# A Versatile Audio Amplifier Chip

## *How to use the popular LM386 IC in a variety of applications*

**By Michael A. Covington**

National Semiconductor's LM386 integrated circuit is an easy-to-use audio amplifier that delivers as much as 0.4 watt into an 8-ohm speaker load. You can use this 8-pin chip in such projects as receivers, intercoms, alarms, and all types of battery-operated audio equipment. In this article we'll explore how to use the LM386 effectively.

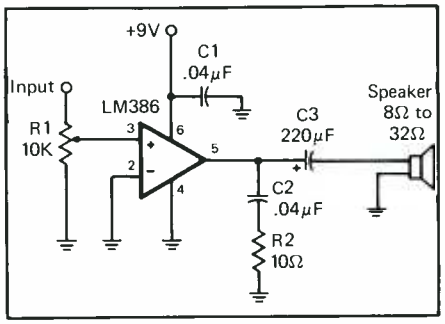



*Fig. 1. Basic LM386 amplifier circuit. Place C1 as close as possible to the LM386 integrated circuit.*

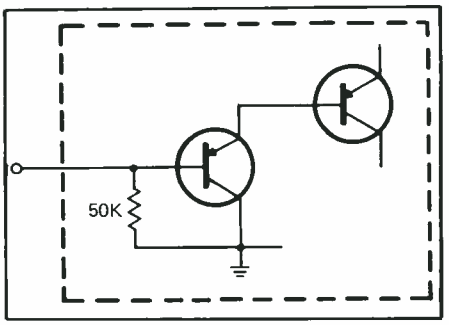



*Fig. 2. An LM386 input's upside-down emitter-follower stage allows input voltage to swing below ground.*

### *Low-Gain Amplifier*

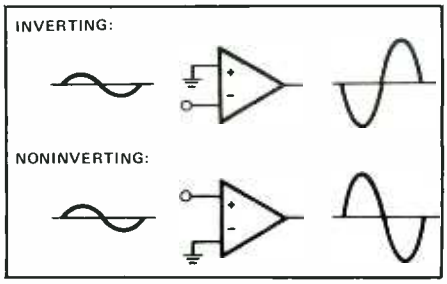
Figure 1 shows the simplest LM386 circuit, an amplifier with a voltage gain of 20. Its input can come from a tuner, a tape deck, or a crystal phono cartridge. (If you wish to drive this circuit from a magnetic cartridge, the LM386 circuit will have to be preceded by a preamplifier.) An output signal of about 400 millivolts peak-to-peak is sufficient to drive the speaker to full volume. This circuit is exactly what you need to use a speaker with a Sony Walkman or the like. Stereo sound, of course, requires two such amplifiers, one for each channel. Harmonic distortion in this circuit is well below 0.5% almost up to maximum volume.

In the circuit shown, potentiometer *R1* serves as a volume control. Its value determines the input impedance, which can be anything from 500 to 20,000 ohms. The value of *C3* can range from about 50 microfarads (which gives rather poor bass response) up to 1000 microfarads or more. Capacitors *C1 and C2* and resistor *R2* are needed to prevent high-frequency oscillation that would result in garbled sound. Although the manufacturer's literature states that these last three components are optional, I've found that trying to do without them is a very risky proposition. During assembly, be sure to keep all leads short and adequately isolate the input from the output.

If you use a 16-ohm or greater impedance speaker, supply voltage can be anywhere between 4 and 14 volts. With an 8-ohm speaker, however, keep supply voltage to less than 10 volts to prevent overheating the LM386. With a 4-ohm speaker, the supply should not exceed 7 volts.

