# LIGHT-BULB VOLUME EXPANDER

By **GIL ARROYO** / Hughes Aircraft Co.

## Complete analysis and design of a simple bridge circuit that will increase the dynamic range of a hi-fi system.

EDITOR'S NOTE: *The idea of using the changing resistance of a light bulb in a volume-expander circuit is not new. We have run articles in the past showing various circuit arrangements that can be used. However, the article below is a fairly comprehensive study by our author, and we felt that our readers would be interested in it. Because of the thermal lag of the bulb filaments, there may be objectionably long attack times and "overhang" with this circuit, particularly if it is adjusted to give maximum expansion. Also, the expansion will change at different listening levels. However, the circuit is simple to build, uses a handful of inexpensive parts, and is easy to try.*

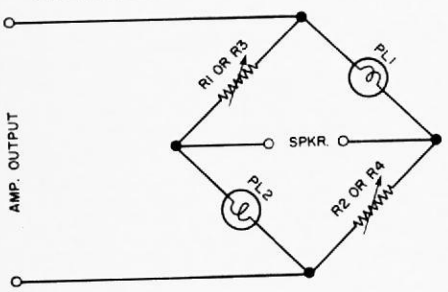
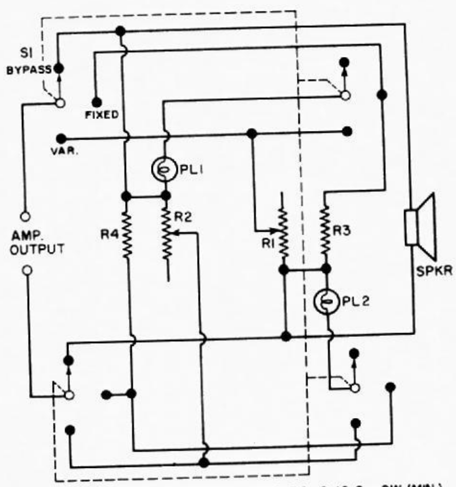



Fig. 1. Basic bridge circuit used.

SOME TIME ago the writer came to the conclusion that record and tape recordings did not seem to have the same dynamic range that is heard in live performances. This is because of the volume compression that is usually employed when a record is made or when a program is broadcast over the air. To compensate for this, a volume expander is required. Investigation of various expansion circuits, some involving considerable complexity, revealed that the use of some of the circuits resulted in an increase of the intermodulation distortion effects.

It was decided to build a simple circuit (Fig. 1) using the changing resistance of two ordinary miniature lamp bulbs in order to bring about expansion.




PLI, PL2-SELECTED LAMPS
R3, R4-0-10Ω, 5W. (MIN.) ADJ.
SPKR-8-16Ω
RI, R2-0-10Ω, 2W. (MIN.)
SI-4P3T SWITCH

Fig. 3. Circuit diagram of unit which permits fixed and variable volume expansion.

This circuit is connected between the output of the power amplifier and the loudspeaker as shown. At low-level passages of music, the resistance of the lamps is low, the bridge is almost balanced, and there is very little output to the speaker. During high-level passages, the lamps light, their resistance increases, and the bridge becomes unbalanced. This increases the output to the speaker much more than it would ordinarily. Expansion of dynamic level has occurred. Fig. 5 shows the resistance characteristic of a #44 panel lamp bulb (6-8 volts at .25 amp.) at various values of applied voltage. Note the increasing slope at the lower voltage end. It is this low-voltage characteristic that is responsible for the increasing attenuation of quiet music passages and finally residual noise.

Several circuit configurations were tried, but none of them had the over-all simplicity, flexibility, and low distortion capability of the circuit adopted. See Fig. 3. A four-pole, triple-throw switch (*Allied* 34B357 or equivalent) is used in the circuit in order to bypass the expander or to provide a choice of adjustable tapped resistors for a fixed expansion ratio or a pair of rheostats for varying the expansion for a particular type and level of music at the moment. The rheostats should be adjusted to equal resistance values.

Fig. 2. Amount of expansion for various resistance values.

