

## TABLE OF CONTENTS

|                                           |   |
|-------------------------------------------|---|
| Features .....                            | 1 |
| Applications .....                        | 1 |
| Pin Configurations .....                  | 1 |
| General Description .....                 | 1 |
| Revision History .....                    | 2 |
| Specifications.....                       | 3 |
| ADR440 Electrical Characteristics.....    | 3 |
| ADR441 Electrical Characteristics.....    | 4 |
| ADR443 Electrical Characteristics.....    | 5 |
| ADR444 Electrical Characteristics.....    | 6 |
| ADR445 Electrical Characteristics.....    | 7 |
| Absolute Maximum Ratings.....             | 8 |
| Thermal Resistance .....                  | 8 |
| ESD Caution.....                          | 8 |
| Typical Performance Characteristics ..... | 9 |

## REVISION HISTORY

### 9/2016—Rev. E to Rev. F

|                           |    |
|---------------------------|----|
| Changes to Figure 38..... | 16 |
|---------------------------|----|

### 11/2010—Rev. D to Rev. E

|                                                  |    |
|--------------------------------------------------|----|
| Deleted Negative Reference Section.....          | 15 |
| Deleted Figure 37; Renumbered Sequentially ..... | 15 |

### 3/2010—Rev. C to Rev. D

|                                  |    |
|----------------------------------|----|
| Changes to Figure 37 .....       | 15 |
| Updated Outline Dimensions ..... | 18 |

### 3/2008—Rev. B to Rev. C

|                                  |    |
|----------------------------------|----|
| Changes to Table 8.....          | 8  |
| Change to Figure 11 .....        | 10 |
| Changes to Figure 36.....        | 15 |
| Changes to Figure 39.....        | 16 |
| Changes to Figure 41.....        | 17 |
| Updated Outline Dimensions ..... | 18 |

### 8/2007—Rev. A to Rev. B

|                                                               |   |
|---------------------------------------------------------------|---|
| Change to Table 2, Ripple Rejection Ratio Specification ..... | 3 |
| Change to Table 3, Ripple Rejection Ratio Specification ..... | 4 |
| Change to Table 4, Ripple Rejection Ratio Specification ..... | 5 |
| Change to Table 5, Ripple Rejection Ratio Specification ..... | 6 |
| Change to Table 6, Ripple Rejection Ratio Specification ..... | 7 |

|                                                     |    |
|-----------------------------------------------------|----|
| Theory of Operation .....                           | 14 |
| Power Dissipation Considerations.....               | 14 |
| Basic Voltage Reference Connections .....           | 14 |
| Noise Performance .....                             | 14 |
| Turn-On Time .....                                  | 14 |
| Applications Information .....                      | 15 |
| Output Adjustment .....                             | 15 |
| Bipolar Outputs .....                               | 15 |
| Programmable Voltage Source .....                   | 15 |
| Programmable Current Source .....                   | 16 |
| High Voltage Floating Current Source .....          | 16 |
| Precision Output Regulator (Boosted Reference)..... | 16 |
| Outline Dimensions .....                            | 17 |
| Ordering Guide .....                                | 18 |

### 9/2006—Rev. 0 to Rev. A

|                                                           |           |
|-----------------------------------------------------------|-----------|
| Updated Format.....                                       | Universal |
| Changes to Features .....                                 | 1         |
| Changes to Pin Configurations .....                       | 1         |
| Changes to Specifications Section.....                    | 3         |
| Changes to Figure 4 and Figure 5.....                     | 9         |
| Inserted Figure 6 and Figure 7.....                       | 9         |
| Changes to Figure 15.....                                 | 11        |
| Changes to Power Dissipation Considerations Section ..... | 14        |
| Changes to Figure 35 and Figure 36.....                   | 15        |
| Changes to Figure 38 and Table 9.....                     | 16        |
| Updated Outline Dimensions.....                           | 18        |
| Changes to Ordering Guide .....                           | 19        |

### 10/2005—Revision 0: Initial Version

## SPECIFICATIONS

## ADR440 ELECTRICAL CHARACTERISTICS

$V_{IN} = 3\text{ V to }18\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $C_{IN} = C_{OUT} = 0.1\text{ }\mu\text{F}$ , unless otherwise noted.

Table 2.

| Parameter                        | Symbol                       | Conditions                                                                                                             | Min   | Typ   | Max   | Unit                   |
|----------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|------------------------|
| OUTPUT VOLTAGE                   | $V_O$                        |                                                                                                                        |       |       |       |                        |
| A Grade                          |                              |                                                                                                                        | 2.045 | 2.048 | 2.051 | V                      |
| B Grade                          |                              |                                                                                                                        | 2.047 | 2.048 | 2.049 | V                      |
| INITIAL ACCURACY                 | $V_{OERR}$                   |                                                                                                                        |       |       |       |                        |
| A Grade                          |                              |                                                                                                                        |       |       | 3     | mV                     |
|                                  |                              |                                                                                                                        |       |       | 0.15  | %                      |
| B Grade                          |                              |                                                                                                                        |       |       | 1     | mV                     |
|                                  |                              |                                                                                                                        |       |       | 0.05  | %                      |
| TEMPERATURE DRIFT                | $TCV_O$                      |                                                                                                                        |       |       |       |                        |
| A Grade                          |                              | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                         |       | 2     | 10    | ppm/ $^\circ\text{C}$  |
| B Grade                          |                              | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                         |       | 1     | 3     | ppm/ $^\circ\text{C}$  |
| LINE REGULATION                  | $\Delta V_O/\Delta V_{IN}$   | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                         | -20   | +10   | +20   | ppm/V                  |
| LOAD REGULATION                  | $\Delta V_O/\Delta I_{LOAD}$ | $I_{LOAD} = 0\text{ mA to }10\text{ mA}$ , $V_{IN} = 3.5\text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50   |       | +50   | ppm/mA                 |
|                                  | $\Delta V_O/\Delta I_{LOAD}$ | $I_{LOAD} = 0\text{ mA to }-5\text{ mA}$ , $V_{IN} = 3.5\text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50   |       | +50   | ppm/mA                 |
| QUIESCENT CURRENT                | $I_{IN}$                     | No load, $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                |       | 3     | 3.75  | mA                     |
| VOLTAGE NOISE                    | $e_N\text{ p-p}$             | 0.1 Hz to 10 Hz                                                                                                        |       | 1     |       | $\mu\text{V p-p}$      |
| VOLTAGE NOISE DENSITY            | $e_N$                        | 1 kHz                                                                                                                  |       | 45    |       | nV/ $\sqrt{\text{Hz}}$ |
| TURN-ON SETTLING TIME            | $t_R$                        |                                                                                                                        |       | 10    |       | $\mu\text{s}$          |
| LONG-TERM STABILITY <sup>1</sup> | $V_O$                        | 1000 hours                                                                                                             |       | 50    |       | ppm                    |
| OUTPUT VOLTAGE HYSTERESIS        | $V_{O\_HYS}$                 |                                                                                                                        |       | 70    |       | ppm                    |
| RIPPLE REJECTION RATIO           | RRR                          | $f_{IN} = 1\text{ kHz}$                                                                                                |       | -80   |       | dB                     |
| SHORT CIRCUIT TO GND             | $I_{SC}$                     |                                                                                                                        |       | 27    |       | mA                     |
| SUPPLY VOLTAGE OPERATING RANGE   | $V_{IN}$                     |                                                                                                                        | 3     |       | 18    | V                      |
| SUPPLY VOLTAGE HEADROOM          | $V_{IN} - V_O$               |                                                                                                                        | 500   |       |       | mV                     |

<sup>1</sup> The long-term stability specification is noncumulative. The drift in the subsequent 1000-hour period is significantly lower than in the first 1000-hour period.

# ADR441 ELECTRICAL CHARACTERISTICS

$V_{IN} = 3\text{ V to }18\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $C_{IN} = C_{OUT} = 0.1\text{ }\mu\text{F}$ , unless otherwise noted.

