Since 1984

Boulder

2150

Class A Mono Power Amplifier

Technical Information

An introduction to the technology in the 2150 Mono Power Amplifier. The 2150 is the successor to the renowned 2050 Mono Power Amplifier and the flagship of the 2100 Series.

Basic Design

The 2150 Mono Amplifier is the second generation of Boulder's 2000 level mono power amplifier. After the original 2050's original release, the 2000 Series mono amplifiers remained unchanged for seventeen years, a run of stable production unheard of in the high-performance audio industry. Eventually, demand from previous owners, dealers and distributors was such that a new and revised version was needed to meet the demands of the market.

The 2150 was created from conception entirely as a monaural design. It is not a bridged derivative of a stereo amplifier. The left and right chassis casework are physically identical, making multiple chassis in cinema applications a simple installation. All metalwork is interlocking, machined from solid billet and non-resonant to eliminate microphonic resonance distortions. Physical changes from the original 2050 are subtle, more evolution than revolution, in order to maintain the iconic look of the original.

Gain stages within the 2150 are the new and proprietary Boulder 99H2, an advancement of the modular and discrete 993 gain stage used in Boulder's 2000 Series products until 2013. 99H2 gain stages are only used in 2100 Series products. The "H" in 99H signifies "high voltage," while the "2" signifies use in amplification. The 99H2 is a surface-mount, circuit board-implemented, fully-discrete, extremely high-current gain stage that provides the best possible distortion figures and exceptionally low noise.

The 2150's bias operation is Class A to full rated output power. An analog bias circuit continually monitors voltage output, current draw and load to adjust the bias current as necessary. If a musical transient requiring more bias current is detected, the circuit will raise the bias much faster than the audio signal to keep the amplifier operating within the Class A window. After the transient has passed, it will then gently lower the bias in a decreasing analog manner over a period of 28 seconds until another transient peak is detected. This has the benefit of keeping the 2150 operating in full Class A mode without the drawbacks of massive power consumption, excessive heat generation and the audible steps or "sliding" of other digitally-controlled active bias management systems.

Power output is 1,000 watts continuous into an 8, 4, or 2-ohm load. Peak output will double to 2,000 watts into a 4-ohm load, and 4,000 watts into a 2-ohm load. The ability to deliver power under load contributes to unmatched control and dynamic impact during transient swings and a sense of effortlessness during low frequency passages into any and all loads.

The 2150 is true differentially balanced at the inputs and outputs for optimal common-mode noise cancellation in tandem with the use of the 99H2 gain stage. Lower distortion, and in particular, a much lower noise floor, contribute to vastly increased fine detail resolution.

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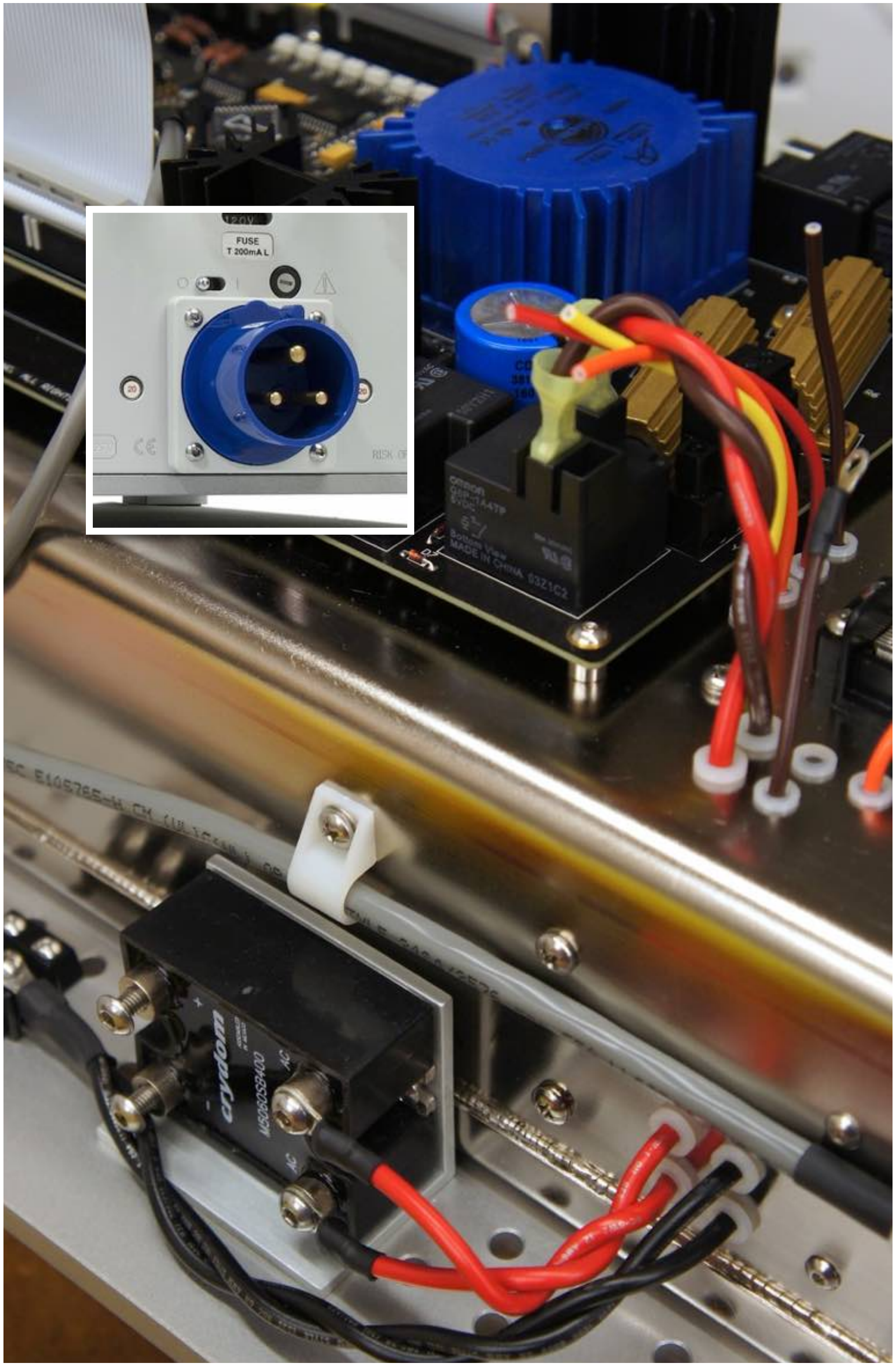


