

## LHV870 44V Single High Performance, High Voltage Operational Amplifier

Check for Samples: [LHV870](#)

### FEATURES

- Easily drives 600Ω loads
- Output short circuit protection
- PSRR and CMRR exceed 120dB (typ)

### APPLICATIONS

- Low noise industrial applications including test, measurement, and ultrasound
- High quality audio amplification
- High fidelity preamplifiers, phono preamps, and multimedia
- High performance professional audio
- High fidelity equalization and crossover networks with active filters
- High performance line drivers and receivers

### DESCRIPTION

The LHV870 is an ultra-low distortion, low noise, high slew rate operational amplifier optimized and fully specified for high performance, high voltage applications. Combining advanced leading-edge process technology with state-of-the-art circuit design, the LHV870 operational amplifier delivers superior signal amplification for outstanding performance. The LHV870 combines extremely low voltage noise density (2.7nV/√Hz) with vanishingly low DC Gain Linearity Error (0.000009%) to easily satisfy the most demanding applications. To ensure that the most challenging loads are driven without compromise, the LHV870 has a high slew rate of ±20V/μs and an output current capability of ±26mA. Further, dynamic range is maximized by an output stage that drives 2kΩ loads to within 1V of either power supply voltage and to within 1.4V when driving 600Ω loads.

The LHV870's outstanding CMRR (120dB), PSRR (120dB), and  $V_{OS}$  (0.1mV) give the amplifier excellent DC performance.

The LHV870 operates over a wide supply range of ±2.5V to ±22V and is unity gain stable. This operational amplifier achieves outstanding AC performance while driving complex loads with values as high as 100pF.

The LHV870 is available in 10-lead LLP package.

**Table 1. Key Specifications**

	VALUE	UNIT
■ Power Supply Voltage Range	±2.5V to ±22	V
■ Input Noise Density	2.7nV/√Hz (typ)	
■ Slew Rate	±20V/μs (typ)	
■ Gain Bandwidth Product	55	MHz (typ)
■ Open Loop Gain ( $R_L = 600\Omega$ )	140	dB (typ)
■ Input Bias Current	10nA (typ)	
■ Input Offset Voltage	0.1mV (typ)	
■ DC Gain Linearity Error	0.000009%	■ THD+N ( $A_V = 1$ , $V_{OUT} = 3V_{RMS}$ , $f_{IN} = 1kHz$ )
$R_L = 2k\Omega$	0.00003% (typ)	
$R_L = 600\Omega$	0.00003% (typ)	



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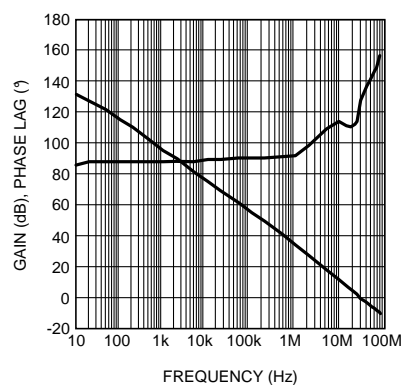
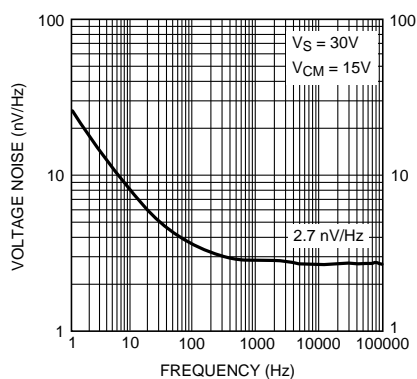
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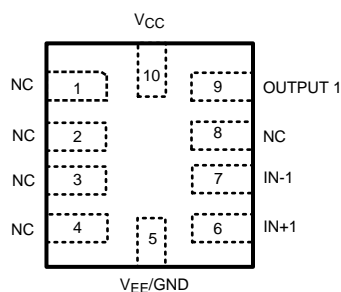
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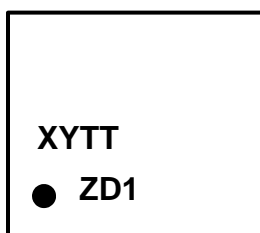
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.



**LHV870LC  
Top View**



**LHV870  
Top View**



XY = 2 Digit Date Code, TT = Lot Traceability, ZD1 = LHV870LC

**Absolute Maximum Ratings** <sup>(1) (2)</sup>

Power Supply Voltage ( $V_S = V^+ - V^-$ )	46V
Storage Temperature	–65°C to 150°C
Input Voltage	(V-) - 0.7V to (V+) + 0.7V
Output Short Circuit <sup>(3)</sup>	Continuous
Power Dissipation	Internally Limited
ESD Rating <sup>(4)</sup>	2000V
ESD Rating <sup>(5)</sup>	
Pins 1, 4, 7 and 8	200V
Pins 2, 3, 5 and 6	100V
Junction Temperature	150°C
Thermal Resistance	
$\theta_{JA}$ (LLP)	168°C/W

- (1) “*Absolute Maximum Ratings*” indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the *Absolute Maximum Ratings* or other conditions beyond those indicated in the *Recommended Operating Conditions* is not implied. The *Recommended Operating Conditions* indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified.
- (2) The *Electrical Characteristics* tables list guaranteed specifications under the listed *Recommended Operating Conditions* except as otherwise modified or specified by the *Electrical Characteristics Conditions* and/or Notes. Typical specifications are estimations only and are not guaranteed.
- (3) The maximum power dissipation must be derated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation is  $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$  or the number given in *Absolute Maximum Ratings*, whichever is lower.
- (4) Human body model, applicable std. JESD22-A114C.
- (5) Machine model, applicable std. JESD22-A115-A.

**Operating Ratings**

Temperature Range	
$T_{MIN} \leq T_A \leq T_{MAX}$	–40°C $\leq T_A \leq$ 85°C
Supply Voltage Range	$\pm 2.5V \leq V_S \leq \pm 22V$

## Electrical Characteristics for the LHV870 <sup>(1)</sup>

The following specifications apply for  $V_S = \pm 18V$  and  $\pm 22V$ ,  $R_L = 2k\Omega$ ,  $R_{SOURCE} = 10\Omega$ ,  $f_{IN} = 1kHz$ ,  $T_A = 25^\circ C$ , unless otherwise specified.

Symbol	Parameter	Conditions	LHV870		Units (Limits)
			Typical	Limit	
			(2)	(3)	
THD+N	Total Harmonic Distortion + Noise	$A_V = 1$ , $V_{OUT} = 3V_{RMS}$ $R_L = 2k\Omega$	0.00003		%
IMD	Intermodulation Distortion	$A_V = 1$ , $V_{OUT} = 3V_{RMS}$ Two-tone, 60Hz & 7kHz 4:1	0.00005		%
GBWP	Gain Bandwidth Product		55	45	MHz (min)
SR	Slew Rate		$\pm 20$		V/ $\mu s$
FPBW	Full Power Bandwidth	$V_{OUT} = 1V_{P-P}$ , $-3dB$ referenced to output magnitude at $f = 1kHz$	10		MHz
$t_s$	Settling time	$A_V = -1$ , 10V step, $C_L = 100pF$ 0.1% error range	1.2		$\mu s$
$e_n$	Equivalent Input Noise Voltage	$f_{BW} = 20Hz$ to $20kHz$	0.34	0.65	$\mu V_{RMS}$ (max)
	Equivalent Input Noise Density	$f = 1kHz$	2.5	4.7	$nV/\sqrt{Hz}$ (max)
$i_n$	Current Noise Density	$f = 1kHz$	1.6		$pA/\sqrt{Hz}$
$V_{OS}$	Offset Voltage	$V_S = \pm 18V$	$\pm 0.12$		mV
		$V_S = \pm 22V$	$\pm 0.14$	$\pm 2$	mV (max)
$\Delta V_{OS}/\Delta Temp$	Average Input Offset Voltage Drift vs Temperature	$-40^\circ C \leq T_A \leq 85^\circ C$	0.1		$\mu V/^\circ C$
PSRR	Average Input Offset Voltage Shift vs Power Supply Voltage	$V_S = \pm 18V$ , $\Delta V_S = 24V$ <sup>(4)</sup> $V_S = \pm 22V$ , $\Delta V_S = 30V$	120 120	110	dB (min)
$I_B$	Input Bias Current	$V_{CM} = 0V$	10	300	nA (max)
$\Delta I_{OS}/\Delta Temp$	Input Bias Current Drift vs Temperature	$-40^\circ C \leq T_A \leq 85^\circ C$	0.2		nA/ $^\circ C$
$I_{OS}$	Input Offset Current	$V_{CM} = 0V$	11	100	nA (max)
$V_{IN-CM}$	Common-Mode Input Voltage Range	$V_S = \pm 18V$	+17.1 -16.9		V V
		$V_S = \pm 22V$	+21.0 -20.8	(V+) - 2.0 (V-) + 2.0	V (min) V (min)
CMRR	Common-Mode Rejection	$V_S = \pm 18V$ $-12V \leq V_{CM} \leq 12V$	120		dB
		$V_S = \pm 22V$ $-15V \leq V_{CM} \leq 15V$	120	110	dB (min)
$Z_{IN}$	Differential Input Impedance		30		k $\Omega$
	Common Mode Input Impedance	$-10V < V_{CM} < 10V$	1000		M $\Omega$
$A_{VOL}$	Open Loop Voltage Gain	$V_S = \pm 18V$ $-12V \leq V_{OUT} \leq 12V$ $R_L = 2k\Omega$	140		dB
		$V_S = \pm 22V$ $-15V \leq V_{OUT} \leq 15V$ $R_L = 2k\Omega$	140		dB

(1) "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur, including inoperability and degradation of device reliability and/or performance. Functional operation of the device and/or non-degradation at the *Absolute Maximum Ratings* or other conditions beyond those indicated in the *Recommended Operating Conditions* is not implied. The *Recommended Operating Conditions* indicate conditions at which the device is functional and the device should not be operated beyond such conditions. All voltages are measured with respect to the ground pin, unless otherwise specified.

