FEATURES

Initial accuracy
A grade: ±0.70% (maximum)
B grade: ±0.35% (maximum)

Maximum temperature coefficient
A grade: 50 ppm/°C
B grade: 25 ppm/°C

CLOAD = 0.1 μF to 1 μF

Output current: +4 mA/−2 mA
Low operating current: 80 μA (typical)
Output noise: 6 μV p-p at 1.0 V output
Input range: 2.0 V to 18 V
Temperature range: −40°C to +125°C
Tiny, Pb-free TSOT package

APPLICATIONS

Battery-powered instrumentation
Portable medical equipment
Communication infrastructure equipment

GENERAL DESCRIPTION

The ADR130 is the first family of tiny, micropower, low voltage, high precision voltage references in the industry. Featuring 0.35% initial accuracy and 25 ppm/°C of temperature drift in the tiny TSOT-23 package, the ADR130 voltage reference only requires 80 μA for typical operation. The ADR130 design includes a proprietary temperature drift curvature correction technique that minimizes the nonlinearities in the output voltage vs. temperature characteristics.

Available in the industrial temperature range of −40°C to +125°C, the ADR130 is housed in a tiny TSOT package.

For 0.5 V output, tie SET (Pin 5) to VOUT (Pin 4). For 1.0 V output, tie SET (Pin 5) to GND (Pin 2).
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REVISION HISTORY

8/2018—Rev. C to Rev. D
  Change to General Description Section ............................................. 1
  Change to Specified Temperature Range Parameter, Table 3 ..... 5
  Added Junction Temperature Range Parameter, Table 3 ........... 5
  Changes to Ordering Guide ............................................................. 15

  Changes to Figure 34 and Figure 35 ................................................. 13

  Change to CLOAD in Features Section ............................................. 1
  Changed 10 μF to 1 μF in Output Capacitor Section .................. 12
  Deleted Negative Precision Reference Without Precision
  Resistors Section ............................................................................. 14

9/2011—Rev. 0 to Rev. A
  Changes to Lead Temperature (Soldering, 60 sec) Parameter,
  Table 3 ............................................................................................ 5

