National Semiconductor

May 25, 2010

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, $A_V = 1$,
  $f_{IN} = 1kHz$, $R_L = 10kΩ$
  ($V_{OUT} = 3.5V_{P-P}$, $V_{DD} = 5.0V$)   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 ($R_L = 10kΩ$)   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
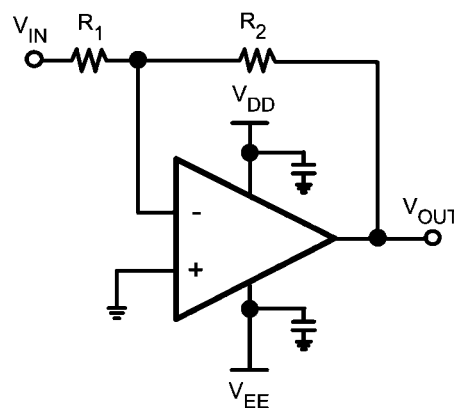
300386p6

FIGURE 1. Inverting Configuration Split Supplies

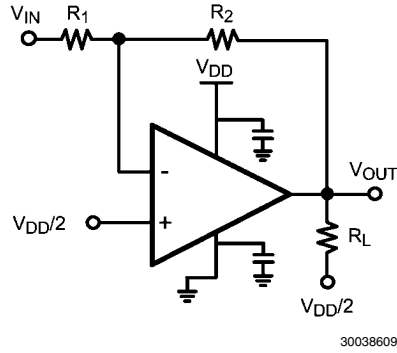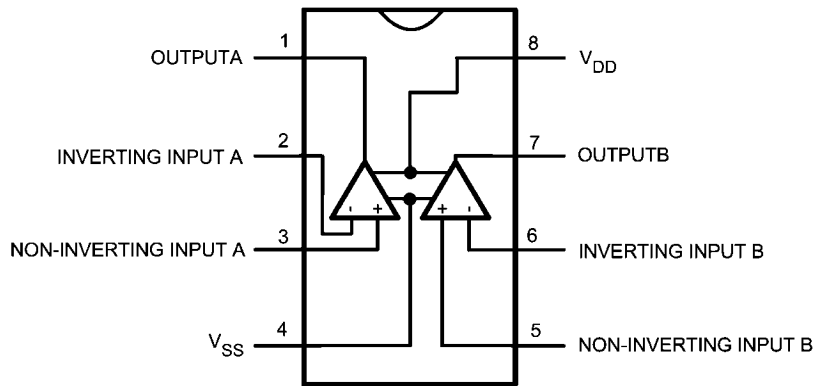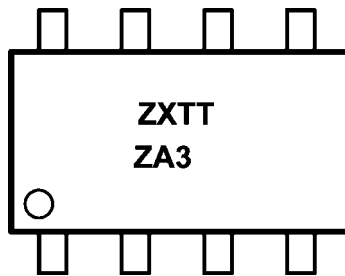## Typical Connection, Pinout, and Package Marking

30038609

FIGURE 2. Inverting Configuration Single Supply

30038610

Order Number LME49726MY
See NS Package Number MUY08A

Package Marking

300386x7

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 (*Note 1*, *Note 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 ≤ T_A ≤ 125°C
Supply Voltage Range	2.5V ≤ V_S ≤ 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		Units (Limits)
			Typical	**Limit**	
			(*Note 6*)	(*Note 7*)	
THD+N	Total Harmonic Distortion + Noise	A_V = −1, V_{OUT} = 3.5V_{p-p}, V_{DD} = 5V			
		R_L = 600Ω	0.0008		%
		R_L = 2kΩ	0.0002		%
		R_L = 10kΩ	0.00008		%
		A_V = −1, V_{OUT} = 1.5V_{p-p}, V_{DD} = 2.5V			
		R_L = 600Ω	0.001		%
		R_L = 2kΩ	0.0008		%
		R_L = 10kΩ	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	800		ns
		0.001% error range	1.2		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/√Hz
		f = 1kHz (A-weighted)	15		nV/√Hz
		f = 100Hz (A-weighted)	35		nV/√Hz
I_N	Current Noise Density	f = 1kHz	0.75		pA/√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 ≤ T_A ≤ 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 ≤ T_A ≤ 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)

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Symbol	Parameter	Conditions	LME49726		Units (Limits)
			Typical	Limit	
			(*Note 6*)	(*Note 7*)	
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$_A$) / θ$_{JA}$ 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.

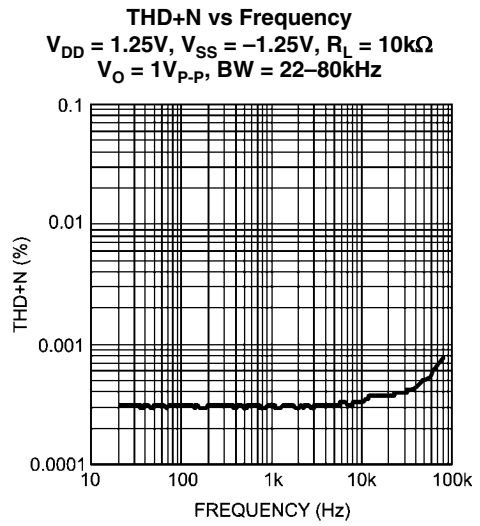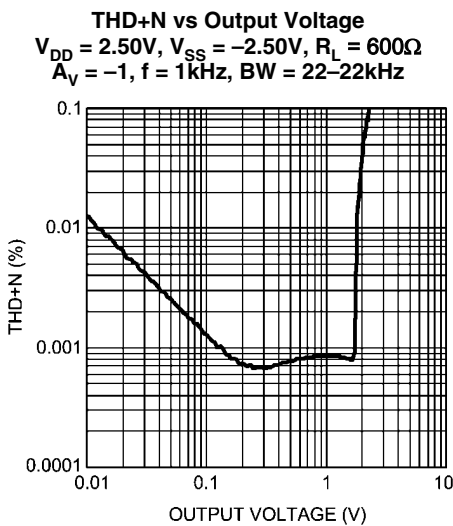# Typical Performance Characteristics

