FEATURES

High accuracy
- 0.02% maximum nonlinearity, 0 V to 2 V rms input
- 0.1% additional error to crest factor of 3

Wide bandwidth
- 8 MHz at 2 V rms input
- 600 kHz at 100 mV rms

Computes
- True rms
- Square
- Mean square
- Absolute value

dB output (60 dB range)

Chip select/power-down feature allows
- Analog three-state operation
- Quiescent current reduction from 2.2 mA to 350 µA

GENERAL DESCRIPTION

The AD637 is a complete, high accuracy, rms-to-dc converter that computes the true rms value of any complex waveform. It offers performance that is unprecedented in integrated circuit rms-to-dc converters and comparable to discrete and modular techniques in accuracy, bandwidth, and dynamic range. The AD637 computes the true root mean square, mean square, or absolute value of any complex ac (or ac plus dc) input waveform and gives an equivalent dc output voltage. The true rms value of a waveform is more useful than an average rectified signal because it relates directly to the power of the signal. The rms value of a statistical signal relates to the standard deviation of the signal.

Superior crest factor compensation permits measurements of signals with crest factors of up to 10 with less than 1% additional error. The wide bandwidth of the AD637 permits the measurement of signals up to 600 kHz with inputs of 200 mV rms and up to 8 MHz when the input levels are above 1 V rms.

Direct dB value of the rms output with a range of 60 dB is available on a separate pin. An externally programmed reference current allows the user to select the 0 dB reference voltage to correspond to any level between 0.1 V and 2.0 V rms.

A chip select connection on the AD637 permits the user to decrease the supply current from 2.2 mA to 350 µA during periods when the rms function is not in use. This feature facilitates the addition of precision rms measurement to remote or handheld applications where minimum power consumption is critical. In addition, when the AD637 is powered down, the output goes to a high impedance state. This allows several AD637s to be tied together to form a wideband true rms multiplexer.

The input circuitry of the AD637 is protected from overload voltages in excess of the supply levels. The inputs are not damaged by input signals if the supply voltages are lost.

The AD637 is laser wafer trimmed to achieve rated performance without external trimming. The only external component required is a capacitor that sets the averaging period. The value of this capacitor also determines low frequency accuracy, ripple level, and settling time.

The on-chip buffer amplifier is used either as an input buffer or in an active filter configuration. The filter can be used to reduce the amount of ac ripple, thereby increasing accuracy.

The AD637 is available in accuracy Grade J and Grade K for commercial temperature range (0°C to 70°C) applications, accuracy Grade A and Grade B for industrial range (−40°C to +85°C) applications, and accuracy Grade S rated over the −55°C to +125°C temperature range. All versions are available in hermetically sealed, 14-lead SBDIP, 14-lead CERDIP, and 16-lead SOIC_W packages.
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**SPECIFICATIONS**

At 25°C, test frequency = 1 kHz, $V_{IN}$ units are $V_{RMS}$, $VS = \pm 15$ V dc, unless otherwise noted.

### Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions/Comments</th>
<th>AD637J/AD637A</th>
<th>Unit</th>
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<td><strong>TRANSFER FUNCTION</strong></td>
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<td></td>
<td>$V_{OUT} = \sqrt{\text{avg} \times (V_{IN})^2}$</td>
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<tr>
<td><strong>CONVERSION ACCURACY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Error, Internal Trim</td>
<td>See Figure 5</td>
<td>$\pm 1 \pm 0.5$</td>
<td>mV rms ±% of reading</td>
</tr>
<tr>
<td>$V_N = 300$ mV</td>
<td>30</td>
<td>150</td>
<td>$\mu$V/V</td>
</tr>
<tr>
<td>$V_N = -300$ mV</td>
<td>100</td>
<td>300</td>
<td>$\mu$V/V</td>
</tr>
<tr>
<td>DC Reversal</td>
<td>$-2 &lt; V_{IN} &lt; +2$ V</td>
<td>0.25</td>
<td>% of reading</td>
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<tr>
<td>Nonlinearity</td>
<td>2 V full scale</td>
<td>0.04</td>
<td>% of FSR</td>
</tr>
<tr>
<td></td>
<td>7 V full scale</td>
<td>0.05</td>
<td>% of FSR</td>
</tr>
<tr>
<td>Total Error</td>
<td>External trim</td>
<td>$\pm 0.5 \pm 0.1$</td>
<td>mV ± % of reading</td>
</tr>
<tr>
<td><strong>ERROR VS. CREST FACTOR (CF)</strong></td>
<td>Additional, at 1 V rms</td>
<td>Specified accuracy</td>
<td>CF, %</td>
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<tr>
<td>For CF = 1 to 2</td>
<td></td>
<td>$\pm 0.1$</td>
<td>% of reading</td>
</tr>
<tr>
<td>For CF = 3</td>
<td></td>
<td>$\pm 1.0$</td>
<td>% of reading</td>
</tr>
<tr>
<td>For CF = 10</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>AVERAGING TIME CONSTANT</strong></td>
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<td>25</td>
<td>ms/$\mu$F $C_{AV}$</td>
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<tr>
<td><strong>INPUT CHARACTERISTICS</strong></td>
<td>VS = ±15 V</td>
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<td></td>
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<tr>
<td>Signal Range</td>
<td>Continuous</td>
<td>0 to 7</td>
<td>V rms</td>
</tr>
<tr>
<td>Transient</td>
<td>$\pm 15$</td>
<td>V p-p</td>
<td></td>
</tr>
<tr>
<td>VS = ±5 V</td>
<td>Continuous</td>
<td>0 to 4</td>
<td>V rms</td>
</tr>
<tr>
<td>Transient</td>
<td>$\pm 6$</td>
<td>V p-p</td>
<td></td>
</tr>
<tr>
<td>Input Resistance</td>
<td></td>
<td>6.4</td>
<td>kΩ</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>mV</td>
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<td><strong>FREQUENCY RESPONSE</strong></td>
<td>$V_N = 20$ mV</td>
<td>11</td>
<td>kHz</td>
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<tr>
<td>Bandwidth for 1% (0.09 dB)</td>
<td>$V_N = 200$ mV</td>
<td>66</td>
<td>kHz</td>
</tr>
<tr>
<td>Additional Error</td>
<td>$V_N = 2$ V</td>
<td>200</td>
<td>kHz</td>
</tr>
<tr>
<td>±3 dB</td>
<td>$V_N = 20$ mV</td>
<td>150</td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td>$V_N = 200$ mV</td>
<td>1</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>$V_N = 2$ V</td>
<td>8</td>
<td>MHz</td>
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<tr>
<td><strong>OUTPUT CHARACTERISTICS</strong></td>
<td>Offset Voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>vs. temperature</td>
<td>$\pm 0.05$</td>
<td>mV</td>
</tr>
<tr>
<td>Voltage Swing, 2 kΩ load</td>
<td>$VS = \pm 3$ V</td>
<td>$\pm 0.089$</td>
<td>mV/$^\circ$C</td>
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<td>Output Current</td>
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<td>13.5</td>
<td>V</td>
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<td>Short-Circuit Current</td>
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<td>2.2</td>
<td>mA</td>
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<tr>
<td>Resistance</td>
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<td>k$\Omega$</td>
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Parameter | Test Conditions/Comments | AD637J/AD637A |
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<tr>
<td>dB OUTPUT</td>
<td>Error</td>
<td>$V_N = 7 \text{ mV to 7 V rms, 0 dBV}$</td>
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<tr>
<td>Scale Factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale Factor Tempco</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{REF} for 0 dB = 1 V rms</td>
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</tr>
<tr>
<td>I_{REF} Range</td>
<td></td>
<td></td>
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</tbody>
</table>

**BUFFER AMPLIFIER**

- Input Output Voltage Range
- Input Offset Voltage
- Input Current
- Input Resistance
- Output Current
- Short-Circuit Current
- Small Signal Bandwidth
- Slew Rate