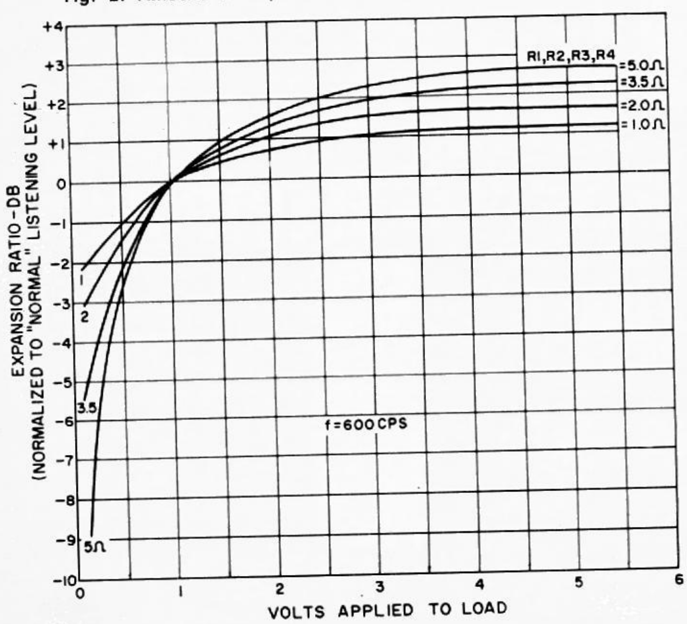
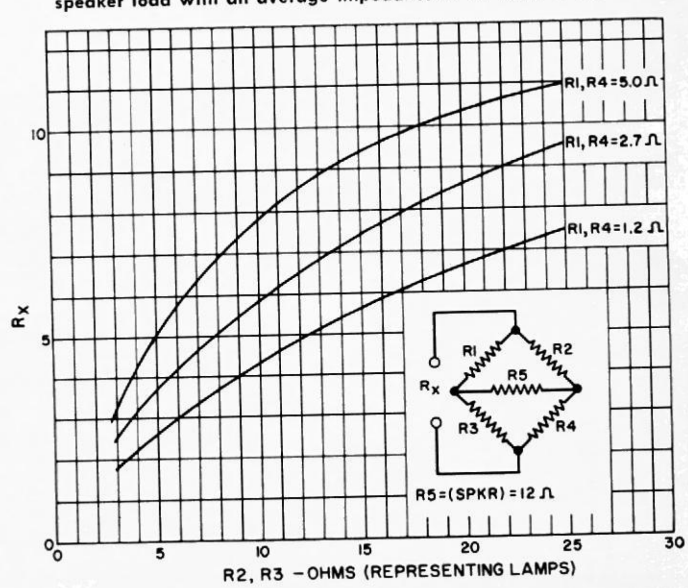



Fig. 4. Range of values of the circuit's input resistance ($R_X$) for various amounts of bridge and lamp resistance when a loudspeaker load with an average impedance of 12 ohms is utilized.



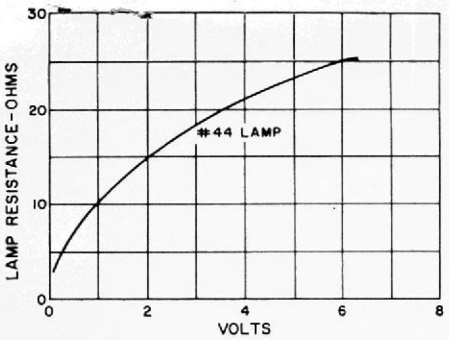


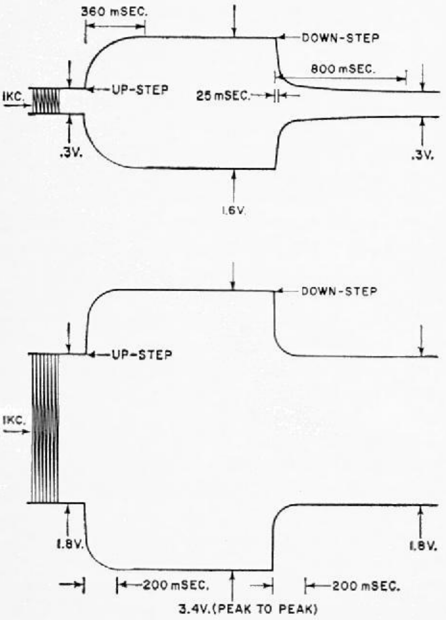

**Fig. 5. Resistance at various voltages of the panel lamps used by the author.**

Expansion range for any given amplifier is determined by the setting of the adjustable resistors or rheostats in the circuit and the pilot-lamp selection. Lamps that might be tried are: #55, #44, #1891, #50, #40, and #47, in order of decreasing sensitivity.

