February 2007

National Semiconductor

LME49740 Quad High Performance, High Fidelity Audio Operational Amplifier

General Description

The LME49740 is part of the ultra-low distortion, low noise, high slew rate operational amplifier series optimized and fully specified for high performance, high fidelity applications. Combining advanced leading-edge process technology with state-of-the-art circuit design, the LME49740 audio operational amplifiers deliver superior audio signal amplification for outstanding audio performance. The LME49740 combines extremely low voltage noise density (2.7nV/$\sqrt{HZ}$) with vanishingly low THD+N (0.00003%) to easily satisfy the most demanding audio applications. To ensure that the most challenging loads are driven without compromise, the LME49740 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 LME49740's outstanding CMRR(120dB), PSRR(120dB), and V_{OS}(0.1mV) give the amplifier excellent operational amplifier DC performance.

The LME49740 has a wide supply range of ±2.5V to ±17V. Over this supply range the LME49740's input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LME49740 is unity gain stable. The Audio Operational Amplifier achieves outstanding AC performance while driving complex loads with values as high as 100pF.

The LME49740 is available in 14–lead narrow body SOIC and 14–lead plastic DIP. Demonstration boards are available for each package.

Key Specifications

- Power Supply Voltage Range: ±2.5V to ±17V
- THD+N (A_V = 1, V_{OUT} = 3V_{RMS}, f_{IN} = 1kHz)
  - R_L = 2kΩ: 0.00003% (typ)
  - R_L = 600Ω: 0.00003% (typ)
- Input Noise Density: 2.7nV/$\sqrt{Hz}$ (typ)
- Slew Rate: ±20V/μs (typ)
- Gain Bandwidth Product: 55MHz (typ)
- Open Loop Gain (R_L = 600Ω): 140dB (typ)
- Input Bias Current: 10nA (typ)
- Input Offset Voltage: 0.1mV (typ)
- DC Gain Linearity Error: 0.000009%

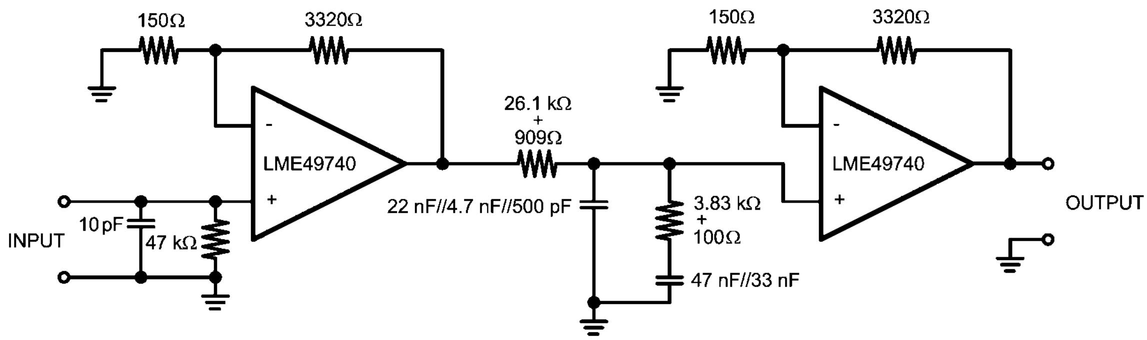
Features

- Easily drives 600Ω loads
- Optimized for superior audio signal fidelity
- Output short circuit protection
- PSRR and CMRR exceed 120dB (typ)
- SOIC and DIP packages

Applications

- Ultra high quality audio amplification
- High fidelity preamplifiers
- High fidelity multimedia
- State of the art phono pre amps
- High performance professional audio
- High fidelity equalization and crossover networks
- High performance line drivers
- High performance line receivers
- High fidelity active filters

Typical Application



Note: 1% metal film resistors, 5% polypropylene capacitors

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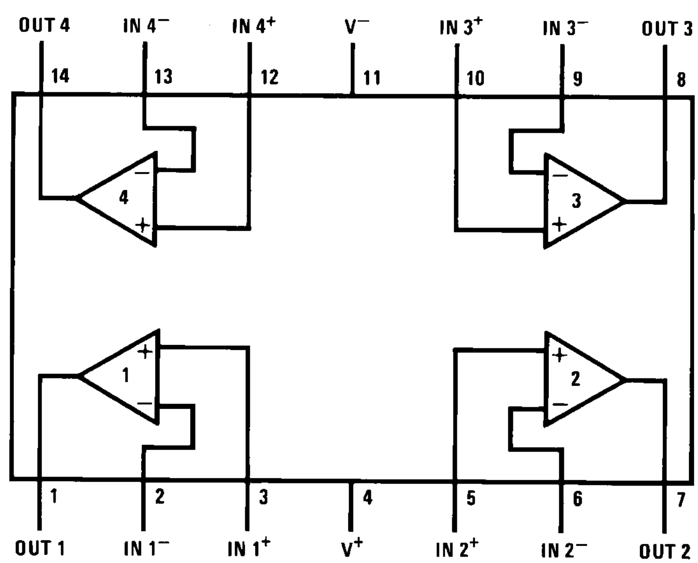
FIGURE 1. Passively Equalized RIAA Phono Preamplifier

Connection Diagram



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Order Number LME49740MA
See NS Package Number — M14A
Order Number LME49740NA
See NS Package Number — N14A

Absolute Maximum Ratings (Notes 1, 2)

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

Power Supply Voltage (V_S = V+ - V-)	36V
Storage Temperature	–65°C to 150°C
Input Voltage	(V-) - 0.7V to (V+) + 0.7V
Output Short Circuit (Note 3)	Continuous
Power Dissipation	Internally Limited
ESD Susceptibility (Note 4)	2000V
ESD Susceptibility (Note 5)	200V
Junction Temperature	150°C
Thermal Resistance	
θ_{JA} (MA)	107°C/W
θ_{JA} (NA)	74°C/W
Temperature Range	
$T_{MIN} \le T_A \le T_{MAX}$	$-40°C \le T_A \le 85°C$
Supply Voltage Range	$\pm 2.5V \le V_S \le \pm 17V$

Electrical Characteristics (Notes 1, 2)

The following specifications apply for V_S = ±15V, R_L = 2kΩ, f_{IN} = 1kHz, and T_A = 25C, unless otherwise specified.

