CROWN®

THE PROFESSIONAL AUDIO DIVISION OF CROWN INTERNATIONAL, INC.

CROWN PRO AUDIO SERVICE SCHOOL

RESOURCE TEXT

For The

Crown® Professional Products SERVICE SCHOOL

PART 2

Notes

Crown Designs

The Crown amplifier technologies are all based on meeting the customer demand for high reliability, clean undistorted and controlled high power, and all within the smallest and lightest—yet most durable—package possible. The major designs that require detailed explanation include the grounded bridge output topology, Output Device Emulation Protection (ODEP), and Variable Impedance (VZ) power supply technology. While many other Crown innovations are important, these are the core of Crown amplifier technologies upon which all other Crown circuit designs are added.

THE GROUNDED BRIDGE

Refer to the included sketches for this detailed description of the grounded bridge topology. In brief, the grounded bridge consists of four Darlington composite output quadrants and an ungrounded power supply. While two of the output quadrants operate much like a conventional (AB+B push-pull) linear amplifier, the other two work in a push-pull configuration to control ground reference for the supply rails. The two quadrants driving the load are, together, called the High Side. The other quadrants controlling ground reference are called the Low Side.

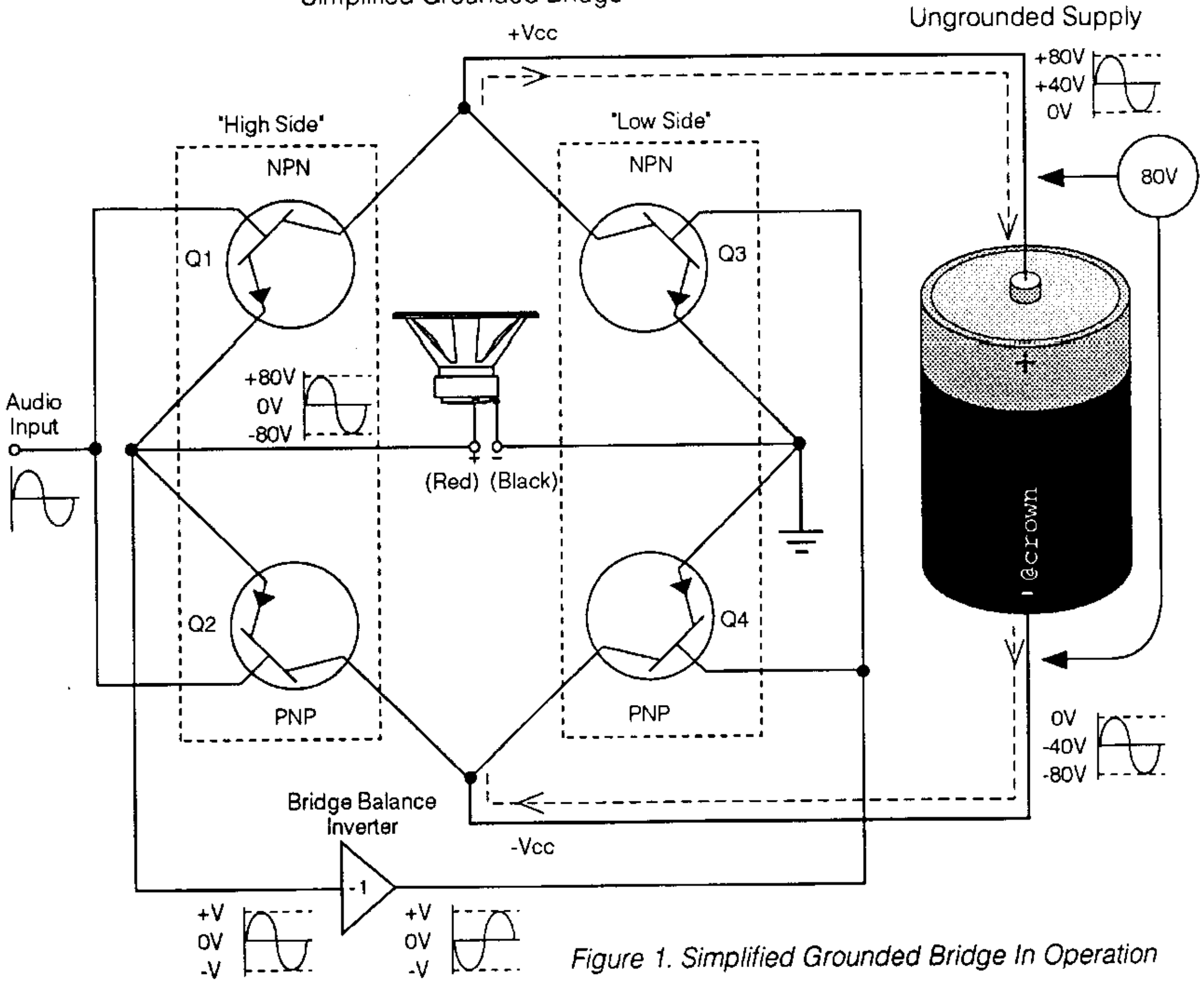

Figure 1. Simplified Grounded Bridge In Operation

The high side of the bridge operates similar to a conventional bipolar push-pull output configuration. As the input drive voltage becomes more positive the high side NPN conducts current and delivers positive voltage to the speaker load. Eventually full +VCC is across the load. At this time the high side PNP is biased off. When the drive signal is negative going the high side PNP conducts to deliver -VCC to the load and the high side NPN stage is off. In principle, this is no different from any conventional linear push-pull output stage.

The low side operates quite differently. The power supply bridge rectifier is not ground referenced, and the transformer secondary is not center-tapped. This allows the power supply to deliver +VCC and -VCC from the same bridge rectifier and filter as a total difference in potential regardless of their voltages with respect to ground. The low side of bridge uses inverted feedback from the high side output to control the ground reference for the rails.