(2) Typical values represent most likely parametric norms at  $T_A = +25^\circ C$ , and at the *Recommended Operation Conditions* at the time of product characterization and are not ensured.

(3) Datasheet min/max specification limits are guaranteed by test or statistical analysis.

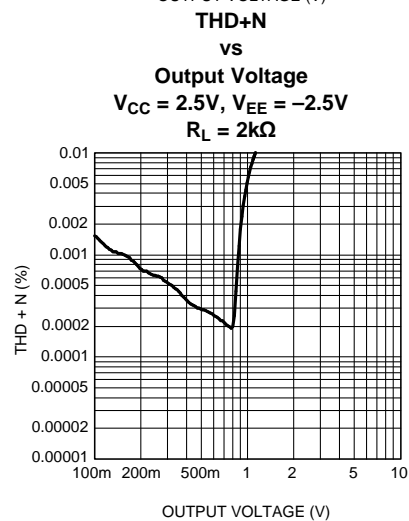
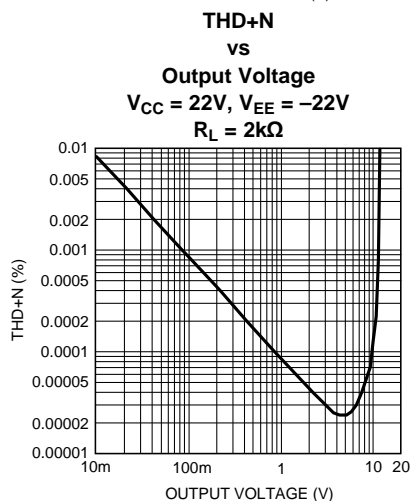
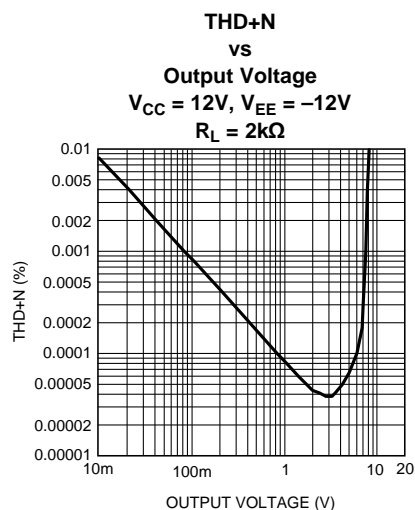
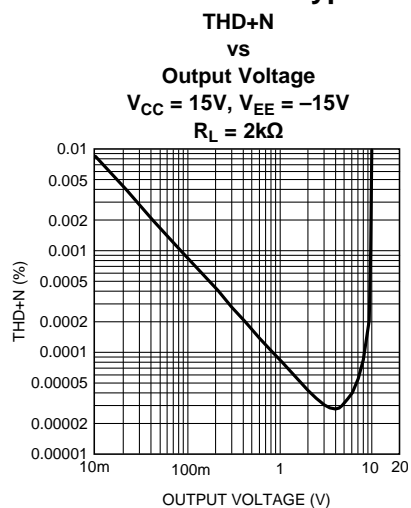
(4) PSRR is measured as follows: For  $V_S$ ,  $V_{OS}$  is measured at two supply voltages,  $\pm 7V$  and  $\pm 22V$ ,  $PSRR = |20\log(\Delta V_{OS} / \Delta V_S)|$ .

**Electrical Characteristics for the LHV870 <sup>(1)</sup> (continued)**

The following specifications apply for  $V_S = \pm 18V$  and  $\pm 22V$ ,  $R_L = 2k\Omega$ ,  $R_{SOURCE} = 10\Omega$ ,  $f_{IN} = 1kHz$ ,  $T_A = 25^\circ C$ , unless otherwise specified.

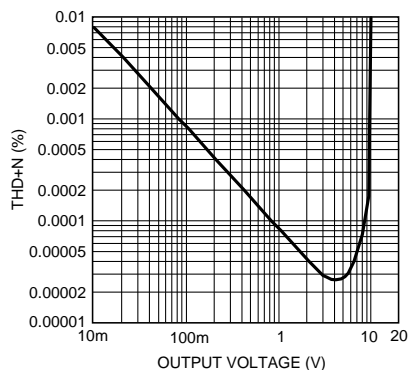
Symbol	Parameter	Conditions	LHV870		Units (Limits)
			Typical	Limit	
			(2)	(3)	
$V_{OUTMAX}$	Maximum Output Voltage Swing	$R_L = 600\Omega$ $V_S = \pm 18V$ $V_S = \pm 22V$	$\pm 16.7$ $\pm 20.4$	$\pm 19.0$	V V (min)
		$R_L = 2k\Omega$ $V_S = \pm 18V$ $V_S = \pm 22V$	$\pm 17.0$ $\pm 21.0$		V V
$I_{OUT}$	Output Current	$R_L = 600\Omega$ $V_S = \pm 20V$ $V_S = \pm 22V$	$\pm 31$ $\pm 37$	$\pm 30$	mA mA (min)
$I_{OUT-CC}$	Instantaneous Short Circuit Current		+53 –42		mA
$R_{OUT}$	Output Impedance	$f_{IN} = 10kHz$ Closed-Loop Open-Loop	0.01 13		$\Omega$ $\Omega$
$I_S$	Total Quiescent Current	$I_{OUT} = 0mA$	5	6.5	mA (max)

## Typical Performance Characteristics

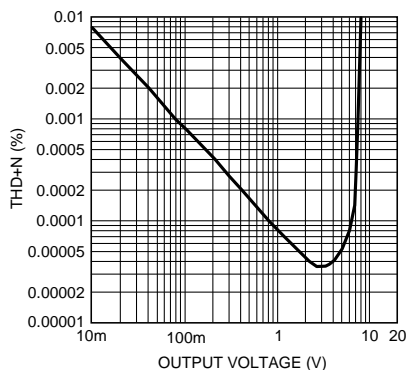


## Typical Performance Characteristics (continued)

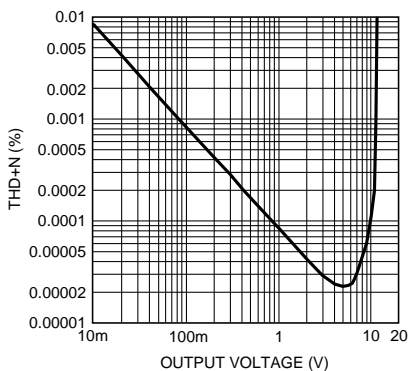
**THD+N  
vs  
Output Voltage**  
 $V_{CC} = 15V$ ,  $V_{EE} = -15V$   
 $R_L = 600\Omega$



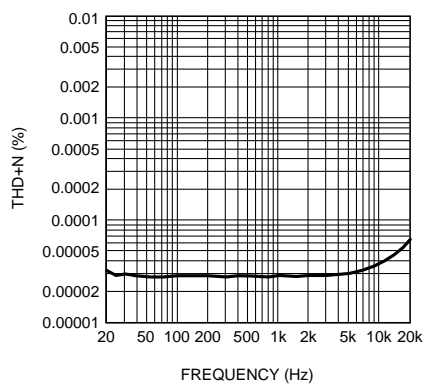
**THD+N  
vs  
Output Voltage**  
 $V_{CC} = 12V$ ,  $V_{EE} = -12V$   
 $R_L = 600\Omega$