Symbol	Parameter	Conditions	LME49740		Units (Limits)
			Typical	Limit	
			(Note 6)	(Notes 7, 8)	
THD+N	Total Harmonic Distortion + Noise	A_V = 1, V_{OUT} = 3V_{RMS} R_L = 2kΩ R_L = 600Ω	 0.00003 0.00003	 0.00009	% (max) % (max)
IMD	Intermodulation Distortion	A_V = 1, V_{OUT} = 3V_{RMS} Two-tone, 60Hz & 7kHz 4:1	0.00005		% (max)
GBWP	Gain Bandwidth Product		55	45	MHz (min)
SR	Slew Rate		±20	±15	V/μs (min)
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		μs
e_n	Equivalent Input Noise Voltage	f_{BW} = 20Hz to 20kHz	0.34	0.65	μV_{RMS}
	Equivalent Input Noise Density	f = 1kHz f = 10Hz	2.7 6.4	4.7	$nV/\sqrt{Hz}$ $nV/\sqrt{Hz}$
i_n	Current Noise Density	f = 1kHz f = 10Hz	1.6 3.1		$pA/\sqrt{Hz}$ $pA/\sqrt{Hz}$
V_{OS}	Offset Voltage		±0.1	±0.7	mV (max)
$\Delta V_{OS}/\Delta Temp$	Average Input Offset Voltage Drift vs Temperature	$40°C \le T_A \le 85°C$	0.2		μV/°C
PSRR	Average Input Offset Voltage Shift vs Power Supply Voltage	ΔV_S = 20V (Note 9)	120	110	dB (min)
ISO_{CH-CH}	Channel-to-Channel Isolation	f_{IN} = 1kHz f_{IN} = 20kHz	118 112		dB dB
I_B	Input Bias Current	V_{CM} = 0V	10	72	nA (max)
$\Delta I_{OS}/\Delta Temp$	Input Bias Current Drift vs Temperature	$-40°C \le T_A \le 85°C$	0.1		nA/°C
I_{OS}	Input Offset Current	V_{CM} = 0V	11	65	nA (max)
V_{IN-CM}	Common-Mode Input Voltage Range		+14.1 –13.9	(V+)–2.0 (V-)+2.0	V (min) V (min)
CMRR	Common-Mode Rejection	$-10V<V_{CM}<10V$	120	110	dB (min)
Z_{IN}	Differential Input Impedance		30		kΩ
	Common Mode Input Impedance	$-10V<V_{CM}<10V$	1000		MΩ
A_{VOL}	Open Loop Voltage Gain	$-10V<V_{OUT}<10V$, R_L = 600Ω	140		dB (min)
		$-10V<V_{OUT}<10V$, R_L = 2kΩ	140		dB (min)
		$-10V<V_{OUT}<10V$, R_L = 10kΩ	140	125	dB (min)

Symbol	Parameter	Conditions	LME49740 Typical (Note 6)	LME49740 Limit (Notes 7, 8)	Units (Limits)
V_{OUTMAX}	Maximum Output Voltage Swing	R_L = 600Ω	±13.6	±12.5	V (min)
		R_L = 2kΩ	±14.0		V (min)
		R_L = 10kΩ	±14.1		V (min)
I_{OUT}	Output Current	R_L = 600Ω, V_S = ±17V	±26	±23	mA (min)
I_{OUT-CC}	Short Circuit Current		+30 –38		mA mA
R_{OUT}	Output Impedance	f_{IN} = 10kHz Closed-Loop Open-Loop	 0.01 13		 Ω Ω
C_{LOAD}	Capacitive Load Drive Overshoot	100pF	16		%
I_S	Total Quiescent Current	I_{OUT} = 0mA	18.5	20	mA (max)

Note 1: *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur.

Note 2: Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 3: Amplifier output connected to GND, any number of amplifiers within a package.

Note 4: Human body model, 100pF discharged through a 1.5kΩ resistor.

Note 5: Machine Model ESD test is covered by specification EIAJ IC-121-1981. A 200pF cap is charged to the specified voltage and then discharged directly into the IC with no external series resistor (resistance of discharge path must be under 50Ω).

Note 6: Typical specifications are specified at +25ºC and represent the most likely parametric norm.

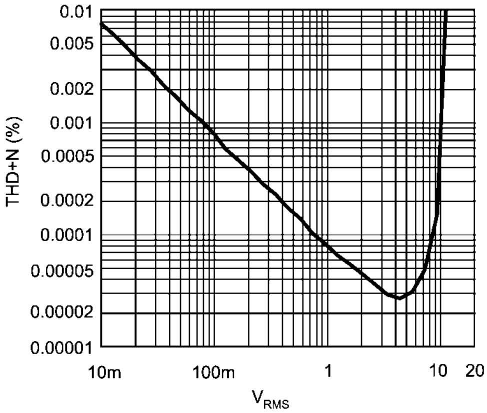
Note 7: Tested limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note 9: PSRR is measured as follows: V_{OS} is measured at two supply voltages, ±5V and ±15V. PSRR = $|20\log(\Delta V_{OS}/\Delta V_S)|$.

Typical Performance Characteristics

THD+N vs Output Voltage
V_{CC} = 15V, V_{EE} = –15V, R_L = 2kΩ



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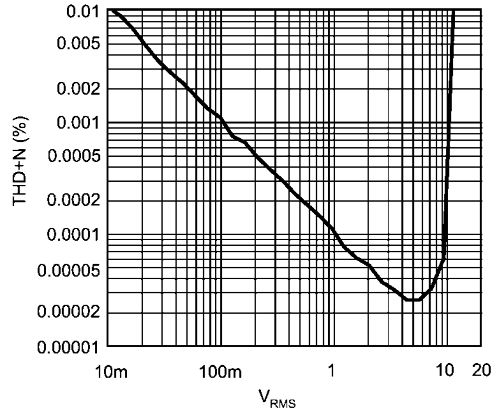
THD+N vs Output Voltage
V_{CC} = 17V, V_{EE} = –17V, R_L = 2kΩ



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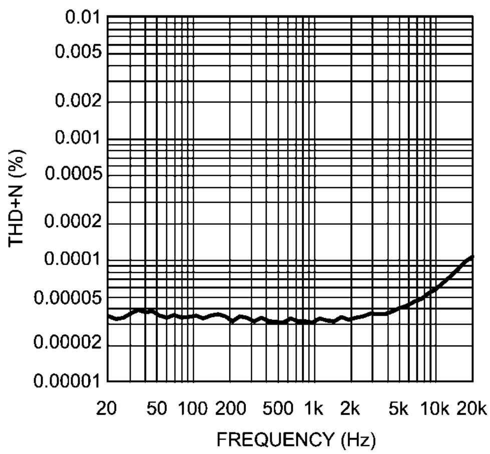
THD+N vs Frequency
V_{CC} = 15V, V_{EE} = –15V, R_L = 2kΩ, V_{OUT} = 3V_{RMS}



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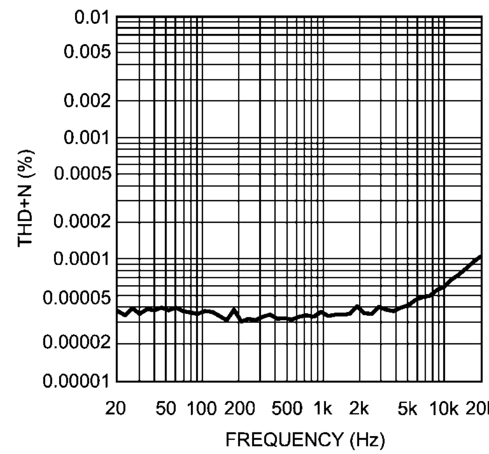
THD+N vs Frequency
V_{CC} = 17V, V_{EE} = –17V, R_L = 2kΩ, V_{OUT} = 3V_{RMS}



