Audio Volume Limiter

Limit your audio volume to prevent clipping and distortion.

LOWELL D. JOHNSON

HAVE YOU EVER BEEN ANNOYED BY A PAGing system that makes the speaker difficult to understand, or by a stage-show performer who rattles the speakers by singing loudly into a microphone? Most people assume that the equipment is malfunctioning, and that repairs are needed. However, in many cases that's not so; and the real culprit that's causing the distortion is audio-level mismatching.

Basically, if the gain of an audio amplifier is adjusted for a small input signal, and a large signal is applied, then the amplifier is driven beyond its capabilities and distortion results, even though the amplifier is working perfectly. And, if the amplifier is adjusted for a strong input signal, and a weak signal is applied, then it is difficult to understand what the speaker is saying. In either case, it sounds awful, and the message doesn't get across. However, if you build the circuit described in this article, it will eliminate those kinds of problems; the circuit maintains a constant output-voltage level, regardless of the input signal.

The circuit produces no clipping, which would flatten the peaks of the signal, and virtually zero distortion, because the shape of the output signal is a true replica of the shape of the input signal. The circuit introduces little noise, so none is heard at the output. Pumping, or changes in amplifier gain that can be detected by the listener, is almost imperceptible. Transient spike handling is excellent—if it weren't, the limiter would not be fast enough to control instantaneous fast-rising spikes, such as a percussive sound.

Volume limiters aren't always desirable. For example, the circuit we'll present was installed in a church PA system to compensate for the different voice levels of the various members of the congregation who made short announcements. Everyone loved it—except the minister. After the sermon, he very strongly requested that a switch be installed that could disable the limiter. It seems that he preached fire-and-brimstone, and he *wanted* to rattle the speakers.

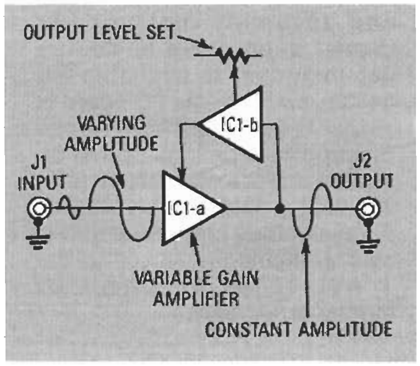


FIG. 1—BLOCK DIAGRAM of the audio limiter. The feedback loop of IC1-a controls the gain of the circuit.

Circuitry

Figure 1 shows the block diagram of the audio limiter. Amplifier IC1-a can change its gain from ¹⁄₁₀₀th to ×100, depending on the net effect of its feedback loop. That way, the overall gain of the circuit is such that the output level remains constant. If we put a potentiometer in the feedback loop of IC1-a that we could continuously adjust to maintain a steady output level, that would do the trick. However, that would be extremely impractical, as well as being boring; what we need is a resistor that can instantly change its value in accordance with the output voltage of IC1-a. An optically coupled *L*ight-*D*ependent *R*esistor, or LDR would do the trick.

An optocoupler is a device that contains both a light source (an LED) and some kind of light-sensitive device (in this particular case it happens to be an LDR) inside one package,

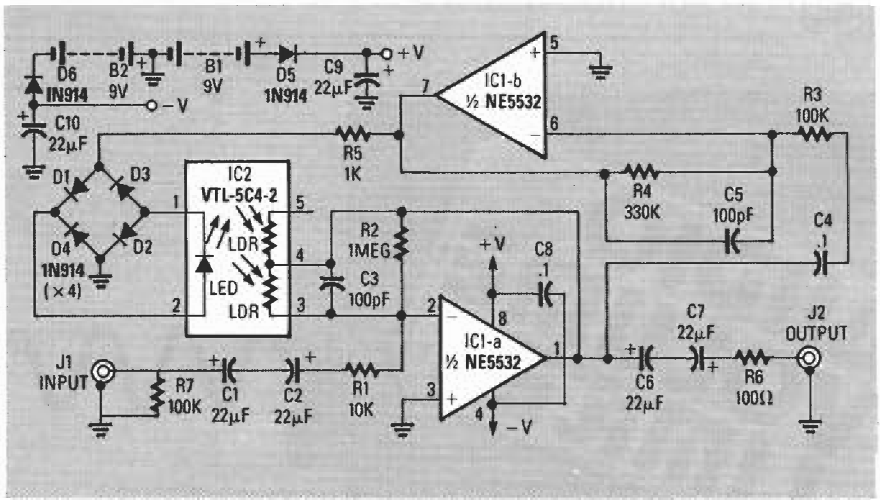


FIG. 2—SCHEMATIC OF THE VOLUME LIMITER. IC1-a is connected as an inverting amplifier whose gain is controlled by the LDR portion of an optocoupler.

