# Integrated Circuit True RMS-to-DC Converter

Data Sheet **AD536A**

## FEATURES

- True rms-to-dc conversion
- Laser trimmed to high accuracy
  - ±0.2% maximum error (AD536AK)
  - ±0.5% maximum error (AD536AJ)
- Wide response capability
  - Computes rms of ac and dc signals
  - 450 kHz bandwidth: V rms > 100 mV
  - 2 MHz bandwidth: V rms > 1 V
  - Signal crest factor of 7 for 1% error
- dB output with 60 dB range
- Low power: 1.2 mA quiescent current
- Single- or dual-supply operation
- Monolithic integrated circuit
- −55°C to +125°C operation (AD536AS)

## GENERAL DESCRIPTION

The AD536A is a complete monolithic integrated circuit that performs true rms-to-dc conversion. It offers performance comparable or superior to that of hybrid or modular units costing much more. The AD536A directly computes the true rms value of any complex input waveform containing ac and dc components. A crest factor compensation scheme allows measurements with 1% error at crest factors up to 7. The wide bandwidth of the device extends the measurement capability to 300 kHz with less than 3 dB errors for signal levels greater than 100 mV.

An important feature of the AD536A, not previously available in rms converters, is an auxiliary dB output pin. The logarithm of the rms output signal is brought out to a separate pin to allow the dB conversion, with a useful dynamic range of 60 dB. Using an externally supplied reference current, the 0 dB level can be conveniently set to correspond to any input level from 0.1 V to 2 V rms.

The AD536A is laser trimmed to minimize input and output offset voltage, to optimize positive and negative waveform symmetry (dc reversal error), and to provide full-scale accuracy at 7 V rms. As a result, no external trims are required to achieve the rated unit accuracy.

The input and output pins are fully protected. The input circuitry can take overload voltages well beyond the supply levels. Loss of supply voltage with the input connected to external circuitry does not cause the device to fail. The output is short-circuit protected.

## FUNCTIONAL BLOCK DIAGRAM

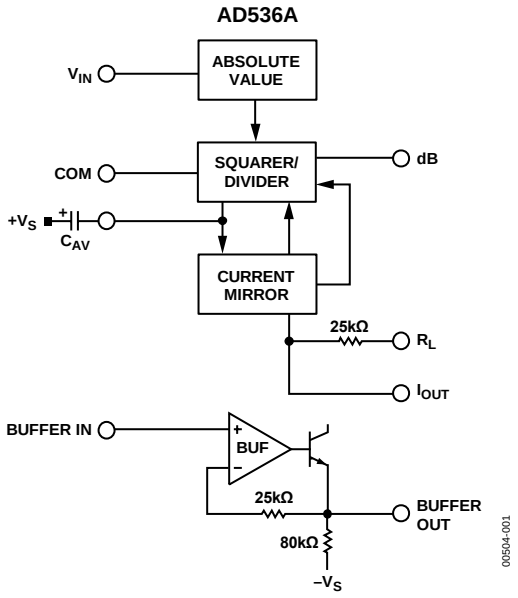



*Figure 1.*

The AD536A is available in two accuracy grades (J and K) for commercial temperature range (0°C to 70°C) applications, and one grade (S) rated for the −55°C to +125°C extended range. The AD536AK offers a maximum total error of ±2 mV ± 0.2% of reading, while the AD536AJ and AD536AS have maximum errors of ±5 mV ± 0.5% of reading. All three versions are available in a hermetically sealed 14-lead DIP or a 10-pin TO-100 metal header package. The AD536AS is also available in a 20-terminal leadless hermetically sealed ceramic chip carrier.

The AD536A computes the true root-mean-square level of a complex ac (or ac plus dc) input signal and provides an equivalent dc output level. The true rms value of a waveform is a more useful quantity than the average rectified value because it relates directly to the power of the signal. The rms value of a statistical signal also relates to its standard deviation.

An external capacitor is required to perform measurements to the fully specified accuracy. The value of this capacitor determines the low frequency ac accuracy, ripple amplitude, and settling time.

The AD536A operates equally well from split supplies or a single supply with total supply levels from 5 V to 36 V. With 1 mA quiescent supply current, the device is well suited for a wide variety of remote controllers and battery-powered instruments.

**Rev. E**
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## REVISION HISTORY

**7/12—Rev. D to Rev. E**

Reorganized Layout ... Universal
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**3/06—Rev. B to Rev. C**

Updated Format ... Universal
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**6/99—Rev. A to Rev. B**

**1/76—Revision 0: Initial Version**

# SPECIFICATIONS

$T_A$ = +25°C and ±15 V dc, unless otherwise noted.