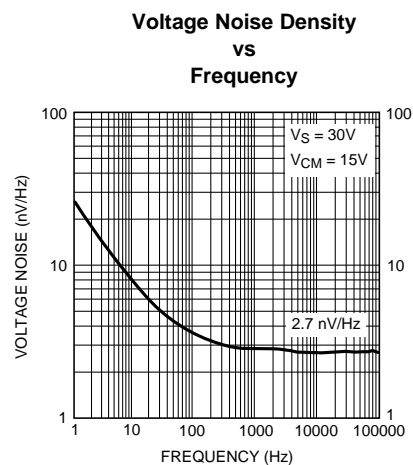
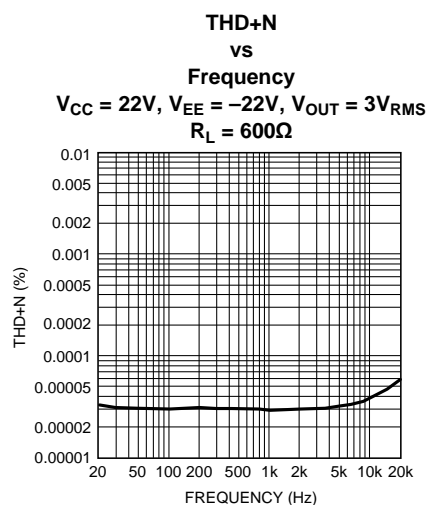
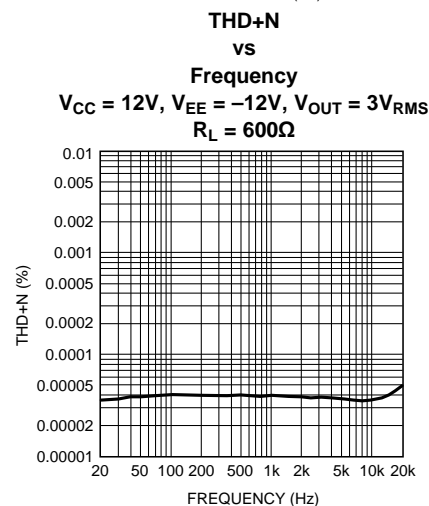
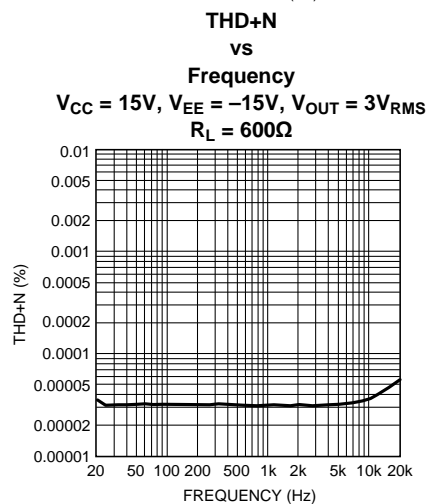
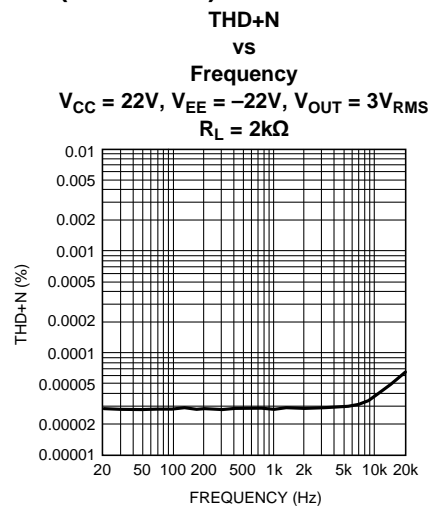
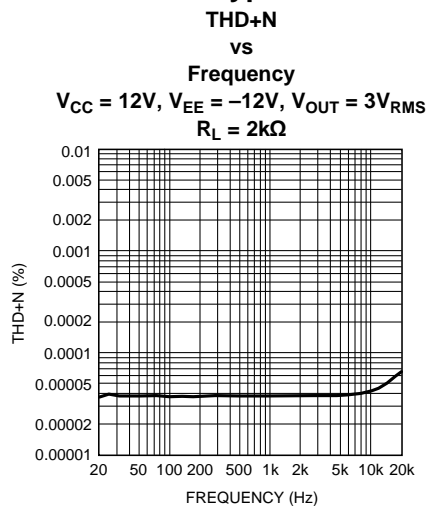
**THD+N  
vs  
Output Voltage**  
 $V_{CC} = 22V$ ,  $V_{EE} = -22V$   
 $R_L = 600\Omega$



**THD+N  
vs  
Frequency**  
 $V_{CC} = 15V$ ,  $V_{EE} = -15V$ ,  $V_{OUT} = 3V_{RMS}$   
 $R_L = 2k\Omega$

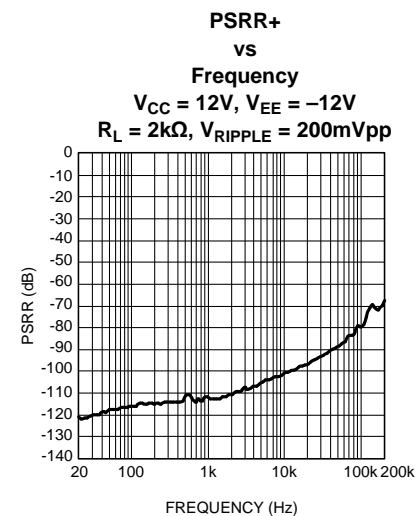
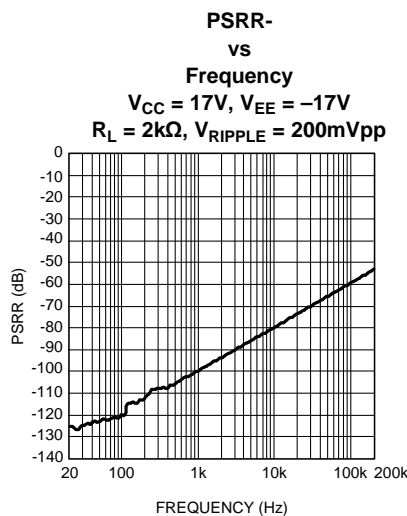
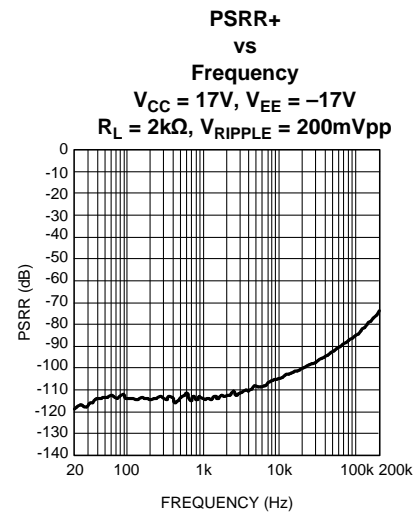
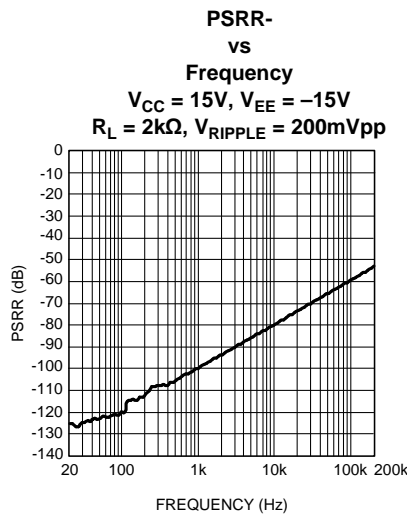
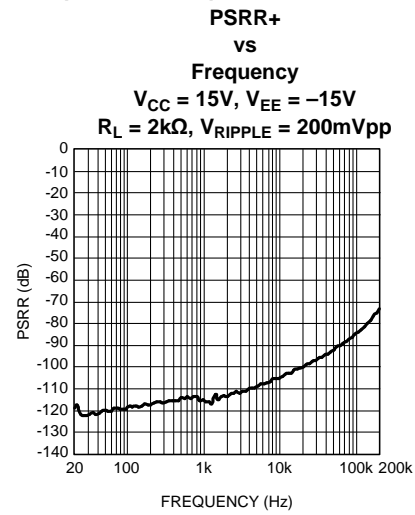
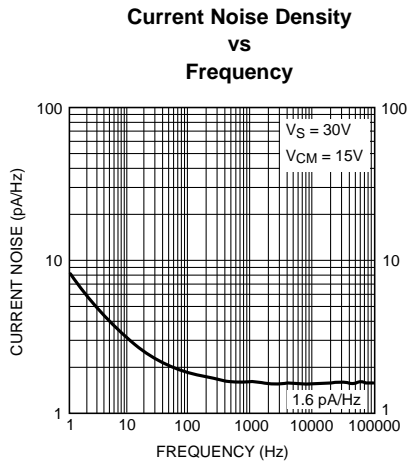