Table 3.

| Parameter                        | Symbol                       | Conditions                                                                                                           | Min   | Typ   | Max   | Unit                   |
|----------------------------------|------------------------------|----------------------------------------------------------------------------------------------------------------------|-------|-------|-------|------------------------|
| OUTPUT VOLTAGE                   | $V_O$                        |                                                                                                                      |       |       |       |                        |
| A Grade                          |                              |                                                                                                                      | 2.497 | 2.500 | 2.503 | V                      |
| B Grade                          |                              |                                                                                                                      | 2.499 | 2.500 | 2.501 | V                      |
| INITIAL ACCURACY                 | $V_{OERR}$                   |                                                                                                                      |       |       |       |                        |
| A Grade                          |                              |                                                                                                                      |       |       | 3     | mV                     |
|                                  |                              |                                                                                                                      |       |       | 0.12  | %                      |
| B Grade                          |                              |                                                                                                                      |       |       | 1     | mV                     |
|                                  |                              |                                                                                                                      |       |       | 0.04  | %                      |
| TEMPERATURE DRIFT                | $TCV_O$                      |                                                                                                                      |       |       |       |                        |
| A Grade                          |                              | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                       |       | 2     | 10    | ppm/ $^\circ\text{C}$  |
| B Grade                          |                              | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                       |       | 1     | 3     | ppm/ $^\circ\text{C}$  |
| LINE REGULATION                  | $\Delta V_O/\Delta V_{IN}$   | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                       |       | 10    | 20    | ppm/V                  |
| LOAD REGULATION                  | $\Delta V_O/\Delta I_{LOAD}$ | $I_{LOAD} = 0\text{ mA to }10\text{ mA}$ , $V_{IN} = 4\text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50   |       | +50   | ppm/mA                 |
|                                  | $\Delta V_O/\Delta I_{LOAD}$ | $I_{LOAD} = 0\text{ mA to }-5\text{ mA}$ , $V_{IN} = 4\text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50   |       | +50   | ppm/mA                 |
| QUIESCENT CURRENT                | $I_{IN}$                     | No load, $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                              |       | 3     | 3.75  | mA                     |
| VOLTAGE NOISE                    | $e_N\text{ p-p}$             | 0.1 Hz to 10 Hz                                                                                                      |       | 1.2   |       | $\mu\text{V p-p}$      |
| VOLTAGE NOISE DENSITY            | $e_N$                        | 1 kHz                                                                                                                |       | 48    |       | nV/ $\sqrt{\text{Hz}}$ |
| TURN-ON SETTLING TIME            | $t_R$                        |                                                                                                                      |       | 10    |       | $\mu\text{s}$          |
| LONG-TERM STABILITY <sup>1</sup> | $V_O$                        | 1000 hours                                                                                                           |       | 50    |       | ppm                    |
| OUTPUT VOLTAGE HYSTERESIS        | $V_{O\_HYS}$                 |                                                                                                                      |       | 70    |       | ppm                    |
| RIPPLE REJECTION RATIO           | RRR                          | $f_{IN} = 1\text{ kHz}$                                                                                              |       | -80   |       | dB                     |
| SHORT CIRCUIT TO GND             | $I_{SC}$                     |                                                                                                                      |       | 27    |       | mA                     |
| SUPPLY VOLTAGE OPERATING RANGE   | $V_{IN}$                     |                                                                                                                      | 3     |       | 18    | V                      |
| SUPPLY VOLTAGE HEADROOM          | $V_{IN} - V_O$               |                                                                                                                      | 500   |       |       | mV                     |

<sup>1</sup> The long-term stability specification is noncumulative. The drift in subsequent 1000-hour period is significantly lower than in the first 1000-hour period.

**ADR443 ELECTRICAL CHARACTERISTICS**

$V_{IN} = 3.5 \text{ V to } 18 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $C_{IN} = C_{OUT} = 0.1 \mu\text{F}$ , unless otherwise noted.

**Table 4.**

| Parameter                        | Symbol                         | Conditions                                                                                                               | Min    | Typ   | Max    | Unit                   |
|----------------------------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------|--------|-------|--------|------------------------|
| OUTPUT VOLTAGE                   | $V_O$                          |                                                                                                                          |        |       |        |                        |
| A Grade                          |                                |                                                                                                                          | 2.996  | 3.000 | 3.004  | V                      |
| B Grade                          |                                |                                                                                                                          | 2.9988 | 3.000 | 3.0012 | V                      |
| INITIAL ACCURACY                 | $V_{OERR}$                     |                                                                                                                          |        |       |        |                        |
| A Grade                          |                                |                                                                                                                          |        |       | 4      | mV                     |
|                                  |                                |                                                                                                                          |        |       | 0.13   | %                      |
| B Grade                          |                                |                                                                                                                          |        |       | 1.2    | mV                     |
|                                  |                                |                                                                                                                          |        |       | 0.04   | %                      |
| TEMPERATURE DRIFT                | $TCV_O$                        |                                                                                                                          |        |       |        |                        |
| A Grade                          |                                | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                           |        | 2     | 10     | ppm/ $^\circ\text{C}$  |
| B Grade                          |                                | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                           |        | 1     | 3      | ppm/ $^\circ\text{C}$  |
| LINE REGULATION                  | $\Delta V_O / \Delta V_{IN}$   | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                           |        | 10    | 20     | ppm/V                  |
| LOAD REGULATION                  | $\Delta V_O / \Delta I_{LOAD}$ | $I_{LOAD} = 0 \text{ mA to } 10 \text{ mA}$ , $V_{IN} = 5 \text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50    |       | +50    | ppm/mA                 |
|                                  | $\Delta V_O / \Delta I_{LOAD}$ | $I_{LOAD} = 0 \text{ mA to } -5 \text{ mA}$ , $V_{IN} = 5 \text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50    |       | +50    | ppm/mA                 |
| QUIESCENT CURRENT                | $I_{IN}$                       | No load, $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                  |        | 3     | 3.75   | mA                     |
| VOLTAGE NOISE                    | $e_N \text{ p-p}$              | 0.1 Hz to 10 Hz                                                                                                          |        | 1.4   |        | $\mu\text{V p-p}$      |
| VOLTAGE NOISE DENSITY            | $e_N$                          | 1 kHz                                                                                                                    |        | 57.6  |        | nV/ $\sqrt{\text{Hz}}$ |
| TURN-ON SETTLING TIME            | $t_R$                          |                                                                                                                          |        | 10    |        | $\mu\text{s}$          |
| LONG-TERM STABILITY <sup>1</sup> | $V_O$                          | 1000 hours                                                                                                               |        | 50    |        | ppm                    |
| OUTPUT VOLTAGE HYSTERESIS        | $V_{O\_HYS}$                   |                                                                                                                          |        | 70    |        | ppm                    |
| RIPPLE REJECTION RATIO           | RRR                            | $f_{IN} = 1 \text{ kHz}$                                                                                                 |        | -80   |        | dB                     |
| SHORT CIRCUIT TO GND             | $I_{SC}$                       |                                                                                                                          |        | 27    |        | mA                     |
| SUPPLY VOLTAGE OPERATING RANGE   | $V_{IN}$                       |                                                                                                                          | 3.5    |       | 18     | V                      |
| SUPPLY VOLTAGE HEADROOM          | $V_{IN} - V_O$                 |                                                                                                                          | 500    |       |        | mV                     |

<sup>1</sup> The long-term stability specification is noncumulative. The drift in the subsequent 1000-hour period is significantly lower than in the first 1000-hour period.

**ADR444 ELECTRICAL CHARACTERISTICS**

$V_{IN} = 4.6 \text{ V to } 18 \text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $C_{IN} = C_{OUT} = 0.1 \mu\text{F}$ , unless otherwise noted.

