

## AUDIO PRE AMP IC'S

An in-depth look at National Semiconductor's LM38X series of audio preamp IC's.

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ONE OF THE MOST VERSATILE SERIES OF linear preamp IC's is the LM38X versions from National Semiconductor. They're extremely useful for audio and tone-control applications, and have excellent ripple rejection, low signal distortion, wide bandwidth, and low noise. You'll find them in virtually any modern piece of audio gear. This discussion will investigate how they work, and look at several useful applications.

### The LM38X IC's

Figure 1 shows a representative block diagram of a conventional stereo system channel with both volume and tone control. National Semiconductor produces five low-noise dual preamps in the LM38X series, the LM381, LM381A, LM382, LM387, and LM387A; the "A" denotes versions with superior noise figure performance. Figures 2-4 show the configurations of the three different versions for one of the two amplifiers in

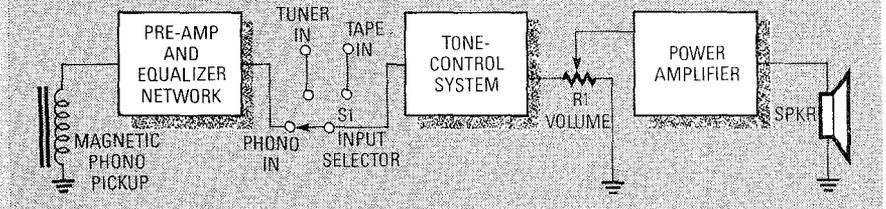


FIG. 1—BLOCK DIAGRAM OF ONE CHANNEL of a stereo system.

each Dual-In-line Package (DIP), while Table 1 gives a performance summary.

Tone control may involve refinements like "scratch" and "rumble" filters. All five IC's in the LM38X family use single-ended power supplies, and have the same basic amplifier circuitry, but differ in internal details and pinouts. Also, all five have internal compensation, power-supply decoupling and regulation, large capacity for output-voltage swing, and wide power bandwidth. They'd be used for both the preamp and tone-control blocks in Fig. 1, since both functions occur prior to power amplification. The differences are:

- The LM381 and LM381A, shown in Fig. 2, allow external noise figure optimization and compensation (nar-

row-band or low-gain use). They're normally used differentially, but can be used single-ended for ultra-low-noise purposes.

- The LM382, shown in Fig. 3, doesn't provide for external compensation or single-ended operation, but has a built-in resistor matrix to let the user select from among several closed-loop gain and frequency-response options.

- The LM387 and LM387A, shown in Fig. 4, are utility versions of the LM381/1A, with only the input and output terminals accessible, and no provision for external compensation or single-ended operation.