Power Supply

The 2150 incorporates two main power supplies; a massive, primary brute supply for the input and output sections and a smaller, regulated, independent supply for supervising the microprocessor control section. All supplies are linear. No switching supplies are used in Boulder products, as switch-mode supplies are noisy and a solution based on economy rather than performance.

1. AC Mains

AC mains power to the 2150 is provided via a detachable 32-amp IEC connector. A 32A connector was selected due the amplifier's potential to draw nearly 30A peak current during high power outputs into low-impedance loads. The next greatest amperage rating for a safety approved detachable IEC connector above 20A is 32A. The 32A IEC connector incorporates low resistance, machined brass contacts for safe and efficient electrical transfer. All 2150s can be built to operate at 100, 120 and 240 VAC while still providing full rated output power.

2. Brute Supply

The large, main brute supply features two toroidal transformers, one for each phase of output. Dual transformers ensure ideal noise isolation between each phase as well as faster and more efficient operation during periods of high output. The toroidal transformer design was specifically selected for power handling efficiency and low noise radiation. All transformers are manufactured in the United States to Boulder's standards. Transformer hum is not permitted.

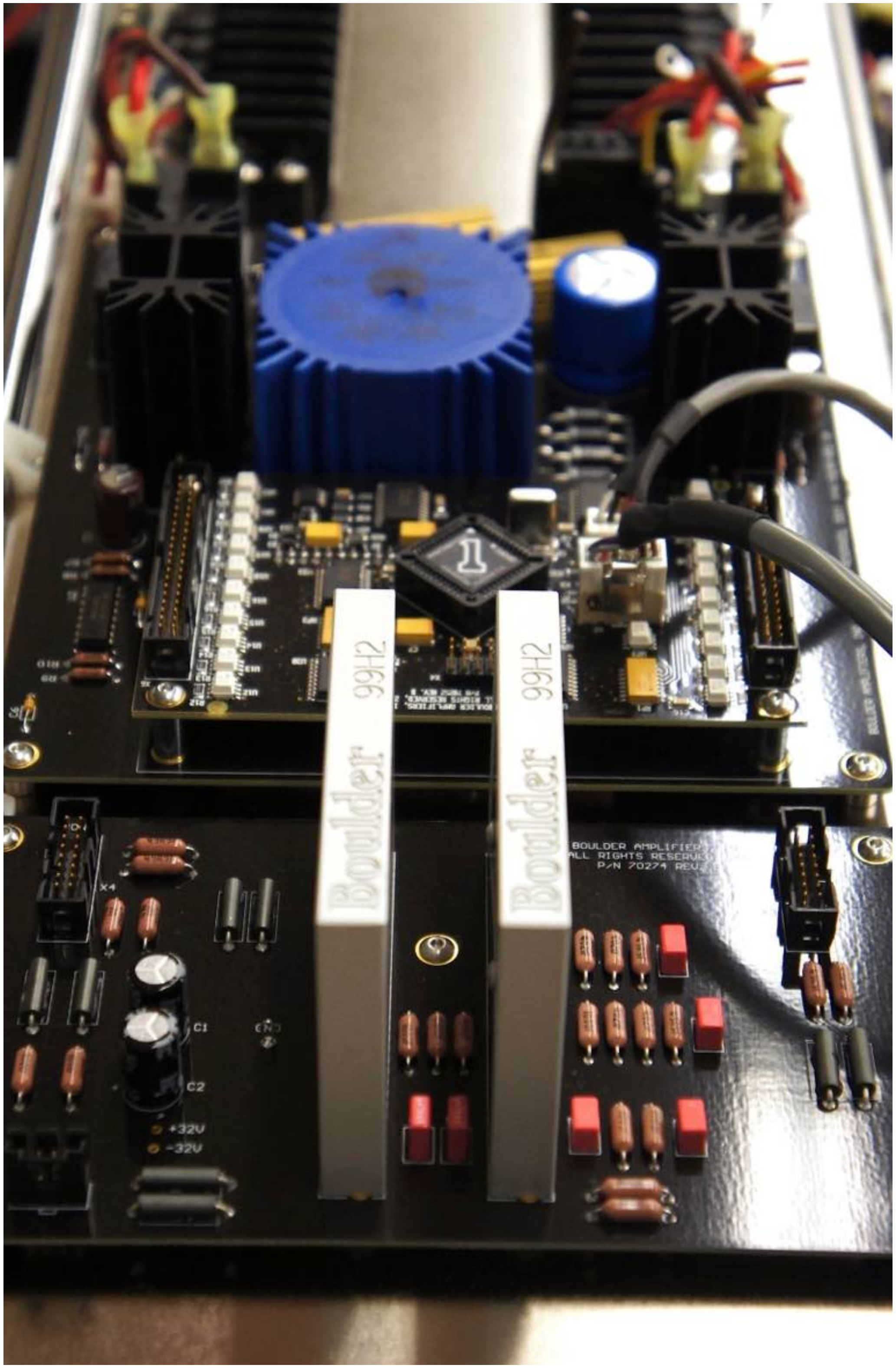
Both transformers "float" in a welded, nickel-plated, rectangular steel case running the length of the floor of the amplifier. Each transformer is isolated from the case so that no contact is made between the transformer and anything that may transmit vibration. The case is magnetically shielded and high-mass encapsulated in a unique mineral, glass and resin potting compound to eliminate any hum or operational vibration. The complete assembly weighs over 65 lbs. (30 kg).

