Technical Notes Volume 2, Number 2

JBL/UREI Power Amplifier Design Philosophy

Introduction:

JBL/UREI's dual channel amplifiers answer a long standing need for reliable, cost effective designs. They are intended for all applications involving JBL transducers and loudspeaker systems.

Over the years, professional amplifier design has often emphasized reliability and ruggedness over sonic quality. All too often, the very circuits which protected the output transistors from overdrive had an adverse effect on sound quality in normal operation. Today, professional sound system designers insist on both requirements, and there are not many amplifiers which combine reliability and sonic performance to the degree which the JBL models provide.

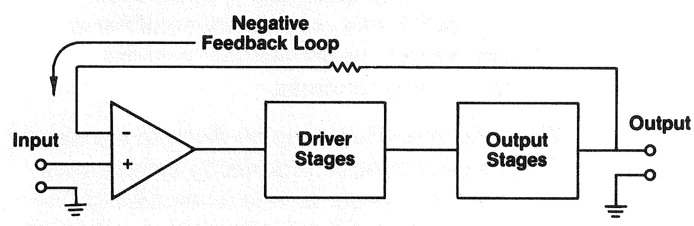
Design Considerations:

Negative feedback is essential in reducing the distortion of any amplifier, but it can be applied in various ways. Some amplifier designers take the approach shown in Figure 1. Here, an overall feedback loop is used to reduce distortion, increase bandwidth, and establish the gain of the amplifier. An amplifier designed along these lines may produce very low steady-state distortion characteristics, but its performance under transient signal conditions will likely suffer.

Such an amplifier may sound "edgy" or harsh on high-frequency program material. The reason for this is that the amplifier's output is compared, by way of the feedback look, with its input, and any discrepancies in the output are corrected. However, because of the finite transit time of the signal through the amplifier, the correction signal is delayed; it is always playing a "catch-up" game with the input, and only under steady-state conditions will the output signal show low distortion.

Figure 1. **A Single Feedback Loop Around A High-gain Amplifier**

A. **Amplifier Block Diagram**



B. **Bandwidth Increases And Gain Decreases As Feedback Is Increased**

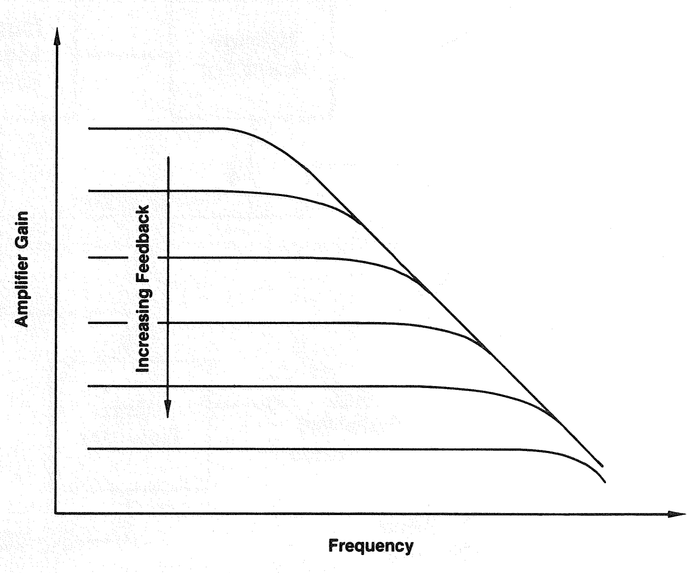
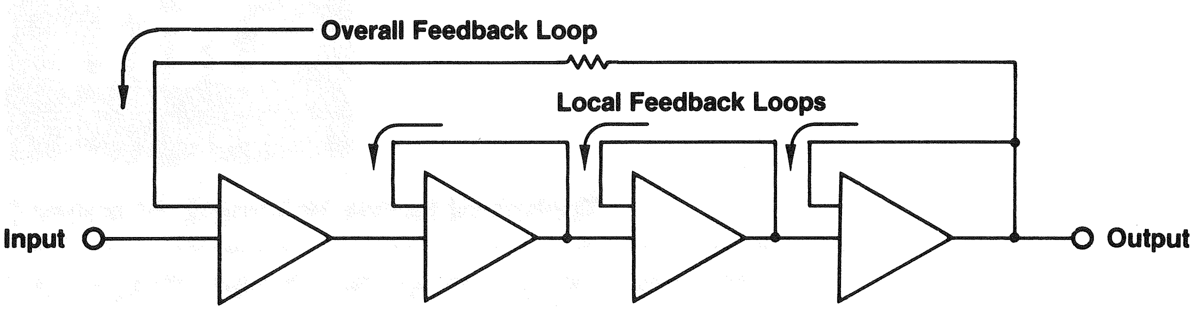


