

The thermodynamics of power-amplifier operation

By David R. Engstrom

Thermal management techniques directly affect audio power-amplifier reliability and performance.

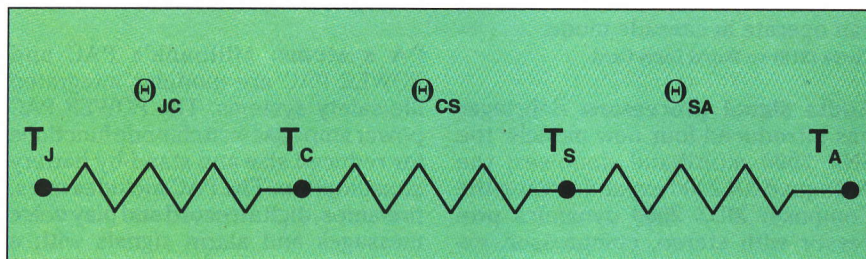


Figure 1. Thermal circuit.

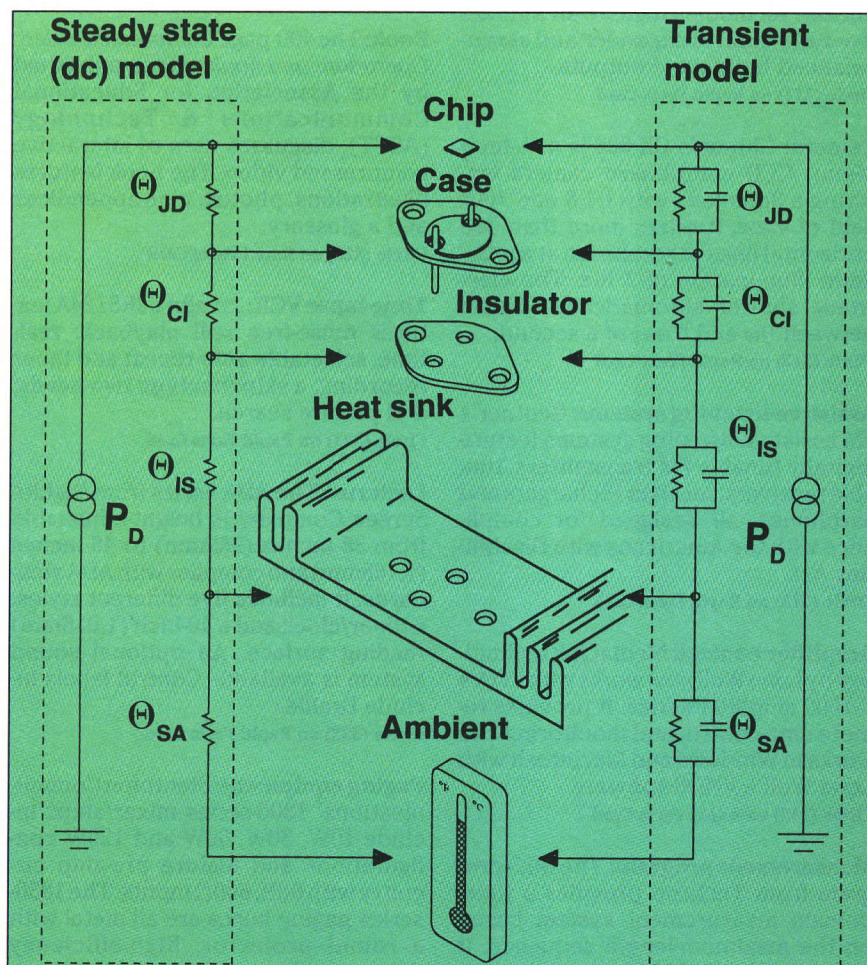


Figure 2. Between the transistor chip and ambient air, there are several thermal resistance interfaces.

In today's market, most professional audio amplifier designs are semiconductor-based. Therefore, audio power-amplifier reliability and performance are directly affected by the thermal management techniques incorporated into the design. Semiconductors have a basic characteristic that affects reliability: the junction operating temperature. The safe, efficient and economical removal of heat from this junction is the purpose of thermal management.

For maximum heat dissipation, the method of cooling (natural convection vs. forced convection) and the heat-sink style must be considered early in the design stage. The primary purpose of a heat sink is to dissipate heat and maintain an acceptably low device temperature in the semiconductor's environment of normal operation.

In selecting a heat sink, the designer must know four specific parameters about the application:

- The amount of power, in watts, being dissipated by the amplifier's output stage.
- The maximum allowable temperature of the semiconductor junction (available from the manufacturer's data book).
- The maximum temperature of the surrounding air.
- If forced air is used, the velocity of the air in cubic feet/minute (CFM).

The thermal circuit

An audio power amplifier must deliver substantial levels of power. The heat that it generates must be removed to avoid destruction of the amp. Heat is similar to electric current: It flows from a point of higher concentration — high voltage — to a point of lower heat concentration — low voltage. To carry the analogy further, just as some materials have a lower resistance to current flow than others, so some ma-

Engstrom is with Crown International's technical support group.

terials have lower thermal resistance.

As resistance decreases within an electrical circuit, the current flow increases. In a thermal circuit, a lower thermal resistance to heat flow increases heat transfer. Thermal resistance is the rate of heat conductivity of a material (usually metal). Various metals will conduct heat differently. Thermal resistance, like electrical resistance, is rated in ohms. Between the transistor chip and the ambient air, there are several thermal resistance interfaces:

- Between the transistor chip and the case.
- Between the transistor case and the insulator.
- Between the insulator and the heat sink.
- Between the heat sink and the ambient air.