A *Heathkit* W5M (25-watt amplifier) was used in the initial tests. The #44 pilot lamps were found to be ideal for the operating range of the amplifier at the listening levels desired. In later tests, a *Heathkit* W7A (55-watt amplifier) was used with #1891 lamps and equally satisfying results were obtained.

Expansion ratios obtained are shown in Fig. 2 (as measured in the W5M, #44 lamp set-up). As can be seen, the expansion ratio increases with increasing rheostat resistance. The curves are based on a "nominal" listening level of one volt (r.m.s.) applied to the speaker terminals. It will be noted that the curve of expansion tends to flatten as the power to the speaker increases. The flattening is due to the decreasing resistance to voltage slope of the lamps in the circuit. On the low-voltage end, it will be noted that considerable range of listening expansion is achieved by the bridge circuit. It will be found that at normal listening, expansion will average 6 to 8 db and that an additional 10 db or more attenuation occurs at the residual noise level. (The negative numbers on the db scale refer to levels below the "nominal" level.)

**Fig. 6. Rise and decay times at two values of input. An 8-ohm speaker was used as the load and the bridge resistors were 5 ohms each. Type #44 miniature lamps were used.**




Distortion levels were checked before and after the expander installation and the distortion increases were small and probably all attributable to the unavoidable impedance mismatch generated by this type of circuit.

Fig. 4 shows the input resistance for various lamp and bridge-arm resistances. With an average speaker impedance of 12 ohms, the input resistance ($R_o$) is in the 5-10 ohm range. It is suggested that the 4-ohm amplifier tap be used with 8-ohm speakers. The resistance relationships are not critical and individual choice of damping factor, amplifiers, expander lamps, and resistor values will determine the best match. The reader is urged to experiment.

Fig. 6 shows the attack and decay times for two voltage levels in response to step changes (as seen on a scope). It will be noted that the attack and decay times are longer at the lower listening levels. This characteristic tends to produce a more even listening level.

## Set-Up Procedure

Connect the expander circuit with a pair of #44 lamps installed between the speaker and the amplifier output. Use one-half the usual driving impedance tap (*i.e.*, 8-ohm output tap for 16-ohm speaker). Put the selector switch in the "Bypass" position. Set the variable resistors to mid-range (about 4 to 5 ohms each). Care should be exercised to avoid burning out the lamps while setting up.

Establish a normal listening level using music containing short passages of soft and loud material. It should be emphasized that the device should not be used for background music. It operates best in the normal listening range. When the listening level is established, switch in the rheostats ("Var" position of switch). Then re-establish normal listening level using the amplifier volume control. The soft passages should be quite noticeably quieter and the loud passages louder than before. When the music stops, there should be no audible noise. If the music seems to undulate or if the soft passages are inaudible, try setting the resistance arms to lower values. This will reduce the expansion range. If a lower setting is satisfactory, then the next lower amplifier output tap should be tried for optimum power transfer.

If the full range of the rheostats does not produce the desired effect, try using a pair of #55 lamps for more, and #1891 lamps for less "sensitivity" before using different rheostat values.

Once the average expansion characteristics are established, the tapped adjustable resistors ("Fixed" position of switch) may be set to the rheostat values; the rheostats are then used for the custom setting of particular music levels or types of music.

The device as described is for a single channel. A companion unit should be constructed for use with stereo or dual-channel sound systems. ▲

# STATE OF SOLID STATE

## An interesting expander circuit for your hi-fi

**ROBERT F. SCOTT,** SEMICONDUCTOR EDITOR

IN THIS COLUMN, WE TRY TO BRING YOU news and details of new and interesting semiconductors and related matters without any month-to-month continuity. This month, because of long-time reader interest in volume expanders and audio noise reduction, we are deviating from the established format to show the circuit of the volume expander that complements the volume compressor discussed last month.