It usually isn't practical to drive more than one speaker from a single LM386. However, if you must do so, connect the speakers in series rather than in parallel with each other to maintain a relatively high total impedance. The LM386 consumes very little power. The only significant power drawn by the circuit is what is

*Fig. 3. In low-gain mode, LM386 can be used as noninverter (upper) or inverter (lower); high gain requires operation in noninverting mode.*



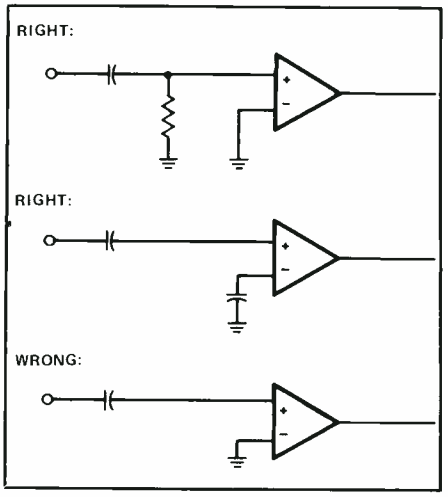



*Fig. 4. For best results, provide a dc path from both inputs or neither.*

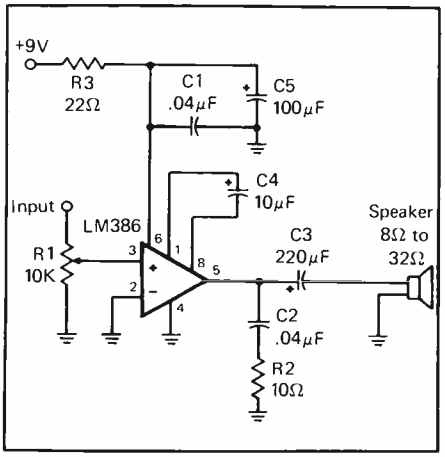



*Fig. 5. In the high-gain mode, be sure to place C1 as close as possible to the IC, isolate input from output.*

actually delivered to the speaker. With no input, current consumption is typically 2 mA. At moderate volume this increases to 15 mA and can go as high as 70 mA at high volume or when driving a large speaker.

The LM386 looks a lot like an operational amplifier, but there are some important differences to keep in mind. For example, unlike an op amp, the LM386 requires only a single positive supply voltage. Also the output at pin 5 is automatically biased to a dc level halfway between the supply voltage and ground, with *C3* preventing dc from flowing through the speaker.

In an operational amplifier, the inputs would normally be at the same dc level as the output. But the inputs of the LM386 operate at ground level, and the input signal can swing to either side of ground. Figure 2 shows how this is achieved—the input stage is an emitter-follower whose "ground" is actually the positive supply voltage. The internal 50,000-ohm resistor sets maximum input impedance.

Like an op-amp, the LM386 has both inverting and noninverting inputs (Fig. 3). In the low-gain circuit shown in Figure 1, you can apply the signal to either input, depending on whether or not you want it to come out inverted. Inversion has no effect on sound quality, and there is little reason to prefer one configuration over the other. For other applications, such as higher-gain amplifiers and oscillators, only the noninverting configuration will work.

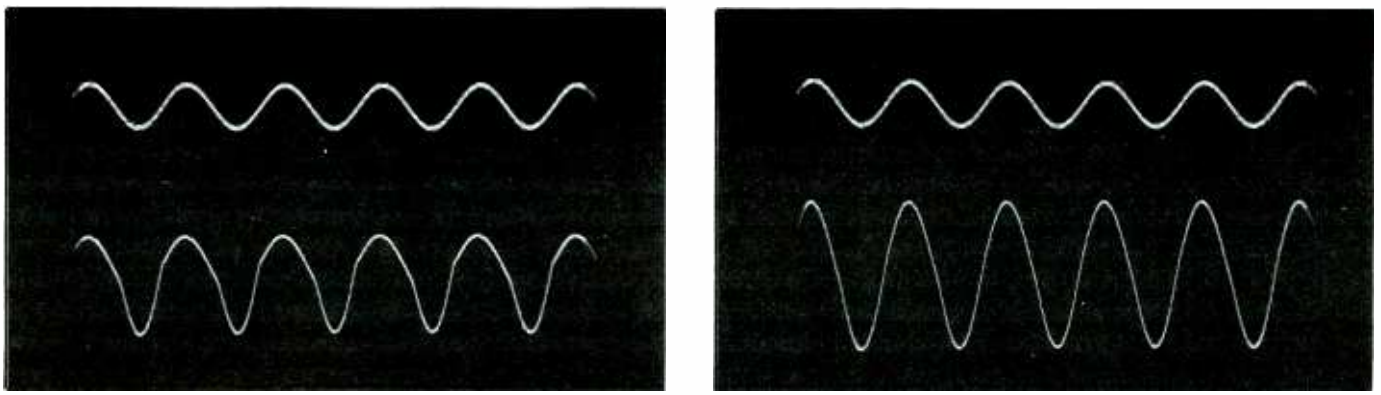
The LM386 performs best if the dc resistance to ground from both inputs is roughly the same ("roughly" here means within 10,000 ohms or so). If you ground one input, you should provide a path from the other one to ground through a resistor (Fig. 4). If the input signal is coupled to the LM386 through a capacitor, so that there is no dc path to ground, the other input should be grounded through a capacitor or simply left unconnected.