Many audio amplifiers have the insulator interface because insulators are used between the output transistor and the heat sink. This fourth interface increases the quantity of thermal junctions. In most Crown amplifiers, the heat sink is used as the power-supply source for the power output devices. This direct connection maintains good electrical conduction with the power transistors and reduces the quantity of thermal resistance layers, allowing for higher efficiency of heat transfer

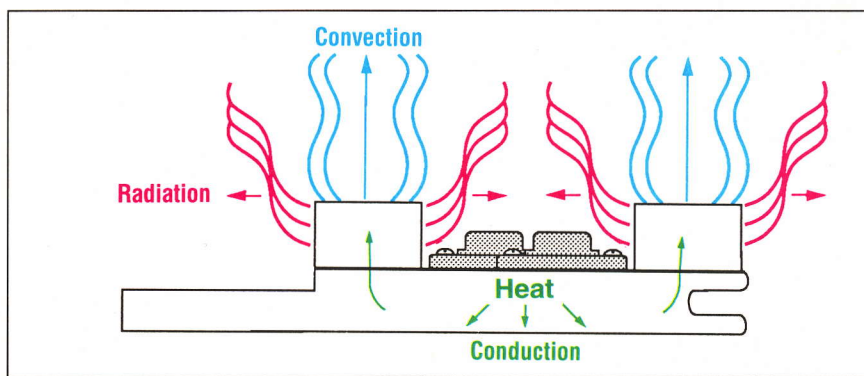


Figure 3. The purpose of the heat sink is to dissipate heat through conduction, convection and radiation.

and dissipation.

The total thermal resistance is the sum of the separate interface resistances. Any heat should be dissipated as quickly as possible. Therefore, the designing engineer uses semiconductors, heat-sink compound and heat sinks with the lowest possible thermal resistance. The heat generated by an output transistor can be defined as the prod-

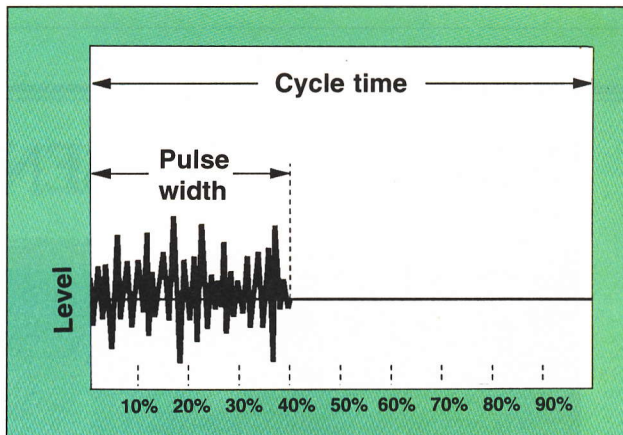
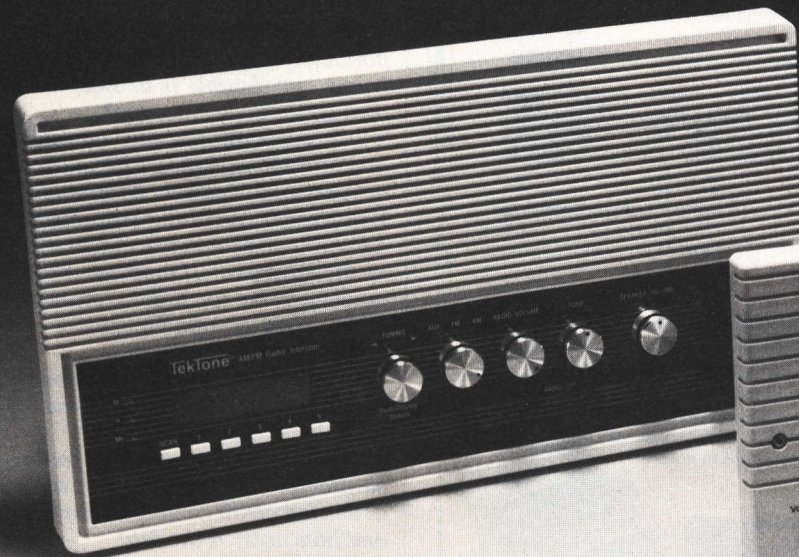


Figure 4. The duty cycle of a waveform indicates the percentage of each cycle (period of time) that is taken up in the pulse width.

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Specifying power amps

By David Marsh

As a sound-system consultant, I select and specify audio products from which competing sound contractors may choose when bidding for an installation. Products I list in the specification as "approved" or "accepted" should be equal in their ability to fulfill the system design requirements

Marsh is with Pelton Marsh Kinsella, Dallas.

and providing similar sound quality. I have been asked how I chose a power amplifier for a particular situation. Do I just pick one with the same power rating as the loudspeaker it is driving? Do I consider only those manufacturers whose reps take me to lunch?

Selecting an audio power amplifier for a commercial sound installation may seem mundane compared to selecting a mixing console or a loudspeaker. The difference in sound quality from one power amplifier to

another is not as obvious as what we hear when comparing loudspeakers or microphones. Nevertheless, a power amplifier is a basic component of any sound system, and its performance affects sound quality in several ways.

I begin every sound-system design by choosing the most appropriate type of loudspeaker system (such as single cluster, multiple cluster or distributed) and loudspeaker components. As part of this process, I must know what sound-pressure level (SPL) is required at the most distant seats covered by each loudspeaker. Some amount of headroom must be added to this SPL to allow for peaks in the program material (typically 10dB for speech and music systems). I use the total SPL (nominal + peak) along with the loudspeaker's sensitivity rating to calculate the total electrical power, in watts, required of the power amplifier.

I usually choose the size of the power amplifier according to the EIA power rating for the intended load. However, the FTC power rating (with its tighter distortion parameters) might be more appropriate in rooms that have optimized listening conditions, such as studio control rooms. The 1.0% THD allowed by the EIA rating within the -3dB bandpass is generally appropriate for most commercial sound installations.