To further prevent the transformers from creating mechanical noise, a DC filter circuit blocks up to 3VDC on the AC mains. DC is one of the primary causes of transformer hum, thus this circuit is essential to guarantee silent operation in any environment.

After bridge rectification, 48 large, 4,700µF electrolytic filter capacitors are used to ensure a low-impedance supply to the output stage. The use of many distributed capacitors provides faster power delivery and recharging, as well as lower harmonic noise during operation regardless of output power or load. Dynamic and transient response are thus greatly improved.

3. Microprocessor Supply

The smaller supply is fully-regulated and powers only the microprocessor control system. It is fully independent and optically isolated to prevent any noise from the logic system affecting any of the analog amplification stages. The microprocessor system controls power-up, Boulder Link, and protection circuitry.



Input Stage

1. Input Circuitry and Topology

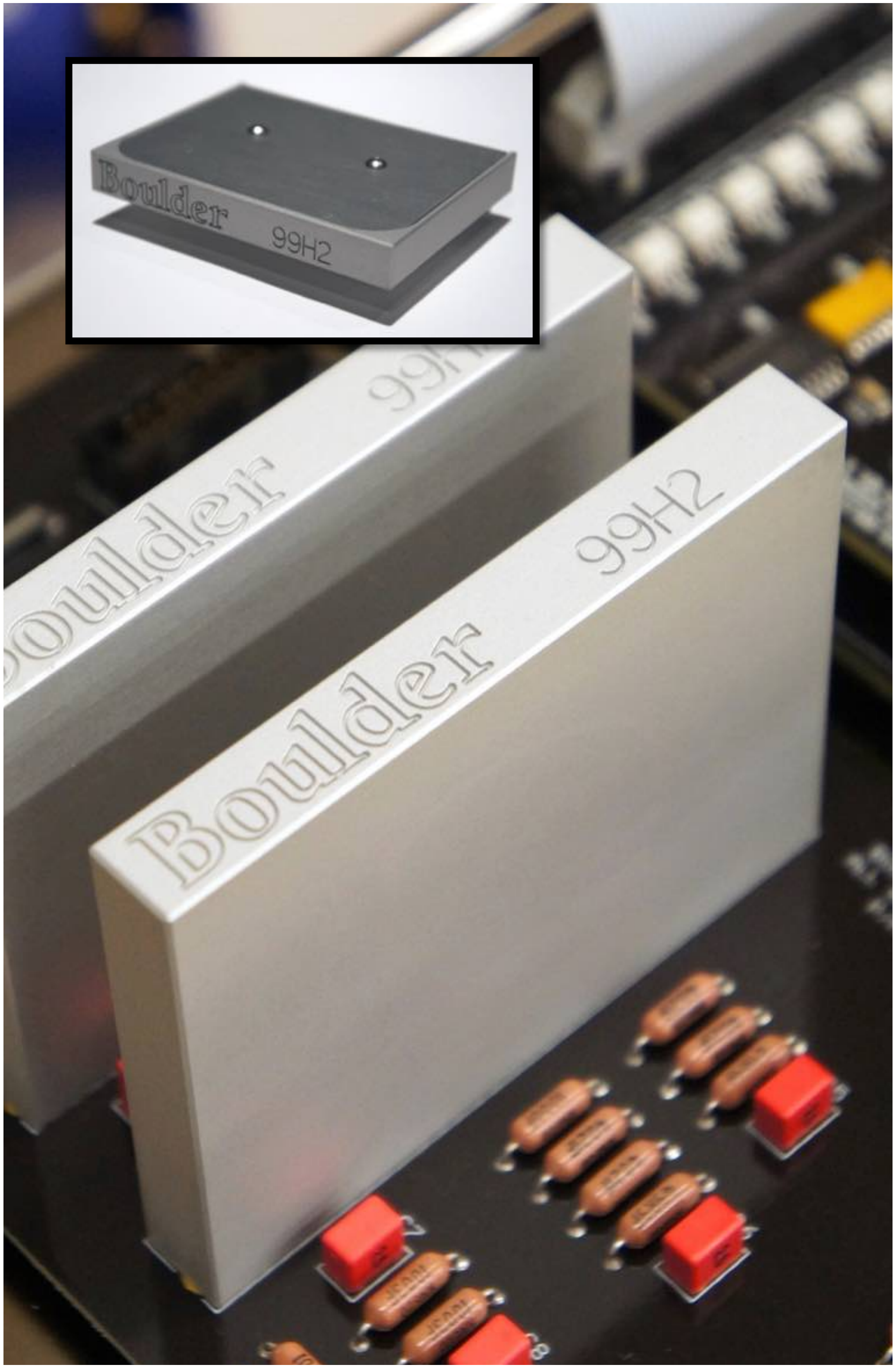
The input circuit is a true, fully-balanced, differential, three-stage instrumentation-style circuit initiated with three-pin XLR connectors. This ensures that the audio signal passes from the source to the amplifier free of distortion and noise by keeping the input impedance as high as possible in comparison to the output impedance of the source. Input impedance is a tested and verified balanced 200k ohms (100k ohms per leg). This high input impedance means a much greater resistance to noise and also guarantees flat frequency response. The instrumentation input design also ensures consistent input impedance and electrical characteristics regardless of frequency or load termination.