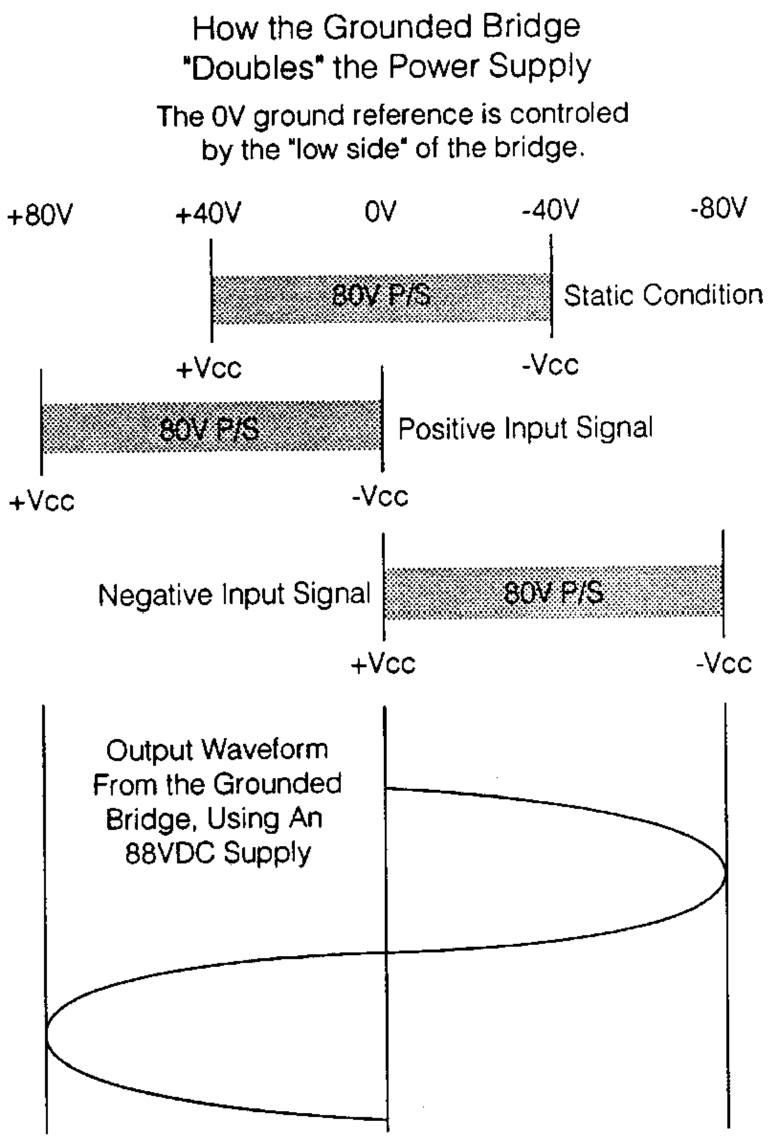

Figure 2. Power Supply Shifts With Audio

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As the output swings positive the output signal is fed to the low side and is inverted to drive the low side with a negative signal. The negative signal causes the low side PNP to conduct (as the high side NPN conducts) shifting the ground reference to toward -VCC until, at the peak, -VCC = 0V. At this time +VCC equals the full potential of the power supply with positive polarity. Because the high side is delivering +VCC to the speaker load (which is ground referenced at all times), the speaker sees the full potential developed by the power supply with a positive polarity.

When the input drive signal is negative and the high side PNP conducts to deliver a negative voltage to the load, that output is again fed to the low side and inverted to cause the low side NPN to conduct. As the low side NPN conducts this causes +VCC to swing toward the 0V ground potential. At the peak +VCC = 0V. At this time -VCC equals the full potential developed by the power supply, but with negative polarity. Since the high side is delivering the -VCC to the speaker load, it sees the full potential developed by the power supply with a negative polarity.

The total effect is to deliver a peak to peak voltage to the speaker load which is twice the voltage produced by the power supply. For example, the example of the quasi-linear design in the Amplifier Basics section used four power supplies which produced a maximum of ±80V at the output. A grounded bridge amplifier with a single 80VDC power supply will accomplish the same output level. Under static conditions (no input signal) the low side balances the rails to an even ±40V with respect to