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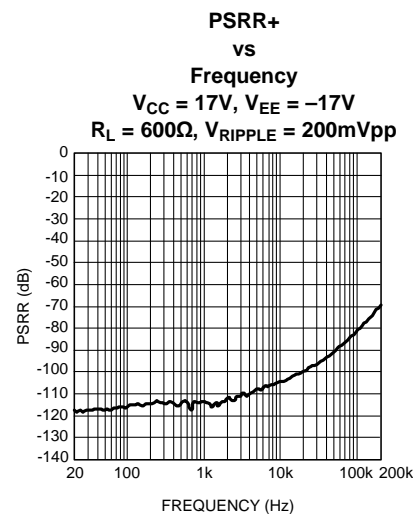
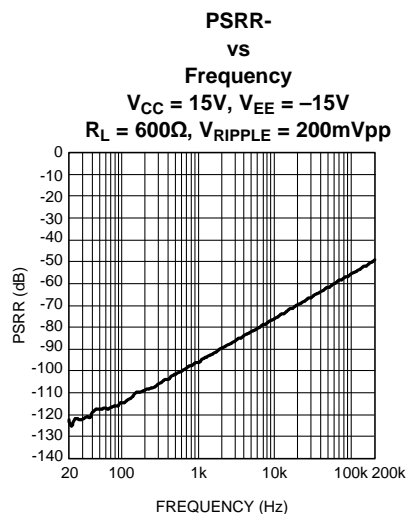
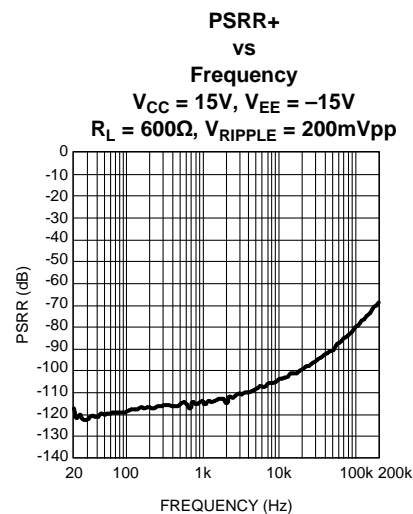
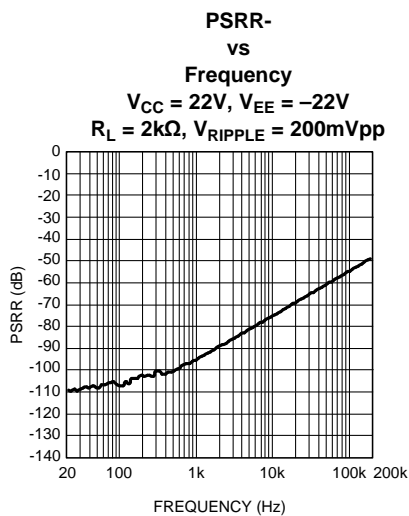
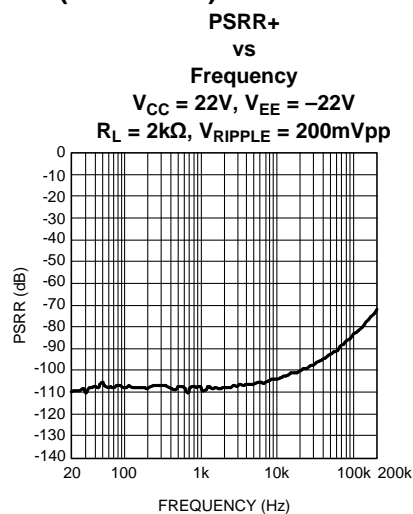
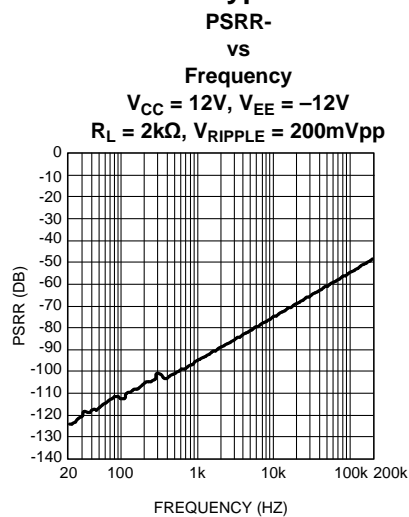