**Table 1.**

| | AD536AJ | | | AD536AK | | | AD536AS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Min** | **Typ** | **Max** | **Min** | **Typ** | **Max** | **Min** | **Typ** | **Max** | **Unit** |
| TRANSFER FUNCTION | | $V_{OUT} = \sqrt{Avg(V_{IN})^2}$ | | | $V_{OUT} = \sqrt{Avg(V_{IN})^2}$ | | | $V_{OUT} = \sqrt{Avg(V_{IN})^2}$ | | |
| CONVERSION ACCURACY | | | | | | | | | | |
| Total Error, Internal Trim[1] (See Figure 13) | | | ±5 ± 0.5 | | | ±2 ± 0.2 | | | ±5 ± 0.5 | mV ± % of rdg |
| vs. Temperature | | | | | | | | | | |
| $T_{MIN}$ to +70°C | | | ±0.1 ± 0.01 | | | ±0.05 ± 0.005 | | | ±0.1 ± 0.005 | mV ± % of rdg/°C |
| +70°C to +125°C | | | | | | | | | ±0.3 ± 0.005 | mV ± % of rdg/°C |
| vs. Supply Voltage | | ±0.1<br>±0.01 | | | ±0.1 ± 0.01 | | | ±0.1<br>±0.01 | | mV ± % of rdg/°C |
| dc Reversal Error | | ±0.2 | | | ±0.1 | | | ±0.2 | | mV ± % of rdg |
| Total Error, External Trim[1] (See Figure 16) | | ±3 ± 0.3 | | | ±2 ± 0.1 | | | ±3 ± 0.3 | | mV ± % of rdg |
| ERROR VS. CREST FACTOR[2] | | | | | | | | | | |
| Crest Factor 1 to Crest Factor 2 | | Specified accuracy | | | Specified accuracy | | | Specified accuracy | | |
| Crest Factor = 3 | | −0.1 | | | −0.1 | | | −0.1 | | % of rdg |
| Crest Factor = 7 | | −1.0 | | | −1.0 | | | −1.0 | | % of rdg |
| FREQUENCY RESPONSE[3] | | | | | | | | | | |
| Bandwidth for 1% Additional Error (0.09 dB) | | | | | | | | | | |
| $V_{IN}$ = 10 mV | | 5 | | | 5 | | | 5 | | kHz |
| $V_{IN}$ = 100 mV | | 45 | | | 45 | | | 45 | | kHz |
| $V_{IN}$ = 1 V | | 120 | | | 120 | | | 120 | | kHz |
| ±3 dB Bandwidth | | | | | | | | | | |
| $V_{IN}$ = 10 mV | | 90 | | | 90 | | | 90 | | kHz |
| $V_{IN}$ = 100 mV | | 450 | | | 450 | | | 450 | | kHz |
| $V_{IN}$ = 1 V | | 2.3 | | | 2.3 | | | 2.3 | | MHz |
| AVERAGING TIME CONSTANT (See Figure 19) | | 25 | | | 25 | | | 25 | | ms/µF |
| INPUT CHARACTERISTICS | | | | | | | | | | |
| Signal Range, ±15 V Supplies | | | | | | | | | | |
| Continuous RMS Level | | 0 to 7 | | | 0 to 7 | | | 0 to 7 | | V rms |
| Peak Transient Input | | | ±20 | | | ±20 | | | ±20 | V peak |
| Continuous RMS Level, $V_S$ = ±5 V | | 0 to 2 | | | 0 to 2 | | | 0 to 2 | | V rms |
| Peak Transient Input, $V_S$ = ±5 V | | | ±7 | | | ±7 | | | ±7 | V peak |
| Maximum Continuous Nondestructive Input Level (All Supply Voltages) | | | ±25 | | | ±25 | | | ±25 | V peak |
| Input Resistance | 13.33 | 16.67 | 20 | 13.33 | 16.67 | 20 | 13.33 | 16.67 | 20 | kΩ |
| Input Offset Voltage | | 0.8 | ±2 | | 0.5 | ±1 | | 0.8 | ±2 | mV |
| OUTPUT CHARACTERISTICS | | | | | | | | | | |
| Offset Voltage, $V_{IN}$ = COM (See Figure 13) | | ±1 | ±2 | | ±0.5 | ±1 | | | ±2 | mV |
| vs. Temperature | | ±0.1 | | | ±0.1 | | | | ±0.2 | mV/°C |
| vs. Supply Voltage | | ±0.1 | | | ±0.1 | | | ±0.2 | | mV/V |
| Voltage Swing, ±15 V Supplies | 0 to +11 | +12.5 | | 0 to +11 | +12.5 | | 0 to +11 | +12.5 | | V |
| ± 5 V Supply | 0 to +2 | | | 0 to +2 | | | 0 to +2 | | | V |
| dB OUTPUT, 0 dB = 1 V rms (See Figure 7) | | | | | | | | | | |
| Error, 7 mV < $V_{IN}$ < 7 V rms | | ±0.4 | ±0.6 | | ±0.2 | ±0.3 | | ±0.5 | ±0.6 | dB |
| Scale Factor | | −3 | | | −3 | | | −3 | | mV/dB |
| Scale Factor Temperature Coefficient | | −0.033 | | | −0.033 | | | −0.033 | | dB/°C |
| Uncompensated | | +0.33 | | | +0.33 | | | +0.33 | | % of rdg/°C |
| $I_{REF}$ for 0 dB = 1 V rms | 5 | 20 | 80 | 5 | 20 | 80 | 5 | 20 | 80 | µA |
| $I_{REF}$ Range | 1 | | 100 | 1 | | 100 | 1 | | 100 | µA |

| Parameter | AD536AJ Min | AD536AJ Typ | AD536AJ Max | AD536AK Min | AD536AK Typ | AD536AK Max | AD536AS Min | AD536AS Typ | AD536AS Max | Unit |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_{OUT}$ TERMINAL | | | | | | | | | | |
| $I_{OUT}$ Scale Factor | | 40 | | | 40 | | | 40 | | μA/V rms |
| $I_{OUT}$ Scale Factor Tolerance | | ±10 | ±20 | | ±10 | ±20 | | ±10 | ±20 | % |
| Output Resistance | 20 | 25 | 30 | 20 | 25 | 30 | 20 | 25 | 30 | kΩ |
| Voltage Compliance | | $-V_S$ to ($+V_S$ − 2.5 V) | | | $-V_S$ to ($+V_S$ − 2.5 V) | | | $-V_S$ to ($+V_S$ − 2.5 V) | | V |
| BUFFER AMPLIFIER | | | | | | | | | | |
| Input and Output Voltage Range | $-V_S$ to ($+V_S$ − 2.5V) | | | $-V_S$ to ($+V_S$ − 2.5V) | | | $-V_S$ to ($+V_S$ − 2.5V) | | | V |
| Input Offset Voltage, $R_S$ = 25 kΩ | | ±0.5 | ±4 | | ±0.5 | ±4 | | ±0.5 | ±4 | mV |
| Input Bias Current | | 20 | 60 | | 20 | 60 | | 20 | 60 | nA |
| Input Resistance | | $10^8$ | | | $10^8$ | | | $10^8$ | | Ω |
| Output Current | (+5 mA, −130 μA) | | | (+5 mA, −130 μA) | | | (+5 mA, −130 μA) | | | |
| Short-Circuit Current | | 20 | | | 20 | | | 20 | | mA |
| Output Resistance | | | 0.5 | | | 0.5 | | | 0.5 | Ω |
| Small-Signal Bandwidth | | 1 | | | 1 | | | 1 | | MHz |
| Slew Rate[4] | | 5 | | | 5 | | | 5 | | V/μs |
| POWER SUPPLY | | | | | | | | | | |
| Voltage Rated Performance | | ±15 | | | ±15 | | | ±15 | | V |
| Dual Supply | ±3.0 | | ±18 | ±3.0 | | ±18 | ±3.0 | | ±18 | V |
| Single Supply | +5 | | +36 | +5 | | +36 | +5 | | +36 | V |
| Quiescent Current | | | | | | | | | | |
| Total $V_S$, 5 V to 36 V, $T_{MIN}$ to $T_{MAX}$ | | 1.2 | 2 | | 1.2 | 2 | | 1.2 | 2 | mA |
| TEMPERATURE RANGE | | | | | | | | | | |
| Rated Performance | 0 | | +70 | 0 | | +70 | −55 | | +125 | °C |
| Storage | −55 | | +150 | −55 | | +150 | −55 | | +150 | °C |
| NUMBER OF TRANSISTORS | | 65 | | | 65 | | | 65 | | |

[1] Accuracy is specified for 0 V to 7 V rms, dc or 1 kHz sine wave input with the AD536A connected as in the figure referenced.
[2] Error vs. crest factor is specified as an additional error for 1 V rms rectangular pulse input, pulse width = 200 μs.
[3] Input voltages are expressed in volts rms, and error is expressed as a percentage of the reading.
[4] With 2kΩ external pull-down resistor.