Having determined the output requirements of the power amplifier, I consider its functional requirements within the system:

- Will the amplifier be used in a portable equipment rack? If so, how heavy and durable is it? How much rack space does it occupy?
- Will an operator need to adjust the amplifier during a show? Should front- or rear-panel controls be provided? What types of metering are required?
- If the sound racks are inaccessible to the operator, should the power amplifiers be remotely controlled? What types of remote control are available?
- If the amplifier is not to be tampered with, can the controls be secured? How reliable is this security?
- Can sufficient convection cooling be provided for the amplifier racks, or will forced-air cooling be required, and how noisy is the fan?
- What types of internal overload protection and speaker protection are appropriate? For example, must you remove the unit from the rack and open it up to change a fuse?

Some products offer unique features that can affect the overall system design. For example, it might be desirable to combine limiting, equaliza-

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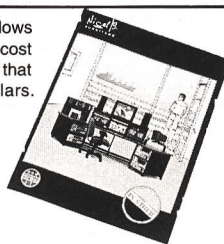
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tion and crossover functions within the power amplifier unit via modules or octal sockets. If the size of the system or space constraints suggest a mainframe approach with power-amplifier modules, I might use only modular equipment on the rest of the system.

The answers to these questions considerably narrow the field of choices. Among the remaining candidates, I review the technical specifications—including frequency response, distortion, damping factor and power efficiency and their relative importance to the overall system design. Damping factor might have little relevance in a hotel restaurant background music system using 8-inch loudspeakers with transformers. Distortion specs might have little relevance in a sound-masking system. However, they are both important in a sound-reinforcement system for a performing-arts center.

Finally, I consider less technical factors: cost, reliability (based on our experience) and warranty terms. Once the system is installed, these last two might be more important to the owner than everything else.

uct of the voltage drop across the collector-to-emitter junction, multiplied by the current flow through the junction ($P=EI$).

The thermal equivalent circuits so far discussed are somewhat incomplete. If our power amplifier were designed as a dc power source, it would eventually reach a steady state (heat generated equals heat conducted away), and the thermal characteristics would become linear.

With transient-type signals (such as in audio), the model takes on nonlinear characteristics. Thermal rise and decay characteristics respond exponentially with time. Thermal modeling, therefore, can be accomplished with RC (resistor/capacitor) networks, and the term 'thermal resistance' might be more aptly named "thermal transient impedance."

The design engineer's control over the interface impedances is somewhat limited. Thermal impedances within a transistor (yes, there are two) are not at the engineer's disposal, though a semiconductor with a low thermal impedance value is usually selected. The next thermal impedance encountered, external to the semiconductor, is the interface between the transistor case and the heat sink, if there is no insulator. The final thermal impedance is the heat-sink-to-ambient-air interface.

The heat sink

Now that we have seen where power

amplifier heat comes from and the characteristics of conduction to our heat sink, let's discuss the function of the heat sink itself.

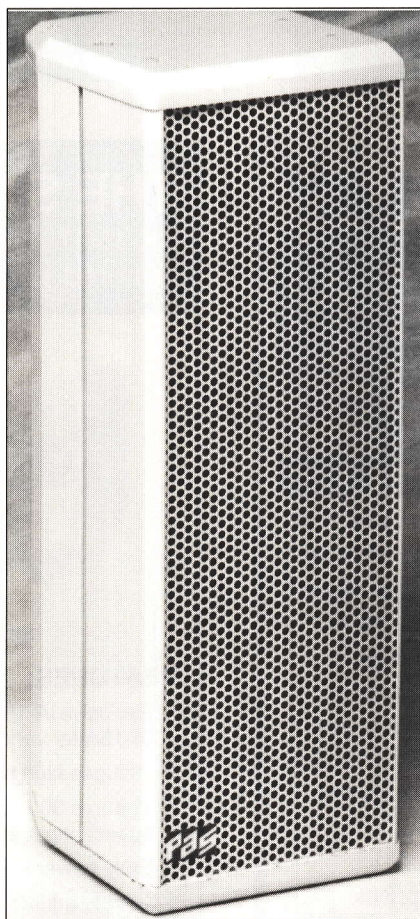
Dissipation from a heat sink results from the interaction of three distinct modes of heat transfer:

- **Conduction:** The transmittal of heat throughout the material of the heat sink. Because of the principle of entropy, heat will always flow from points of higher to points of lower temperature. The heat conducted from a power transistor is transferred to the ambient air by radiation or by radiation with convection.
- **Convection:** The transfer of heat from

one place to another by the actual motion of material. The rate of heat flow by convection from a solid surface (the heat sink) to a fluid (in this case, air) is a function of the velocity of the air and the surface area of the heat sink in contact with the air. The contact of air with a hotter heat sink reduces the density of the air and causes it to rise. Circulation resulting from this phenomenon is known as free or natural convection.

- **Radiation:** The continual emission of energy from the surface of a heat sink. If you place your hand above the hot heat sink but not in contact with it, heat will reach your hand by way of

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The elimination of heat-sink thermal gradients

By Bob Rodgers

All power amplifiers generate heat. The long-term success or failure of a power-amplifier design can probably be traced to the effectiveness of its heat-removal system. Designers approach the problem of waste heat by first looking at how the amplifier will be used. An amplifier designed for use in a refrigerator, for example, won't need as efficient a cooling system as one designed for a sauna.

Unfortunately, the sauna owner will always buy the amplifier that is designed for the refrigerator because it costs less. This is one of the hardest lessons for designers to learn —

Rodgers is senior project engineer at Altec Lansing, Oklahoma City.

which is perhaps why companies hire product marketing managers and let the designers focus on waste-heat removal.

The successful removal of heat involves many considerations, including heat-sink design, cooling method (fan-cooled or convection-cooled), ef-

iciency of the amplifier's topology and power supply, mounting technique for power transistors, chassis design, and location of other heat-producing components, such as the power transformer. Designers sometimes overlook the elimination of thermal gradients on the heat sink,

or, more specifically, the output devices. Failure to eliminate them can ruin an otherwise excellent amplifier design by creating a weak link in the chain of factors that contribute to the product's reliability.

