National Semiconductor

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LH0091 True RMS to DC Converter

General Description

The LH0091, rms to dc converter generates a dc output equal to the rms value of any input per the transfer function:

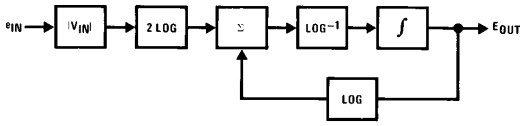
$$E_{OUT(DC)} = \sqrt{\frac{1}{T}\int_0^T E_{IN}^2(t)\,dt}$$

The device provides rms conversion to an accuracy of 0.1% of reading using the external trim procedure. It is possible to trim for maximum accuracy (0.5 mV ± 0.05% typ) for decade ranges i.e., 10 mV ⟶ 100 mV, 0.7V ⟶ 7V, etc.

Features

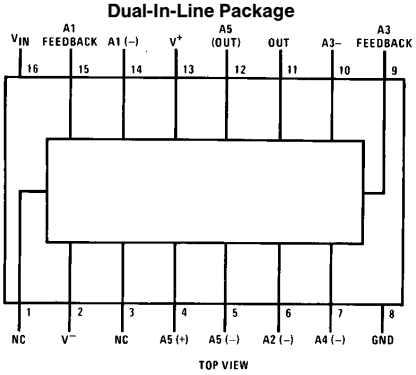
- Low cost
- True rms conversion
- 0.5% of reading accuracy untrimmed
- 0.05% of reading accuracy with external trim
- Minimum component count
- Input voltage to ±15V peak for $V_S = \pm 15V$
- Uncommitted amplifier for filtering, gain, or high crest factor configuration
- Military or commercial temperature range.

Block and Connection Diagrams



Dual-In-Line Package
Order Number LH0091CD
See Package D16D

Dual-In-Line Package



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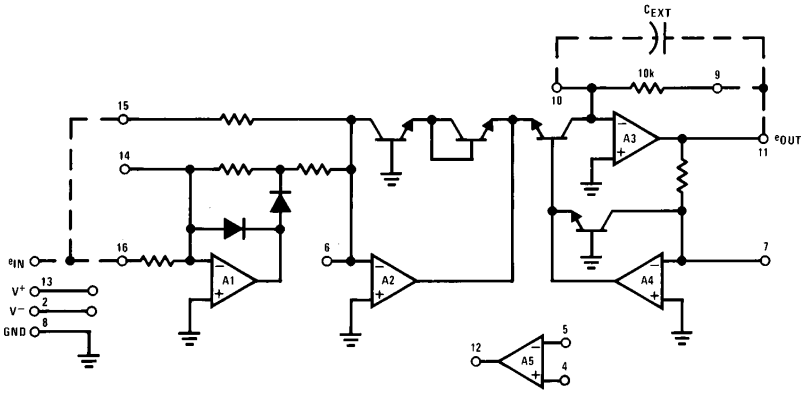
Simplified Schematic



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Note: Dotted lines denote external connections.

RRD-B30M115/Printed in U. S. A.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	±22V
Input Voltage	±15V peak
Output Short Circuit Duration	Continuous

	T_{MIN}	T_{MAX}
Operating Temperature Range		
LH0091C	−25°C	85°C
Storage Temperature Range		
LH0091C	−25°C to +85°C	
Lead Temp. (Soldering, 10 seconds)		260°C