10/2006—Revision 0: Initial Version
### SPECIFICATIONS

#### ELECTRICAL CHARACTERISTICS

$T_A = 25°C$, $V_{IN} = 2.0$ V to 18 V, unless otherwise noted. SET (Pin 5) tied to $V_{OUT}$ (Pin 4).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUTPUT VOLTAGE</td>
<td>$V_O$</td>
<td></td>
<td>0.49650</td>
<td>0.5</td>
<td>0.50350</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.49825</td>
<td>0.5</td>
<td>0.50175</td>
<td>V</td>
</tr>
<tr>
<td>INITIAL ACCURACY ERROR</td>
<td>$V_{OERR}$</td>
<td></td>
<td>$-3.50$</td>
<td>+3.50</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$-1.75$</td>
<td>+1.75</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>TEMPERATURE COEFFICIENT</td>
<td>$TC_{V_O}$</td>
<td>$-40°C &lt; T_A &lt; +125°C$</td>
<td>15</td>
<td>50</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ppm/°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOAD REGULATION</td>
<td></td>
<td>$-40°C &lt; T_A &lt; +125°C; 3$ V $\leq V_{IN} \leq 18$ V; $0$ mA $&lt; I_{OUT} &lt; 4$ mA</td>
<td>$-0.13$</td>
<td>+0.13</td>
<td>mV/mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-40°C &lt; T_A &lt; +125°C; 3$ V $\leq V_{IN} \leq 18$ V; $-2$ mA $&lt; I_{OUT} &lt; 0$ mA</td>
<td>$-1.0$</td>
<td>+1.0</td>
<td>mV/mA</td>
<td></td>
</tr>
<tr>
<td>LINE REGULATION</td>
<td></td>
<td>2.0 V to 18 V, $I_{OUT} = 0$ mA</td>
<td>$-40$</td>
<td>+10</td>
<td>+40</td>
<td>ppm/V</td>
</tr>
<tr>
<td>QUIESCENT CURRENT</td>
<td>$I_Q$</td>
<td>$-40°C &lt; T_A &lt; +125°C$, no load</td>
<td>75</td>
<td>150</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>SHORT-CIRCUIT CURRENT TO GROUND</td>
<td></td>
<td>$V_{IN} = 2.0$ V</td>
<td>15</td>
<td></td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = 18.0$ V</td>
<td>50</td>
<td></td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>VOLTAGE NOISE</td>
<td></td>
<td>0.1 Hz to 10 Hz</td>
<td>3</td>
<td></td>
<td>μV p-p</td>
<td></td>
</tr>
<tr>
<td>TURN-ON SETTLING TIME</td>
<td></td>
<td>To 0.1%, $C_{LOAD} = 0.1$ μF</td>
<td>80</td>
<td></td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>LONG-TERM STABILITY</td>
<td></td>
<td>1000 hours at 25°C</td>
<td>100</td>
<td></td>
<td>ppm/1000 hours</td>
<td></td>
</tr>
<tr>
<td>OUTPUT VOLTAGE HYSTERESIS</td>
<td></td>
<td></td>
<td>150</td>
<td></td>
<td></td>
<td>ppm</td>
</tr>
</tbody>
</table>
TA = 25°C, VIN = 2.0 V to 18 V, unless otherwise noted. SET (Pin 5) tied to GND (Pin 2).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUTPUT VOLTAGE</td>
<td>VO</td>
<td></td>
<td>0.9930</td>
<td>1.0</td>
<td>1.0070</td>
<td>V</td>
</tr>
<tr>
<td>A Grade</td>
<td></td>
<td></td>
<td>0.9965</td>
<td>1.0</td>
<td>1.0035</td>
<td>V</td>
</tr>
<tr>
<td>B Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INITIAL ACCURACY ERROR</td>
<td>VOERR</td>
<td>−40°C &lt; TA &lt; +125°C</td>
<td>−7.0</td>
<td>+7.0</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>A Grade</td>
<td></td>
<td></td>
<td>−3.5</td>
<td>+3.5</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>B Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEMPERATURE COEFFICIENT</td>
<td>TCVo</td>
<td>−40°C &lt; TA &lt; +125°C</td>
<td></td>
<td></td>
<td></td>
<td>ppm/°C</td>
</tr>
<tr>
<td>A Grade</td>
<td></td>
<td></td>
<td>15</td>
<td>50</td>
<td></td>
<td>ppm/°C</td>
</tr>
<tr>
<td>B Grade</td>
<td></td>
<td></td>
<td>5</td>
<td>25</td>
<td></td>
<td>ppm/°C</td>
</tr>
<tr>
<td>LOAD REGULATION</td>
<td></td>
<td>−40°C &lt; TA &lt; +125°C; 3 V ≤ VIN ≤ 18 V;</td>
<td>−0.25</td>
<td>+0.25</td>
<td></td>
<td>mV/mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 mA &lt; IOUT &lt; 4 mA</td>
<td>−2.0</td>
<td>+2.0</td>
<td></td>
<td>mV/mA</td>
</tr>
<tr>
<td>LINE REGULATION</td>
<td></td>
<td>2.0 V to 18 V, IOUT = 0 mA</td>
<td>−40</td>
<td>+10</td>
<td>+40</td>
<td>ppm/V</td>
</tr>
<tr>
<td>QUIESCENT CURRENT</td>
<td>IQ</td>
<td>−40°C &lt; TA &lt; +125°C; no load</td>
<td>85</td>
<td>150</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>SHORT-CIRCUIT CURRENT TO GROUND</td>
<td></td>
<td>VIN = 2.0 V</td>
<td>15</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VIN = 18.0 V</td>
<td>50</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>VOLTAGE NOISE</td>
<td></td>
<td>0.1 Hz to 10 Hz</td>
<td>6</td>
<td></td>
<td></td>
<td>µV p-p</td>
</tr>
<tr>
<td>TURN-ON SETTLING TIME</td>
<td></td>
<td>To 0.1%, CLOAD = 0.1 µF</td>
<td>80</td>
<td></td>
<td></td>
<td>µs</td>
</tr>
<tr>
<td>LONG-TERM STABILITY</td>
<td></td>
<td>1000 hours at 25°C</td>
<td>100</td>
<td></td>
<td></td>
<td>ppm/1000 hours</td>
</tr>
<tr>
<td>OUTPUT VOLTAGE HYSTERESIS</td>
<td></td>
<td></td>
<td>150</td>
<td></td>
<td></td>
<td>ppm</td>
</tr>
</tbody>
</table>
ABSOLUTE MAXIMUM RATINGS

Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN to GND</td>
<td>20 V</td>
</tr>
<tr>
<td>Internal Power Dissipation</td>
<td>40 mW</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>−65°C to +150°C</td>
</tr>
<tr>
<td>Specified Temperature Range</td>
<td>−40°C to +125°C</td>
</tr>
<tr>
<td>Junction Temperature Range</td>
<td>−65°C to +150°C</td>
</tr>
<tr>
<td>Lead Temperature (Soldering, 60 sec)</td>
<td>300°C</td>
</tr>
</tbody>
</table>