## *High-Gain Amplifier*

Figure 5 shows the LM386 configured as a high-gain amplifier, with a voltage gain of 200. The main change here is that *C4* has been added to bypass an internal feedback resistor. Resistor *R3* and capacitor *C5* change the dynamic characteristics of the power supply.

Figure 6 shows why *R3* and *C5* are necessary. Without them, the LM386 suffers from noticeable distortion when driving a low-impedance (8- or 16-ohm) load. The distortion isn't affected by the signal level or the impedance of the signal source, nor by bypassing pin 7 to ground through a capacitor as suggested in the manufacturer's literature. In fact, the distortion surprised me so much that I

*Fig. 6. Distortion in high-gain mode (left) is cured (right) by using R3 and C5 in Fig. 5. Top traces are input.*



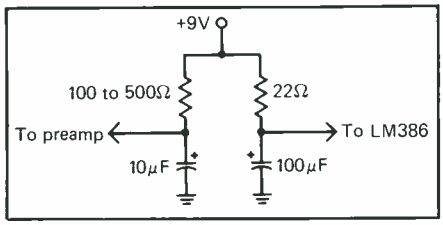



*Fig. 7. Split power supply prevents feedback when using a preamplifier.*

tried two LM386s from different manufacturing lots, just to make sure I wasn't dealing with a defective IC.

Apparently, the explanation is that the LM386 is designed to be battery powered, and the internal resistance of the battery is figured into its feedback network. The internal resistance of a 9-volt battery is between 10 and 100 ohms, whereas the resistance of a well-regulated power supply is nearly zero. So *R3* takes the place of the resistance of the battery, and *C5* is the bypass capacitor that would normally be used with battery-powered equipment. If the power supply is in fact a battery, or if the load impedance is more than 32 ohms, *R3* can be omitted.

Even a gain of 200 isn't quite enough to drive a speaker with the signal from a microphone, tape head, or magnetic phono cartridge. As mentioned earlier for the Fig. 1 circuit, an extra stage of preamplification is required. If the LM286 and the premaplifier are connected to the same power supply, feedback may cause oscillation—usually an audio-frequency squeal or a low putt-putt sound ("motorboating"). Figure 7 shows how to prevent this. The resistors and capacitors send the incoming power down two paths that are isolated from each other.

Figure 8 shows a complete amplifier for microphone-level input. Total voltage gain is about 4000. The transistor in the first stage can be any small-signal npn transistor with a beta ($h_{fe}$) of at least 50. For experiments, you can use a second 8-ohm speaker as a microphone; by doing this and adding a switch to interchange the two speakers, you have an intercom. In a high-gain circuit like this, it is doubly important to keep leads short and isolate the input from the output.

## Oscillator Configuration

Finally, Fig. 9 shows how to use the LM386 as an oscillator. The output is a square wave with a frequency (in Hertz) of $2.5/(R_tC_t)$, where $R_t$ is between 10,000 and 100,000 ohms. Because the circuit is designed to oscillate, the anti-oscillation measures used in the amplifier circuits aren't needed here, and the power supply voltage isn't critical. Also, since linear amplification isn't required, pins 1 and 8 can be joined by a direct connection, rather than through a capacitor.

