National Semiconductor

November 5, 2008

LME49726
High Current, Low Distortion, Rail-to-Rail Output Audio Operational Amplifier

General Description

The LME49726 is a low distortion, low noise rail-to-rail output audio operational amplifier optimized and fully specified for high performance, high fidelity applications. The LME49726 delivers superior audio signal amplification for outstanding audio performance. The LME49726 has a very low THD+N to easily satisfy demanding audio applications. To ensure that the most challenging loads are driven without compromise, the LME49726 provides output current greater than 300mA at 5V. Further, dynamic range is maximized by an output stage that drives 2kΩ loads to within 4mV of either power supply voltage.

The LME49726 has a supply range of 2.5V to 5.5V. Over this supply range the LME49726's input circuitry maintains excellent common-mode and power supply rejection, as well as maintaining its low input bias current. The LME49726 is unity gain stable.

Key Specifications

■ Power Supply Voltage Range	2.5V to 5.5V
■ Quiescent Current per Amplifier at 5V	0.7mA (typ)
■ THD+N, $A_V = 1$, $f_{IN} = 1kHz$, $R_L = 10k\Omega$	
($V_{OUT} = 3.5V_{P-P}$, $V_{DD} = 5.0V$)	0.00008% (typ)
($V_{OUT} = 1.5V_{P-P}$, $V_{DD} = 2.5V$)	0.00002% (typ)
■ Equivalent Input Noise (f = 10k, A-weighted)	$6.9nV/\sqrt{Hz}$ (typ)
■ Slew Rate	±3.7V/μs (typ)
■ Gain Bandwidth Product	6.25MHz (typ)
■ Open Loop Gain ($R_L = 10k\Omega$)	120dB (typ)
■ Input Bias Current	0.2pA (typ)
■ Input Offset Voltage	0.5mV (typ)
■ PSRR (DC)	104dB (typ)

Features

- Rail-to-rail output
- Easily drives 2kΩ loads to within 4mV of each power supply voltage rail
- Optimized for superior audio signal fidelity
- Output short circuit protection
- High output drive (>300mA)
- Available in mini-SOIC exposed-DAP package

Applications

- Portable audio amplification
- Preamplifiers and multimedia
- Equalization and crossover networks
- Line drivers and receivers
- Active filters
- DAC I–V converter gain stage
- ADC front-end signal conditioning

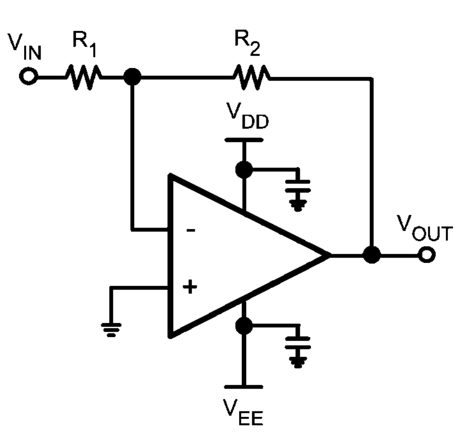


FIGURE 1. Inverting Configuration Split Supplies

Typical Connection, Pinout, and Package Marking

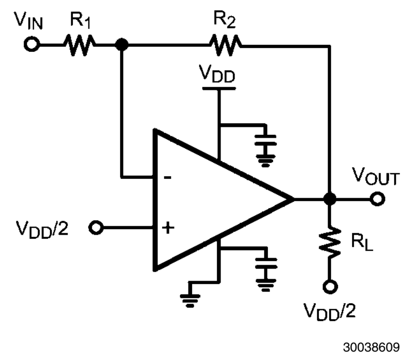
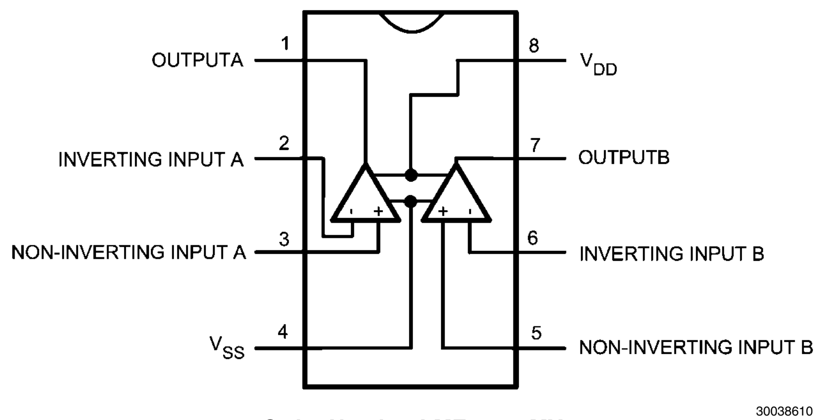
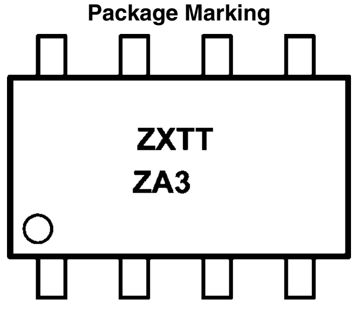


FIGURE 2. Inverting Configuration Single Supply



Order Number LME49726MY
See NS Package Number MUY08A

Package Marking



Z = Assembly plant code
X = 1 Digit date code
TT = Lot traceability
ZA3 = LME49726

Ordering Information

Order Number	Package	Package Drawing Number	Transport Media	MSL Level	Green Status
LME49726MY	MSOP EXPOSE PAD	MUY08A	1000 units on tape on reel	1	RoHS & no Sb/Br
LME49726MYX	MSOP EXPOSE PAD	MUY08A	3500 units on tape on reel	1	RoHS & no Sb/Br

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 $V_S = V_{SS}-V_{DD}$	6V
Storage Temperature	–65°C to 150°C
Input Voltage	$(V_{SS}) - 0.7V$ to $(V_{DD}) + 0.7V$
Output Short Circuit (Note 3)	Continuous
Power Dissipation	Internally Limited
ESD Rating (Note 4)	2000V
ESD Rating (Note 5)	200V
Junction Temperature	150°C
Thermal Resistance	
θ_{JA} (MUY-08)	72°C/W

Operating Ratings (Note 1)

Temperature Range	
$T_{MIN} \leq T_A \leq T_{MAX}$	$-40°C \leq T_A \leq 85°C$
Supply Voltage Range	$2.5V \leq V_S \leq 5.5V$

Electrical Characteristics (V_{DD} = 5.0V and V_{DD} = 2.5V)