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

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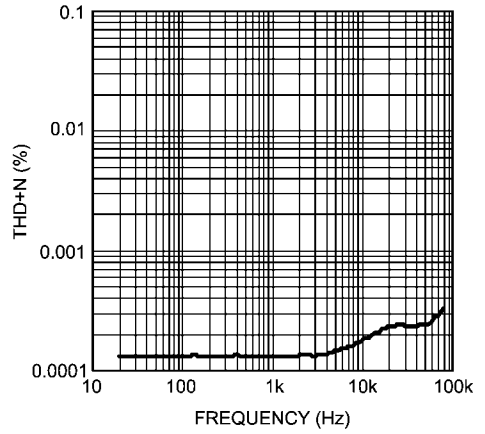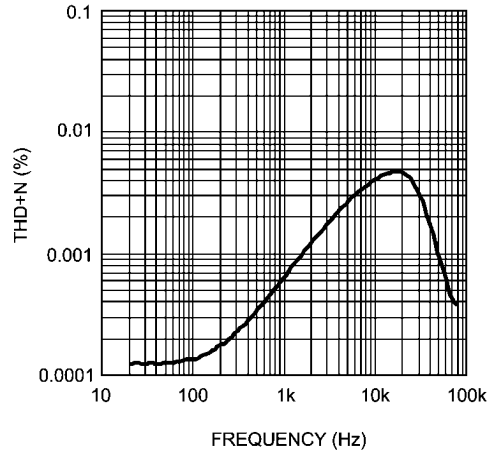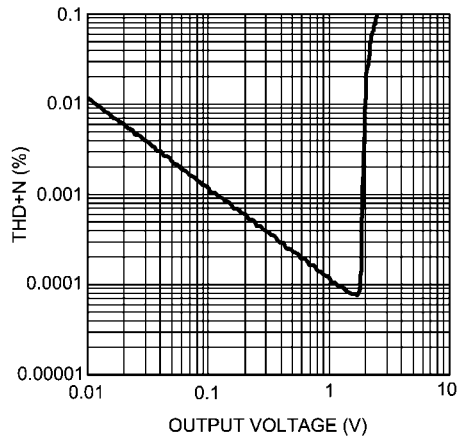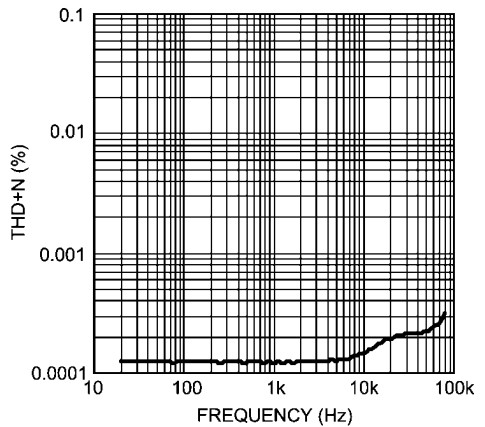$V_{DD} = 1.25V$, $V_{SS} = -1.25V$, $R_L = 600\Omega$
$V_O = 1.5V_{P-P}$, $BW = 22–80kHz$

30038612

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

30038615

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

30038634

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

30038619
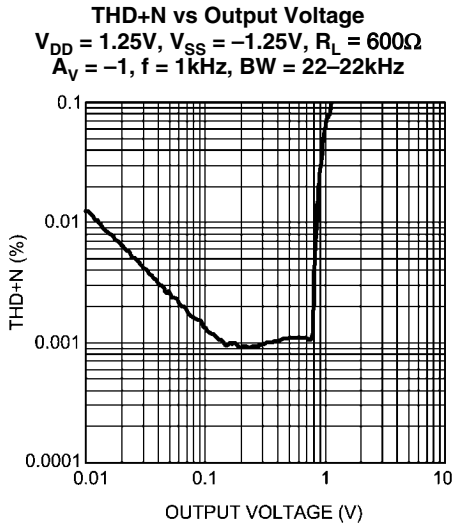
THD+N vs Frequency
$V_{DD} = 2.50V$, $V_{SS} = -2.50V$, $R_L = 600\Omega$
$V_O = 3.5V_{P-P}$, $BW = 22–80kHz$
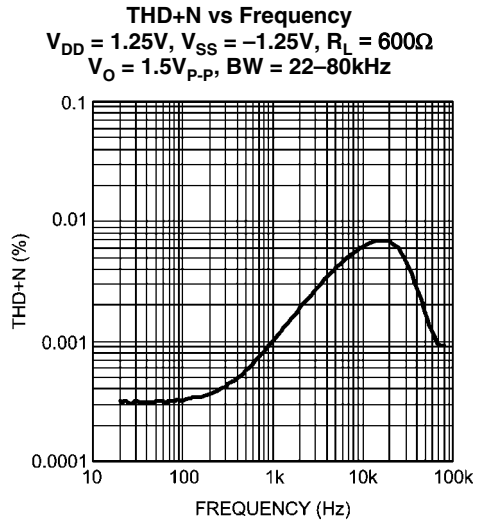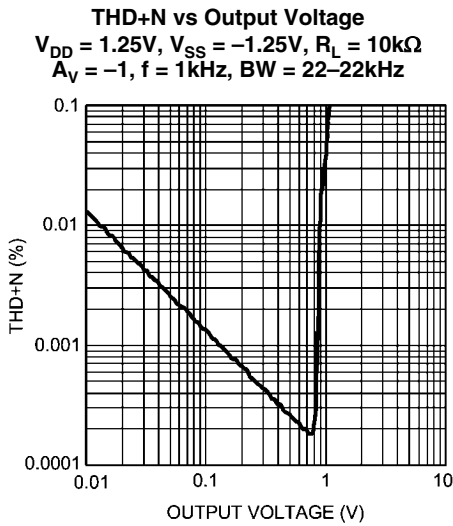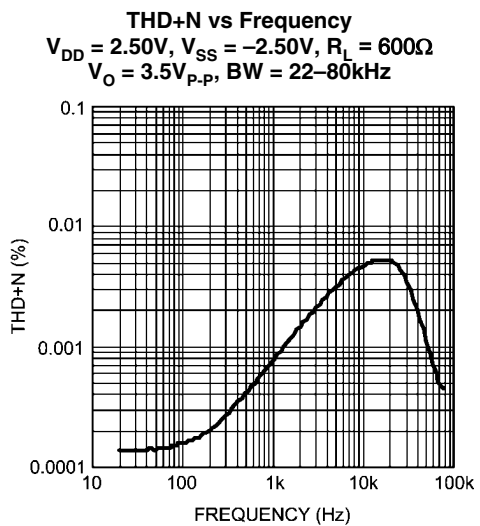
30038613

