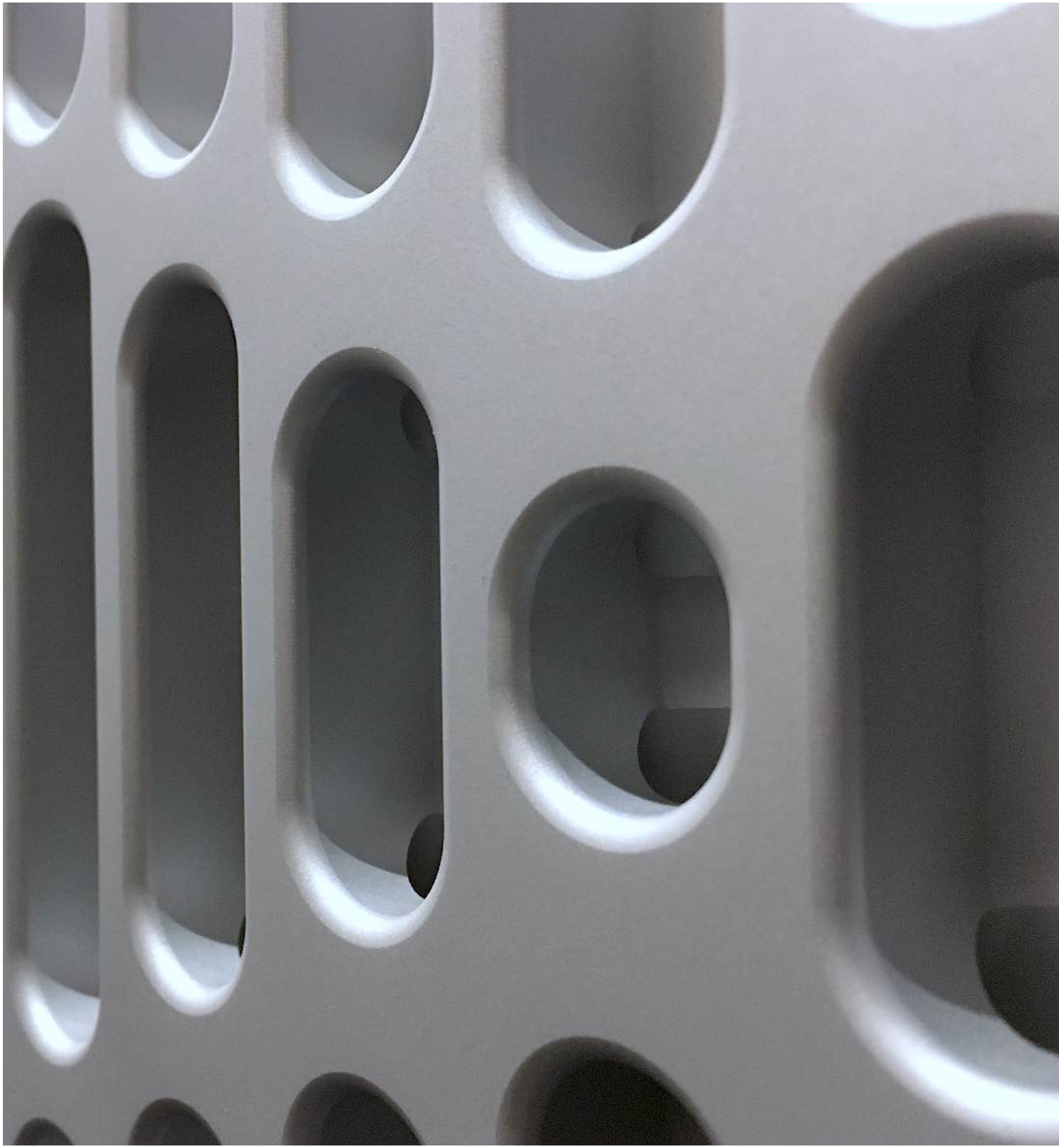


Since 1984

Boulder

# 1160

## Stereo Power Amplifier

# Technical Information

*An introduction to the technology within the 1160 Stereo Power Amplifier.*


## Basic Design

The 1160 Stereo Amplifier is the second generation of 1000-level power amplifier from Boulder, replacing the original 1060 Stereo Power Amplifier and slotted below the 2100 Series amplifiers: the 2150 Mono Amplifier (1,000wpc) and the 2160 Stereo Amplifier (600wpc). At the time of its development, the 1160 occupied the mid-level price point and power rating in the Boulder lineup of stereo amplifiers.

