National *Semiconductor*

August 2000

LM386
Low Voltage Audio Power Amplifier

General Description

The LM386 is a power amplifier designed for use in low voltage consumer applications. The gain is internally set to 20 to keep external part count low, but the addition of an external resistor and capacitor between pins 1 and 8 will increase the gain to any value from 20 to 200.

The inputs are ground referenced while the output automatically biases to one-half the supply voltage. The quiescent power drain is only 24 milliwatts when operating from a 6 volt supply, making the LM386 ideal for battery operation.

Features

- Battery operation
- Minimum external parts
- Wide supply voltage range: 4V–12V or 5V–18V
- Low quiescent current drain: 4mA
- Voltage gains from 20 to 200
- Ground referenced input
- Self-centering output quiescent voltage
- Low distortion: 0.2% (A_V = 20, V_S = 6V, R_L = 8Ω, P_O = 125mW, f = 1kHz)
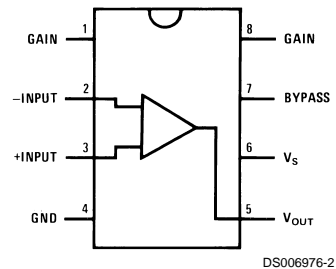- Available in 8 pin MSOP package

Applications

- AM-FM radio amplifiers
- Portable tape player amplifiers
- Intercoms
- TV sound systems
- Line drivers
- Ultrasonic drivers
- Small servo drivers
- Power converters

Equivalent Schematic and Connection Diagrams

DS006976-1
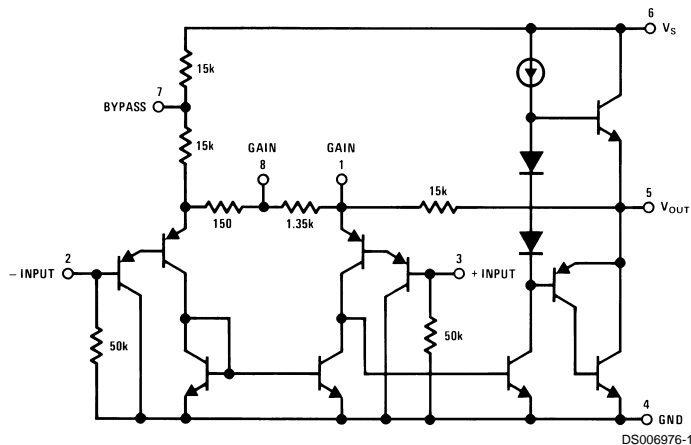
Small Outline, Molded Mini Small Outline, and Dual-In-Line Packages

DS006976-2

Top View
Order Number LM386M-1, LM386MM-1, LM386N-1, LM386N-3 or LM386N-4
See NS Package Number M08A, MUA08A or N08E

www.national.com

Absolute Maximum Ratings (Note 2)

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

Supply Voltage	
(LM386N-1, -3, LM386M-1)	15V
Supply Voltage (LM386N-4)	22V
Package Dissipation (Note 3)	
(LM386N)	1.25W
(LM386M)	0.73W
(LM386MM-1)	0.595W
Input Voltage	±0.4V
Storage Temperature	−65˚C to +150˚C
Operating Temperature	0˚C to +70˚C
Junction Temperature	+150˚C
Soldering Information	

Dual-In-Line Package	
Soldering (10 sec)	+260˚C
Small Outline Package	
(SOIC and MSOP)	
Vapor Phase (60 sec)	+215˚C
Infrared (15 sec)	+220˚C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Thermal Resistance	
θ_{JC} (DIP)	37˚C/W
θ_{JA} (DIP)	107˚C/W
θ_{JC} (SO Package)	35˚C/W
θ_{JA} (SO Package)	172˚C/W
θ_{JA} (MSOP)	210˚C/W
θ_{JC} (MSOP)	56˚C/W

Electrical Characteristics (Notes 1, 2)