The following specifications apply for the circuit shown in Figure 1. V_{DD} = 5.0V and V_{DD} = 2.5V, V_{SS} = 0.0V, $V_{CM} = V_{DD/2}$, R_L = 10kΩ, C_{LOAD} = 20pF, f_{IN} = 1kHz, BW = 20–20kHz, and T_A = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	LME49726 Typical (Note 6)	LME49726 Limit (Note 7)	Units (Limits)
THD+N	Total Harmonic Distortion + Noise	$A_V = -1$, $V_{OUT} = 3.5V_{p-p}$, V_{DD} = 5V R_L = 600Ω R_L = 2kΩ R_L = 10kΩ	 0.0008 0.0002 0.00008		 % % %
		$A_V = -1$, $V_{OUT} = 1.5V_{p-p}$, V_{DD} = 2.5V R_L = 600Ω R_L = 2kΩ R_L = 10kΩ	 0.001 0.0008 0.0002		 % % %
GBWP	Gain Bandwidth Product		6.25	5.0	MHz (min)
SR	Slew Rate	A_V = +1, R_L = 10kΩ	3.7	2.5	V/μs (min)
t_s	Settling time	A_V = 1V step 0.1% error range 0.001% error range	 800 1.2		 ns μs
e_N	Equivalent Input Noise Voltage	f_{BW} = 20Hz to 20kHz (A-weighted)	0.7	1.25	μV_{RMS} (max)
e_N	Equivalent Input Noise Density	f = 10kHz (A-weighted)	6.9		$nV/\sqrt{Hz}$
		f = 1kHz (A-weighted)	15		$nV/\sqrt{Hz}$
		f = 100Hz (A-weighted)	35		$nV/\sqrt{Hz}$
I_N	Current Noise Density	f = 1kHz	0.75		$pA/\sqrt{Hz}$
V_{OS}	Input Offset Voltage	$V_{IN} = V_{DD/2}$, $V_O = V_{DD/2}$, A_V = 1	0.5	2.25	mV (max)
$\Delta V_{OS}/\Delta Temp$	Average Input Offset Voltage Drift vs Temperature	$40°C \leq T_A \leq 85°C$	1.2		μV/°C
PSRR	Power Supply Rejection Ratio	2.5 to 5.5V, V_{CM} = 0, $V_{DD}/2$	104	85	dB (min)
ISO_{CH-CH}	Channel-to-Channel Isolation	f_{IN} = 1kHz	94		dB
I_B	Input Bias Current	$V_{CM} = V_{DD}/2$	±0.2		pA
$\Delta I_{OS}/\Delta Temp$	Input Bias Current Drift vs Temperature	$-40°C \leq T_A \leq 85°C$	35		nA/°C
I_{OS}	Input Offset Current	$V_{CM} = V_{DD}/2$	±0.2		pA
V_{IN-CM}	Common-Mode Input Voltage Range			$V_{DD}-1.6$ $V_{SS}+0.1$	V (min)
CMRR	Common Mode Rejection Ratio	$0.1V < V_{DD} - 1.6V$	95	80	dB (min)
1/f	1/f Corner Frequency		2		kHz
A_{VOL}	Open-Loop Voltage Gain	$V_{OUT} = V_{DD}/2$	120	100	dB (min)

Symbol	Parameter	Conditions	LME49726 Typical (Note 6)	LME49726 Limit (Note 7)	Units (Limits)
$V_{OUTSWING}$	Maximum Output Voltage Swing	R_L = 2kΩ to $V_{DD}/2$	V_{DD}–0.004 V_{SS} +0.004		V (min) V (max)
		R_L = 16Ω to $V_{DD}/2$	V_{DD} –0.33 V_{SS}+0.33		V (min) V (max)
I_{OUT}	Output Current	V_{OUT} = 5V, V_{DD} = 5V	350		mA
		V_{OUT} = 2.5V, V_{DD} = 2.5V	160		mA
I_S	Quiescent Current per Amplifier	I_{OUT} = 0mA, V_{DD} = 5V	0.7	1.1	mA (max)
		I_{OUT} = 0mA, V_{DD} = 2.5V	0.64	1.0	mA (max)

Note 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.

Note 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.

Note 3: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{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. For the LME49726, see Power Derating curve for additional information.

Note 4: Human body model, applicable std. JESD22-A114C.

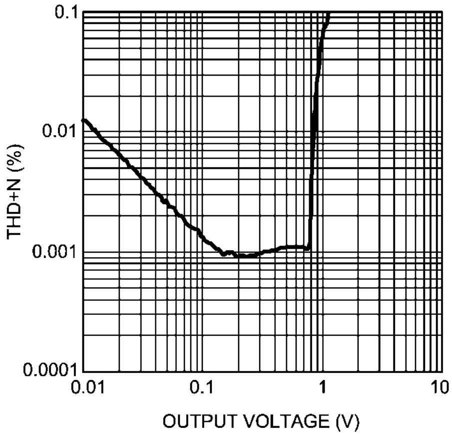
Note 5: Machine model, applicable std. JESD22-A115-A.

Note 6: Typical values represent most likely parametric norms at T_A = +25ºC, and at the *Recommended Operation Conditions* at the time of product characterization and are not guaranteed.

Note 7: Datasheet min/max specification limits are guaranteed by test or statistical analysis.

Typical Performance Characteristics

THD+N vs Output Voltage
V_{DD} = 1.25V, V_{SS} = –1.25V, R_L = 600Ω
A_V = –1, f = 1kHz, BW = 22–22kHz



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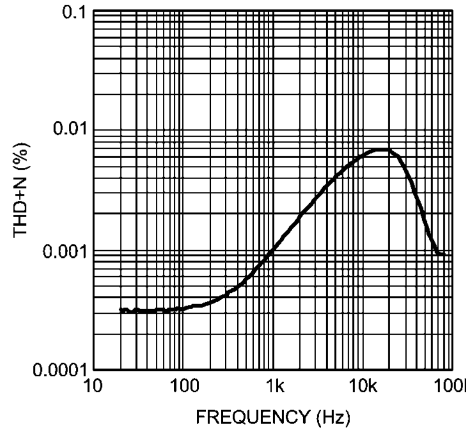
THD+N vs Frequency
V_{DD} = 1.25V, V_{SS} = –1.25V, R_L = 600Ω
V_O = 1.5V_{P-P}, BW = 22–80kHz



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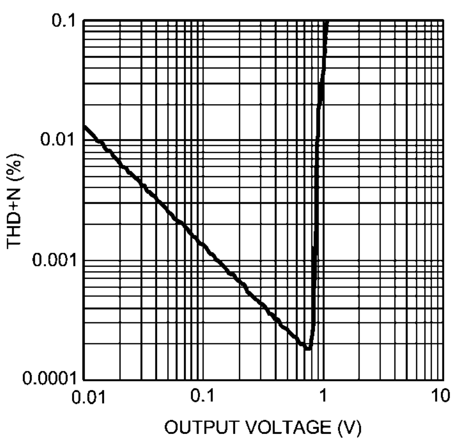
THD+N vs Output Voltage
V_{DD} = 1.25V, V_{SS} = –1.25V, R_L = 10kΩ
A_V = –1, f = 1kHz, BW = 22–22kHz



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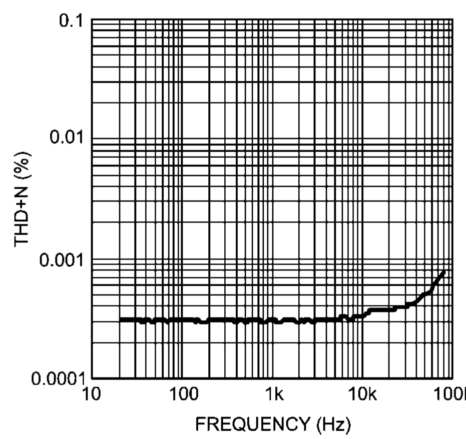
THD+N vs Frequency
V_{DD} = 1.25V, V_{SS} = –1.25V, R_L = 10kΩ
V_O = 1V_{P-P}, BW = 22–80kHz



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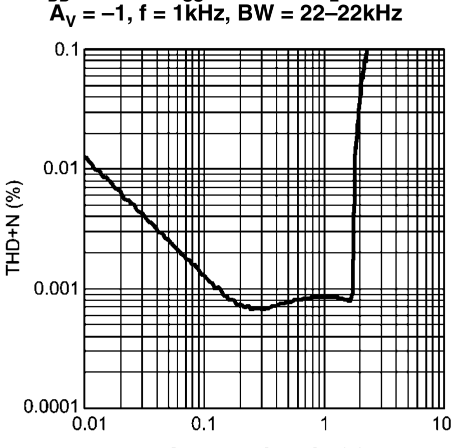
THD+N vs Output Voltage
V_{DD} = 2.50V, V_{SS} = –2.50V, R_L = 600Ω
A_V = –1, f = 1kHz, BW = 22–22kHz