The hi-fi expander in Fig. 1 includes de-emphasis and attack and decay times to complement the compressor. Again, an external op-amp is substituted for the one in the Signetics NE570 compandor IC. In this case, the circuit performance demands a slew rate better than the 0.6 volts-per-microsecond provided by the NE570 op-amp. The expander, like the compressor, has a unity-gain level of 0 dBm. Adjustments are provided for harmonic distortion and DC shift.

Make the THD TRIM adjustments first using a 10-kHz 0-dBm (774.6 mV) signal. Adjust the DC SHIFT TRIM for minimum envelope bounce when tone bursts are fed through the circuit.

Performance is reported to be spectacular when the expander is applied to consumer tape recorders.

### Op amp and voltage-reference IC

The National Semiconductor LM10-series comprises a group of monolithic linear IC's consisting of a precision voltage reference, an adjustable reference buffer, and an independent high-quality op-amp. The device has an absolute maximum supply-voltage rating of 45 volts for the LM10, LM10B, and LM10C; and 7 volts for the LM10BL and LM10CL. Supply voltage can be as low as 1.1 volts. Typical supply current is 270 $\mu$A.

The complementary output stage in the independent op-amp is capable of swinging to within 15 mV of the supply voltage or delivering +20-mA output current with +0.5 volt saturation. The reference output can be as low as 200 mV with 0.1% regulation.

The LM10's ability to operate from a single power supply with high output-current capabilities make it a very versatile general-purpose device. It can operate in a floating mode, independent of fixed supplies so it can be used in such applications as remote amplifiers for vibration sensors, flame detectors, resistance thermometers, optical pyrometers, and logarithmic light sensors. Its ability to operate from a wide range of voltages and currents makes the LM10 applicable in a wide range of voltage and current regulators.

The LM10 features such characteristics as 2.0 mV (max) input offset voltage, 0.7 nA (max) input offset current, 20 nA maximum input bias current, and offset-voltage drift of 2 microvolts-per-°C. The device comes in a metal can and an 8-pin dual-in-line package.

Full electrical specifications, including 33 typical-performance-characteristics charts are in the 15-page data booklet along with 33 schematics illustrating typical applications.—**National Semiconductor**, Literature Dept., M/S 16251, 1090 Kifer Rd., Sunnyvale, CA 94086

### SCR's go MOS

Motorola's new state-of-the-art MCR1000 series of SCR's uses MOS technology to offer the designer three devices that have the high input-impedance and fast turn-on time of a power MOSFET and the regenerative latching action of a thyristor. The new 200-ns turn-on SCR's can be driven directly from logic circuits without the need for interfacing devices.

The MCR1000 MOS SCR series has a 15-amp current rating and is designed primarily for high-speed switching and high-current pulse applications such as laser modulators, printers, fluorescent lighting, and switching power supplies. Features include: A forward voltage application rate of 1000 volts-per-microsecond at $T_j$ = 125 °C and a fast switching (turn-on) time of 200 ns at $T_j$ = 25 °C. ($T_j$ is the operating temperature.)

The MCR1000-4, -6 and -8 devices are in TO-220 packages and feature peak forward blocking voltages of 200, 400, and 600 volts, respectively. Prices are $5.20, $5.70, and $6.90 in 100-999 quantities.—Contact Chris Field, **Motorola Semiconductor Products**, PO Box 20912, Phoenix; AZ 85026

### 1-watt power MOSFET's

International Rectifier has introduced a family of four new n-channel transistors using the company's HEXFET technology. A particular advantage of the devices is their low on-state resistance—about half that of many similar devices. Designated IRFD1Z0 through IRFD1Z3, the four devices have typical rise and fall times of 15 ns and 10 ns, respectively when $I_D$ (continuous drain current) is 0.25 A. On-state resistance is 2.4 ohms for the IRFD1Z0 and -1Z1 and 3.2 ohms for the IRFD1Z2 and -1Z3.