ground. With a positive input -VCC goes to 0V and +VCC goes to +80V. When the input goes negative, +VCC shifts to ground reference and -VCC goes to -80V. As a result no device ever sees more than 80V across it, nor does any device go into saturation before the clip point. Note that the total differential voltage from rail to rail of a grounded bridge is 80V, while the total differential for the quasi-linear is 160V. As a result, when the positive half of a quasi-linear output is at full conduction (+80V at the output), the total differential of 160V is across the negative pair of devices.

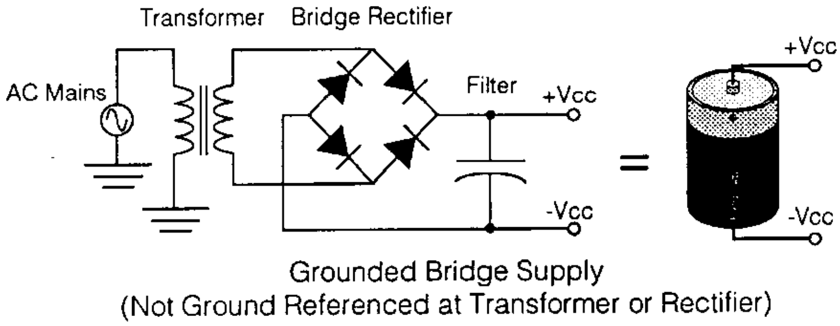

Figure 3. Ungrounded Power Supply

Another benefit is full utilization of the power supply. It conducts current during both halves of the output signal and requires only two connections, not even a center tap. This means that only one rectifier and one filter capacitor is required per channel. Conventional designs require two power supplies per channel, one positive and one negative. The grounded bridge also affords dramatically improved thermal performance. For more information about thermal management with the grounded bridge, refer to the ODEP discussion later in this section.

The grounded bridge was patented by Crown in the early 1970s, and first employed in the M-600 amplifier (1974). This amplifier was primary sold as an industrial power supply, though some did find their way into audio systems. After several years of heavy use in the industrial market, the grounded bridge was next used in the MT-1000 in 1984. Out of the MT-1000 came the MT-600 and MT-1200 in 1986. From the MT Series came the PBs, MAs, CTs, PTs, and the Macro Reference. Today the mainstay amplifiers for Crown are entirely grounded bridge designs.

