LM386 Low Voltage Audio Power Amplifier

1 Features

- Battery Operation
- Minimum External Parts
- Wide Supply Voltage Range: 4 V–12 V or 5 V–18 V
- Low Quiescent Current Drain: 4 mA
- Voltage Gains from 20 to 200
- Ground-Referenced Input
- Self-Centering Output Quiescent Voltage
- Low Distortion: 0.2% (A_V = 20, V_S = 6 V, R_L = 8 Ω, P_O = 125 mW, f = 1 kHz)
- Available in 8-Pin MSOP Package

2 Applications

- AM-FM Radio Amplifiers
- Portable Tape Player Amplifiers
- Intercoms
- TV Sound Systems
- Line Drivers
- Ultrasonic Drivers
- Small Servo Drivers
- Power Converters

3 Description

The LM386M-1 and LM386MX-1 are power amplifiers 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.

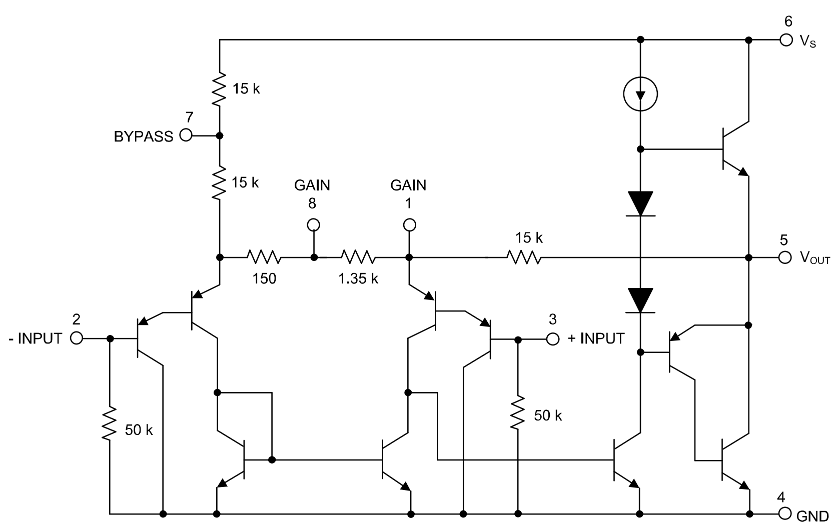
The inputs are ground referenced while the output automatically biases to one-half the supply voltage. The quiescent power drain is only 24 mW when operating from a 6-V supply, making the LM386M-1 and LM386MX-1 ideal for battery operation.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM386N-1	PDIP (8)	9.60 mm × 6.35 mm
LM386N-3	PDIP (8)	9.60 mm × 6.35 mm
LM386N-4	PDIP (8)	9.60 mm × 6.35 mm
LM386M-1	SOIC (8)	4.90 mm × 3.90 mm
LM386MX-1	SOIC (8)	4.90 mm × 3.90 mm
LM386MMX-1	VSSOP (8)	3.00 mm × 3.00 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Schematic



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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision B (March 2017) to Revision C — **Page**

- Changed devices LM386M-1/LM386MX-1 To: LM386 in the data sheet title 1
- Changed From: LM386N-4 To: Speaker Impedance in the *Recommended Operating Conditions* table 4
- Changed From: 5 Ω to 12 Ω To: 5 V to 12 V for Supply Voltage in Table 1 8
- Changed kW To: kΩ in the *Gain Control* section 8
- Changed kW To: kΩ in the *Input Biasing* section 9
- Changed Figure 11 9
- Changed From: 5 Ω to 12 Ω To: 5 V to 12 V for Supply Voltage in Table 2 10
- Changed Figure 13 10
- Changed From: 5 Ω to 12 Ω To: 5 V to 12 V for Supply Voltage in Table 3 11
- Changed Figure 15 11
- Changed From: 5 Ω to 12 Ω To: 5 V to 12 V for Supply Voltage in Table 4 12
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- Changed From: 5 Ω to 12 Ω To: 5 V to 12 V for Supply Voltage in Table 5 13
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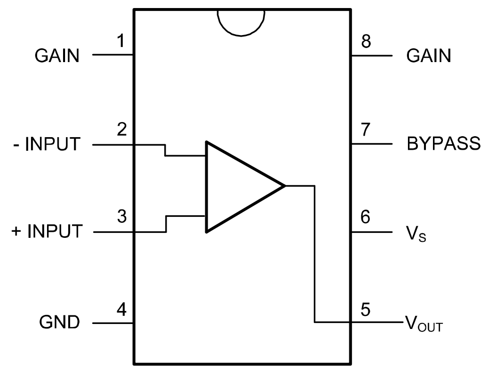
- Changed Figure 21 14
- Changed From: 5 Ω to 12 Ω To: 5 V to 12 V for Supply Voltage in Table 7 15
- Changed Figure 23 15