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

30038616

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

30038635

THD+N vs Output Voltage
V_{DD} = 2.75V, V_{SS} = −2.75V, R_L = 600Ω
A_V = −1, f = 1kHz, BW = 22–22kHz
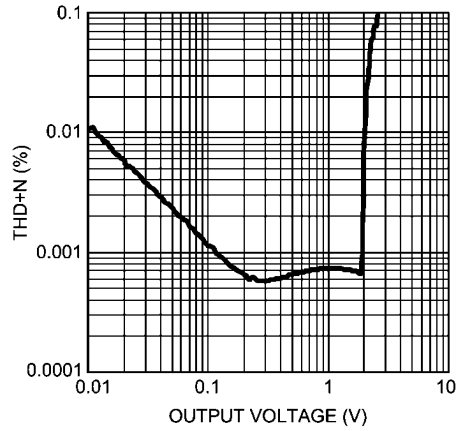
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THD+N vs Frequency
V_{DD} = 2.75V, V_{SS} = −2.75V, R_L = 600Ω
V_O = 3.5V_{P-P}, BW = 22–80kHz

30038636

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

30038617

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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LME49726

PSRR+ vs Frequency
$V_{DD} = 1.25V$, $V_{SS} = -1.25V$, $V_{RIPPLE} = 200mV_{P-P}$
Input terminated, BW = 22–80kHz
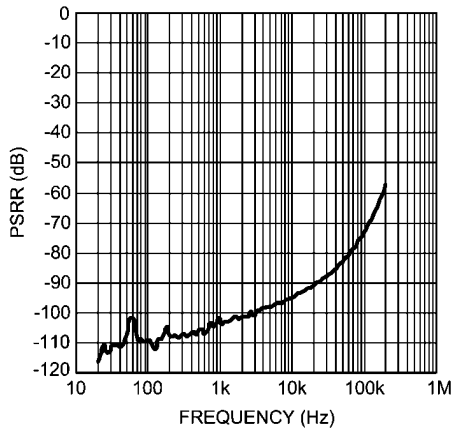
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PSRR– vs Frequency
$V_{DD} = 1.25V$, $V_{SS} = -1.25V$, $V_{RIPPLE} = 200mV_{P-P}$
Input terminated, BW = 22–80kHz
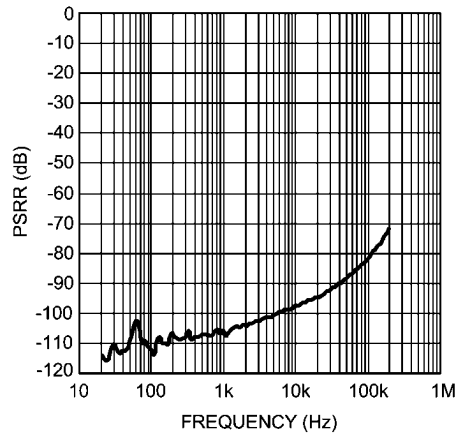
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PSRR+ vs Frequency
$V_{DD} = 2.50V$, $V_{EE} = -2.50V$, $V_{RIPPLE} = 200mV_{P-P}$
Input terminated, BW = 22–80kHz
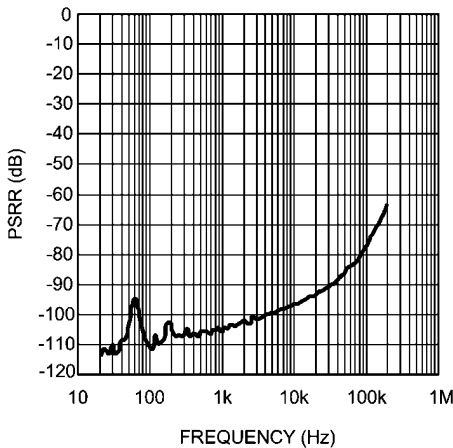
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PSRR– vs Frequency
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Input terminated, BW = 22–80kHz
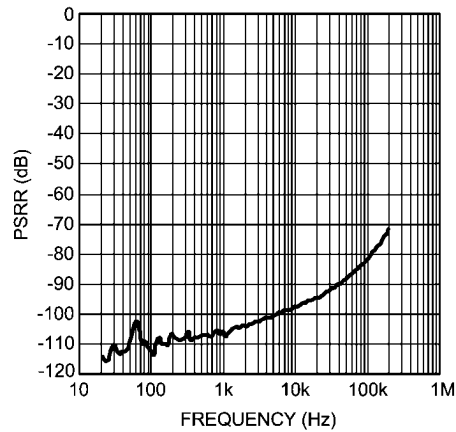
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PSRR+ vs Frequency
$V_{DD} = 2.75V$, $V_{SS} = -2.75V$, $V_{RIPPLE} = 200mV_{P-P}$
Input terminated, BW = 22–80kHz
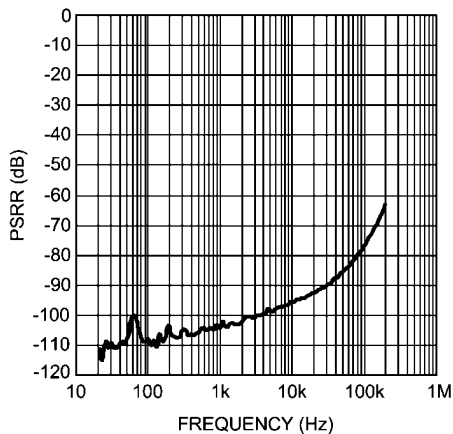
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PSRR– vs Frequency
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Input terminated, BW = 22–80kHz
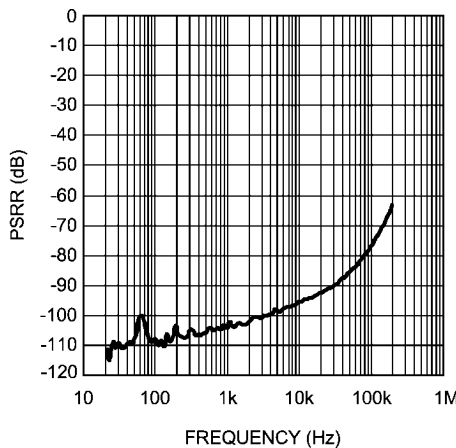
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Output Voltage vs Supply Voltage
$R_L = 600\Omega$, $A_V = -1$
$f = 1kHz$, THD+N = 1%, BW = 22–80kHz
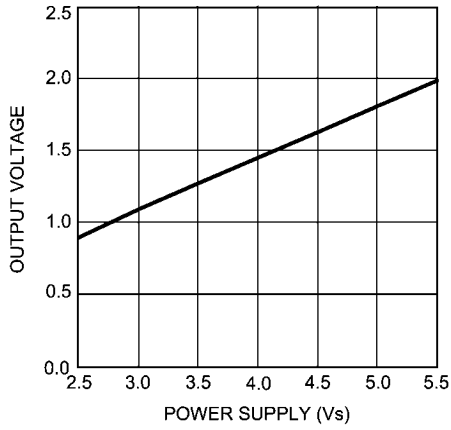
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Output Voltage vs Supply Voltage
$R_L = 10k\Omega$, $A_V = -1$
$f = 1kHz$, THD+N = 1%, BW = 22–80kHz
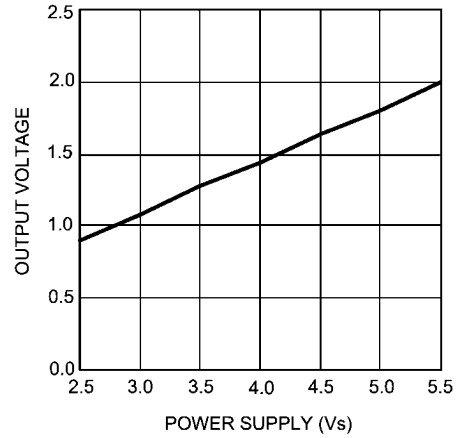
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Crosstalk vs Frequency
$V_{DD} = 2.50V$, $V_{SS} = -2.50V$, $R_L = 10k\Omega$
$A_V = -1$, $f = 1kHz$, BW = 80kHz
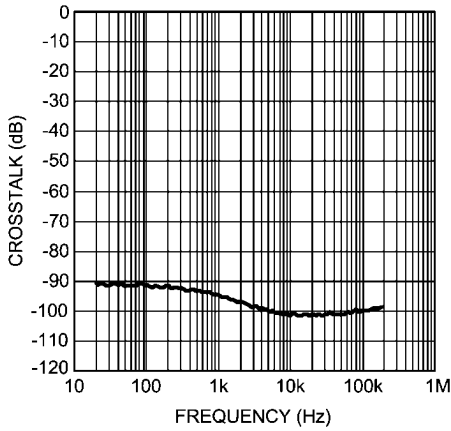
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Supply Current vs Supply Voltage
per Amplifier, R_L = No Load, $A_V = -1$
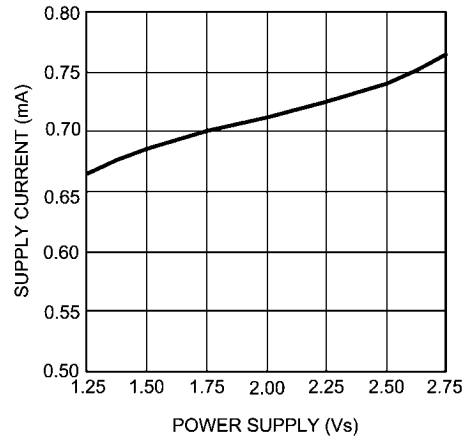
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CMRR vs Frequency
$V_{DD} = 2.5V$, $V_{SS} = -2.5V$, $V_{RIPPLE} = 200mV_{P-P}$
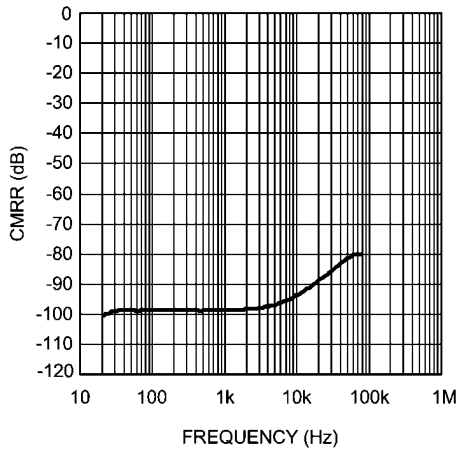
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Application Information