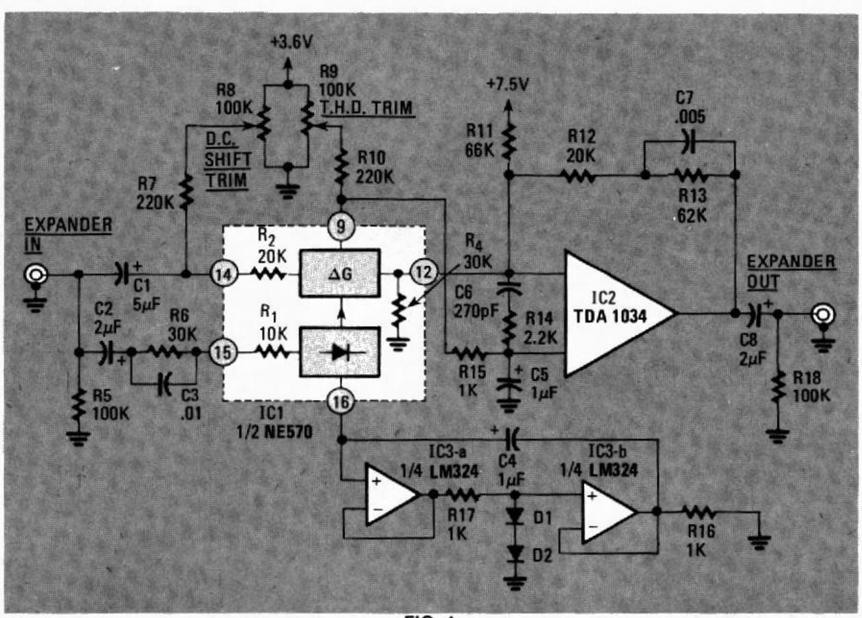



FIG. 1

BY CRAIG ANDERTON

# SIMPLE COMPRESSOR-EXPANDER

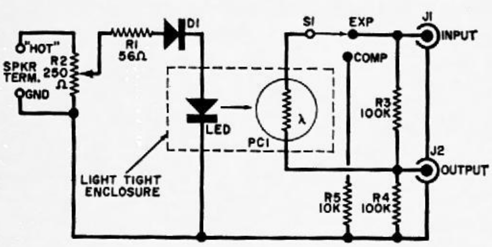
## "SNAPS UP" ANY PROGRAM MATERIAL

TWO very useful techniques for the audio experimenter are compression and expansion. The compression of the dynamic range of program material (type, records, or off the air), permits maintaining a constantly high modulation level; while expansion, when used with the compressed material, restores the dynamic realism. You can also use the expansion mode in reproducing conventional program material with some surprising results in many cases.

Creating these effects can be costly and complex; but it need not be if the circuit shown here is used. Although simple in form, this circuit works surprisingly well. It gives a slight, though measurable, amount of distortion, a certain amount of loss (since it is a passive circuit), and some (almost unnoticeable) delay. Nevertheless, in all but the most critical audio applications, the circuit will prove very useful.

As shown in the accompanying diagram, an *LED* is attached to the speaker terminals (via a limiting resistor and volume control) of the audio system to sample the program material. Diode *D1* and resistor *R1* protect the *LED* against drawing excessive current. Volume control *R2* is used to vary the sensitivity of the circuit. The exact value of *R1* is determined experimentally—with a high-power audio system, a correspondingly high value of *R1* is required to prevent the *LED* from burning out.

**An LED samples audio output of system.**




The audio modulated light from the *LED* falls on the sensitive surface of a photo-resistive cell. *PC1*. To prevent ambient light from becoming a factor, both the *LED* and *PC1* are enclosed in a light-tight tube.

With *S1* switched to *EXPAND*, *PC1* is connected across the high end of the *R3-R4* voltage divider. The output signal at *J2* is then a function of the resistance ratio of *R3* to *R4*. When audio-modulated light from the *LED* strikes *PC1*, which is connected in parallel with *R3*, the composite resistance lowers thus increasing the audio output level. With *S1* on COMPRESS, *PC1* and *R5* are in parallel with *R4* and when *PC1* is illuminated by the modulated light from the *LED*, the composite resistance is lowered thus lowering the audio level at *J2*. This, in effect, compresses the signal.

The amount of expansion depends on the resistance values of *R3* and *R4*. A higher value for *R3* means a greater expansion range is possible. Compression depends on the resistance of *R5*. As this value is decreased, the compression effect is increased.