Changes from Revision A (May 2004) to Revision B — **Page**

- Added LM386MX-1 device to the data sheet. 1
- Added Device Information, Application and Implementation, Power Supply Recommendation, Layout, and Device and Documentation Support sections 1
- Inserted Functional Block Diagram 7

5 Pin Configuration and Functions

D Package
8-Pin MSOP
Top View



Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
GAIN	1	–	Gain setting pin
–INPUT	2	I	Inverting input
+INPUT	3	I	Noninverting input
GND	4	P	Ground reference
V_{OUT}	5	O	Output
V_S	6	P	Power supply voltage
BYPASS	7	O	Bypass decoupling path
GAIN	8	–	Gain setting pin

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Supply Voltage, V_{CC}	LM386N-1/-3, LM386M-1		15	V
	LM386N-4		22	
Package Dissipation	LM386N		1.25	W
	LM386M		0.73	
	LM386MM-1		0.595	
Input Voltage, V_I		–0.4	0.4	V
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_{CC}	Supply Voltage	4		12	V
	LM386N-4	5		18	V
	Speaker Impedance	4			Ω
VI	Analog input voltage	–0.4		0.4	V
TA	Operating free-air temperature	0		70	°C

6.4 Thermal Information

THERMAL METRIC(1)		LM386 D (SOIC)	LM386 DGK (VSSOP)	LM386 P (PDIP)	UNIT
		8	8	8	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	115.7	169.3	53.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	59.7	73.1	42.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	56.2	100.2	30.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	12.4	9.2	19.0	°C/W
ψ_{JB}	Junction-to-board characterization parameter	55.6	99.1	50.5	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_S	Operating Supply Voltage	LM386N-1, -3, LM386M-1, LM386MM-1	4		12	V
		LM386N-4	5		18	
I_Q	Quiescent Current	V_S = 6 V, V_{IN} = 0		4	8	mA
P_{OUT}	Output Power	V_S = 6 V, R_L = 8 Ω, THD = 10% (LM386N-1, LM386M-1, LM386MM-1)	250	325		mW
		V_S = 9 V, R_L = 8 Ω, THD = 10% (LM386N-3)	500	700		
		V_S = 16 V, R_L = 32 Ω, THD = 10% (LM386N-4)	700	100		
A_V	Voltage Gain	V_S = 6 V, f = 1 kHz		26		dB
		10 µF from Pin 1 to 8		46		
BW	Bandwidth	V_S = 6 V, Pins 1 and 8 Open		300		kHz
THD	Total Harmonic Distortion	V_S = 6 V, R_L = 8 Ω, POUT = 125 mW f = 1 kHz, Pins 1 and 8 Open		0.2%		
PSRR	Power Supply Rejection Ratio	V_S = 6 V, f = 1 kHz, CBYPASS = 10 µF Pins 1 and 8 Open, Referred to Output		50		dB
R_{IN}	Input Resistance			50		kΩ
I_{BIAS}	Input Bias Current	V_S = 6 V, Pins 2 and 3 Open		250		nA