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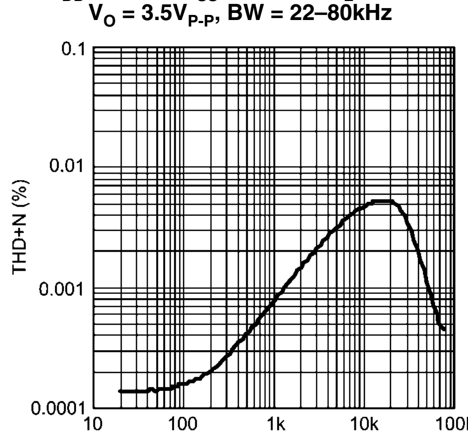
THD+N vs Frequency
V_{DD} = 2.50V, V_{SS} = –2.50V, R_L = 600Ω
V_O = 3.5V_{P-P}, BW = 22–80kHz



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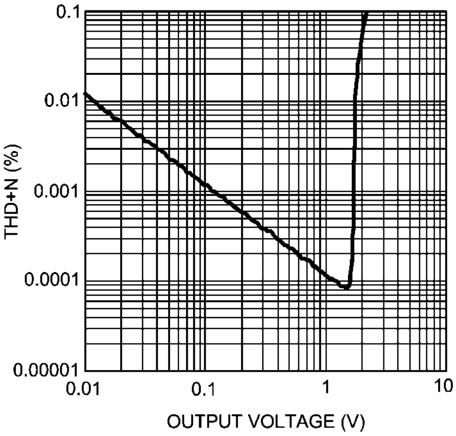
THD+N vs Output Voltage
V_{DD} = 2.50V, V_{SS} = –2.50V, R_L = 10kΩ
A_V = –1, f = 1kHz, BW = 22–22kHz



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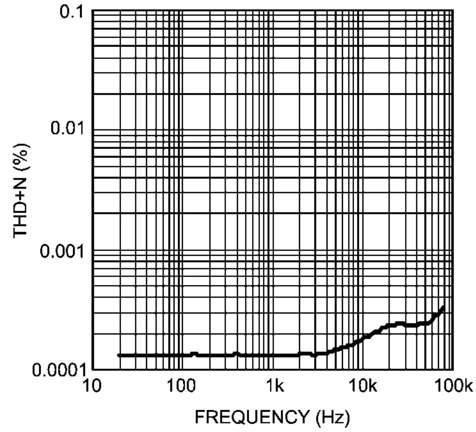
THD+N vs Frequency
V_{DD} = 2.50V, V_{SS} = –2.50V, R_L = 10kΩ
V_O = 1V_{P-P}, BW = 22–80kHz



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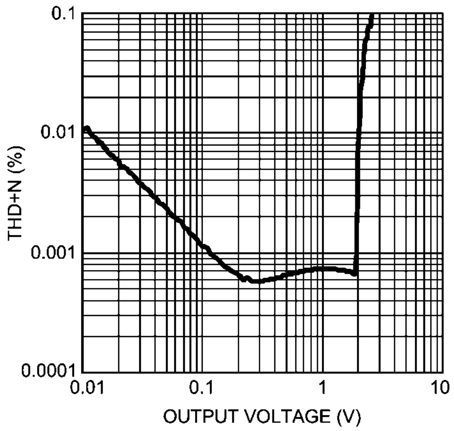
THD+N vs Output Voltage
V_{DD} = 2.75V, V_{SS} = –2.75V, R_L = 600Ω
A_V = –1, f = 1kHz, BW = 22–22kHz



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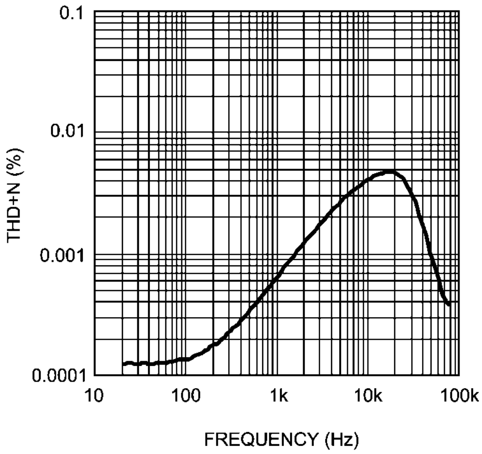
THD+N vs Frequency
V_{DD} = 2.75V, V_{SS} = –2.75V, R_L = 600Ω
V_O = 3.5V_{P-P}, BW = 22–80kHz



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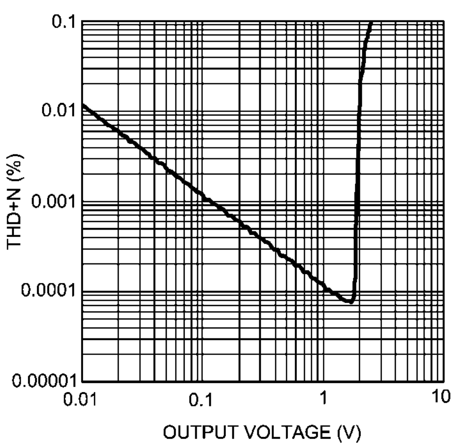
THD+N vs Output Voltage
V_{DD} = 2.75V, V_{SS} = –2.75V, R_L = 10kΩ
A_V = –1, f = 1kHz, BW = 22–22kHz



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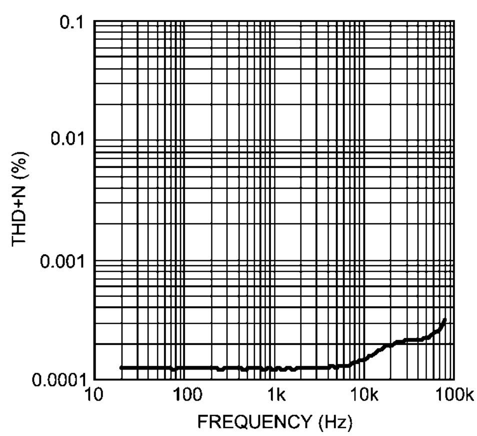
THD+N vs Frequency
V_{DD} = 2.75V, V_{SS} = –2.75V, R_L = 10kΩ
V_O = 3.5V_{P-P}, BW = 22–80kHz



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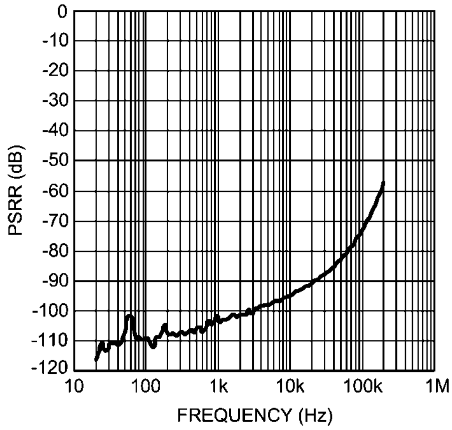
PSRR+ vs Frequency
V_{DD} = 1.25V, V_{SS} = –1.25V, V_{RIPPLE} = 200mV_{P-P}
Input terminated, BW = 22–80kHz



