THE PROFESSIONAL AUDIO DIVISION OF CROWN INTERNATIONAL, INC.

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.

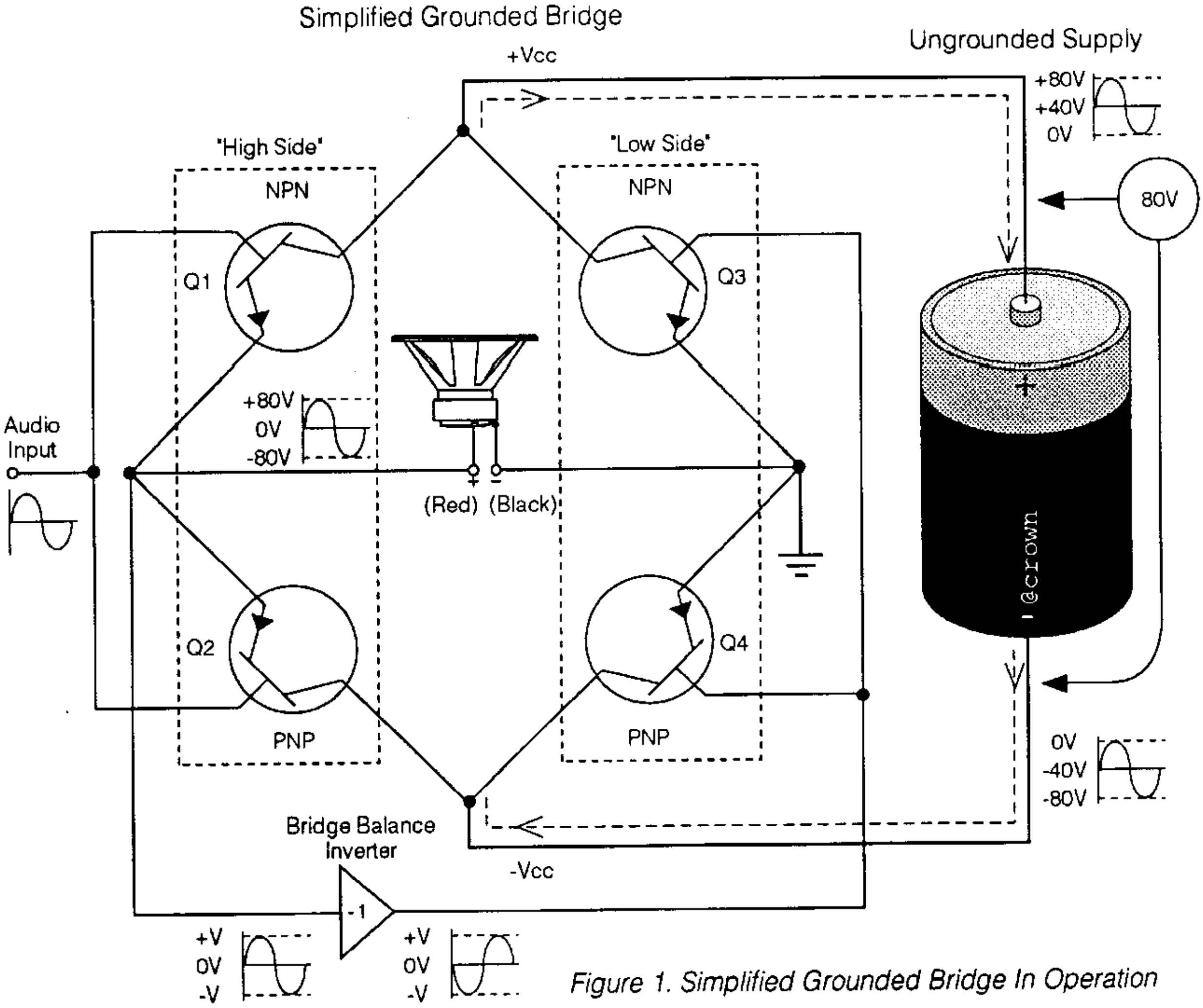

Figure 1. Simplified Grounded Bridge In Operation

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.