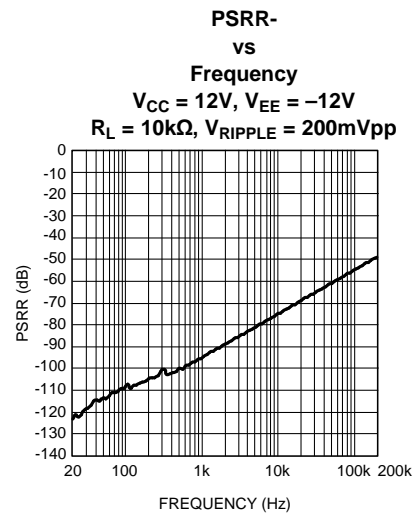
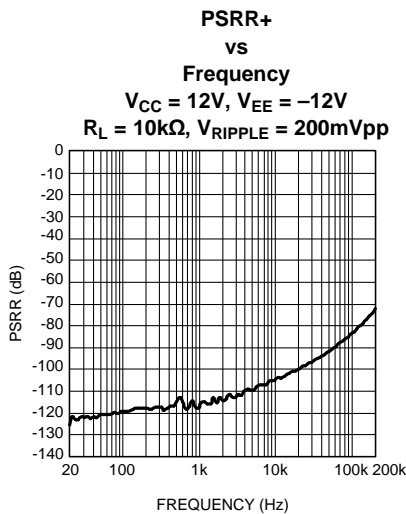
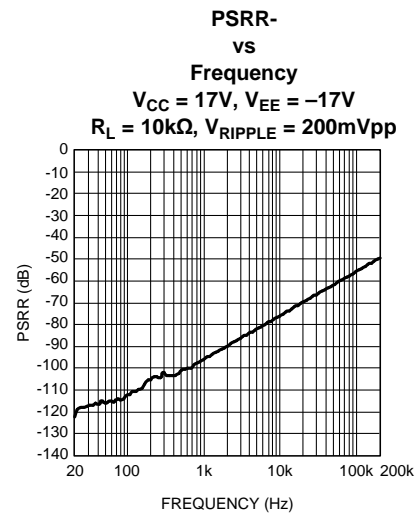
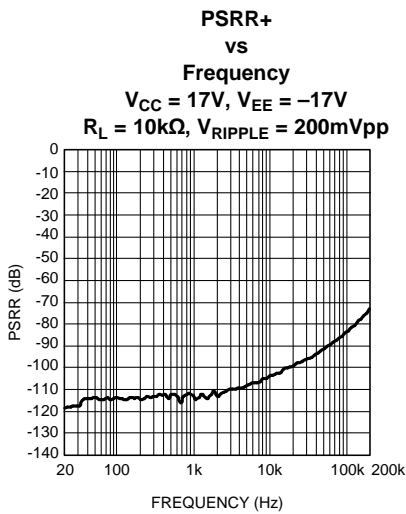
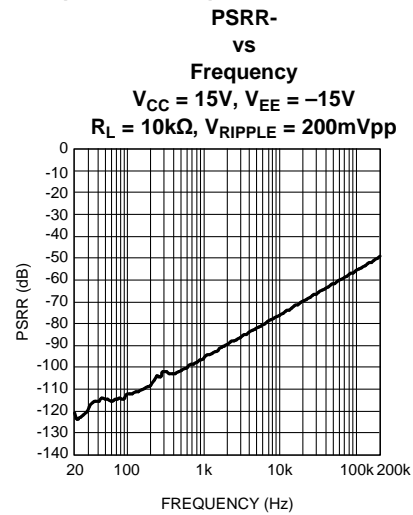
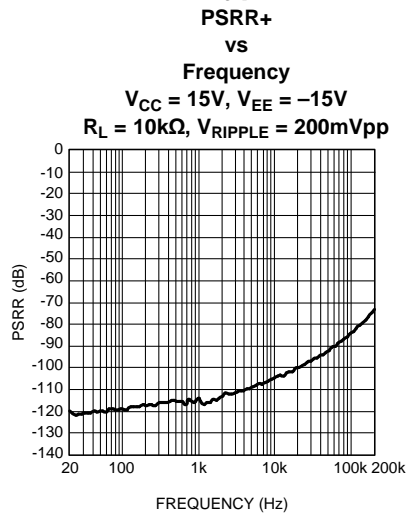
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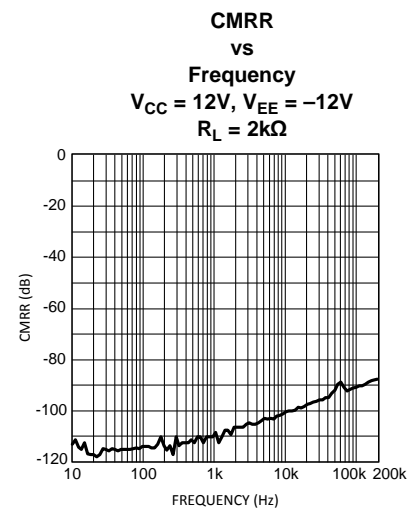
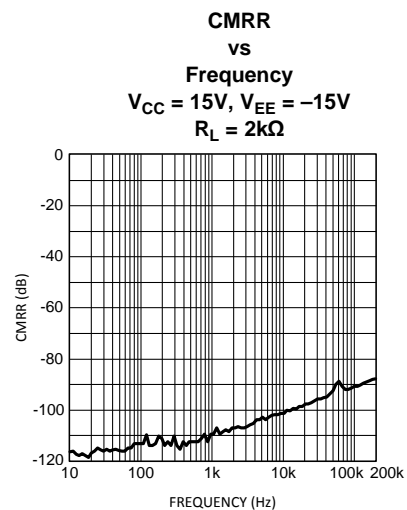
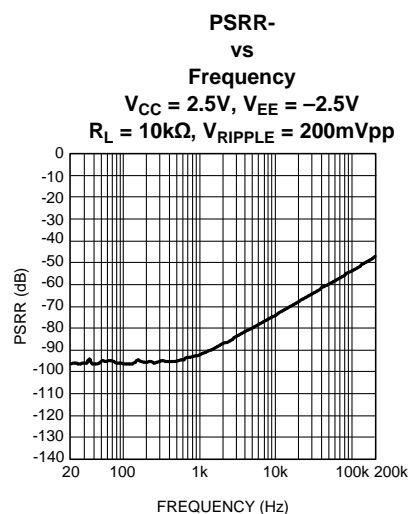
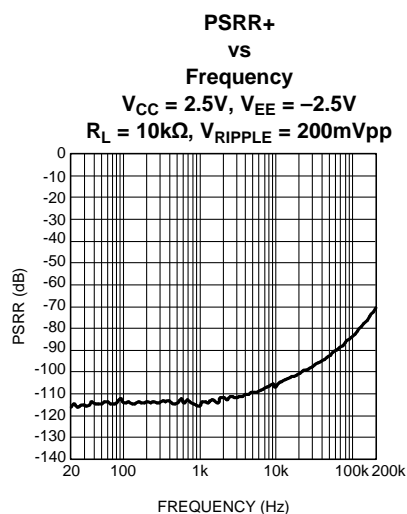
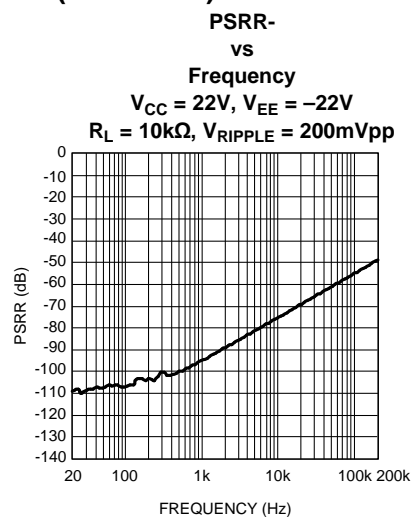
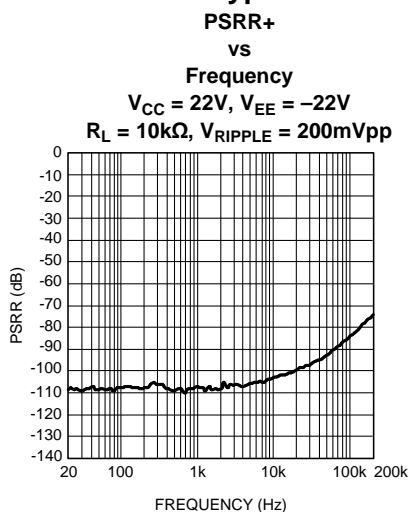
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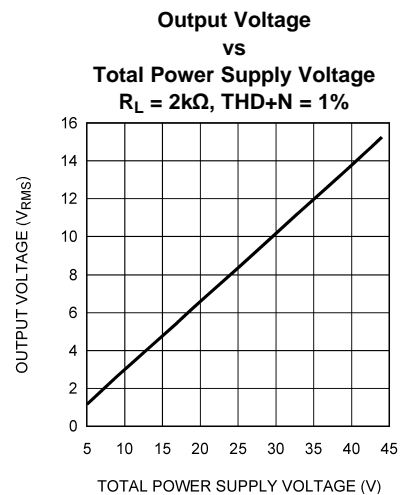
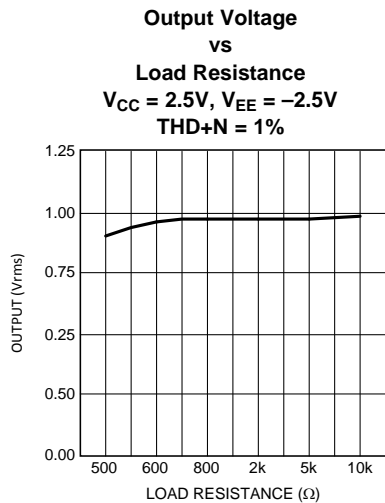
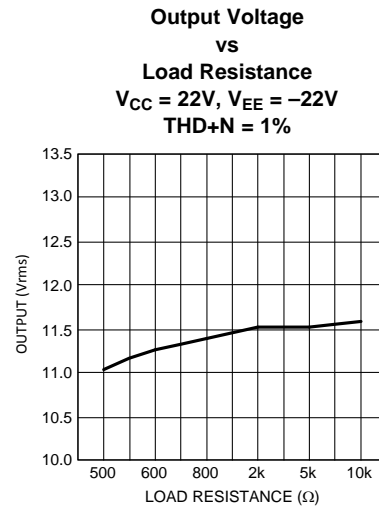
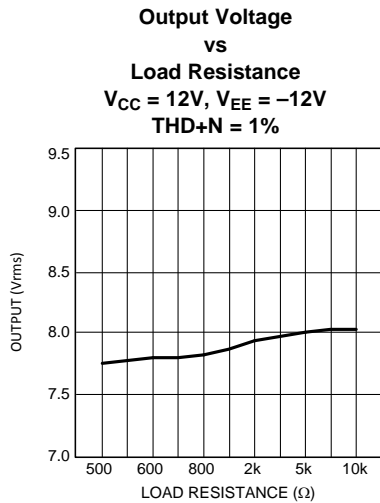
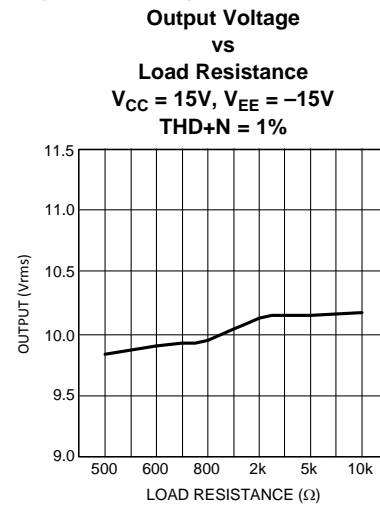
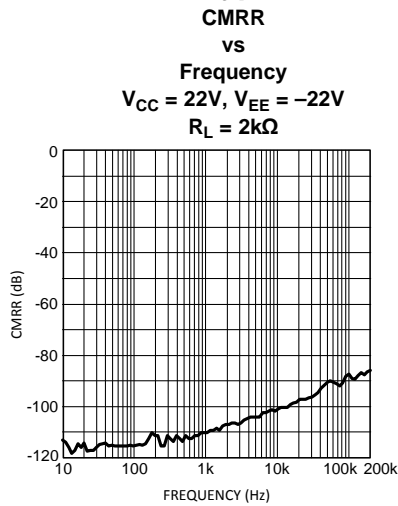
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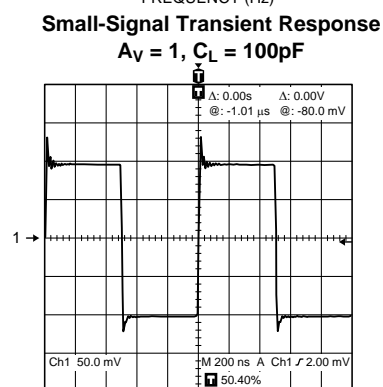
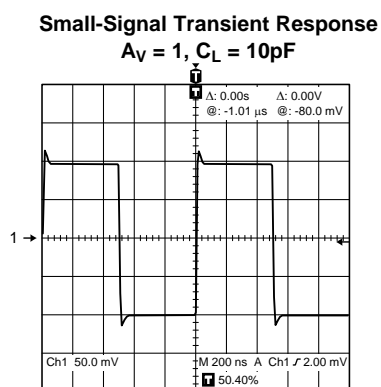
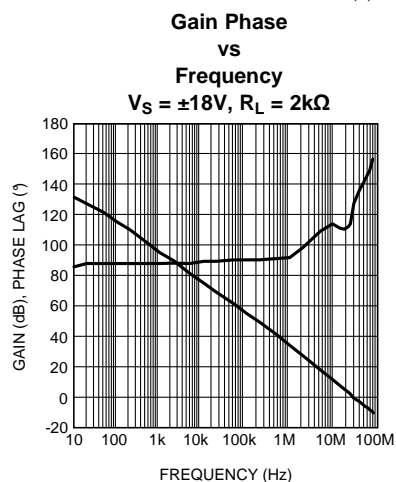
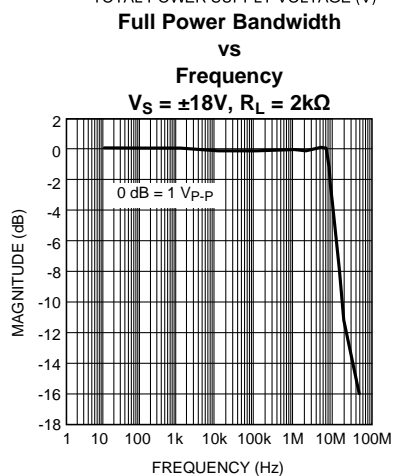
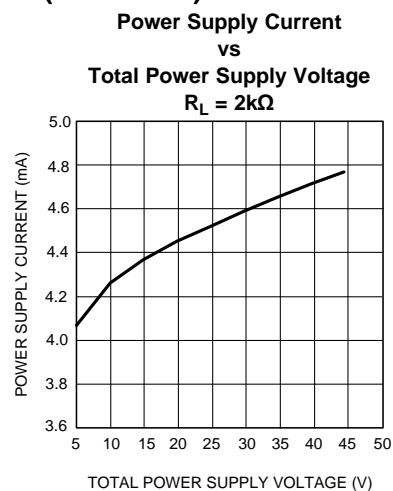
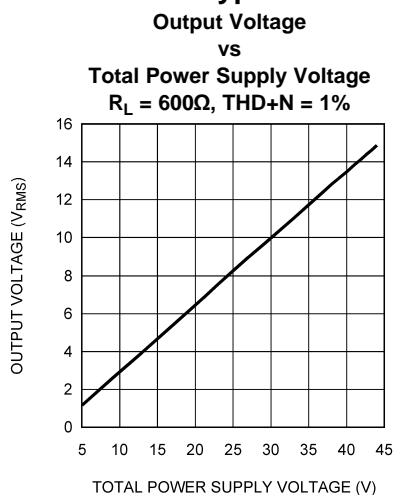
## Typical Performance Characteristics (continued)