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.
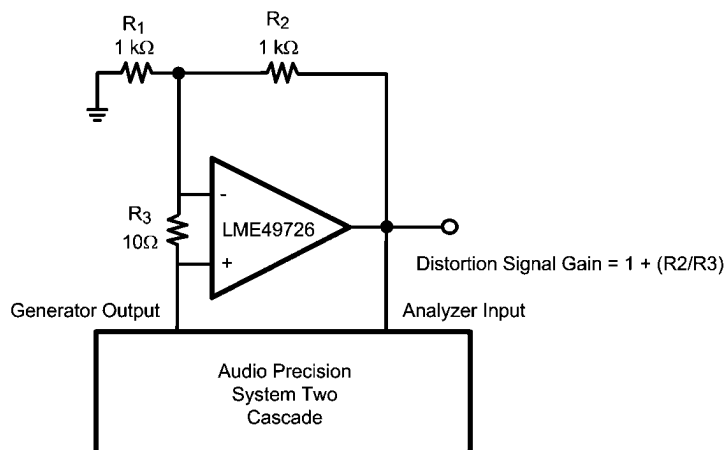
FIGURE 3. THD+N and IMD Distortion Test Circuit

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*.
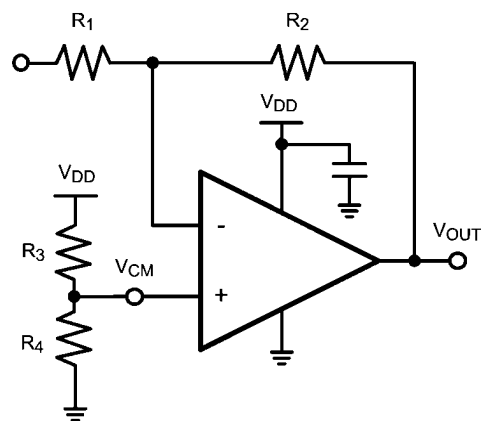
FIGURE 4. Single Supply Inverting Op Amp