Table 5.

| Parameter                        | Symbol                         | Conditions                                                                                                                 | Min    | Typ   | Max    | Unit                   |
|----------------------------------|--------------------------------|----------------------------------------------------------------------------------------------------------------------------|--------|-------|--------|------------------------|
| OUTPUT VOLTAGE                   | $V_O$                          |                                                                                                                            |        |       |        |                        |
| A Grade                          |                                |                                                                                                                            | 4.091  | 4.096 | 4.101  | V                      |
| B Grade                          |                                |                                                                                                                            | 4.0944 | 4.096 | 4.0976 | V                      |
| INITIAL ACCURACY                 | $V_{OERR}$                     |                                                                                                                            |        |       |        |                        |
| A Grade                          |                                |                                                                                                                            |        |       | 5      | mV                     |
|                                  |                                |                                                                                                                            |        |       | 0.13   | %                      |
| B Grade                          |                                |                                                                                                                            |        |       | 1.6    | mV                     |
|                                  |                                |                                                                                                                            |        |       | 0.04   | %                      |
| TEMPERATURE DRIFT                | $TCV_O$                        |                                                                                                                            |        |       |        |                        |
| A Grade                          |                                | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                             |        | 2     | 10     | ppm/ $^\circ\text{C}$  |
| B Grade                          |                                | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                             |        | 1     | 3      | ppm/ $^\circ\text{C}$  |
| LINE REGULATION                  | $\Delta V_O / \Delta V_{IN}$   | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                             |        | 10    | 20     | ppm/V                  |
| LOAD REGULATION                  | $\Delta V_O / \Delta I_{LOAD}$ | $I_{LOAD} = 0 \text{ mA to } 10 \text{ mA}$ , $V_{IN} = 5.5 \text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50    |       | +50    | ppm/mA                 |
|                                  | $\Delta V_O / \Delta I_{LOAD}$ | $I_{LOAD} = 0 \text{ mA to } -5 \text{ mA}$ , $V_{IN} = 5.5 \text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50    |       | +50    | ppm/mA                 |
| QUIESCENT CURRENT                | $I_{IN}$                       | No load, $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                    |        | 3     | 3.75   | mA                     |
| VOLTAGE NOISE                    | $e_N \text{ p-p}$              | 0.1 Hz to 10 Hz                                                                                                            |        | 1.8   |        | $\mu\text{V p-p}$      |
| VOLTAGE NOISE DENSITY            | $e_N$                          | 1 kHz                                                                                                                      |        | 78.6  |        | nV/ $\sqrt{\text{Hz}}$ |
| TURN-ON SETTLING TIME            | $t_R$                          |                                                                                                                            |        | 10    |        | $\mu\text{s}$          |
| LONG-TERM STABILITY <sup>1</sup> | $V_O$                          | 1000 hours                                                                                                                 |        | 50    |        | ppm                    |
| OUTPUT VOLTAGE HYSTERESIS        | $V_{O\_HYS}$                   |                                                                                                                            |        | 70    |        | ppm                    |
| RIPPLE REJECTION RATIO           | RRR                            | $f_{IN} = 1 \text{ kHz}$                                                                                                   |        | -80   |        | dB                     |
| SHORT CIRCUIT TO GND             | $I_{SC}$                       |                                                                                                                            |        | 27    |        | mA                     |
| SUPPLY VOLTAGE OPERATING RANGE   | $V_{IN}$                       |                                                                                                                            | 4.6    |       | 18     | V                      |
| SUPPLY VOLTAGE HEADROOM          | $V_{IN} - V_O$                 |                                                                                                                            | 500    |       |        | mV                     |

<sup>1</sup> The long-term stability specification is noncumulative. The drift in the subsequent 1000-hour period is significantly lower than in the first 1000-hour period.

**ADR445 ELECTRICAL CHARACTERISTICS**

$V_{IN} = 5.5\text{ V to }18\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $C_{IN} = C_{OUT} = 0.1\text{ }\mu\text{F}$ , unless otherwise noted.

**Table 6.**

| Parameter                        | Symbol                       | Conditions                                                                                                             | Min   | Typ   | Max   | Unit                   |
|----------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|------------------------|
| OUTPUT VOLTAGE                   | $V_O$                        |                                                                                                                        |       |       |       |                        |
| A Grade                          |                              |                                                                                                                        | 4.994 | 5.000 | 5.006 | V                      |
| B Grade                          |                              |                                                                                                                        | 4.998 | 5.000 | 5.002 | V                      |
| INITIAL ACCURACY                 | $V_{OERR}$                   |                                                                                                                        |       |       |       |                        |
| A Grade                          |                              |                                                                                                                        |       |       | 6     | mV                     |
|                                  |                              |                                                                                                                        |       |       | 0.12  | %                      |
| B Grade                          |                              |                                                                                                                        |       |       | 2     | mV                     |
|                                  |                              |                                                                                                                        |       |       | 0.04  | %                      |
| TEMPERATURE DRIFT                | $TCV_O$                      |                                                                                                                        |       |       |       |                        |
| A Grade                          |                              | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                         |       | 2     | 10    | ppm/ $^\circ\text{C}$  |
| B Grade                          |                              | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                         |       | 1     | 3     | ppm/ $^\circ\text{C}$  |
| LINE REGULATION                  | $\Delta V_O/\Delta V_{IN}$   | $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                         |       | 10    | 20    | ppm/V                  |
| LOAD REGULATION                  | $\Delta V_O/\Delta I_{LOAD}$ | $I_{LOAD} = 0\text{ mA to }10\text{ mA}$ , $V_{IN} = 6.5\text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50   |       | +50   | ppm/mA                 |
|                                  | $\Delta V_O/\Delta I_{LOAD}$ | $I_{LOAD} = 0\text{ mA to }-5\text{ mA}$ , $V_{IN} = 6.5\text{ V}$ ,<br>$-40^\circ\text{C} < T_A < +125^\circ\text{C}$ | -50   |       | +50   | ppm/mA                 |
| QUIESCENT CURRENT                | $I_{IN}$                     | No load, $-40^\circ\text{C} < T_A < +125^\circ\text{C}$                                                                |       | 3     | 3.75  | mA                     |
| VOLTAGE NOISE                    | $e_N\text{ p-p}$             | 0.1 Hz to 10 Hz                                                                                                        |       | 2.25  |       | $\mu\text{V p-p}$      |
| VOLTAGE NOISE DENSITY            | $e_N$                        | 1 kHz                                                                                                                  |       | 90    |       | nV/ $\sqrt{\text{Hz}}$ |
| TURN-ON SETTLING TIME            | $t_R$                        |                                                                                                                        |       | 10    |       | $\mu\text{s}$          |
| LONG-TERM STABILITY <sup>1</sup> | $V_O$                        | 1000 hours                                                                                                             |       | 50    |       | ppm                    |
| OUTPUT VOLTAGE HYSTERESIS        | $V_{O\_HYS}$                 |                                                                                                                        |       | 70    |       | ppm                    |
| RIPPLE REJECTION RATIO           | RRR                          | $f_{IN} = 1\text{ kHz}$                                                                                                |       | -80   |       | dB                     |
| SHORT CIRCUIT TO GND             | $I_{SC}$                     |                                                                                                                        |       | 27    |       | mA                     |
| SUPPLY VOLTAGE OPERATING RANGE   | $V_{IN}$                     |                                                                                                                        | 5.5   |       | 18    | V                      |
| SUPPLY VOLTAGE HEADROOM          | $V_{IN} - V_O$               |                                                                                                                        | 500   |       |       | mV                     |

<sup>1</sup> The long-term stability specification is noncumulative. The drift in the subsequent 1000-hour period is significantly lower than in the first 1000-hour period.

## ABSOLUTE MAXIMUM RATINGS

$T_A = 25^\circ\text{C}$ , unless otherwise noted.

Table 7.

| Parameter                            | Rating                                      |
|--------------------------------------|---------------------------------------------|
| Supply Voltage                       | 20 V                                        |
| Output Short-Circuit Duration to GND | Indefinite                                  |
| Storage Temperature Range            | $-65^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Operating Temperature Range          | $-40^\circ\text{C}$ to $+125^\circ\text{C}$ |
| Junction Temperature Range           | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temperature, Soldering (60 sec) | $300^\circ\text{C}$                         |

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

$\theta_{JA}$  is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages.

Table 8. Thermal Resistance

| Package Type            | $\theta_{JA}$ | $\theta_{JC}$ | Unit                      |
|-------------------------|---------------|---------------|---------------------------|
| 8-Lead SOIC (R-Suffix)  | 130           | 43            | $^\circ\text{C}/\text{W}$ |
| 8-Lead MSOP (RM-Suffix) | 132.5         | 43.9          | $^\circ\text{C}/\text{W}$ |

## 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

$V_{IN} = 7\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $C_{IN} = C_{OUT} = 0.1\text{ }\mu\text{F}$ , unless otherwise noted.