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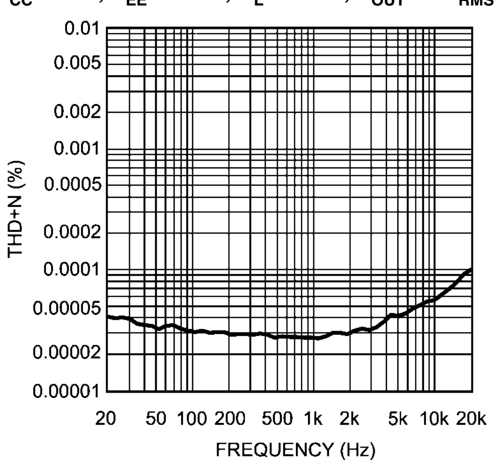
THD+N vs Frequency
V_{CC} = 15V, V_{EE} = –15V, R_L = 600Ω, V_{OUT} = 3V_{RMS}



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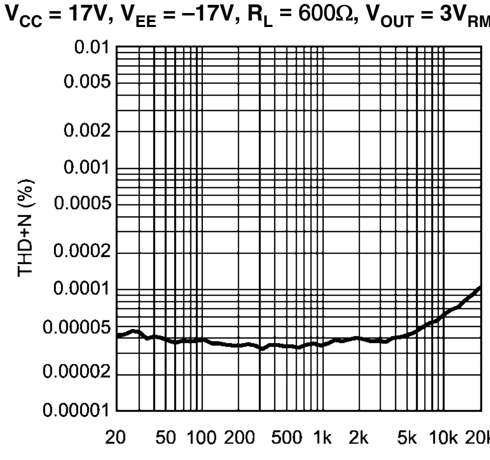
THD+N vs Frequency
V_{CC} = 17V, V_{EE} = –17V, R_L = 600Ω, V_{OUT} = 3V_{RMS}



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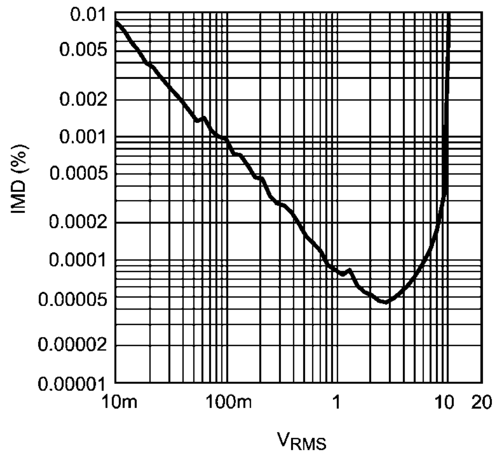
IMD vs Output Voltage
V_{CC} = 15V, V_{EE} = –15V, R_L = 2kΩ



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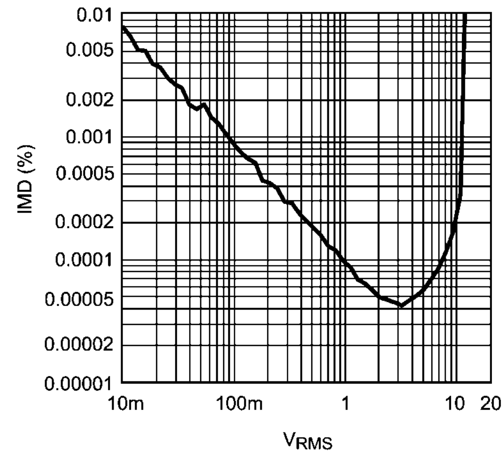
IMD vs Output Voltage
V_{CC} = 17V, V_{EE} = –17V, R_L = 2kΩ



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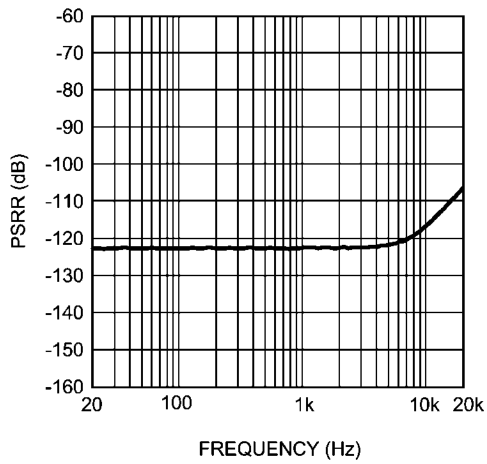
PSRR+ vs Frequency
V_{CC} = 15V, V_{EE} = –15V,
R_L = 2kΩ, V_{RIPPLE} = 200mVpp



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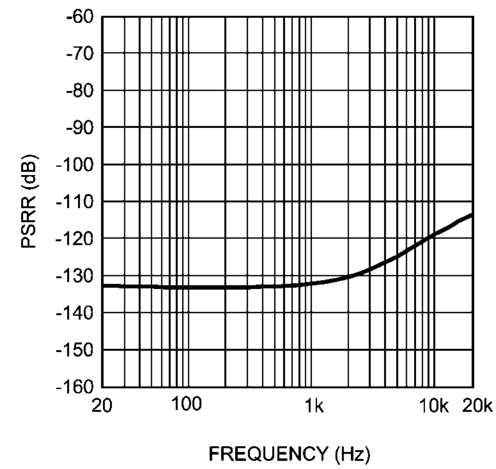
PSRR- vs Frequency
V_{CC} = 15V, V_{EE} = –15V, R_L = 2kΩ
R_L = 2kΩ, V_{RIPPLE} = 200mVpp



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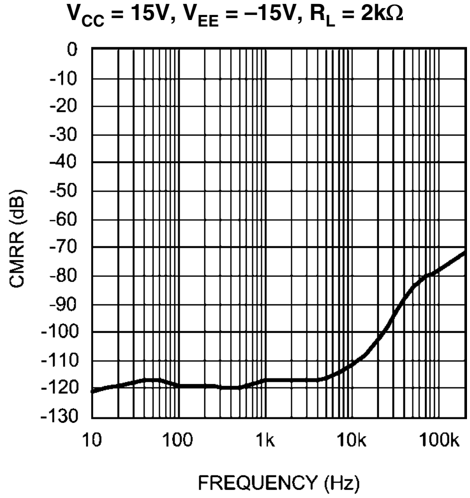
CMRR vs Frequency
V_{CC} = 15V, V_{EE} = –15V, R_L = 2kΩ



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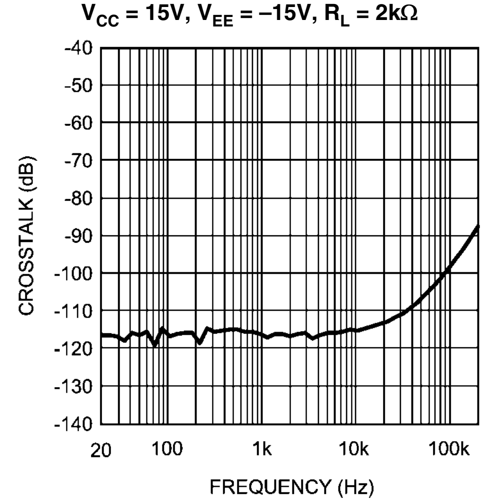
Crosstalk vs Frequency
V_{CC} = 15V, V_{EE} = –15V, R_L = 2kΩ