Electrical Characteristics $V_S = \pm 15V$, $T_A = 25°C$ unless otherwise noted

Transfer Function $= E_{O(DC)} = \sqrt{\frac{1}{T}\int_0^T E_{IN}^2(t)\,dt}$

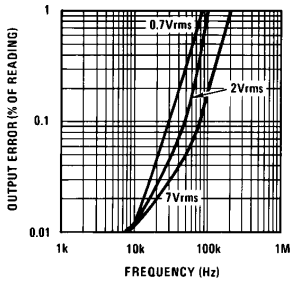
Parameter	Conditions	Min	Typ	Max	Units
ACCURACY (See Definition of Terms)					
Total Unadjusted Error	50 mVrms ≤ V_{IN} ≤ 7Vrms *(Figure 1)*		20, ±0.5	40, ±1.0	mV, %
Total Adjusted Error	50 mVrms ≤ V_{IN} ≤ 7Vrms *(Figure 3)*		0.5, ±0.05	1, ±0.2	mV, %
Total Unadjusted Error vs Temperature	−25°C ≤ T_A ≤ +70°C		0.25, ±0.2%		mV, %/°C
Total Unadjusted Error vs Supply Voltage			1		mV/V
AC PERFORMANCE					
Frequency for Specified Adjusted Error	Input = 7Vrms, Sinewave *(Figure 3)* Input = 0.7Vrms, Sinewave *(Figure 3)* Input = 0.1Vrms, Sinewave *(Figure 3)*	30	70 40 20		kHz KHz kHz
Frequency for 1% Additional Error	Input = 7Vrms, Sinewave *(Figure 3)* Input = 0.7Vrms, Sinewave *(Figure 3)* Input = 0.1Vrms, Sinewave *(Figure 3)*	100	200 75 50		kHz kHz kHz
Bandwidth (3 dB)	Input = 7Vrms, Sinewave *(Figure 3)* Input = 0.7Vrms, Sinewave *(Figure 3)* Input = 0.1Vrms, Sinewave *(Figure 3)*		2 1.5 0.8		MHz MHz MHz
Crest Factor	Rated Adjusted Accuracy Using the High Crest Factor Circuit *(Figure 5)*	5	10		
INPUT CHARACTERISTICS					
Input Voltage Range	For Rated Performance	±0.05		±11	Vpeak
Input Impedance		4.5	5		kΩ
OUTPUT CHARACTERISTICS					
Rated Output Voltage	$R_L \geq 2.5$ kΩ	10			V
Output Short Circuit Current			22		mA
Output Impedance			1		Ω
POWER SUPPLY REQUIREMENTS					
Operating Range		±5		±20	V
Quiescent Current	$V_S = \pm 15V$		14	18	mA

Op Amp Electrical Characteristics $V_S = \pm 15V$, $T_A = 25°C$ unless otherwise noted

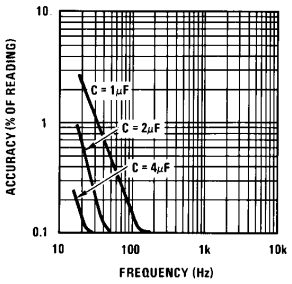
Parameter		Conditions	Min	Typ	Max	Units
V_{OS}	Input Offset Voltage	$R_S \leq 10\ k\Omega$		1.0	10	mV
I_{OS}	Input Offset Current			4.0	200	nA
I_B	Input Bias Current			30	500	nA
R_{IN}	Input Resistance			2.5		MΩ
A_{OL}	Large Signal Voltage Gain	$V_{OUT} = \pm 10V$, $R_L \geq 2\ k\Omega$	15	160		V/mv
V_O	Output Voltage Swing	$R = 10\ k\Omega$	±10	±13		V
V_I	Input Voltage Range		±10			V
CMRR	Common-Mode Rejection Ratio	$R_S \leq 10\ k\Omega$		90		dB
PSRR	Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$		96		dB
I_{SC}	Output Short-Circuit Current			25		mA
S_r	Slew Rate (Unity Gain)			0.5		V/μs
BW	Small Signal Bandwidth			1.0		MHz

Typical Performance Characteristics

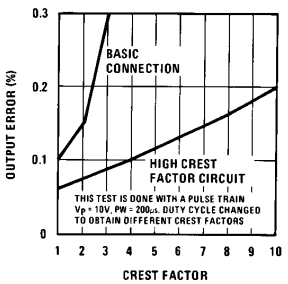
Error vs Frequency



Error vs Frequency



Error vs Crest Factor



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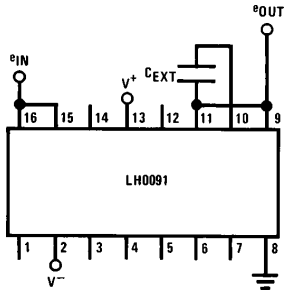
Typical Applications (All applications require power supply by-pass capacitors.)



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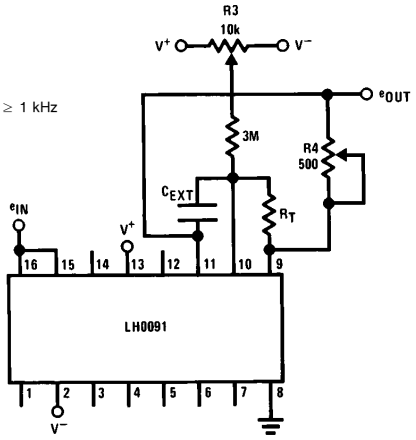
$C_{EXT} \geq 1\ \mu F$; frequency ≥ 1 kHz

FIGURE 1. LH0091 Basic Connection (No Trim)

Typical Applications (Continued)