The 1160 is the only amplifier in Boulder's 1100 Series. The chassis exterior features rounded or radiused edges and a front panel design motif that features 3D topographical mapping of the Flagstaff mountain area west of Boulder, Colorado. All metalwork is interlocking, machined from solid billet and non-resonant to eliminate microphonic distortions.

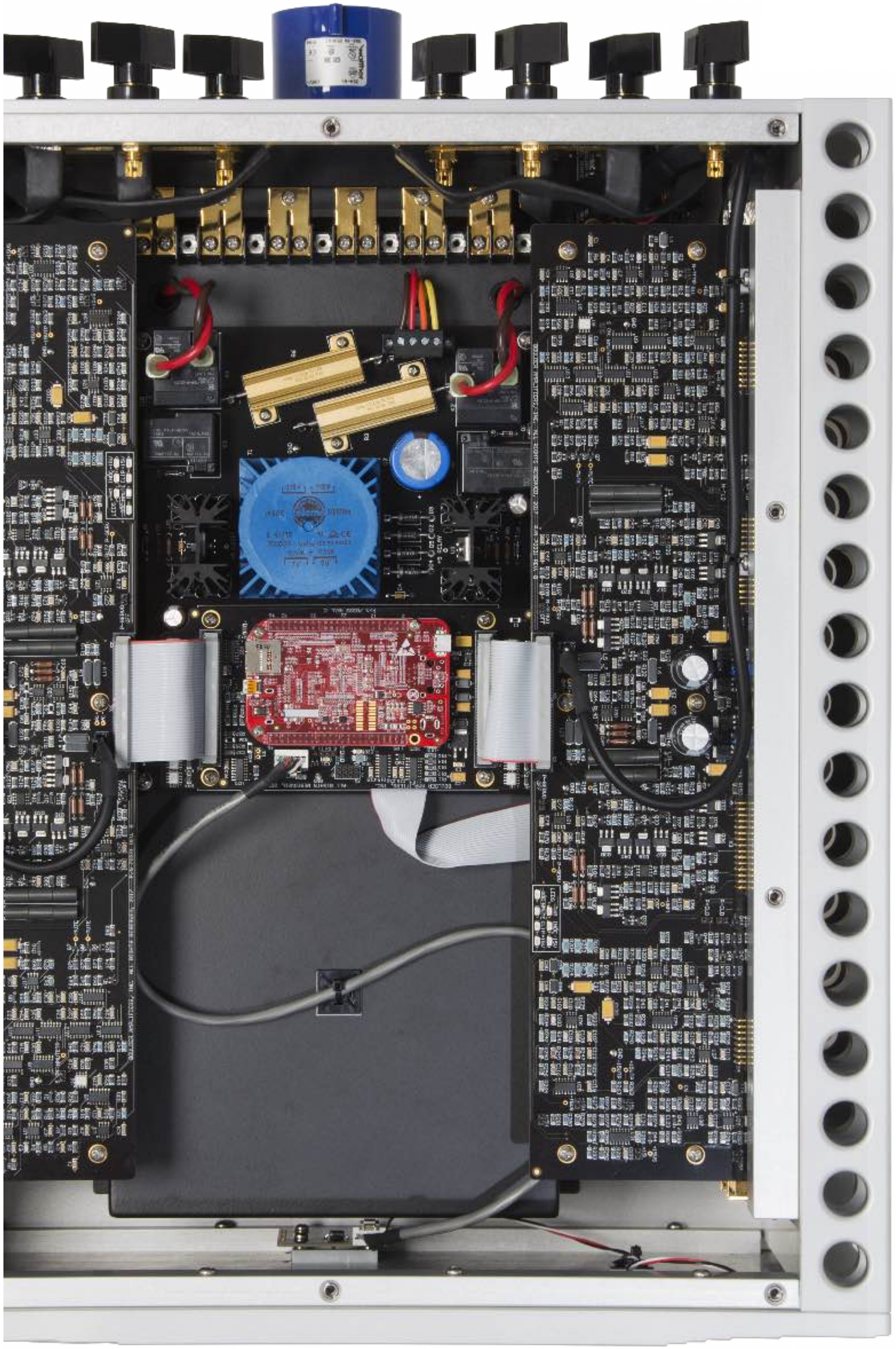
Gain stages within the 1160 are Boulder's proprietary Boulder 983, based on the modular and discrete 99H2 gain stage used the Boulder 2100 Series amplifiers. The 983 is a circuit board-implemented, high-current gain stage featuring a mix of discrete and monolithic microcircuit parts that provides the best possible distortion figures and exceptionally low noise in a small, board-mounted design.

