}{R4 + R5} \quad (16)$$

$$V_{UV-} = -2.971 \text{ V}$$

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**

| Monitored Voltage | Fault    | DS1 | DS2 | DS3 | DS4 |
|-------------------|----------|-----|-----|-----|-----|
| $V_{M+}$          | $V_{OV}$ |     |     |     |     |
|                   | $V_{UV}$ |     |     |     |     |
| $V_{M-}$          | $V_{OV}$ |     |     |     |     |
|                   | $V_{UV}$ |     |     |     |     |

**SWITCH, JUMPER, LED, AND CONNECTOR FUNCTIONS****Table 2. Pin Header Functions**

| Connector       | Description                                         |
|-----------------|-----------------------------------------------------|
| V <sub>CC</sub> | Supply connector. Connect 2.3 V to 5.5 V.           |
| EXT_VPULL       | Input pin for the pull-up voltage.                  |
| EXT_VREF        | Input pin for an external reference voltage.        |
| VM+             | Input pin for the positive voltage being monitored. |
| VM–             | Input pin for the negative voltage being monitored. |
| OUTA            | Output pin of Channel A.                            |
| OUTB            | Output pin of Channel B.                            |
| OUTC            | Output pin of Channel C.                            |
| OUTD            | Output pin of Channel D.                            |

**Table 3. LED Functions**

| LED | Description                                                              |
|-----|--------------------------------------------------------------------------|
| DS1 | This LED used to indicate an undervoltage event in the positive voltage. |
| DS2 | This LED used to indicate an overvoltage event in the positive voltage.  |
| DS3 | This LED used to indicate an overvoltage event in the negative voltage.  |
| DS4 | This LED used to indicate an undervoltage event in the negative voltage. |

**Table 4. Test Points**

| Test Point | Description                                       |
|------------|---------------------------------------------------|
| VPH        | Positive high-side voltage.                       |
| VPL        | Positive low-side voltage.                        |
| VNH        | Negative high-side voltage.                       |
| VNL        | Negative low-side voltage.                        |
| TP_REF     | <a href="#">ADCMP396</a> reference test point.    |
| TP_VREF    | Reference voltage used for the resistor dividers. |
| TP_VPULL   | External pull-up voltage.                         |
| TP_VCC     | Supply voltage.                                   |
| TP_VM+     | Positive voltage.                                 |
| TP_VM–     | Negative voltage.                                 |
| GND1       | Ground.                                           |
| GND2       | Ground.                                           |
| GND3       | Ground.                                           |
| GND4       | Ground.                                           |
| GND5       | Ground.                                           |
| GND6       | Ground.                                           |
| TP_OUTA    | OUTA.                                             |
| TP_OUTB    | OUTB.                                             |
| TP_OUTC    | OUTC.                                             |
| TP_OUTD    | OUTD.                                             |

## EVALUATION BOARD OVERVIEW

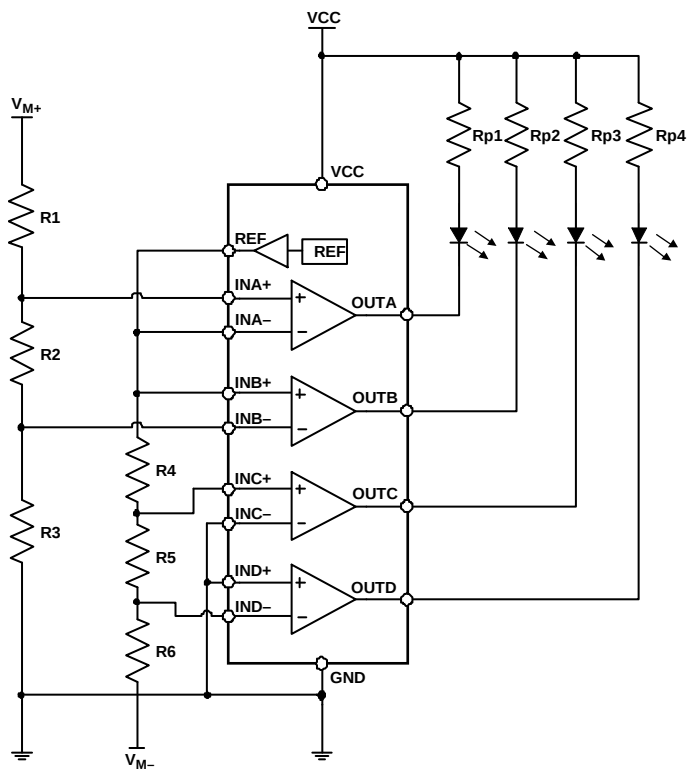


Figure 4. Evaluation Board Simplified Schematic

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## EVALUATION BOARD SCHEMATIC AND ARTWORK