ODEP AND THERMAL MANAGEMENT

It is well known that overvoltage and overheating are the two primary causes for failure of otherwise good transistors. Since it is impossible, with current economical technology, to measure temperature at the internal junction die another method measurement is required to accurately assess the dynamic thermal condition of the devices.

Output Device Emulation Protection (ODEP) is another Crown patented circuit design. It is an analog computer that senses output power and heatsink temperature and from this calculates the dynamic thermal headroom of the amplifier output devices. If these devices run out of thermal headroom the ODEP circuit will know and pull drive away before they exceed their safe operating area (SOA).

To sense output power, ODEP actually senses both output current and VCC. Output current is measured by the voltage dropped across output device emitter resistors. A voltage multiplier combines the current and VCC information to produce a voltage proportional to actual instantaneous output power. There are two thermal sensors mounted on the heatsinks which ODEP uses. Once of these is a PTC (positive temperature coefficient) device which serves the function of failsafe. If the heatsink reaches an excessive temperature, without regard to the ODEP computed thermal condition, the PTC steps in to force the amplifier into hard limiting. The other device is an LM-334Z thermal sensing current source device which conducts in proportion to the sensed temperature.

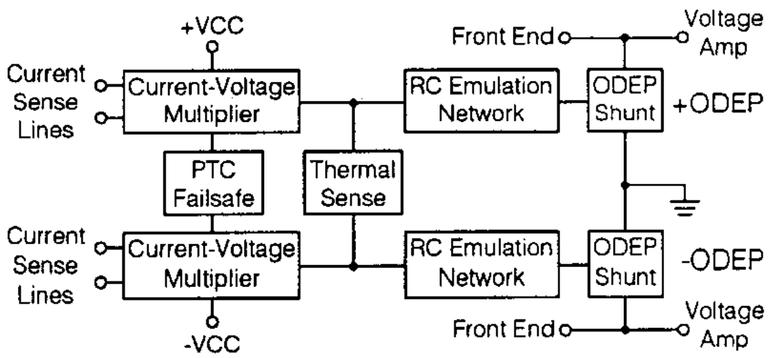

Figure 4. Basic ODEP Block Diagram

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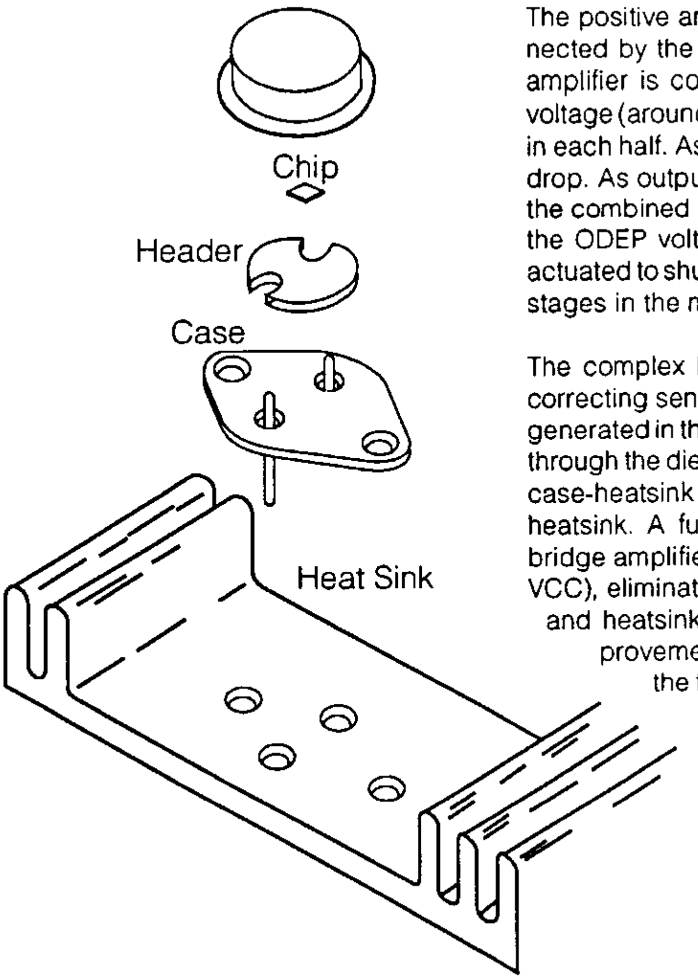

