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.

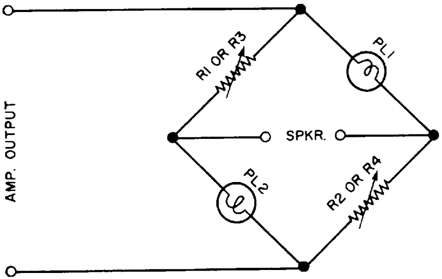


Fig. 1. Basic bridge circuit used.

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.

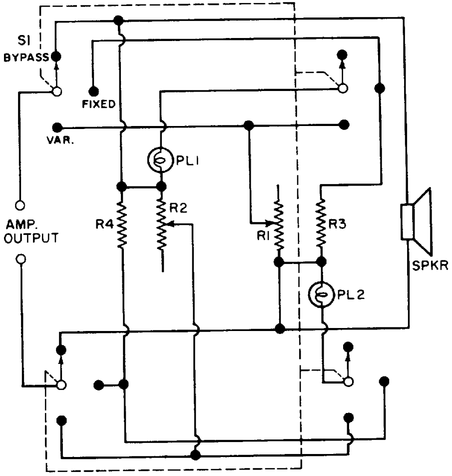


Fig. 3. Circuit diagram of unit which permits fixed and variable volume expansion.

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.

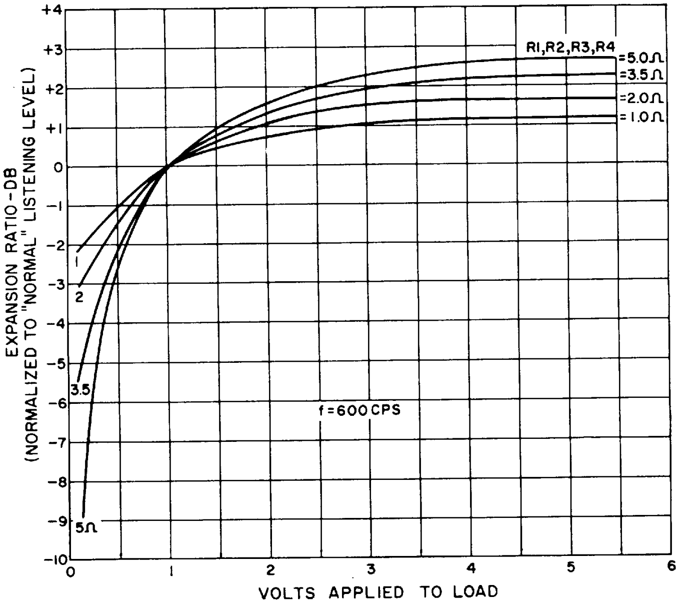
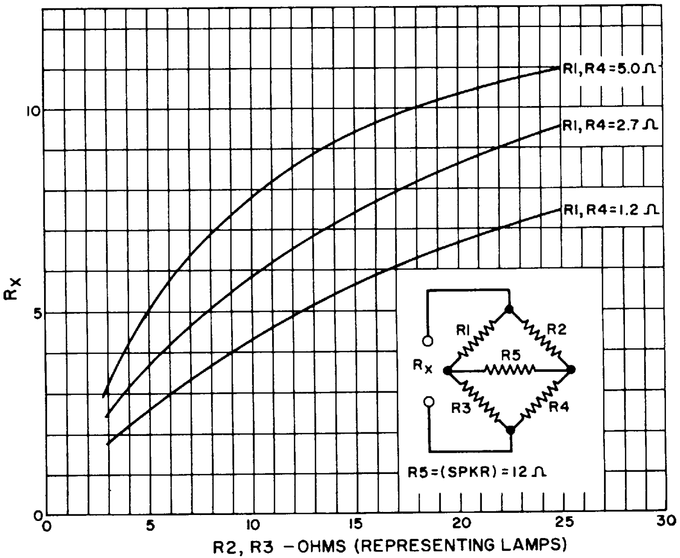


Fig. 4. Range of values of the circuit's input resistance (R_X) for various amounts of bridge and lamp resistance when a loudspeaker load with an average impedance of 12 ohms is utilized.



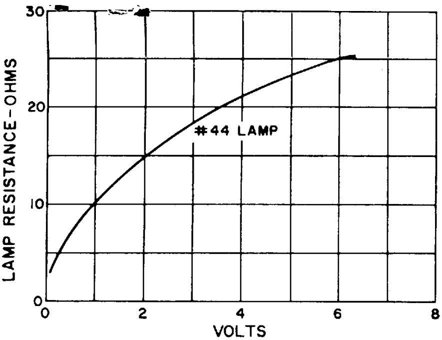


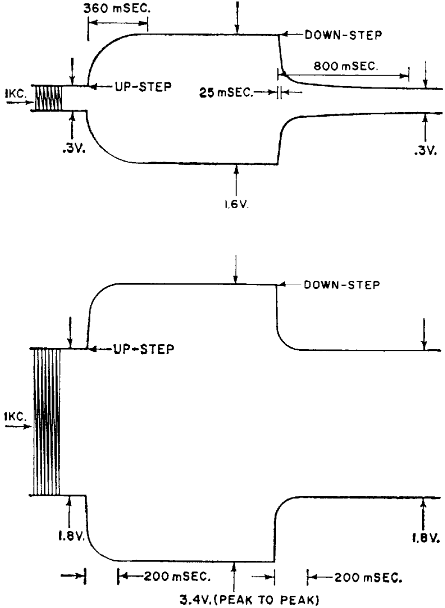
Fig. 5. Resistance at various voltages of the panel lamps used by the author.

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

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.



db or more attenuation occurs at the residual noise level. (The negative numbers on the db scale refer to levels below the "nominal" level.)

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,) 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. A