Consider the heat-sink assembly pictured in Figure A. Several power transistors are mounted on the U-shaped heat-sink chan-

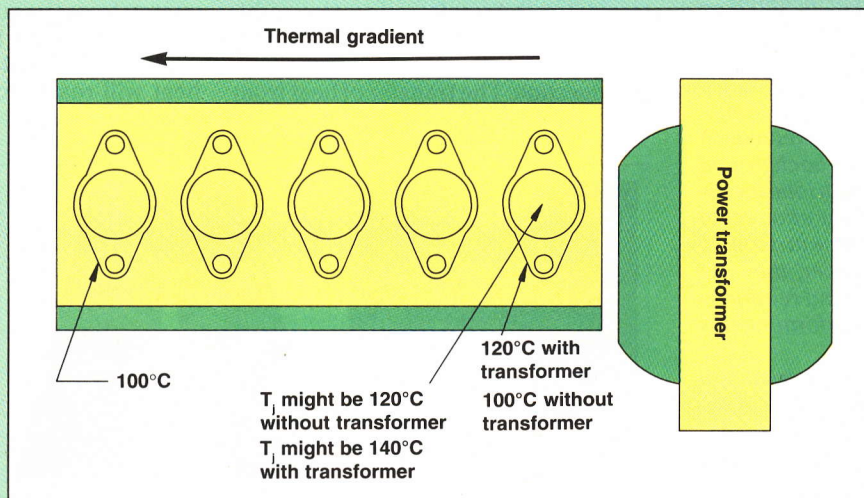


Figure A. A thermal gradient is introduced to this basic heat-sink assembly by the proximity of the power transformer.

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nel. The transistors are equally spaced so that each has the same amount of heat-sink surface area. If we assume that no thermal gradients exist, the heat-sink surface temperature under each device should be the same.

Now suppose that, because of mechanical constraints, the power transformer must be located near one end of the heat sink. Can the transformer actually get hot enough to radiate thermal energy into the heat sink? If you said no, you must be a company president. Transformers can get quite hot — certainly hot enough to affect the device temperatures on a heat sink. What is not known is how much effect the transformer's proximity will have. Designers who don't take the time to find out will likely underestimate the problem.

A power transformer designed with a class-130 insulation system can reach a maximum temperature of 130°C (266°F) under continuous operation. That's hot enough for the power transformer to radiate thermal energy into a heat sink. As shown by the blue arrows in Figure A, the output transistor closest to the power transformer operates at 120°C. This is the surface temperature of the heat sink directly under the center of the device. At the other end, the temperature is 100°C. This 20°C difference creates a thermal gradient across the length of the heat sink.

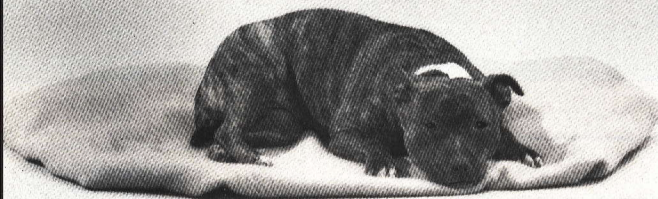
The actual junction temperature inside a device might be 10°C to 20°C hotter than the surface of the heat sink, which means the internal junction temperature of the transistor might be as high as 140°C under normal conditions. If the device has a maximum junction temperature rating of 150°C, we have only a 10°C safety margin. In higher ambient temperature environments, this transistor will likely fail.

If the transformer can't be relocated, one way to eliminate the gradient is to redistribute the devices asymmetrically along the heat sink, which forces them to operate at the same temperature. The heat-sink surface area will therefore be reduced for the leftmost device, and there will be progressively more surface area for the devices closest to the power transformer. The devices operate at the same temperature and equally share the thermal stress.

It's easy to see what happens when a heat-producing component is located in close proximity to a heat sink. Did you know that a fan can induce a thermal gradient? If you said no, you must be a VP of engineering.

Suppose a fan replaces the transformer in Figure A and is positioned

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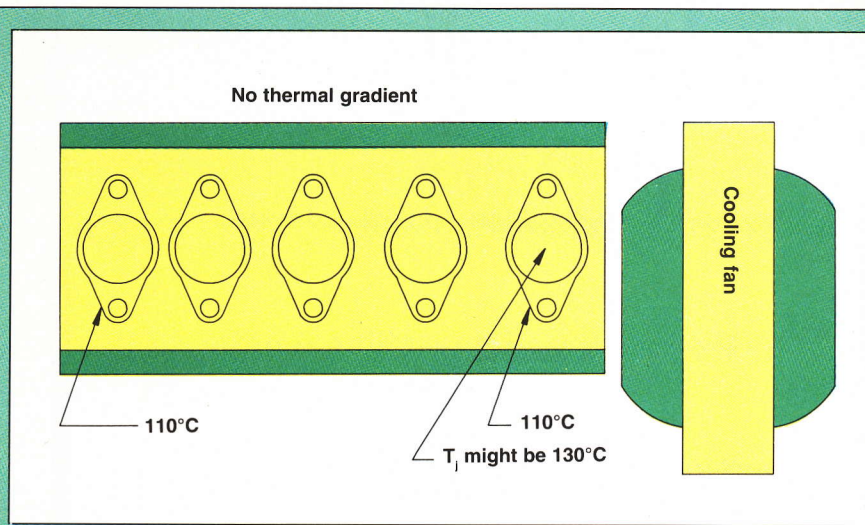


Figure B. An asymmetric spacing of the transistors eliminates the thermal gradient.

so that the air flows down the center of the heat-sink channel. (See Figure B.) The transistor closest to the fan will run the coolest. Each preceding device will operate at a progressively higher temperature relative to its distance from the fan. The device that is farthest from the fan is the most stressed. In this case, you can eliminate the thermal gradient by providing more heat-sink surface area for the device farthest from the fan and

progressively less for each succeeding device.