6.6 Typical Characteristics

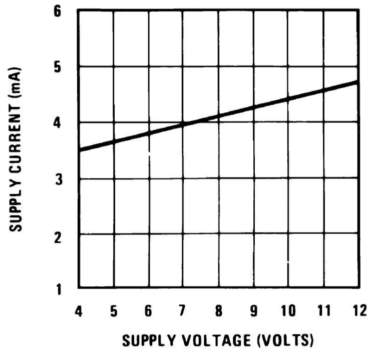


Figure 1. Supply Current vs Supply Voltage

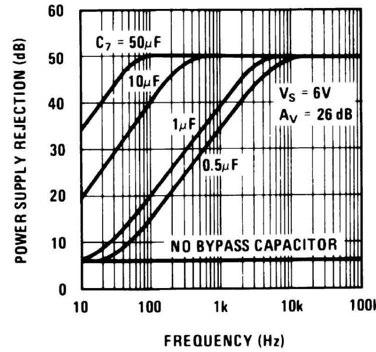


Figure 2. Power Supply Rejection vs Frequency

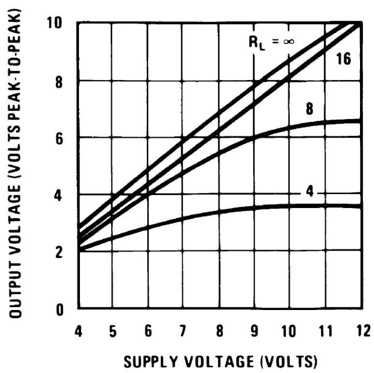


Figure 3. Output Voltage vs Supply Voltage

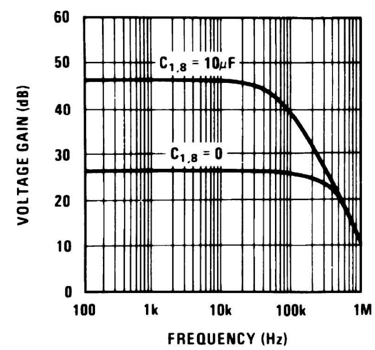


Figure 4. Voltage Gain vs Frequency

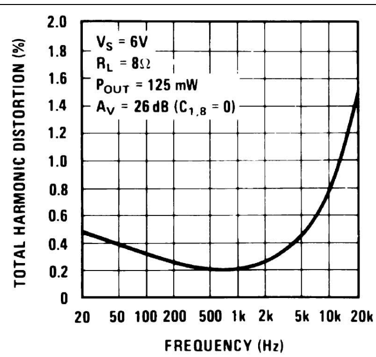


Figure 5. Total Harmonic Distortion vs Frequency

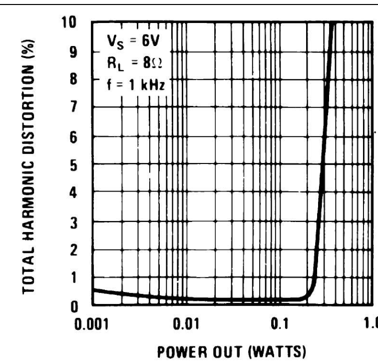


Figure 6. Total Harmonic Distortion vs Power Out

Typical Characteristics (continued)