Figure 2. **Multiple Feedback Loops Within An Amplifier**



At the other end of the scale, there is the design approach shown in Figure 2. Here, local feedback around each stage reduces distortion as the signal is amplified, and moderate overall feedback is added just to stabilize gain and establish the DC operating point of the amplifier. The transit time problem is minimized, since the correction signal is fed around each stage. The JBL/UREI amplifiers are designed according to this philosophy.

Figure 3 shows the block diagram of a single channel in one of our amplifiers. The input operational amplifier configuration provides balanced or unbalanced bridging input. An additional operational amplifier is used in the bridged mode to provide the required inverted drive to the other channel.

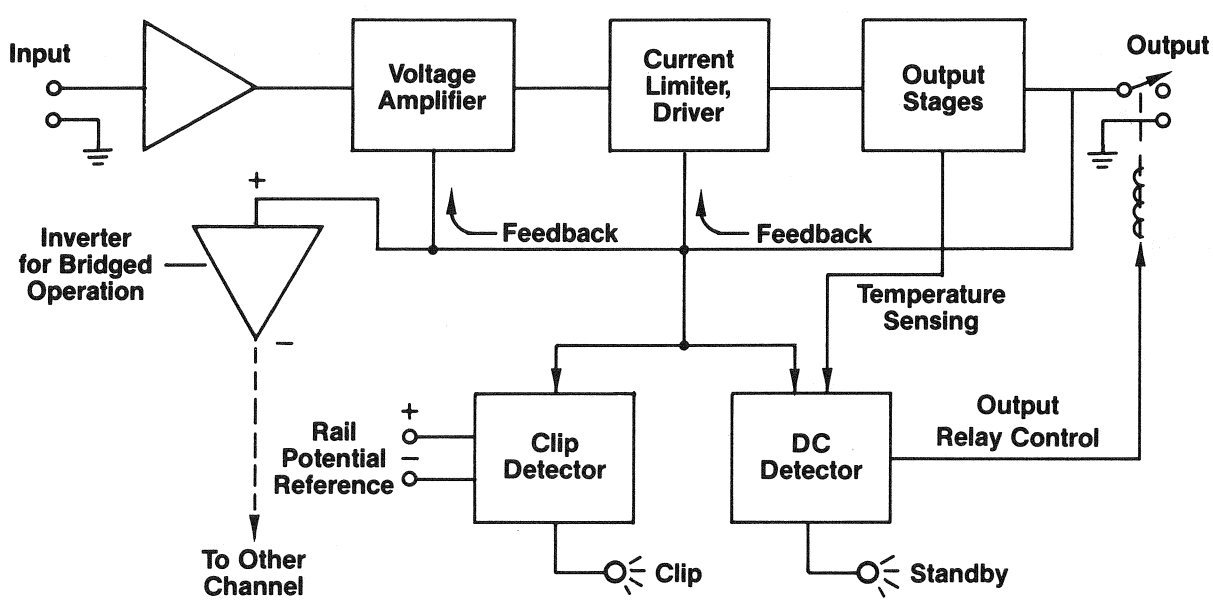
The JBL/UREI amplifiers employ discrete transistor circuitry after the gain control. A perfectly symmetrical topology was chosen in order to take advantage of distortion cancellation effects inherent in such circuits and the equal group delay for each half of the amplified signal. This configuration allows simple compensation, exceedingly wide open-loop frequency response, and excellent transient intermodulation performance.