**DENOMINATOR INPUT**

- Input Range
- Input Resistance
- Offset Voltage

**CHIP SELECT (CS)**

- RMS On Level
- RMS Off Level
- I_{OUT} of Chip Select

**POWER SUPPLY**

- Operating Voltage Range
- Quiescent Current
- Standby Current
Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions/Comments</th>
<th><strong>AD637K/AD637B</strong></th>
<th>Unit</th>
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<tr>
<td><strong>TRANSFER FUNCTION</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>V_{out} = \sqrt{\text{avg} \times (V_{in})^2}</td>
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<td><strong>CONVERSION ACCURACY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Error, Internal Trim</td>
<td>See Figure 5</td>
<td>±0.5 ± 0.2</td>
<td>mV rms ±% of reading</td>
</tr>
<tr>
<td>T_{MIN} to T_{MAX}</td>
<td></td>
<td>±2.0 ± 0.3</td>
<td>mV ± % of reading</td>
</tr>
<tr>
<td>vs. Supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{IN} = 300 mV</td>
<td></td>
<td>30</td>
<td>μV/V</td>
</tr>
<tr>
<td>V_{IN} = −300 mV</td>
<td></td>
<td>100</td>
<td>μV/V</td>
</tr>
<tr>
<td>DC Reversal</td>
<td>−2 V &lt; V_{IN} &lt; +2 V</td>
<td>0.1</td>
<td>% of reading</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>2V full scale</td>
<td>0.02</td>
<td>% of FSR</td>
</tr>
<tr>
<td></td>
<td>7V full scale</td>
<td>0.05</td>
<td>% of FSR</td>
</tr>
<tr>
<td>Total Error</td>
<td>External trim</td>
<td>±0.25 ± 0.05</td>
<td>mV ± % of reading</td>
</tr>
<tr>
<td><strong>ERROR VS. CREST FACTOR (CF)</strong></td>
<td>Additional, at 1 V rms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For CF = 1 to 2</td>
<td>Specified accuracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For CF = 3</td>
<td>±0.1</td>
<td></td>
<td>% of reading</td>
</tr>
<tr>
<td>For CF = 10</td>
<td>±1.0</td>
<td></td>
<td>% of reading</td>
</tr>
<tr>
<td><strong>AVERAGING TIME CONSTANT</strong></td>
<td></td>
<td>25</td>
<td>ms/μF C_{AV}</td>
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<tr>
<td><strong>INPUT CHARACTERISTICS</strong></td>
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<tr>
<td>Signal Range</td>
<td>VS = ±15 V</td>
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<td>Continuous</td>
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<td>V rms</td>
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<td>VS = ±5 V</td>
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<td>Continuous</td>
<td>0 to 4</td>
<td>V rms</td>
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<td></td>
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<tr>
<td>Input Offset Voltage</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>±0.2</td>
<td></td>
<td>mV</td>
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<tr>
<td><strong>FREQUENCY RESPONSE</strong></td>
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<tr>
<td>Bandwidth for 1% (0.09 dB)</td>
<td>V_{IN} = 20 mV</td>
<td>11</td>
<td>kHz</td>
</tr>
<tr>
<td>Additional Error</td>
<td>V_{IN} = 200 mV</td>
<td>66</td>
<td>kHz</td>
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<td></td>
<td>V_{IN} = 2 V</td>
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<td>V_{IN} = 20 mV</td>
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<td>kHz</td>
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<td></td>
<td>V_{IN} = 200 mV</td>
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<td>MHz</td>
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<td>V_{IN} = 2 V</td>
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<td>MHz</td>
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<td><strong>OUTPUT CHARACTERISTICS</strong></td>
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<tr>
<td>Offset Voltage</td>
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<td>V</td>
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<td>0 to 12.0</td>
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<td>V</td>
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<td></td>
<td>0 to 2</td>
<td>6</td>
<td>mA</td>
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<tr>
<td></td>
<td>6</td>
<td>20</td>
<td>mA</td>
</tr>
<tr>
<td>Output Current</td>
<td>CS high</td>
<td>0.5</td>
<td>Ω</td>
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<tr>
<td>Short-Circuit Current</td>
<td>CS low</td>
<td>100</td>
<td>kΩ</td>
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<tr>
<td>Resistance</td>
<td></td>
<td></td>
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<tr>
<td>dB OUTPUT</td>
<td>V_{IN} = 7 mV to 7 V rms, 0 dBV</td>
<td>±0.3</td>
<td>dBV</td>
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<td>Error</td>
<td>Scale Factor</td>
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<td>mV/dB</td>
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<td>Scale Factor Tempco</td>
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<td>±0.033</td>
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<td>μA</td>
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<td><strong>BUFFER AMPLIFIER</strong></td>
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<td>Input Output Voltage Range</td>
<td>−Vs to (+Vs − 2.5)</td>
<td>0 to 10</td>
<td>V</td>
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<td>Input Offset Voltage</td>
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<td>±0.2</td>
<td>mV</td>
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<tr>
<td>Input Current</td>
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<td>±2</td>
<td>nA</td>
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<td>Input Resistance</td>
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<td>Output Current</td>
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<td>mA</td>
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<td>Short-Circuit Current</td>
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<td>MHz</td>
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<td>Small Signal Bandwidth</td>
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<td>5</td>
<td>V/μs</td>
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<tr>
<td>Slew Rate</td>
<td>2 kΩ load, to −Vs</td>
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<tr>
<td><strong>DENOMINATOR INPUT</strong></td>
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</tr>
<tr>
<td>Input Range</td>
<td>0 to 10</td>
<td>20</td>
<td>V</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>20</td>
<td>25</td>
<td>kΩ</td>
</tr>
<tr>
<td>Offset Voltage</td>
<td>±0.2</td>
<td>±0.5</td>
<td>mV</td>
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<tr>
<td><strong>CHIP SELECT (CS)</strong></td>
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<td>RMS On Level</td>
<td>Open or 2.4 &lt; Vc &lt; +Vs</td>
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<td>V</td>
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<tr>
<td>RMS Off Level</td>
<td>Vc &lt; 0.2</td>
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<td>V</td>
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<td>I\text{OUT} of Chip Select</td>
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<td>μA</td>
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<td>CS high</td>
<td>0</td>
<td>μA</td>
</tr>
<tr>
<td>On Time Constant</td>
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<td>μs</td>