$T_A = 25$˚C

Parameter	Conditions	Min	Typ	Max	Units
Operating Supply Voltage (V_S)					
LM386N-1, -3, LM386M-1, LM386MM-1		4		12	V
LM386N-4		5		18	V
Quiescent Current (I_Q)	$V_S = 6$V, $V_{IN} = 0$		4	8	mA
Output Power (P_{OUT})					
LM386N-1, LM386M-1, LM386MM-1	$V_S = 6$V, $R_L = 8\Omega$, THD = 10%	250	325		mW
LM386N-3	$V_S = 9$V, $R_L = 8\Omega$, THD = 10%	500	700		mW
LM386N-4	$V_S = 16$V, $R_L = 32\Omega$, THD = 10%	700	1000		mW
Voltage Gain (A_V)	$V_S = 6$V, f = 1 kHz		26		dB
	10 µF from Pin 1 to 8		46		dB
Bandwidth (BW)	$V_S = 6$V, Pins 1 and 8 Open		300		kHz
Total Harmonic Distortion (THD)	$V_S = 6$V, $R_L = 8\Omega$, $P_{OUT} = 125$ mW		0.2		%
	f = 1 kHz, Pins 1 and 8 Open				
Power Supply Rejection Ratio (PSRR)	$V_S = 6$V, f = 1 kHz, $C_{BYPASS} = 10$ µF		50		dB
	Pins 1 and 8 Open, Referred to Output				
Input Resistance (R_{IN})			50		kΩ
Input Bias Current (I_{BIAS})	$V_S = 6$V, Pins 2 and 3 Open		250		nA

Note 1: All voltages are measured with respect to the ground pin, unless otherwise specified.

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 3: For operation in ambient temperatures above 25˚C, the device must be derated based on a 150˚C maximum junction temperature and 1) a thermal resistance of 107˚C/W junction to ambient for the dual-in-line package and 2) a thermal resistance of 170˚C/W for the small outline package.

Application Hints

GAIN CONTROL

To make the LM386 a more versatile amplifier, two pins (1 and 8) are provided for gain control. With pins 1 and 8 open the 1.35 kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 1 to 8, bypassing the 1.35 kΩ resistor, the gain will go up to 200 (46 dB). If a resistor is placed in series with the capacitor, the gain can be set to any value from 20 to 200. Gain control can also be done by capacitively coupling a resistor (or FET) from pin 1 to ground.

Additional external components can be placed in parallel with the internal feedback resistors to tailor the gain and frequency response for individual applications. For example, we can compensate poor speaker bass response by frequency shaping the feedback path. This is done with a series RC from pin 1 to 5 (paralleling the internal 15 kΩ resistor). For 6 dB effective bass boost: R $\simeq$ 15 kΩ, the lowest value for good stable operation is R = 10 kΩ if pin 8 is open. If pins 1 and 8 are bypassed then R as low as 2 kΩ can be used. This restriction is because the amplifier is only compensated for closed-loop gains greater than 9.

INPUT BIASING

The schematic shows that both inputs are biased to ground with a 50 kΩ resistor. The base current of the input transistors is about 250 nA, so the inputs are at about 12.5 mV when left open. If the dc source resistance driving the LM386 is higher than 250 kΩ it will contribute very little additional offset (about 2.5 mV at the input, 50 mV at the output). If the dc source resistance is less than 10 kΩ, then shorting the unused input to ground will keep the offset low (about 2.5 mV at the input, 50 mV at the output). For dc source resistances between these values we can eliminate excess offset by putting a resistor from the unused input to ground, equal in value to the dc source resistance. Of course all offset problems are eliminated if the input is capacitively coupled.

When using the LM386 with higher gains (bypassing the 1.35 kΩ resistor between pins 1 and 8) it is necessary to bypass the unused input, preventing degradation of gain and possible instabilities. This is done with a 0.1 µF capacitor or a short to ground depending on the dc source resistance on the driven input.
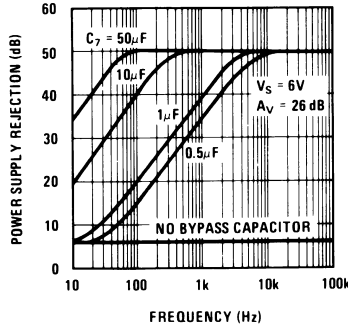
Typical Performance Characteristics
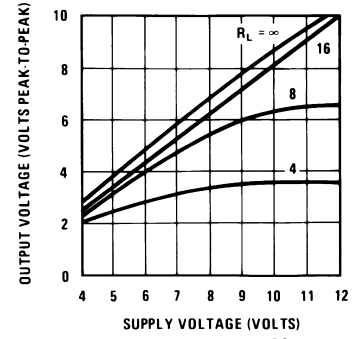
Quiescent Supply Current vs Supply Voltage
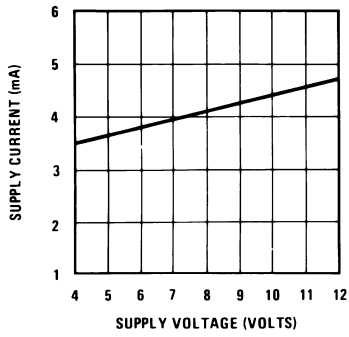
DS006976-5