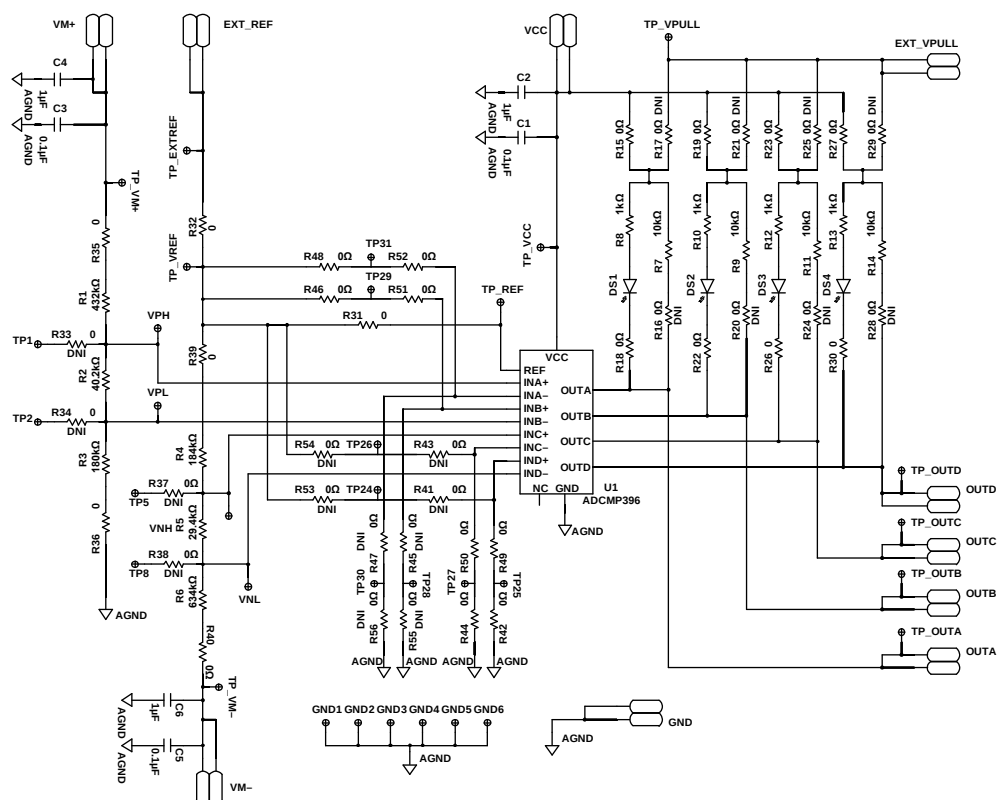
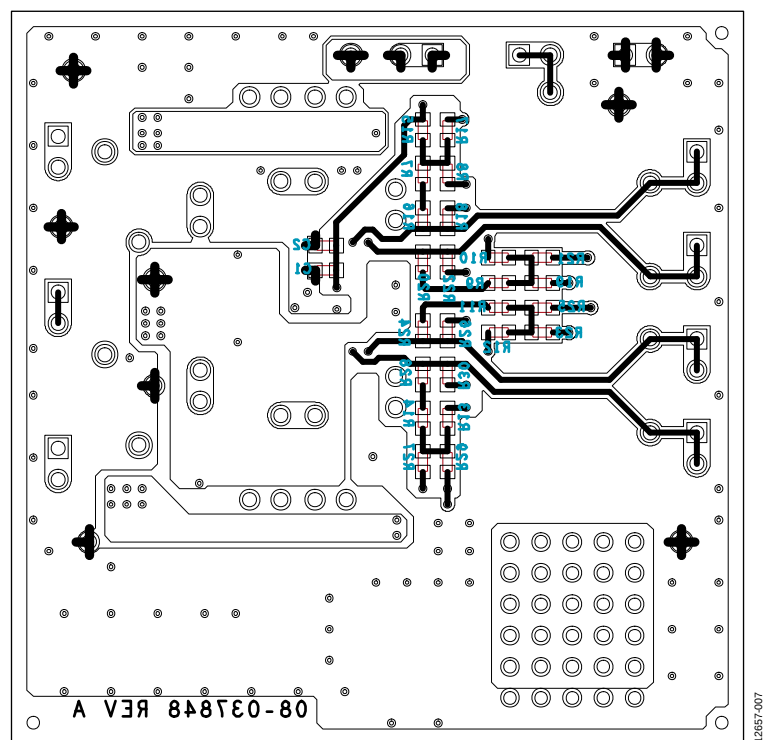
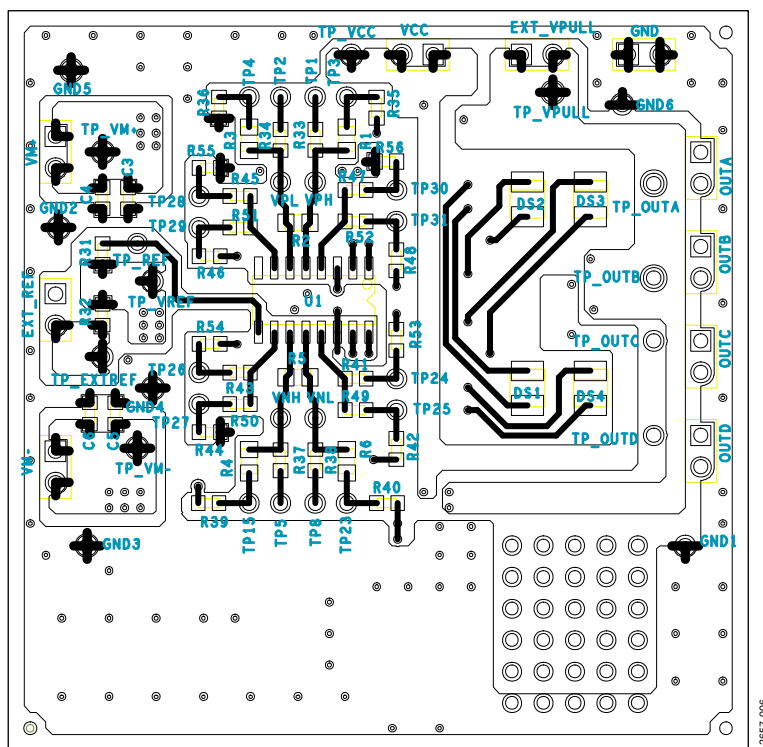