### LM381/1A basics

All the IC's in the LM38X family can be understood by examining the

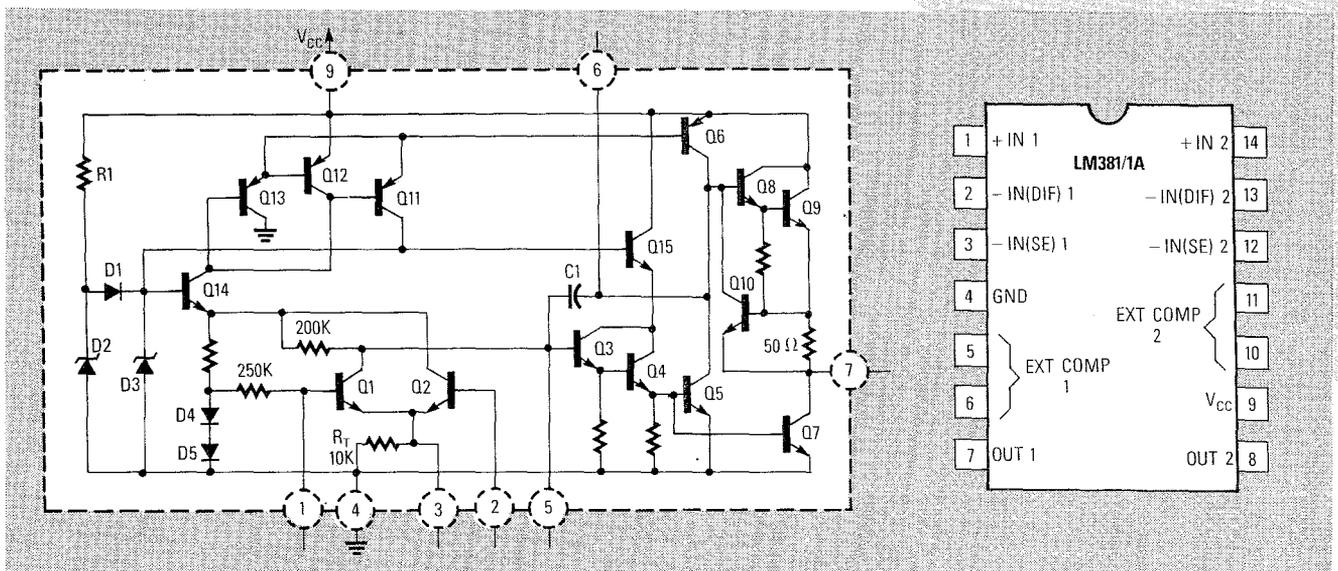
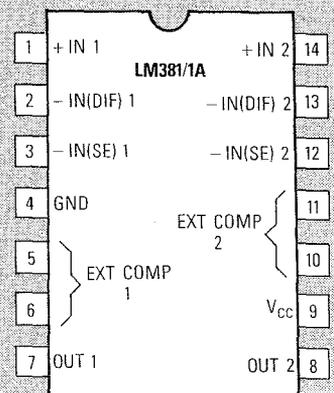


FIG. 2—THE LM381/1A DUAL LOW-NOISE PREAMP.



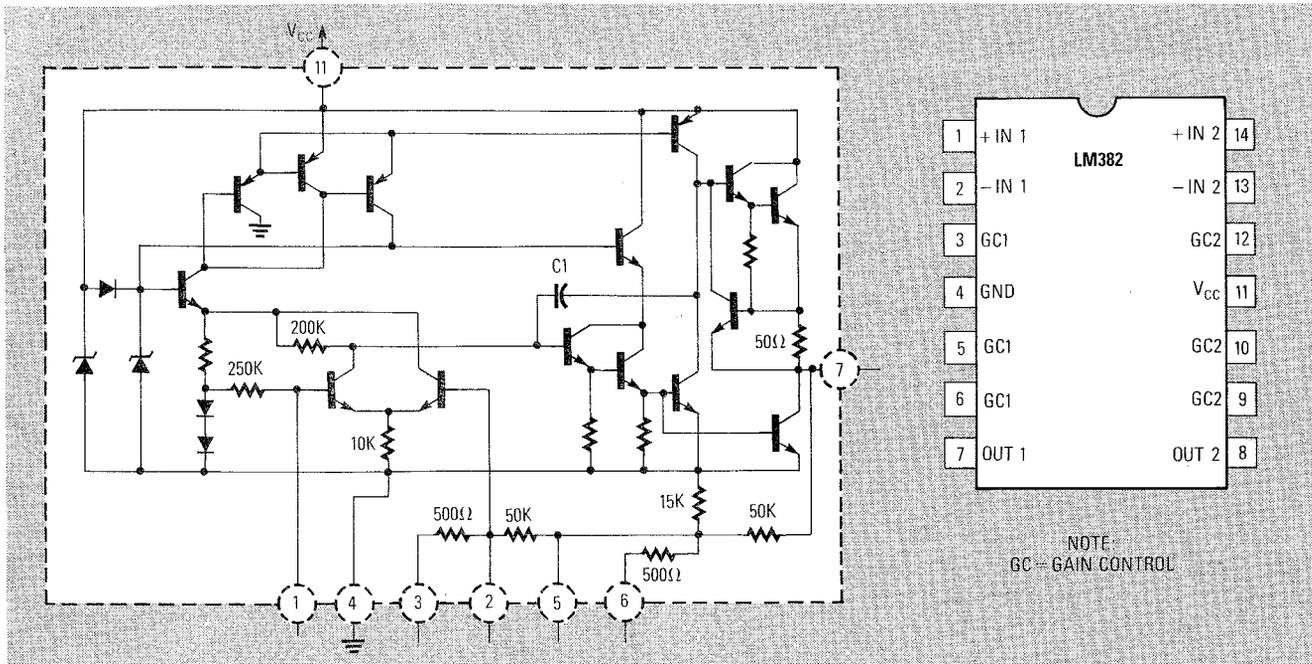


FIG. 3—THE LM382 DUAL LOW-NOISE PREAMP.