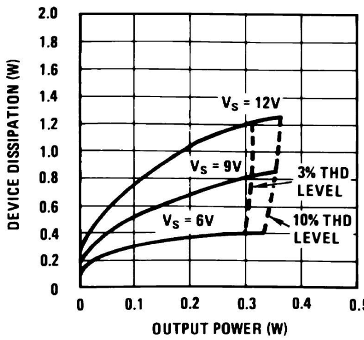


Figure 7. Device Dissipation vs Output Power

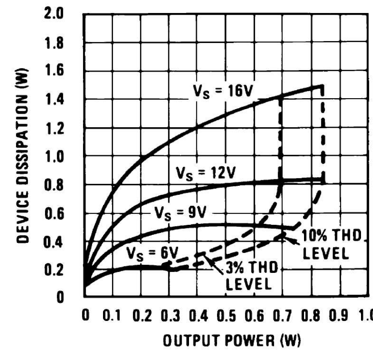


Figure 8. Device Dissipation vs Output Power

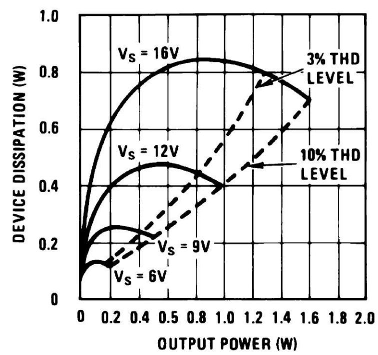


Figure 9. Device Dissipation vs Output Power

7 Parameter Measurement Information

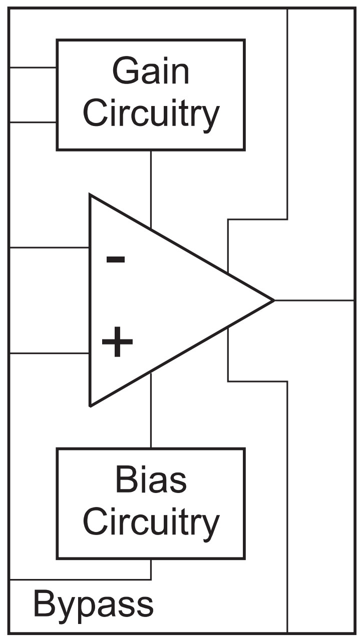
All parameters are measured according to the conditions described in the *Specifications* section.

8 Detailed Description

8.1 Overview

The LM386 is a mono low voltage amplifier that can be used in a variety of applications. It can drive loads from 4 Ω to 32 Ω. The gain is internally set to 20 but it can be modified from 20 to 200 by placing a resistor and capacitor between pins 1 and 8. This device comes in three different 8-pin packages as PDIP, SOIC and VSSOP to fit in different applications.

8.2 Functional Block Diagram



8.3 Feature Description

There is an internal 1.35-KΩ resistor that sets the gain of this device to 20. The gain can be modified from 20 to 200. Detailed information about gain setting can be found in the *Detailed Design Procedure* section.

8.4 Device Functional Modes

As this is an Op Amp it can be used in different configurations to fit in several applications. The internal gain setting resistor allows the LM386 to be used in a very low part count system. In addition a series resistor can be placed between pins 1 and 5 to modify the gain and frequency response for specific applications.

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

Below are shown different setups that show how the LM386 can be implemented in a variety of applications.

9.2 Typical Application

9.2.1 LM386 with Gain = 20

Figure 10 shows the minimum part count application that can be implemented using LM386. Its gain is internally set to 20.

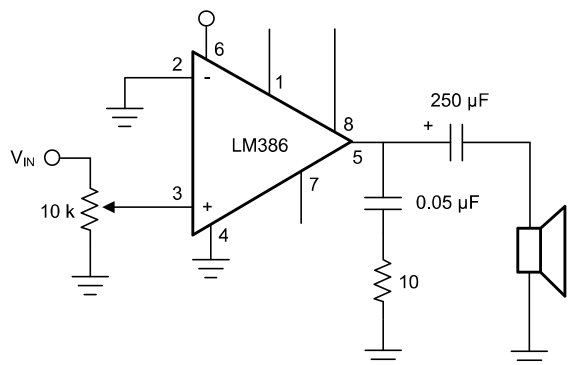


Figure 10. LM386 with Gain = 20

9.2.1.1 Design Requirements

Table 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.1.2 Detailed Design Procedure

9.2.1.2.1 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 ~= 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.

9.2.1.2.2 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.

9.2.1.3 Application Curve

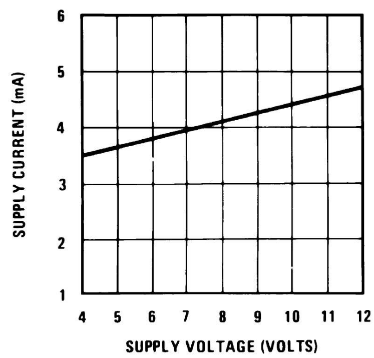


Figure 11. Supply Current vs Supply Voltage

9.2.2 LM386 with Gain = 200

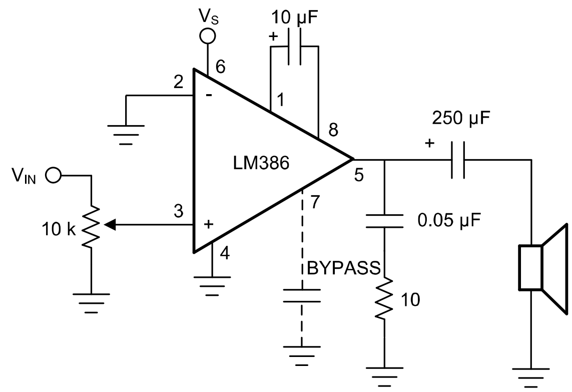


Figure 12. LM386 with Gain = 200

9.2.2.1 *Design Requirements*

Table 2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.2.2 *Detailed Design Procedure*

The Detailed Design Procedure can be found in the *Detailed Design Procedure* section.

