A UNIVERSAL STEREO NOISE FILTER AND COMPRESSOR

with SSM200 Analog Devices - Hush integrated circuit

Reduce noise and increase clarity of any audio signal.

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While there are many techniques for reducing noise on audio signals, few are universal or "single-ended." Most noise-reduction methods need the original signal to be encoded at the source and decoded at the receiving end; examples of that method include Dolby and dbx. Also, noise-reduction systems many times require a license from the patent owner to use the encoding system (and sometimes the decoding!).

The best solution would be a "universal" noise-reduction system. Such a system should be able to work with any signal without any encoding. What's more, the circuit should be usable by anyone who has the ability to pick up a soldering iron without worry of running afoul of the law.

The good news is that a truly universal noise-reduction system exists. The Universal Noise Reducer presented here has those features that make it a delightful addition to any audio system. Built around a special noise-reduction integrated circuit, it does not require encoded material; the signal-to-noise ratio of any signal can be improved by 25 dB. Any line-level audio source such as tapes, records, FM radio, stereo TV, and satellite signals will benefit. It is also quite effective with CD copies of older analog sources. The system also improves the sound quality of video games and electronic keyboards.

Noise-Reduction Basics. Figure 1 illustrates the frequency and amplitude envelope of a typical audio signal within the bandwidth of an audio amplifier. While the signal might occupy any frequency or amplitude within the amplifier envelope, it does not occupy that area completely at all times. That is especially true during quiet passages or a pause in either the music or speech. During those periods, the large audio bandwidth is not required and noise becomes quite evident. By its nature, noise has a wide bandwidth and is perceived as a hissing sound known as *white noise*. When the audio signal is present, the noise is covered up, or "masked", by the signal. That concept is well known to the field of *psychoacoustics*, which studies the psychological aspect of sound and its perception. Whenever a sound is being perceived, it reduces the ability of the listener to hear another sound. During those quiet passages, the noise is "unmasked" and heard as a hiss.

The unmasked white noise that occurs during those quiet passages can be reduced with a reduction of the overall audio bandwidth. That technique has been available for a number of years and is referred to *as Dynamic Noise Reduction* (DNR is the registered trademark of National Semiconductor). An example of that technique was covered in an article that appeared in the July 1994 issue of our sister publication, **Popular Electronics**. That project used a voltage-controlled variable low-pass filter to track the audio-frequency envelope and maintain the required bandwidth to pass the signal information. Since the signal-to-noise ratio is improved with the square root of the bandwidth reduction, a reduction in bandwidth from 35 kHz to 1 kHz can improve the signal-to-noise ratio by

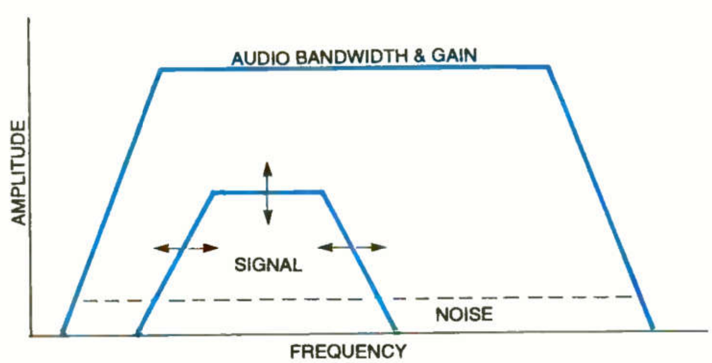


Fig. 1. Noise is inherent in any audio signal. As long as the level of the audio is loud enough, our ears ignore the noise. It's when the music becomes quiet that the noise becomes apparent.

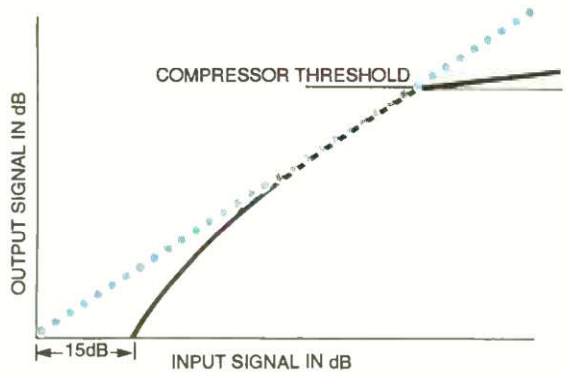


Fig. 2. If louder passages are attenuated and softer passages boosted, a further reduction in noise can occur.

nearly a factor of 6, or about 15 dB.