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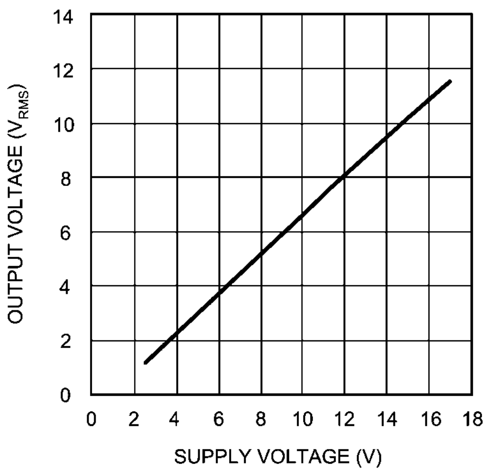
Output Voltage vs Supply Voltage
R_L = 2kΩ, THD+N = 1%



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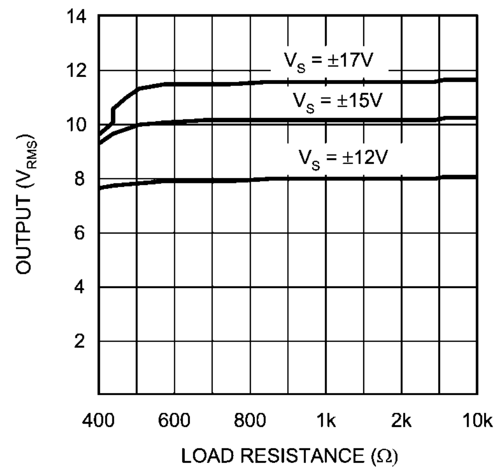
Output Voltage vs Load Resistance
THD+N = 1%



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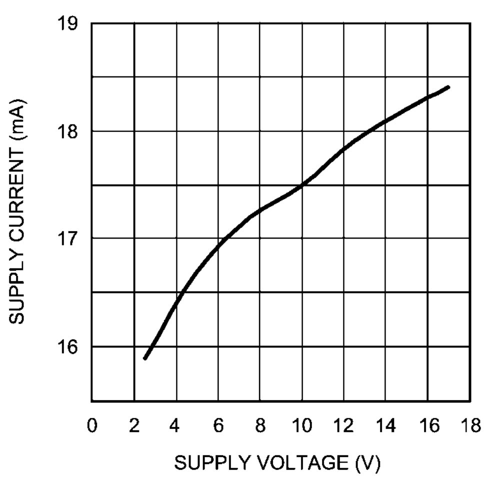
Supply Current vs Supply Voltage
R_L = 2kΩ, THD+N = 1%



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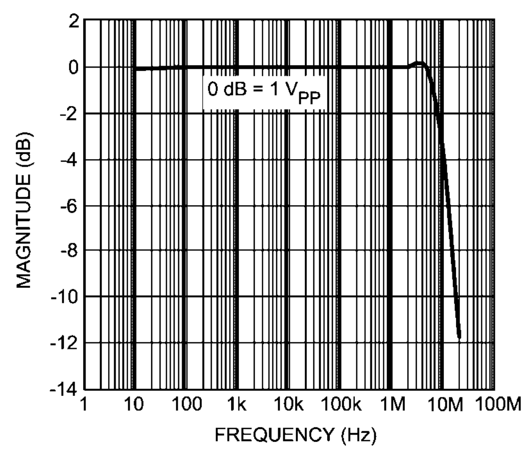
Full Power Bandwidth vs Frequency



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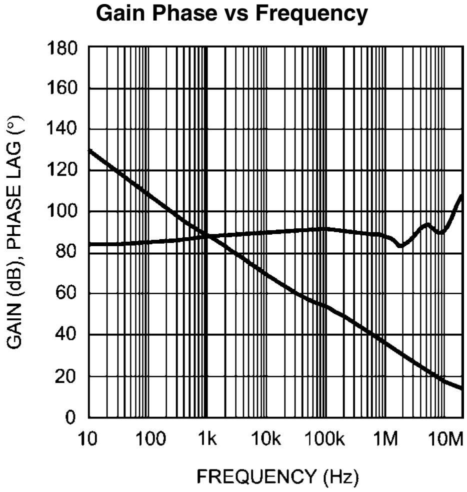
Gain Phase vs Frequency



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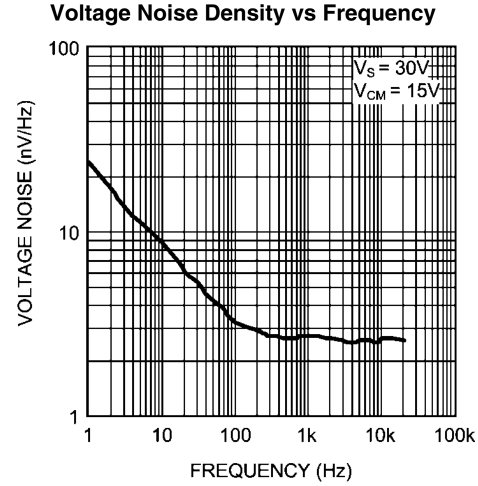
Voltage Noise Density vs Frequency



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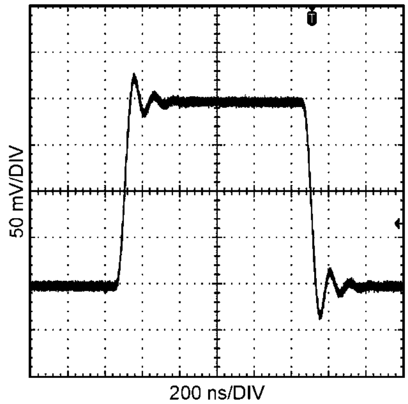
Small-Signal Transient Response
$A_V = 1$, $C_L = 100pF$



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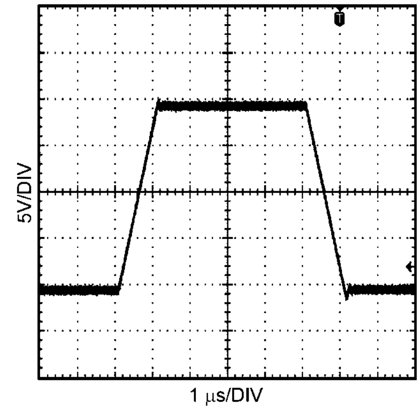
Large-Signal Transient Response
$A_V = 1$, $C_L = 100pF$



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Application Information

DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49740 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 LME49740's low residual distortion is an input referred internal error. As shown in Figure 2, 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 2.

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.