9.2.2.3 *Application Curve*

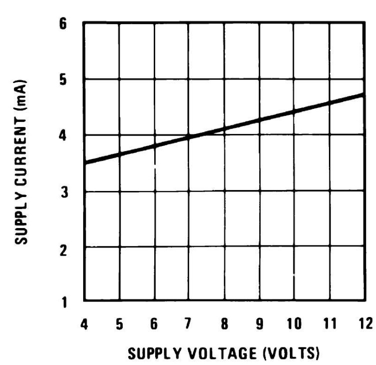


Figure 13. Supply Current vs Supply Voltage

9.2.3 LM386 with Gain = 50

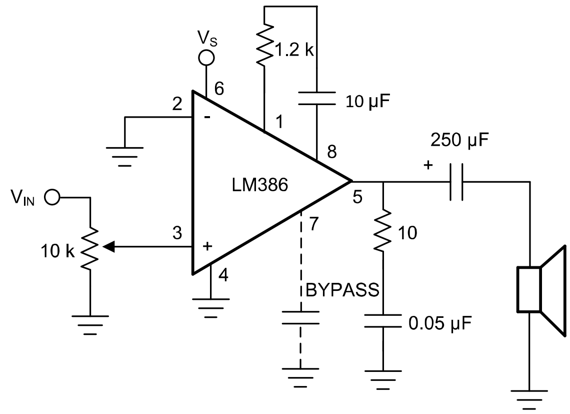


Figure 14. LM386 with Gain = 50

9.2.3.1 Design Requirements

Table 3. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.3.2 Detailed Design Procedure

The Detailed Design Procedure can be found in the *Detailed Design Procedure* section.

9.2.3.3 Application Curve

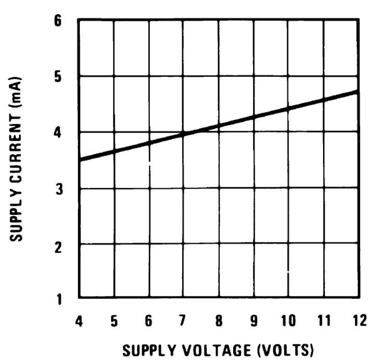


Figure 15. Supply Current vs Supply Voltage

9.2.4 Low Distortion Power Wienbridge Oscillator

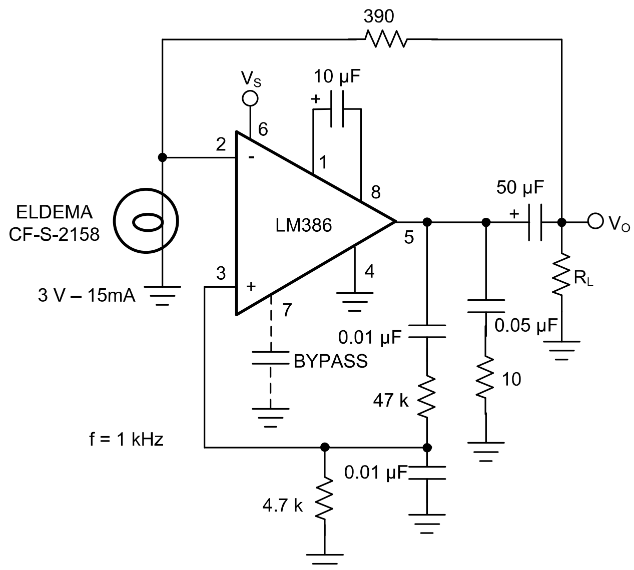


Figure 16. Low Distortion Power Wienbridge Oscillator

9.2.4.1 Design Requirements

Table 4. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.4.2 Detailed Design Procedure

The Detailed Design Procedure can be found in the *Detailed Design Procedure* section.