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

THERMAL RESISTANCE

θJA is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

Table 4. Thermal Resistance

<table>
<thead>
<tr>
<th>Package Type</th>
<th>θJA</th>
<th>θJC</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-Lead TSOT (UJ-6)</td>
<td>186</td>
<td>67</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

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.
TYPICAL PERFORMANCE CHARACTERISTICS

Figure 2. $V_{OUT}$ vs. Temperature, $V_{OUT} = 0.5$ V

Figure 3. Temperature Coefficient, $V_{OUT} = 0.5$ V

Figure 4. Minimum Input Voltage vs. Load Current, $V_{OUT} = 0.5$ V

Figure 5. $V_{OUT}$ vs. Temperature, $V_{OUT} = 1$ V

Figure 6. Temperature Coefficient, $V_{OUT} = 1$ V

Figure 7. Minimum Input Voltage vs. Load Current, $V_{OUT} = 1$ V
Figure 8. Supply Current vs. Input Voltage, $V_{OUT} = 0.5\ V$

Figure 11. Supply Current vs. Input Voltage, $V_{OUT} = 1\ V$

Figure 9. Supply Current vs. Load Current, $V_{OUT} = 0.5\ V$

Figure 12. Supply Current vs. Load Current, $V_{OUT} = 1\ V$

Figure 10. Line Regulation vs. Temperature, $V_{OUT} = 0.5\ V$

Figure 13. Line Regulation vs. Temperature, $V_{OUT} = 1\ V$
Figure 14. Load Regulation (Source) vs. Temperature, $V_{OUT} = 0.5\, V$

Figure 17. Load Regulation (Source) vs. Temperature, $V_{OUT} = 1\, V$

Figure 15. Load Regulation (Sink) vs. Temperature, $V_{OUT} = 0.5\, V$

Figure 18. Load Regulation (Sink) vs. Temperature, $V_{OUT} = 1\, V$

Figure 16. 0.1 Hz to 10 Hz Noise, $V_{OUT} = 0.5\, V$

Figure 19. 0.1 Hz to 10 Hz Noise, $V_{OUT} = 1\, V$
CIN = COUT = 0.1µF

Figure 20. 10 Hz to 10 kHz Noise, VOUT = 0.5 V

Figure 23. 10 Hz to 10 kHz Noise, VOUT = 1 V

Figure 21. Turn-On Response, VOUT = 0.5 V

Figure 24. Turn-On Response, VOUT = 1 V

Figure 22. Turn-Off Response, VOUT = 0.5 V

Figure 25. Turn-Off Response, VOUT = 1 V
**TERMINOLOGY**

**Temperature Coefficient**
Temperature coefficient is the change of output voltage with respect to the operating temperature change normalized by the output voltage at 25°C. This parameter is expressed in ppm/°C and is determined by

\[
TCV_o[\text{ppm/°C}] = \frac{V_o(T_2) - V_o(T_1)}{V_o(25°C) \times (T_2 - T_1)} \times 10^6
\]

where:
- \( V_o(25°C) = V_o \) at 25°C.
- \( V_o(T_1) = V_o \) at Temperature 1.
- \( V_o(T_2) = V_o \) at Temperature 2.

**Line Regulation**
Line regulation is the change in the output due to a specified change in input voltage. This parameter accounts for the effects of self-heating. Line regulation is expressed in either %/V, ppm/V, or µV/ΔVIN.

**Load Regulation**
Load regulation is the change in output voltage due to a specified change in load current. This parameter accounts for the effects of self-heating. Load regulation is expressed in either mV/mA, ppm/mA, or dc output resistance (Ω).

**Long-Term Stability**
Long-term stability is the typical shift of output voltage at 25°C on a sample of parts subjected to a test of 1000 hours at 25°C.

\[
\Delta V_o = V_o(t_0) - V_o(t_1)
\]

\[
\Delta V_o[\text{ppm}] = \frac{V_o(t_0) - V_o(t_1)}{V_o(t_0)} \times 10^6
\]

where:
- \( V_o(t_0) = V_o \) at 25°C at Time 0.
- \( V_o(t_1) = V_o \) at 25°C after 1000 hours operating at 25°C.

**Thermal Hysteresis**
Thermal hysteresis is the change of output voltage after the device is cycled through temperatures from +25°C to −40°C to +125°C, then back to +25°C. This is a typical value from a sample of parts put through such a cycle.

where:
- \( V_o(25°C) = V_o \) at 25°C.
- \( V_{OTC} = V_o \) at 25°C after temperature cycle from +25°C to −40°C to +125°C, then back to +25°C.
THEORY OF OPERATION
The ADR130 sub-band gap reference is the high performance solution for low supply voltage and low power applications. The uniqueness of this product lies in its architecture.