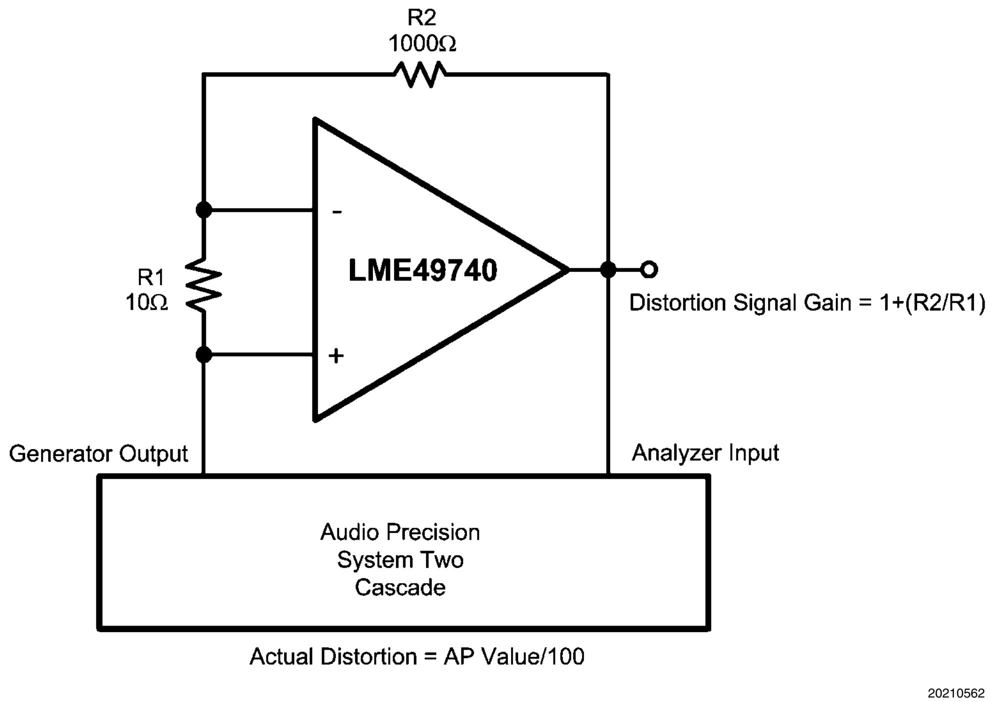


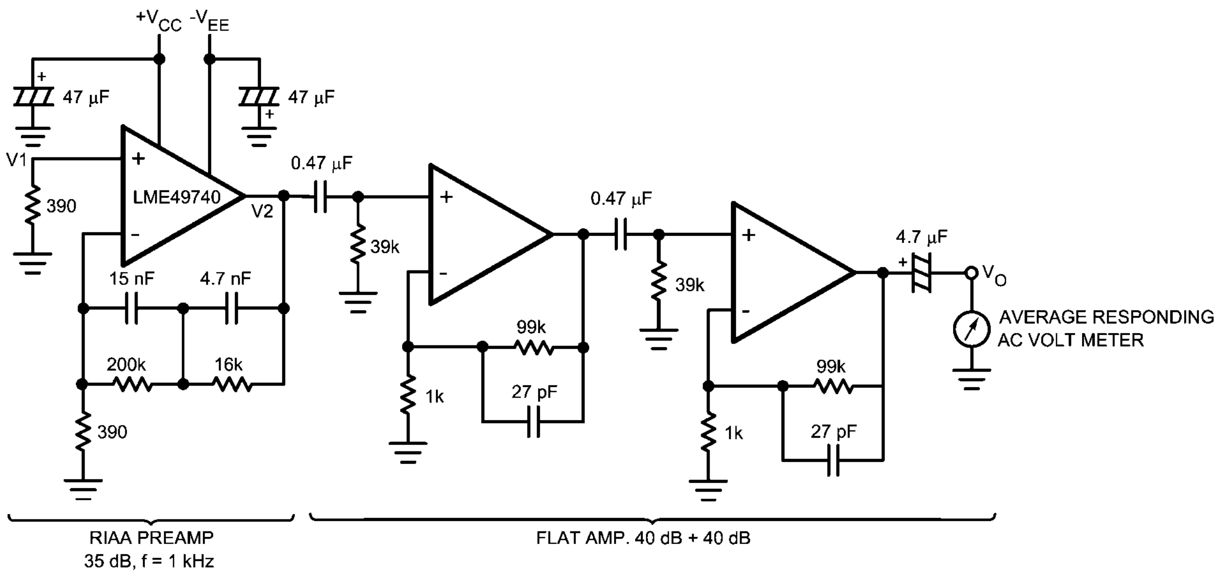
FIGURE 2. THD+N and IMD Distortion Test Circuit

Application Hints

The LME49740 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.

Noise Measurement Circuit



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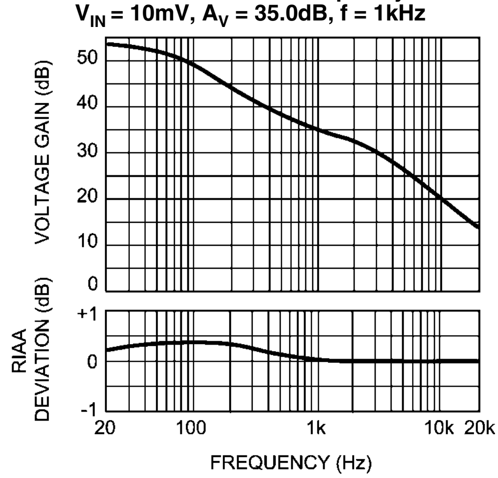
Complete shielding is required to prevent induced pick up from external sources. Always check with oscilloscope for power line noise.

Total Gain: 115 dB at f = 1 kHz
Input Referred Noise Voltage: $e_n = V_O/560{,}000$ (V)

RIAA Preamp Voltage Gain, RIAA Deviation vs Frequency
V_{IN} = 10mV, A_V = 35.0dB, f = 1kHz



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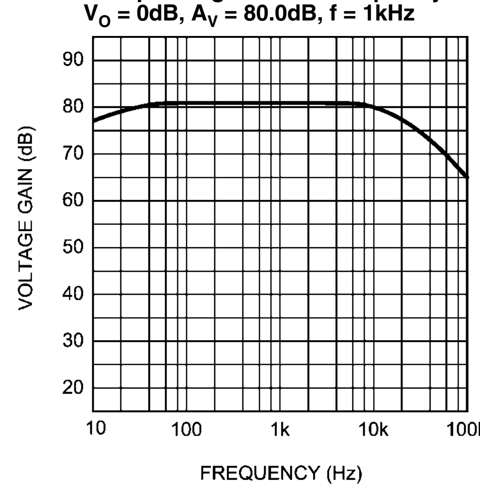
Flat Amp Voltage Gain vs Frequency
V_O = 0dB, A_V = 80.0dB, f = 1kHz