Another technique allows you to adjust the surface area for each device, yet keep equal spacing between the transistors, by graduating the heat sink's height. For example, when the power transformer is next to the heat sink, you can increase the height of the heat sink at the right end.

In your future equipment evaluations, if you observe the possibility of

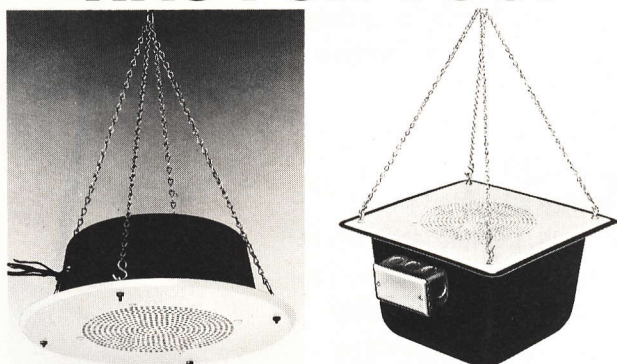
a thermal gradient and question the manufacturer about it, then I've done my job. If you don't, you must be a salesman.

Author's note: The heat sink and device temperatures shown in Figure B are actual measurements taken from a popular commercially available amplifier. The illustrations have been simplified for clarity.

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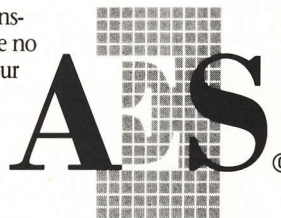
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Heat exhaustion

By Bob Lee

In an audio power amplifier, any electrical energy coming in through the mains cable that doesn't leave through the audio power outputs (not counting the minuscule amounts of light energy from LEDs or mechanical energy from cooling fans) must dissipate as waste heat. Crest Audio takes a 2-step approach to managing waste heat in its Professional series amps: minimize waste heat by improving the amplifier's power efficiency, and quickly and efficiently remove the remaining waste heat from the chassis.

One long quest in amplifier design has been greater efficiency without audio degradation. If audio wasn't so dynamic and didn't span 10 octaves, it would be so easy! But an audio power amp must reproduce a signal faithfully regardless of its spectral content, and with enough power reserve to handle repeated kick drums, cymbal crashes and other dynamic extremes without distortion or failure. Even an incredibly efficient amp is useless if it sounds bad.

Therein lies the challenge. The

Lee is technical support specialist for Crest Audio.

higher-powered amplifiers in the Professional series — the 4801, 6001, 7001, 8001, 10001 and 10004 — use class-H operation in their output sections. This amplification mode offers efficiency improvement with little effect on the audio signal.

Class-H operation uses dual bipolar power-supply rails: positive and nega-

tive low-voltage rails and high-voltage rails. When the output signal is below the one-third power level, the output section essentially operates in Class AB, powered by the low-voltage rails alone. When the audio signal waveform voltage reaches a threshold several volts below the low-voltage rails, transistors between the low

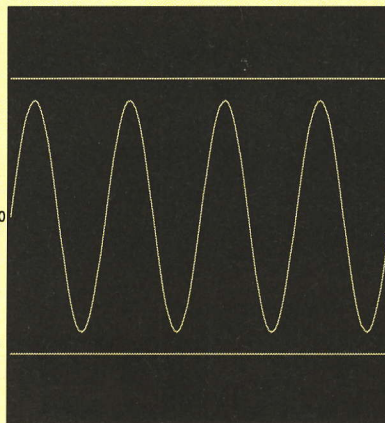


Figure X. In Class H operation, the output section is powered by the low-voltage rails alone when the output signal is below the one-third power level.

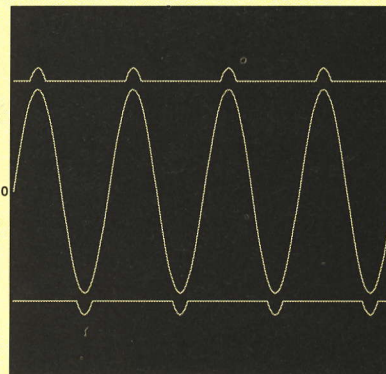


Figure Y. When the audio signal waveform voltage reaches a threshold several volts below the low-voltage rails, transistors between the low and high rails start to conduct, modulating the low rails to follow above the signal waveform.

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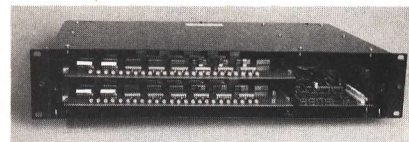
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Power transistors
are mounted to
these four surfaces

Arrows represent
cooling airflow
through heatsink

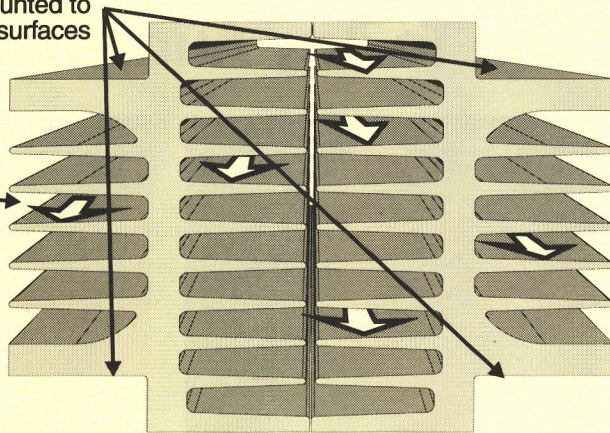


Figure Z. Heat sinks are set back-to-back to form a "tunnel." Fans produce an airflow through the tunnel.

and high rails start to conduct, actually modulating the low rails to follow above the signal waveform.

As a result, the low-voltage rails do full-time duty, and the high rails are only used for the peaks; they are not expended until necessary. Less power-supply energy goes unused, which in turn generates less waste heat. The increased efficiency also reduces power demand on the mains, meaning lower electricity and wiring

costs. In this age of super-high-power amplification, that's important.