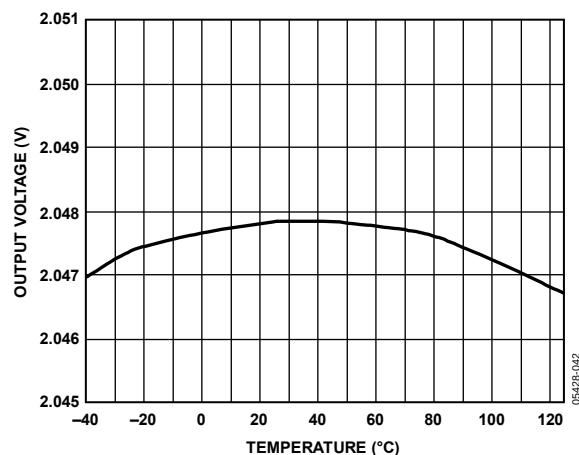


Figure 3. ADR440 Output Voltage vs. Temperature

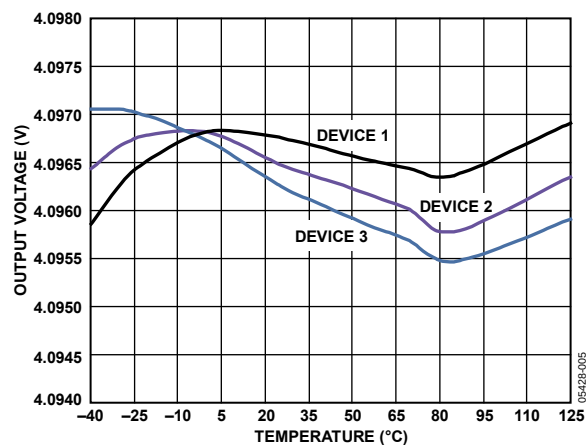


Figure 6. ADR444 Output Voltage vs. Temperature

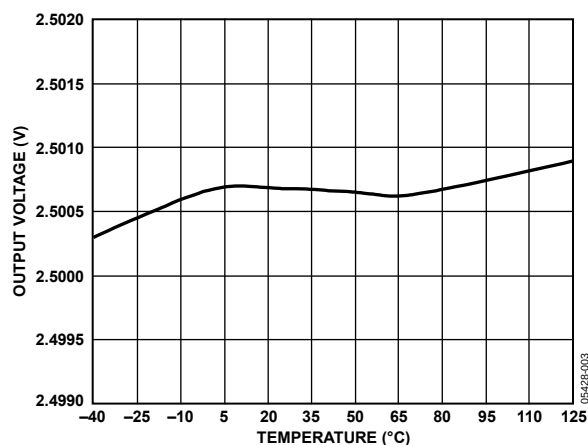


Figure 4. ADR441 Output Voltage vs. Temperature

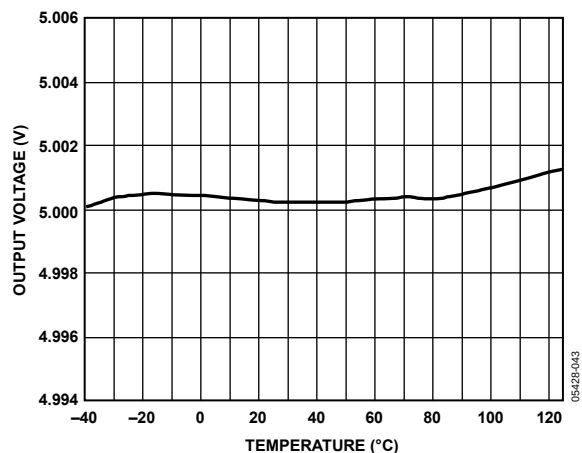


Figure 7. ADR445 Output Voltage vs. Temperature

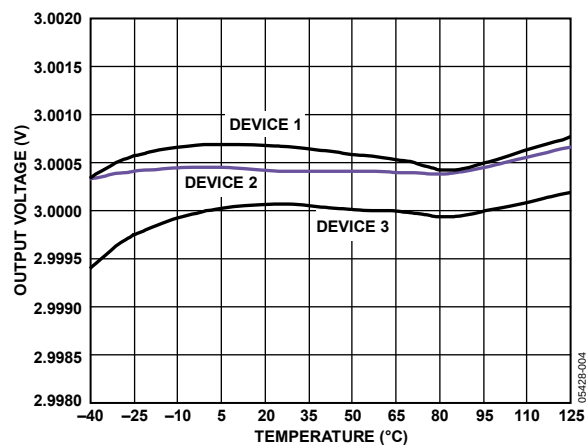


Figure 5. ADR443 Output Voltage vs. Temperature

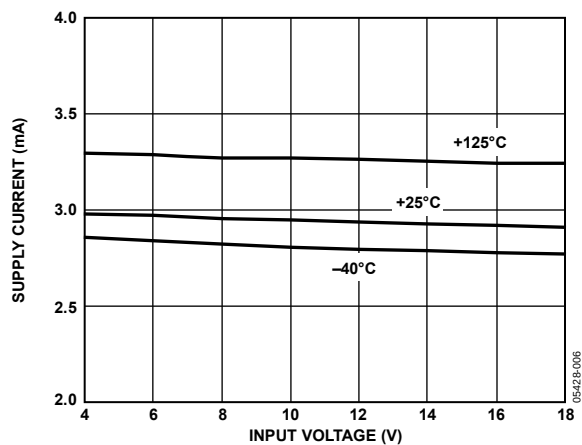


Figure 8. ADR441 Supply Current vs. Input Voltage

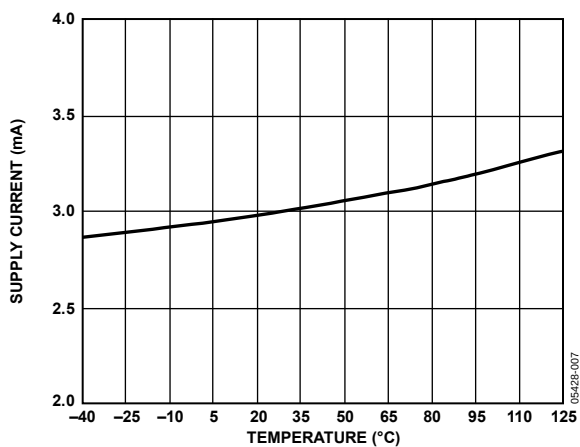


Figure 9. ADR441 Supply Current vs. Temperature

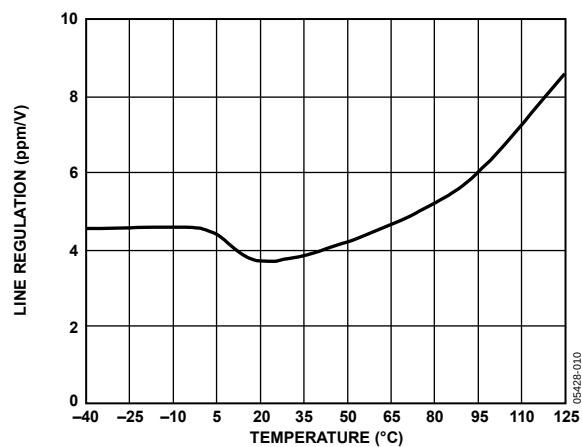


Figure 12. ADR441 Line Regulation vs. Temperature

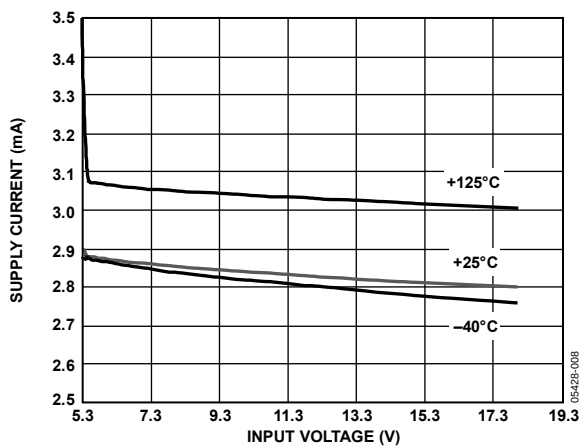


Figure 10. ADR445 Supply Current vs. Input Voltage

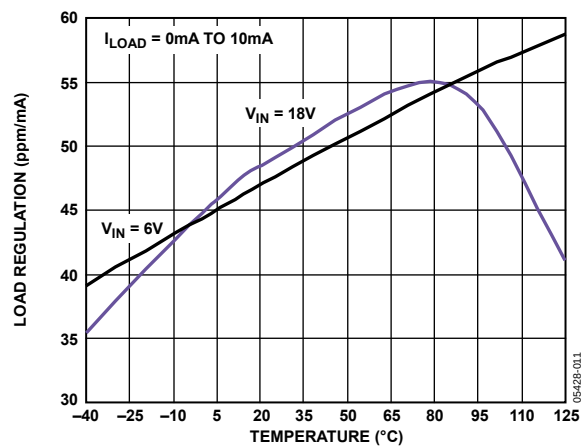


Figure 13. ADR441 Load Regulation vs. Temperature

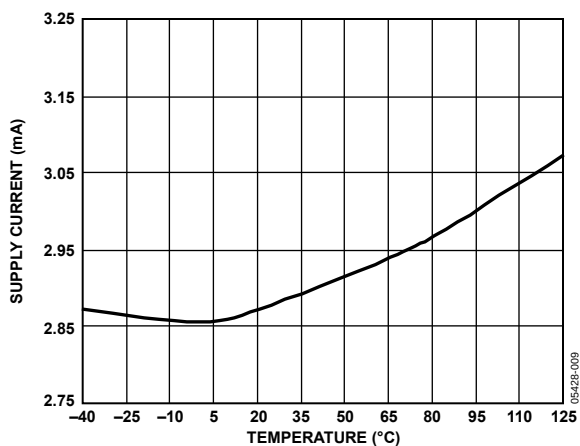


Figure 11. ADR445 Supply Current vs. Temperature

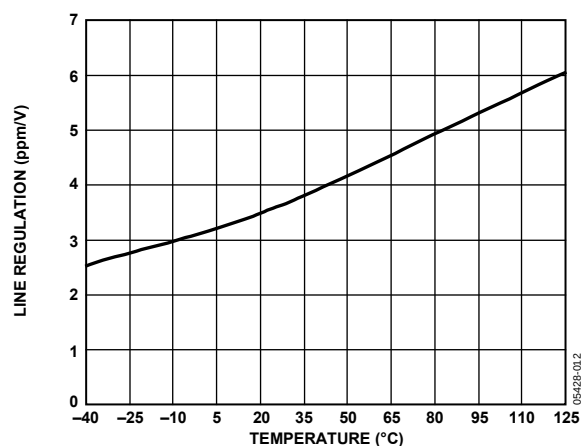


Figure 14. ADR445 Line Regulation vs. Temperature

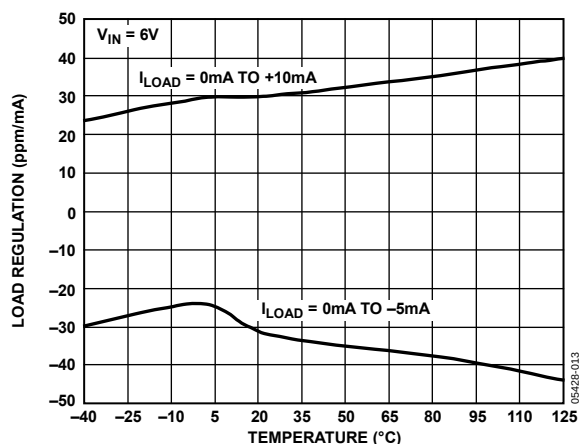


Figure 15. ADR445 Load Regulation vs. Temperature

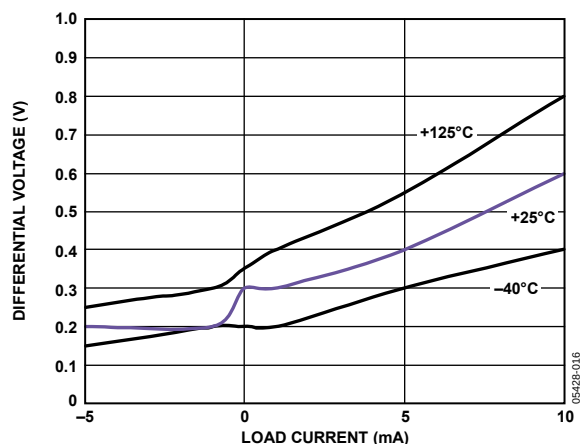


Figure 18. ADR445 Minimum Input/Output Differential Voltage vs. Load Current

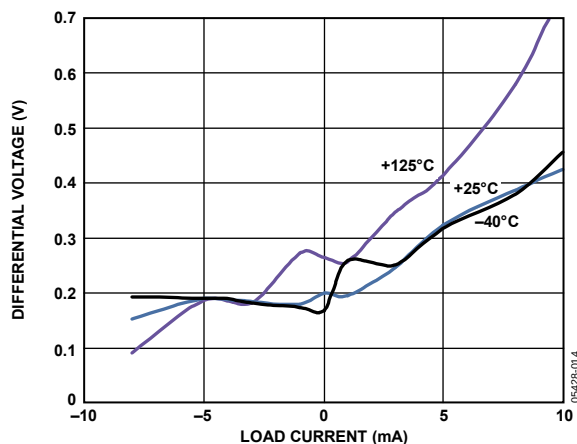


Figure 16. ADR441 Minimum Input/Output Differential Voltage vs. Load Current

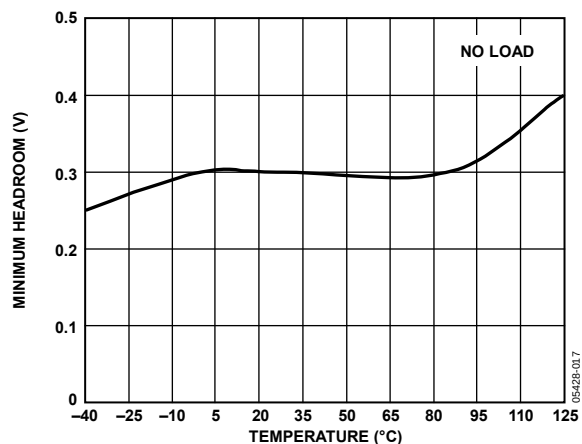


Figure 19. ADR445 Minimum Headroom vs. Temperature

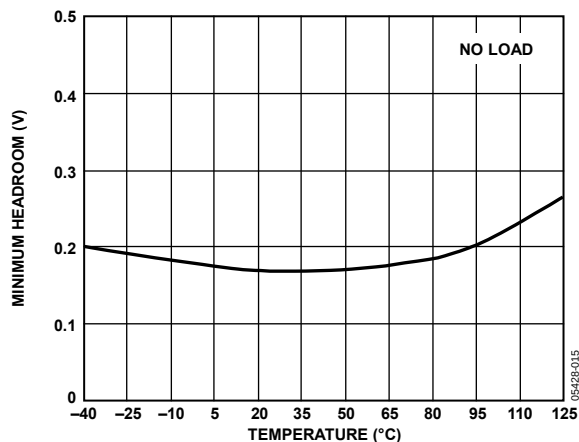


Figure 17. ADR441 Minimum Headroom vs. Temperature

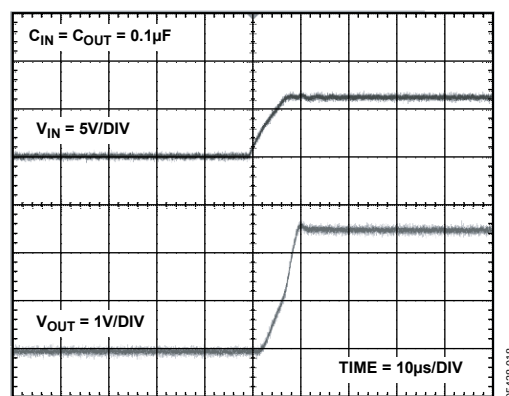


Figure 20. ADR441 Turn-On Response

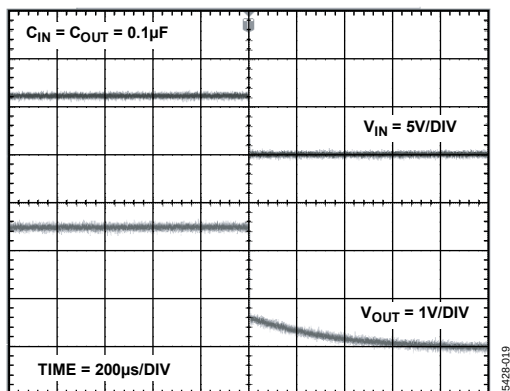


Figure 21. ADR441 Turn-Off Response

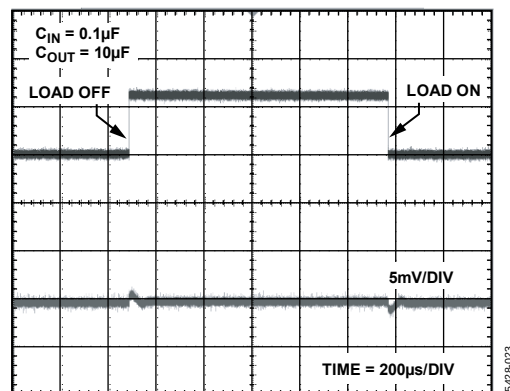


Figure 24. ADR441 Load Transient Response

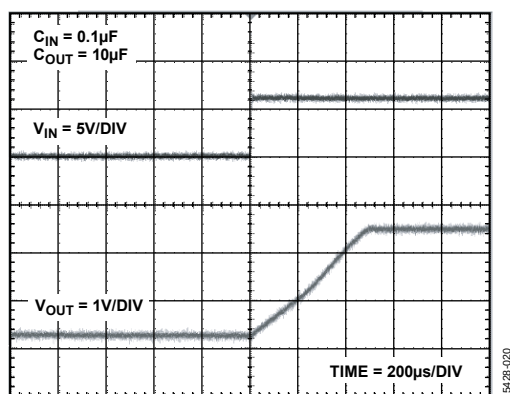


Figure 22. ADR441 Turn-On Response

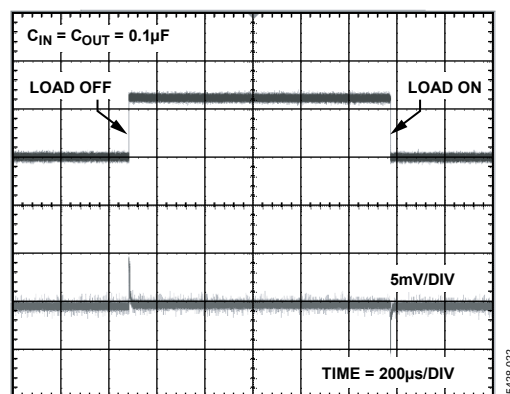


Figure 25. ADR441 Load Transient Response

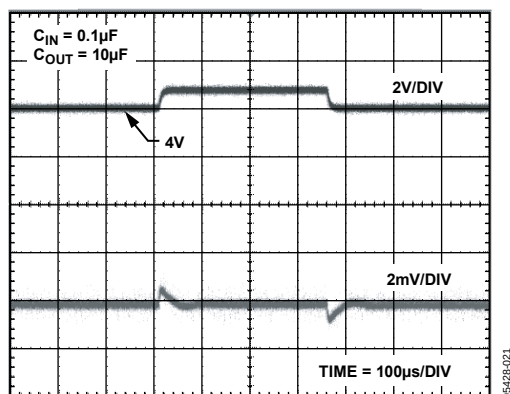


Figure 23. ADR441 Line Transient Response

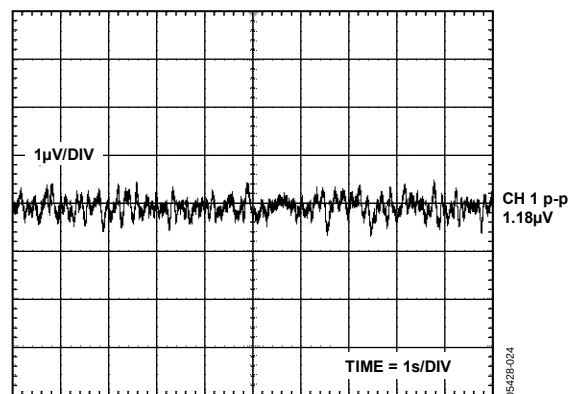