# ABSOLUTE MAXIMUM RATINGS

**Table 2.**

| Parameter | Rating |
|---|---|
| Supply Voltage | |
| Dual Supply | ±18 V |
| Single Supply | +36 V |
| Internal Power Dissipation | 500 mW |
| Maximum Input Voltage | ±25 V peak |
| Buffer Maximum Input Voltage | $\pm V_S$ |
| Maximum Input Voltage | ±25 V peak |
| Storage Temperature Range | −55°C to +150°C |
| Operating Temperature Range | |
| AD536AJ/AD536AK | 0°C to +70°C |
| AD536AS | −55°C to +125°C |
| Lead Temperature (Soldering, 60 sec) | 300°C |
| ESD Rating | 1000 V |
| Thermal Resistance $\theta_{JA}$[1] | |
| 10-Pin Header (H-10 Package) | 150°C/W |
| 20-Terminal LCC (E-20 Package) | 95°C/W |
| 14-Lead SBDIP (D-14 Package) | 95°C/W |
| 14-Lead CERDIP (Q-14 Package) | 95°C/W |

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

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

## 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.

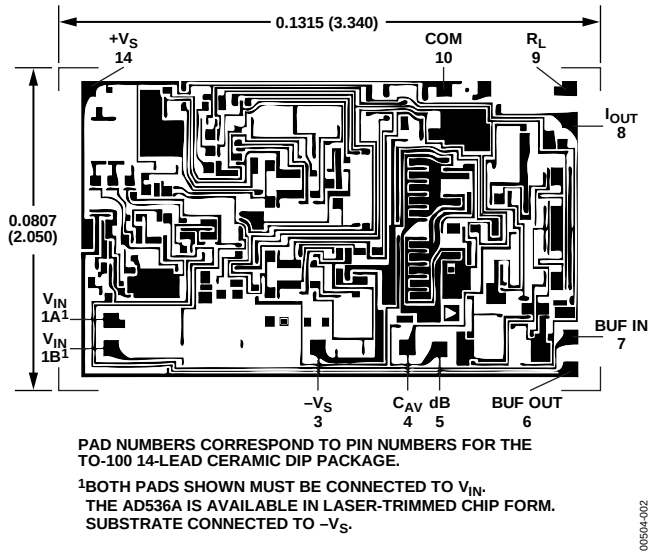



*Figure 2. Die Dimensions and Pad Layout*
*Dimensions shown in inches and (millimeters)*

# PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

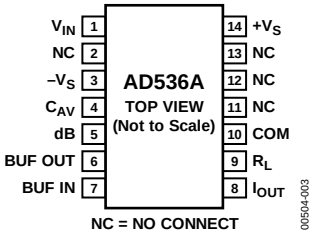



*Figure 3. D-14 and Q-14 Packages Pin Configuration*

**Table 3. D-14 and Q-14 Packages Pin Function Descriptions**

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | $V_{IN}$ | Input Voltage |
| 2 | NC | No Connection |
| 3 | $-V_S$ | Negative Supply Voltage |
| 4 | $C_{AV}$ | Averaging Capacitor |
| 5 | dB | Log (dB) Value of the RMS Output Voltage |
| 6 | BUF OUT | Buffer Output |
| 7 | BUF IN | Buffer Input |
| 8 | $I_{OUT}$ | RMS Output Current |
| 9 | $R_L$ | Load Resistor |
| 10 | COM | Common |
| 11 | NC | No Connection |
| 12 | NC | No Connection |
| 13 | NC | No Connection |
| 14 | $+V_S$ | Positive Supply Voltage |

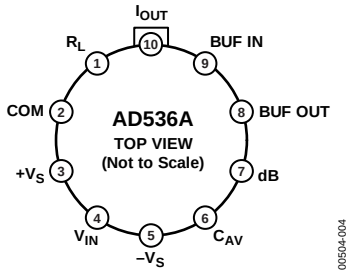



*Figure 4. H-10 Package Pin Configuration*

**Table 4. H-10 Package Pin Function Descriptions**

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | $R_L$ | Load Resistor |
| 2 | COM | Common |
| 3 | $+V_S$ | Positive Supply Voltage |
| 4 | $V_{IN}$ | Input Voltage |
| 5 | $-V_S$ | Negative Supply Voltage |
| 6 | $C_{AV}$ | Averaging Capacitor |
| 7 | dB | Log (dB) Value of the RMS Output Voltage |
| 8 | BUF OUT | Buffer Output |
| 9 | BUF IN | Buffer Input |
| 10 | $I_{OUT}$ | RMS Output Current |

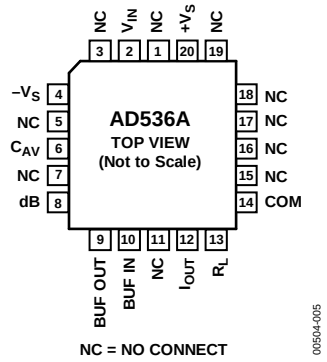



*Figure 5. E-20 Package Pin Configuration*

**Table 5. E-20 Package Pin Function Descriptions**

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | NC | No Connection |
| 2 | $V_{IN}$ | Input Voltage |
| 3 | NC | No Connection |
| 4 | $-V_S$ | Negative Supply Voltage |
| 5 | NC | No Connection |
| 6 | $C_{AV}$ | Averaging Capacitor |
| 7 | NC | No Connection |
| 8 | dB | Log (dB) Value of the RMS Output Voltage |
| 9 | BUF OUT | Buffer Output |
| 10 | BUF IN | Buffer Input |
| 11 | NC | No Connection |
| 12 | $I_{OUT}$ | RMS Output Current |
| 13 | $R_L$ | Load Resistor |
| 14 | COM | Common |
| 15 | NC | No Connection |
| 16 | NC | No Connection |
| 17 | NC | No Connection |
| 18 | NC | No Connection |
| 19 | NC | No Connection |
| 20 | $+V_S$ | Positive Supply Voltage |