A second technique that can be used for noise reduction is the use of a variable voltage-controlled amplifier. By controlling the amplifier's gain, the level of the background white noise, or *system noise floor*, can be further attenuated. With this method, signals that are above a certain threshold are passed with a gain of one so that no distortion is added to the program material. However, signals below the threshold are attenuated as shown in Fig. 2; the result is an additional noise reduction of 15 dB. Combining those two techniques results in an improvement of about 25 dB or a factor of nearly 18:1!

A drawback in trying to reduce noise in unencoded signals is that different recording equipment, media, and environments have different requirements. In addition to the methods discussed above, the Universal Noise Reducer uses an automatic adaptive threshold that senses the noise floor of different audio sources. This lets the unit automatically maintain the best possible signal-to-noise level at all times.

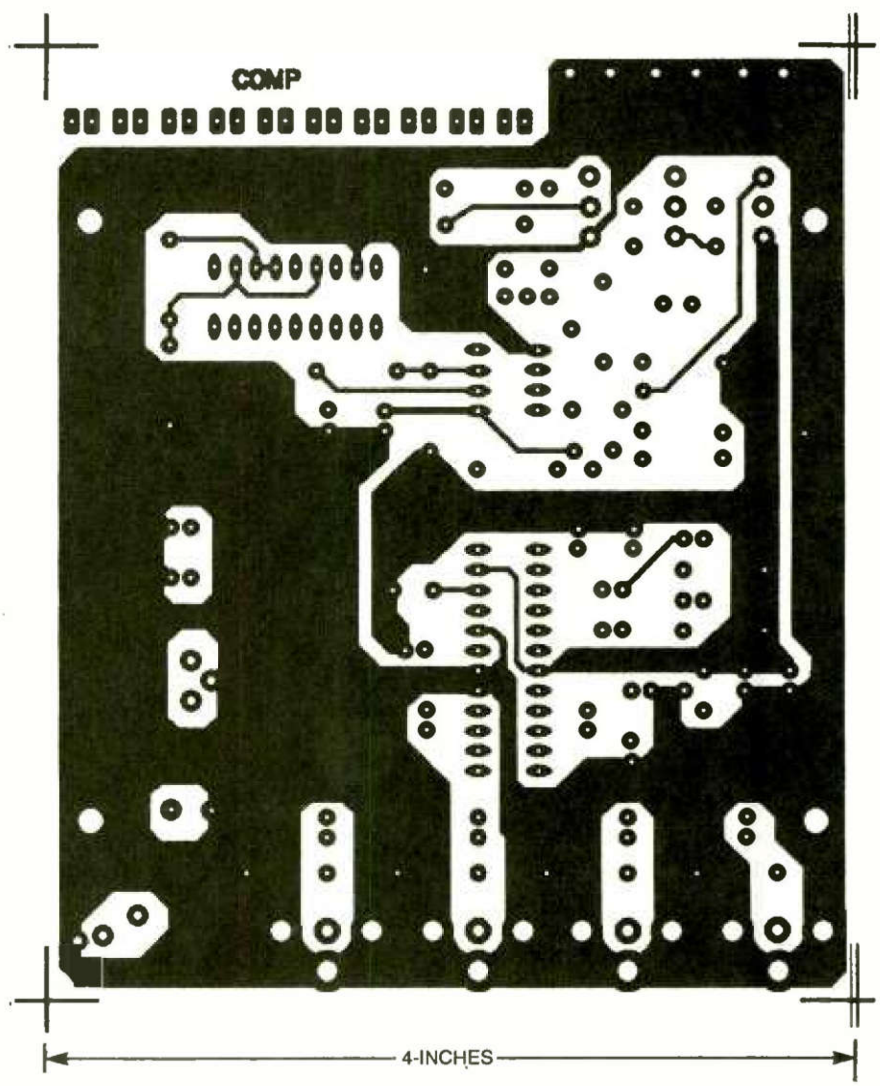
An added bonus noise-reduction technique available through the use of the voltage-controlled amplifier circuit is a *compressor*. In the compressor mode, signal levels above an adjustable threshold level will be attenuated. That feature is particularly useful to attenuate commercials that are sometimes much louder than the program material. It can also be used to improve softer sounds below the threshold by attenuating loud sounds, thereby reducing the dynamic range. The compressor and nose reduction functions are independent and can be used individually or together.