The amplifier must still remove waste heat, however minimized it is; excessive temperature is too hard on electronic circuitry in general and transistors in particular. Therefore, you need good heat-sink design and efficient cooling airflow. A Crest Audio Professional-series amplifier uses extruded aluminum heat sinks, to which the output modules are

mounted, set back-to-back to form a "tunnel." One or two (depending on the model) rear-mounted fans pressurize the chassis and produce a straight-through airflow through the tunnel, which exhausts through the slots in the faceplate.

Because the airflow through the heat-sink tunnel is straight and free of bends, curves and large obstructions, it is relatively laminar (that is, free of turbulence), which would cause back pressure. Minimizing back pressure in the cooling air helps guarantee that the airflow will be adequate at virtually any power level. In all models except the 8001, the cooling fans are driven by a dc voltage produced by a temperature-sensing circuit monitoring the heat sinks. This circuit sets the fan speeds according to the specific cooling needs to keep fan noise to a minimum. A small array of exhaust holes in a corner of the chassis creates a cooling draft for the power transformer.

An extruded heat sink serves two functions: conducting heat away from the transistors and other heat-producing devices, and transferring the heat to the air, which removes it from the chassis. The heat sink's capacity to absorb heat from the heat-producing

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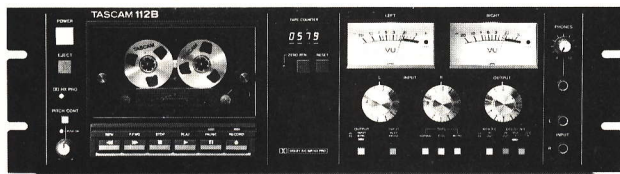
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devices is often called thermal mass. To maximize a heat sink's thermal mass, the material from which it is made should have a high specific heat. Fortunately, aluminum is a light-weight metal and has a high specific heat: It takes 0.22 kilocalorie (0.256 watt-hour) to raise the temperature of 1kg of aluminum 1°C. A kilogram of steel will rise 1°C when it absorbs only 0.11 kilocalorie of heat.

The shape of the heat sink places its mass against the power transistors (with mica insulators and thermal grease in between for electrical insulation) and provides an extremely large surface area exposed to the cooling airflow to dissipate the heat. The cooling fins themselves are fairly thick to promote the conduction of heat to their surfaces, which have a knurled texture to increase surface area.

If the cooling air is too free of turbulence, it forms a boundary layer: The same layer of flowing air stays in contact with the heat-sink surface through its entire length. A boundary layer inhibits cooling by dumping the entire burden of absorbing heat on a small portion of the airflow, leaving the rest of it unused.

To prevent boundary layers, Crest Audio mounts the power transistors to the heat sink with screws that are long enough to protrude through the heat sink and into the cooling airflow. This design, along with the knurling of the heat-sink surface, creates a microturbulence that keeps fresh layers of air circulating onto the surface but is small enough to prevent significant increase in back pressure against the fan.

the upward-moving convection currents of the warm air. However, if you hold your hand at one side of the heat sink, it still becomes warm, even though conduction through the air is negligible and your hand is not in the path of the convection currents. Energy (heat) is reaching your hand by radiation.

Natural vs. forced convection

Natural convection is the process of allowing the air that surrounds a heat sink to remove heat without use of externally forced air movement. This heat-removal process is the result of the natural physical behavior of air molecules as they gain heat. The actual flow of heat is caused by a difference in temperature. This temperature difference between the heat sink and the surrounding air causes air movement, creating its own natural air velocity.

Heat-sink dimensions and orientation

Forced air

By Richard Wood

The term "hot air" can be used to best describe the subject of forced-air cooling for electronics. In reality, cooling is the most important part of any electronics system. All electronics have a maximum operating temperature. Above this temperature, manufacturers will not guarantee performance, and component failure is likely. Air cooling directly affects the need for product maintenance and operating longevity.

Heat within equipment racks results from the internal resistance of individual components. This resistance blocks the flow of moving electrons, which causes heat buildup. Without adequate airflow, local hot spots will occur. These hot spots develop an air film, which resists the flow of cooling air.

There are several factors that you must consider when designing an air-cooling system. One of the most important of these is to determine air velocity. You must know the component body and surrounding air temperature, which combine to determine the amount of heat that must be removed.

The next factor is the quantity of air. This figure is based on the amount of heat to be removed and the amount of increase in coolant temperature that can be permitted. Once this figure is known, it is best to provide a 25% overhead to the amount of excess air required.

Broken down into its simplest components, the amount of airflow required to cool a system is a function of the input wattage to the system's components and the allowable temperature increase within the system. With these two factors, you can calculate the required airflow:

$$Q = C_p MT$$

where Q is the heat removed, M is the mass of the coolant, C_p is the specific heat of the coolant, and T is the desired temperature rise through the system. In general, the temperature increase of the surrounding air coolant should be limited to about 10°C or 18°F.

The amount of air pressure required is also a critical factor in component cooling. As hot pockets develop within an electronics rack, the surrounding air pressure changes. The velocity of the forced air must be adequate to evenly distribute the air even with

Wood is engineering manager at Zero Stantron.

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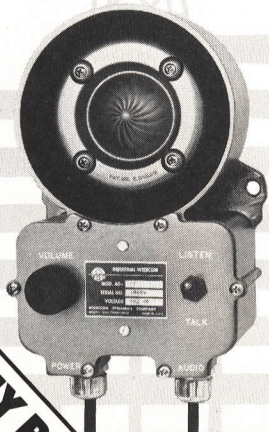
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changes in internal pressure. Higher-pressure areas will require greater air velocities.

When heat differs within a rack, the differences in internal pressures will vary greatly. In some cases, these differences will require the use of a separate fan to create different air velocities.

In any case, it is important to match the operating specifications of the fans to the required cooling needs. It is just too easy to take a simple approach by using a high-speed fan. The extra power will require a fan with a larger and heavier motor. The additional weight will often add to the cost of mounting and supporting the fan.