Figure 5. Heat Dissipation Structure

The positive and negative ODEP circuits are mirror images interconnected by the thermal sense and a complex RC network. When the amplifier is cool the thermal sense conducts very little and a high voltage (around ±10V, depending on the model and vintage) is present in each half. As temperature builds at the heatsink the ODEP voltages drop. As output power increase the ODEP voltages also drop. When the combined forces of instantaneous power and temperature cause the ODEP voltage to drop low enough, ODEP drive transistors are actuated to shunt some of the drive away from the voltage amplification stages in the main signal path.

The complex RC networks perform the heat dissipation emulation, correcting sensed conditions for real heat transfer conditions. Heat is generated in the die of an output transistor. This heat is then conducted through the die-case interface; then through the body of the case to the case-heatsink interface; then the heat is dissipated out through the heatsink. A fully complimentary design was chosen for grounded bridge amplifiers to allow the heatsinks to be electrically hot (carrying VCC), eliminating the need for electrical insulation between the case and heatsink. Removing this boundary allows for a significant improvement in heat transfer out of the device case and away from the transistor. The heatsink itself is electrically isolated from the chassis. In all but the smallest grounded bridge amplifiers, fins are added to the heat spreader. The intention behind the fin design is taken from air conditioner technology. By increasing the surface to volume ratio with thin convoluted fins, the heat can more easily be transferred out to passing air which picks up the heat and carries it out and away from the amplifier. In addition, the heatsinks are laid out such that the air only passes a short distance to get across the heatsinks, and they present a wide cross-section. Many other manufacturers utilize a "wind tunnel" design that forces air though a small cross-section chamber in which all major heat producing devices are located. It is also worth noting that the metal used for heatsinks in larger Crown amplifiers is made of copper instead of aluminum for superior heat conduction.

Within a dynamic audio thermal model the applied power waveform is nonlinear and transient. Thermal rise and decay take on a logarithmic form. Thermal modeling, therefore, must be done with RC networks.

jh = junction to header ½
hc = header to case ½
cs = case to heat sink ½
T_A = ambient temperature
P_D = power dissipated in the junction

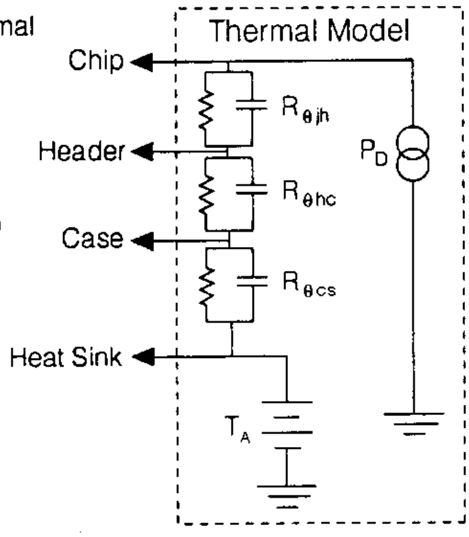

Figure 6. ODEP Electrical Emulation of Thermal Conditions

The RC networks in the ODEP circuit emulate the heat transfer characteristics of the various materials between the junction die and the thermal sensor located out on the heatsink. This serves to temper the instantaneous power peaks and carry a thermal history of the ever changing dynamics of the audio. Completing the thermal model of the output devices, a final voltage is presented to the transistors which are used to limit signal drive. With this level of accuracy, the ODEP circuit is able to limit only as much as necessary to maintain a safety margin without shutting down the amplifier.