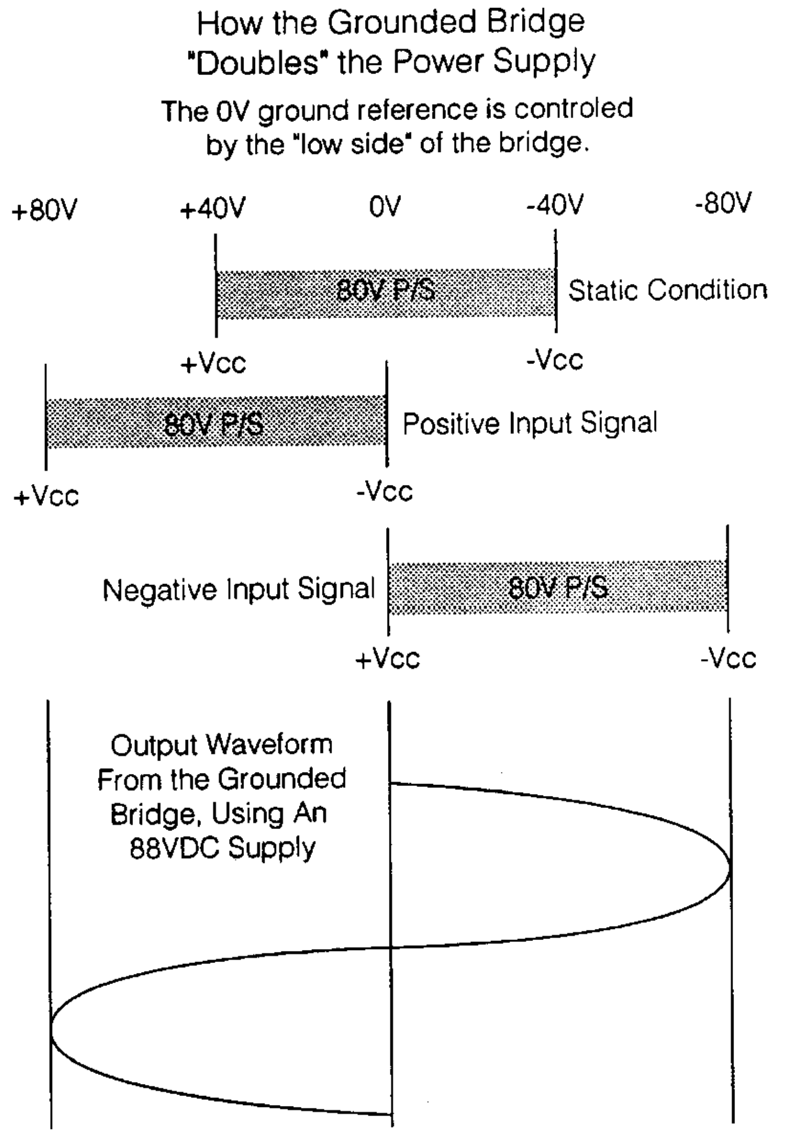

Figure 2. Power Supply Shifts With Audio

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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.

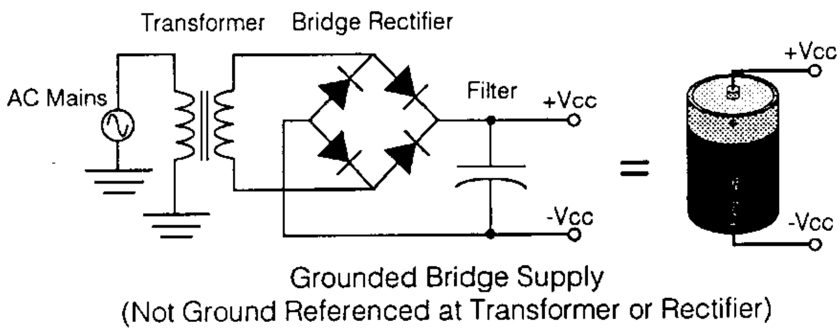

Figure 3. Ungrounded Power Supply

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.

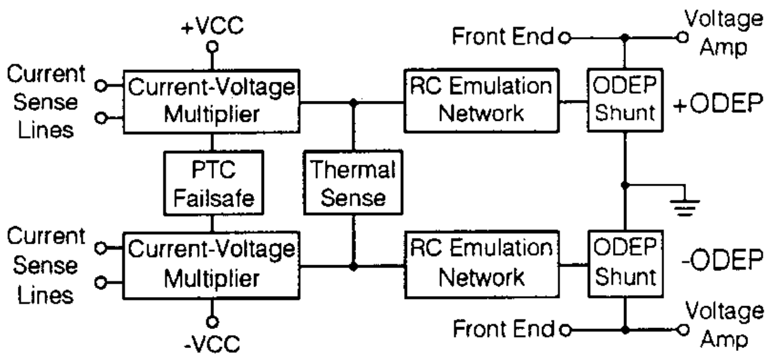

Figure 4. Basic ODEP Block Diagram

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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.