R_T = 240k
$C_{EXT} \geq 1\mu F$, f ≥ 1 kHz



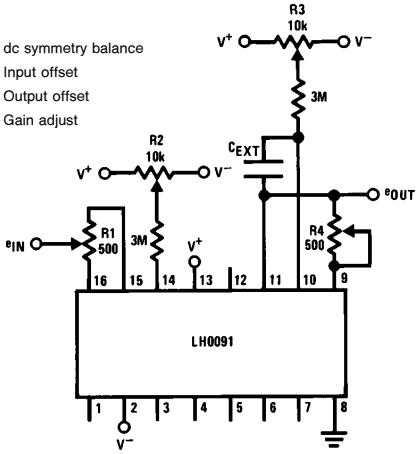
Note. The easy trim procedure is used for ac coupled input signals. It involves two trims and can achieve accuracies of 2 mV offset ±0.1% reading.

Procedure:

1. Apply 100 mV rms (sine wave) to input, adjust R3 until the output reads 100 mV_{DC}.
2. Apply 5 V_{rms} (sine wave) to input, adjust R4 until the output reads 5 V_{DC}.
3. Repeat steps 1 and 2 until the desired initial accuracy is achieved.

FIGURE 2. LH0091 "Easy Trim" (For ac Inputs Only)

R1 = dc symmetry balance
R2 = Input offset
R3 = Output offset
R4 = Gain adjust

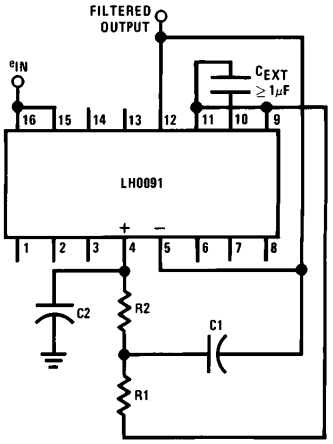


Note. This procedure will give accuracies of 0.5 mV offset ±0.05% reading for inputs from 0.05V peak to 10V peak.

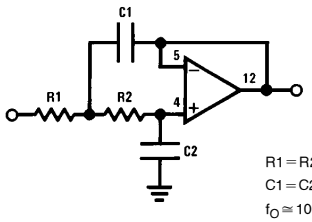
Procedure:

1. Apply 50 mV_{DC} to the input. Read and record the output.
2. Apply −50 mV_{DC} to the input. Use R2 to adjust for an output of the same magnitude as in step 1.
3. Apply 50 mV to the input. Use R3 to adjust the output for 50 mV.
4. Apply −50 mV to input. Use R2 to adjust the output for 50 mV.
5. Apply ±10V alternately to the input. Adjust R1 until the output readings for both polarities are equal (not necessary that they be exactly 10V).
6. Apply 10V to the input. Use R4 to adjust for 10V at the output.
7. Repeat this procedure to obtain the desired accuracy.

FIGURE 3. LH0091 Standard dc Trim Procedure



Note. The additional op amp in the LH0091 may be used as a low pass filter as shown in *Figure 4.*



R1 = R2 = 16k
C1 = C2 = 1μF
$f_O \cong 10$ Hz

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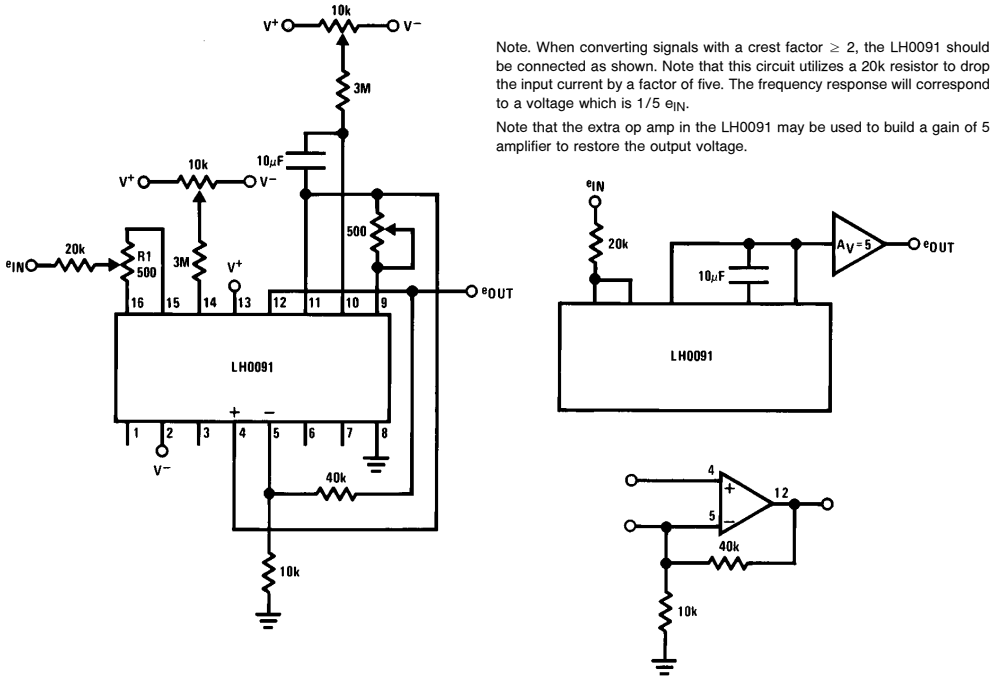
FIGURE 4. Output Filter Connection Using the Internal Op Amp