## Typical Performance Characteristics (continued)



## Typical Performance Characteristics (continued)



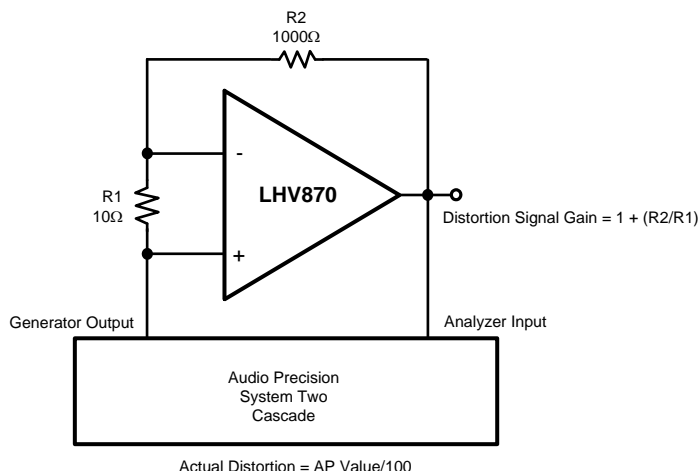
## APPLICATION INFORMATION

### DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LHV870 is below the capabilities of all commercially available equipment. This makes distortion measurements just slightly more difficult than simply connecting a distortion meter to the amplifier's inputs and outputs. The solution, however, is quite simple: an additional resistor. Adding this resistor extends the resolution of the distortion measurement equipment.

The LHV870's low residual distortion is an input referred internal error. As shown in [Figure 1](#), adding the 10Ω resistor connected between the amplifier's inverting and non-inverting inputs changes the amplifier's noise gain. The result is that the error signal (distortion) is amplified by a factor of 101. Although the amplifier's closed-loop gain is unaltered, the feedback available to correct distortion errors is reduced by 101, which means that measurement resolution increases by 101. To ensure minimum effects on distortion measurements, keep the value of R1 low as shown in [Figure 1](#).

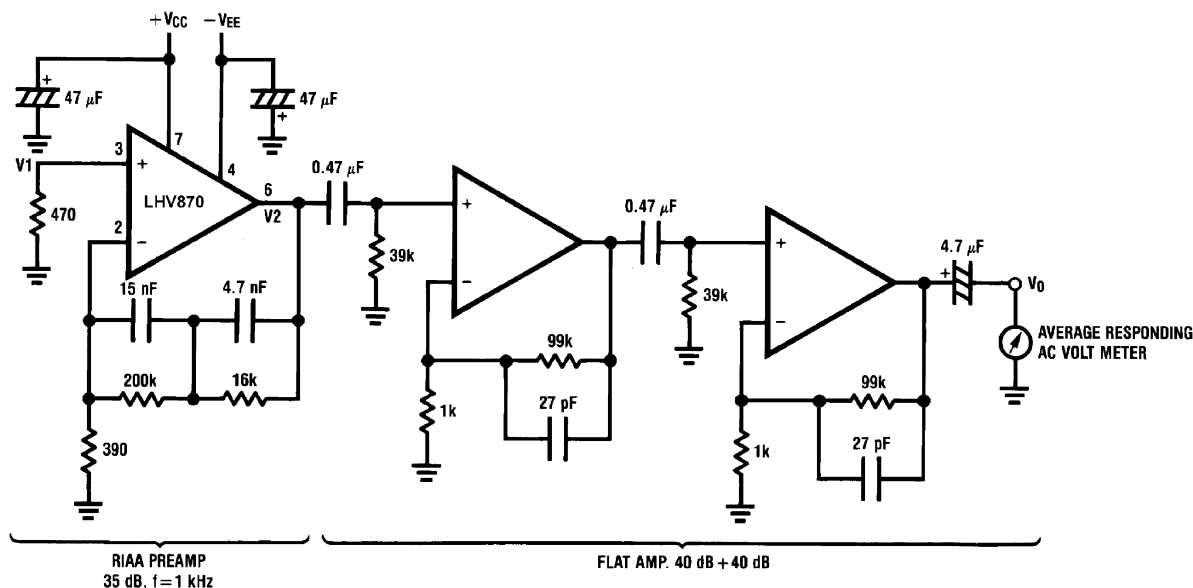
This technique is verified by duplicating the measurements with high closed loop gain and/or making the measurements at high frequencies. Doing so produces distortion components that are within the measurement equipment's capabilities. This datasheet's THD+N and IMD values were generated using the above described circuit connected to an Audio Precision System Two Cascade.



**Figure 1. THD+N and IMD Distortion Test Circuit**

The LHV870 is a high speed op amp with excellent phase margin and stability. Capacitive loads up to 100pF will cause little change in the phase characteristics of the amplifiers and are therefore allowable.

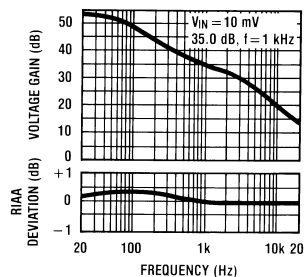
Capacitive loads greater than 100pF must be isolated from the output. The most straightforward way to do this is to put a resistor in series with the output. This resistor will also prevent excess power dissipation if the output is accidentally shorted.



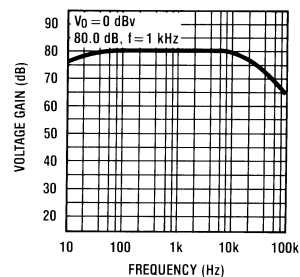
Complete shielding is required to prevent induced pick up from external sources. Always check with oscilloscope for power line noise.

**Figure 2. Noise Measurement Circuit**  
**Total Gain: 115 dB @  $f = 1$  kHz**  
**Input Referred Noise Voltage:  $e_n = V_0/560,000$  (V)**

**RIAA Preamp Voltage Gain, RIAA  
Deviation  
vs  
Frequency**



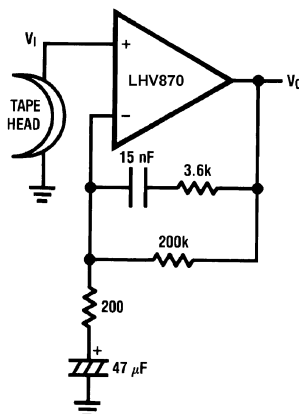
**Flat Amp Voltage Gain vs  
Frequency**





## TYPICAL APPLICATIONS

Figure 3. NAB Preamp



$A_V = 34.5$   
 $F = 1 \text{ kHz}$   
 $E_n = 0.38 \mu\text{V}$   
 A Weighted

Figure 4. NAB Preamp Voltage Gain vs Frequency

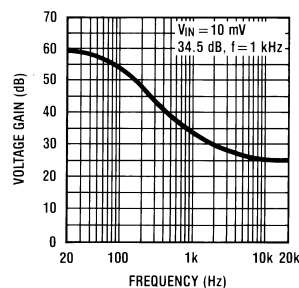
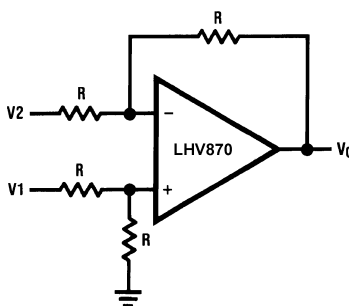
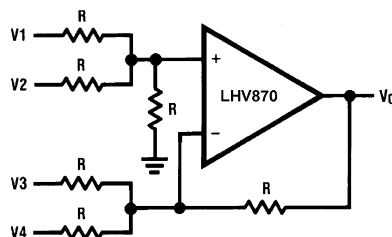


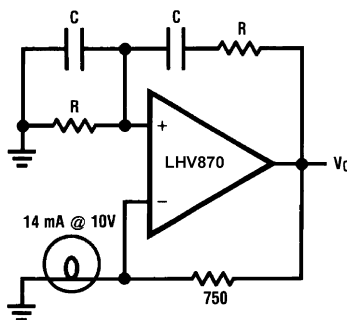
Figure 5. Balanced to Single Ended Converter