Power output for the 1160 is 300 watts continuous into an 8, 4, or 2-ohm load. Peak output will double to 600 watts into a 4-ohm load, and 1,200 watts into a 2-ohm load. The ability to deliver accurate and ample power output contributes to greater authority and dynamic impact during transient and low frequency passages as well as into difficult loudspeaker loads. Bias operation is Class AB, with a circuit designed to eliminate crossover distortion. This elimination of crossover distortion enables the 1160 to outperform other Class AB amplifiers without the energy inefficiencies traditionally associated with Class A designs.

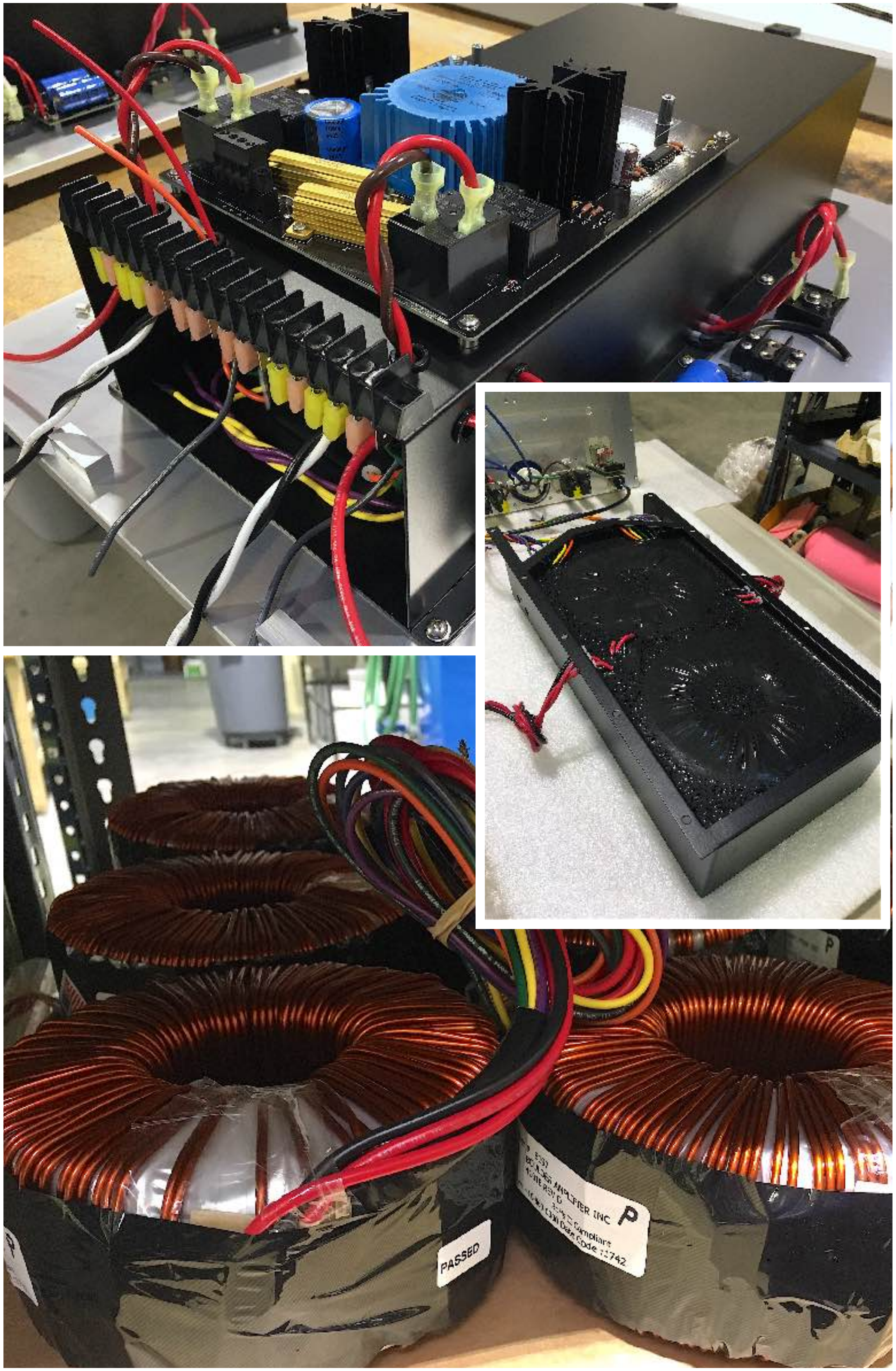
As with all Boulder products, the elimination of noise and distortion were paramount in the design of the 1160. The 1160 is true differentially balanced at the inputs and outputs for optimal common-mode noise rejection. Balanced operation in tandem with the use of the 983 gain stage assures low noise. Lower distortion, and in particular, lower noise as it relates to the amplifier's noise floor, contribute to increased clarity and greater resolution of fine detail, meaning a more faithful reproduction of recordings.