The voltage amplifier (preamplifier) stage is configured as a cascode connected current-mode circuit capable of extremely high bandwidth.

The output stage is a complementary Darlington design using high-speed complementary bipolar transistors. Field effect transistors (FET's) are not used because of the present inability of the manufacturers of such devices to produce complementary pairs for the power range required of this amplifier type.

A popular alternative design approach makes use of only NPN transistors in the output stages. Such a design is called "quasi-complementary," and it exhibits higher distortion than the complementary approach. While negative feedback can reduce this distortion to acceptable levels, at least with steady state test signals, the sonic quality of these designs remains questionable.

Figure 3. **One Channel of JBL/UREI Amplifier, Block Diagram**



Details of Fail-safe Operation:

Many of the blocks in Figure 3 have to do with the various fail-safe features of the amplifiers. Considerable attention has been paid to protecting the output devices themselves, as well as the loudspeaker load.

Output Relay: During power-up and power-down phases, considerable DC offset will exist momentarily at the amplifier's output. The DC offset could stress, if not permanently damage, some loudspeaker loads. In the JBL/UREI amplifiers, the load is connected only after the amplifier has stabilized itself, and it is disconnected immediately upon power-down or in the event of some internal fault in the amplifier. Under all of these conditions, the "Standby" indicator on the front panel will light. The output relay will also disconnect when a thermistor located on the output heatsink senses excessive temperature. Under conditions of insufficient ventilation, the amplifier, if overdriven for long periods, will simply shut itself off until the output devices have cooled down to a safer temperature.

Current Limiting: The stage prior to the output acts as a current limiter, preventing the driver transistors and the output devices from exceeding their current rating. This action, when it occurs, is quite clean and not usually audible.

Some highly reactive loads driven at full output level may trigger the action. More usually, operating the amplifier at high levels with loads less than four ohms will trigger this action on an instantaneous basis. Under conditions of normal loading, it is doubtful that current limiting will ever be required. Amplifier drive levels will not trigger current limiting as long as loading is normal; only adverse loading conditions will give rise to current limiting. With their individual rating of 200 watts each, the multiple output devices cannot be stressed to the danger point, and reliable operation is assured at all times.

Clipping Indicators: When output voltage levels are driven close to the power supply rail potentials, the clipping indicator will light. While occasional clipping resulting from high crest factor input signals will not normally be audible, it should be avoided in routine system operation.

Taken all together, the fail-safe features of the amplifiers provide automatic protection of the amplifier and its load, as well as provide diagnostic indication of potential trouble. Few amplifiers, either consumer or professional, are as well equipped.

Performance Data:

Careful attention has been paid in the design of these amplifiers to those parameters which relate directly to sonic quality. In recent years, Transient Intermodulation Distortion (TIM) has been identified as a significant factor in sonic performance. While certain other forms of distortion result from the natural nonlinearities of the active devices employed in the design, TIM results from *slewing rate* limitations in the devices. The slewing rate of a device is a measure of how fast that device can linearly change from one operating condition to another.

For example, consider a stepped input signal (step function), as shown in Figure 4A. At the output of a non-slewing (but band-limited) amplifier, we would see an output like that shown at B. However, if the steep rise time of the input signal exceeds the slewing limitation of any active element in the amplifier, then the output will look like that shown at C.

As measured at the output of an amplifier, slewing rate is expressed in volts per microsecond. In the case of the JBL/UREI models, the slewing rate is 40 volts per microsecond. If we put a step function at the input, the output will change to the new stepped output value at a rate of 40 volts per microsecond. This rate is quite fast, and it is sufficient to allow the amplifier to produce full output at frequencies well beyond the audible range.