Figure 26. ADR441 0.1 Hz to 10.0 Hz Voltage Noise

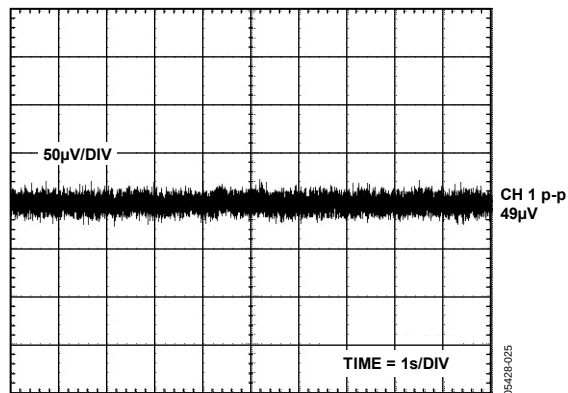


Figure 27. ADR441 10 Hz to 10 kHz Voltage Noise

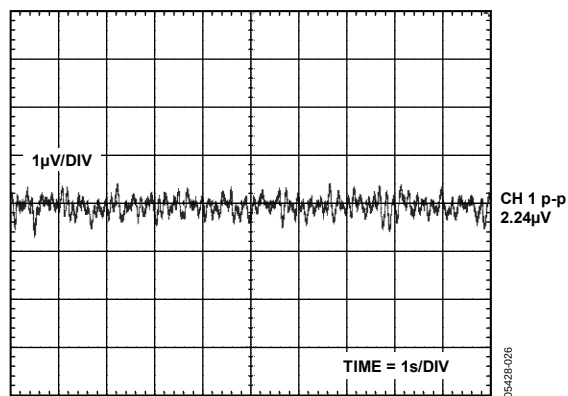


Figure 28. ADR445 0.1 Hz to 10.0 Hz Voltage Noise

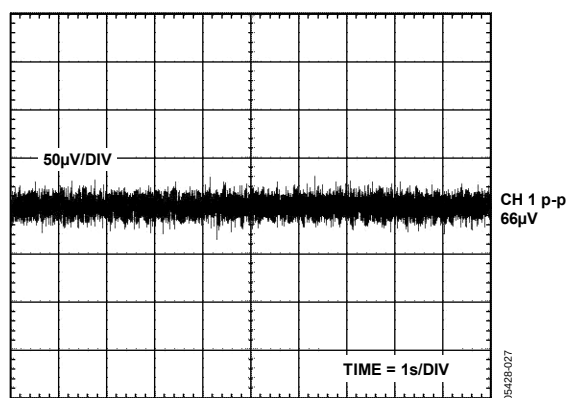


Figure 29. ADR445 10 Hz to 10 kHz Voltage Noise

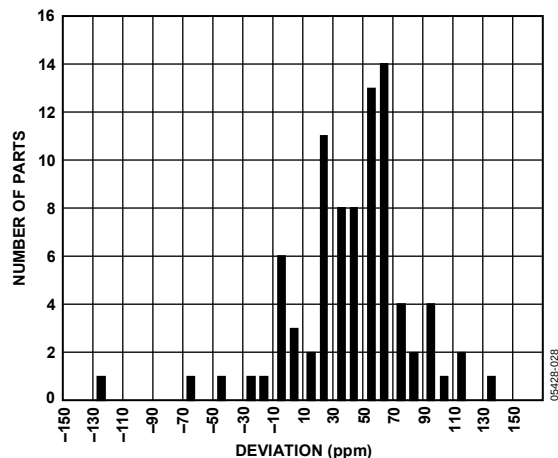


Figure 30. ADR441 Typical Output Voltage Hysteresis

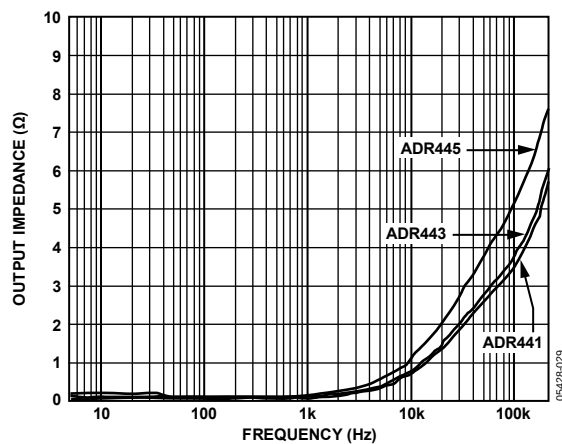


Figure 31. Output Impedance vs. Frequency

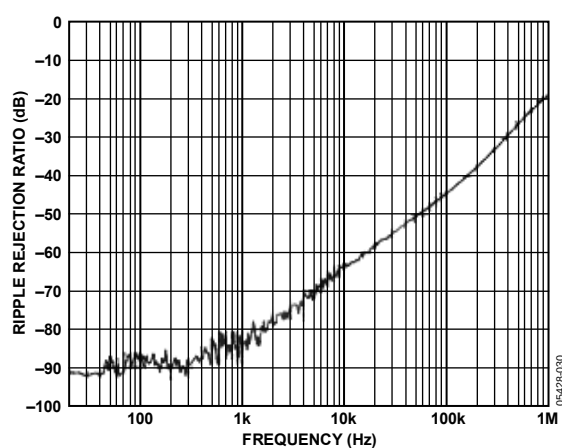


Figure 32. Ripple Rejection Ratio vs. Frequency

## THEORY OF OPERATION

The ADR44x series of references uses a new reference generation technique known as XFET (eXtra implanted junction FET). This technique yields a reference with low dropout, good thermal hysteresis, and exceptionally low noise. The core of the XFET reference consists of two junction field-effect transistors (JFETs), one of which has an extra channel implant to raise its pinch-off voltage. By running the two JFETs at the same drain current, the difference in pinch-off voltage can be amplified and used to form a highly stable voltage reference.

The intrinsic reference voltage is around 0.5 V with a negative temperature coefficient of about  $-120 \text{ ppm}/^\circ\text{C}$ . This slope is essentially constant to the dielectric constant of silicon, and it can be closely compensated for by adding a correction term generated in the same fashion as the proportional-to-absolute temperature (PTAT) term used to compensate band gap references. The advantage of an XFET reference is its correction term, which is approximately 20 times lower and requires less correction than that of a band gap reference. Because most of the noise of a band gap reference comes from the temperature compensation circuitry, the XFET results in much lower noise.

Figure 33 shows the basic topology of the ADR44x series. The temperature correction term is provided by a current source with a value designed to be proportional to the absolute temperature. The general equation is

$$V_{OUT} = G (\Delta V_P - R1 \times I_{PTAT}) \quad (1)$$

where:

$G$  is the gain of the reciprocal of the divider ratio.

$\Delta V_P$  is the difference in pinch-off voltage between the two JFETs.

$I_{PTAT}$  is the positive temperature coefficient correction current.

ADR44x devices are created by on-chip adjustment of  $R2$  and  $R3$  to achieve the different voltage options at the reference output.

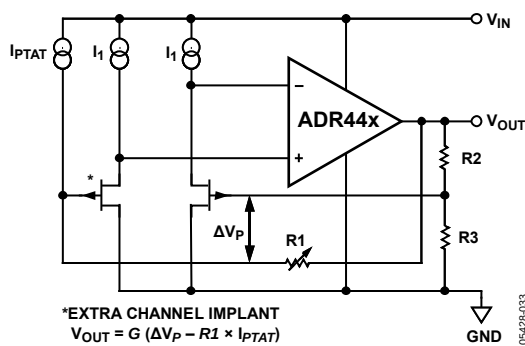


Figure 33. Simplified Schematic Device

## POWER DISSIPATION CONSIDERATIONS

The ADR44x family of references is guaranteed to deliver load currents to 10 mA with an input voltage that ranges from 3 V to 18 V. When these devices are used in applications at higher currents, use the following equation to account for the temperature effects of increases in power dissipation:

$$T_J = P_D \times \theta_{JA} + T_A \quad (2)$$

where:

$T_J$  and  $T_A$  are the junction and ambient temperatures, respectively.

$P_D$  is the device power dissipation.

$\theta_{JA}$  is the device package thermal resistance.

## BASIC VOLTAGE REFERENCE CONNECTIONS

The ADR44x family requires a  $0.1 \mu\text{F}$  capacitor on the input and the output for stability. Although not required for operation, a  $10 \mu\text{F}$  capacitor at the input can help with line voltage transient performance.

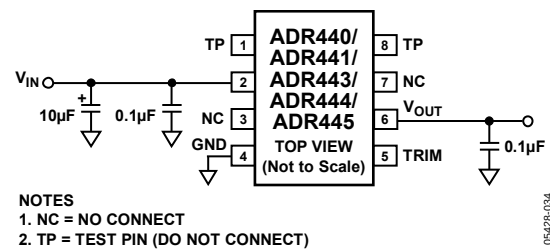


Figure 34. Basic Voltage Reference Configuration

## NOISE PERFORMANCE

The noise generated by the ADR44x family of references is typically less than  $1.4 \mu\text{V p-p}$  over the 0.1 Hz to 10.0 Hz band for ADR440, ADR441, and ADR443. Figure 26 shows the 0.1 Hz to 10 Hz noise of the ADR441, which is only  $1.2 \mu\text{V p-p}$ . The noise measurement is made with a band-pass filter composed of a 2-pole high-pass filter with a corner frequency at 0.1 Hz and a 2-pole low-pass filter with a corner frequency at 10.0 Hz.

## TURN-ON TIME

Upon application of power (cold start), the time required for the output voltage to reach its final value within a specified error band is defined as the turn-on settling time. Two components normally associated with this are the time for the active circuits to settle and the time for the thermal gradients on the chip to stabilize. Figure 20 and Figure 21 show the turn-on and turn-off settling times for the ADR441.