POWER DISSIPATION CONSIDERATIONS
The ADR130 is capable of delivering load currents to 4 mA with an input range from 3.0 V to 18 V. When this device is used in applications with large input voltages, care must be taken to avoid exceeding the specified maximum power dissipation or junction temperature, because this results in premature device failure.

Use the following formula to calculate the maximum junction temperature or dissipation:

\[ P_D = \frac{T_J - T_A}{\theta_{JA}} \]

where:
- \( T_J \) is the junction temperature.
- \( T_A \) is the ambient temperature.
- \( P_D \) is the device power dissipation.
- \( \theta_{JA} \) is the device package thermal resistance.

INPUT CAPACITOR
Input capacitors are not required on the ADR130. There is no limit for the value of the capacitor used on the input, but a 1 µF to 10 µF capacitor on the input improves transient response in applications where there is a sudden supply change. An additional 0.1 µF capacitor in parallel also helps reduce noise from the supply.

OUTPUT CAPACITOR
The ADR130 requires a small 0.1 µF output capacitor for stability. Additional 0.1 µF to 1 µF capacitance in parallel can improve load transient response. This acts as a source of stored energy for a sudden increase in load current. The only parameter that is affected by the additional capacitance is turn-on time.
APPLICATION NOTES

BASIC VOLTAGE REFERENCE CONNECTION

The circuits in Figure 32 and Figure 33 illustrate the basic configuration for the ADR130 voltage reference.

![Figure 32. Basic Configuration, V_out = 0.5 V](image)

![Figure 33. Basic Configuration, V_out = 1 V](image)

STACKING REFERENCE ICs FOR ARBITRARY OUTPUTS

Some applications may require two reference voltage sources that are a combined sum of the standard outputs. Figure 34 and Figure 35 show how these stacked output references can be implemented.

![Figure 34. Stacking References with ADR130, V_out1 = 1.0 V, V_out2 = 2.0 V](image)

![Figure 35. Stacking References with ADR130, V_out1 = 0.5 V, V_out2 = 1.5 V](image)

Two reference ICs are used and fed from an unregulated input, V_IN. The outputs of the individual ICs that are connected in series provide two output voltages, V_OUT1 and V_OUT2. V_OUT1 is the terminal voltage of U1, and V_OUT2 is the sum of this voltage and the terminal voltage of U2. U1 and U2 are chosen for the two voltages that supply the required outputs (see Table 5). For example, if U1 is set to have an output of 1 V or 0.5 V, the user can stack on top of U2 to get an output of 2 V or 1.5 V.

Table 5. Required Outputs

<table>
<thead>
<tr>
<th>U1/U2</th>
<th>Comments</th>
<th>V_OUT1</th>
<th>V_OUT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADR130/ADR130</td>
<td>See Figure 34</td>
<td>1 V</td>
<td>2 V</td>
</tr>
<tr>
<td>ADR130/ADR130</td>
<td>See Figure 35</td>
<td>0.5 V</td>
<td>1.5 V</td>
</tr>
</tbody>
</table>
PRECISION CURRENT SOURCE

In low power applications, the need can arise for a precision current source that can operate on low supply voltages. The ADR130 can be configured as a precision current source (see Figure 36). The circuit configuration shown is a floating current source with a grounded load. The reference output voltage is bootstrapped across RSET, which sets the output current into the load. With this configuration, circuit precision is maintained for load currents ranging from the reference supply current, typically 85 µA, to approximately 4 mA.

Figure 36. ADR130 as a Precision Current Source
OUTLINE DIMENSIONS

Figure 37. 6-Lead Thin Small Outline Transistor Package (TSOT) (UJ-6)
Dimensions shown in millimeters

ORDERING GUIDE

<table>
<thead>
<tr>
<th>Model</th>
<th>Temperature Coefficient (ppm/°C)</th>
<th>Temperature Range</th>
<th>Package Description</th>
<th>Package Option</th>
<th>Marking Code</th>
<th>Ordering Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADR130AUJZ-REEL7</td>
<td>50</td>
<td>−40°C to +125°C</td>
<td>6-Lead TSOT</td>
<td>UJ-6</td>
<td>R0W</td>
<td>3,000</td>
</tr>
<tr>
<td>ADR130BUDJZ-REEL7</td>
<td>25</td>
<td>−40°C to +125°C</td>
<td>6-Lead TSOT</td>
<td>UJ-6</td>
<td>R0X</td>
<td>3,000</td>
</tr>
</tbody>
</table>

1 Z = RoHS Compliant Part.