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<tr>
<td>Off Time Constant</td>
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<td>μs</td>
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<td><strong>POWER SUPPLY</strong></td>
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<td>Operating Voltage Range</td>
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<tr>
<td>Standby Current</td>
<td>350</td>
<td>450</td>
<td>μA</td>
</tr>
</tbody>
</table>
Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Conditions/Comments</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSFER FUNCTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( V_{OUT} = \sqrt{\text{avg} \times (V_{IN})^2} )</td>
</tr>
<tr>
<td>CONVERSION ACCURACY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>mV rms ±% of reading</td>
</tr>
<tr>
<td>Total Error, Internal Trim</td>
<td>See Figure 5</td>
<td>±1</td>
<td>±0.5</td>
<td>±0.7</td>
<td>mV ±% of reading</td>
</tr>
<tr>
<td>vs. Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( V_{IN} = 300 \text{ mV} )</td>
<td>30</td>
<td>150</td>
<td>300</td>
<td>μV/V</td>
</tr>
<tr>
<td></td>
<td>( V_{IN} = -300 \text{ mV} )</td>
<td>100</td>
<td>300</td>
<td></td>
<td>μV/V</td>
</tr>
<tr>
<td>DC Reversal</td>
<td>(-2 \text{ V} &lt; V_{IN} &lt; +2 \text{ V})</td>
<td>0.25</td>
<td></td>
<td></td>
<td>% of reading</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>2V full scale</td>
<td>0.04</td>
<td></td>
<td></td>
<td>% of FSR</td>
</tr>
<tr>
<td></td>
<td>7V full scale</td>
<td>0.05</td>
<td></td>
<td></td>
<td>% of FSR</td>
</tr>
<tr>
<td>Total Error</td>
<td>External trim</td>
<td>±0.5</td>
<td>±0.1</td>
<td></td>
<td>mV ±% of reading</td>
</tr>
<tr>
<td>ERROR VS. CREST FACTOR (CF)</td>
<td>Additional, at 1 V rms</td>
<td></td>
<td></td>
<td></td>
<td>CF, %</td>
</tr>
<tr>
<td>For CF = 1 to 2</td>
<td>Specified accuracy</td>
<td>±0.1</td>
<td></td>
<td></td>
<td>% of reading</td>
</tr>
<tr>
<td>For CF = 3</td>
<td></td>
<td>±1.0</td>
<td></td>
<td></td>
<td>% of reading</td>
</tr>
<tr>
<td>AVERAGING TIME CONSTANT</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>ms/μF C_{in}</td>
</tr>
<tr>
<td>INPUT CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signal Range</td>
<td>( VS = \pm 15 \text{ V} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous</td>
<td>0 to 7</td>
<td></td>
<td></td>
<td></td>
<td>V rms</td>
</tr>
<tr>
<td>Transient</td>
<td>( VS = \pm 5 \text{ V} )</td>
<td>±15</td>
<td></td>
<td></td>
<td>V p-p</td>
</tr>
<tr>
<td>Continuous</td>
<td>0 to 4</td>
<td></td>
<td></td>
<td></td>
<td>V rms</td>
</tr>
<tr>
<td>Transient</td>
<td>( VS = \pm 3 \text{ V} )</td>
<td>±6</td>
<td></td>
<td></td>
<td>V p-p</td>
</tr>
<tr>
<td>Input Resistance</td>
<td></td>
<td>6.4</td>
<td>8</td>
<td>9.6</td>
<td>kΩ</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td></td>
<td>±0.5</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>FREQUENCY RESPONSE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bandwidth for 1% (0.09 dB) Error</td>
<td>( V_{IN} = 20 \text{ mV} )</td>
<td>11</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td>( V_{IN} = 200 \text{ mV} )</td>
<td>66</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td>( V_{IN} = 2 \text{ V} )</td>
<td>200</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>±3 dB</td>
<td>( V_{IN} = 20 \text{ mV} )</td>
<td>150</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td>( V_{IN} = 200 \text{ mV} )</td>
<td>1</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td>( V_{IN} = 2 \text{ V} )</td>
<td>8</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>OUTPUT CHARACTERISTICS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset Voltage</td>
<td>vs. temperature</td>
<td>±1</td>
<td>±0.04</td>
<td>±0.07</td>
<td>mV/mV°C</td>
</tr>
<tr>
<td>Voltage Swing, 2 kΩ load</td>
<td>( VS = \pm 3 \text{ V} )</td>
<td>0 to 12.0</td>
<td>13.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output Current</td>
<td></td>
<td>0 to 2</td>
<td>2.2</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Short-Circuit Current</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Resistance</td>
<td>CS high</td>
<td>0.5</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td></td>
<td>CS low</td>
<td>100</td>
<td></td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td>dB OUTPUT</td>
<td>( V_{IN} = 7 \text{ mV to 7 V rms, 0 dBV} )</td>
<td>±0.5</td>
<td></td>
<td></td>
<td>dBV</td>
</tr>
<tr>
<td>Scale Factor</td>
<td></td>
<td>−3</td>
<td></td>
<td></td>
<td>mV/dB</td>
</tr>
<tr>
<td>Scale Factor Tempco</td>
<td></td>
<td>+0.33</td>
<td>±% of reading/°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>−0.033</td>
<td></td>
<td></td>
<td>dB/C</td>
</tr>
<tr>
<td>I_{REF} for 0 dB = 1 V rms</td>
<td></td>
<td>5</td>
<td>20</td>
<td>80</td>
<td>μA</td>
</tr>
<tr>
<td>I_{REF} Range</td>
<td></td>
<td>1</td>
<td>100</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Parameter</td>
<td>Test Conditions/Comments</td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Unit</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>BUFFER AMPLIFIER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Output Voltage Range</td>
<td>−Vs to (+Vs − 2.5)</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>±0.8 ±2</td>
<td></td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>Input Current</td>
<td>±2 ±10</td>
<td></td>
<td></td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>10Ω</td>
<td></td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>Output Current</td>
<td>−0.13 +5</td>
<td></td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Short-Circuit Current</td>
<td>20 mA</td>
<td></td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Small Signal Bandwidth</td>
<td>1 MHz</td>
<td></td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>2 kΩ load, to −Vs</td>
<td></td>
<td></td>
<td></td>
<td>V/μs</td>
</tr>
<tr>
<td>DENOMINATOR INPUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Range</td>
<td>0 to 10</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>20 25 30</td>
<td></td>
<td></td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td>Offset Voltage</td>
<td>±0.2 ±0.5</td>
<td></td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>CHIP SELECT (CS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMS On Level</td>
<td>Open or 2.4 &lt; Vc &lt; +Vs</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>RMS Off Level</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IOUT of Chip Select</td>
<td>CS low</td>
<td>10 μA</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td>CS high</td>
<td>0 μA</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>On Time Constant</td>
<td>10 + ((25 kΩ) × CAV)</td>
<td></td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>Off Time Constant</td>
<td>10 + ((25 kΩ) × CAV)</td>
<td></td>
<td></td>
<td></td>
<td>μs</td>
</tr>
<tr>
<td>POWER SUPPLY</td>
<td></td>
<td>±3.0 ±18</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Operating Voltage Range</td>
<td>±3.0 ±18</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>2.2 3</td>
<td></td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Standby Current</td>
<td>350 450</td>
<td></td>
<td></td>
<td></td>
<td>μA</td>
</tr>
</tbody>
</table>
### ABSOLUTE MAXIMUM RATINGS