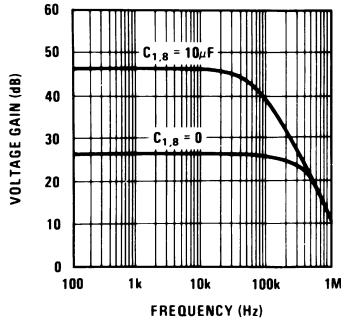### Power Supply Rejection Ratio (Referred to the Output) vs Frequency

DS006976-12

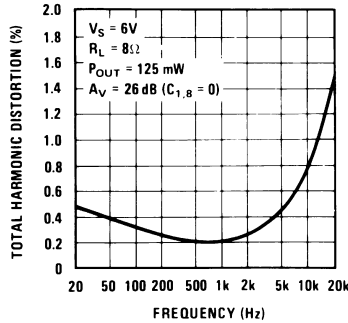### Peak-to-Peak Output Voltage Swing vs Supply Voltage

DS006976-13

Voltage Gain vs Frequency

DS006976-14

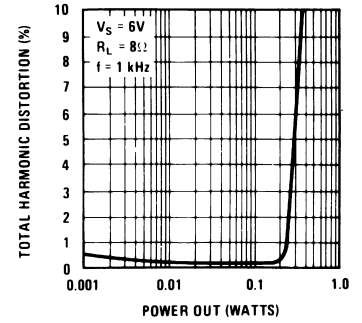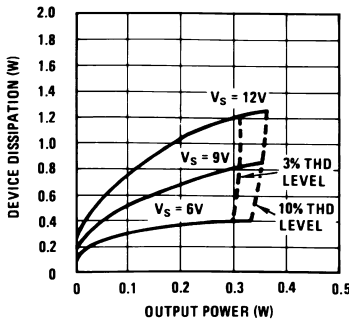### Distortion vs Frequency

DS006976-15

Distortion vs Output Power

DS006976-16

Device Dissipation vs Output Power—4Ω Load

DS006976-17

Device Dissipation vs Output Power—8Ω Load
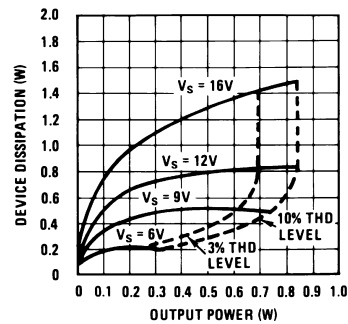
DS006976-18

Device Dissipation vs Output Power—16Ω Load
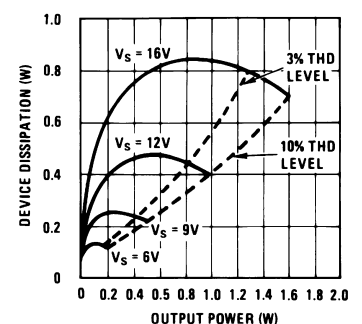
DS006976-19

Typical Applications

Amplifier with Gain = 20
Minimum Parts

DS006976-3

Amplifier with Gain = 200

DS006976-4

Amplifier with Gain = 50

DS006976-6

Low Distortion Power Wienbridge Oscillator

DS006976-7

Amplifier with Bass Boost

DS006976-8

Square Wave Oscillator

DS006976-9

www.national.com
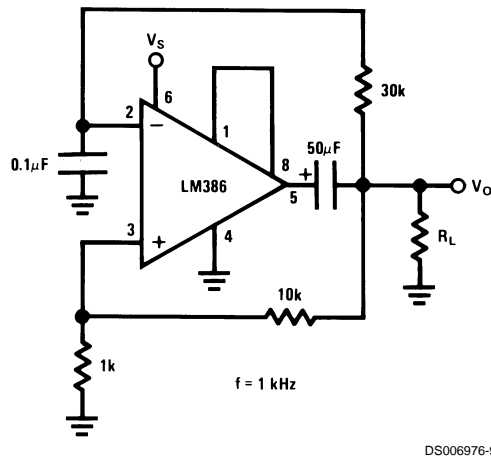
Typical Applications (Continued)

Frequency Response with Bass Boost

DS006976-10

AM Radio Power Amplifier

DS006976-11

Note 4: Twist Supply lead and supply ground very tightly.

Note 5: Twist speaker lead and ground very tightly.

Note 6: Ferrite bead in Ferroxcube K5-001-001/3B with 3 turns of wire.

Note 7: R1C1 band limits input signals.

Note 8: All components must be spaced very closely to IC.