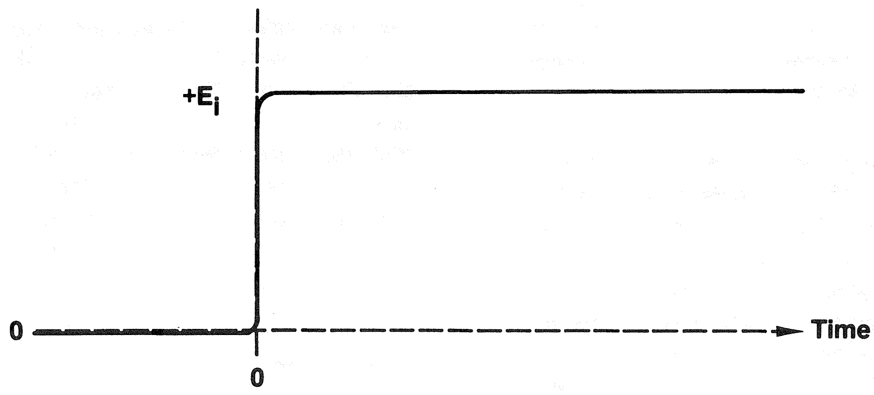
One way to ensure that an amplifier will never slew is to band-limit its input so that the amplifier will never see an input signal steep enough to cause slewing. This may have the disadvantage of producing considerable phase shift of the input signal in the audible band if the filter cut-off is quite steep. A better solution is to use a gentle input roll-off slope in combination with semiconductor devices which are sufficiently "fast" so that the onset of slewing occurs only at output levels greater than the maximum which the amplifier can produce. In the case of our new amplifiers, TIM at full output is less than 0.03%. Full bandwidth total harmonic distortion (THD) at the same output level is less than 0.1% for 8-ohm loads, so it can be seen that TIM is significantly less than THD.

A special test signal is used for measuring TIM (see reference). This signal is composed of a square wave with a fundamental frequency of 3.18 kHz and a sine wave at 15 kHz. The signal is band-limited at 100 kHz, and the amplitudes of the two signals are adjusted to a four-to-one ratio.

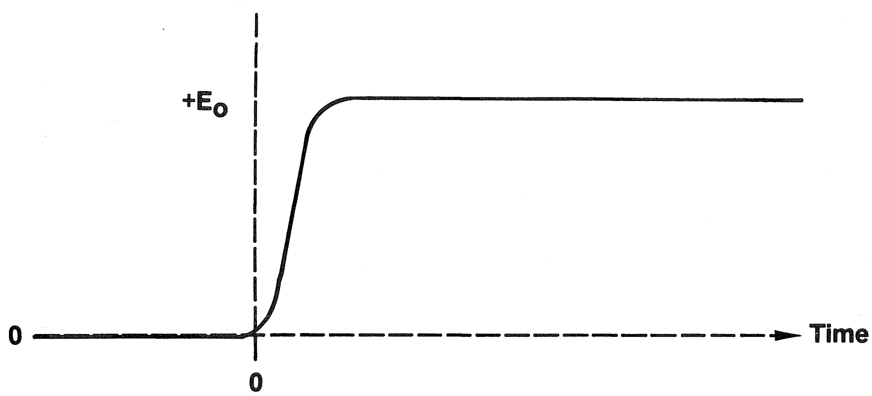
Figure 5 shows the output spectrum for the model 6260 amplifier when the test signal is adjusted for full output. Only the spectrum up to 20 kHz is shown in this and the following graph. The tall spikes in the graph