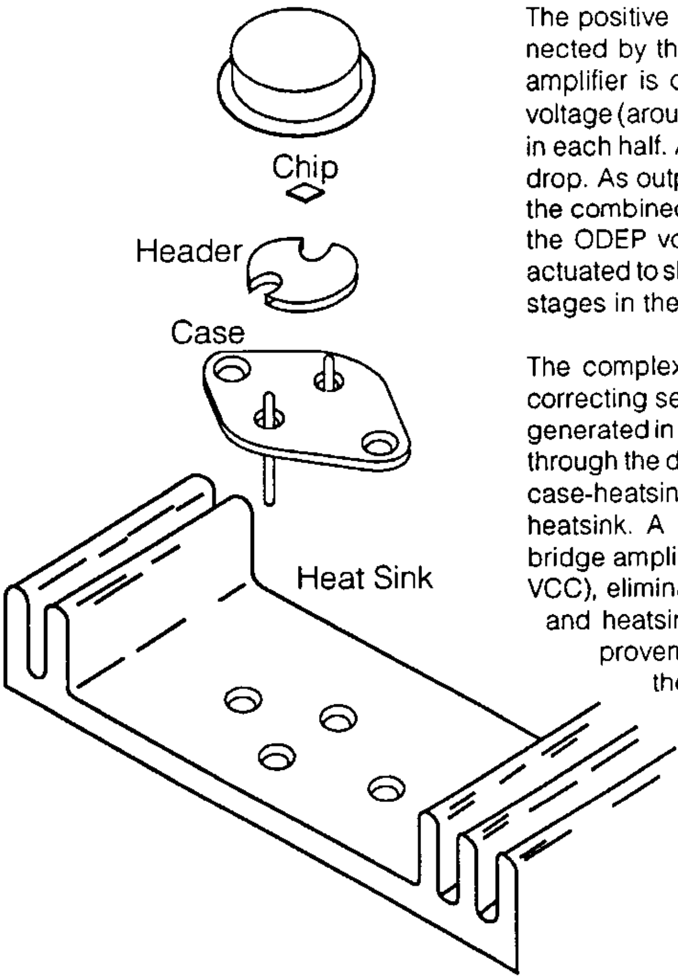

Figure 5. Heat Dissipation Structure

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

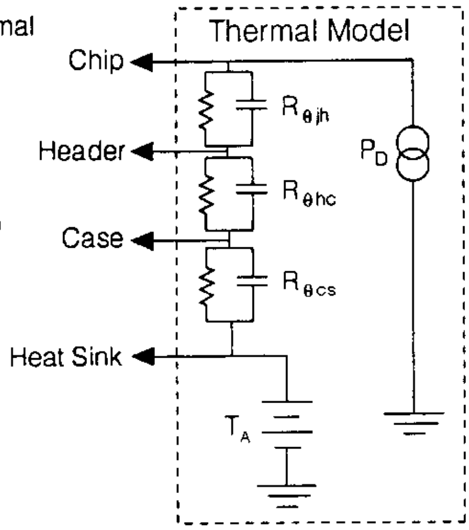

Figure 6. ODEP Electrical Emulation of Thermal Conditions

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.

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.

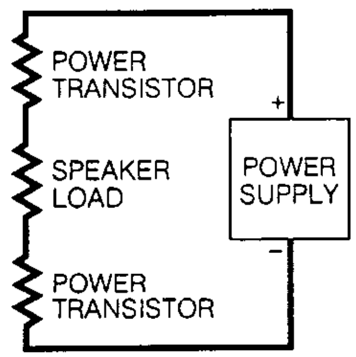

Figure 7. Audio Application

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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.

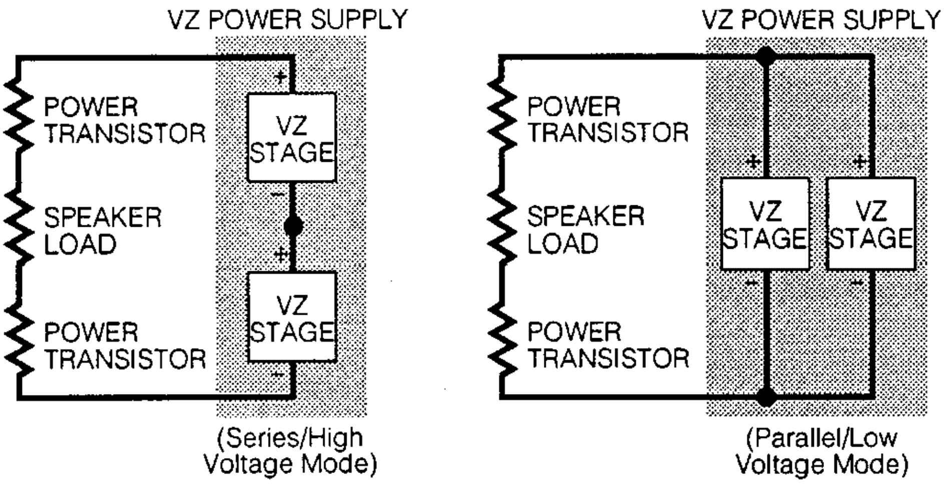

Figure 8. Examples of VZ Operation at High Signal Levels (Left) and Low Signal Levels (Right)

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.