Table 9. Digital Potentiometer Parts

| Part No. | No. of Channels | No. of Positions | ITF              | R (k $\Omega$ ) | V <sub>DD</sub> <sup>1</sup> (V) |
|----------|-----------------|------------------|------------------|-----------------|----------------------------------|
| AD5251   | 2.00            | 64.00            | I <sup>2</sup> C | 1, 10, 50, 100  | 5.5                              |
| AD5207   | 2.00            | 256.00           | SPI              | 10, 50, 100     | 5.5                              |
| AD5242   | 2.00            | 256.00           | I <sup>2</sup> C | 10, 100, 1M     | 5.5                              |
| AD5262   | 2.00            | 256.00           | SPI              | 20, 50, 200     | 15                               |
| AD5282   | 2.00            | 256.00           | I <sup>2</sup> C | 20, 50, 100     | 15                               |
| AD5252   | 2.00            | 256.00           | I <sup>2</sup> C | 1, 10, 50, 100  | 5.5                              |
| AD5232   | 2.00            | 256.00           | SPI              | 10, 50, 100     | 5.5                              |
| AD5235   | 2.00            | 1024.00          | SPI              | 25, 250         | 5.5                              |
| ADN2850  | 2.00            | 1024.00          | SPI              | 25, 250         | 5.5                              |

<sup>1</sup> Can also use a negative supply.

Adding a negative supply to the operational amplifier allows the user to produce a negative programmable reference by connecting the reference output to the inverting terminal of the operational amplifier. Choose feedback resistors to minimize errors over temperature.

## PROGRAMMABLE CURRENT SOURCE

It is possible to build a programmable current source using a setup similar to the programmable voltage source, as shown in Figure 38. The constant voltage on the gate of the transistor sets the current through the load. Varying the voltage on the gate changes the current. This circuit does not require a dual digital potentiometer.