Matched impedance or “transmission line” circuits are not used (as in video circuits), as the frequency spectrum of audio is not high enough to present reflected waves from the signal receiver and the benefit of resistance to hum or noise is thus preferable.

Pin 2 of the XLR input connector is designated as positive or “hot,” and the amplifier’s overall output is non-inverting.

All signal transistors in the input circuit are bipolar. FET-type transistors are not used to carry audio.

The 2150 is a direct-coupled design, with a servo eliminating any DC voltage offset passed along by the front-end source. An offset of 50mV or more engages a speaker-protection circuit that immediately mutes the amplifier’s output.



Gain Stage

1. 99H2 Gain Stage

The 2150 incorporates +26 dB of total overall gain. The gain stages in the 2150 are Boulder's proprietary 99H2 gain stage, a surface-mount, discretely implemented and encapsulated operational amplifier. The 99H2 is an extremely high-current output design utilizing the benefits and low distortion of discrete implementation. Two stages of gain are used in each 2150, with the majority of gain (+20 dB) handled by the initial 99H2 stage, thus maximizing bandwidth. The remaining +6 dB of gain is handled by the output stage. The 99H2 operates with +/-32V rails and features exceptional headroom for ideal signal-to-noise ratio. Each 99H2 provides input buffering and voltage gain with a high slew rate, wide bandwidth, high current output, low distortion and low output impedance.

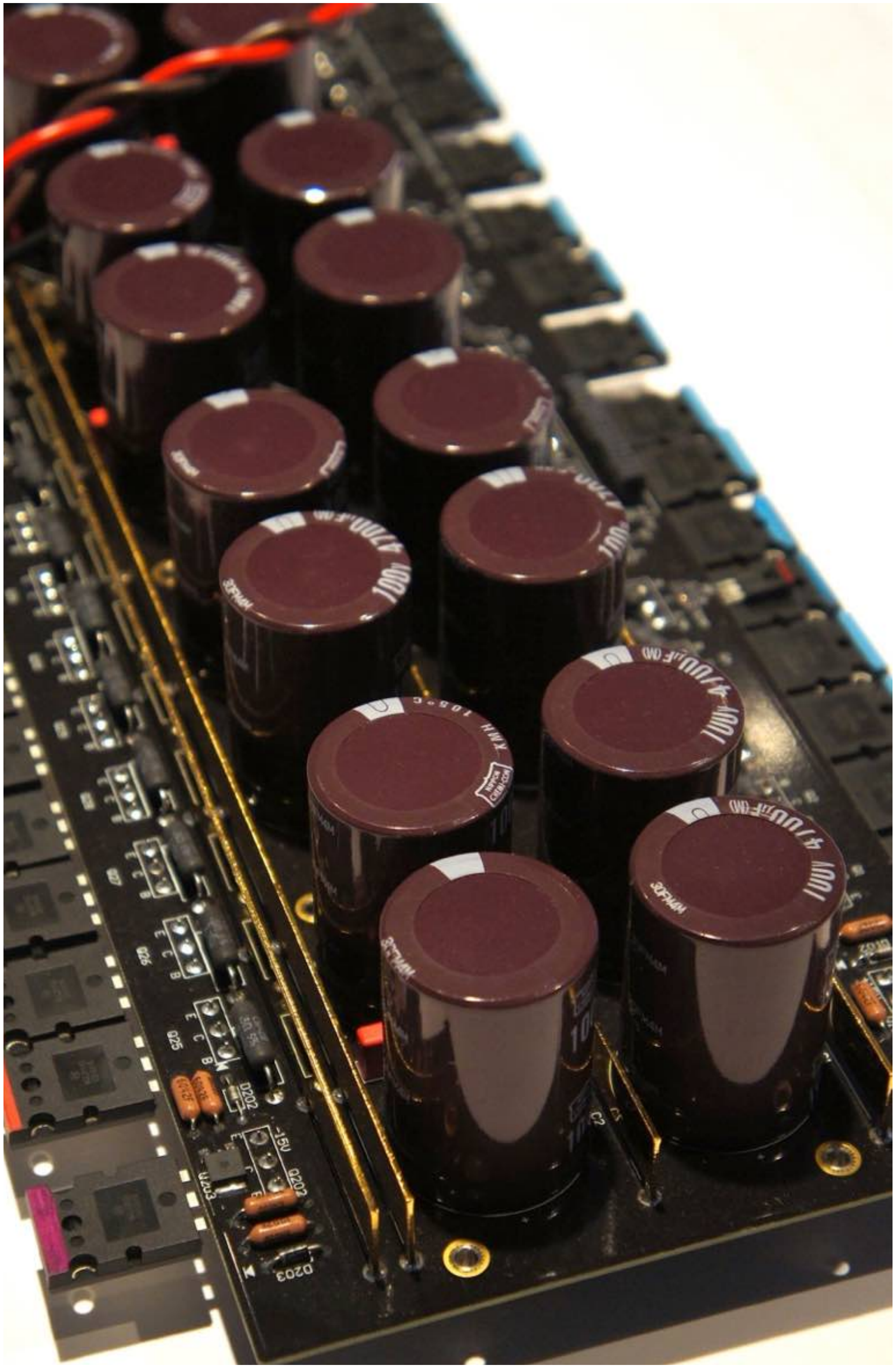
The 99H2s in the 2150 are implemented on small, surface-mount circuit boards that are assembled in-house on Boulder's own pick-and-place machines and board ovens. Surface-mount technology allows for much smaller solder joints (which reduce connection resistance) as well as elimination of lead inductance and optimized ground planing. After the circuit board assemblies pass initial testing, the boards are mounted in a Boulder machined housing and potted with a proprietary mineral and epoxy compound to control microphonic resonances and evenly distribute and stabilize heat within the circuitry. The entire 99H2 assemblies (one each for positive and negative halves of the waveform) are then retested prior to installation. During operation they are plugged into the input circuit board and pass the audio signal to the output sections.