Most conventional amplifiers use a thermal sensor on the heatsink. To ensure safety the sensor must cause a protective action which might not be required. To allow for maximum power the sensor must be desensitized to the point where it would act too late to prevent damage under worst case conditions. In most cases protection takes place in the form of a complete shutdown. Many manufactures supply a temperature indicator to let the operator know that its too late to do anything about it. All grounded bridge Crown amplifiers in production today include the ODEP circuit, and several models include ODEP indicators that inform the operator of actual thermal conditions. ODEP lights are normally on to indicate thermal headroom, and dim as the thermal headroom approaches zero. When the light goes out all thermal reserve is exhausted. ODEP lights also serve as power supply indicators and will go off suddenly with a loss of the high energy power supply.

Notes

VZ TECHNOLOGY

Variable Impedance (VZ) is the name of Crown's patented articulated power supply technology. It enables Crown to pack tremendous power into smaller than usual rack space.

Background

A power supply must be large enough to handle the maximum voltage and current necessary for the amplifier to drive its maximum rated power into a specified load. In the process of fulfilling this requirement conventional power supply designs produce lots of heat, are heavy, and take up precious chassis space. It is no secret that heat is one of a power amplifier's worst enemies. According to Ohm's Law, the bigger the power supply, the more heat the power transistors must dissipate—even when idle. Also, the lower the resistance of the power transistors, the more voltage you can deliver to the load. But at the same time that you lower the resistance of the transistors, you increase the current passing through them, and again increase the amount of heat they must dissipate.

An articulated power supply, like VZ, can circumvent much of this problem by reducing the voltage applied to the transistors when less voltage is required. Reducing the voltage reduces the heat. Since the amplifier runs cooler, you can safely pack more power into the chassis.

The example sketches provided are based on the MA-5000VZ. Though circuit designations and a variety of specifics vary from the MA-3600VZ and MA-36X12, they remain substantially the same.

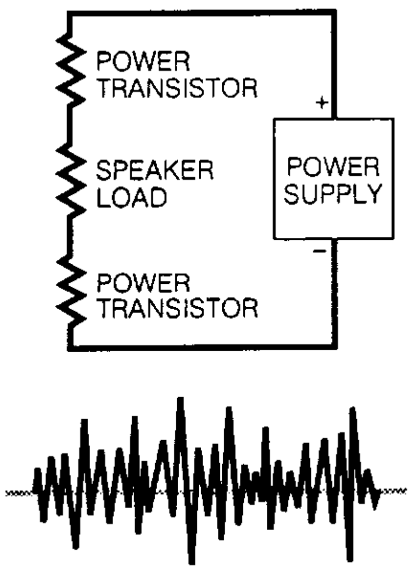

Figure 7. Audio Application

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The VZ Supply

Remember that audio signals like music are complex waveforms. For music the average level is always much less than the peak level. This means a power supply does not need to produce full voltage all the time.

In the discussion of how the grounded bridge operates, the power supply was shown as a battery. It was floating with respect to ground because a portion of the output stage is dedicated to that task. The VZ supply also floats, and ultimately the grounded bridge operates just the same whether the supply articulates or not.

The VZ supply is divided into segments to better match the voltage and current requirements of the power transistors. When the voltage requirements are not high, it operates in a parallel mode to produce less voltage and more current. The power transistors stay cooler and are not forced to needlessly dissipate heat. This is the normal operating mode of the VZ power supply. When the voltage requirements are high—for dynamic musical peaks—the VZ supply switches to a series mode to produce higher voltage and less current. The amplified output signal never misses a beat and gets full voltage when it needs it—not when it doesn't need it. It is further important to note that the articulation takes place in the power supply; the output transistors are not forced into a saturation mode as serial devices are switched into circuit for higher output voltage levels. The result is no switching distortion in the audio, as is found in quasi-linear designs.