Table 4.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESD Rating</td>
<td>500 V dc</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>±18 V dc</td>
</tr>
<tr>
<td>Internal Quiescent Power Dissipation</td>
<td>108 mW</td>
</tr>
<tr>
<td>Output Short-Circuit Duration</td>
<td>Indefinite</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>−65°C to +150°C</td>
</tr>
<tr>
<td>Lead Temperature (Soldering 10 sec)</td>
<td>300°C</td>
</tr>
<tr>
<td>Rated Operating Temperature Range</td>
<td></td>
</tr>
<tr>
<td>AD637J, AD637K</td>
<td>0°C to 70°C</td>
</tr>
<tr>
<td>AD637A, AD637B</td>
<td>−40°C to +85°C</td>
</tr>
<tr>
<td>AD637S, 5962-896301CA</td>
<td>−55°C to +125°C</td>
</tr>
</tbody>
</table>

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

### 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.
PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

Table 5. 14-Lead SBDIP/CERDIP Pin Function Descriptions

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Mnemonic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BUFF IN</td>
<td>Buffer Input</td>
</tr>
<tr>
<td>2, 12</td>
<td>NIC</td>
<td>No Internal Connection</td>
</tr>
<tr>
<td>3</td>
<td>COMMON</td>
<td>Analog Common</td>
</tr>
<tr>
<td>4</td>
<td>OUTPUT OFFSET</td>
<td>Output Offset</td>
</tr>
<tr>
<td>5</td>
<td>CS</td>
<td>Chip Select</td>
</tr>
<tr>
<td>6</td>
<td>DEN INPUT</td>
<td>Denominator Input</td>
</tr>
<tr>
<td>7</td>
<td>dB OUTPUT</td>
<td>dB Output</td>
</tr>
<tr>
<td>8</td>
<td>C\text{AV}</td>
<td>Averaging Capacitor Connection</td>
</tr>
<tr>
<td>9</td>
<td>RMS OUT</td>
<td>RMS Output</td>
</tr>
<tr>
<td>10</td>
<td>−V\text{S}</td>
<td>Negative Supply Rail</td>
</tr>
<tr>
<td>11</td>
<td>+V\text{S}</td>
<td>Positive Supply Rail</td>
</tr>
<tr>
<td>13</td>
<td>V\text{IN}</td>
<td>Signal Input</td>
</tr>
<tr>
<td>14</td>
<td>BUFF OUT</td>
<td>Buffer Output</td>
</tr>
</tbody>
</table>

Table 6. 16-Lead SOIC_W Pin Function Descriptions

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Mnemonic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BUFF IN</td>
<td>Buffer Input</td>
</tr>
<tr>
<td>2, 8, 9, 14</td>
<td>NIC</td>
<td>No Internal Connection</td>
</tr>
<tr>
<td>3</td>
<td>COMMON</td>
<td>Analog Common</td>
</tr>
<tr>
<td>4</td>
<td>OUTPUT OFFSET</td>
<td>Output Offset</td>
</tr>
<tr>
<td>5</td>
<td>CS</td>
<td>Chip Select</td>
</tr>
<tr>
<td>6</td>
<td>DEN INPUT</td>
<td>Denominator Input</td>
</tr>
<tr>
<td>7</td>
<td>dB OUTPUT</td>
<td>dB Output</td>
</tr>
<tr>
<td>10</td>
<td>C\text{AV}</td>
<td>Averaging Capacitor Connection</td>
</tr>
<tr>
<td>11</td>
<td>RMS OUT</td>
<td>RMS Output</td>
</tr>
<tr>
<td>12</td>
<td>−V\text{S}</td>
<td>Negative Supply Rail</td>
</tr>
<tr>
<td>13</td>
<td>+V\text{S}</td>
<td>Positive Supply Rail</td>
</tr>
<tr>
<td>15</td>
<td>V\text{IN}</td>
<td>Signal Input</td>
</tr>
<tr>
<td>16</td>
<td>BUFF OUT</td>
<td>Buffer Output</td>
</tr>
</tbody>
</table>
The AD637 embodies an implicit solution of the rms equation that overcomes the inherent limitations of straightforward rms computation. The actual computation performed by the AD637 follows the equation:

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

Figure 4 is a simplified schematic of the AD637, subdivided into four major sections: absolute value circuit (active rectifier), squarer/divider, filter circuit, and buffer amplifier. The input voltage ($V_{IN}$), which can be ac or dc, is converted to a unipolar current ($I_1$) by the A1 and A2 absolute value circuit. $I_1$ drives one input of the squarer/divider, which has the transfer function:

$$I_4 = \frac{I_2^2}{I_3}$$

The output current of the squarer/divider, $I_4$, drives A4, forming a low-pass filter with the external averaging capacitor. If the RC time constant of the filter is much greater than the longest period of the input signal, then the A4 output is proportional to the average of $I_4$. The output of this filter amplifier is used by A3 to provide the denominator current $I_3$, which equals Avg $I_4$ and is returned to the squarer/divider to complete the implicit rms computation

$$I_4 = \text{Avg} \left[ \frac{I_2^2}{I_4} \right] = I_4 \text{ rms}$$

and

$$V_{OUT} = V_{IN \ rms}$$

To compute the absolute value of the input signal, the averaging capacitor is omitted. However, a small capacitance value at the averaging capacitor pin is recommended to maintain stability; 5 pF is sufficient for this purpose. The circuit operates identically to that of the rms configuration, except that $I_3$ is now equal to $I_4$, giving

$$I_4 = \frac{I_2^2}{I_3}$$

$$I_4 = |I_1|$$

The denominator current can also be supplied externally by providing a reference voltage ($V_{REF}$) to Pin 6. The circuit operates identically to the rms case, except that $I_3$ is now proportional to $V_{REF}$. Therefore,

$$I_4 = \text{Avg} \frac{I_2^2}{I_3}$$

and

$$V_{OUT} = \frac{V_{IN}^2}{V_{DEN}}$$

This is the mean square of the input signal.
APPLICATIONS INFORMATION

STANDARD CONNECTION
The AD637 is simple to connect for a majority of rms measurements. In the standard rms connection shown in Figure 5, only a single external capacitor is required to set the averaging time constant. In this configuration, the AD637 computes the true rms of any input signal. An averaging error, the magnitude of which is dependent on the value of the averaging capacitor, is present at low frequencies. For example, if the filter capacitor, CAV, is 4 µF, the error is 0.1% at 10 Hz and increases to 1% at 3 Hz. To measure ac signals, the AD637 can be ac-coupled by adding a nonpolar capacitor in series with the input, as shown in Figure 5.

![Figure 5. Standard RMS Connection](image)

The performance of the AD637 is tolerant of minor variations in the power supply voltages; however, if the supplies used exhibit a considerable amount of high frequency ripple, it is advisable to bypass both supplies to ground through a 0.1 µF ceramic disc capacitor placed as close to the device as possible.

The output signal range of the AD637 is a function of the supply voltages, as shown in Figure 6. Use the output voltage buffered or nonbuffered, depending on the characteristics of the load. Connect the buffer input (Pin 1) to common if buffering is not required. The output of the AD637 is capable of driving 5 mA into a 2 kΩ load without degrading the accuracy of the device.

![Figure 6. Maximum Vout vs. Supply Voltage](image)

CHIP SELECT
The AD637 includes a chip select feature that allows the user to decrease the quiescent current of the device from 2.2 mA to 350 µA. This is done by driving CS, Pin 5, to below 0.2 V dc. Under these conditions, the output goes into a high impedance state. In addition to reducing the power consumption, the outputs of multiple devices can be connected in parallel to form a wide bandwidth rms multiplexer. Tie Pin 5 high to disable the chip select.

OPTIONAL TRIMS FOR HIGH ACCURACY
The AD637 includes provisions for trimming out output offset and scale factor errors resulting in significant reduction in the maximum total error, as shown in Figure 7. The residual error is due to a fixed input offset in the absolute value circuit and the residual nonlinearity of the device.

![Figure 7. Maximum Total Error vs. Input Level AD637K Internal and External Trims](image)
Referring to Figure 8 for optional external gain and offset trim schematic. The following sections describe trimming for greater accuracy in detail.

**Offset Trim**

Ground the input signal (VIN) and adjust R1 until the output voltage at Pin 9 measures 0 V. Alternatively, apply the least expected value of VIN at the input VIN and adjust R1 until the dc output voltage at Pin 9 measures the same value as the rms input.

**Scale Factor Trim**

Insert Resistor R4 in series with the input to decrease the range of the scale factor. Connect a precision source to Pin 13 and adjust the output for the desired full-scale input to VIN, using either a calibrated dc or 1 kHz ac voltage, and adjust Resistor R3 to give the correct output at Pin 9 (that is, 1 V rms at the input results in a dc output voltage of 1.000 V dc). A 2 V p-p sine wave input yields 0.707 V dc at the output. Remaining errors are due to the nonlinearity.

Increasing the value of the averaging capacitor or adding a post-rms filter network reduces the ripple error.