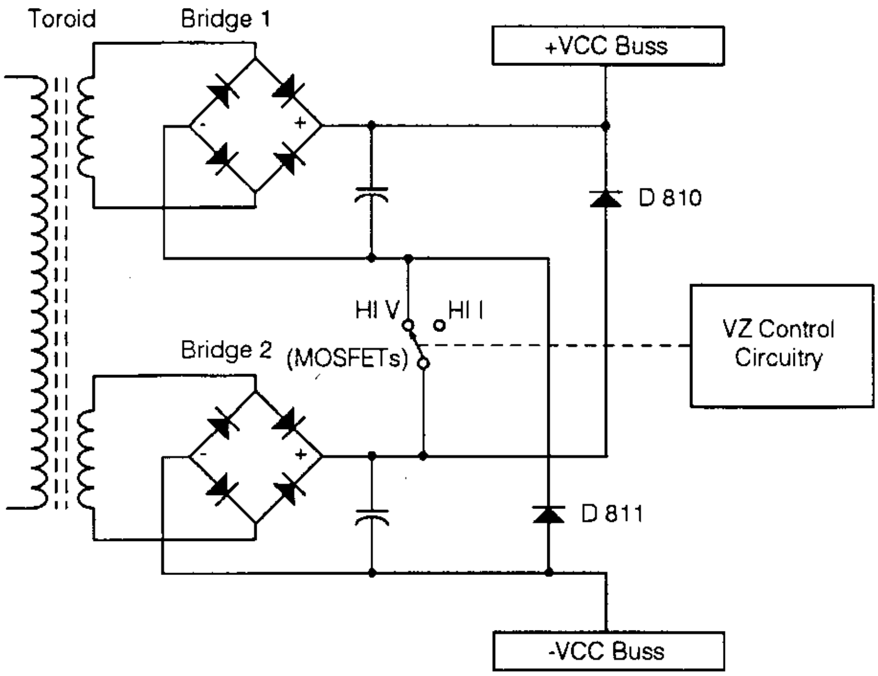

Figure 9. VZ Switch Operation

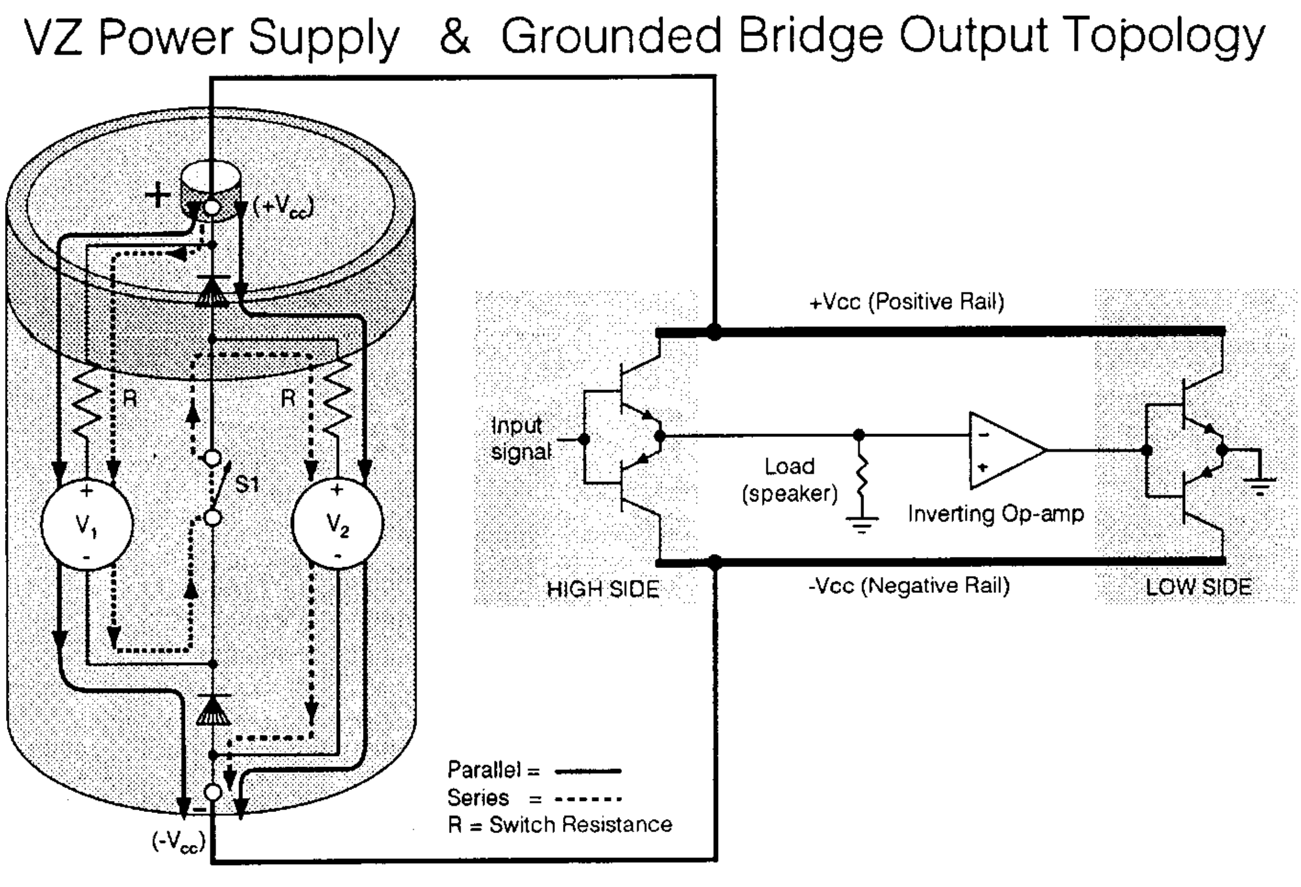

Figure 10. VZ Combined With The Grounded Bridge

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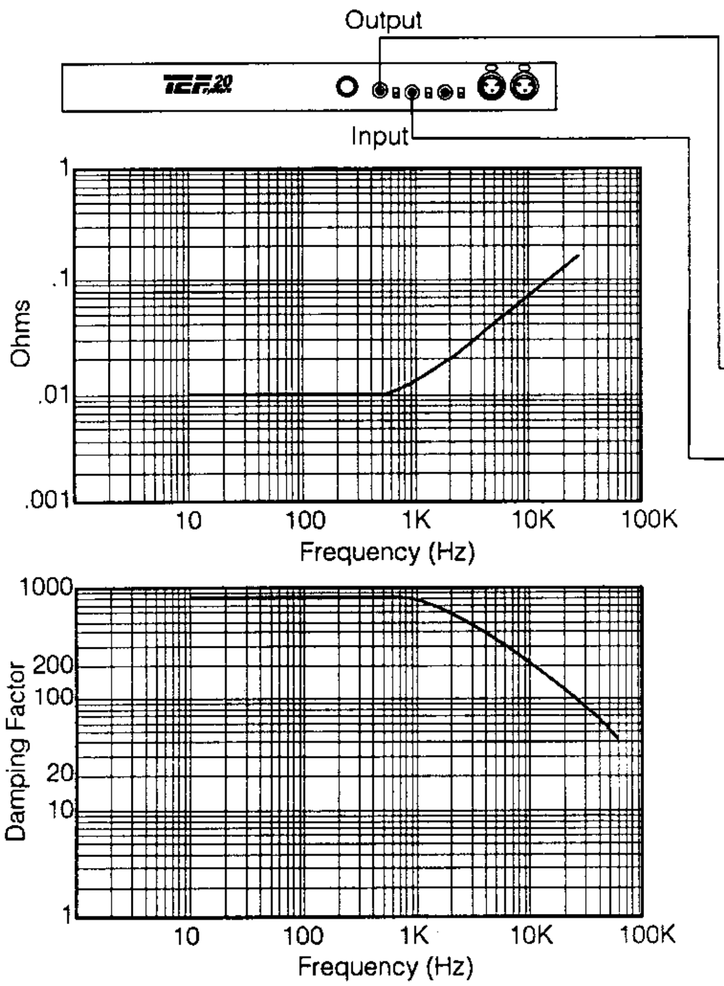
Specifications

Many specifications are important when deciding which amplifier product is best suited for a particular application. These specifications fall into a variety of categories, but primary include power, sonic quality, features, and economy. What follows in this section is a breakdown of several important electrical specifications, plus a few notes on other types of specifications and features pertaining to Crown products.

DAMPING FACTOR

Damping Factor of a power amplifier is a number found by dividing the load impedance by the amplifier output impedance (see Figure 1). The quantity and implementation of Negative Feedback (NFb) effects the amplifier output impedance, which in turn effects Damping Factor. Damping Factor is, therefore, largely a parameter of NFb. Greater control over the back EMF generated by the mechanical motion of the voice coil within the speaker magnet can be exerted from an amplifier with a higher Damping Factor (low output impedance) as opposed to an amplifier with a low Damping Factor (higher outputimpedance). In other words, better Damping is affected by improved negative feedback techniques, better back EMF control, and a lower overall output impedance. Crown uses a primary and several nested NFb loops for the best damping characteristics possible. Crown does not use output transformers or output relays because these devices greatly increase output impedance and reduce Damping.