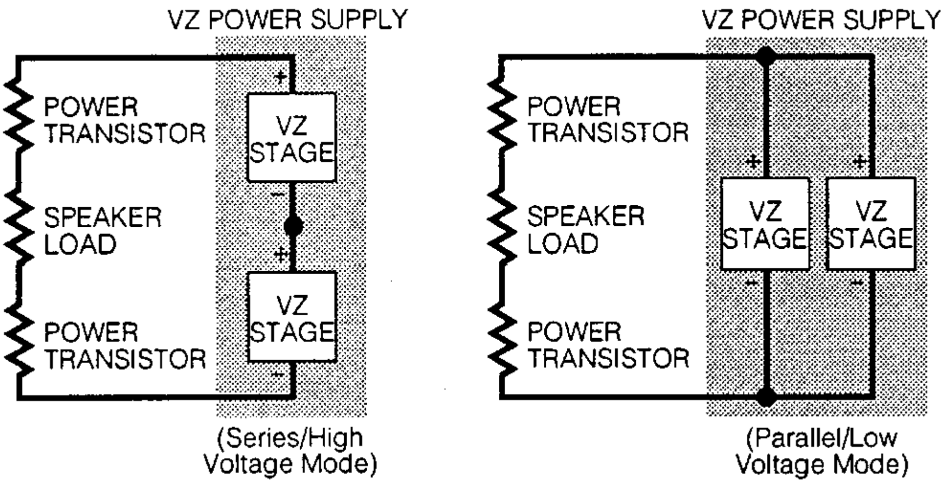

Figure 8. Examples of VZ Operation at High Signal Levels (Left) and Low Signal Levels (Right)

VZ Switch Control

Sensing circuitry watches the voltage of the signal to determine when to switch VZ modes. The switching circuitry is designed to prevent audible switching distortion and yield the highest dynamic transfer function—you hear only the music, not the amplifier. You get not only the maximum power with the maximum safety, you also get the best power matching to your load. The switch up occurs when the output signal is rising through approximately 80% of the parallel mode supply voltage. An RC time constant keeps the supply locked into high voltage (series) mode for about 200 milliseconds.

The MA-5000VZ includes extra control circuitry that allows the user to select alternative modes of VZ operation. These include Lock Low, Auto VZ, and VZ-ODEP. Lock Low mode forces the power supply to remain locked into low voltage (parallel) mode regardless signal level. Auto VZ allows the VZ articulation to occur automatically. VZ-ODEP mode allows for normal automatic VZ operation except when the ODEP circuit begins to limit audio. The VZ control circuitry senses when ODEP limiting occurs, and if it does then it locks the power supply into low voltage mode until the ODEP condition clears, plus a short additional period to prevent oscillation. This locking action prevents power supply switching while an ODEP protective event is in progress.