2. Feedback Theory and Use

Correct and appropriate levels of feedback are used for achieving ideal operating parameters, including gain determination, constant group delay across the entire bandwidth (maximizing linear phase response) and bandwidth limiting.

A hallmark of Boulder designs is a thorough *understanding* and *proper use* of feedback. Decades ago, the use of feedback developed a poor reputation as designers asked the then new, integrated operational amplifiers to do something they weren't capable of due to their slow speed. Early monolithic op-amp designs were not fast enough to keep up with feedback loops in wide-bandwidth applications, resulting in horrible distortions. Less enlightened designers who didn't know how to solve the problem simply tried to remove the feedback, which also resulted in further compromised sound and again increased distortion.

In 1984 the Boulder' 500 showed the audio community, perhaps for the first time, that the proper use of feedback in combination with proper discrete operational amplifier design results in vastly improved sound and measurably lowered distortion. The gain of the output stage can thus be reduced and its bandwidth increased. The resulting design has lower distortion than any single-stage design.



Output Section

The 2150 is full Class A biased to maximum rated output (1,000W). The output impedance of the 2150 is a specified and tested 0 ohms, meaning the output and operation of the amplifier is non-reactive.

The 2150's output voltage rails operate at +/-85V. Maximum power output is 1,000 watts into 8 ohms, with peaks of 2,000W and 4,000W into 4 and 2 ohms respectively. One of the primary goals of the 2150 was to be able to drive any loudspeaker, regardless of efficiency or impedance, to realistic playback levels. This requires no increase in distortion, even during the most demanding passages or largest transient peaks. To meet the goal of wide dynamic range necessitated a particularly high voltage capability.

Starting with the microphone and throughout the entire recording and playback process, an audio signal is stored as *voltage*, not current. An amplifier must be able to produce a high output voltage in order to accurately recreate an audio signal, whereas current is a result of load.

The power supply and transistor complement were designed around the 1,000W output figure, regardless of impedance, guaranteeing that the 2150 will produce a minimum of the rated output power into any load.

1. Output Circuit and Transistors

The output section of the 2150 is comprised of 80 bipolar output devices. Bipolar devices were chosen over FET-type designs for the same reasons as the input section. Each half of the chassis amplifies either the positive or the negative half of the analog waveform as expected in a true differentially balanced, mono design.

The use of a larger number of output transistors reduces the thermal cycling range required of each individual device and the amount of stress placed upon each one during high power handling–each device is responsible for only a tiny fraction of the total output power demanded at any given time. Better distortion figures are also realized, as each device handles only a portion of its rated output power. The larger number of output devices also more effectively eliminates the EMF backwaves caused by loudspeaker drivers, as the energy is divided and dissipated amongst a greater total number of transistors.

2. Clamp Bar, Heatsink and Resonance Damping

Each output device is clamped to a non-resonant heatsink via a custom CNC machined clamp bar. The unique clamping design eliminates the individual screw-down method that would secure each transistor to the heatsink via a screw and reduce long-term reliability. It also keeps the clamping pressure uniform for all output devices. A special heat transfer material between the clamp bar and the output device keeps clamping pressure uniform without exposing the housings of the devices to potential damage in the event of over-tightening or loosening of the screw over years of repeated thermal cycling. The overall

benefit of this methodology is that every output device operates at a uniform temperature due to the elimination of variance of the clamping pressures that occur when each device is individually attached to a heatsink, and the prevention of eventual electrical failure that occurs when a device is no longer clamped to the heatsink properly.

The 2150 heatsink is cut from an 80 lb. (36 kg) solid billet of aluminum and features a variation of Boulder's familiar digital waveform pattern on the exterior surface. Standalone fins are avoided to prevent any resonant ringing. Each heatsink is resonance damped to well above the audio spectrum by securing it to chassis panels and circuitry of differing resonant frequencies. This stops microphonic distortion effects from leeching into the output of the amplifier by preventing any mechanical resonance from reaching the output devices attached directly to the heatsink.

In addition to complete elimination of microphonic resonances, the heatsink of the 2150 was also designed for efficient heat dissipation. Each heatsink utilizes convection to dissipate heat generated by the amplifier while taking advantage of metal mass to retain enough heat to prevent rapid temperature variations during loud and quiet passages of music. Vertical holes are drilled along the entire length of the heatsink to initiate convective air-flow cooling. Vents are also cut into the top cover directly above the output driver boards to ventilate specific areas of the internal circuitry that are temperature sensitive.