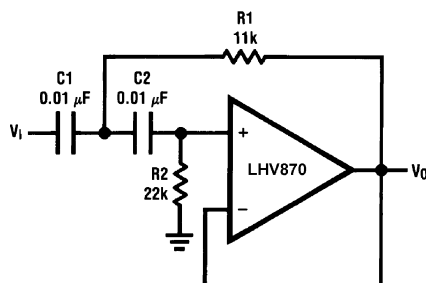
$$V_O = V1 - V2$$

**Figure 6. Adder/Subtractor**

$$V_O = V_1 + V_2 - V_3 - V_4$$

**Figure 7. Sine Wave Oscillator**

$$f_o = \frac{1}{2\pi RC}$$

**Figure 8. Second Order High Pass Filter (Butterworth)**

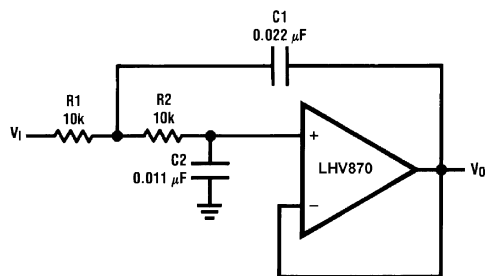
$$\text{if } C_1 = C_2 = C$$

$$R_1 = \frac{\sqrt{2}}{2\omega_o C}$$

$$R_2 = 2 \cdot R_1$$

Illustration is  $f_o = 1 \text{ kHz}$

**Figure 9. Second Order Low Pass Filter (Butterworth)**



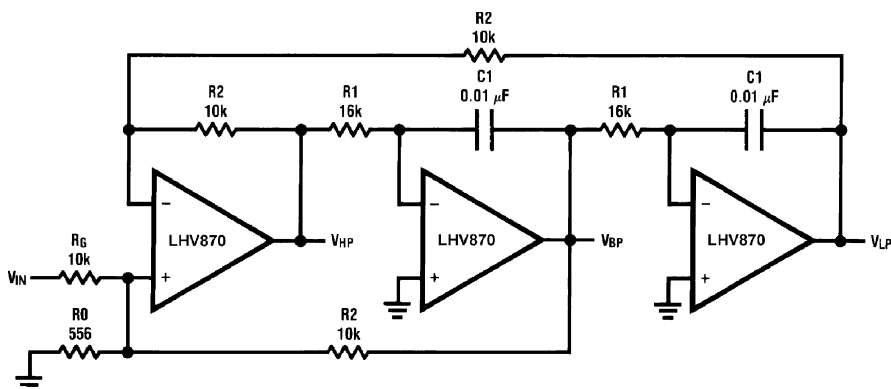
if  $R1 = R2 = R$

$$C1 = \frac{\sqrt{2}}{\omega_0 R}$$

$$C2 = \frac{C1}{2}$$

Illustration is  $f_0 = 1 \text{ kHz}$

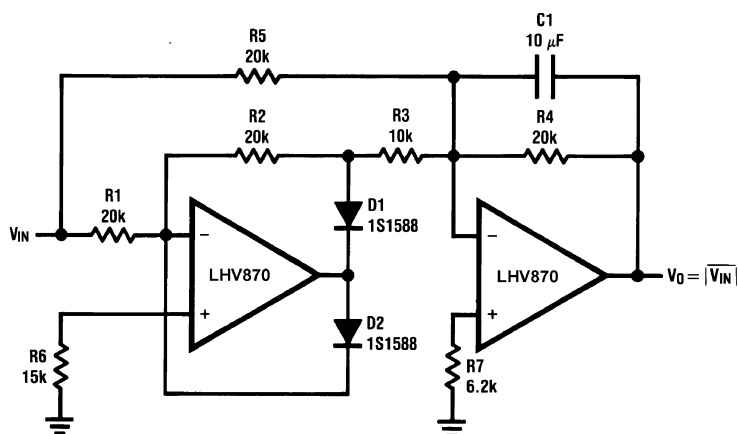
**Figure 10. State Variable Filter**



$$f_0 = \frac{1}{2\pi C1 R1}, Q = \frac{1}{2} \left( 1 + \frac{R2}{R0} + \frac{R2}{RG} \right), A_{BP} = Q A_{LP} = Q A_{LH} = \frac{R2}{RG}$$

Illustration is  $f_0 = 1 \text{ kHz}$ ,  $Q = 10$ ,  $A_{BP} = 1$

**Figure 11. AC/DC Converter**



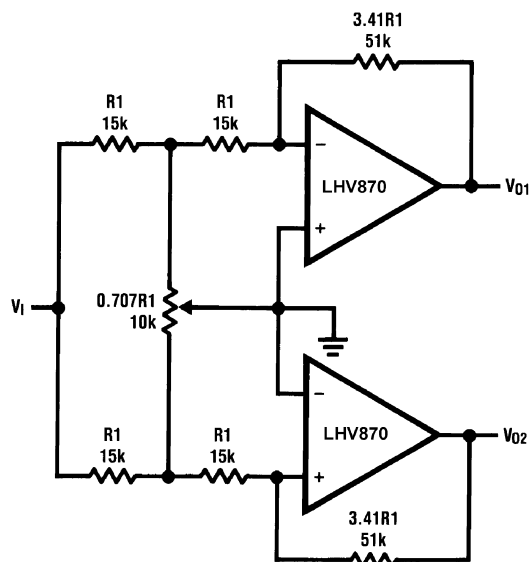
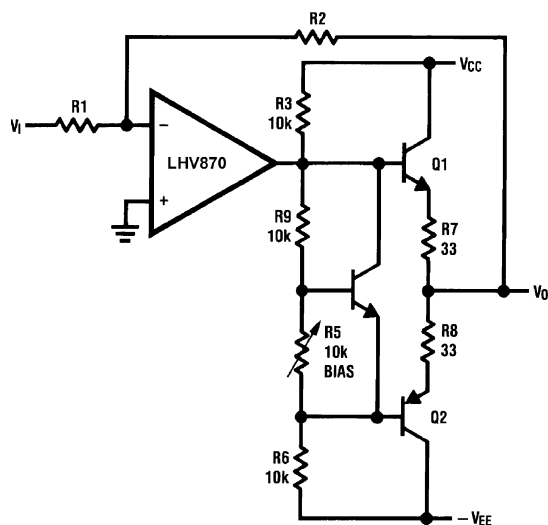
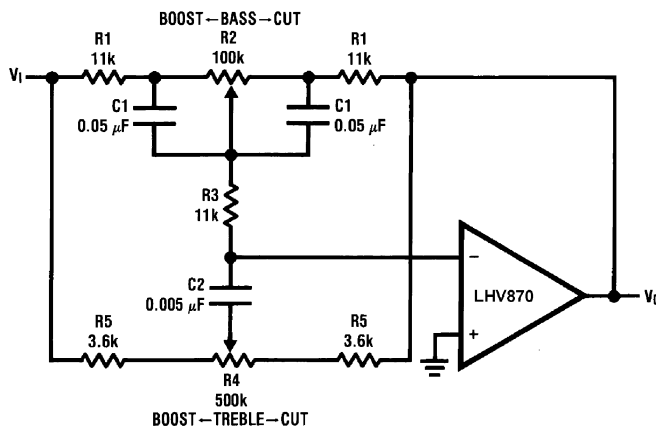
**Figure 12. 2 Channel Panning Circuit (Pan Pot)****Figure 13. Line Driver**

Figure 14. Tone Control



$$f_L = \frac{1}{2\pi R_2 C_1}, f_{LB} = \frac{1}{2\pi R_1 C_1}$$

$$f_H = \frac{1}{2\pi R_5 C_2}, f_{HB} = \frac{1}{2\pi (R_1 + R_5 + 2R_3) C_2}$$

Illustration is:

$$f_L = 32 \text{ Hz}, f_{LB} = 320 \text{ Hz}$$

$$f_H = 11 \text{ kHz}, f_{HB} = 1.1 \text{ kHz}$$

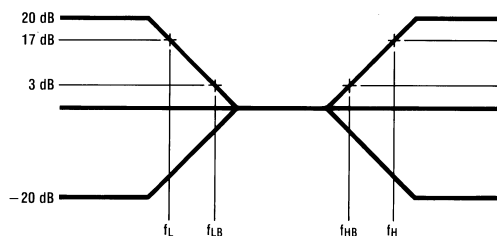
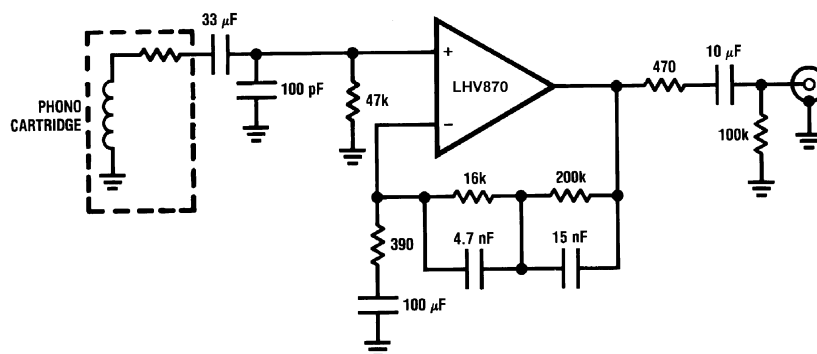
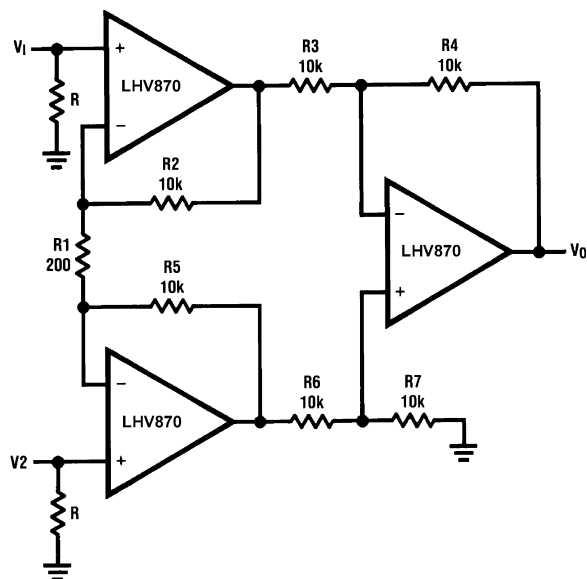