9.2.4.3 Application Curve

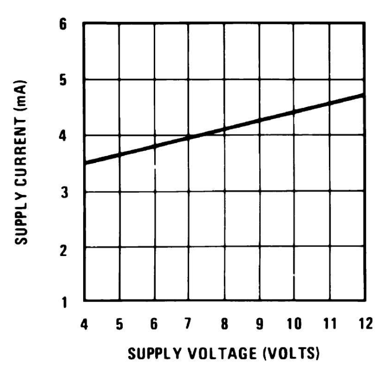


Figure 17. Supply Current vs Supply Voltage

9.2.5 LM386 with Bass Boost

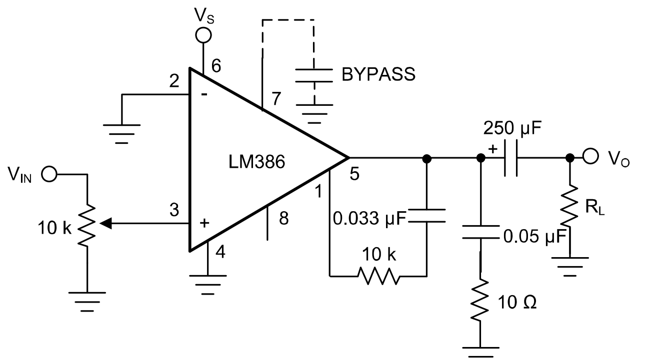


Figure 18. LM386 with Bass Boost

9.2.5.1 Design Requirements

Table 5. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.5.2 Detailed Design Procedure

The Detailed Design Procedure can be found in the *Detailed Design Procedure* section.

9.2.5.3 Application Curve

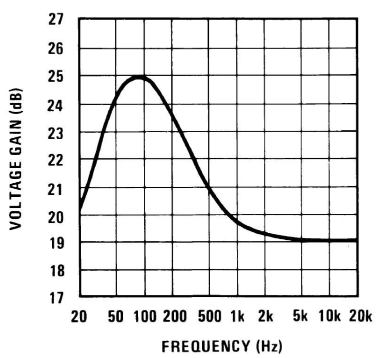


Figure 19. Voltage Gain vs Frequency

9.2.6 Square Wave Oscillator

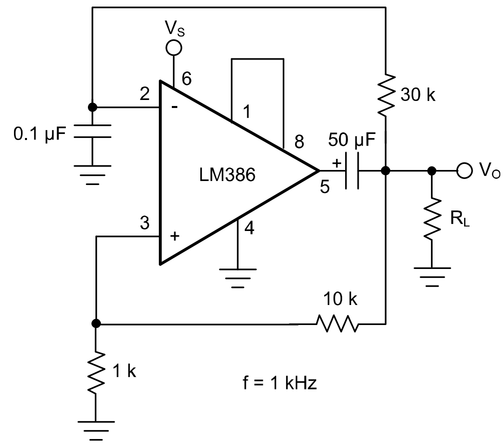


Figure 20. Square Wave Oscillator

Table 6. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.6.1 Detailed Design Procedure

The Detailed Design Procedure can be found in the *Detailed Design Procedure* section.