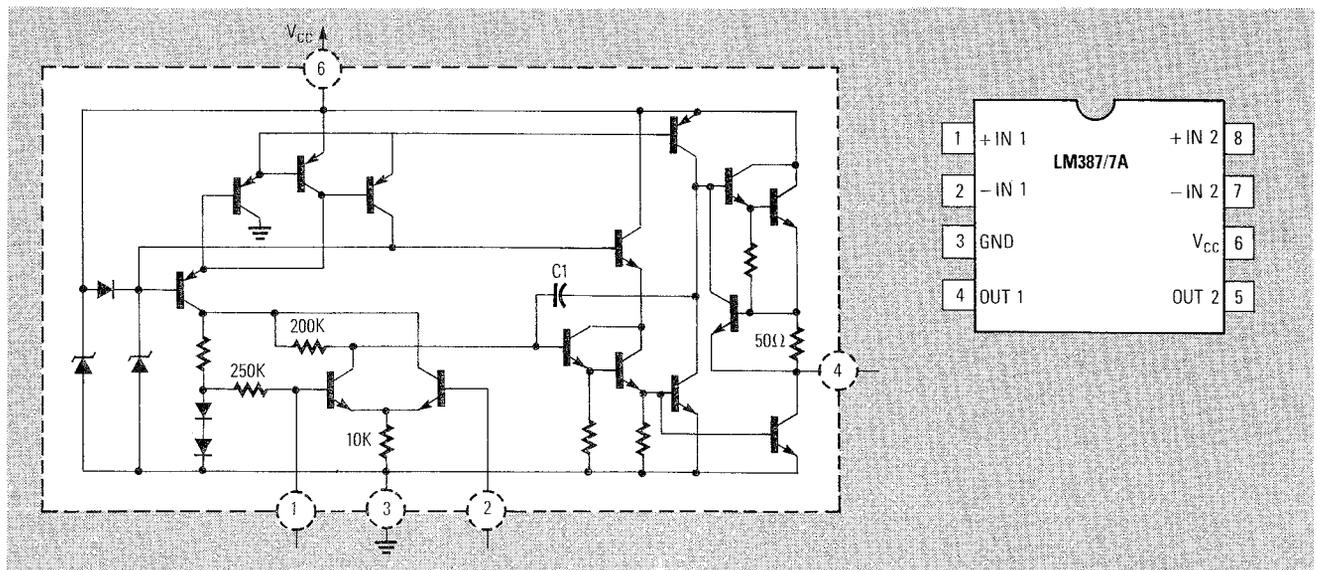


FIG. 4—THE LM387/7A DUAL LOW-NOISE PREAMP.

LM381/1A shown in Fig. 2. It has a first stage (Q1 and Q2), second stage (Q3-Q6), output stage (Q7-Q10), and bias network (Q11-Q15); Fig. 5 shows a simplified equivalent. The first stage is biased at 1.2 volts via R1, and can be operated either differentially or single-ended, although differential operation generates 41% more noise.

In differential use, the first stage has to be balanced by externally biasing the base of Q2 at 1.2 volts. In single-ended mode, Q2 has to be turned off by grounding its base, and Q1 has to be balanced by externally biasing the emitter of Q2 at 600 milli-

volts. The first stage has a differential voltage gain of 80, or 160 when used single-ended.

The second stage uses common-emitter Q5 and constant-current load Q6, and is driven by Q1 via Darlington emitter follower Q3-Q4. Its voltage gain is 2000, and it's internally compensated via C1 for unity gain at 15 MHz, giving stability at closed-loop gains of 10 or more. At lower gains, an external capacitor can go in parallel with C1 for compensation purposes.