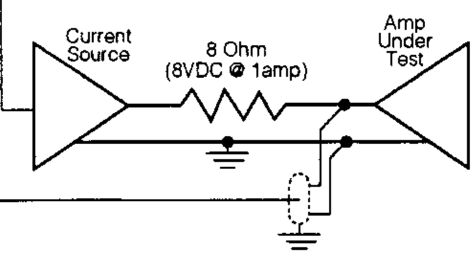


Figure 1. Damping Factor

Damping Factor is most important at lower frequencies where exacting control of large cone motion is required for clear, crisp, solid bass reproduction. The Damping Factor of most Crown amplifiers is greater than 1000 below 400 Hz, where it counts. The Macro Reference is enhanced to provide Damping in excess of 20,000 below 200 Hz.

POWER RATINGS

Through the years a variety of testing methods have appeared. Among these are the following: FTC Power, EIA Power, Dynamic Headroom, Music/Peak Power, and Musically Instantaneous Peak Transient Dynamic Headroom. The method published in most current Crown literature is called Maximum Average Power. This variety of test methods will often produce different power output values for the same amplifier and can, of course, be confusing to say the least.

The FTC testing method was first introduced in 1974. In an attempt to bring order out of chaos in the Hi-Fi industry of that day, the FTC issued a testing method that was supposed to end the great debate and allow comparison of apples with apples. However, the FTC test seemed to be a test geared toward an industrial shaker table type amplifier rather than an audio amplifier. According to the FTC testing method a number of audio amplifiers should have been rerated from a 200 watt amplifier to a 12 watt amplifier. The IHF (Institute of High Fidelity), who later became a division of the Electronics Industry Association (EIA), in 1975 realized there was much more to specifying an amplifier than just power. The EIA standard was completed in 1978 and has been accepted as a U.S. measurement standard since 1981. While the FTC and EIA standardized the way in which all manufacturers measure continuous or sine wave power, it became obvious most people do not usually listen to sine waves or continuous tones. The standards committee felt that the ability of an amplifier to deliver more than its rated power, with actual program material, would be useful information. In order to prevent further confusion by adding another power spec the test and term Dynamic Headroom was created. Dynamic Headroom being a logarithmic relationship between the rated output power (EIA standard) and the peak power output capability rated in dB. An amplifier's Dynamic Headroom depends largely upon how its power supply is designed. A high level of Dynamic Headroom is not necessarily a measure of quality. It simply tells the user that, under musical conditions, the amplifier could sound louder.

Crown presently uses a testing method which provides what is called Maximum Average Power. FTC testing requires a pre-heating period which unrealistically limits amplifier capacity under "real world" conditions. The EIA standard is a closer approximation of real world conditions with music, and often provides results similar to Max. Ave. Power. Maximum Average Power is measured by monitoring distortion and increasing output level until the specified distortion level is reached. At this point the RMS voltage is recorded. With the known load, this information is converted to a power measurement. This is not

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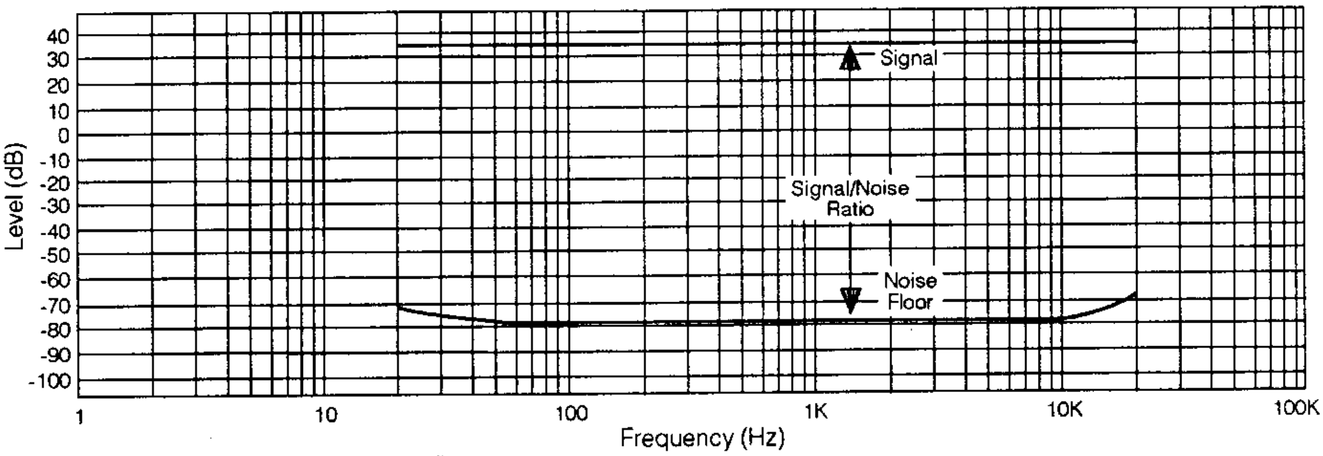

Figure 2. Signal To Noise Ratio

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a burst measurement, nor is it a "continuous" (1 hour sine wave) measurement. This quick and simple measurement is easily repeatable and does accurately represent amplifier capability with continuous music of any type.