In reality, increasing fan power does not result in a direct increase in cooling power. If you double the fan horsepower, the heat transfer rate will increase by less than a quarter of a percent. The actual needs of electronics systems can only be determined by analysis.

Most card-cage assemblies provide spacing to maintain an even pressure over the general area. However, the same cannot be applied to individual component spacing on a printed circuit board. These considerations are the responsibility of board designers who must consider the need for heat dissipation.

Finally, we must consider the air resistance created by the use of filtering. The denser the filter, the more resistance to airflow. The filter must have a sufficient area to permit adequate airflow while blocking dust particles. In general, a filter should block particles as small as 5 microns. Some filters will use an adhesive coating to capture dust particles. When using a coated filter, take care that the adhesive material is not drawn into the fan.

Fan location

The most misunderstood area of rack cooling, although the easiest for a system installer to control, is the location of the fan. The fan assembly should be located at the air inlet to the equipment, not at the air outlet. For most racks, this means that the fan should be located in the lower section of the cabinet. This arrangement allows the air to be drawn into the rack and filtered before reaching the equipment.

Avoid the urge to place fans directly at the bottom of the cabinet so that they blow air directly up. Dirt and other material lying on the floor will be sucked onto the filter and even into the cabinet.

When you are considering possible

locations for the fan, the old adage "hot air rises" also applies. If the fan is positioned at the top of the rack, then the forced air will have to fight against the pressure created by the heated air within the rack. This condition will in turn increase the fan power requirements, giving you little or no gain in air cooling. However, if air is forced in from the bottom of the rack, it will be heated by the internal components.

The natural convection process will force the air up and therefore increase air turbulence. This condition is similar to the bumpiness of an airplane landing during the summer. In a rack, the air turbulence helps in the heat-transfer process. The most efficient design is to draw air in from the bottom and exhaust air from the top.

Design considerations

Fans are available in several configurations. Two of the most popular are fan trays and packaged fan assemblies. The former blows air horizontally through the rack; the latter can direct air in a 90° pattern. Fans are usually not seen, but they certainly can be heard. Noise from fans can come from the internal components or from the movement of air through the rack.

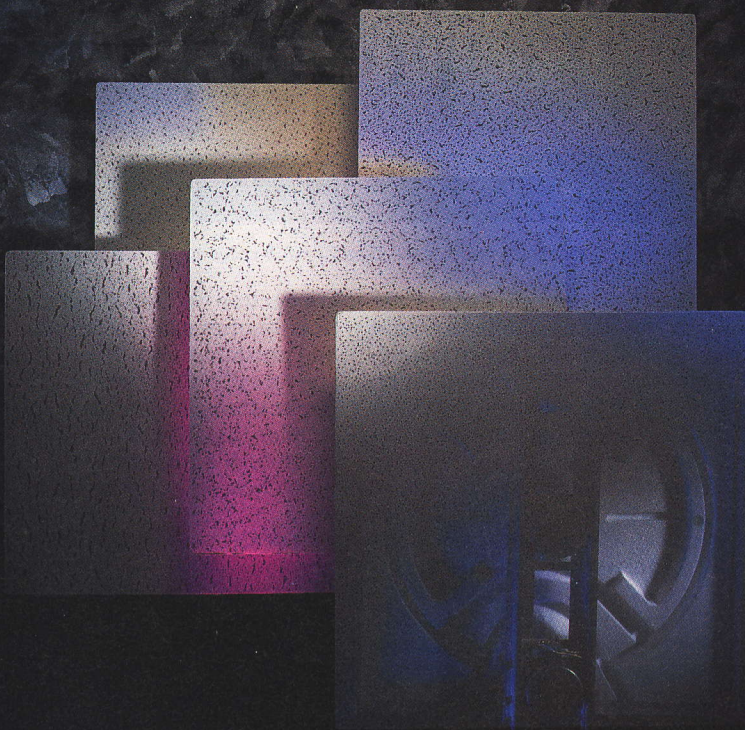
In designing cooling systems for racks, you should always be prepared to deal with the "what if" principle. Fans are electromechanical devices and will eventually fail. The typical life expectancy of a fan should be about 75,000 hours, depending on operating conditions. The absence of cooling could lead to an overheat condition, which, without a method of system shutdown, will result in equipment damage.

There are several ways to design cooling systems to avoid equipment overheating. The first is to operate different cooling fans off of separate power supplies. If you lose one power supply, at least half of your cooling will be operational. The next method is to use a relay system. If you experience power loss, a relay will activate a cooling system driven by an alternative power supply. You can also consider the use of fans driven by dc motors. If you lose power, a battery system can power the fans for a limited time.

The design of cooling systems is one of the most critical, yet often overlooked, aspects of electronic system design. Although the problem is complex, most design system aspects can be brought down to an understandable level with the help of rack manufacturers.

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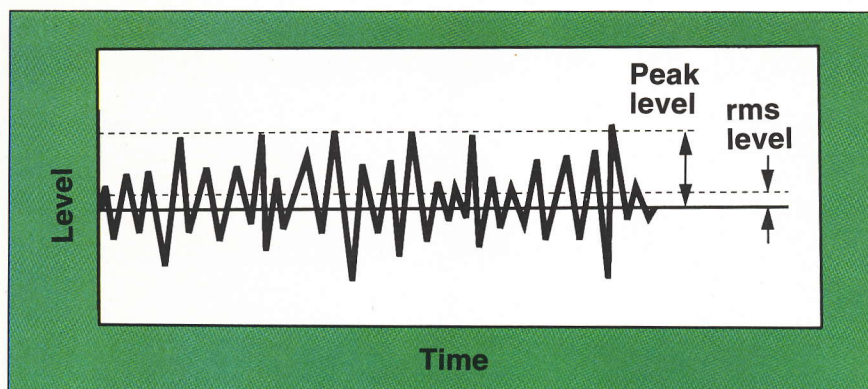


Figure 5. The crest factor is the ratio of the signal's peak value to the rms value.

and the finish of the hot surface are technical variables available to create greater air movement. Unfortunately, with today's high-powered amplifiers, the size and weight required for a heat sink would render this approach impractical and unpopular.