Circuit Description. Follow the schematic diagram shown in Fig. 3 during the following description of the Universal Noise Reducer's circuit.

Power from a 12-volt DC wall transformer is connected to J5. The voltage is regulated to a 9-volt level by IC4. That supply voltage is also divided in half by IC5 to provide a "pseudo ground;" working with op-amps is much easier with a "split" power supply.

Stereo audio signals are input through J1 and J2. Those signals are applied to the heart of the Universal Noise Reducer, IC1. That chip, made by Analog Devices, handles all of the noise-reduction and signal-compression techniques discussed before.

Stereo FM and stereo TV signals use a pilot signal to separate the left and right channels. A tuned passive filter formed by L1, C16, and C13 attenuate any 15-kHz or 19-kHz



Here's the foil pattern for the component side of the Universal Noise Reducer. A large ground plane aids in reducing stray noise pickup.

nal; newer equipment removes the signal better.

Each section of IC2 handles a different function. Op-amp IC2-b is used as a high-gain buffer to isolate pin 11 of IC1—the control voltage for the voltage-tuned low-pass filter's bandwidth. Note that IC1 processes that voltage internally to remove any variations in amplitude. The voltage level present at pin 11 is still a function of signal amplitude but for normal line-level signals it is suitable for an indication of filter bandwidth. The buffered signal is displayed on a bar-graph LED display with IC3; variations in the low-pass filter bandwidth can be tracked. During quiet passages in the audio signal, the low-pass filter should be at the minimum bandwidth of 1 kHz; the first LED should be extinguished. If a pilot signal is leaking into the control loop, the lower LEDs will remain on, indicating that noise reduction is not working as well as it should be.

The other op-amp, IC2-a, closes IC1's compressor loop. It monitors the level of the source-signal detector on pin 12 of IC1. That voltage level is compared to the threshold level set by R20. Levels above the threshold level switch Q1 on. The feedback signal passes through S3 to pin 7 of IC1, which then attenuates the signal until the level falls enough to turn IC1-a and Q1 off. If the compressor feature is not wanted, simply throwing S3 breaks the feedback loop. When Q1 switches on, the voltage drop developed by R11 switches on Q2 and, in turn, LED2, indicating that the compressor is active.

The processed output signal is available on J3 and J4. Switch S1 is used to bypass the Universal Noise Reducer without having to disconnect the unit from the signal path. By switching the unit in and out of the audio path, an "A-B" type of comparison is easily done as to the effectiveness of the various settings of the Universal Noise Reducer.