The output stage uses Darlington emitter follower Q8-Q9, with active current sink Q7. Then, Q10 provides

short-circuit protection by limiting output current to 12 mA. The bias network gives 120 dB of supply-signal rejection, and includes the high-impedance constant-current generator Q11-Q12-Q13, which generates ripple-free reference voltage across D3. That reference voltage operates the first two stages via Q14 and Q15, and biases the base of Q1 internally.

### Differential operation

In differential mode, the IC output is given a positive quiescent value independent of supply-voltage variations, by connecting divider R1-R2 as a DC negative-feedback loop, as

shown in Fig. 6. The inverting input is biased internally at 1.2 volts. When R1 and R2 are used as in Fig. 6, DC negative feedback makes the non-inverting input go to 1.2 volts, and the amplifier output to  $1.2 \text{ volts} \times [1 + (R1/R2)]$ . In practice:  $R2 < 250K$ .

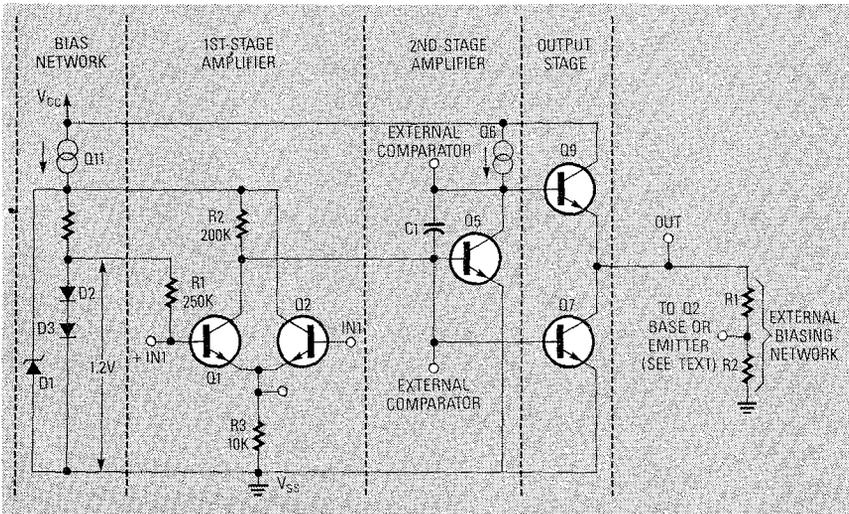
Figure 7 shows a non-inverting AC amplifier with an input impedance of 250K; input signals must be limited to 300 mV RMS to avoid distortion. The DC voltage gain is determined by R1 and R2, while the desired AC gain is set by AC shunting one of the bias resistors. Here, the DC gain is fixed by R1 and R2 at less than 10, but the AC gain is fixed by R1 and R3 at 100.

That shunting technique can be expanded for frequency-dependent AC gain in various filter applications. Fig-

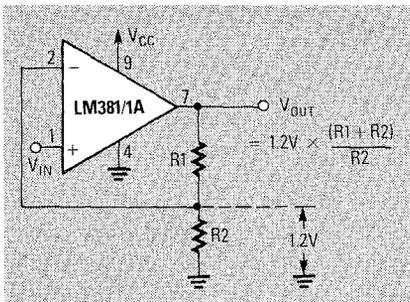
**TABLE 1—PERFORMANCE OF THE LM381/1A/2/7/7A LINEAR IC'S**

Characteristic	LM381	LM381A	LM382	LM387	LM387A
Supply Voltage (VDC)	9-40	9-40	9-40	9-30	9-40
Quiescent Current (mA)	10	10	10	10	10
Power Bandwidth (kHz)*	75	75	75	75	75
Supply Rejection Ratio (dB at 1 kHz)	120	120	120	110	110
Equiv. Noise Input Figure ( $\mu\text{V RMS}$ )	Typ.	0.5	0.5	0.8	0.65
	Max.	1.0	0.7	1.2	0.9

\* NOTE: Power bandwidth is the audio frequency range over which an amplifier can produce half of its rated power, without exceeding its rated distortion. It indicates how much power is available at the critical high and low frequencies, and the wider the power bandwidth, the better the amplifier.