**Applications.** The circuit can be used as the volume control between the preamp and the power amplifier in an audio system, between the tape deck and preamp, etc.

It can also be used in musical instrument amplifiers to extend the signal-to-noise ratio on expansion or prevent speaker blowout on compression; in PA systems; and in making tape recordings so as to add several dB of signal-to-noise improvement.

By using a switch with a neutral center position for S1, the signal can be left unaffected. Two of these units can be connected to a stereo system, to put new life into overly-compressed recordings. ◈

### PARTS LIST

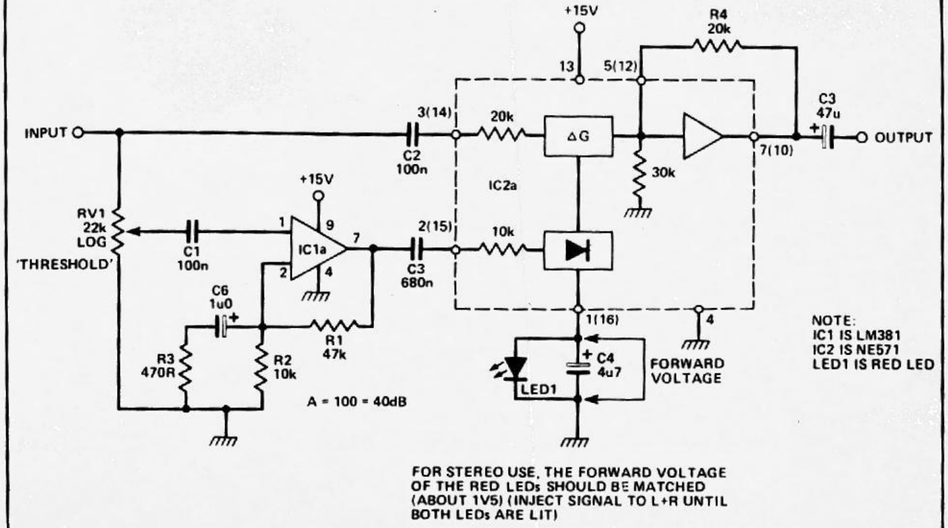
*D1—50PIV, 1A silicon diode*
*J1,J2—Phono connectors*
*LED—Light-emitting diode (Radio Shack 276-026 or similar)*
*PC1—General-purpose cadmium-sulfide cell (Radio Shack 276-116 or similar)*
*R1—56-ohm resistor (see text)*
*R2—250-ohm, 2-watt potentiometer*
*R3,R4—100,000-ohm, ½-watt resistor (see text)*
*R5—10,000-ohm, ½-watt resistor (see text)*
*S1—Spdt switch*
*Misc.—Opaque tube for light-tight enclosure, suitable chassis, knob, etc.*

## Expander Gate

W.K. Todd

This circuit is a simple expander gate and can be used to reduce the surface noise of records and tapes. It is based around an NE571 compander chip, used as an expander below the threshold set by the red LED. The LM381 amplifies the input signal by 40 dB; this is rectified in the 571 by a current mirror circuit and is smoothed by C4. When the voltage reaches the forward voltage of LED1 it draws current and hence limits the current to the gain cell. This causes linear operation above the threshold.

For stereo operation the LEDs should be matched for forward voltage. The circuit as shown is designed for 15 V; if other supplies are to be used R2 will have to be changed. Better DC biasing around the op-amp in the 571 will improve the DC offset.



# IC compresses, expands analog signals

## Bipolar linear chip replaces discrete components as communications compandor; includes reference voltage, converters, high-gain op amp

*by Bernard Cole, San Francisco bureau manager*

**It usually takes** 20 to 30 transistors, as many capacitors, and about 100 resistors to build a compandor system, which compresses or expands the analog signals used in telecommunications trunk lines.

A monolithic equivalent of such a system has been developed by Exar Integrated Systems Inc. The bipolar linear IC, designated the XR-2216, is intended to compress or expand the dynamic range of speech or other kinds of analog signals—and it costs about three to five times less than a discrete system.

In a speech transmission system, the dynamic range of the input signal is first compressed at the transmitting end; then transmitted through the system; and finally expanded back to the original amplitude at the receiving end. Thus, the compressor and the expander sections of a compandor system have reciprocal functions. In a bidirectional transmission system, there is a compandor at each end of the line: one compresses the outgoing signal, and the other expands the incoming signal.