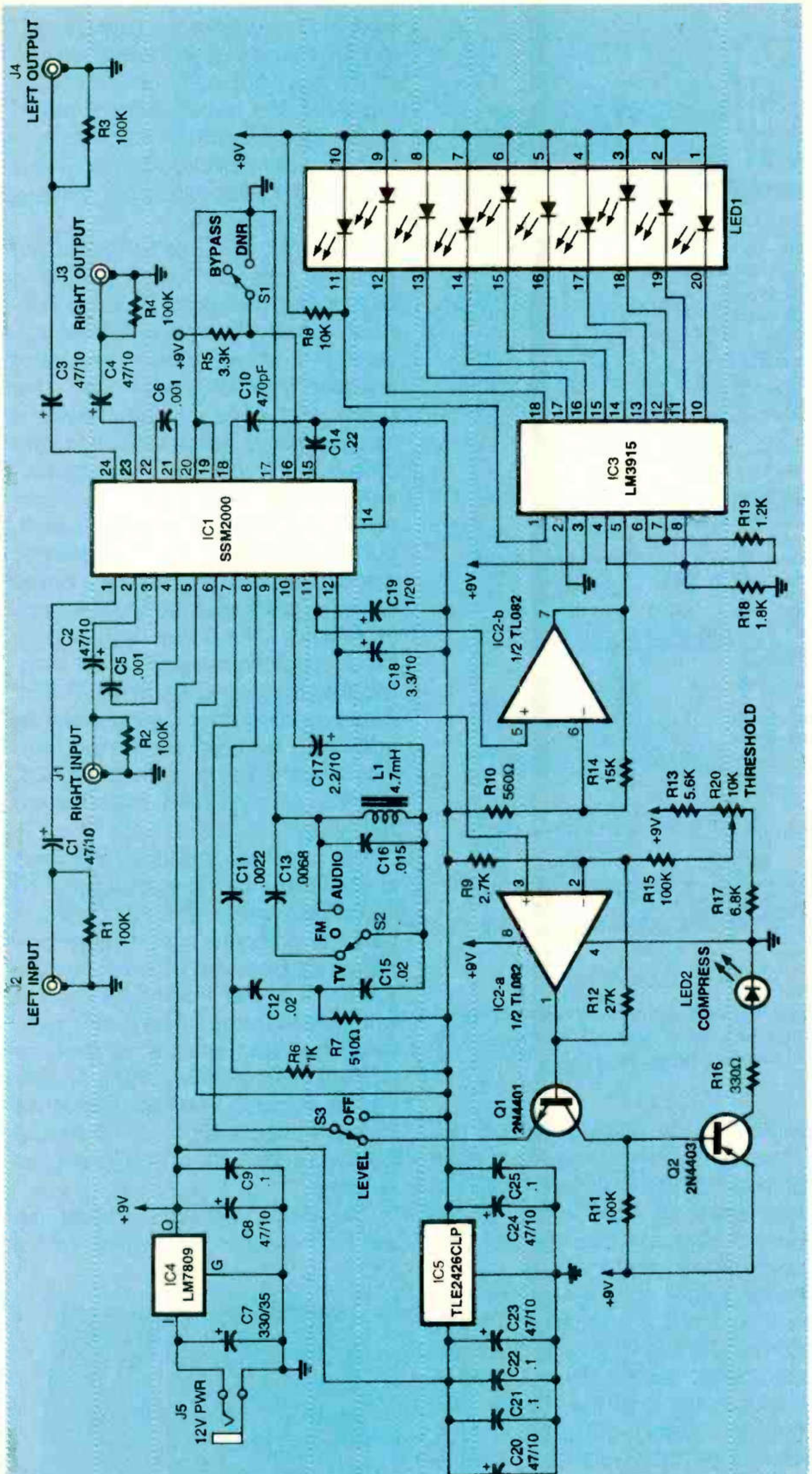


Fig. 3. The Universal Noise Reducer is built around an Analog Devices component that handles all of the noise reduction and compression tasks.

pilot signals if they are present in IC1's control loop. A 15-kHz pilot is used to encode the stereo or SAP (secondary audio program) signals in television; 19 kHz is used for stereo FM. Switch S2 is used to select filtering for one of those frequencies or no filtering at all. Older audio equipment was more prone to leak the pilot signal into the audio signal.

Construction. Because of the nature of audio circuits, the Universal Noise Reducer is best built on a PC board; less stray noise and hum will be picked up. After all, the pur-