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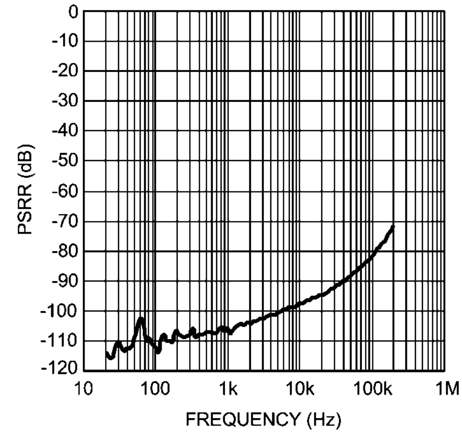
PSRR– vs Frequency
V_{DD} = 1.25V, V_{SS} = –1.25V, V_{RIPPLE} = 200mV_{P-P}
Input terminated, BW = 22–80kHz



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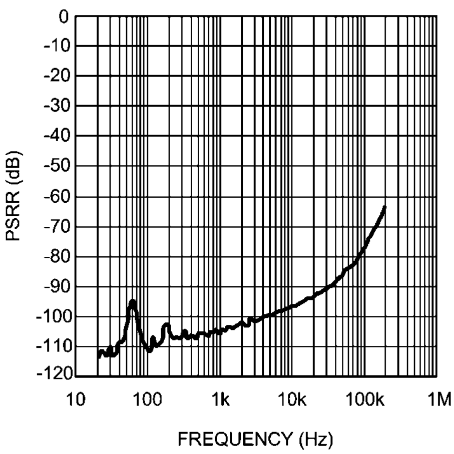
PSRR+ vs Frequency
V_{DD} = 2.50V, V_{EE} = –2.50V, V_{RIPPLE} = 200mV_{P-P}
Input terminated, BW = 22–80kHz



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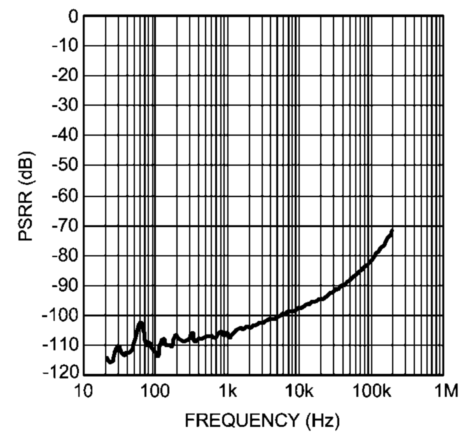
PSRR– vs Frequency
V_{DD} = 2.50V, V_{SS} = –2.50V, V_{RIPPLE} = 200mV_{P-P}
Input terminated, BW = 22–80kHz



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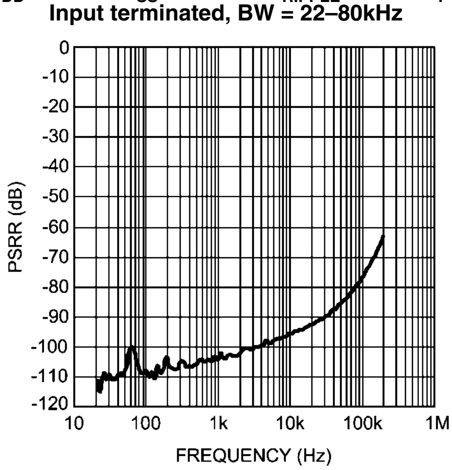
PSRR+ vs Frequency
V_{DD} = 2.75V, V_{SS} = –2.75V, V_{RIPPLE} = 200mV_{P-P}
Input terminated, BW = 22–80kHz



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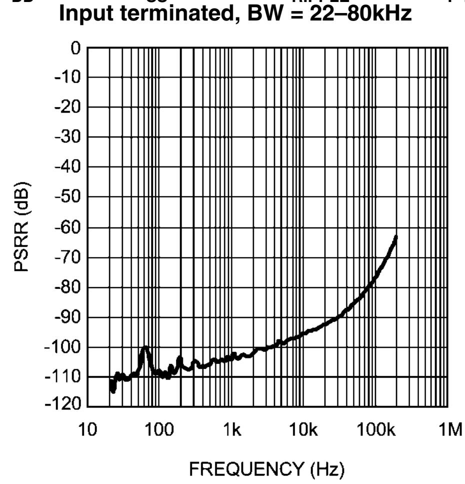
PSRR– vs Frequency
V_{DD} = 2.75V, V_{SS} = –2.75V, V_{RIPPLE} = 200mV_{P-P}
Input terminated, BW = 22–80kHz



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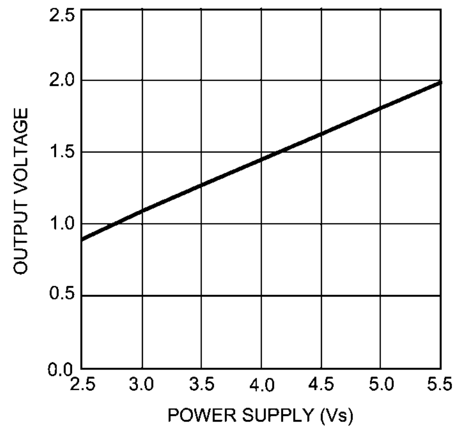
Output Voltage vs Supply Voltage
R_L = 600Ω, A_V = –1
f = 1kHz, THD+N = 1%, BW = 22–80kHz



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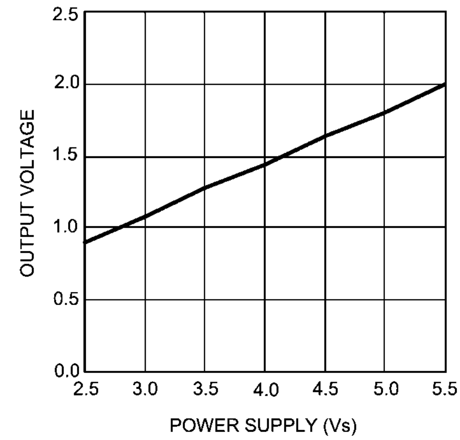
Output Voltage vs Supply Voltage
R_L = 10kΩ, A_V = –1
f = 1kHz, THD+N = 1%, BW = 22–80kHz



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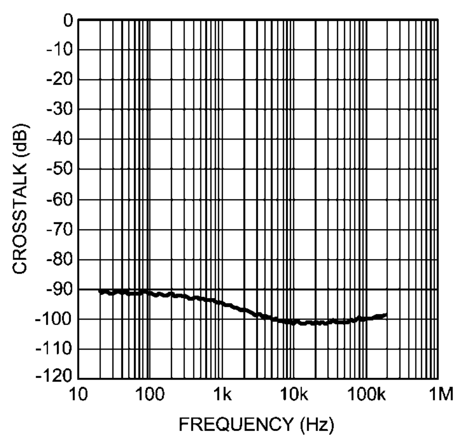
Crosstalk vs Frequency
V_{DD} = 2.50V, V_{SS} = –2.50V, R_L = 10kΩ
A_V = –1, f = 1kHz, BW = 80kHz



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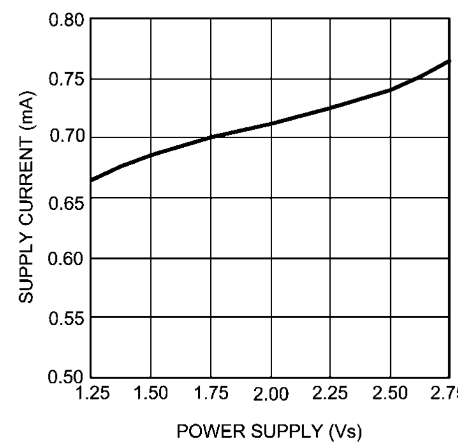
Supply Current vs Supply Voltage
per Amplifier, R_L = No Load, A_V = –1



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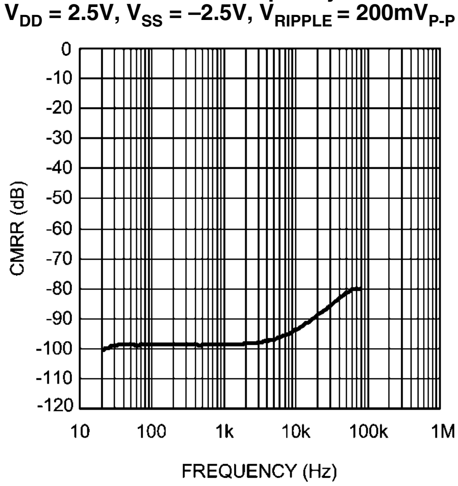
CMRR vs Frequency
V_{DD} = 2.5V, V_{SS} = –2.5V, V_{RIPPLE} = 200mV_{P-P}



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Application Information

DISTORTION MEASUREMENTS

The vanishingly low residual distortion produced by LME49726 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 LME49726's low residual is an input referred internal error. As shown in Figure 3, adding the 10Ω resistor connected between athe 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. To ensure minimum effects on distortion measurements, keep the value of R1 low as shown in Figure 3.