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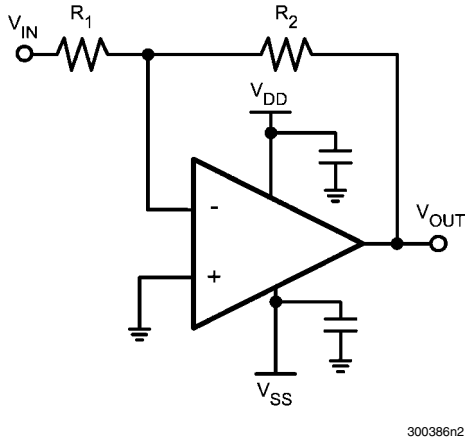

FIGURE 5. Dual Supply Inverting Configuration

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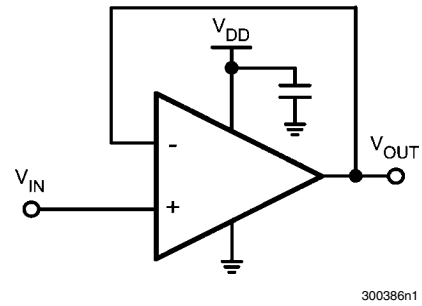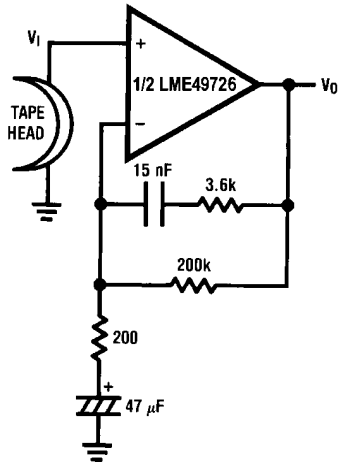

FIGURE 6. Unity-Gain Buffer Configuration
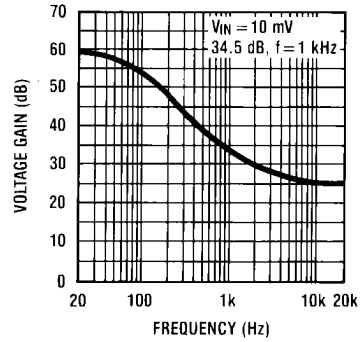
Typical Applications

NAB Preamp
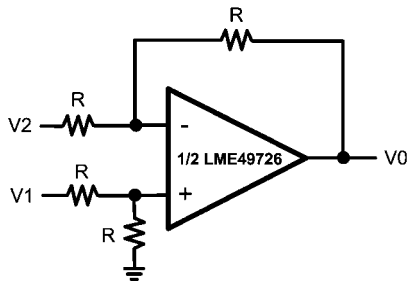

300386n4

$A_V = 34.5$
$F = 1$ 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
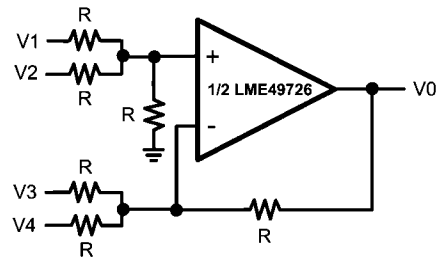
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$V_O = V1 + V2 – V3 – V4$

Sine Wave Oscillator
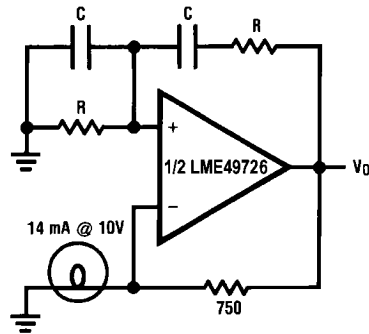
300386n8

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

Second Order High Pass Filter (Butterworth)

R1
11k

C1
0.01 µF

C2
0.01 µF

V1

+

1/2 LME49726

−

V0

R2
22k
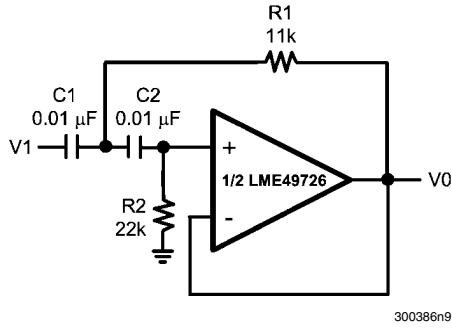
300386n9

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)