Figure 4. **Transient Intermodulation Distortion (TIM)**

A. **Input Step Function**



B. **Output of Band Limited, Non-slewing Amplifier**



C. **Output of Slewing Amplifier**

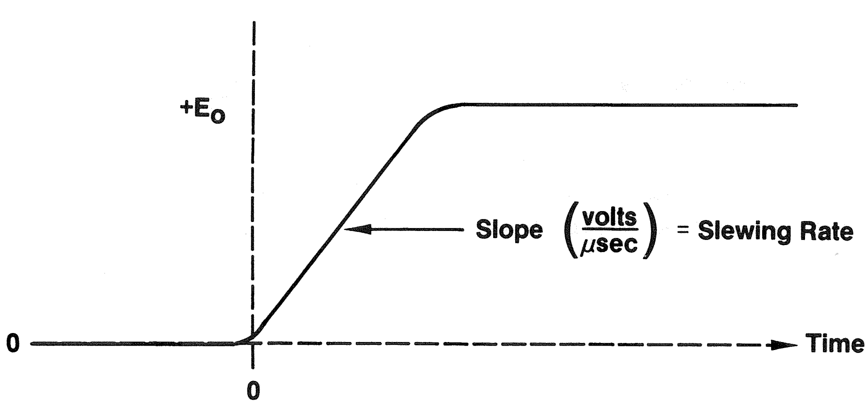
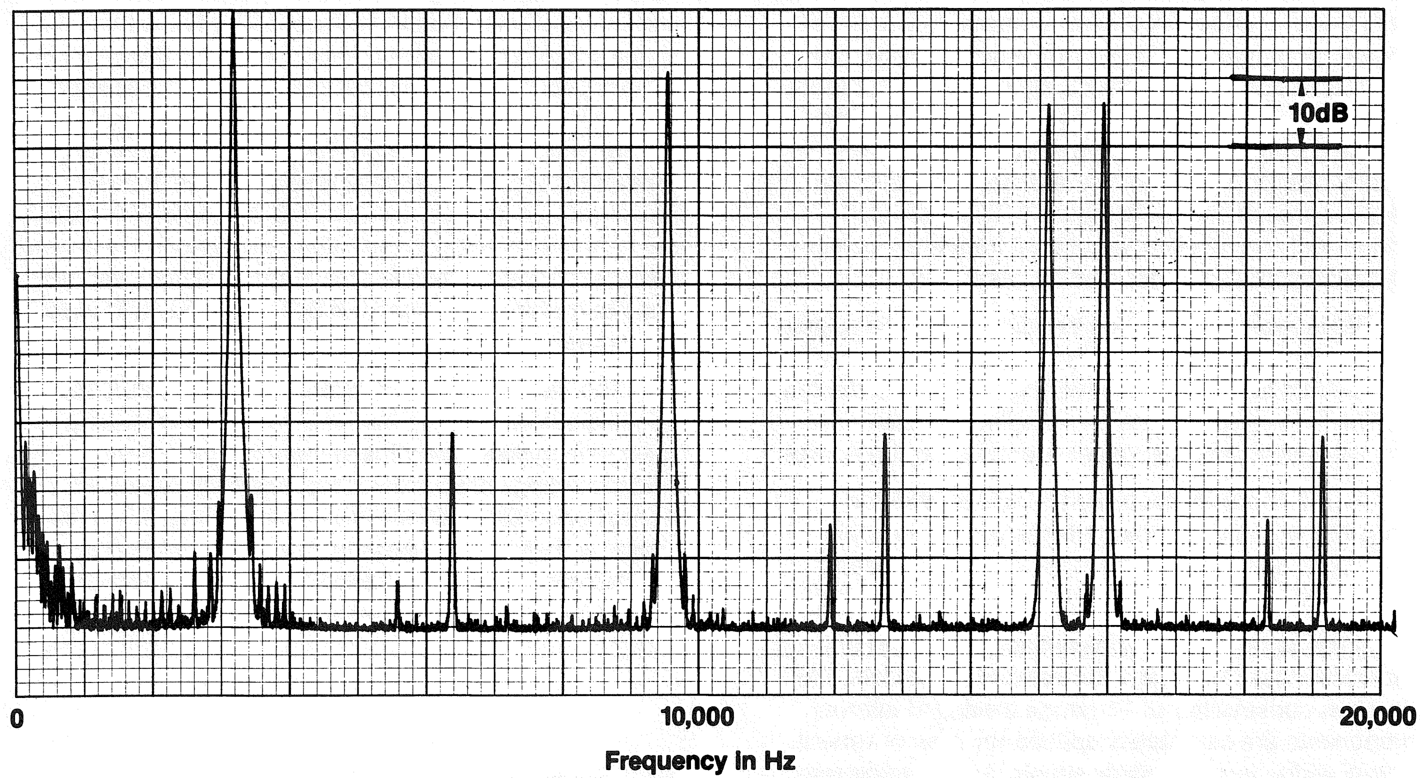
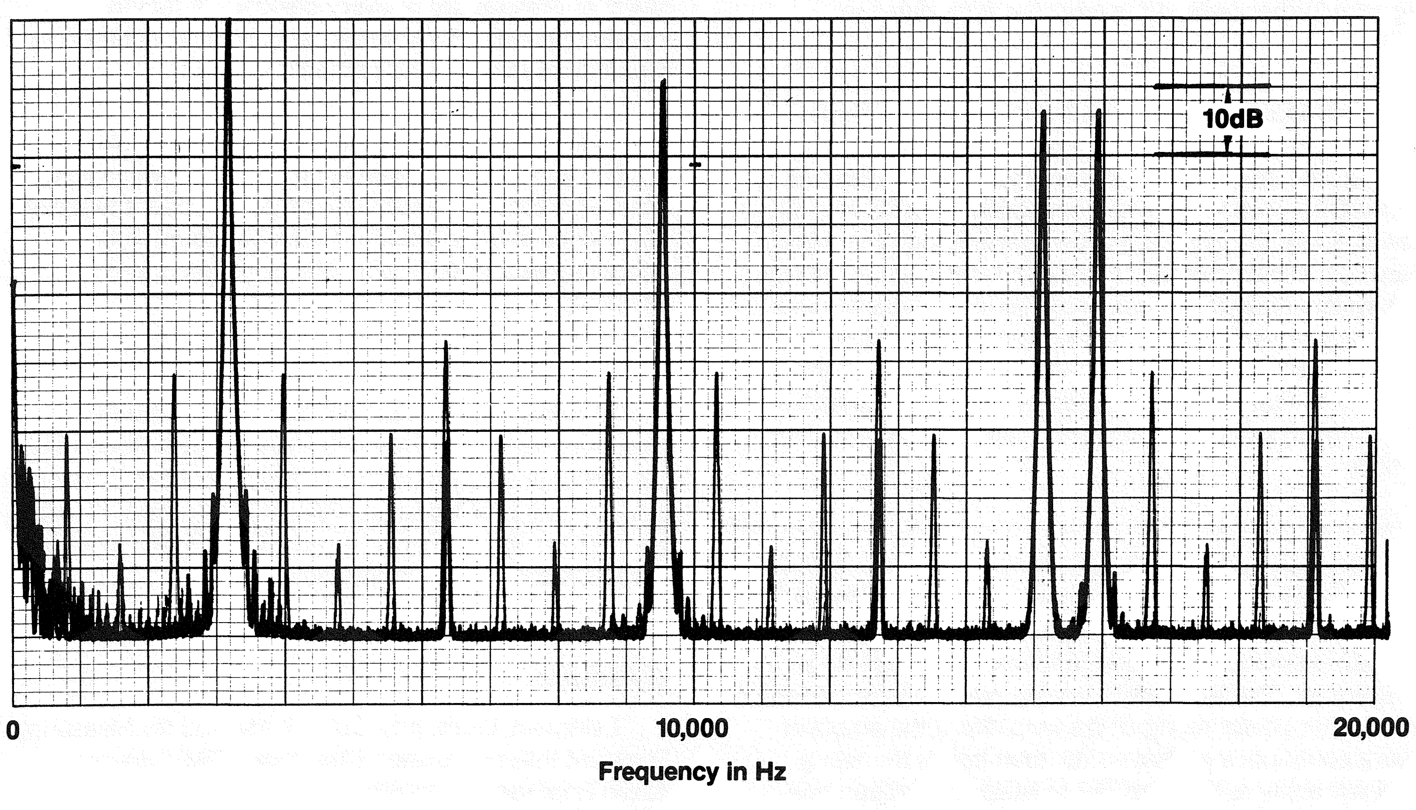