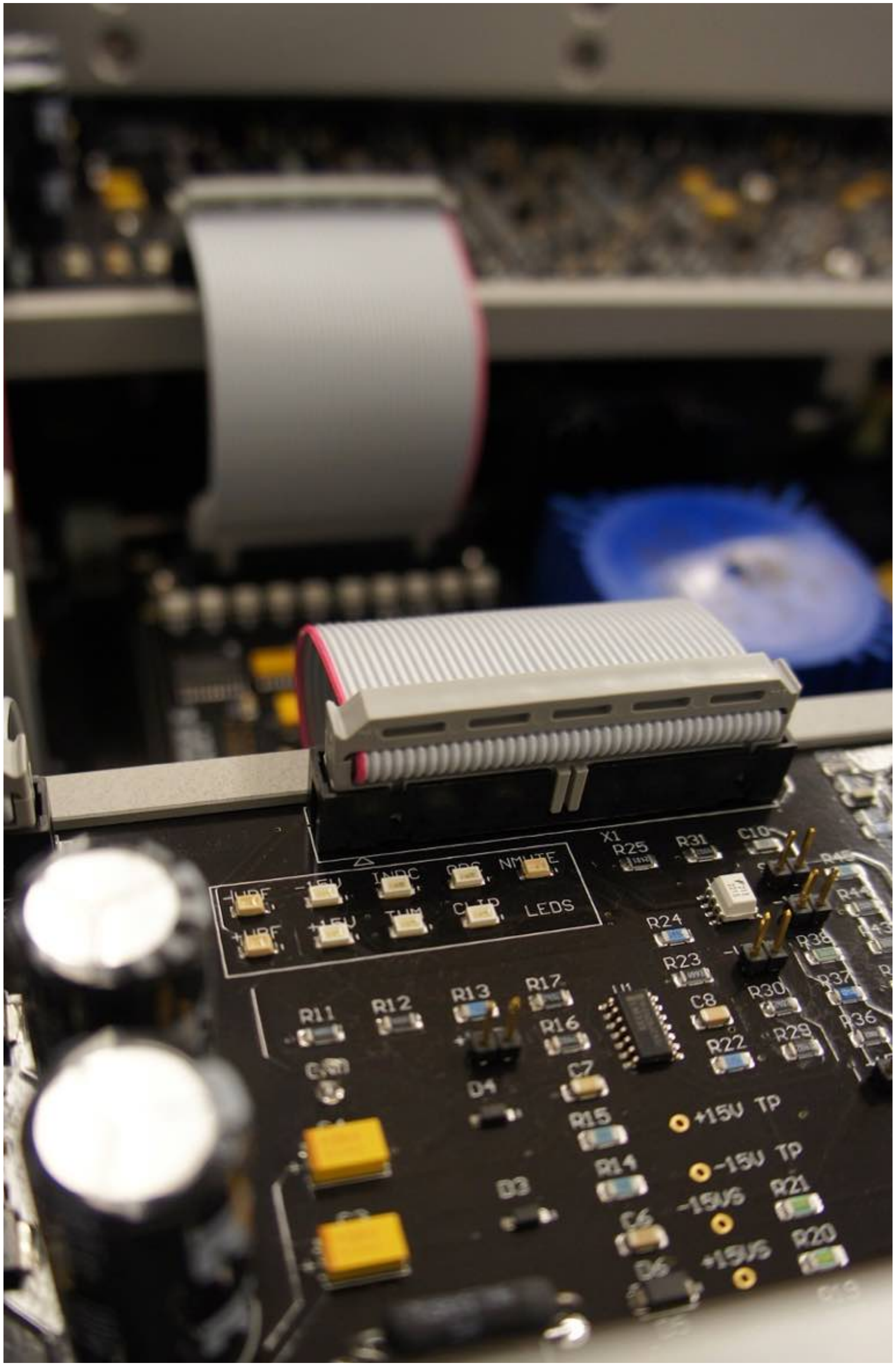
Every piece of the 2150's chassis is machined from solid plates of 6061-T6 aerospace-grade aluminum. Machining is performed on Boulder's own CNC machining centers that operate at speeds up to 65,000 RPM. The water and bead-blasted finish is applied in Boulder's own sealed blasting chamber prior to clear anodizing.

3. Output Terminals

Output is delivered to the loudspeaker via two pairs of custom, spade-only, ¼" binding posts. The internal connection of both pairs of binding posts is parallel, so no advantage exists in connecting one set over the other. A large contact area is provided to maintain the lowest possible contact resistance.

Connection options for banana plugs or bare wire are not supported. Banana plugs have been shown to reduce spring tension over time, which in turn increases resistance through the connector, while bare wire is a haphazard form of connection with the very real potential for shorted outputs.

At no point is the 2150 "voiced" or tuned for a specific sound or type of loudspeaker. All engineering and testing verify numerous distortion specifications and these results are then verified by ear prior to shipment for every unit produced. All harmonic distortions (including those that produce "pleasant" though inaccurate sound) are eliminated as much as possible during the design stage.



Protection Circuitry

1. Monitoring and Protection

The 2150 includes a complete array of protection circuits, all intended to prevent damage to either the amplifier or loudspeakers. All protection circuits are microprocessor controlled. In the event of a microprocessor failure, the amplifier will power off.

A current limiting circuit prevents damage to the output section in the event of shorted outputs or overdriving. When the current limiting circuit is engaged, the amplifier will mute output for three seconds via a timer circuit. The 2150 will then try to re-engage the outputs unless the over-current fault is still present, at which time the amplifier will again mute. This will continue until the source of the fault is removed.

The 2150 incorporates two DC detection circuits, one at the inputs and one at the outputs of the amplifier. In the event that DC is present on the inputs of the 2150, a servo system will null any DC offset detected. A secondary protection circuit will mute the amplifier if 50mV or more is detected. The amplifier will remain muted until the offset falls below 50mV, at which time it will again be nulled by the servo system. The amplifier will mute if any DC is detected at the outputs.

All power supplies within the amplifier are continuously monitored via the microprocessor system. In the event that any supply does not meet specification, the amplifier will power down and cannot be restarted until the problematic supply is operating correctly to prevent potential damaging voltages from appearing at the output terminals. If this occurs, the front panel LED of the 2150 will blink a specific color pattern and sequence, indicating the cause of the shut down in order to aid troubleshooting. The LED will also indicate AC mains over voltage, AC mains under voltage, DC at the inputs, DC at the outputs, and thermal limiting at the heatsink.

The heatsink thermal protection circuit monitors the temperature of the output devices and protection is triggered when the individual transistor cases reach 80° C. This corresponds to approximately 65° C at the heatsink. Temperature will be continuously monitored and current output will be limited until the temperature of the output device cases again falls below 80° C, at which point normal amplifier operation will resume.

External Control

1. Boulder Link and IP Control

The 2150 has been designed to be seamlessly integrated into custom home installations as well as incorporated into systems with legacy or current Boulder Linked products.