The dc error appears as a frequency dependent offset at the output of the AD637 and follows the relationship

\[
\text{DC Error} = \text{Average of Output} - \text{Ideal}
\]

The ac ripple component of averaging error is greatly reduced by increasing the value of the averaging capacitor. However, the value of the averaging capacitor increases exponentially while the settling time increases directly proportion to the value of the averaging capacitor (Ts = 115 ms/µF of averaging capacitance).
A preferable ripple reduction method is to use a post conversion one or two-pole low-pass filter, as shown in Figure 11. Usually a single-pole filter gives the best overall compromise between ripple and settling time. Use the two-pole Sallen-Key for more ripple attenuation.

Figure 11. 2-Pole Sallen-Key Filter

Figure 12 shows values of \( C_{AW} \) and the corresponding averaging error as a function of sine wave frequency for the standard rms connection. The 1% settling time is shown on the right side of Figure 12.

Figure 13 shows the relationship between the averaging error, signal frequency settling time, and averaging capacitor value. Figure 13 is drawn for filter capacitor values of 3.3\( \times \) the averaging capacitor value. This ratio sets the magnitude of the ac and dc errors equal at 50 Hz. As an example, by using a 1 \( \mu \)F averaging capacitor and a 3.3 \( \mu \)F filter capacitor, the ripple for a 60 Hz input signal is reduced from 5.3% of the reading using the averaging capacitor alone to 0.15% using the 1-pole filter. This gives a factor of 30 reduction in ripple, and yet the settling time only increases by a factor of 3. The values of Filter Capacitor \( C_{AW} \) and Filter Capacitor \( C_2 \) can be calculated for the desired value of averaging error and settling time by using Figure 13.

The symmetry of the input signal also has an effect on the magnitude of the averaging error. Table 7 gives the practical component values for various types of 60 Hz input signals. These capacitor values can be directly scaled for frequencies other than 60 Hz—that is, for 30 Hz, these values are doubled, and for 120 Hz they are halved.

Use Figure 14 to determine the required value of \( C_{AW} \), \( C_2 \), and \( C_3 \) for the desired level of ripple and settling time.
Table 7. Practical Values of C_{AV} and C2 for Various Input Waveforms

<table>
<thead>
<tr>
<th>Input Waveform and Period</th>
<th>Absolute Value Circuit Waveform and Period</th>
<th>Minimum R × C_{AV} Time Constant</th>
<th>Recommended Standard Values for C_{AV} and C2 for 1% Averaging Error @ 60 Hz with T = 16.6 ms</th>
<th>1% Settling Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><img src="image" alt="Symmetrical Sine Wave" /></td>
<td>1/2T</td>
<td></td>
<td>0.47</td>
</tr>
<tr>
<td>B</td>
<td><img src="image" alt="Sine Wave with dc Offset" /></td>
<td>T</td>
<td></td>
<td>0.82</td>
</tr>
<tr>
<td>C</td>
<td><img src="image" alt="Pulse Train Waveform" /></td>
<td>10 (T − T_2)</td>
<td></td>
<td>6.8</td>
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<tr>
<td>D</td>
<td><img src="image" alt="Pulse Train Waveform" /></td>
<td>10 (T − 2T_2)</td>
<td></td>
<td>5.6</td>
</tr>
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</table>

FREQUENCY RESPONSE

The frequency response of the AD637 at various signal levels is shown in Figure 15. The dashed lines show the upper frequency limits for 1%, 10%, and ±3 dB of additional error. For example, note that for 1% additional error with a 2 V rms input, the highest frequency allowable is 200 kHz. A 200 mV signal can be measured with 1% error at signal frequencies up to 100 kHz.

To take full advantage of the wide bandwidth of the AD637, use care in the selection of the input buffer amplifier. To ensure that the input signal is accurately presented to the converter, the input buffer must have a ~3 dB bandwidth that is wider than that of the AD637. Note the importance of slew rate in this application. For example, the minimum slew rate required for a 1 V rms, 5 MHz, sine wave input signal is 44 V/μs. The user is cautioned that this is the minimum rising or falling slew rate and that care must be exercised in the selection of the buffer amplifier, because some amplifiers exhibit a two-to-one difference between rising and falling slew rates. The AD845 is recommended as a precision input buffer.

![Figure 15. Frequency Response](image)
AC MEASUREMENT ACCURACY AND CREST FACTOR

Crest factor is often overlooked in determining the accuracy of an ac measurement. Crest factor is defined as the ratio of the peak signal amplitude to the rms value of the signal (\( \text{CF} = \frac{V_p}{V_{\text{rms}}} \)). Most common waveforms, such as sine and triangle waves, have relatively low crest factors (\( \leq 2 \)). 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 (\( \text{CF} = \frac{1}{\eta} \)).

\[
\eta = \frac{V_p}{V_{\text{rms}}} = \frac{2V}{V} = 2\sqrt{2} = 2.828
\]

\[
e_{\text{IN(RMS)}} = 1 \text{ V RMS}
\]

\[
100\mu\text{s} = \text{DUTY CYCLE} = \frac{100\mu\text{s}}{10\mu\text{s}} = 10
\]

\[
\text{CF} = 10\sqrt{\eta}
\]