9.2.6.2 Application Curve

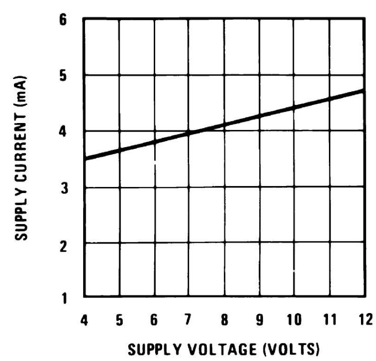


Figure 21. Supply Current vs Supply Voltage

9.2.7 AM Radio Power Amplifier

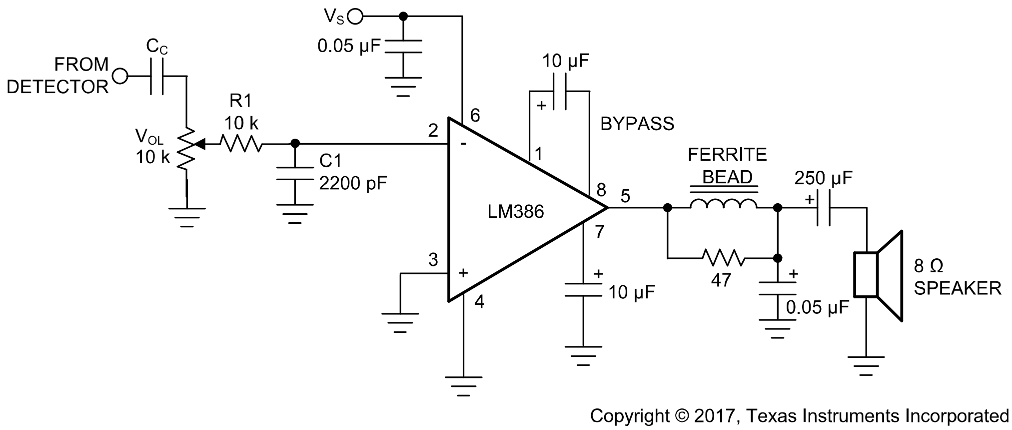


Figure 22. AM Radio Power Amplifier

9.2.7.1 Design Requirements

Table 7. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Load Impedance	4 Ω to 32 Ω
Supply Voltage	5 V to 12 V

9.2.7.2 Detailed Design Procedure

The Detailed Design Procedure can be found in the *Detailed Design Procedure* section.

9.2.7.3 Application Curve

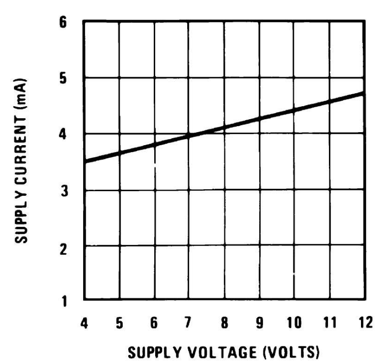


Figure 23. Supply Current vs Supply Voltage

10 Power Supply Recommendations

The LM386 is specified for operation up to 12 V or 18 V. The power supply should be well regulated and the voltage must be within the specified values. It is recommended to place a capacitor to GND close to the LM386 power supply pin.

11 Layout

11.1 Layout Guidelines

Place all required components as close as possible to the device. Use short traces for the output to the speaker connection. Route the analog traces far from the digital signal traces and avoid crossing them.