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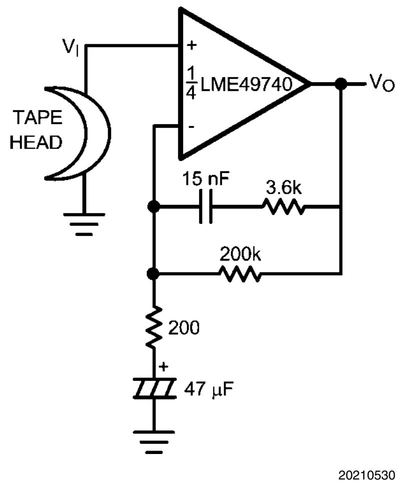
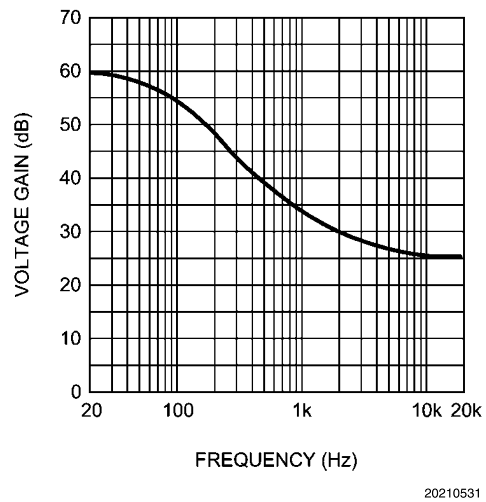
Typical Applications

NAB Preamp

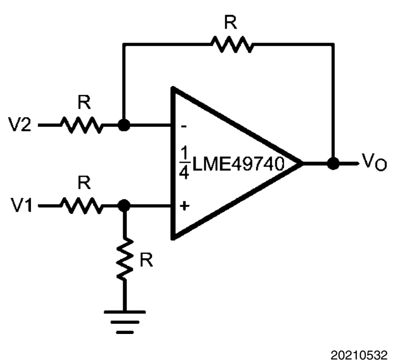


$A_V = 34.5$
F = 1 kHz
$E_n = 0.38\ \mu V$
A Weighted

NAB Preamp Voltage Gain vs Frequency
V_{IN} = 10mV, A_V = 34.5dB, f = 1kHz

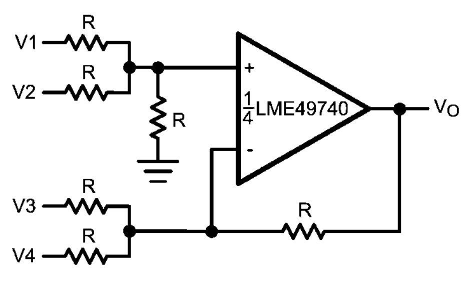


Balanced to Single Ended Converter



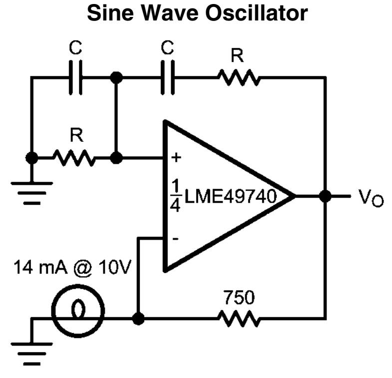
$V_O = V1 - V2$

Adder/Subtracter



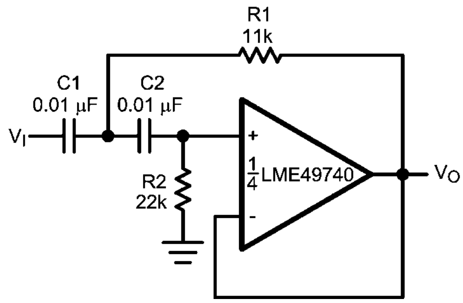
$V_O = V1 + V2 - V3 - V4$

Sine Wave Oscillator



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

Second Order High Pass Filter (Butterworth)



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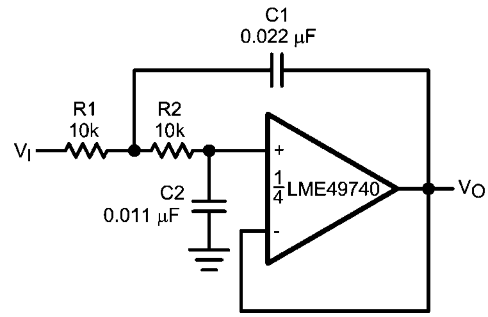
if C1 = C2 = C

$$R1 = \frac{\sqrt{2}}{2\omega_0 C}$$

R2 = 2•R1

Illustration is f_0 = 1 kHz

Second Order Low Pass Filter (Butterworth)



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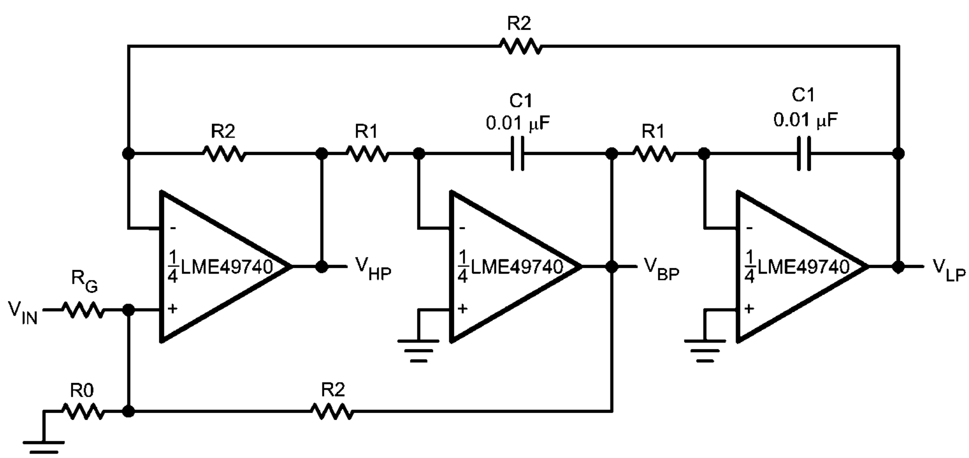
if R1 = R2 = R

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

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

Illustration is f_0 = 1 kHz

State Variable Filter



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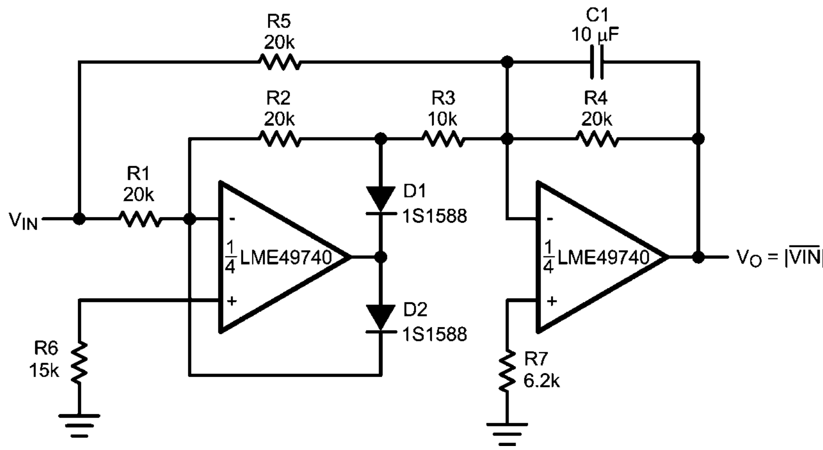
$$f_0 = \frac{1}{2\pi C1R1}, Q = \frac{1}{2}\left(1 + \frac{R2}{R0} + \frac{R2}{RG}\right), A_{BP} = QA_{LP} = QA_{LH} = \frac{R2}{RG}$$