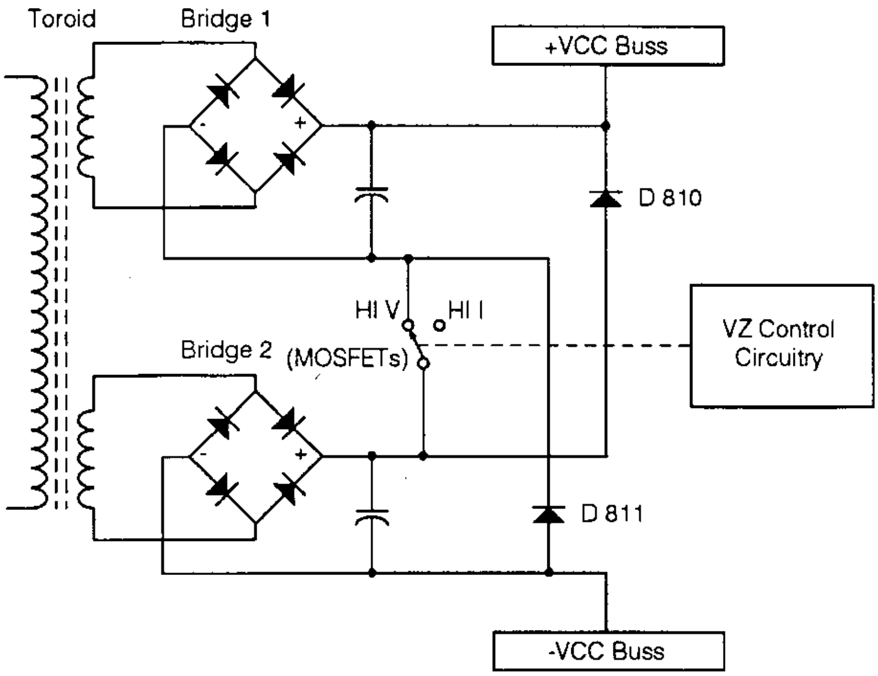

Figure 9. VZ Switch Operation

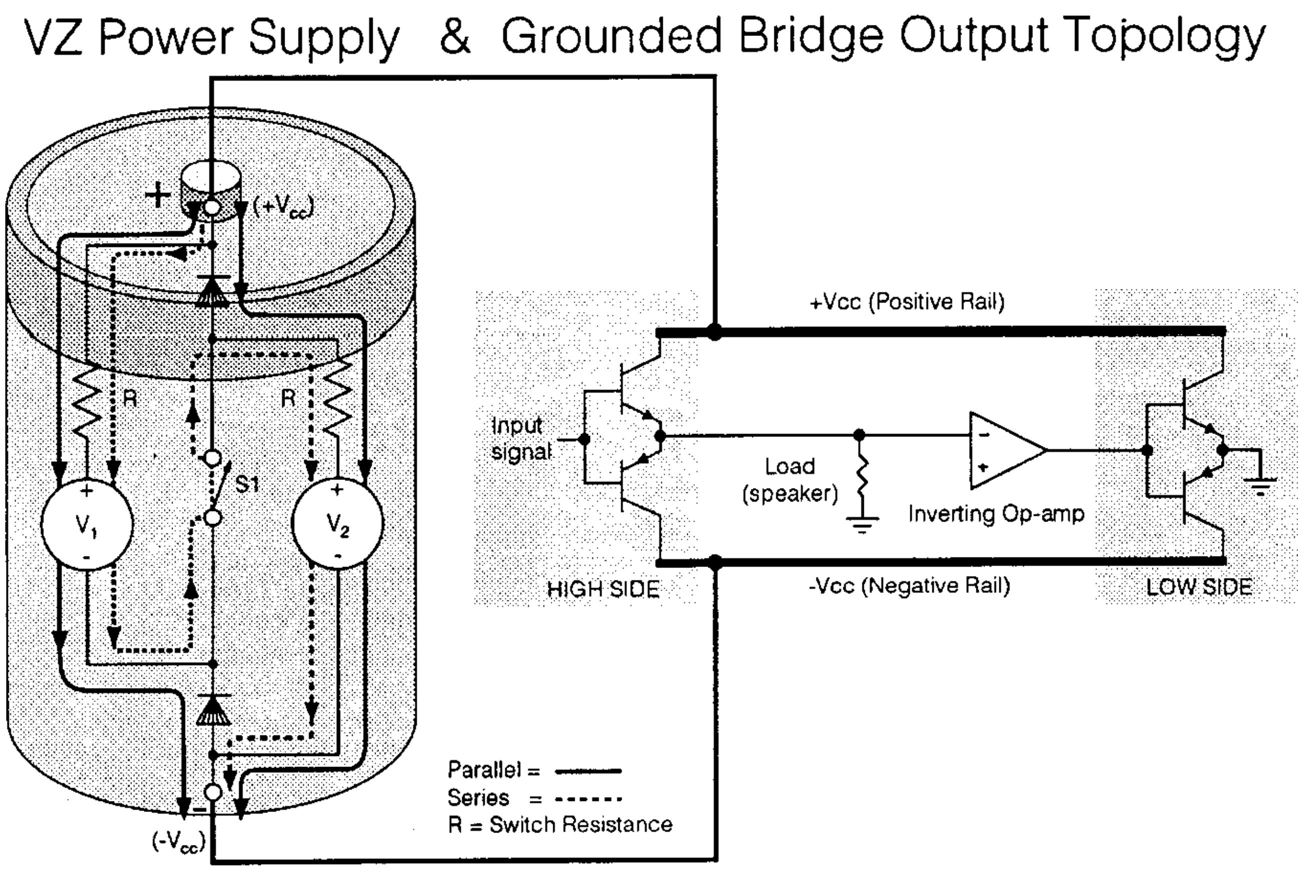

Figure 10. VZ Combined With The Grounded Bridge