Boulder is the last high-performance audio manufacturer operating in North America that is still responsible for 100% of its manufacturing: engineering, design, circuit boards and metalwork are all manufactured and assembled at our factory in Louisville, Colorado.

This form of production is more costly than outsourcing, though the resulting quality control and reliability are never compromised in any Boulder component.



# Contents




## Power Supply

The 1160 incorporates two main power supplies: a large, brute supply for the output portion of the amplifier, and a smaller, locally regulated, independent supply responsible for the supervising control section. A secondary, locally regulated supply run off of the brute supply powers the input section of the amplifier. All supplies are linear. No switching power supplies are used in the 1160.

### 1. AC Mains

AC mains power is delivered to the 1160 via a detachable, 32-amp IEC connector. A 32A connector was selected due the amplifier's ability to draw up to 3000W during high power usage into low-impedance loads at 100V operating voltages, resulting in a 30A current draw. The appropriate amperage rating for a safety approved detachable IEC connector above 30A is 32A. The 32A IEC connector incorporates low-resistance, precision-machined brass pin-and-sleeve connections for safe and reliable high-current electrical transfer. 1160s can be built to operate at 100, 120 or 240 VAC.

### 2. Brute Power Supply

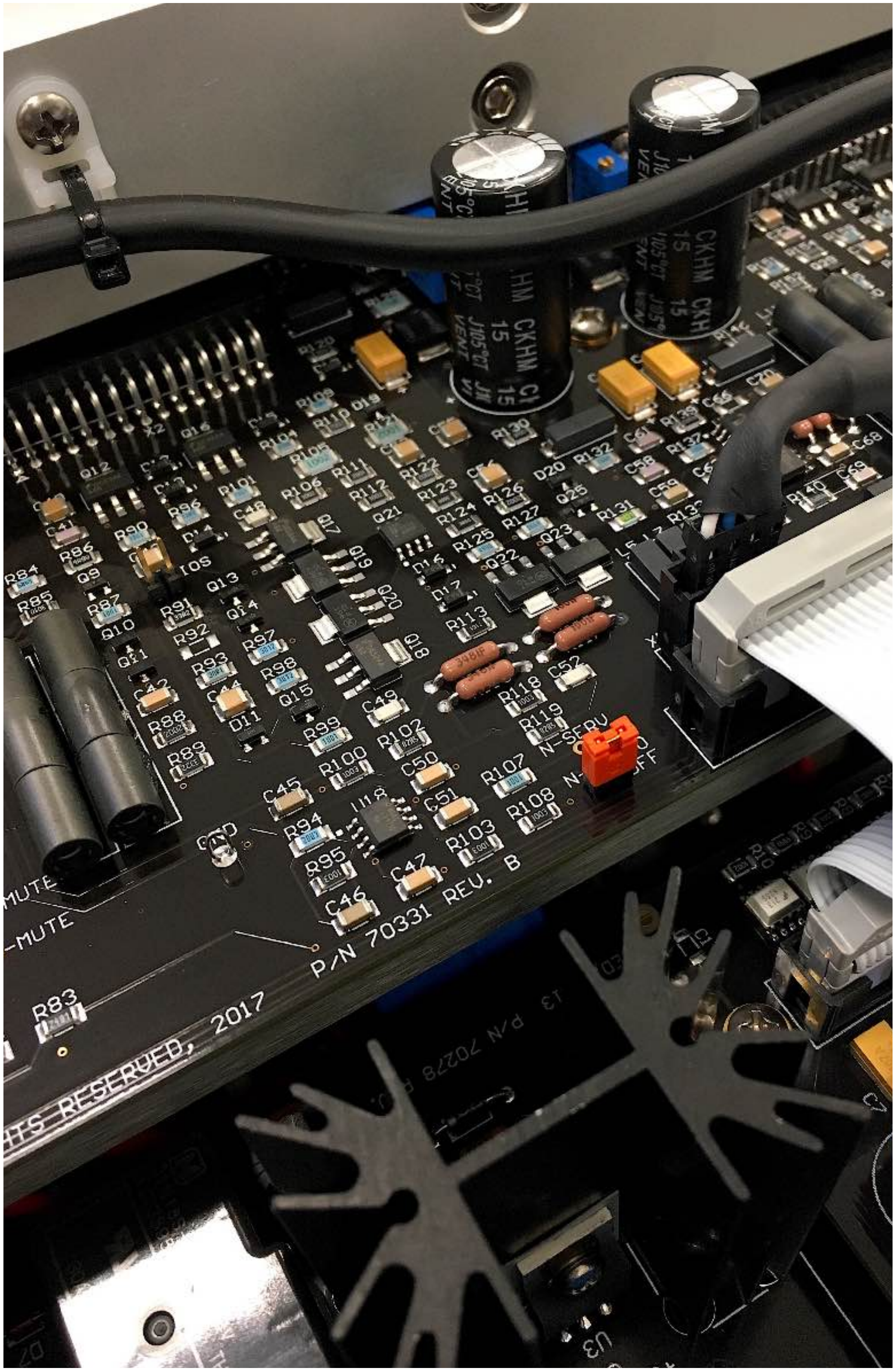
The large, main brute power supply features dual toroidal transformers, one for each channel of output. Dual transformers ensure ideal noise separation between each channel. The toroidal transformer design was specifically selected for power handling efficiency and low noise radiation. All transformers are designed, specified, and custom built in the US to Boulder's requirements. Both transformers "float" in a shielded, welded steel enclosure and are high-mass encapsulated in a unique proprietary epoxy potting resin to eliminate any audible hum or operational vibration, regardless of AC mains purity.