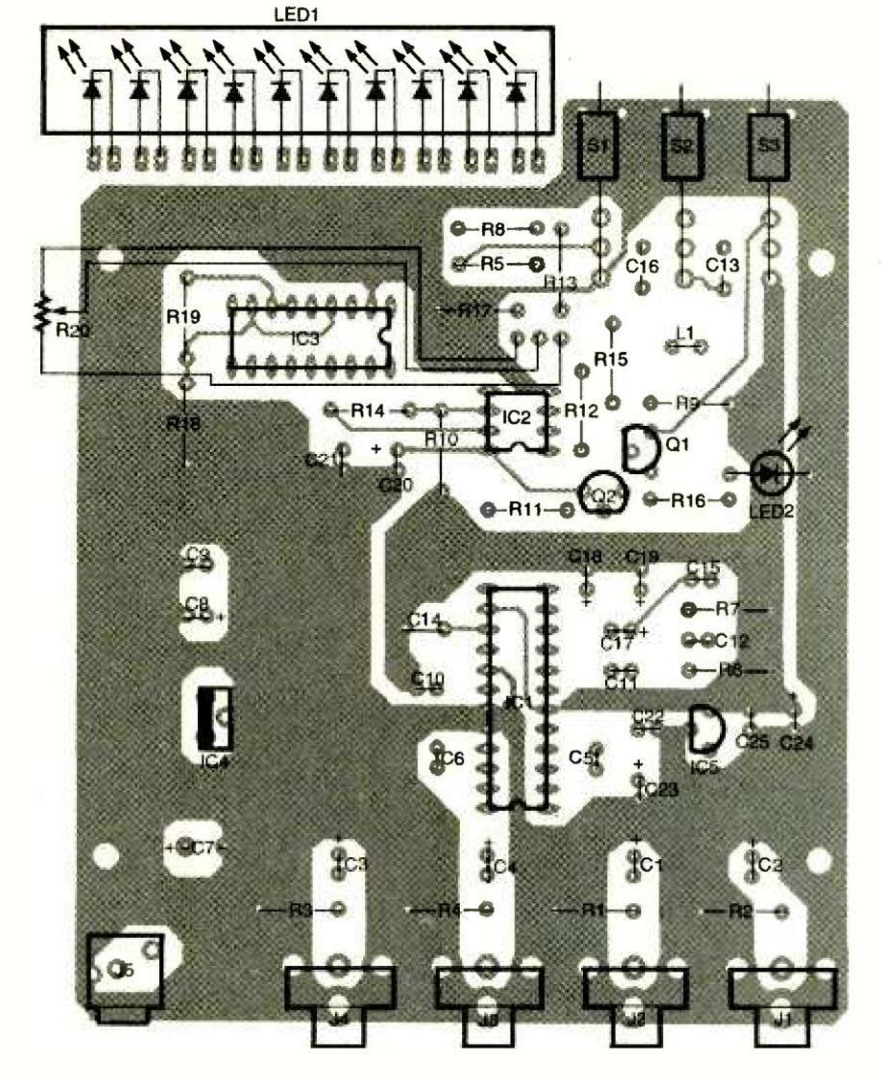


Fig. 4. The Universal Noise Reducer uses a double-sided PC board. If your board doesn't have plated-through holes, don't forget to solder the traces where pads are on both sides of the board. No jumpers are needed; all connections between sides are made at component leads.

pose of the project is to *reduce* noise—not add to it!

Foil patterns for a double-sided layout have been included here for those who wish to etch and drill their own board. If you do not want to etch a board, one is available from the source given in the Parts List.

If you are using a board from the source given in the Parts List or one made from the foil patterns, use the parts-placement diagram shown in Fig. 4. The best order for mounting the components is to start with the smallest parts first; electrostatic-sensitive parts, such as semiconductors, should be mounted last irrespective of their size. If you want to use sockets for the integrated circuits, mount them first, followed by the resistors and capacitors.

Note that if you are using a PC board that you etched yourself, you will have to make some provision for making connections between both sides of the board where there are traces on both sides. One method (certainly the easiest) is to simply solder to the component lead on the top side as well as the bottom side. Special eyelets have also been used with success in both industry and the hobby. The ultimate solution, of course, is plated-through holes. While that technique is simple to do in an industrial or commercial setting, it is messy, time-consuming, and occasionally dangerous due to the type of chemicals and equipment needed for creating a plated-through hole. The foil patterns do not have any "via" holes (holes that pass a signal from trace to trace between the two sides without a component lead in them) in their design, so you don't have to worry about soldering short pieces of jumper wires to make those connections. If you are using a purchased board, all of the holes are plated through, making construction a snap.

Note that all of the semiconductors, as well as the electrolytic capacitors, are polarized; double-check their orientation before soldering them in place. Any part installed backwards will be destroyed as soon as power is applied for the first time. It is also possible that an improperly-installed polarized component can take out other components with it. For example, an electrolytic capacitor that is installed backwards might work for a few seconds or minutes; but it can explode or burst into flames, sending an electrical surge into a nearby IC that could destroy that component as well. Also beware of components that look the same, such as IC5, Q1, and Q2. Always check twice before soldering!

The switches and jacks specified in the Parts List are designed to mount directly to the PC board. If you are going to substitute panel-mounted parts, you'll have to wire them up in the traditional fashion with short pieces of insulated wire. Keep the wire lengths as short as possible, especially where audio signals are being carried. Note that S2 is a three-position unit; it should be in the middle of the group of switches.

The leads for LED1 should be bent down at a 90-degree angle

Fig. 5. The Universal Noise Reducer fits easily into a stylish case.