# THEORY OF OPERATION

The AD536A embodies an implicit solution of the rms equation that overcomes the dynamic range as well as other limitations inherent in a straightforward computation of rms. The actual computation performed by the AD536A follows the equation

$$V\,rms = Avg\left[\frac{V_{IN}{}^2}{V\,rms}\right]$$

Figure 6 is a simplified schematic of the AD536A. Note that it is subdivided into four major sections: absolute value circuit (active rectifier), squarer/divider, current mirror, and buffer amplifier. The input voltage ($V_{IN}$), which can be ac or dc, is converted to a unipolar current ($I_1$) by the active rectifiers ($A_1$, $A_2$). $I_1$ drives one input of the squarer/divider, which has the transfer function

$$I_4 = I_1^2/I_3$$

The output current, $I_4$, of the squarer/divider drives the current mirror through a low-pass filter formed by R1 and the externally connected capacitor, $C_{AV}$. If the R1 $C_{AV}$ time constant is much greater than the longest period of the input signal, then $I_4$ is effectively averaged. The current mirror returns a current $I_3$, which equals Avg[$I_4$], back to the squarer/divider to complete the implicit rms computation. Thus,

$$I_4 = Avg[I_1^2/I_4] = I_1\,rms$$

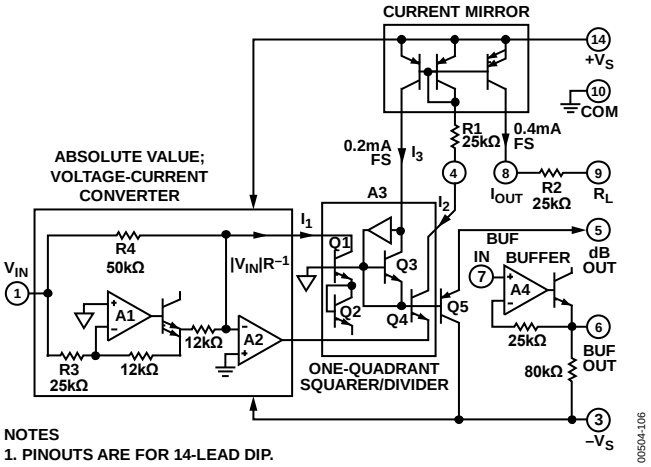



*Figure 6. Simplified Schematic*

The current mirror also produces the output current, $I_{OUT}$, which equals $2I_4$. $I_{OUT}$ can be used directly or can be converted to a voltage with R2 and buffered by A4 to provide a low impedance voltage output. The transfer function of the AD536A results in the following:

$$V_{OUT} = 2R2 \times I\,rms = V_{IN}\,rms$$

The dB output is derived from the emitter of Q3 because the voltage at this point is proportional to –log $V_{IN}$. The emitter follower, Q5, buffers and level shifts this voltage so that the dB output voltage is zero when the externally supplied emitter current ($I_{REF}$) to Q5 approximates $I_3$.

## CONNECTIONS FOR dB OPERATION

The logarithmic (or decibel) output of the AD536A is one of its most powerful features. The internal circuit computing dB works accurately over a 60 dB range. The connections for dB measurements are shown in Figure 7.

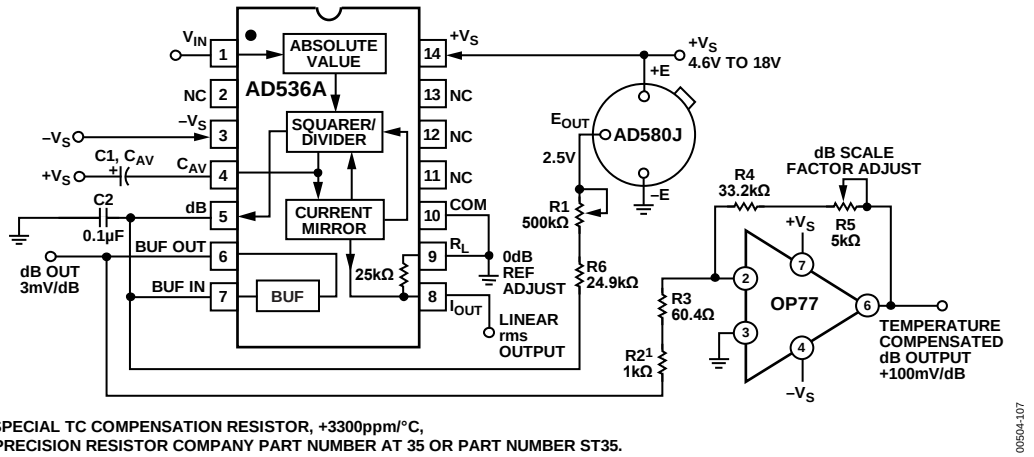
Select the 0 dB level by adjusting R1 for the proper 0 dB reference current (which is set to cancel the log output current from the squarer/divider at the desired 0 dB point). The external op amp provides a more convenient scale and allows compensation of the +0.33%/°C scale factor drift of the dB output pin.

The temperature-compensating resistor, R2, is available online in several styles from Precision Resistor Company, Inc., (Part Number AT35 and Part Number ST35). The average temperature coefficients of R2 and R3 result in the +3300 ppm required to compensate for the dB output. The linear rms output is available at Pin 8 on the DIP or Pin 10 on the header device with an output impedance of 25 kΩ. Some applications require an additional buffer amplifier if this output is desired.

For dB calibration,

1. Set $V_{IN}$ = 1.00 V dc or 1.00 V rms.
2. Adjust R1 for dB output = 0.00 V.
3. Set $V_{IN}$ = +0.1 V dc or 0.10 V rms.
4. Adjust R5 for dB output = −2.00 V.

Any other desired 0 dB reference level can be used by setting $V_{IN}$ and adjusting R1 accordingly. Note that adjusting R5 for the proper gain automatically provides the correct temperature compensation.




[1]SPECIAL TC COMPENSATION RESISTOR, +3300ppm/°C, PRECISION RESISTOR COMPANY PART NUMBER AT 35 OR PART NUMBER ST35.

*Figure 7. dB Connection*

## FREQUENCY RESPONSE

The AD536A utilizes a logarithmic circuit in performing the implicit rms computation. As with any log circuit, bandwidth is proportional to signal level. The solid lines in the graph of Figure 8 represent the frequency response of the AD536A at input levels from 10 mV rms to 7 V rms. The dashed lines indicate the upper frequency limits for 1%, 10%, and ±3 dB of reading additional error. For example, note that a 1 V rms signal produces less than 1% of reading additional error up to 120 kHz. A 10 mV signal can be measured with 1% of reading additional error (100 µV) up to only 5 kHz.