AC/DC Converter



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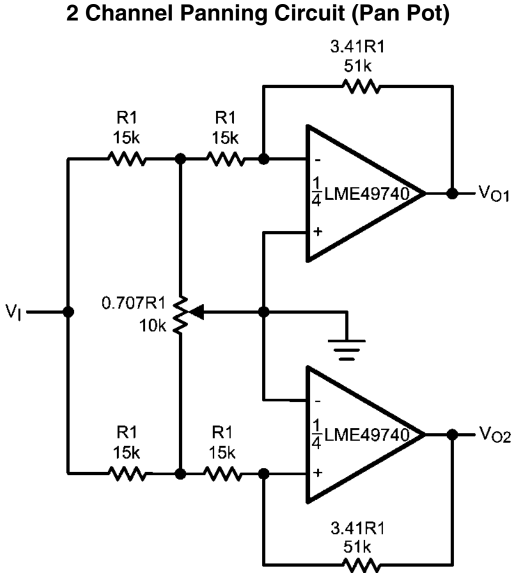
2 Channel Panning Circuit (Pan Pot)



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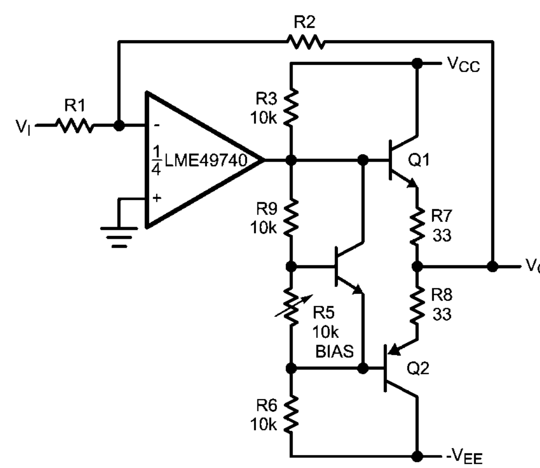
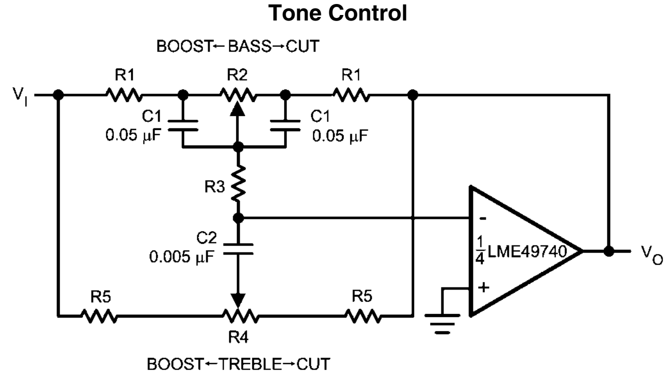
Line Driver



20210540

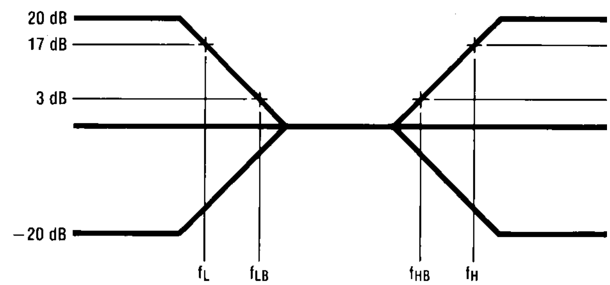
Tone Control



20210541

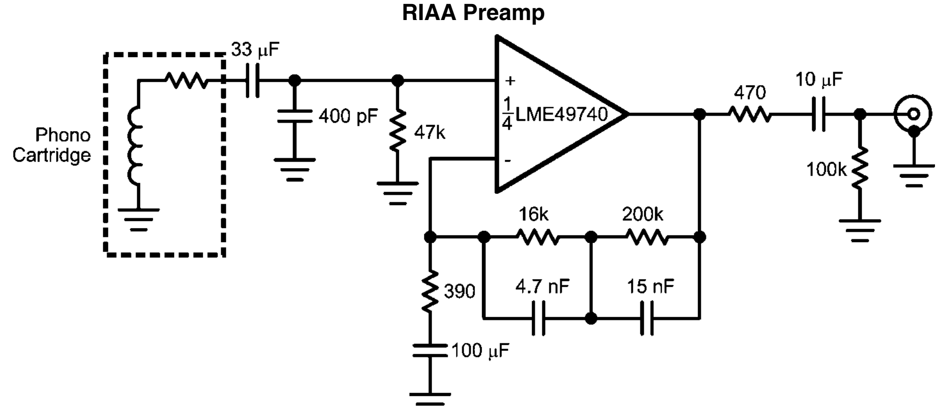
$$f_L = \frac{1}{2\pi R2C1},\ f_{LB} = \frac{1}{2\pi R1C1}$$