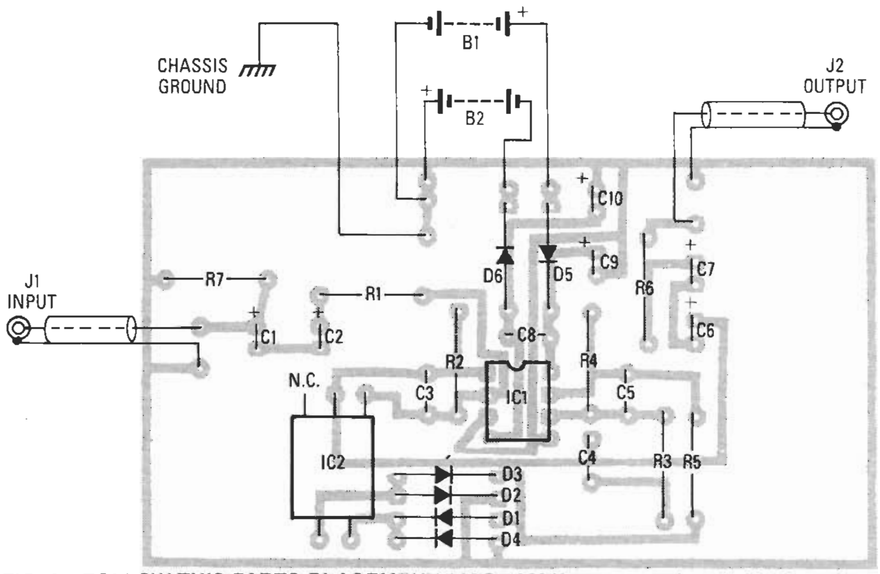


FIG. 3—FOLLOW THIS PARTS-PLACEMENT DIAGRAM if you are using the PC board.

PARTS LIST

All resistors are ¼-watt, 5%.
R1—10,000 ohms
R2—1 megohm
R3, R7—100,000 ohms
R4—300,000 ohms
R5—1000 ohms
R6—100 ohms
Capacitors
C1, C2, C6, C7, C9, C10—22 µF, 35 volts, electrolytic (a larger value will also do)
C3, C5—100 pF, 50 volts
C4, C8—0.1 µF, 50 volts
Semiconductors
IC1—NE5532 low-noise audio amplifier (Signetics)
IC2—VTL-5C4-2 optocoupler device (Vactec)
D1–D6—1N914 diode
Other components
J1, J2—RCA jacks
Miscellaneous: power supply, project case, wire, solder, etc.
Note: A kit of parts, a PC board, and assembly instructions (power supply and enclosure not included) is available for $48.00, and a single PC board is available for $25.00, from Woods Electronics Inc., 4233 Spring St. #117, La Mesa, CA 92041 (619) 265-2551 (order # AVL-42889-K). An assembled and tested unit is also available for $57.00 (order # AVL-42889-A). Check or money order, only.

with the leads of both brought out to external pins, much like an IC. When the LED is turned on via an external input voltage, the LDR's resistance is very small, and when the LED is turned off, the LDR's resistance becomes very large. The resistance of the LDR can therefore be varied at a very fast rate, according to the intensity of the light from the LED. So let's use the LDR portion of an optocoupler in the feedback loop of our amplifier to produce a gain-controlling circuit.

Now, to be more specific, we need an optocoupler with an LDR that can reduce its resistance instantly when its input signal reaches the limiting threshold, thereby reducing the gain of the amplifier to just below the threshold. Then we'd like it to stay at that value until the input signal became weaker, and then gradually increase the gain until the threshold is reached. Fortunately, the VTL-5C4-2 from Vactec Inc. (10900 Page Blvd., St. Louis, MO 63132) has exactly those characteristics. When the light source is illuminated, the resistance decreases in a matter of microseconds (very fast with respect to audio frequencies), and when the light source is removed, the resistance increases over a period of seconds (very slow with respect to audio frequencies). Those combined characteristics can form a limiting circuit that produces a constant output level, but whose action is not easy—in fact, quite difficult—for the listener to detect.

Figure 2 shows the schematic of the volume limiter. IC1-a is connected as an inverting amplifier; ignoring the LDR (assume that its resistance is very high so that it doesn't affect the feedback loop), the gain is R2/R1, or 100. Standard low-impedance-microphone preamplifiers have a gain of 100. Thus, the output at IC1-a pin 1 will be about 2 volts p-p.

The second half of the amplifier, IC1-b, is connected to the output through C4, and its gain is R4/R3, or 3. The optocoupler's LED turns on when the voltage across it is about 2 volts. The higher the current through it, the brighter it illuminates. On positive peaks, it is in series with D1 and D2, and on negative peaks it is in series with D3 and D4. Since D1–D4 are silicon diodes, about 0.7 volts is dropped across each one before they begin to conduct. Therefore, the total positive voltage across the bridge required to illuminate the LED is 0.7V + 0.7V + 2V, or slightly less than 3.4 volts. The same voltage with a negative polarity appearing across the bridge will also illuminate the LED.