Physical Dimensions inches (millimeters) unless otherwise noted

0.189 − 0.197
(4.800 − 5.004)

8 7 6 5

0.228 − 0.244
(5.791 − 6.198)

0.010 MAX
(0.254)

LEAD NO. 1
IDENT

1 2 3 4

30°
TYP

0.150 − 0.157
(3.810 − 3.988)

0.010 − 0.020 × 45°
(0.254 − 0.508)

8° MAX TYP
ALL LEADS

0.004
(0.102)
ALL LEAD TIPS

0.008 − 0.010
(0.203 − 0.254)
TYP ALL LEADS

0.016 − 0.050
(0.406 − 1.270)
TYP ALL LEADS

0.053 − 0.069
(1.346 − 1.753)

0.004 − 0.010
(0.102 − 0.254)

SEATING
PLANE

0.014
(0.356)

0.050
(1.270)
TYP

0.008 TYP
(0.203)

0.014 − 0.020 TYP
(0.356 − 0.508)

M08A (REV H)
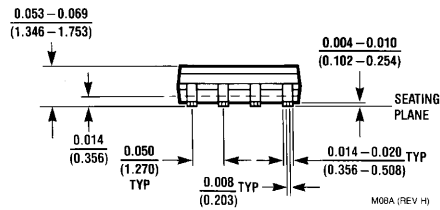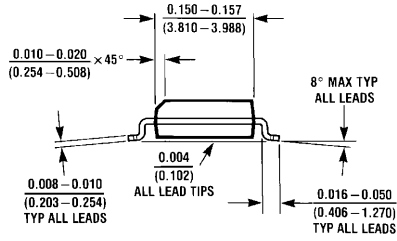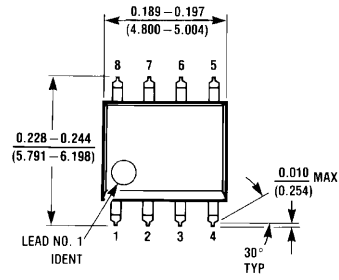
SO Package (M)
Order Number LM386M-1
NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

0.118±0.004
[3±0.1]

8 5

0.193±0.004
[4.9±0.1]

0.118±0.004
[3±0.1]

PIN 1
IDENT
NOTE 2

1 4

(0.0256) TYP
[0.65]

(0.189)
[4.8]

(0.040)
[1.02] TYP

(0.016)
[0.41] TYP

(0.0256) TYP
[0.65]

LAND PATTERN RECOMMENDATION

0.043
[1.09] MAX

0.002[0.05] A

0.002-0.006 TYP
[0.06-0.15]

0.002 [0.05] M B S C S

0.012 +0.004 −0.002 TYP
[0.3 +0.10 −0.05]

(0.034)
[0.86]

R 0.005 TYP
[0.13]

R 0.005 TYP
[0.13]

0.021±0.005
[0.53±0.12]

0.0375
[0.953]

0.007±0.002 TYP
[0.18±0.05]

GAGE
PLANE

(0.010)
[0.25]

0° − 6° TYP

SEATING PLANE

MUA08A (REV B)

8-Lead (0.118" Wide) Molded Mini Small Outline Package
Order Number LM386MM-1
NS Package Number MUA08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

0.373 − 0.400
(9.474 − 10.16)

0.090
(2.286)

0.092
(2.337) DIA

PIN NO. 1 IDENT

OPTION 1

0.250 ± 0.005
(6.35 ± 0.127)

0.032 ± 0.005
(0.813 ± 0.127)
RAD

PIN NO. 1 IDENT

OPTION 2

0.280
(7.112) MIN

0.030
(0.762) MAX

0.300 − 0.320
(7.62 − 8.128)

0.040
(1.016) TYP

0.039
(0.991)

0.145 − 0.200
(3.683 − 5.080)

20° ± 1°

0.130 ± 0.005
(3.302 ± 0.127)

95° ± 5°

0.125 − 0.140
(3.175 − 3.556)

0.020
(0.508) MIN

0.009 − 0.015
(0.229 − 0.381)

0.125
(3.175)
DIA NOM

0.065
(1.651)

90° ± 4°
TYP

0.018 ± 0.003
(0.457 ± 0.076)

0.325 +0.040 −0.015
(8.255 +1.016 −0.381)

0.100 ± 0.010
(2.540 ± 0.254)

0.045 ± 0.015
(1.143 ± 0.381)

0.060
(1.524)

0.050
(1.270)

N08E (REV F)

Dual-In-Line Package (N)
Order Number LM386N-1, LM386N-3 or LM386N-4
NS Package Number N08E

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		Applications	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		

TI E2E Community Home Page   e2e.ti.com