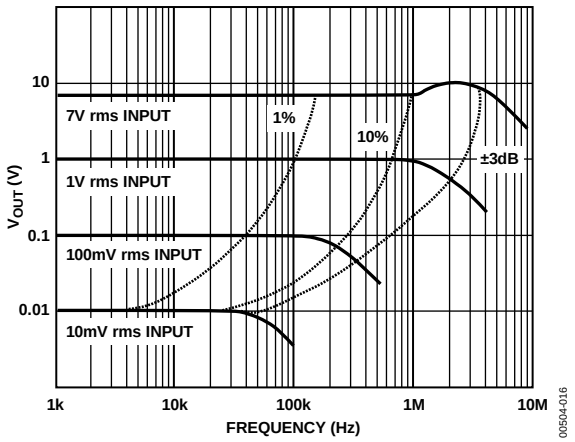
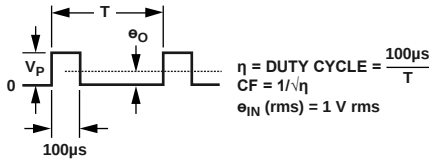



*Figure 8. High Frequency Response*

## AC MEASUREMENT ACCURACY AND CREST FACTOR

Crest factor is often overlooked when determining the accuracy of an ac measurement. The definition of crest factor is the ratio of the peak signal amplitude to the rms value of the signal (CF = $V_p$/V rms). Most common waveforms, such as sine and triangle waves, have relatively low crest factors (<2). Waveforms that resemble low duty cycle pulse trains, such as those occurring in switching power supplies and SCR circuits, have high crest factors. For example, a rectangular pulse train with a 1% duty cycle has a crest factor of 10 (CF = 1√n).

Figure 9 illustrates a curve of reading error for the AD536A for a 1 V rms input signal with crest factors from 1 to 11. A rectangular pulse train (pulse width = 100 µs) was used for this test because it is the worst-case waveform for rms measurement (all of the energy is contained in the peaks). The duty cycle and peak amplitude were varied to produce crest factors from 1 to 11 while maintaining a constant 1 V rms input amplitude.



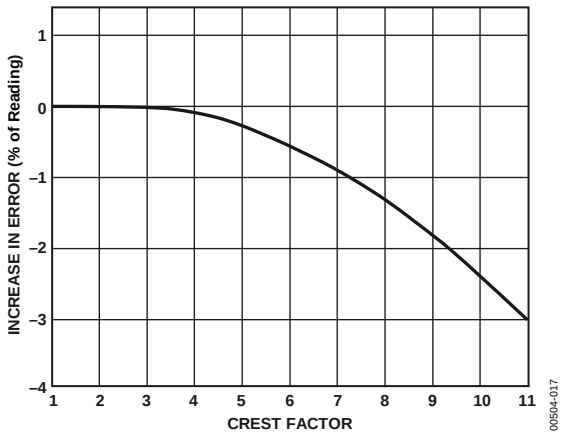




*Figure 9. Error vs. Crest Factor*

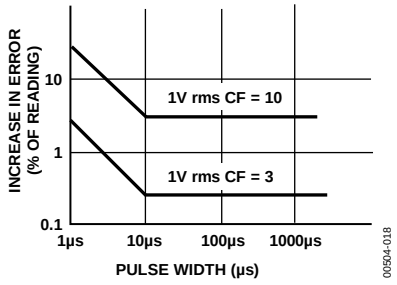



*Figure 10. Error vs. Pulse Width Rectangular Pulse*

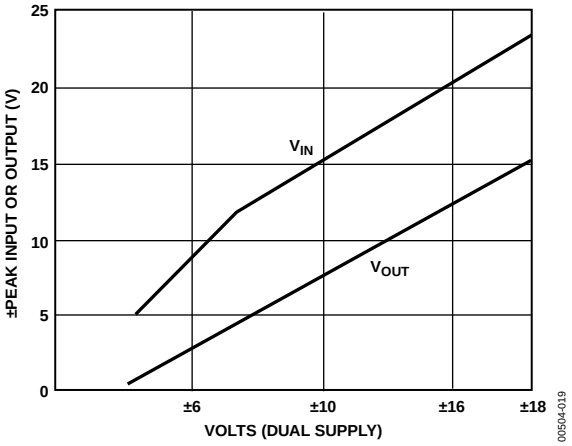



*Figure 11. Input and Output Voltage Ranges vs. Dual Supply*

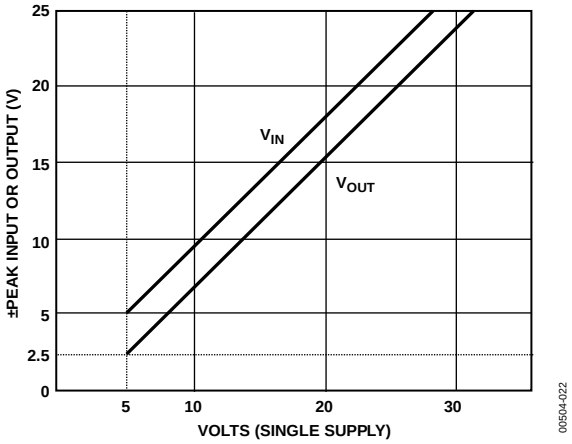



*Figure 12. Input and Output Voltage Ranges vs. Single Supply*

# APPLICATIONS INFORMATION

## TYPICAL CONNECTIONS

The AD536A is simple to connect to for the majority of high accuracy rms measurements, requiring only an external capacitor to set the averaging time constant. The standard connection is shown in Figure 13 through Figure 15. In this configuration, the AD536A measures the rms of the ac and dc levels present at the input, but shows an error for low frequency input as a function of the filter capacitor, $C_{AV}$, as shown in Figure 19. Thus, if a 4 µF capacitor is used, the additional average error at 10 Hz is 0.1%; at 3 Hz, the additional average error is 1%.

The accuracy at higher frequencies is according to specification. To reject the dc input, add a capacitor in series with the input, as shown in Figure 17. Note that the capacitor must be nonpolar. If the AD536A supply rails contain a considerable amount of high frequency ripple, it is advisable to bypass both supply pins to ground with 0.1 µF ceramic capacitors, located as close to the device as possible.