Figure 16. Duty Cycle Timing

Figure 17. AD637 Error vs. Pulse Width Rectangular Pulse

Figure 18. Additional Error vs. Crest Factor

Figure 19. Error vs. RMS Input Level for Three Common Crest Factors

CONNECTION FOR dB OUTPUT

Another feature of the AD637 is the logarithmic, or decibel, output. The internal circuit that computes dB works well over a 60 dB range. Figure 20 shows the dB measurement connection. The user selects the 0 dB level by setting R1 for the proper 0 dB reference current, which is set to cancel the log output current from the squarer/divider circuit at the desired 0 dB point. The external op amp is used to provide a more convenient scale and to allow compensation of the 0.33%/°C temperature drift of the dB circuit. The temperature resistor, R3, as shown in Figure 20, is available from Precision Resistor Co., Inc., in Largo, Fla. (Model PT146).
dB CALIBRATION

Refer to Figure 20:

- Set $V_{in} = 1.00$ V dc or 1.00 V rms
- Adjust $R_1$ for 0 dB output = 0.00 V
- Set $V_{in} = 0.1$ V dc or 0.10 V rms
- Adjust $R_2$ for dB output = −2.00 V

Any other dB reference can be used by setting $V_{in}$ and $R_1$ accordingly.

Figure 20. dB Connection
LOW FREQUENCY MEASUREMENTS

If the frequencies of the signals to be measured are below 10 Hz, the value of the averaging capacitor required to deliver even 1% averaging error in the standard rms connection becomes extremely large. Figure 21 shows an alternative method of obtaining low frequency rms measurements. Determine the averaging time constant by the product of R and CAV1, in this circuit, 0.5 sec/µF of CAV. This circuit permits a 20:1 reduction in the value of the averaging capacitor, permitting the use of high quality tantalum capacitors. It is suggested that the 2-pole, Sallen-Key filter shown in Figure 21 be used to obtain a low ripple level and minimize the value of the averaging capacitor.

If the frequency of interest is below 1 Hz, or if the value of the averaging capacitor is still too large, increase the 20:1 ratio. This is accomplished by increasing the value of R. If this is done, it is suggested that a low input current, low offset voltage amplifier, such as the AD548, be used instead of the internal buffer amplifier. This is necessary to minimize the offset error introduced by the combination of amplifier input currents and the larger resistance.

VECTOR SUMMATION

Use two AD637s for vector summation as shown in Figure 22. Here, the averaging capacitors are omitted (nominal 100 pF capacitors are used to ensure stability of the filter amplifier), and the outputs are summed as shown. The output of the circuit is

\[ V_{OUT} = \sqrt{V_X^2 + V_Y^2} \]

This concept can be expanded to include additional terms by feeding the signal from Pin 9 of each additional AD637 through a 10 kΩ resistor to the summing junction of the AD711 and tying all of the denominator inputs (Pin 6) together.

If CAV is added to IC1 in this configuration, then the output is

\[ \sqrt{V_X^2 + V_Y^2} \]

If the averaging capacitor is included on both IC1 and IC2, the output is

\[ \sqrt{V_X^2 + V_Y^2} \]

This circuit has a dynamic range of 10 V to 10 mV and is limited only by the 0.5 mV offset voltage of the AD637. The useful bandwidth is 100 kHz.
Figure 22. Vector Sum Configuration
EVALUATION BOARD

Figure 23 shows a digital image of the AD637-EVALZ, an evaluation board specially designed for the AD637. It is available at www.analog.com and is fully tested and ready for bench testing after connecting power and signal I/O. The circuit is configured for dual power supplies, and standard BNC connectors serve as the signal input and output ports.

Referring to the schematic in Figure 30, the input connector RMS_IN is capacitively coupled to Pin 15 (Vin of SOIC package) of the AD637. The DC_OUT connector is connected to Pin 11, RMS_OUT, with provisions for connections to the output buffer between Pin 1 and Pin 16. The buffer is an uncommitted op amp, and is configured on the AD637-EVALZ as a low-pass Sallen-Key filter whose fc < 0.5 Hz. Users can connect to the buffer by moving the FILTER switch to the on position. DC_OUT is still the output of the AD637, and the test loop, BUF_OUT, is the output of the buffer. The R2 trimmer adjusts the output offset voltage.

The LPF frequency is changed by changing the component values of CF1, CF2, R4, and R5. See Figure 24 and Figure 30 to locate these components. Note that a wide range of capacitor and resistor values can be used with the AD637 buffer amplifier.
Figure 30. Evaluation Board Schematic

Figure 31. AD637-EVALZ Typical Bench Configuration
OUTLINE DIMENSIONS

CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

Figure 32. 14-Lead Side-Brazed Ceramic Dual In-Line Package [SBDIP] (D-14)
Dimensions shown in inches and (millimeters)

Figure 33. 14-Lead Ceramic Dual In-Line Package [CERDIP] (Q-14)
Dimensions shown in inches and (millimeters)
### ORDERING GUIDE

<table>
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<tr>
<th>Model</th>
<th>Notes</th>
<th>Temperature Range</th>
<th>Package Description</th>
<th>Package Option</th>
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1. ^2 Z = RoHS Compliant Part.
2. ^A standard microcircuit drawing is available.