$$f_H = \frac{1}{2\pi R5C2},\ f_{HB} = \frac{1}{2\pi(R1 + R5 + 2R3)C2}$$



20210542

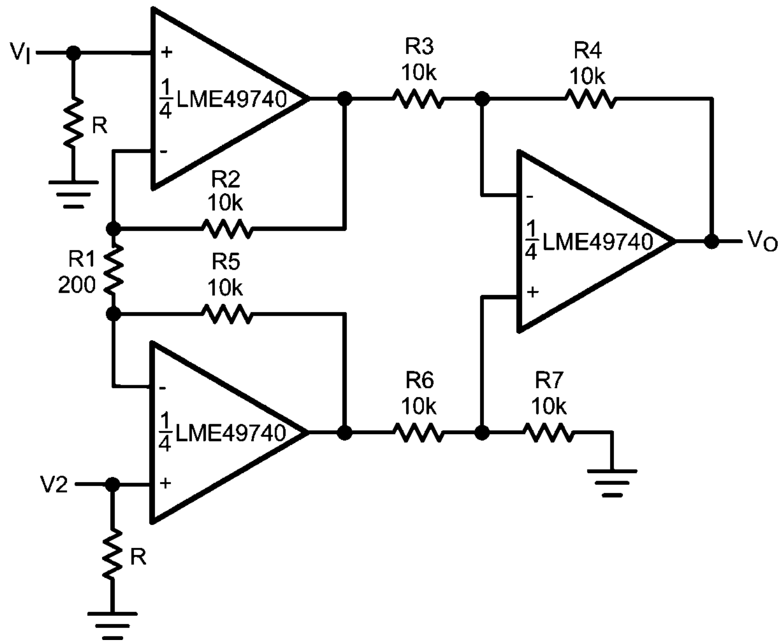
RIAA Preamp



20210503

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

Balanced Input Mic Amp



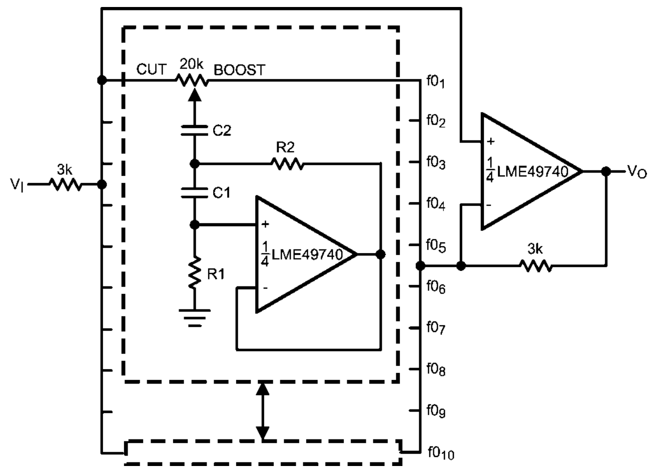
If R2 = R5, R3 = R6, R4 = R7

$$V0 = \left(1 + \frac{2R2}{R1}\right)\frac{R4}{R3}(V2 - V1)$$

Illustration is:

V0 = 101(V2 − V1)

10 Band Graphic Equalizer



20210544

fo (Hz)	C_1	C_2	R_1	R_2
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
4k	1100pF	0.056μF	62kΩ	470Ω
8k	510pF	0.022μF	68kΩ	510Ω
16k	330pF	0.012μF	51kΩ	510Ω

Note 10: At volume of change = ±12 dB

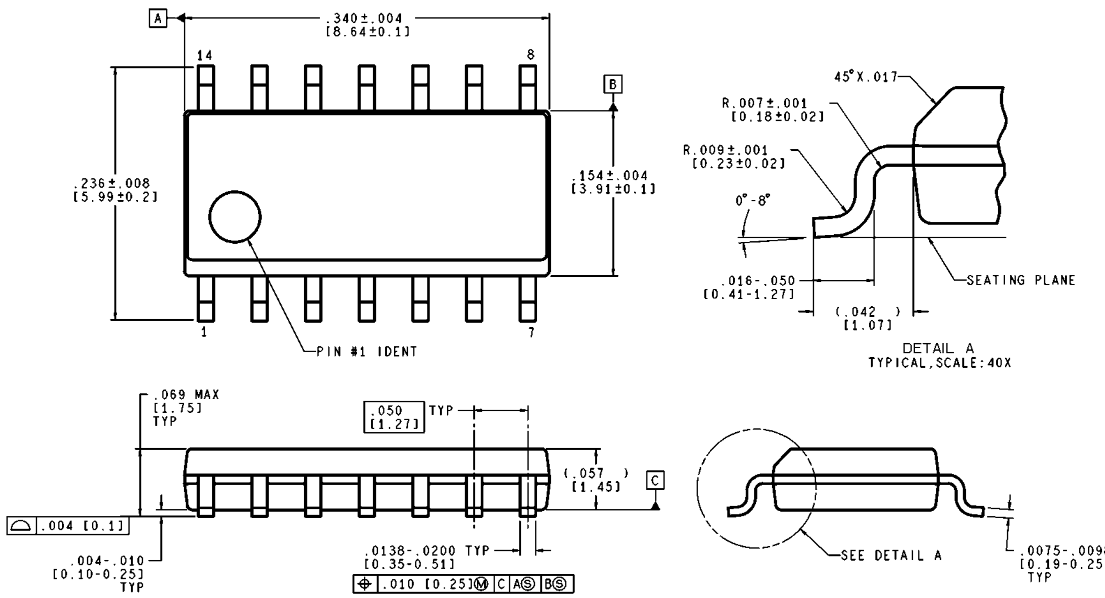
Q = 1.7

Reference: “AUDIO/RADIO HANDBOOK”, National Semiconductor, 1980, Page 2–61

Revision History

Rev	Date	Description
1.0	02/28/07	Initial WEB release.

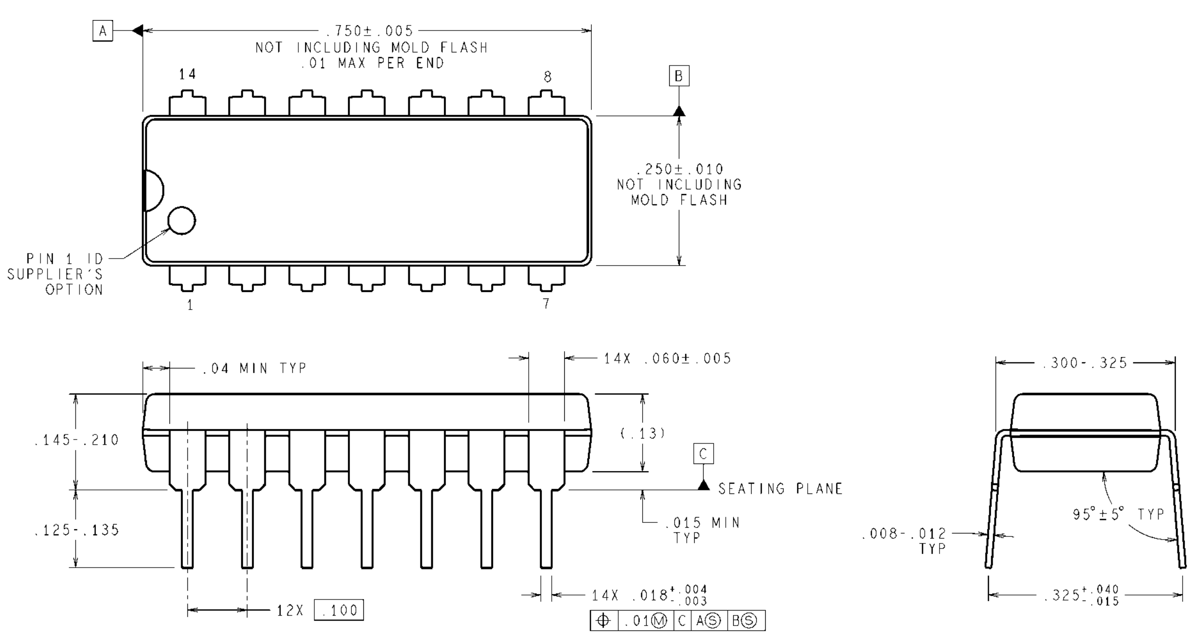
Physical Dimensions inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

M14A (Rev J)

Dual-In-Line Package
Order Number LME49740MA
NS Package Number M14A



DIMENSIONS ARE IN INCHES
DIMENSIONS IN ( ) FOR REFERENCE ONLY

N14A (Rev G)

Dual-In-Line Package
Order Number LME49740NA
NS Package Number N14A

Notes

For the most current product information visit us at www.national.com

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