As the AC signal at IC1-b pin 7 approaches 6.8-volts AC, the LED receives short bursts of current, and the LDR instantly reduces in value to a point where it reduces the gain of IC1-a, thereby reducing the output of IC1-b pin 7 to less than 6.8 volts AC. Because of the slow recovery time of the LDR, it appears effectively as a fixed resistor and therefore produces virtually no distortion. The output voltage, 6.8-volts AC, when divided by the gain of IC1-b, is about 2-volts p-p, which is a standard line level. Since the LDR can go below 100 ohms, the gain of IC1-a can be reduced to LDR/R1, or $1/100$th. That means that signals up to 200-volts p-p can be applied to the input (although you'll never have an input with that magnitude), while maintaining the output at a line level; any input signal ranging from microphone-level to 200 volts will produce a clean line-level output.

If R5 were left out of the circuit, the output level would be so constant that a monotone sound quality would result. By putting a little resistance in series with the bridge, the output voltage will be allowed to vary a little, and the sound is much more natural. A 1K resistor is a good choice for R5, but try out other values for yourself. You may also want to try other R2/R1 and R4/R3 ratios.

The NE5532 (IC1) is a relatively expensive dual op-amp with very-low-noise characteristics. If you can tolerate some noise, feel free to use a 741, 324, or any other general-purpose audio op-amp. If you do, note that the pin numbers may change. Also, C1, C2, C6, and C7 are used to block DC. If no DC exists in your design, then you may omit them. R6 is included for spike protection; if no dangerous spikes will exist, you may omit that resistor, too. Capacitors C3, C5, and C8 are included as standard practice, but if no undesirable effects occur, you may omit them. Use any regulated supply voltage, such as two 9-volt batteries or a ±12-volt DC supply. Just don't exceed the maximum voltage ratings of the IC that you decide to use. The current drawn by the circuit will depend on the op-amp that you decide to use for the project, but it will never be more than a few milliamps per op-amp section.

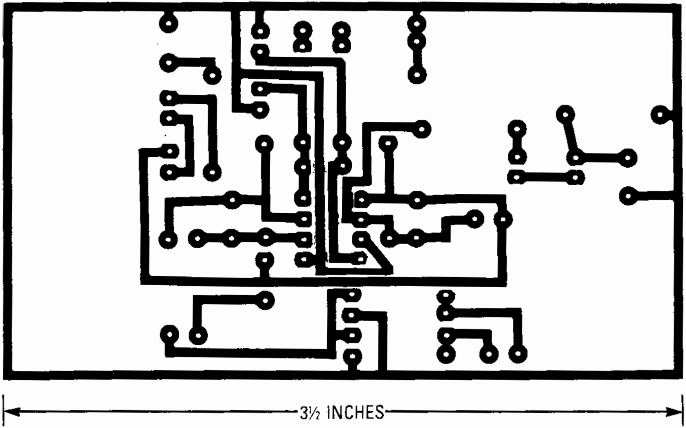
If you want to operate without a negative supply, then connect IC1 pin 4 to ground, and create a $V_{CC}/2$ supply with another unity-gain op-amp section and a voltage divider. Then connect all the ground connections except for the input and output grounds to that, and connect IC1 pin 8 to V_{CC} (just reference everything up to $V_{CC}/2$). Always use at least 15-volts DC—preferably 24-volts DC. Also, the optocoupler used for the project is a dual-element type; they are more versatile. However, you can use the VTL-5C4 (the single-element version) if you like.

Building the circuit

Because IC1-a may have a gain of up to 100, you must keep the leads short in that circuit. Ground loops can defeat any circuit, so keep all power-supply grounds together on one side of the board. Also, remember to use shielded wire on the input and output connections. You can use point-to-point wiring on perforated construction board, but it's best to use the foil pattern provided in PC Service to make a board and use that instead. A ready-to-use PC board is also available from the source mentioned in the parts list.

Figure 3 shows the parts-placement diagram for the audio limiter. Be sure to check for solder shorts and all of that other bad stuff before powering up and testing the circuit. RCA-type jacks are probably the best choice for J1 and J2, but use whatever best suits your application.

To test the circuit, simply connect a microphone, and observe the output on an oscilloscope, or listen to it through a headset (to cut out feedback). The output should remain at the same level, regardless of whether you whisper or scream into the microphone. A note of caution: Remember that the limiter works to correct the gain by looking at seldom-encountered maximum peaks. If you feed in a sine wave, you will notice that the output indeed remains constant, no matter what the input voltage, but a "blip" appears on each and every peak (which would imply high distortion). In a normal audio signal, not all peaks are the same amplitude, and only seldom-occurring maximum peaks are acted upon. Since they occur very infrequently (as compared to audio frequencies), the distortion of the limiter is actually very low—you won't even notice it. **R-E**



AUDIO VOLUME LIMTER FOIL PATTERN.