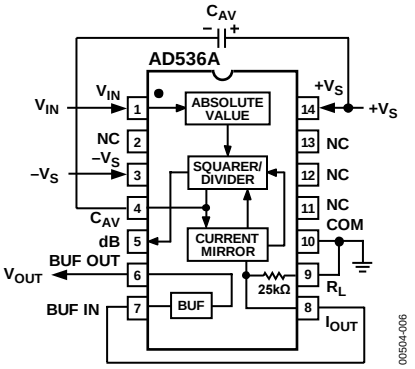



*Figure 13. 14-Lead Standard RMS Connection*

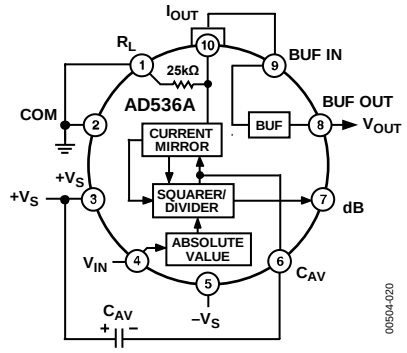



*Figure 14. 10-Pin Standard RMS Connection*

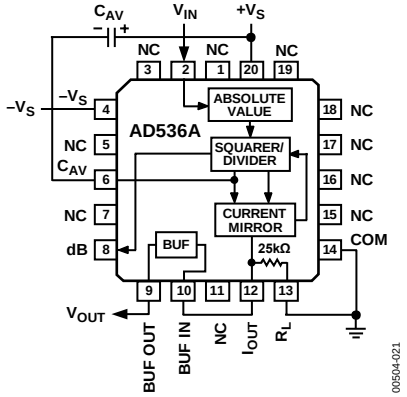



*Figure 15. 20-Terminal Standard RMS Connection*

The input and output signal ranges are a function of the supply voltages; these ranges are shown in Figure 11 and Figure 12. The AD536A can also be used in an unbuffered voltage output mode by disconnecting the input to the buffer. The output then appears unbuffered across the 25 kΩ resistor. The buffer amplifier can then be used for other purposes. Further, the AD536A can be used in a current output mode by disconnecting the 25 kΩ resistor from ground. The output current is available at Pin 8 ($I_{OUT}$, Pin 10 on the H-10 package) with a nominal scale of 40 µA per V rms input positive output.

## OPTIONAL EXTERNAL TRIMS FOR HIGH ACCURACY

The accuracy and offset voltage of the AD536A is adjustable with external trims, as shown in Figure 16. R4 trims the offset. Note that the offset trim circuit adds 365 Ω in series with the internal 25 kΩ resistor. This causes a 1.5% increase in scale factor, which is compensated for by R1. The scale factor adjustment range is ±1.5%.

The trimming procedure is as follows:

1. Ground the input signal, $V_{IN}$, and adjust R4 to provide 0 V output from Pin 6. Alternatively, adjust R4 to provide the correct output with the lowest expected value of $V_{IN}$.
2. Connect the desired full-scale input level to $V_{IN}$, either dc or a calibrated ac signal (1 kHz is the optimum frequency).
3. Trim R1 to provide the correct output at Pin 6. For example, 1.000 V dc input provides 1.000 V dc output. A ±1.000 V peak-to-peak sine wave should provide a 0.707 V dc output. Any residual errors are caused by device nonlinearity.

The major advantage of external trimming is to optimize device performance for a reduced signal range; the AD536A is internally trimmed for a 7 V rms full-scale range.

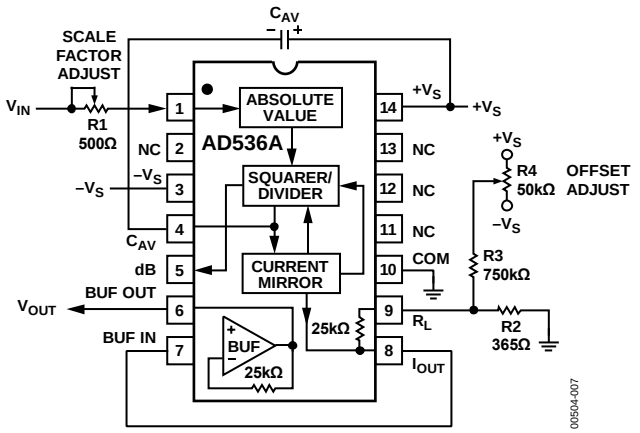



*Figure 16. Optional External Gain and Output Offset Trims*

## SINGLE-SUPPLY OPERATION

Refer to Figure 17 for single supply-rail configurations between 5 V and 36 V. When powered from a single supply, the input stage (VIN pin) is internally biased at a voltage between ground and the supply, and the input signal ac coupled. Biasing the device between the supply and ground is simply a matter of connecting the COM pin to an external resistor divider and bypassing to ground. The resistor values are large, minimizing power consumption, as the COM pin current is only 5 μA.

Note that the 10 kΩ and 20 kΩ resistors connected to the COM pin (Figure 17) are asymmetrical, that is, the voltage at the COM pin is 1/3 of the supply. This ratio of input bias to supply is optimum for the precision rectifier (aka absolute value circuit) input circuit employed for rectifying ac input waveforms and ensures full input symmetry for low signal voltages.

Capacitor C2 is required for AC input coupling, however an external dc return is unnecessary because biasing occurs internally. SelectC2 for the desired low frequency breakpoint using an input resistance of 16.7 kΩ for the 1/ωRC calculation; C2 = 1 μF for a cutoff at 10 Hz. Figure 11 and Figure 12 show the input and output signal ranges for dual and single supply configurations, respectively. The load resistor, RL, provides a path to sink output sink current when an input signal is disconnected.

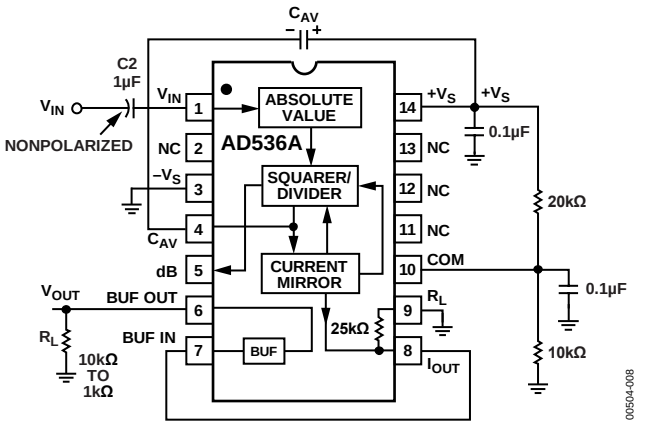



*Figure 17. Single-Supply Connection*

## CHOOSING THE AVERAGING TIME CONSTANT

The AD536A computes the rms of both ac and dc signals. If the input is a slowly varying dc signal, the output of the AD536A tracks the input exactly.

At higher frequencies, the average output of the AD536A approaches the rms value of the input signal. The actual output of the AD536A differs from the ideal output by a dc (or average) error and some amount of ripple, as shown in Figure 18.