Heat transfer by forced convection can be up to 10 times more efficient than natural convection. This increased efficiency reduces the required size of the heat sink. For example, the Crown DC-300A II and Power-Tech 1 amplifiers deliver the same levels of power, yet the Power-Tech 1 weighs 15 pounds less than the DC-300A II.

Important considerations in forced

convection cooling are power dissipation, temperature differential, airflow and pressure drop. When a heat sink is specifically designed for forced air applications, the surface area can be smaller than the area for natural convection. It's important to remove as much heat as possible in the shortest time.

Although some heat-sink designs are immense and appear impressive, they are actually not efficient in their heat dissipation. The tunnel-type heat sink is a prime example. As cool air moves through the tunnel, the air temperature rises, which reduces the cooling of the rear end of the heat sink. The result is thermal stress on transistors

located on the rear of the heat sink.

Crown amplifiers incorporate heat-sink designs where the airflow path is much shorter and preheated air is not used to cool other sections of the heat sink. Cool air flows across the heat-sink fins and exits the amplifier.

Another Crown concept incorporated in the Com-Tech series is convection chassis cooling with on-demand proportional fan assist. This is a hybrid of the natural and forced-convection approaches. The fan-control circuitry uses the ODEP (output device emulator protection) thermal information in determining when to activate the fan and at what speed. For low-demand loads, the fan stays off. If the application requires continuous duty at rated power, the 3-speed fan assist is available. This design allows for the use of the convoluted fin-type heat sink used in Com-Tech amplifiers.

Audio-system heat generation

Our discussion would not be complete if we didn't discuss the environmental effects of the power being dissipated. The thermal counterpart of the power dissipated by all ac-powered devices within a room contributes to the ambient temperature and must be removed by air conditioning. Because all audio products draw a certain amount of quiescent idle power,

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they dissipate this energy in the form of heat.

Cooling of power-conversion equipment primarily involves removing heat from all power amplifiers, although heat produced by signal-processing devices (equalizers, crossovers, signal delays) and computer equipment should not be overlooked.

In the IQ System 2000, reducing the idle current of any Com-Tech or Macro-Tech amplifier when the system is not in use also reduces air-conditioning requirements (which means money). Although most signal processors and computers draw a constant quantity of power, power dissipation by a power amplifier depends upon its application and efficiency factor.

The efficiency factor can be defined as the amount of power an amplifier draws from the ac line to deliver a given quantity of power to the load. Many audio amplifiers today have an efficiency factor of 65% at full-rated output. (The Crown VZ technology increases this figure significantly.) This factor means a 100W amplifier can draw 153W of ac power. However, because the signal source will be music and speech, the power levels will not be a continuous high rms value.

Two characteristics about music and speech determine energy needs:

- Duty cycle: the ratio of pulse width to

total cycle time, measured as a percentage. The duty cycle of a waveform indicates the percentage of each cycle (period of time) that is taken up in the pulse width.

- Crest factor: the ratio of the peak value to the rms value. For example, pink noise typically will have a crest factor of 3 to 1. In other words, the peak value of the signal is three times

When air-conditioning needs are ignored or only roughly estimated, the consequence can be reduced system performance.

as high, in level, as the overall rms value.

The following formula can be used to determine the average power an amplifier will dissipate:

$$W_{\text{diss}} = [(W_{\text{output}} / \eta - W_{\text{output}}) \text{ duty cycle}] + \text{quiescent power}$$

where W_{diss} is the power dissipation of the amp, W_{output} is the total amp output power, and η is efficiency (typically 0.65). The duty cycle would depend on the type of signal: pink noise, 0.5; highly compressed rock'n'roll, 0.4;

rock'n'roll, 0.3; background music, 0.2; or speech, 0.1.

The varying selections portray the different types of signals encountered in our industry. For simplicity, I have averaged the functions of duty cycle and crest factor within the single value listed as duty cycle. By using this formula, you can obtain an approximation of the power to be dissipated from an audio amplifier. The quantity of heat generated by the overall system can be calculated by a total of all quiescent power figures of all components, along with the overall power dissipated by the power amplifiers during normal operation within a given room. Multiply this resulting quantity by the watts-to-BTU/hour conversion constant to obtain the following formula:

$$\text{BTU/hour} = 3.413(W_{\text{rms}})$$

The product will be the heat generated (BTU/hour) by the power dissipation of all electrical components within the room and will give an indication of the air conditioning required. When air-conditioning needs are ignored or only roughly estimated, the consequence can be reduced system performance, caused by elevated temperature (usually during the summer), or excessive air conditioning, resulting in high electric bills. **SVC**



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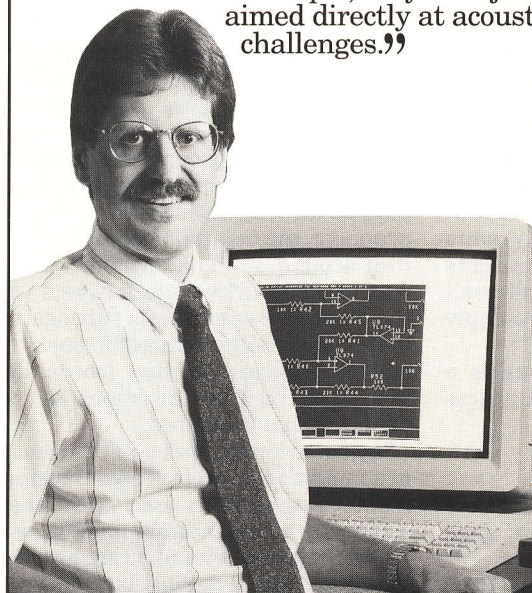
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