Figure 5. **TIM Spectrum, JBL/UREI 6260 Amplifier**



TIM ≈ 0.03% **100V pk-pk/8Ω**

Figure 6. **TIM Spectrum, Industry Standard Amplifier using Quasi-complementary Circuitry**



TIM ≈ 0.8% **100V pk-pk/8Ω**

represent the input signal, and the small spikes represent distortion components. Note that there are relatively few of these spurious frequency components and that they are more than 60 dB below the square wave fundamental frequency of 3.18 kHz. By comparison, Figure 6 shows the output spectrum for a popular amplifier of equivalent output power rating with quasi-complementary design. This amplifier is characteristic of the design approach shown in Figure 1. The increased number and amplitude of additional frequency components represent significant audible distortion.

TIM is expressed as a percentage, and is calculated as the RMS sum of all spurious components, up to 100 kHz, referred to the input frequencies present at the output. The TIM values for the two amplifiers tested have been calculated, and the values are show on the figures.

Overall, these measurements indicate that the JBL/UREI amplifiers are superb performers in sonic terms. They are, in fact, very close in performance to some of the most highly regarded audiophile products.

At the same time, they have the ruggedness and roadworthiness of the best professional amplifiers. The chassis is constructed of 14-gauge steel, and internal components are adequately spaced for ease of service. Internal wiring is surprisingly simple, further minimizing field problems.

The power transformer is located close to the front panel, lessening the bending moment on the front panel should the amplifier rack be dropped. Thick rack mounting ears further protect the amplifier from damage.

Dual Monophonic Mode: In large audio systems several amplifiers will often be fed from the same source. The JBL/UREI amplifiers incorporate a feature called Dual Mono Mode to maximize their utility in such cases. A rear panel switch allows selection of dual Mono Mode (or normal Stereo or Bridged Mono), which allows the system designer to use only one input cable for two channels of amplification, while retaining individual channel gain control. This results in a reduction in the number of input cables required to wire the amplifiers, with consequent savings in time, material, and, therefore, money.

Bridged monophonic use: For many applications in general sound contracting, a stereophonic amplifier is not required. Through bridging, a stereo pair of amplifiers can deliver considerable amounts of power into a single load. The key in determining performance here is the 4-ohm power rating of the amplifier. If the amplifier has a continuous 4-ohm rating, then that is the rating that will apply to the amplifier in bridged configuration operating into 8 ohms.

Figure 7 shows details of bridging. When two amplifiers are bridged, they are effectively placed in series, and the combined output voltage will be twice that of a single amplifier. For a fixed load, the power drawn from the bridged amplifiers will be *four times* that delivered by the single amplifier, since power is proportional to the square of the voltage across the load. In the case of the models 6230, 6260, and 6290 amplifiers, the 4-ohm power ratings are, respectively, 150, 300, and 600 watts per channel. In bridged operation, we replace the 4-ohm loads with 8 ohms (two 4-ohm loads in series), and we can realize bridged outputs of 300, 600, and 1200 watts, respectively.