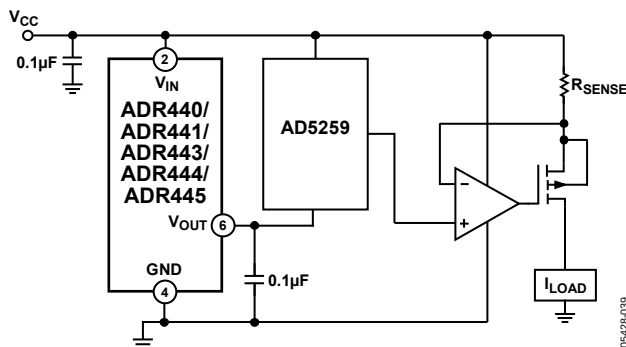


Figure 38. Programmable Current Source

## HIGH VOLTAGE FLOATING CURRENT SOURCE

Use the circuit in Figure 39 to generate a floating current source with minimal self heating. This particular configuration can operate on high supply voltages, determined by the breakdown voltage of the N-channel JFET.

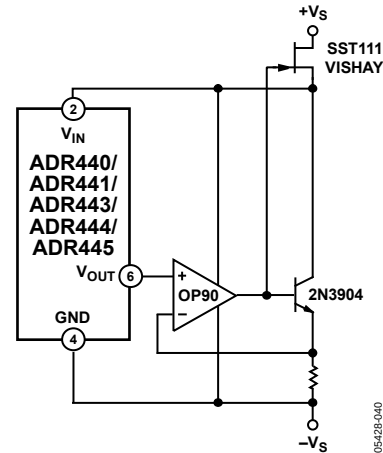


Figure 39. Floating Current Source

## PRECISION OUTPUT REGULATOR (BOOSTED REFERENCE)

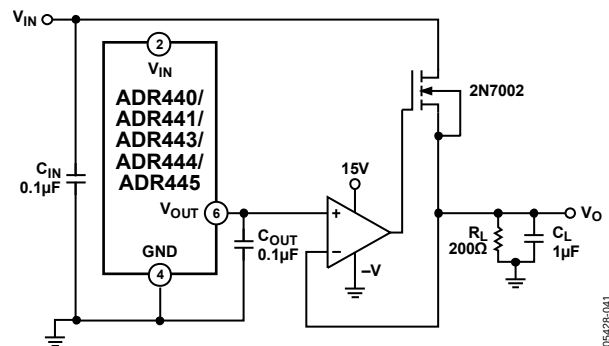
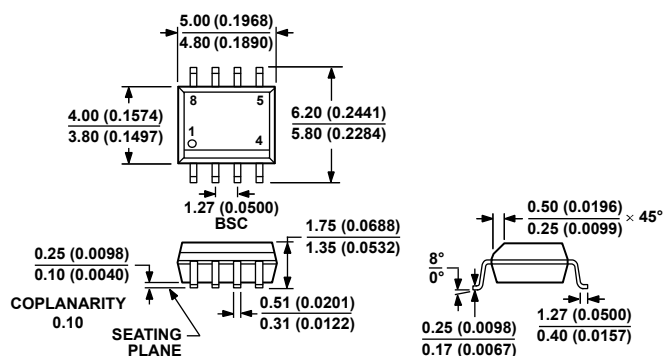


Figure 40. Boosted Output Reference

Higher current drive capability can be obtained without sacrificing accuracy by using the circuit in Figure 40. The operational amplifier regulates the MOSFET turn-on, forcing  $V_O$  to equal the  $V_{REF}$ . Current is then drawn from  $V_{IN}$ , allowing increased current drive capability. The circuit allows a 50 mA load; if higher current drive is required, use a larger MOSFET. For fast transient response, add a buffer at  $V_O$  to aid with capacitive loading.

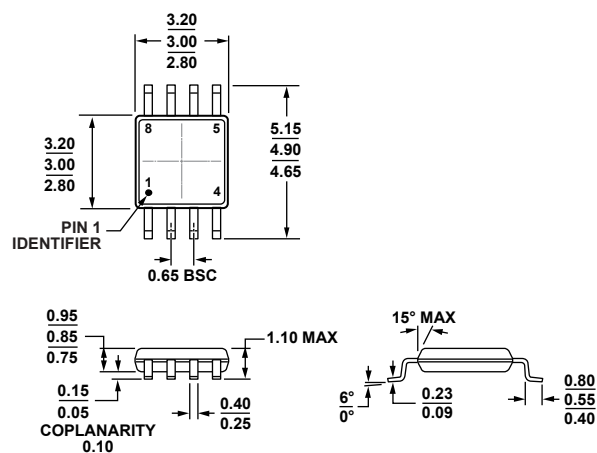
## OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MS-012-AA  
CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS  
(IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR  
REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

Figure 41. 8-Lead Standard Small Outline Package [SOIC\_N]  
Narrow Body  
(R-8)

Dimensions shown in millimeters and (inches)



COMPLIANT TO JEDEC STANDARDS MO-187-AA

Figure 42. 8-Lead Mini Small Outline Package [MSOP]  
(RM-8)

Dimensions show in millimeters

012407-A

10-07-2008-B

## ORDERING GUIDE

| Model <sup>1</sup> | Output Voltage (V) | Initial Accuracy |      | Temperature Coefficient Package (ppm/°C) | Package Description | Branding | Temperature Range | Package Option |
|--------------------|--------------------|------------------|------|------------------------------------------|---------------------|----------|-------------------|----------------|
|                    |                    | ±mV              | %    |                                          |                     |          |                   |                |
| ADR440ARZ          | 2.048              | 3                | 0.15 | 10                                       | 8-Lead SOIC_N       | R01      | –40°C to +125°C   | R-8            |
| ADR440ARZ-REEL7    | 2.048              | 3                | 0.15 | 10                                       | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR440ARMZ         | 2.048              | 3                | 0.15 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR440ARMZ-REEL7   | 2.048              | 3                | 0.15 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR440BRZ          | 2.048              | 1                | 0.05 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR440BRZ-REEL7    | 2.048              | 1                | 0.05 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR441ARZ          | 2.500              | 3                | 0.12 | 10                                       | 8-Lead SOIC_N       | R02      | –40°C to +125°C   | R-8            |
| ADR441ARZ-REEL7    | 2.500              | 3                | 0.12 | 10                                       | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR441ARMZ         | 2.500              | 3                | 0.12 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR441ARMZ-REEL7   | 2.500              | 3                | 0.12 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR441BRZ          | 2.500              | 1                | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR441BRZ-REEL7    | 2.500              | 1                | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR443ARZ          | 3.000              | 4                | 0.13 | 10                                       | 8-Lead SOIC_N       | R03      | –40°C to +125°C   | R-8            |
| ADR443ARZ-REEL7    | 3.000              | 4                | 0.13 | 10                                       | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR443ARMZ         | 3.000              | 4                | 0.13 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR443ARMZ-REEL7   | 3.000              | 4                | 0.13 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR443BRZ          | 3.000              | 1.2              | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR443BRZ-REEL7    | 3.000              | 1.2              | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR444ARZ          | 4.096              | 5                | 0.13 | 10                                       | 8-Lead SOIC_N       | R04      | –40°C to +125°C   | R-8            |
| ADR444ARZ-REEL7    | 4.096              | 5                | 0.13 | 10                                       | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR444ARMZ         | 4.096              | 5                | 0.13 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR444ARMZ-REEL7   | 4.096              | 5                | 0.13 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR444BRZ          | 4.096              | 1.6              | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR444BRZ-REEL7    | 4.096              | 1.6              | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR445ARZ          | 5.000              | 6                | 0.12 | 10                                       | 8-Lead SOIC_N       | R05      | –40°C to +125°C   | R-8            |
| ADR445ARZ-REEL7    | 5.000              | 6                | 0.12 | 10                                       | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR445ARMZ         | 5.000              | 6                | 0.12 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR445ARMZ-REEL7   | 5.000              | 6                | 0.12 | 10                                       | 8-Lead MSOP         |          | –40°C to +125°C   | RM-8           |
| ADR445BRZ          | 5.000              | 2                | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |
| ADR445BRZ-REEL7    | 5.000              | 2                | 0.04 | 3                                        | 8-Lead SOIC_N       |          | –40°C to +125°C   | R-8            |

<sup>1</sup> Z = RoHS Compliant Part.

<sup>12</sup>C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).