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 measurement equipment capabilities. This datasheet's THD+N and IMD values were generated using the above described circuit connected to an Audio Precision System Two Cascade.

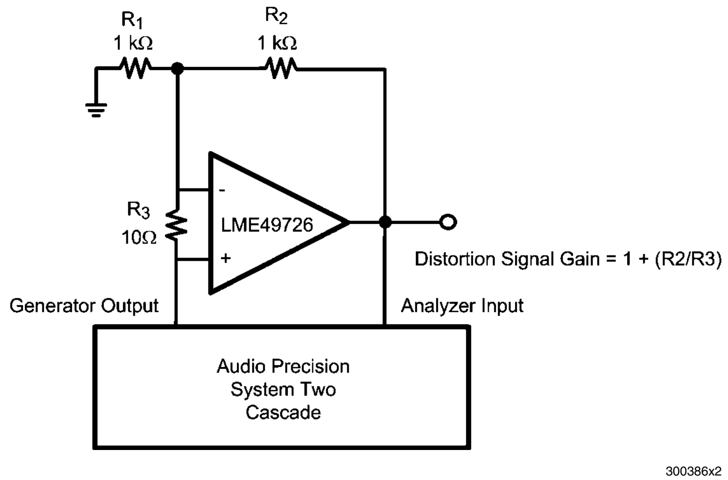


FIGURE 3. THD+N and IMD Distortion Test Circuit

OPERATING RATINGS AND BASIC DESIGN GUIDELINES

The LME49726 has a supply voltage range from +2.5V to +5.5V single supply or ±1.25 to ±2.75V dual supply.

Bypassed capacitors for the supplies should be placed as close to the amplifier as possible. This will help minimize any inductance between the power supply and the supply pins. In addition to a 10μF capacitor, a 0.1μF capacitor is also recommended in CMOS amplifiers.

The amplifier's inputs lead lengths should also be as short as possible. If the op amp does not have a bypass capacitor, it may oscillate.

BASIC AMPLIFIER CONFIGURATIONS

The LME49726 may be operated with either a single supply or dual supplies. Figure 2 shows the typical connection for a single supply inverting amplifier. The output voltage for a single supply amplifier will be centered around the common-mode voltage, V_{CM}. Note, the voltage applied to the V_{CM} insures the output stays above ground. Typically, the V_{CM} should be equal to $V_{DD}/2$. This is done by putting a resistor divider circuit at this node, see *Figure 4*.

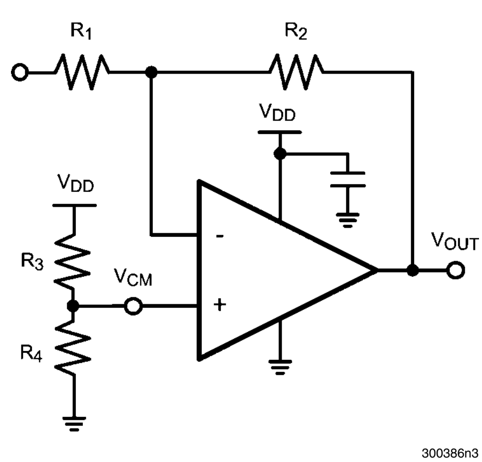


FIGURE 4. Single Supply Inverting Op Amp

Figure 5 shows the typical connection for a dual supply inverting amplifier. The output voltage is centered on zero.

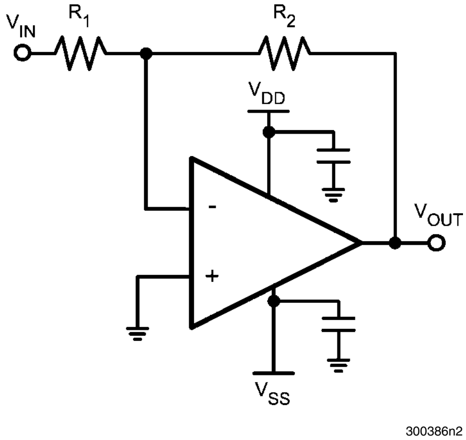


FIGURE 5. Dual Supply Inverting Configuration

Figure 6 shows the typical connection for the Buffer Amplifier or also called a Voltage Follower. The Buffer is a unity gain stable amplifier.

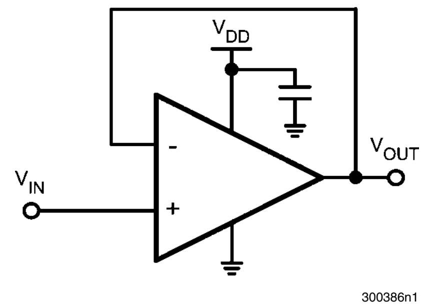
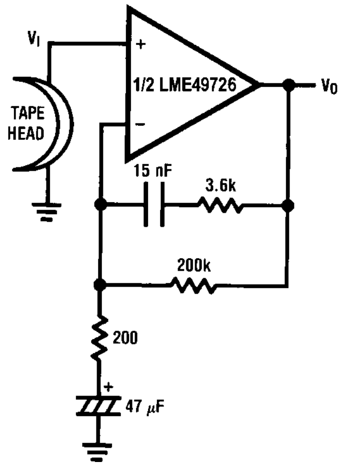