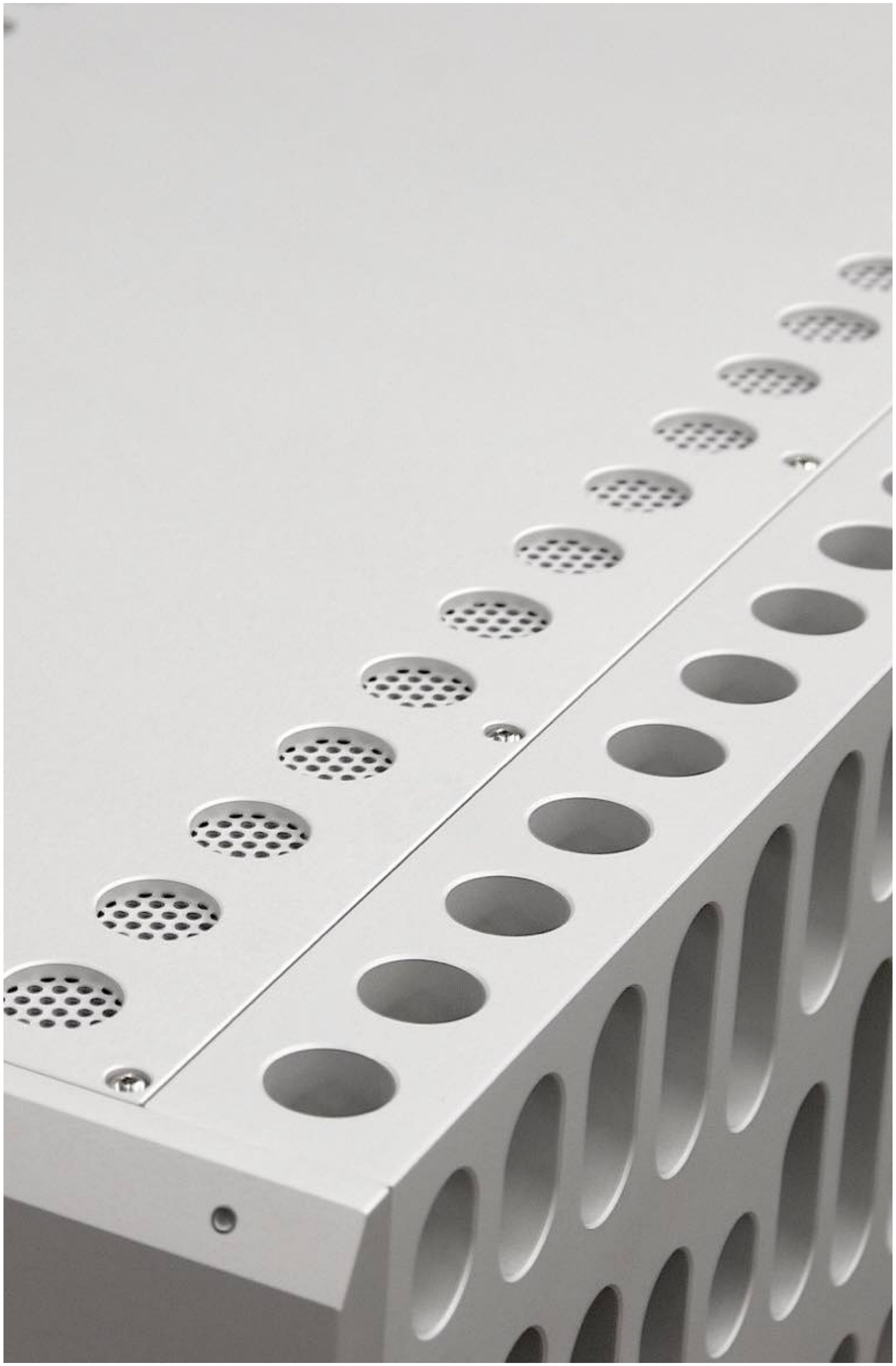
The Boulder Link system is a proprietary system of inter-component communication, specific to Boulder products. It is an RS-435-based communication system that enables a single component to behave as the "master" in a system and initiate power-up, power off and volume commands as well as transmit any protection or warning notices to any Boulder product with an LCD or alpha-numeric display. In the 2100 Series, Boulder Link is a continuously scanning system that monitors and keeps track of individual components and all of their associated protection circuits.

Upon power-up, a 2150 will detect and identify any other 2100 or 3000 Series amplifiers connected via Boulder Link. It will then automatically determine the proper sequence and rate in which to turn on each amplifier so as to prevent excessive AC line current draw.

Ethernet connection options have also been made available that will allow IP (Internet Protocol) control of amplifier turn-on and turn-off.

Provisions are available to inquire with the amplifier about the status of each protection circuit and operating parameter via two-way communication, which can then be fed to outside control displays, such as those from Crestron, Savant, AMX and others.

A 12V trigger via a 1/8" mini-jack connector is also available on the rear panel of the amplifier to control the standby function of the amplifier in a trigger-based system. Both pulse and continuous voltage trigger controls are supported.



Mechanical Design

The mechanical design of the 2150 was centered around three principles: elimination of mechanical resonances, efficient heat dissipation and unique aesthetic design. All casework was designed on advanced 3D CAD systems and machining tolerances are held to within 0.5/1000 or 1/1000 of an inch, depending on the application of the metalwork.

All exterior metalwork of the 2150 is damped, either via the use of direct application of damping materials or by adjoining one subassembly to another in order to significantly raise the resonant frequency of the compound assembly.

All brute supply transformers within the chassis are potted and DC filtered to eliminate mechanical resonances. The smaller microprocessor transformer is mounted a separate circuit board along with all of the microprocessor circuitry for ideal separation and isolation.