SIGNAL TO NOISE RATIO

A ratio, generally stated in decibels, of rated output level to the RMS value of the random noise floor within the frequency range of interest. (20Hz-20KHz). See Figure 2. Limiting the frequency range with a band pass filter is called weighting. Most Crown amplifiers are rated to exceed 105dB signal to noise, and many are well above this level. The Macro Reference is also enhanced in this regard and is rated at 120dB, A-weighted.

INTERMODULATION DISTORTION (IMD)

A spurious output resulting from the mixing of two (or more) signals of different frequencies. SMPTE-IM measurements are a 4:1 ratio of 60Hz and 7KHz. After the IMD signal passes through the circuit under test it is fed back to the IMD analyzer, the original 60Hz/7KHz signal is nulled out and the remainder is distortion. The RMS value of the distortion component reading comes as a percentage of the original IM signal.

Crown does use this standard, and most IMD test apperatus commercially available provides the means to test with this standard. In most cases IMD is more important than THD because it is unpleasant to the human ear. Also, in most cases the THD will follow IMD. Most Crown amplifiers are designed to produce less than 0.05% IMD from rated output down to as low as -35dB.

TOTAL HARMONIC DISTORTION (THD)

Nonlinear distortion of a component characterized by the appearance in the output of harmonics other than the fundamental frequency when the input wave is sinusoidal. After the test signal passes through the circuit under test it is fed back to the THD analyzer. The original fundamental signal is nulled out and the remainder is distortion. The RMS value of the distortion component reading comes as a percentage of the original test signal. Though most published specifications state rated power at .1% THD, the real THD at the published power rating is much lower. Because this is a measure of harmonics generated, the percentage usually remains very low until clipping begins.

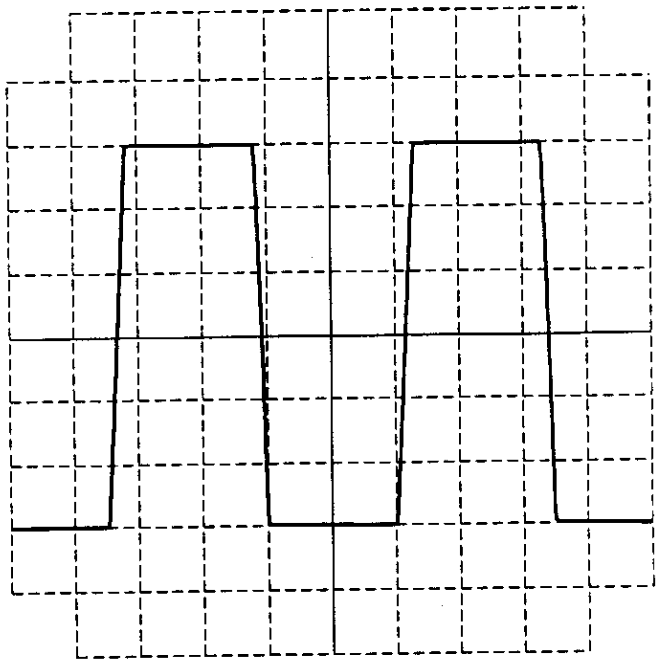

Figure 3. Slew Rate ($\Delta V/\Delta t$)

SLEW RATE

The maximum rate of change of a given waveform. Normally measured at the zero crossing point of the output waveform where the slope is greatest. The test itself is measured with a square wave where rise times are linear from negative to positive peaks. Most Crown amplfiers have a Slew Rate in excess of 13V/μsec in the stereo mode. This rate is more than adequate to provide distortion free reproduction of the input wave form at full power at frequencies up to and beyond 20 kHz. Slew rate is intentionally limited above the audio range to reduce to potential for RF burn-out. As output power requirements increase, given the same frequency requirements, the slew rate does need to be higher. This is why large amplifiers, such as the MA-5000VZ, have higher Slew Rate specifications.

INPUT IMPEDANCE

The Input Impedance, of an amplifier, is the impedance which the previous component's output source sees and must work into when the interconnect cables are connected. The input impedance of the amplifier(s) must be equal to or greater than the output impedance of the previous component. If it is not, load mismatch takes place resulting in loading down of the signal source. Typical input impedances are anywhere from 10K to 50K ohms. Input impedance can effect the noise floor at extemely low levels. The lower the imput impedance, the lower the noise floor (and the better the signal to noise ratio). This is why the MR has a lower input impedance than other Crown amplifiers.