C1
0.022 µF

R1
10k

R2
10k

V1

+

1/2 LME49726

−

V0

C2
0.011 µF
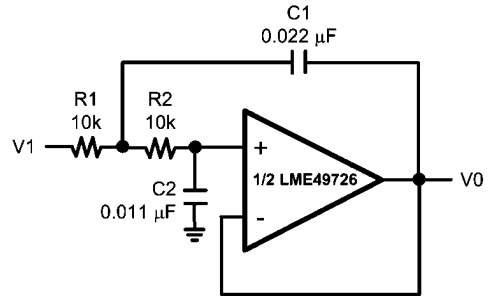
300386o0

if R1 = R2 = R

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

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

Illustration is $f_0 = 1$ kHz

State Variable Filter

R2
10k

R2
10k

R1
16k

C1
0.01 µF

R1
16k

C1
0.01 µF

R_G
10k

V_{IN}

−

1/2 LME49726

+

V_{HP}

−

1/2 LME49726

+

V_{BP}

−

1/2 LME49726

+

V_{LP}

R0
556

R2
10k
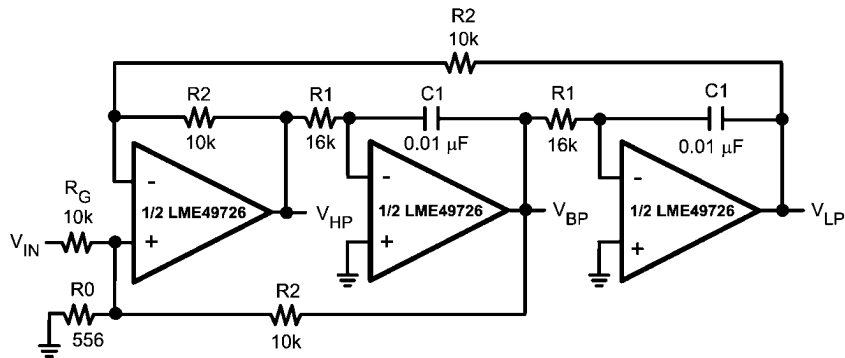
300386o1

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

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

AC/DC Converter

R5
20k

C1
10 µF

R2
20k

R3
10k

R4
20k

R1
20k

V_{IN}

−

1/2 LME49726

+

D1
1S1588

D2
1S1588

−

1/2 LME49726

+

V0 = V_{IN}

R6
15k

R7
6.2k
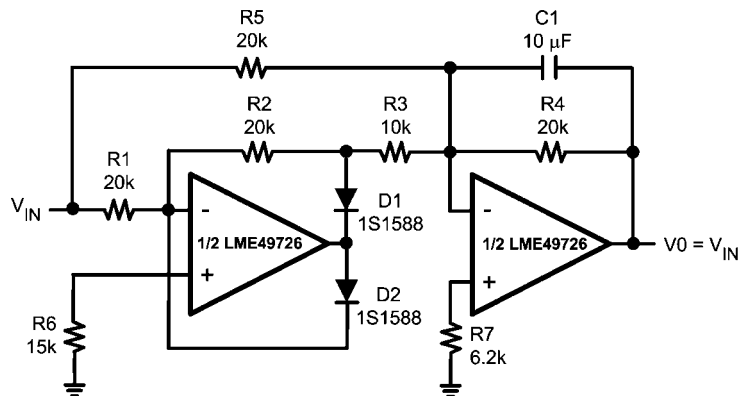
300386o2

2 Channel Panning Circuit (Pan Pot)

R1 15k R1 15k 3.41R1 51k

1/2 LME49726

V01

VI

0.707R1 10k

1/2 LME49726

V02

R1 15k R1 15k

3.41R1 51k

30038o3

Line Driver

R2

R1

V1

1/2 LME49726

R3 10k

VCC

Q1

R9 10k

R7 33

V0

R5 10k BIAS

R8 33

Q2

R6 10k

-VEE

30038o4

Tone Control

BOOST-BASS-CUT
R1 11k   R2 100k   R1 11k

V1

C1 0.05 µF

C1 0.05 µF

R3 11k

C2 0.005 µF

1/2 LME49726

V0

R5 3.6k

R5 3.6k

R4 500k

BOOST-TREBLE-CUT
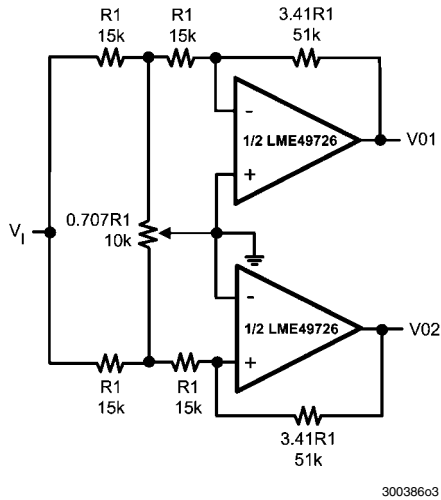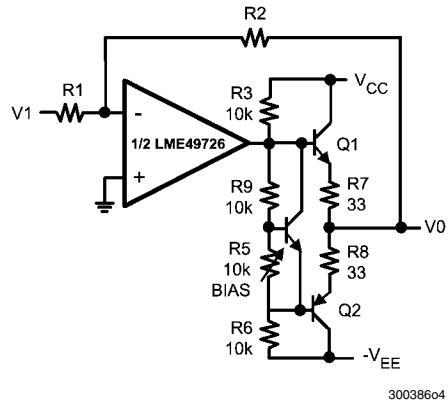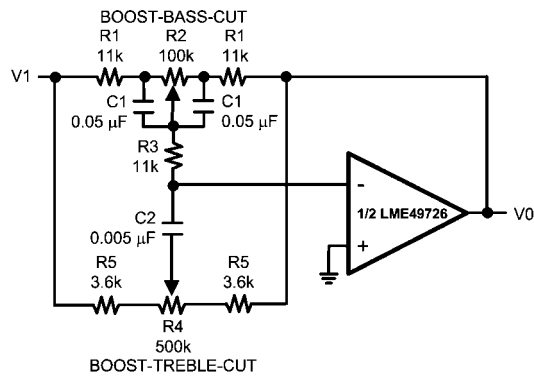
30038o5

$$f_L = \frac{1}{2\pi R2 C1}, \quad f_{LB} = \frac{1}{2\pi R1 C1}$$

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

Illustration is:

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

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

20 dB
17 dB

3 dB

−20 dB

f_L f_{LB} f_{HB} f_H

30038o6

RIAA Preamp

33 μF

100 pF

47k

1/2 LME49726

470

10 μF

100k

PHONO CARTRIDGE

16k

200k

390

4.7 nF

15 nF

100 μF
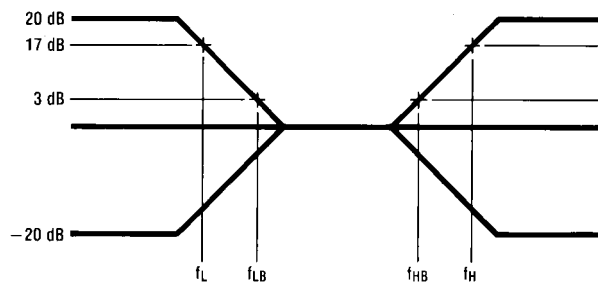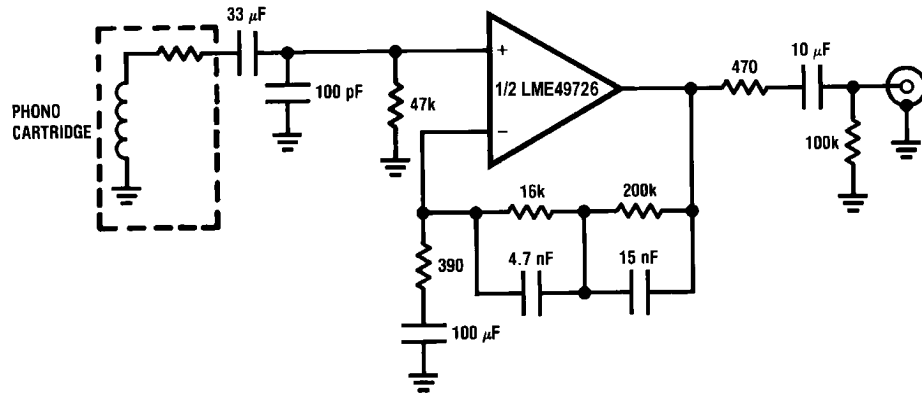
30038608