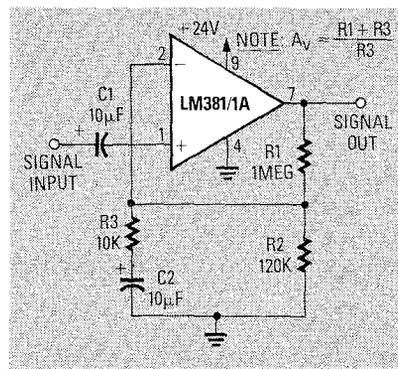
**FIG. 5—EQUIVALENT CIRCUIT OF THE LM381/1A amplifier.**



**FIG. 6—DIFFERENTIAL BIASING OF THE LM381/1A.**

ure 8 shows the same amplifier configuration used as a low-noise phono preamp with Recording Industries Association of America (RIAA) equalization, while Fig. 9 shows a similar tape-playback amplifier with National Association of Broadcasters (NAB) equalization. Figure 10 shows an inverting AC amplifier; here, the non-

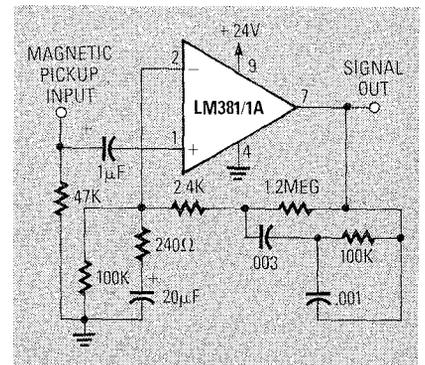
inverting terminal is grounded, and the input signal is fed to the inverting terminal via R1. The AC gain is  $R3/R2 = 10$ , the quiescent output is +12 volts, and the input impedance is about R1. Figure 11 shows a unity-gain, 4-input audio mixer.



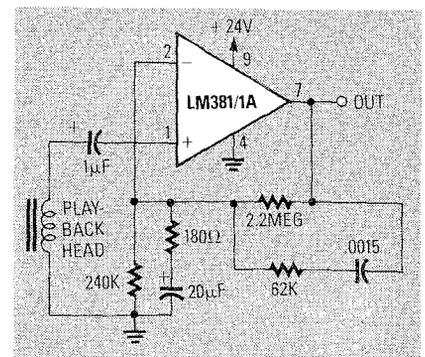
**FIG. 7—A LOW-NOISE LM381/1A non-inverting amplifier, with a gain of 100.**

### Single-ended operation

The differential first stage of an LM381 composed of Q1-Q2 is powered via the internal 5.6-volt regulator, and the collector of Q1 is fed to



**FIG. 8—AN LM381/1A USED AS A low-noise phono preamp with RIAA equalization.**



**FIG. 9—AN LM381/1A used as a tape playback amplifier with NAB equalization.**

the output via a DC amplifier. The IC can be operated in single-ended mode by grounding the base of (and disabling) Q2, but it needs to be biased

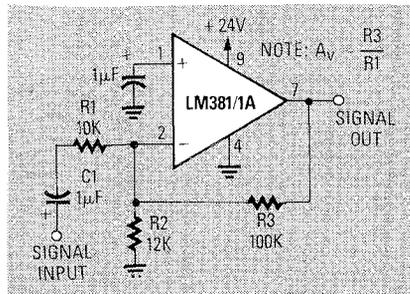


FIG. 10—THIS LM381A low-distortion (less than 0.05%) inverting amplifier has a gain of 10.

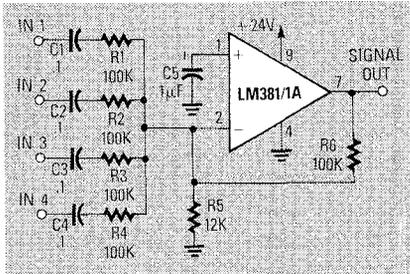


FIG. 11—THE LM381/1A is used here as a 4-input unity-gain audio mixer.

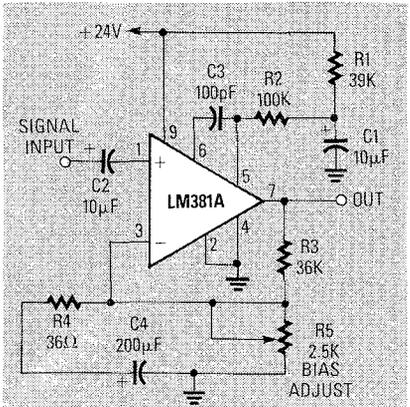


FIG. 12—THIS LM381A ultra-low-noise preamp has a gain of 1000.