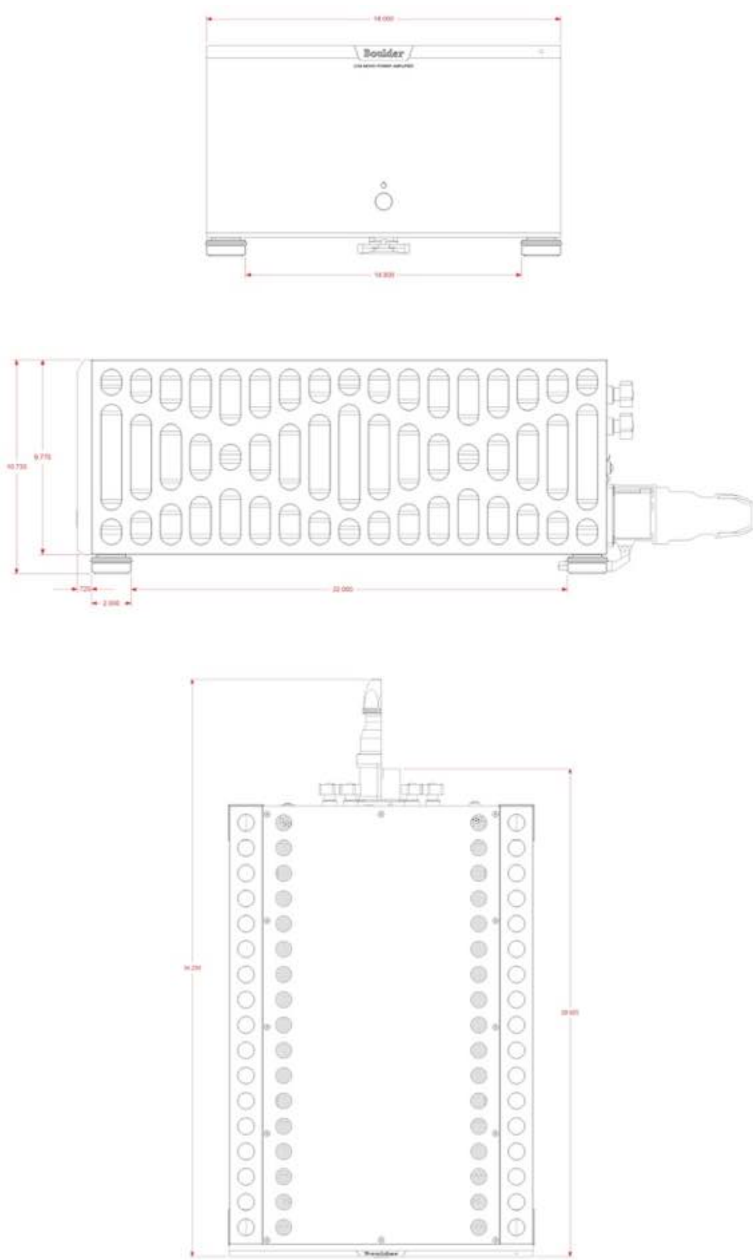
1. PCB Mounting

All circuit boards within the amplifier are slid into custom machined frames designed to fit perfectly around each individual circuit board. Circuit board assemblies are not screwed down onto standoffs or to sheet metal plates. A non-conductive layer of pliable damping material is then sandwiched between the circuit board and the frame assembly to prevent any vibration or resonance from inducing any microphonic distortions.

2. Interlocking Structure and Damping System

All chassis parts are interlocking and are attached via stainless steel screws and/or hardware to prevent corrosion in harsh or salt air environments. The interlocking chassis component design has been utilized to eliminate chassis resonances through harmonic cancellation. When bolted together, the individual harmonic resonances of each chassis part will raise the overall resonant frequency of the entire structure to well outside the audio bandwidth. The heatsinks contain no fins or resonant tongs. The top cover utilizes constrained layer damping by way of a layer of damping material sandwiched between the cover and a plate of stainless steel screwed to the underside of the cover. The top cover itself has a grounding terminal pressed into the metal to make contact with a sprung grounding button at the front of the amplifier's front panel. This pressure performs the dual function of creating shielding as well as keeping the top cover tight and rattle-free. Once in place, the top cover is secured via stainless steel screws that are counter-sunk into the top cover.

The chassis is supported on multi-layer feet comprised of a nine-piece system of damping and shock absorption. Each foot is made of a machined aluminum main housing and a polished stainless steel insert that incorporates two layers of damping material (one firmer and one softer) in a constrained-layer damped arrangement, isolating the amplifier from any direct coupling to the surface on which it is placed. This eliminates the need for any specialty racks, shelves, or isolation accessories.



Specifications

1. Technical Specifications

THD at Continuous Power, 20 Hz to 20 kHz	0.0005%
THD at Continuous Power, at 20 kHz	0.0017%
Continuous Power, 8Ω	1,000W
Continuous Power, 4Ω	1,000W
Continuous Power, 2Ω	1,000W
Peak Power, 8Ω	1,000W
Peak Power, 4Ω	2,000W
Peak Power, 2Ω	4,000W
Magnitude Response, 20 Hz to 20 kHz	+0.00, -0.04 dB
Magnitude Response, -3dB at	0.015 Hz, 200 kHz
Voltage Gain	+26 dB
Signal to Noise Ratio (re: 500W/8Ω)	-135 dB, unweighted, 20 to 22 kHz
Input Impedance	Balanced: 200kΩ, 100kΩ per leg
Common Mode Rejection (Balanced Only)	60 Hz: 90 dB, 10 kHz: 70 dB
Input	3-pin balanced XLR, Pin 2 Hot
Output Connectors	2 sets of 6mm/0.25" wingscrews
Power Requirements	100/120/240 VAC, 50-60Hz, 240W nominal, 5000W at maximum output

All specifications measured at 120VAC mains power

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