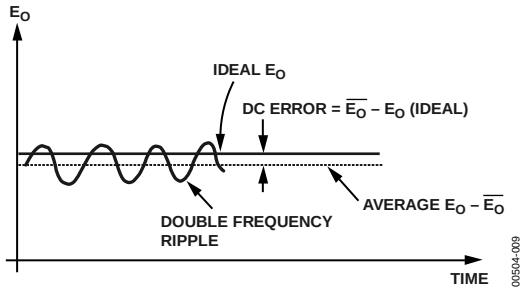


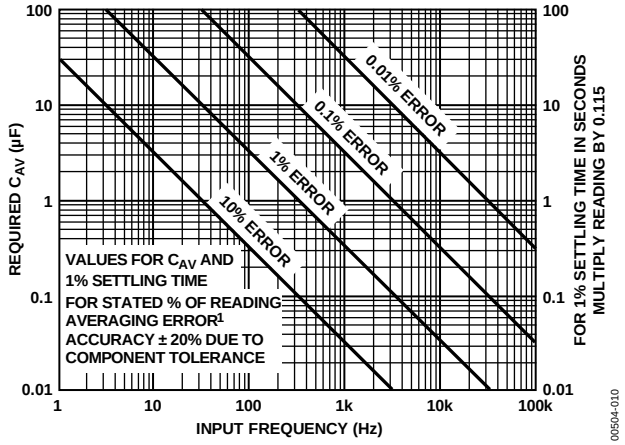

*Figure 18. Typical Output Waveform for Sinusoidal Input*

The dc error is dependent on the input signal frequency and the value of $C_{AV}$. Use Figure 19 to determine the minimum value of $C_{AV}$, which yields a given percentage of dc error above a given frequency using the standard rms connection.

The ac component of the output signal is the ripple. There are two ways to reduce the ripple. The first method involves using a large value of $C_{AV}$. Because the ripple is inversely proportional to $C_{AV}$, a tenfold increase in this capacitance affects a tenfold reduction in ripple.

When measuring waveforms with high crest factors, such as low duty cycle pulse trains, the averaging time constant should be at least 10 times the signal period. For example, a 100 Hz pulse rate requires a 100 ms time constant, which corresponds to a 4 μF capacitor (time constant = 25 ms per μF).

The primary disadvantage in using a large $C_{AV}$ to remove ripple is that the settling time for a step change in input level is increased proportionately. Figure 19 illustrates that the relationship between $C_{AV}$ and 1% settling time is 115 ms for each microfarad of $C_{AV}$. The settling time is twice as great for decreasing signals as it is for increasing signals. The values in Figure 19 are for decreasing signals. Settling time also increases for low signal levels, as shown in Figure 20.




[1]PERCENT DC ERROR AND PERCENT RIPPLE (PEAK)

*Figure 19. Error/Settling Time Graph for Use with the Standard RMS Connection (See Figure 13 Through Figure 15)*

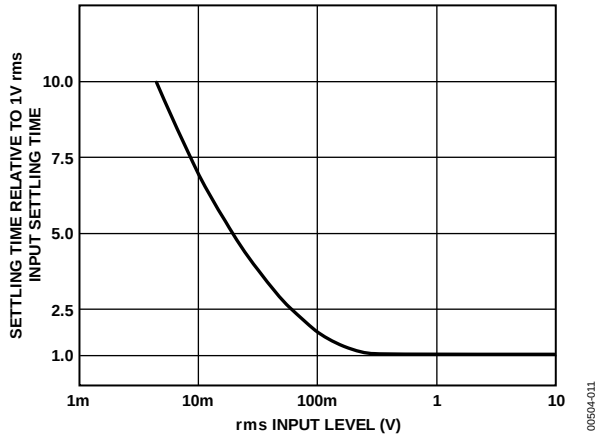


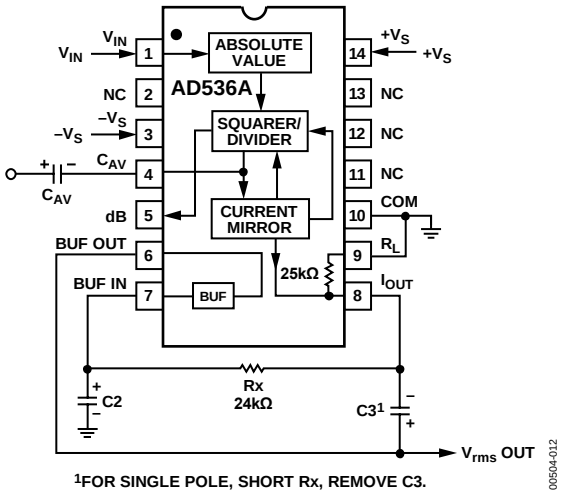

*Figure 20. Settling Time vs. Input Level*

A better method to reduce output ripple is the use of a postfilter. Figure 21 shows a suggested circuit. If a single-pole filter is used (C3 removed, $R_X$ shorted) and C2 is approximately twice the value of $C_{AV}$, the ripple is reduced, as shown in Figure 22, and settling time is increased. For example, with $C_{AV}$ = 1 µF and C2 = 2.2 µF, the ripple for a 60 Hz input is reduced from 10% of reading to approximately 0.3% of reading.

The settling time, however, is increased by approximately a factor of 3. Therefore, the values of $C_{AV}$ and C2 can be reduced to permit faster settling times while still providing substantial ripple reduction.

The two-pole postfilter uses an active filter stage to provide even greater ripple reduction without substantially increasing the settling times over a circuit with a one-pole filter. The values of $C_{AV}$, C2, and C3 can then be reduced to allow extremely fast settling times for a constant amount of ripple. Caution should be exercised in choosing the value of $C_{AV}$, because the dc error is dependent on this value and is independent of the postfilter.

For a more detailed explanation of these topics, refer to the *RMS to DC Conversion Application Guide,* 2nd Edition, available online from Analog Devices, Inc., at www.analog.com.




[1]FOR SINGLE POLE, SHORT Rx, REMOVE C3.