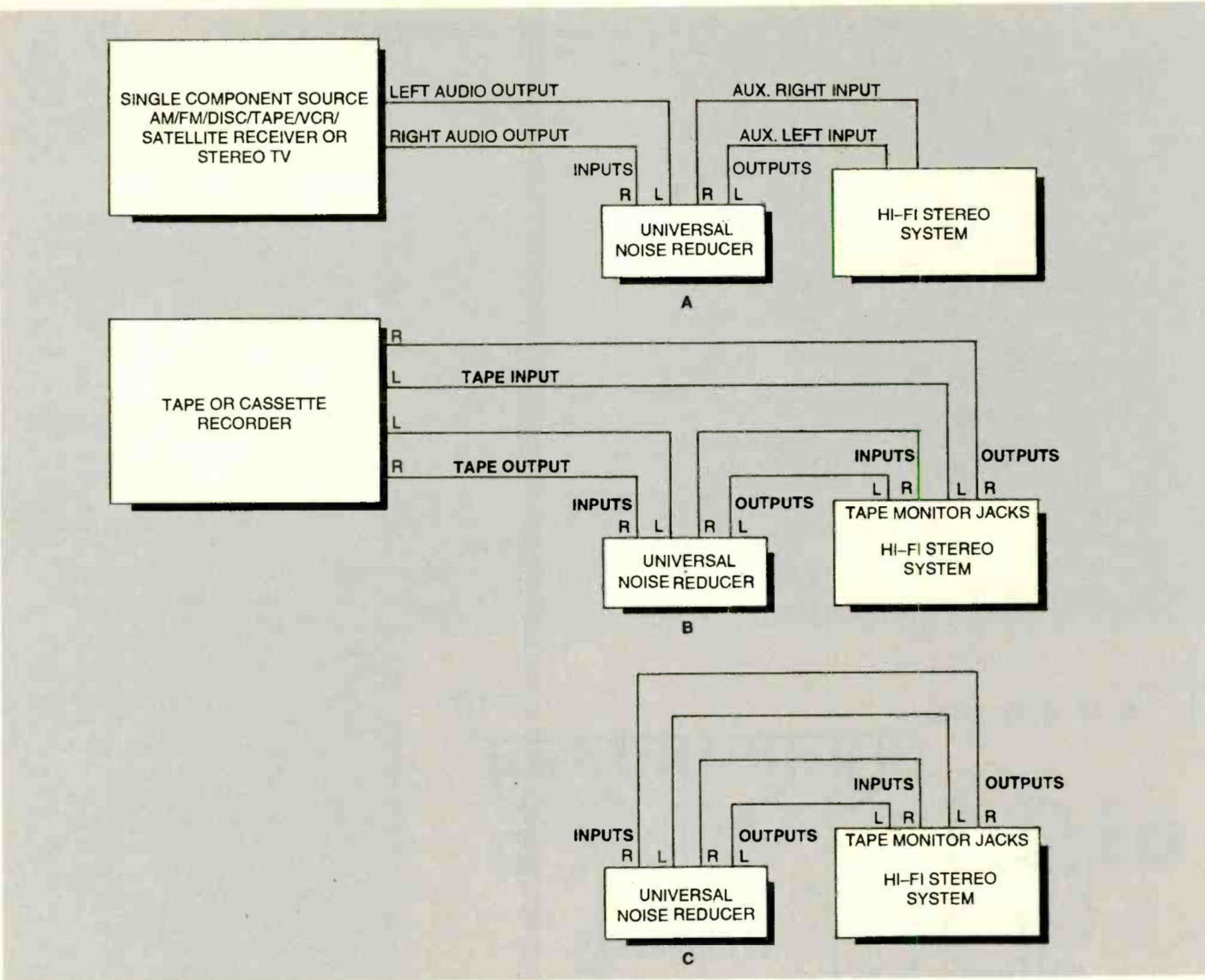


Fig. 6. There are several ways to connect the Universal Noise Reducer to your stereo equipment. It is important to remember that the system works best with an unmodified audio signal. Even if you don't have an amplifier that allows processing equipment to be added to the path, you can always use the tape recording and monitoring jacks.

about /-inch back from the plastic case. A /-inch thick piece of stock can be used as a guide. Check the polarity of the LEDs before bending the leads. A longer (anode) lead will be nearest the corner of the PC board. The display is seated down against the board to obtain the correct height.