Figure 15. RIAA Preamp



$A_v = 35 \text{ dB}$   
 $E_n = 0.33 \text{ μV}$   
 $S/N = 90 \text{ dB}$   
 $f = 1 \text{ kHz}$   
 A Weighted  
 A Weighted,  $V_{IN} = 10 \text{ mV}$   
 @  $f = 1 \text{ kHz}$

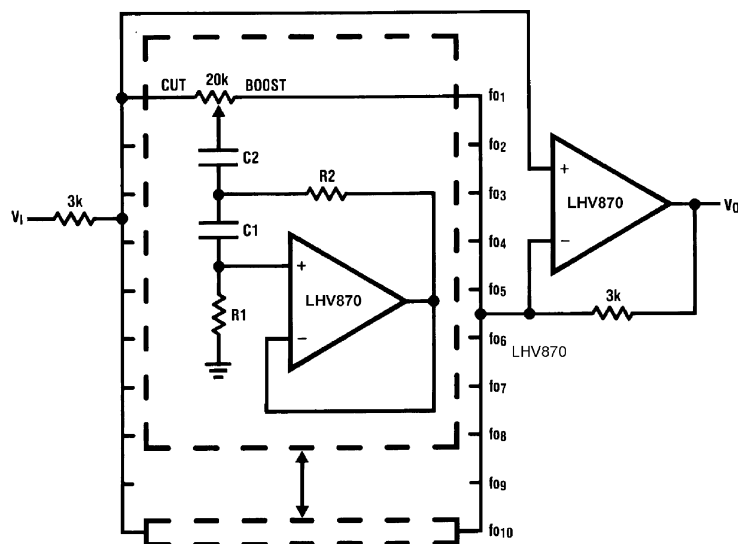
**Figure 16. Balanced Input Mic Amp**

If  $R2 = R5$ ,  $R3 = R6$ ,  $R4 = R7$

$$V_0 = \left(1 + \frac{2R2}{R1}\right) \frac{R4}{R3} (V2 - V1)$$

Illustration is:

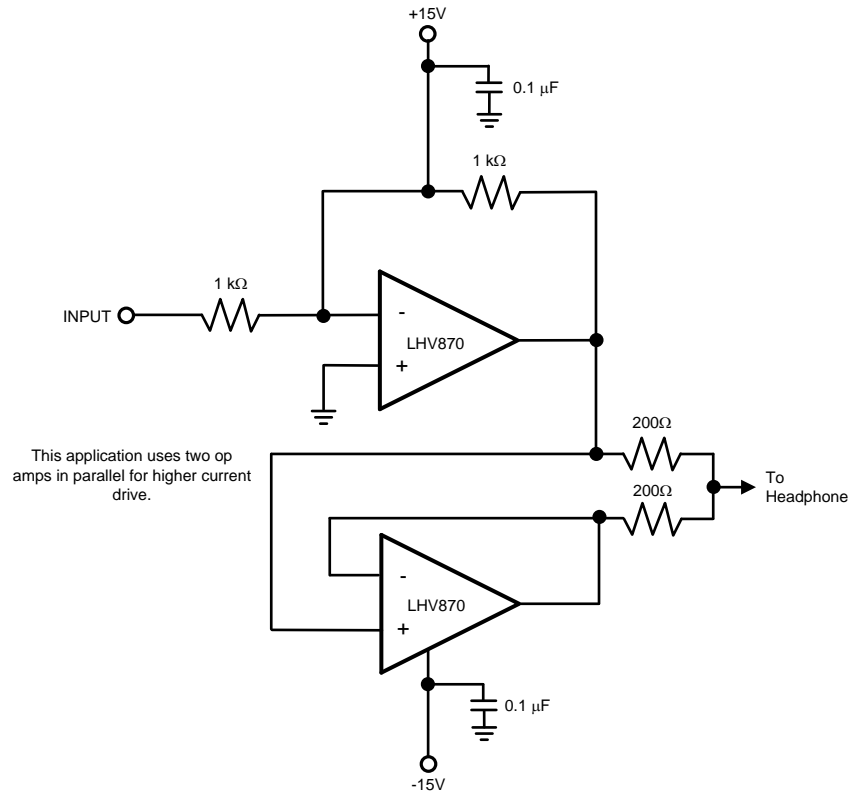
$$V_0 = 101(V2 - V1)$$

**Figure 17. 10 Band Graphic Equalizer**

fo (Hz)	C <sub>1</sub>	C <sub>2</sub>	R <sub>1</sub>	R <sub>2</sub>
32	0.12μF	4.7μF	75kΩ	500Ω
64	0.056μF	3.3μF	68kΩ	510Ω
125	0.033μF	1.5μF	62kΩ	510Ω
250	0.015μF	0.82μF	68kΩ	470Ω
500	8200pF	0.39μF	62kΩ	470Ω
1k	3900pF	0.22μF	68kΩ	470Ω
2k	2000pF	0.1μF	68kΩ	470Ω

fo (Hz)	C <sub>1</sub>	C <sub>2</sub>	R <sub>1</sub>	R <sub>2</sub>
4k	1100pF	0.056μF	62kΩ	470Ω
8k	510pF	0.022μF	68kΩ	510Ω
16k	330pF	0.012μF	51kΩ	510Ω

### Figure 18. Headphone Amplifier



## REVISION HISTORY

<b>Rev</b>	<b>Date</b>	<b>Description</b>
1.0	05/25/11	Initial WEB released.
1.01	12/16/11	Changed the package from LCE10A to LCB10A.
1.02	01/04/12	Re-composed the document to reveal the LCB10A (revB) package.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
LHV870LC/NOPB	ACTIVE	UQFN	NKY	10	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	
LHV870LCX/NOPB	ACTIVE	UQFN	NKY	10	4500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBsolete:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

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**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LHV870LC/NOPB	UQFN	NKY	10	1000	178.0	12.4	2.9	2.9	1.0	8.0	12.0	Q1
LHV870LCX/NOPB	UQFN	NKY	10	4500	330.0	12.4	2.9	2.9	1.0	8.0	12.0	Q1

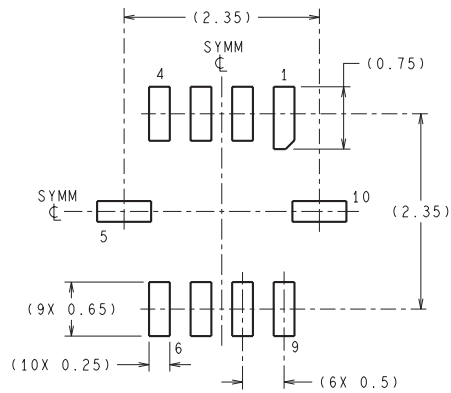
## TAPE AND REEL BOX DIMENSIONS



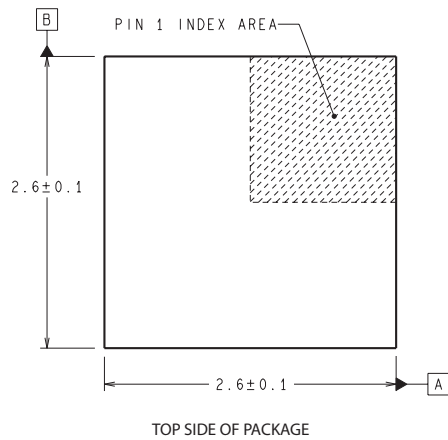
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LHV870LC/NOPB	UQFN	NKY	10	1000	203.0	190.0	41.0
LHV870LCX/NOPB	UQFN	NKY	10	4500	349.0	337.0	45.0

NKY0010A

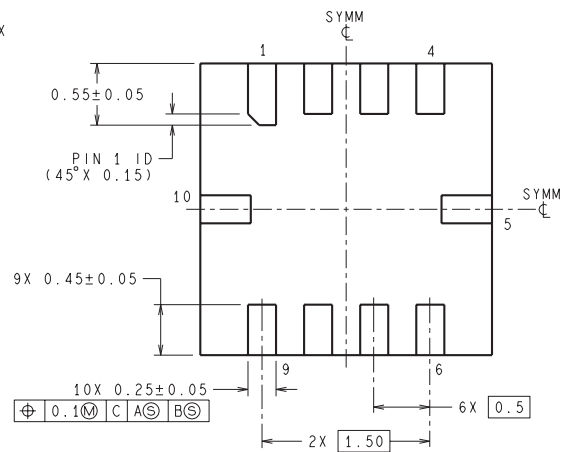
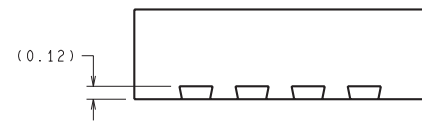


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