**Costs less.** What Exar has done, says vice president Alan B. Grebene, is replace all the discrete circuits with one 105-by-88-mil monolithic chip, which will cost $1 to $1.25 each in 100,000 quantities instead of the $3 to $5 that a system of discrete components would cost. Price of the XR-2216 for 100-lots is $4.80 each; for 25–99, $5.60; and for 1–24, $6.40.

The monolithic circuit consists of four basic blocks: an internal voltage reference; an ac/dc converter which transforms an ac signal input into a dc current level; an impedance converter whose level is a function of a dc control signal; and a high-gain operational amplifier.

When the XR-2216 is connected as a compressor, its output change is 1 decibel for every 2-dB change in input amplitude. However, the output range can be adjusted to -37 to -7 dBm for input signals of 60-dB dynamic range.

As an expander, the input signals of -37 to -7 dBm are expanded to a 60-dB output range up to 0-dBm power-matched output into a 600-ohm load.

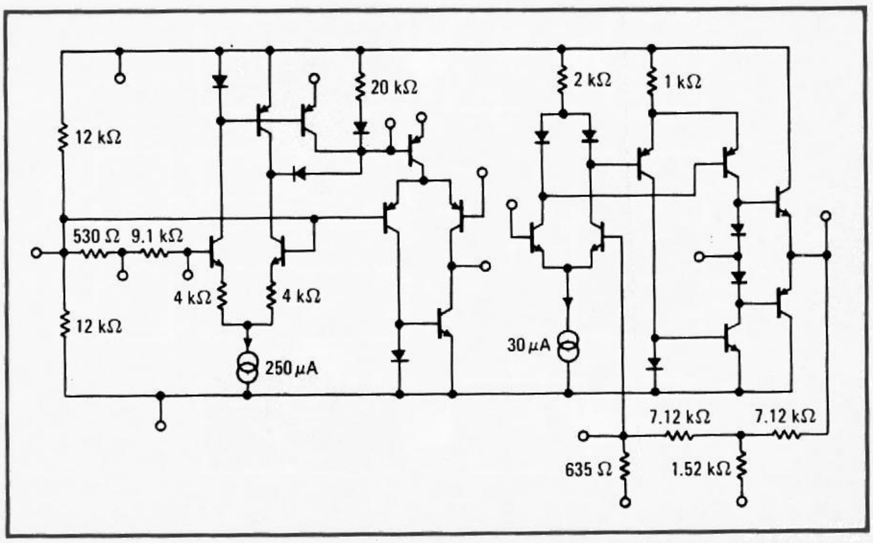
Grebene says the XR-2216 is designed to accommodate a wide range of system configurations. It can be operated with positive or negative single-supply systems, or with balanced power supplies, over a supply range of 6 to 20 volts.

Other key features include excellent transfer-function tracking (at a reference of -14-dB input, output is -4 dB); low power supply drain (3 milliamperes maximum); controlled attack and release times (5 milliseconds to 90% of final value and 10% of final value, respectively); low noise—30 dBrnc (decibels referred to the standard reference noise level of $10^{-12}$ watts at 1 kHz) as a compressor and 5 dBrnc as an expander; and low distortion (3% total harmonic distortion measured at -4 dB across a 600-ohm load at 1 kHz). Over a frequency range of 300 to 500 hertz, gain change over frequency tolerances is ±1 dB.