When you are finished mounting all of the components, double-check your work for bad solder joints, poor workmanship, and missing, incorrect, or backward components. When you are satisfied with your work, mount the board in a suitable enclosure. The author's prototype, shown in Fig. 5, used a PacTec enclosure. Drill holes as needed for the jacks, switches, displays, and controls. Note that R20 is a slide potentiometer rather than the traditional rotary style. It is mounted above LED1 and connected to the board by short lengths of insulated wire.

Once the Universal Noise Reducer is mounted in its case, it is ready for testing and use.

Set-Up and Operation. The Universal Noise Reducer can be hooked up in a couple of ways. The most obvious way is shown in Fig. 6A, where the audio sorce is connected to J1 and J2, with J3 and J4 connected to the amplifier's inputs. Wherever possible, the unit should always be placed in the audio path after any preamplifiers and before the volume control or tone controls. That way, the signals will be of a uniform level and provide a flat-frequency response. Many modern amplifiers have separate preamplifier output jacks for just such a use.

If you don't have such a rig, the Universal Noise Reducer can be placed in the tape-loop or signal-processing loop; see Fig. 6B. Again, that will provide flat-frequency signals with levels in the range of 100 millivolts to 1 volt rms. If you have an equalizer in the same loop, it is important to locate the Universal Noise Reducer *before* the equalizer. Again, the unit works best with a flat bandwidth before you do any equalizing. If you don't have a tape unit, simply connect the Universal Noise Reducer in place of one as shown In Fig. 6C. By monitoring the tape playback, the unit becomes a part of the audio path on even the most basic stereo equipment as long as tape input and output

PARTS LIST FOR THE UNIVERSAL NOISE REDUCER

SEMICONDUCTORS

IC1—SSM2000 stereo noise attenuator/ compressor, integrated circuit (Analog Devices)
IC2—TL082 operational amplifier, integrated circuit
IC3—LM3915 bar-graph display generator, integrated circuit
IC4—LM7809 9-volt positive voltage regulator, integrated circuit
IC5—TLE2426CLP split power supply ground converter, integrated circuit
LED1—Light-emitting diode bargraph display, 10-segment
LED2—Light-emitting diode, green
Q1—2N4401 silicon transistor, NPN
Q2—2N4403 silicon transistor, PNP

RESISTORS

(All resistors are 1/4-watt, 5% units unless otherwise noted.)
R1–R4, R11, R15—100,000-ohm
R5—3300-ohm
R6—1000-ohm
R7—510-ohm
R8—10,000-ohm
R9—2700-ohm
R10—560-ohm
R12—27,000-ohm
R13—5600-ohm
R14—15,000-ohm
R16—330-ohm
R17—6800-ohm
R18—1800-ohm
R19—1200-ohm
R20—10,000-ohm, linear potentiometer