Typical Applications (Continued)



Note. When converting signals with a crest factor ≥ 2, the LH0091 should be connected as shown. Note that this circuit utilizes a 20k resistor to drop the input current by a factor of five. The frequency response will correspond to a voltage which is 1/5 e_{IN}.

Note that the extra op amp in the LH0091 may be used to build a gain of 5 amplifier to restore the output voltage.

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Note. Response time of the dc output voltage is dominated by the RC time constant consisting of the total resistance between pins 9 and 10 and the external capacitor, C_{EX}.

FIGURE 5. High Crest Factor Circuit

Definition of Terms

True rms to dc Converter: A device which converts any signal (ac, dc, ac + dc) to the dc equivalent of the rms value.

Error: is the amount by which the actual output differs from the theoretical value. Error is defined as a sum of a fixed term and a percent of reading term. The fixed term remains constant, regardless of input while the percent of reading term varies with the input.

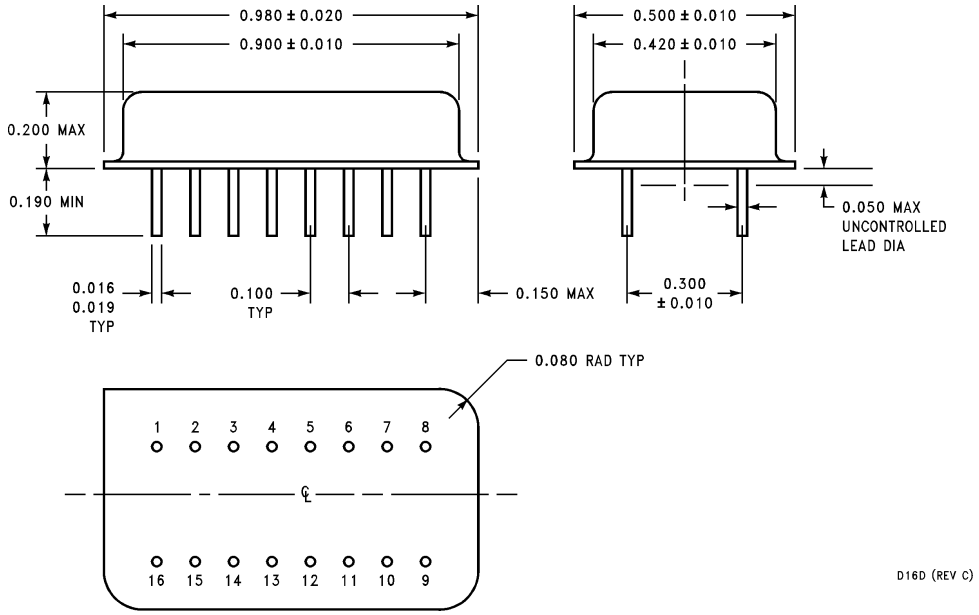
Total Unadjusted Error: The total error of the device without any external adjustments.

Bandwidth: The frequency at which the output dc voltage drops to 0.707 of the dc value at low frequency.

Frequency for Specified Error: The error at low frequency is governed by the size of the external averaging capacitor. At high frequencies, error is dependent on the frequency response of the internal circuitry. The frequency for specified error is the maximum input frequency for which the output will be within the specified error band (i.e., frequency for 1% error means the input frequency must be less than 200 kHz to maintain an output with an error of less than 1% of the initial reading.

Crest Factor: is the peak value of a waveform divided by the rms value of the same waveform. For high crest factor signals, the performance of the LH0091 can be improved by using the high crest factor connection.

Physical Dimensions inches (millimeters)



Dual-In-Line Package
Order Number LH0091CD
NS Package D16D

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