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

V1

R

1/2 LME49726

R3
10k

R4
10k

R2
10k

-

1/2 LME49726

V0

R1
200

+

R5
10k

-

1/2 LME49726

R6
10k

R7
10k

V2

R

+
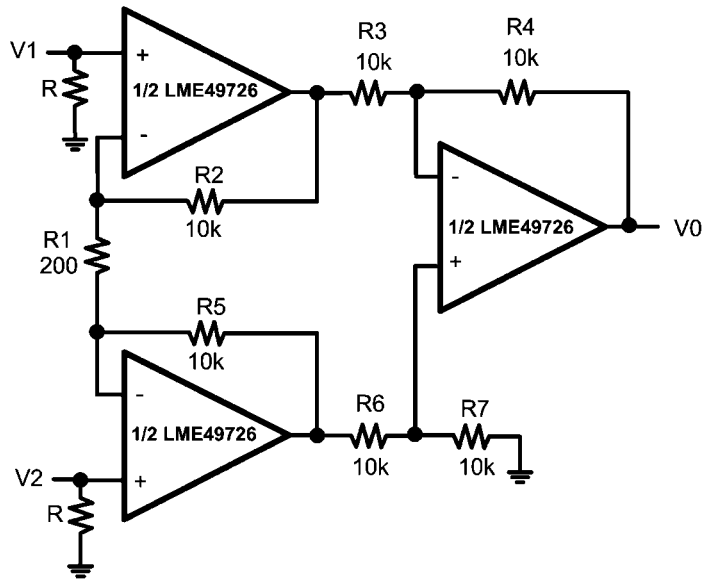
30038607

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
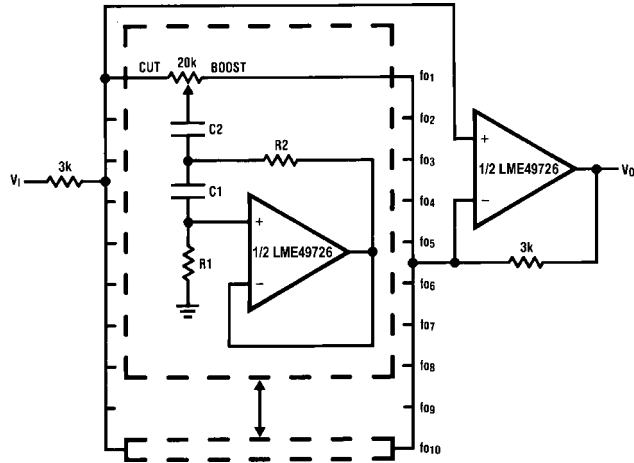
300386p0

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
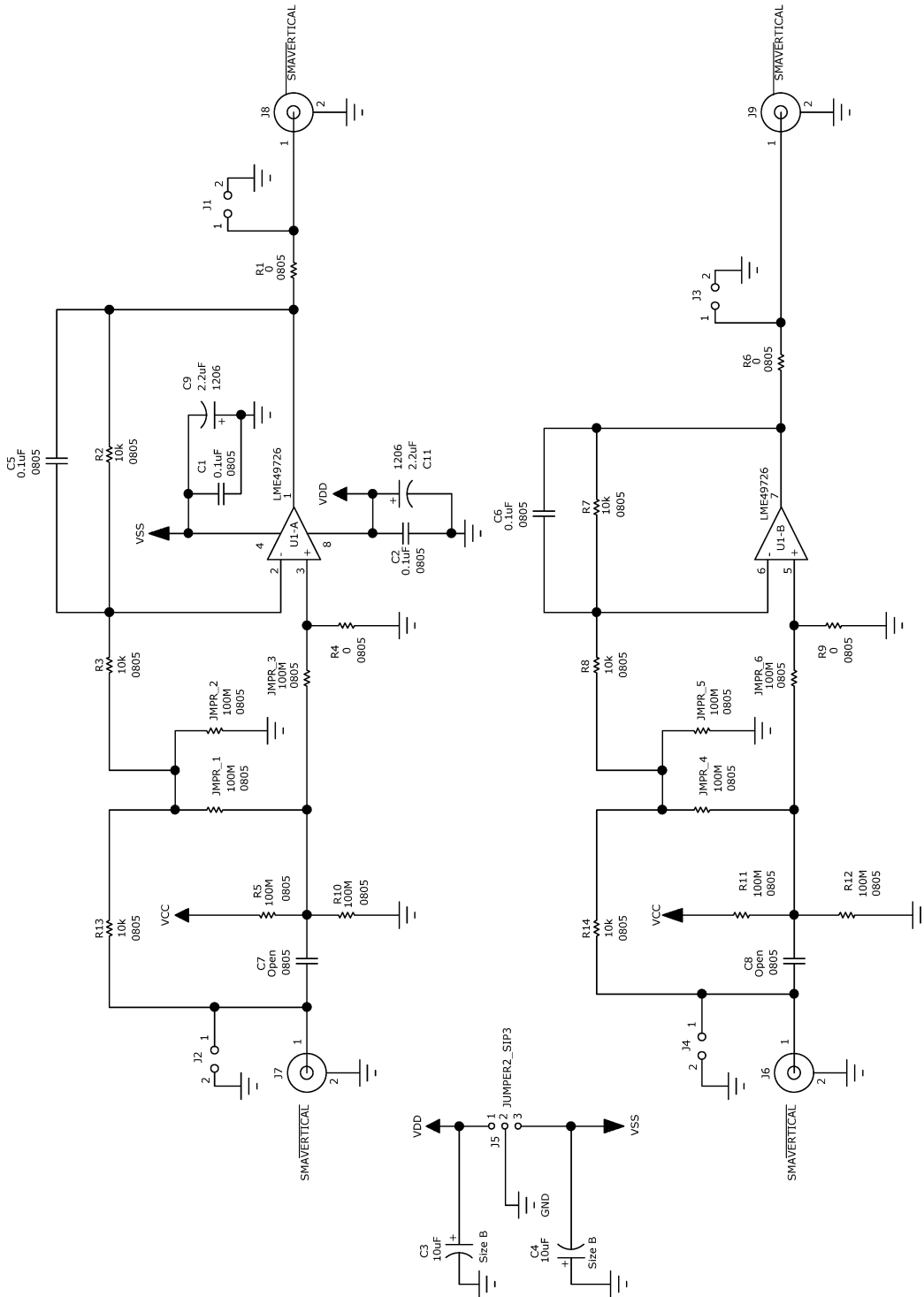
30038640