11.2 Layout Examples

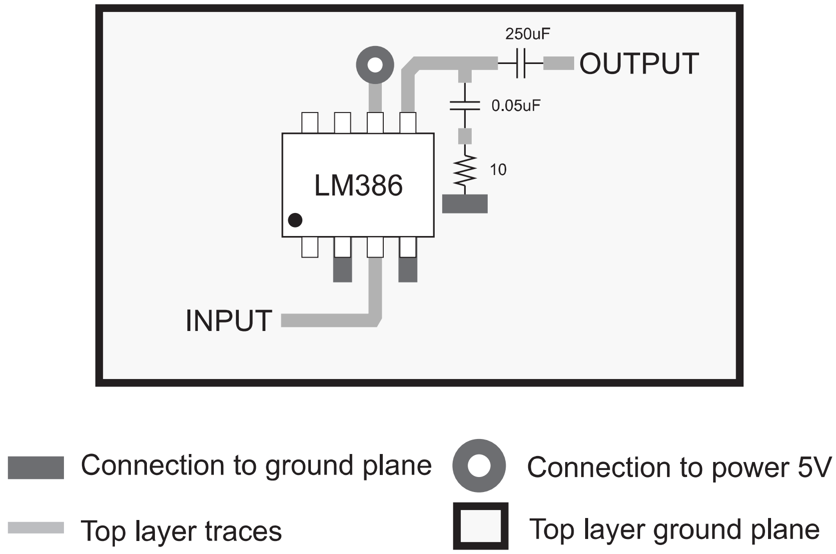


Figure 24. Layout Example for Minimum Parts Gain = 20 dB on PDIP package

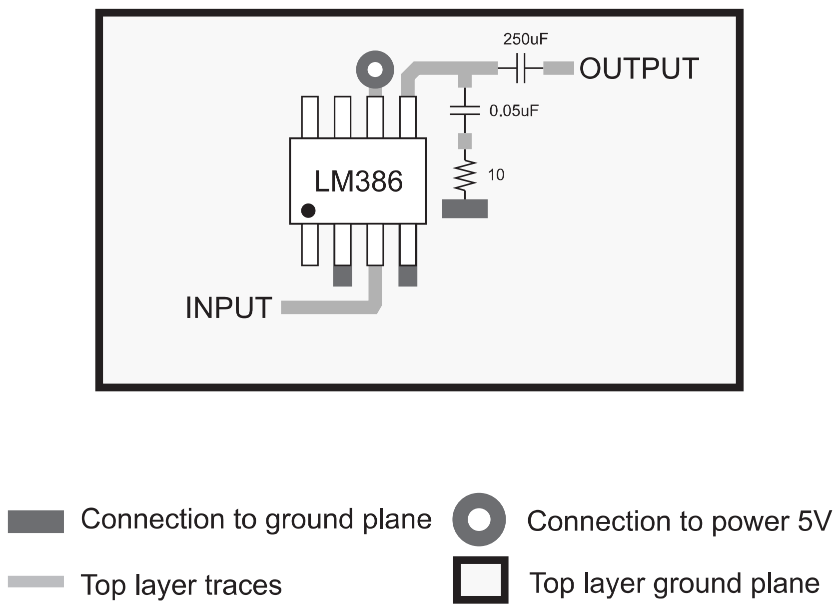


Figure 25. Layout Example for Minimum Parts Gain = 20 dB on SOIC package

Layout Examples (continued)

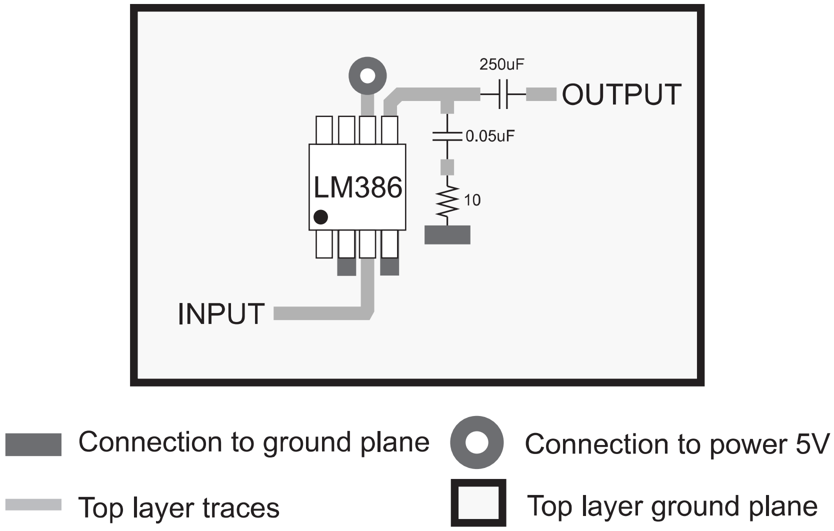


Figure 26. Layout Example for Minimum Parts Gain = 20 dB on VSSOP package

12 Device and Documentation Support

12.1 Device Support

12.1.1 Development Support

12.2 Documentation Support

12.3 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

Table 8. Related Links

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM386M-1	Click here	Click here	Click here	Click here	Click here
LM386MX-1	Click here	Click here	Click here	Click here	Click here

12.4 Receiving Notification of Documentation Updates

To receive notification of documentation updates — go to the product folder for your device on ti.com. In the upper right-hand corner, click the *Alert me* button to register and receive a weekly digest of product information that has changed (if any). For change details, check the revision history of any revised document.

12.5 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.6 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.7 Electrostatic Discharge Caution

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

12.8 Glossary

SLYZ022 — *TI Glossary*.
This glossary lists and explains terms, acronyms, and definitions.