FREQUENCY RESPONSE

This term indicates any amplitude variations in the output signal with respect to frequency. This measurement is made with a constant level input signal over the frequency bandwidth of interest (20Hz-20KHz). To be a meaningful specification, the numeric value must be associated with a particular frequency range, and is usually specified in terms of a level range in dB.

PHASE RESPONSE

Phase Response is the time difference (measured in degrees) between two waves that have the same frequency and are referenced to the same point in time. In an audio amplifier this is the propagation lag within the amplifier. Most amplifiers have no measurable delay, except at the upper end of the audio spectrum where the output terminating network reactance becomes a factor.

SOUND SYSTEM BASICS

Sound systems use various types of equipment for pickup, recording, playback, amplification, and processing. In general, sound systems are really a sub-category of communication.

APPLICATIONS

Sound systems are used to amplify (reinforce) live sound, reproduce pre-recorded material, or record live sound. While there are really dozens of unique types of applications, most fall into one of four broad categories.

Live Reinforcement

Live, or primary reinforcement involves pick-up of live sound. The sound is converted to an electrical signal by the microphones used for pick-up. Because most microphones have an output level of only a few millivolts, their output must be "pre-amplified" to line level (0 dBu) or higher for processing and power amplification. Finally the amplified output of the power amplifier drives one or more loudspeakers.

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Speakers convert the electrical signal to proportional changes in sound pressure which is, hopefully, intelligent to the intended audience. An example of live reinforcement might be a rock & roll band. Microphones on stage pick up the various sources (vocals, instruments, etc.). A mixer accepts the mic and instrument inputs and combines them into a common output. This output may or may not be delivered to special processing gear (EQ's, effects generators, crossovers...) on its way to the power amplifier(s). Usually there will be an amplifier and a set of speakers will be dedicated to driving a monitor system so that the musicians can hear themselves and each other in order to harmonize. Other amplifiers drive the speakers for the audience. Often primary reinforcement systems must be mobile. This often presents additional unique system requirements.

Secondary Reinforcement
Secondary reinforcement involves primarily playback of material such as a disc jockey would use. These systems are often the most simple, having little else but a playback source, a pre-amp (or small mixer), amplifier(s), and speakers. Often secondary reinforcement systems are fully stereo. Home audio systems would also fall into this category, even though the typical type of user would often be quite different.

Studio Reinforcement
Studios are usually the most complex systems. Most studios have live pick-up for reinforcement and recording, as well as playback of recorded material. Between the source and the amplifiers there is usually a myriad of specialized processing gear. These may include such items as equalizers, compressors, effects generators, noise filters, crossovers, and many other specialized items. Recordings may be done on (or played from) any number of recording mediums (ie. tape, disc, computer storage...).

Distributed and Fixed Installation Systems
Distributed systems are found in a variety of commercial applications. The source may be live or recorded, but the intent is to communicate to a people in a large area. An example would be a paging system where one source must be heard by people in different rooms, or even different buildings. Equipment may be very spread out and lines connecting equipment may be very long. Often distributed systems operate at 70V for reduced line loss. The output of the amplifier is usually stepped up (the Crown Com-Tech Series will drive a 70V line directly) to 70V. The speaker line runs out to a number of speakers in remote locations. Often it is desirable to only have a few watts of power delivered to any given speaker. Each speaker will have its own transformer to step down from 70V to the voltage necessary for the wattage desired.

SYSTEM LEVEL TROUBLESHOOTING

Unfortunately, not all sound system users know as much as they should about how the equipment works. Sound people have their own language, and most do know what they are doing. All too often, however, systems are installed by professionals but amatures use them. On the other side of the coin, new technicians fresh out of technical school do not have a good background in audio systems. The result is that communication becomes the weak link in the troubleshooting and repair process. The purpose of troubleshooting a system is to find what piece of gear in the system is defective. In some cases the problem is not the fault of any individual piece, but rather in incorrect hook-up or ground loop. The Grounding Techniques section will address this subject in detail.

HEAT

In a well designed system operating at (or not too far above) room temperature, heat should not be a major problem. All power amplifiers produce some heat. The amount of heat and how it is removed from the amplifier depends on how much power is being produced by the amplifier, the ambient temperature, the speaker load, whether the amplifier is convection or forced air, and the enclosure style. Most forced air Crown amplifiers draw cool air from the front and discharge the hot air from the sides. For these amplifiers, the ideal situation is two inches (minimum) side clearance. If additional rack fans are installed they should draw air out of the rack from behind the amplifiers. It is also recommended that amplifier be mounted without rack spaces separating chassis.

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