LME49726 Demo Board Views
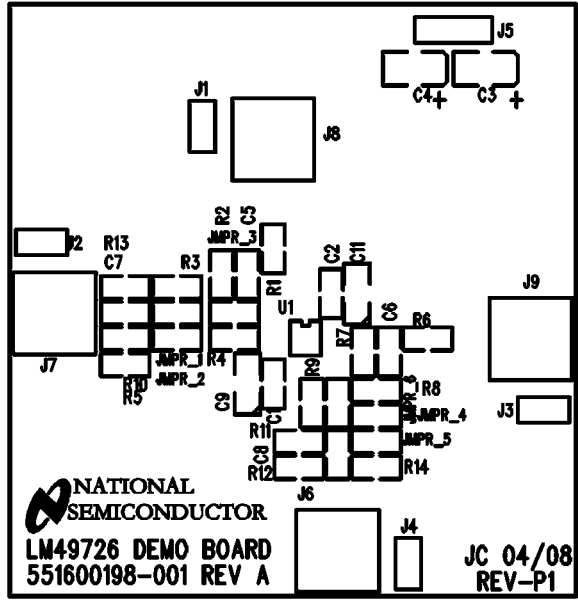
Top Silkscreen

30038641
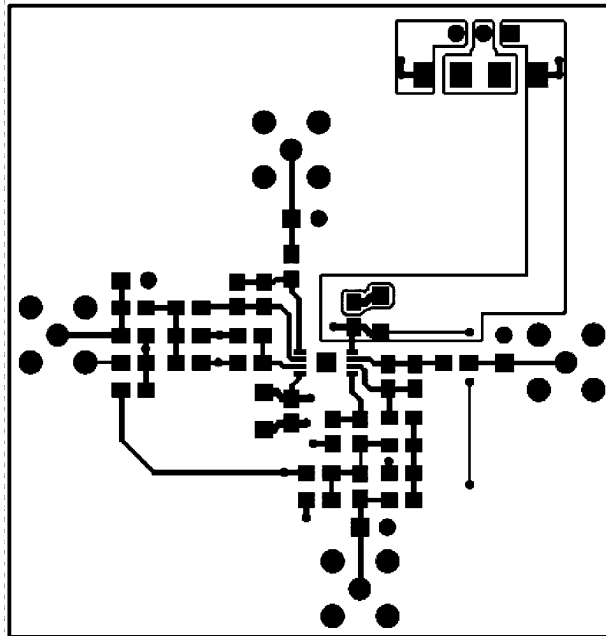
Top Layer

300386x9
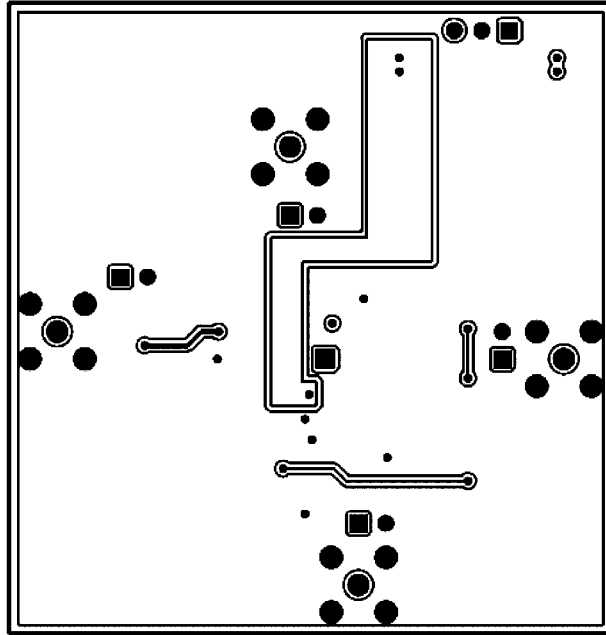
Bottom Layer

300386x8

Revision History

Rev	Date	Description
1.0	11/05/08	Initial release.
1.01	05/25/10	Increased Operating Temperature Range.

Physical Dimensions inches (millimeters) unless otherwise noted

.118±.004
[3±0.1]

.193±.006
[4.9±0.15]

.118±.004
[3±0.1]

PIN 1 ID
HALF OR FULL
CIRCLE OPT

6X .0256
[0.65]

.043 MAX
[1.09]

.004 [0.1] A

(.034)
[0.86]

.002-.006
[0.06-0.15]
TYP

8X .012 +.004 -.002
[0.3 +0.10 -0.05]

⊕ .002 [0.05] M B Ⓢ C Ⓢ

.068±.006
[1.73±0.15]

.073±.006
[1.85±0.15]

RECOMMENDED LAND PATTERN

(.073)
[1.85]

(.068)
[1.73]

(.189)
[4.8]

(8X .040)
[1.02]

(8X .016)
[0.41]

(6X .026)
[0.65]

R.005 TYP
[0.13]

R.005 TYP
[0.13]

GAGE PLANE

.010
[0.25]

A

.007±.002 TYP
[0.18±0.05]

.021±.005
[0.53±0.12]
TYP

SEATING PLANE

0°-6° TYP

(.0375) TYP
[0.953]

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MUY08A (Rev A)

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

Notes

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Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic
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