Figure 5. Evaluation Board Schematic



## ORDERING INFORMATION

### BILL OF MATERIALS

Table 5.

| Reference Designator                                                                          | Part Description                               | Part Number                 |
|-----------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------|
| U1                                                                                            | Quad comparator with accurate reference output | <a href="#">ADCMP396ARZ</a> |
| C1, C3, C5                                                                                    | Capacitor, 0.1 $\mu$ F, 0603, 10%, 100 V       | GCM188R72A104KA64D          |
| C2, C4, C6                                                                                    | Capacitor, 1 $\mu$ F, 0603, 10%, 100 V         | GRM188R71A105KA61D          |
| DS1 to DS4                                                                                    | LED, red                                       | VLMS30J1L2-GS08             |
| R1                                                                                            | Resistor, 432 k $\Omega$ , 0805                | ERA-6AEB4323V               |
| R2                                                                                            | Resistor, 40.2 k $\Omega$ , 0805               | PAT0805E4022BST1            |
| R3                                                                                            | Resistor, 180 k $\Omega$ , 0805                | RC0805JR-07180KL            |
| R4                                                                                            | Resistor, 184 k $\Omega$ , 0805                | PAT0805E1843BST1            |
| R5                                                                                            | Resistor, 29.4 k $\Omega$ , 0805               | ERJ-6ENF2942                |
| R6                                                                                            | Resistor, 634 k $\Omega$ , 0805                | ERA-6AEB6343V               |
| R7, R9, R11, R14                                                                              | Resistor, 10 k $\Omega$ , 0603                 | ERA-3YEB103V                |
| R8, R10, R12, R13                                                                             | Resistor, 1 k $\Omega$ , 0603                  | ERJ-3EKF1001V               |
| R15, R18, R19, R22, R23, R26, R27, R30, R31,<br>R35, R36, R39, R40, R42, R44, R46, R48 to R52 | Resistor, 0 $\Omega$ , 0603                    | ERJ-3GEY0R00V               |



#### ESD Caution

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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