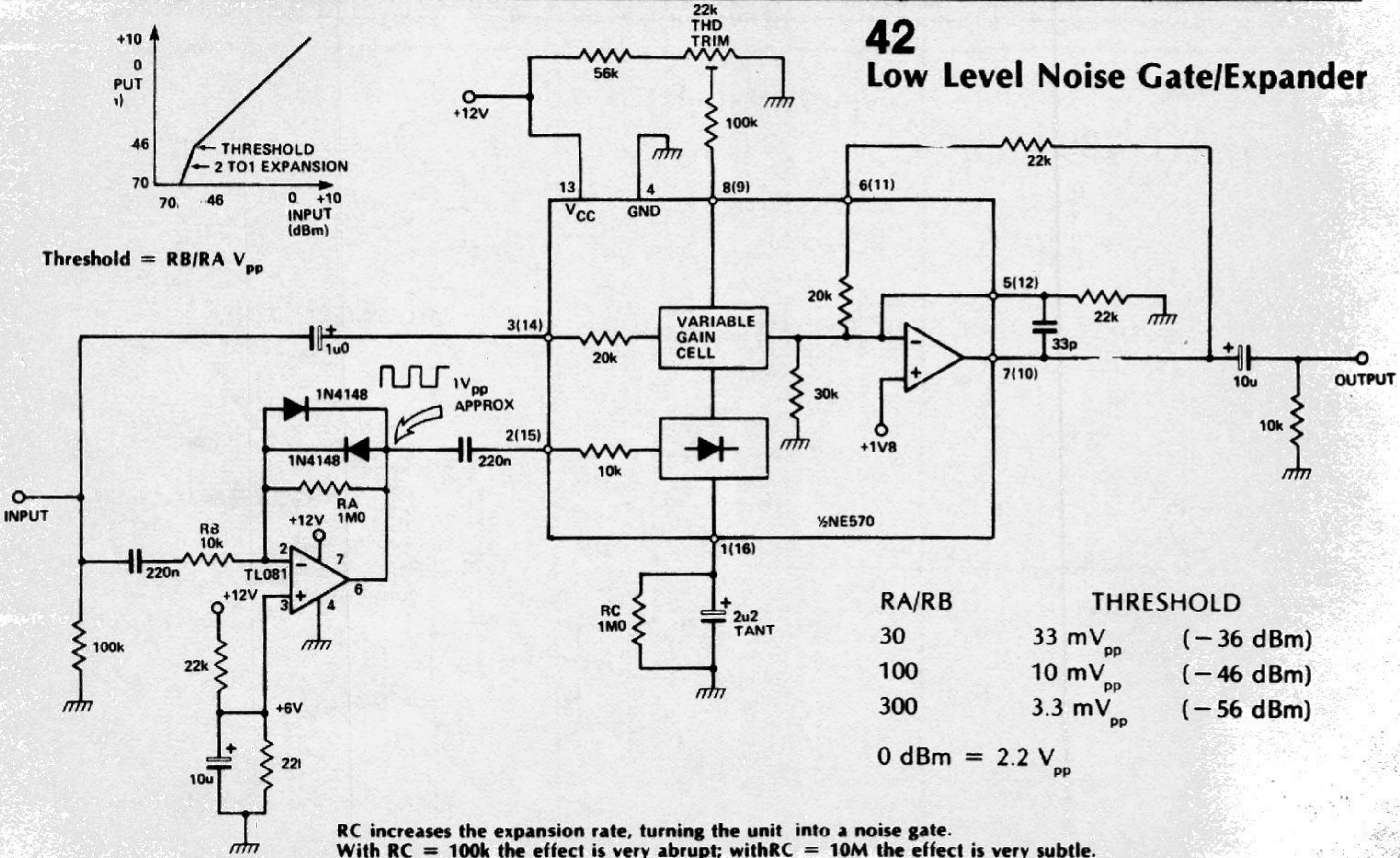
Packaged in a dual in-line 18-pin configuration, the unit has a power dissipation in ceramic of 750 milliwatts with a 6-mW/°C derating above 25° C. In the plastic package, it is 625 mW with a 5-mW derating.

Exar Integrated Systems Inc., 750 Palomar Ave., Sunnyvale, Calif. 94086 [338]

**User's choice.** Schematic shows equivalent circuit of XR-2216 compandor. The device can be connected as either a compressor or expander, depending on external circuitry.



# 42
## Low Level Noise Gate/Expander




| RA/RB | THRESHOLD | |
|---|---|---|
| 30 | 33 mV$_{pp}$ | (−36 dBm) |
| 100 | 10 mV$_{pp}$ | (−46 dBm) |
| 300 | 3.3 mV$_{pp}$ | (−56 dBm) |

0 dBm = 2.2 V$_{pp}$

**RC increases the expansion rate, turning the unit into a noise gate.**
**With RC = 100k the effect is very abrupt; withRC = 10M the effect is very subtle.**