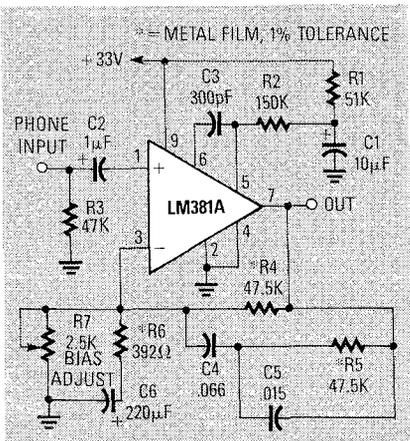


FIG. 13—LM381A ULTRA-LOW-NOISE magnetic phono preamp that includes RIAA equalization.

using emitter feedback.

Suitable DC biasing is obtained by connecting a voltage divider that ap-

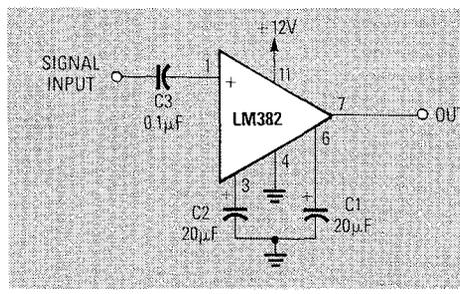


FIG. 14—AN LM382 FIXED-GAIN non-inverting amplifier with a 12-volt power supply.

GAIN	REQUIRED CAPACITOR
40dB	C1 ONLY
55dB	C2 ONLY
80dB	C1 AND C2

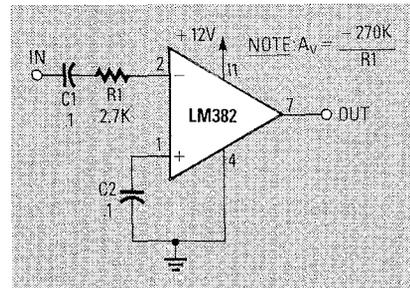


FIG. 15—THE LM382 is used here to make a 40-dB inverting amplifier.

for non-inverting use only, with a typical input impedance of 10K. Ideally, input signals should have source impedances below 2K, and all resistors should be of the low-noise, metal-film variety. Figure 12 is an ultra-low-noise version with a gain of 1000, where C3 limits the upper 3-dB frequency response to 10 kHz, and R5 adjusts the DC output voltage to half-supply value. Figure 13 is a magnetic phono preamp circuit that uses RIAA equalization, with the DC output voltage set by R7.

### LM382 circuits

The internal circuitry of each half of a LM382 is identical to a LM381, except for a 5-resistor matrix and elimination of certain terminal connections. Eliminating those terminals means that an LM382 can't be used single-ended or externally compensated. The resistor matrix greatly simplifies bias- and filter-network design. The matrix is specifically intended for applications where the IC is powered from a +12-volt supply. Figures 14-17 show various ways to use the LM382 with a +12-volt supply. Figure 14 shows a non-inverting amplifier with 40, 55 or 80 dB of AC gain. Figure 15 shows an inverting amplifier with 40 dB gain, Fig. 16 shows a unity-gain inverting amplifier, and Fig. 17 shows a phono preamp with RIAA equalization.

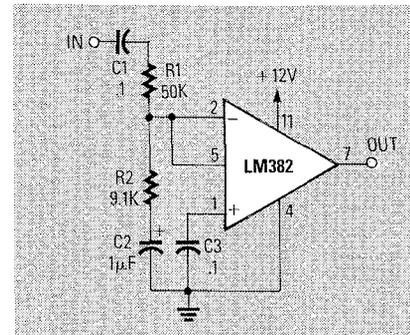


FIG. 16—SHOWN HERE IS AN LM382 unity-gain inverter.