*Figure 21. Two-Pole Postfilter*

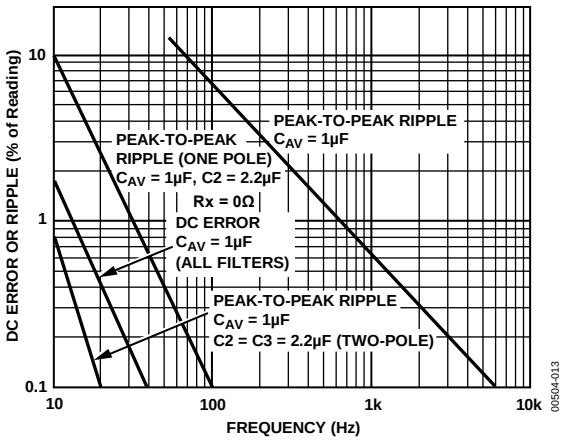
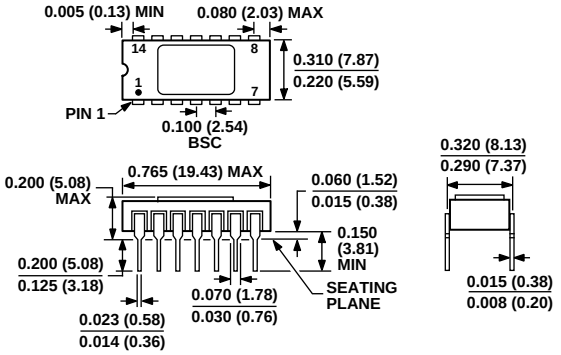


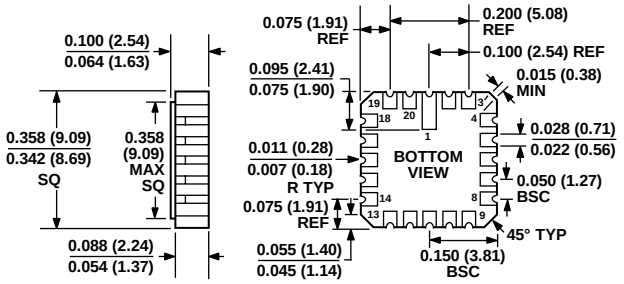

*Figure 22. Performance Features of Various Filter Types (See Figure 13 to Figure 15 for Standard RMS Connection)*

# OUTLINE DIMENSIONS




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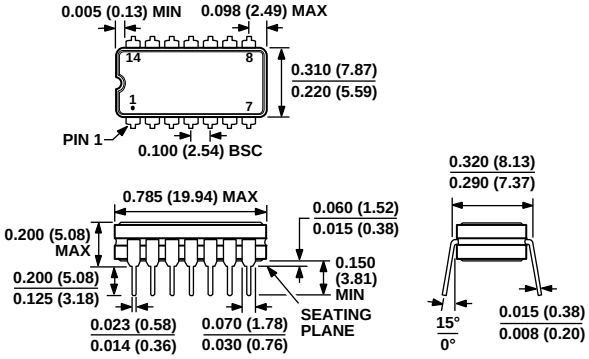
*Figure 23. 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP]*
*(D-14)*
*Dimensions shown in inches and (millimeters)*




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022106-A

*Figure 24. 20-Terminal Ceramic Leadless Chip Carrier [LCC]*
*(E-20-1)*
*Dimensions shown in inches and (millimeters)*




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*Figure 25. 14-Lead Ceramic Dual In-Line Package [CERDIP]*
*(Q-14)*
*Dimensions shown in inches and (millimeters)*

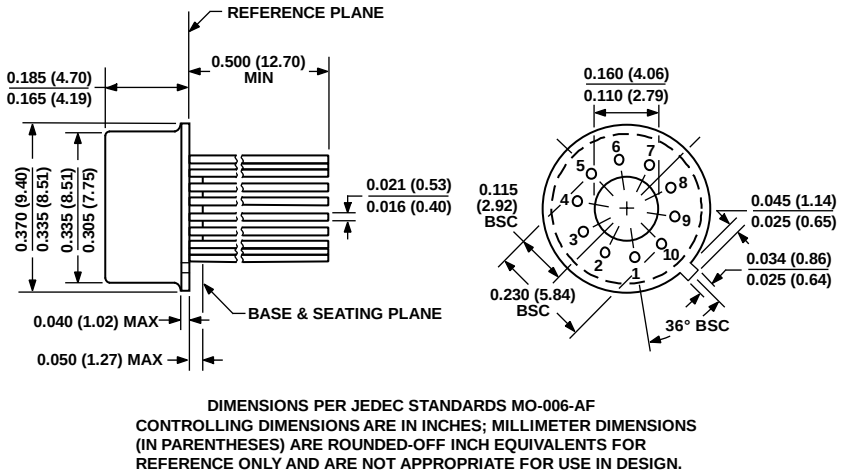



*Figure 26. 10-Pin Metal Header Package [TO-100]*
*(H-10)*
*Dimensions shown in inches and (millimeters)*

## ORDERING GUIDE

| Model[1] | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| AD536AJD | 0°C to +70°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| AD536AJDZ | 0°C to +70°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| AD536AKD | 0°C to +70°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| AD536AKDZ | 0°C to +70°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| AD536AJH | 0°C to +70°C | 10-Pin Metal Header Package [TO-100] | H-10 |
| AD536AJHZ | 0°C to +70°C | 10-Pin Metal Header Package [TO-100] | H-10 |
| AD536AKH | 0°C to +70°C | 10-Pin Metal Header Package [TO-100] | H-10 |
| AD536AKHZ | 0°C to +70°C | 10-Pin Metal Header Package [TO-100] | H-10 |
| AD536AJQ | 0°C to +70°C | 14-Lead Ceramic Dual In-Line Package [CERDIP] | Q-14 |
| AD536AKQ | 0°C to +70°C | 14-Lead Ceramic Dual In-Line Package [CERDIP] | Q-14 |
| AD536ASD | −55°C to +125°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| AD536ASD/883B | −55°C to +125°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| AD536ASE/883B | −55°C to +125°C | 20-Terminal Ceramic Leadless Chip Carrier [LCC] | E-20-1 |
| AD536ASH | −55°C to +125°C | 10-Pin Metal Header Package [TO-100] | H-10 |
| AD536ASH/883B | −55°C to +125°C | 10-Pin Metal Header Package [TO-100] | H-10 |
| AD536ASCHIPS | −55°C to +125°C | Die | |
| 5962-89805012A | −55°C to +125°C | 20-Terminal Ceramic Leadless Chip Carrier [LCC] | E-20-1 |
| 5962-8980501CA | −55°C to +125°C | 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] | D-14 |
| 5962-8980501IA | −55°C to +125°C | 10-Pin Metal Header Package [TO-100] | H-10 |

[1] Z = RoHS Compliant Part.

## NOTES

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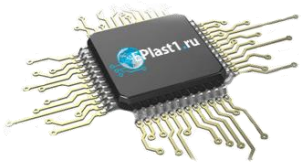
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