FIGURE 6. Unity-Gain Buffer Configuration

Typical Applications

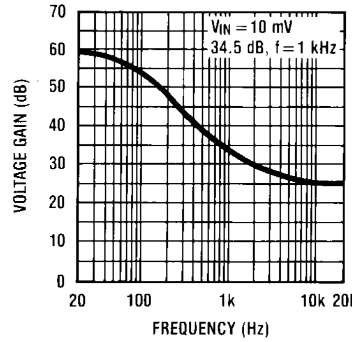
NAB Preamp



300386n4

$A_V = 34.5$
F = 1 kHz
$E_n = 0.38$ µV
A Weighted

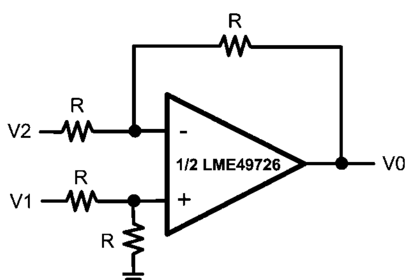
NAB Preamp Voltage Gain vs Frequency



300386n5

$A_V = 34.5$
F = 1 kHz
$E_n = 0.38$ µV
A Weighted

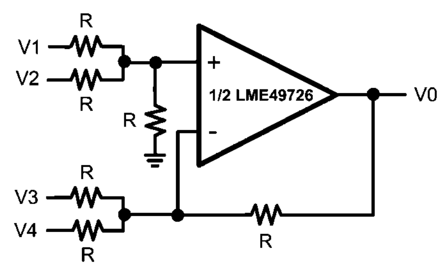
Balanced to Single Ended Converter



300386n6

V_O = V1–V2

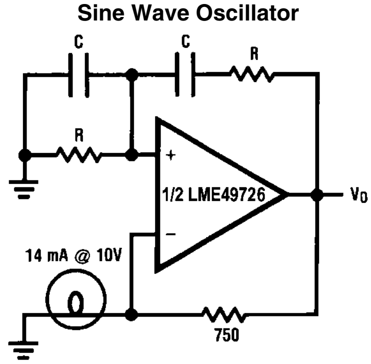
Adder/Subtracter



300386n7

V_O = V1 + V2 − V3 − V4

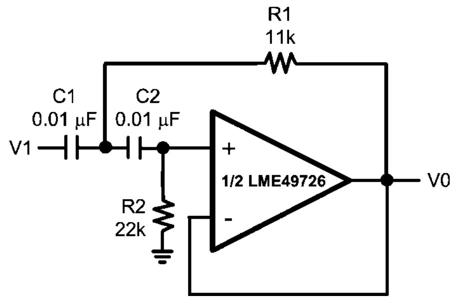
Sine Wave Oscillator



300386n8

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

Second Order High Pass Filter (Butterworth)



300386n9

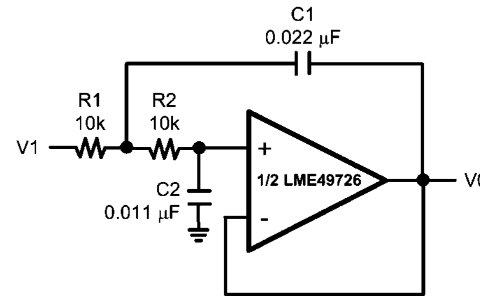
if C1 = C2 = C

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

$$R2 = 2 \bullet R1$$

Illustration is f_0 = 1 kHz

Second Order Low Pass Filter (Butterworth)



300386o0

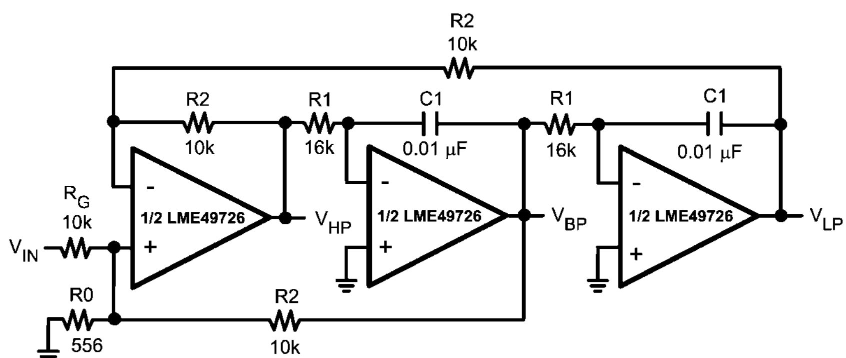
if R1 = R2 = R

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

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

Illustration is f_0 = 1 kHz

State Variable Filter

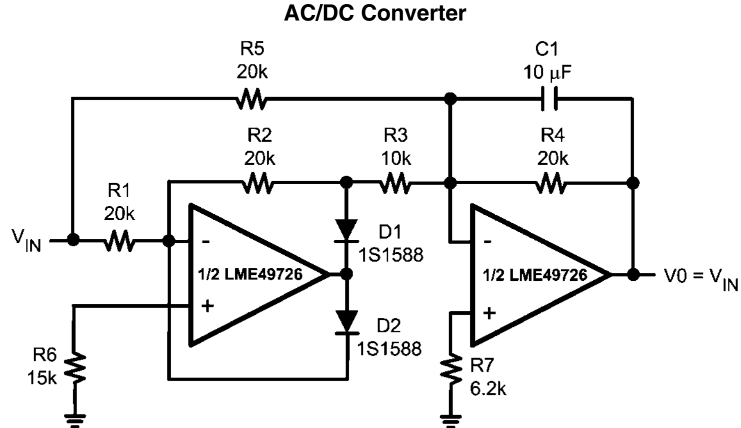


300386o1

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

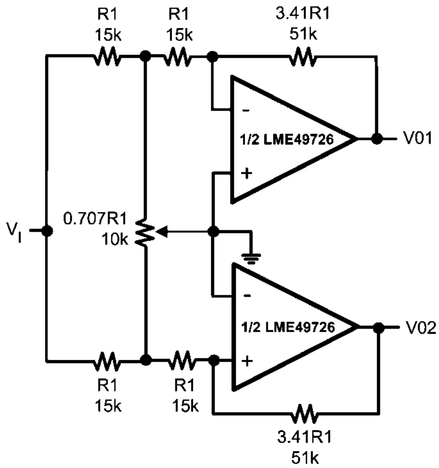
Illustration is f_0 = 1 kHz, Q = 10, A_{BP} = 1

AC/DC Converter



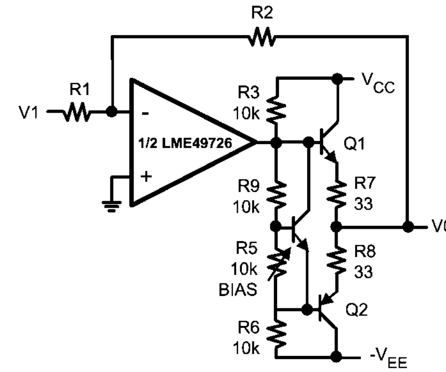
300386o2

2 Channel Panning Circuit (Pan Pot)



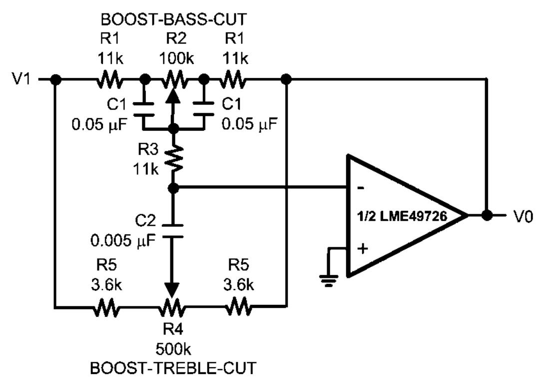
30038603

Line Driver



30038604

Tone Control



30038605

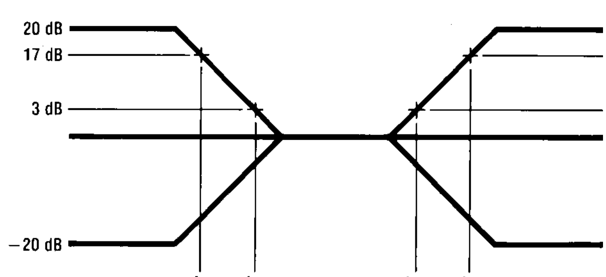
$$f_L = \frac{1}{2\pi R2C1}, f_{LB} = \frac{1}{2\pi R1C1}$$

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

Illustration is:

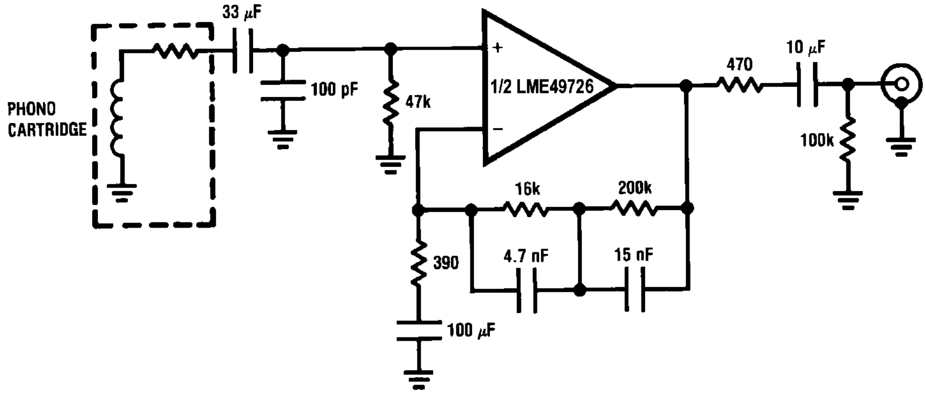
f_L = 32 Hz, f_{LB} = 320 Hz

f_H =11 kHz, f_{HB} = 1.1 kHz



30038606

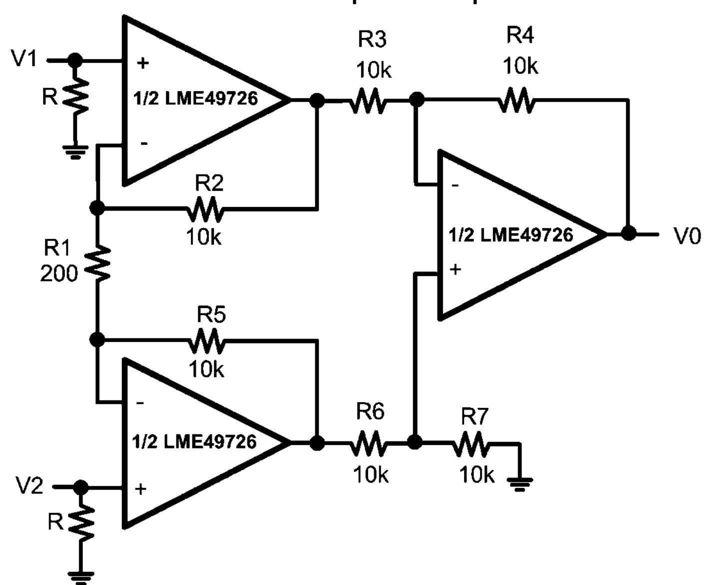
RIAA Preamp



30038608

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



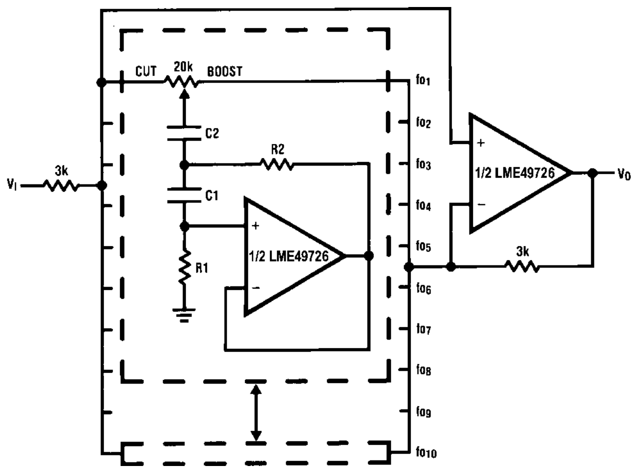
30038607

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



300386p0

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 8: At volume of change = ±12 dB