If you connect a speaker in place of *R3* in this circuit, the output is no longer a square wave. Instead, what you hear will be a loud, piercing squeal that makes a good alarm sounder. The LM386 is an efficient noisemaker. It delivers a lot of sound for a small amount of battery power. To reduce the volume of the sound, connect a 10- to 300-ohm resistor in series with the speaker.

## Going Further

Once you've mastered the LM386, you'll want to look at several of its relatives in the National Semiconductor line. The LM389 consists of an LM386 plus three individual npn transistors, all on one chip. This IC is often used to save space in radio receivers. The popular LM380 is a 2.5-watt power amplifier that requires a 12-to-15 volt supply and delivers a voltage gain of 50. Stepping up to the LM380's big brother, you come to the its big LM384, which delivers a hefty 5 watts of output from a 20-volt supply. You can begin immediately experimenting with the LM380 and LM384, since their external circuitry differs only in minor details from that of the LM386. **ME**

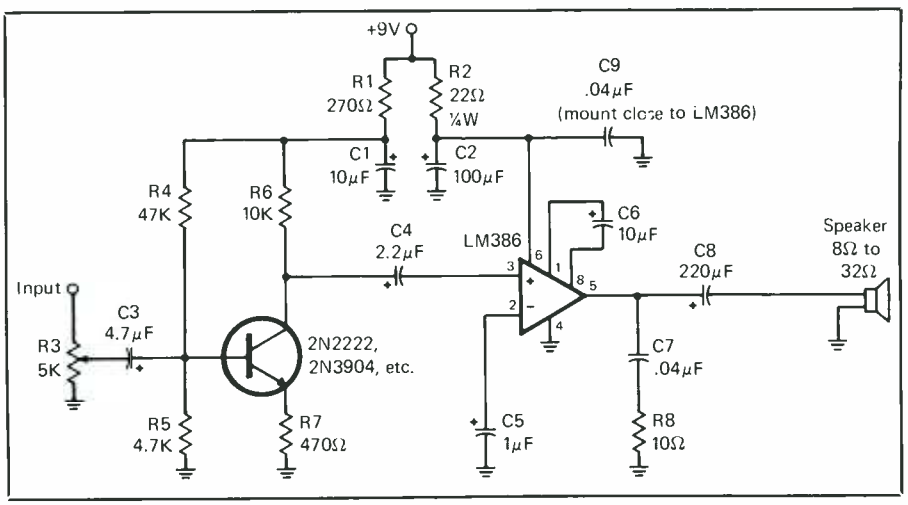
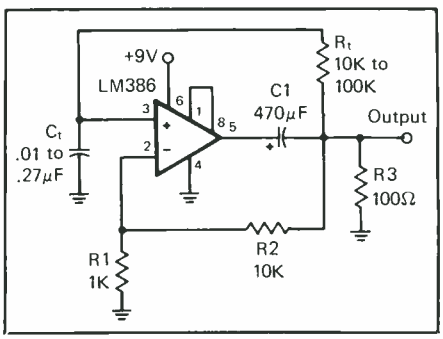
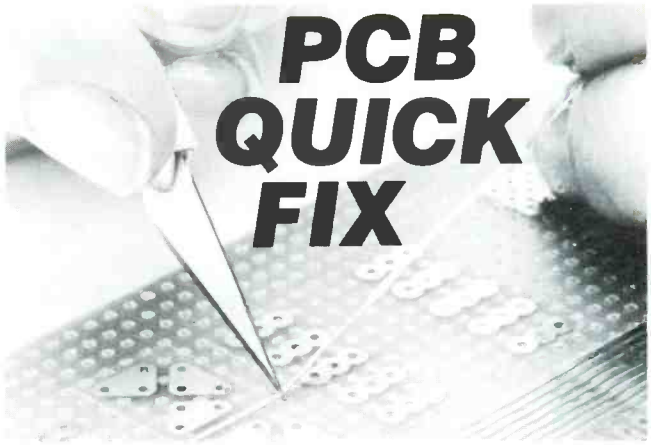



*Fig. 8. A microphone amplifier circuit with total gain of about 4000.*

*Fig. 9. This is an LM386 square-wave generator. A speaker can replace R3.*



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