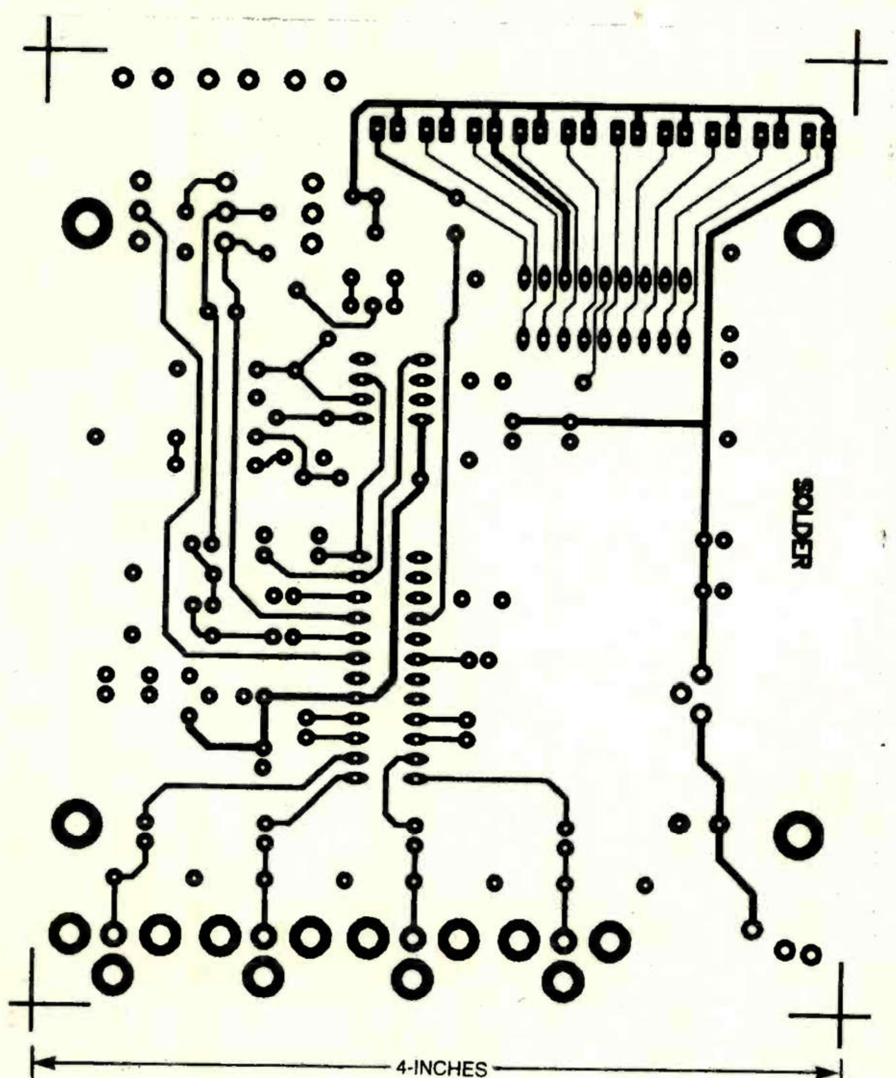
CAPACITORS

C1–C4, C8, C20, C23, C24—47-µF, 10-WVDC, electrolytic
C5, C6—0.001-µF, ceramic-disc
C7—330-µF, 35-WVDC, electrolytic
C9, C21, C22, C25—0.1-µF, ceramic-disc
C10—470-pF, ceramic-disc
C11—0.0022-µF, ceramic-disc
C12, C15—0.02-µF, ceramic-disc
C13—0.0068-µF, ceramic-disc
C14—0.22-µF, ceramic-disc
C16—0.015-µF, ceramic-disc
C17—2.2-µF, 10-WVDC, electrolytic
C18—3.3-µF, 10-WVDC, electrolytic
C19—1-µF, 10-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

J1–J4—RCA-style phono jack, PC-mounted
J5—Co-axial power jack, PC-mounted
L1—4.7mH inductor, shielded
S1, S3—Single-pole, double-throw switch
S2—Single-pole, double-throw, center-off switch
Case (PacTec CM125 or similar), 12-volt DC wall adapter, IC sockets, knob for R20, wire, hardware, etc.

Note: The following items are available from Vista, PO Box 142 Bolingbrook, IL 60440-1532; Tel: 630-378-5534: Assembled and tested unit (SSM-2000-ASSEM), $125.00; Complete kit of all parts and case (SSM-2000-KIT), $95.00; etched, drilled, silk-screened PC board with plated-through holes (SSM-2000-BOARD), $18.00; IC5, $3.90; IC1, $18.00. All mail orders will be shipped by first class US mail with a shipping/handling charge of $3.00. All telephone orders will be shipped by priority mail with a shipping/handling charge of $6.00. Illinois residence must include 7.5% sales tax. Visa, Mastercard, and American Express credit cards are accepted.



Here's the foil pattern for the solder side of the Universal noise Reducer. All connections between the two sides are done at component pads, making it easier to build the unit without using plated-through holes.

jacks are available.

With a 12-volt power source connected to J5, throw S1 to BYPASS, S2 to AUDIO, and S3 to OFF. Unmodified audio should be heard. Switch S1 to DNR and a reduction in noise should be heard. Try using audio sources that have different gain levels, such as a quiet passage of a piece of classical music. If you are using a television or radio as an audio source, you might have to set S2 to the appropriate mode as mentioned before in case the carrier signal is leaking into the audio path. Finally, throw S3 to test the compressor; note that compression takes place at different levels by varying R20. The level of compression should be seen on LED1. Ω