The bonus of bridged operation of the JBL/UREI amplifiers is something that may take a bit of getting used to in system specification and layout. These bridged ratings are conservative, and they represent normal operation without forced air cooling. *The only caveat is that the load seen by the amplifiers in the bridged mode should not drop lower than 8 ohms at any point if it is desired to deliver full output to the load.*

Special Features:

Input Connectors: The JBL/UREI amplifiers offer a choice of XL-type, 3-conductor 6 mm (1/4-inch) phone jack, or barrier strip input connections to satisfy the needs or preferences of every designer. A factory installed jumper on the barrier strip may be removed to separate chassis ground and audio ground.

Security covers: The input gain controls have knobs that can be removed. Gain can then be set with a screwdriver, and security covers can be placed over the holes. This means that the amplifiers can be mounted in accessible rack spaces with little or no chance of tampering.

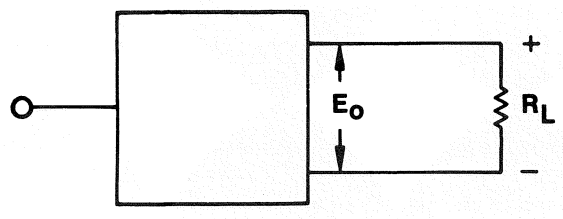
70-volt autoformers: A rack mount autoformer accessory will convert the 6230, 6260, and 6290 so that full output power is available at 70.7 volts RMS. These outputs may be used in any 70-volt application. Where full isolation from the load is required, 70-volt transformers are available on special order.

Reference:

Leinonen, Otala, and Curl, "A Method for Measuring Transient Intermodulation Distortion (TIM)," Journal, Audio Engineering Society, Volume 25, Number 4 (April 1977)

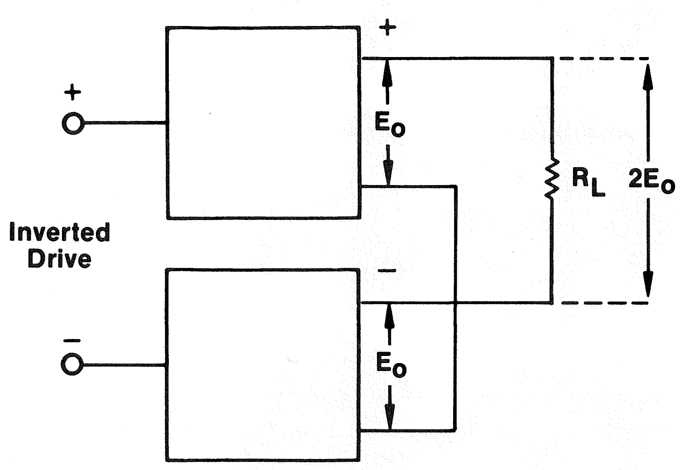
Figure 7. **Amplifier Bridging**

Single Amplifier Section:



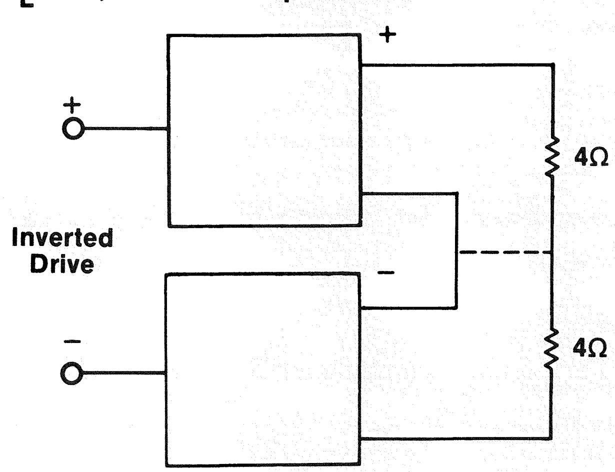
$$\text{Power} = \frac{E_o^2}{R_L}$$

A Bridged Pair:



$$\text{Power} = \frac{(2E_o)^2}{R_L} = \frac{4E_o}{R_L}$$

If R_L = 8Ω, then each amplifier "sees" 4Ω:



Therefore, 4Ω rating applies to bridging with an 8Ω load

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