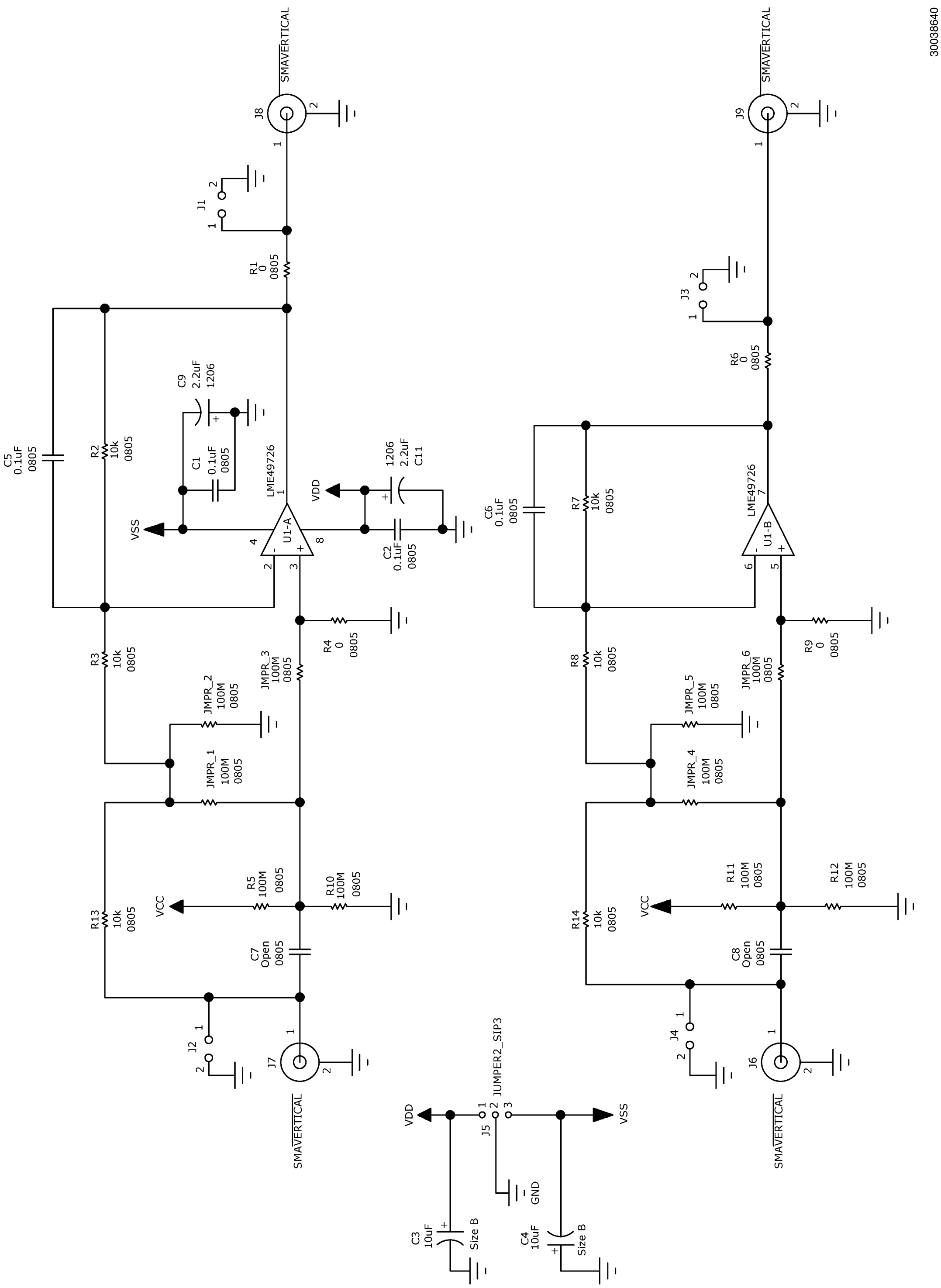
Q = 1.7

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

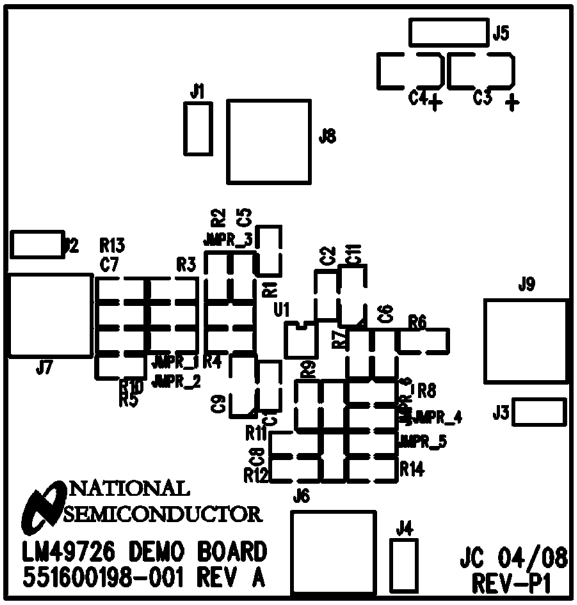
LME49726 Bill of Materials

Description	Designator	Part Number	Manufacturer	Quantity/Brd
Ceramic Capacitor 0.1uF, 10%, 50V 0805 SMD	C1, C2, C5–C8	08055C104KAT2A	AVX	2
Tantalum Capacitor 2.2uF,10%, 20V, A-size	C9, C11	T491A225K020AT	Kemet	Not Stuff
Tantalum Capacitor 10uF,10%, 20V, B-size	C3, C4	T491B106K020AT	Kemet	2
Resistor 0Ω, 1/8W 1% 0805 SMD	R1, R4, R6, R9, R13, R14	CRCW08050000Z0EA	Vishay	6
Header, 2-Pin	JP1, JP2, JP3, JP4	HDR1X2	Header 2	4
Header, 3-Pin	JP5	HDR1X3	Header 3	1
Resistor 10kΩ, 1/8W 1% 0805 SMD	R2, R3, R7, R8	CRCW080510K0FKEA	Vishay	4
Dual Rail-to-Rail Op Amp	U1	LME49726	National Semiconductor	1
Resistor 100meg/open 1/8W 0805 SMD	R5, R10, R11, R12	OPEN N/A	N/A	0

LME49726 Board Circuit

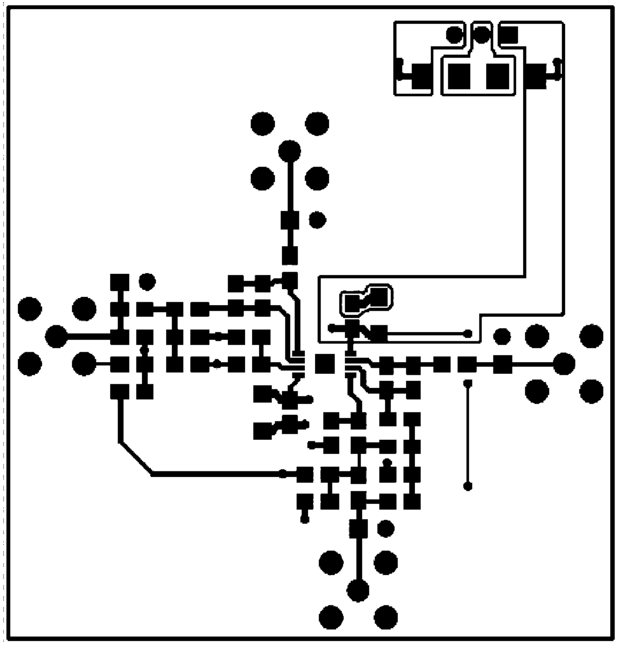


LME49726 Demo Board Views



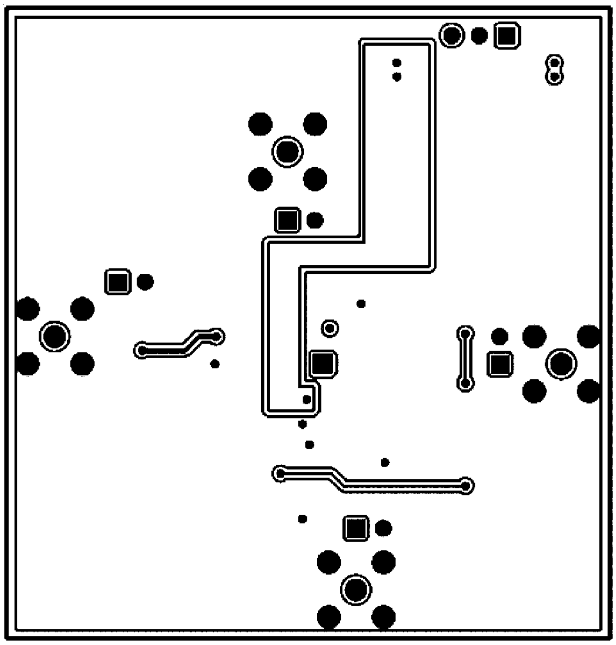
30038641

Top Silkscreen



300386x9

Top Layer

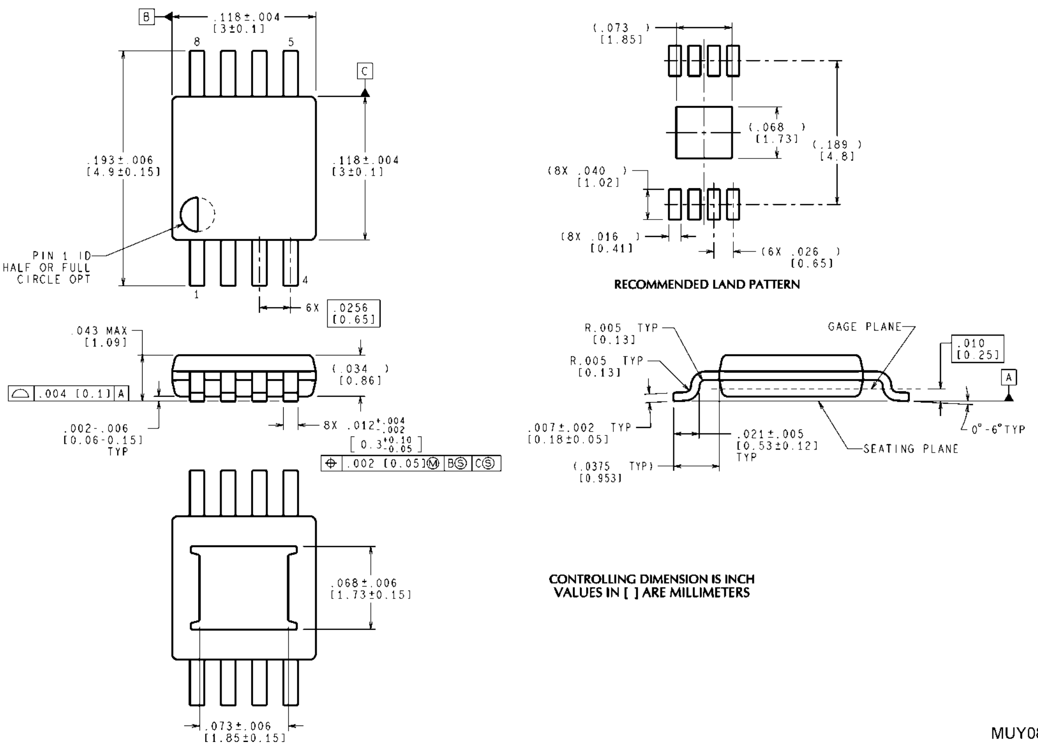


Bottom Layer

Revision History

Rev	Date	Description
1.0	11/05/08	Initial release.

Physical Dimensions inches (millimeters) unless otherwise noted



MUY08A (Rev A)

Mini-SOIC Exposed-DAP Package
Order Number LME49726MY
NS Package Number MUY08A

Notes

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