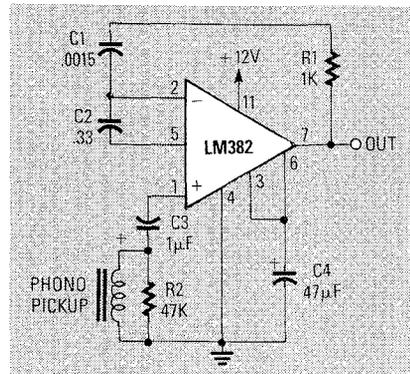


FIG. 17—LM382 phono preamp with RIAA equalization.

plies 600 millivolts to pin 3 when the IC output is at the desired DC level. If a quiescent +12-volt output is needed, the divider needs a DC voltage gain of 20.

In practice, the noise from the input transistor varies with collector current, and is minimized at 170 µA.

A single-ended LM381 is intended

### LM387 circuits

The internal circuitry of each half of a LM387/7A is identical to an LM381, except for eliminating certain terminal connections, letting the IC be used differentially without external compensation. The IC is nevertheless quite versatile, and Figs. 18-24 show some practical applications. Figure 18 shows how to connect an LM387 as a non-inverting amplifier with an AC gain of 52 dB. The DC gain and quiescent output voltage of the amplifier circuit are determined

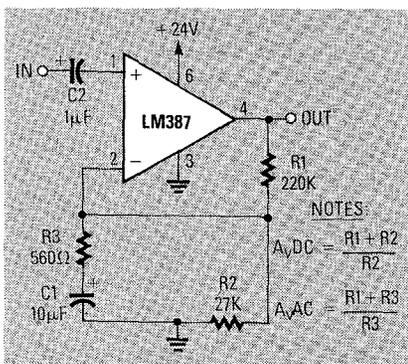


FIG. 18—LM387 NON-INVERTING AC amplifier with a gain of 52 dB.

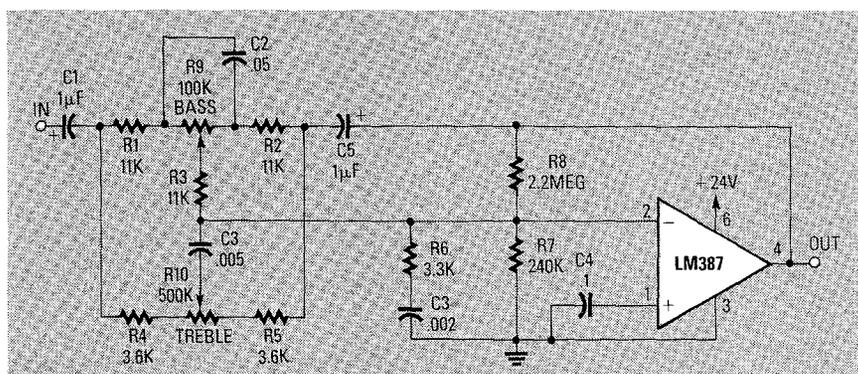


FIG. 21—THE LM387 CAN BE USED TO MAKE an active tone-control circuit.

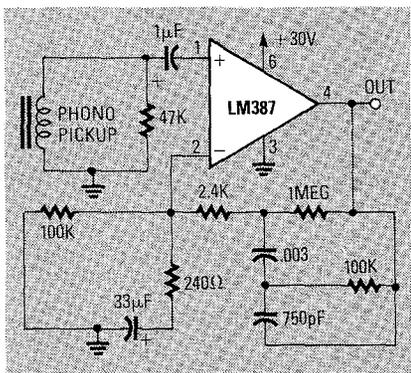


FIG. 19—LM387 PHONO PREAMP with RIAA equalization.

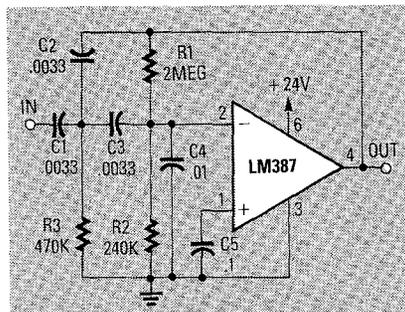


FIG. 22—AN LM387 USED AS A "rumble" filter.

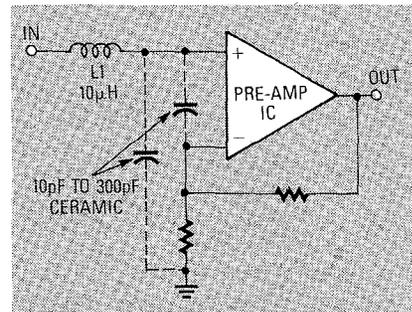


FIG. 25—THE CIRCUIT SHOWN HERE can be used to eliminate RF pickup.

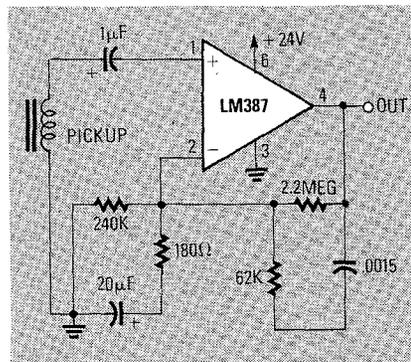


FIG. 20—AN LM387 USED AS a tape playback amplifier (NAB).

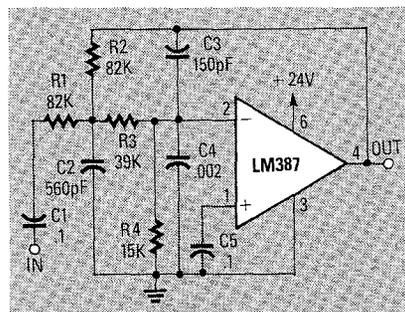


FIG. 23—AN LM387 USED AS A "scratch" filter.

### Usage hints

This article has examined various circuits using the LM38X linear IC's. These are high-gain, wide-band devices, and some care must be taken if they're to work. The two most frequent problems are RF instability and RF pickup. The former, RF instability, is usually caused by inadequate high-frequency power supply decoupling. In all preamps, the IC power supply has to be RF-decoupled by wiring a

by R1 and R2, and the AC gain by R1 and R3. Figure 19 shows an LM387 used as a phono preamp with RIAA equalization, while Fig. 20 shows how it can be used as a NAB tape playback amplifier for use in all kinds of devices ranging from cassette players to telephone-answering machines.

Figure 21 shows an active tone control giving unity gain with its controls in the "flat" position, or 20 dB of boost or rejection with the controls fully rotated. The "rumble" filter of Fig. 22 is a 2nd-order high-pass active filter that rejects signals below 50 Hz at 12 dB/octave. Figures 23 and 24 show various ways of using an LM387 in inverting mode in active filters. The

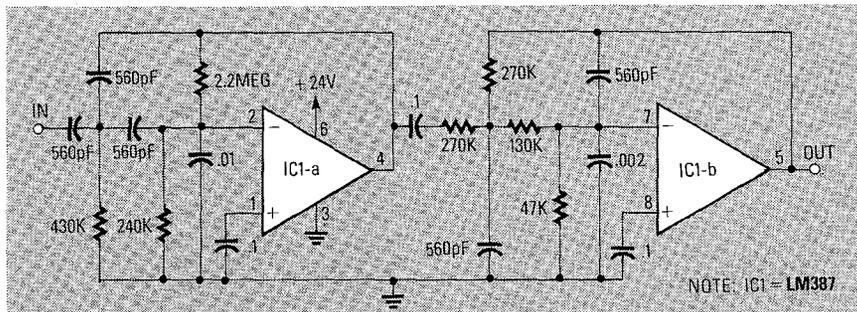


FIG. 24—BOTH HALVES OF AN LM387 make up a two-section "speech" filter (300 Hz–3 kHz).

"scratch" filter of Fig. 23 is a 2nd-order low-pass filter that rejects signals above 10 kHz. The "speech" filter of Fig. 24 consists of a 2nd-order high-pass and a 2nd-order low-pass filter in series, to give 12 dB/octave rejection to signals outside 300 Hz–3 kHz.

0.1 µF ceramic or 0.001 µF tantalum capacitor across the IC power pins. The latter, RF pickup, manifests itself as AM demodulation. It can usually be eliminated with a 10-µH RF choke in series with an IC's input terminals, or by also decoupling the input with a capacitor, as in Fig. 25.

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