Transformer hum is not permitted. To prevent the transformers from humming or creating mechanical noise due to vibration, a DC blocking circuit is utilized to prevent up to 3VDC from making its way to the transformers. DC is one of the primary causes of transformer hum, thus this added circuit is essential to maintain silent operation in any environment.

After bridge rectification, forty-eight filter capacitors (twenty-four for each channel) are used to assure a low impedance supply to the output stage. The use of many smaller, distributed capacitors provides faster power delivery and recharging, as well as lower harmonic noise during operation. Dynamic and transient responses are thus greatly improved with no drawbacks.

### 3. Supervisor Supply

The smaller supervisor supply is fully regulated and powers the supervisor and host computer system. This supply is completely independent and optically isolated to prevent any noise from the digital logic system from bleeding through to any of the analog amplification stages. The supervisor system controls power-up, standby, Boulder Net, protection circuitry, and HTML page operation.




# Input Stage

## 4. Input Circuitry and Topology

The input circuit is a true, full-balanced, differential, three-stage instrumentation-style circuit with three-pin XLR connectors. Although unbalanced connection adaptors are available from Boulder, unbalanced connections are not present to encourage users to operate the 1160 in a manner that will enable them to get the full performance of which the amplifier is capable. Balanced operation 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 100k ohms (50k ohms per leg). This high input impedance ensures a much greater resistance to noise and also provides flat frequency response. The instrumentation-style 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 the frequency spectrum of audio does not present reflected waves from the signal receiver and the benefit of resistance to hum or noise is thus preferable.

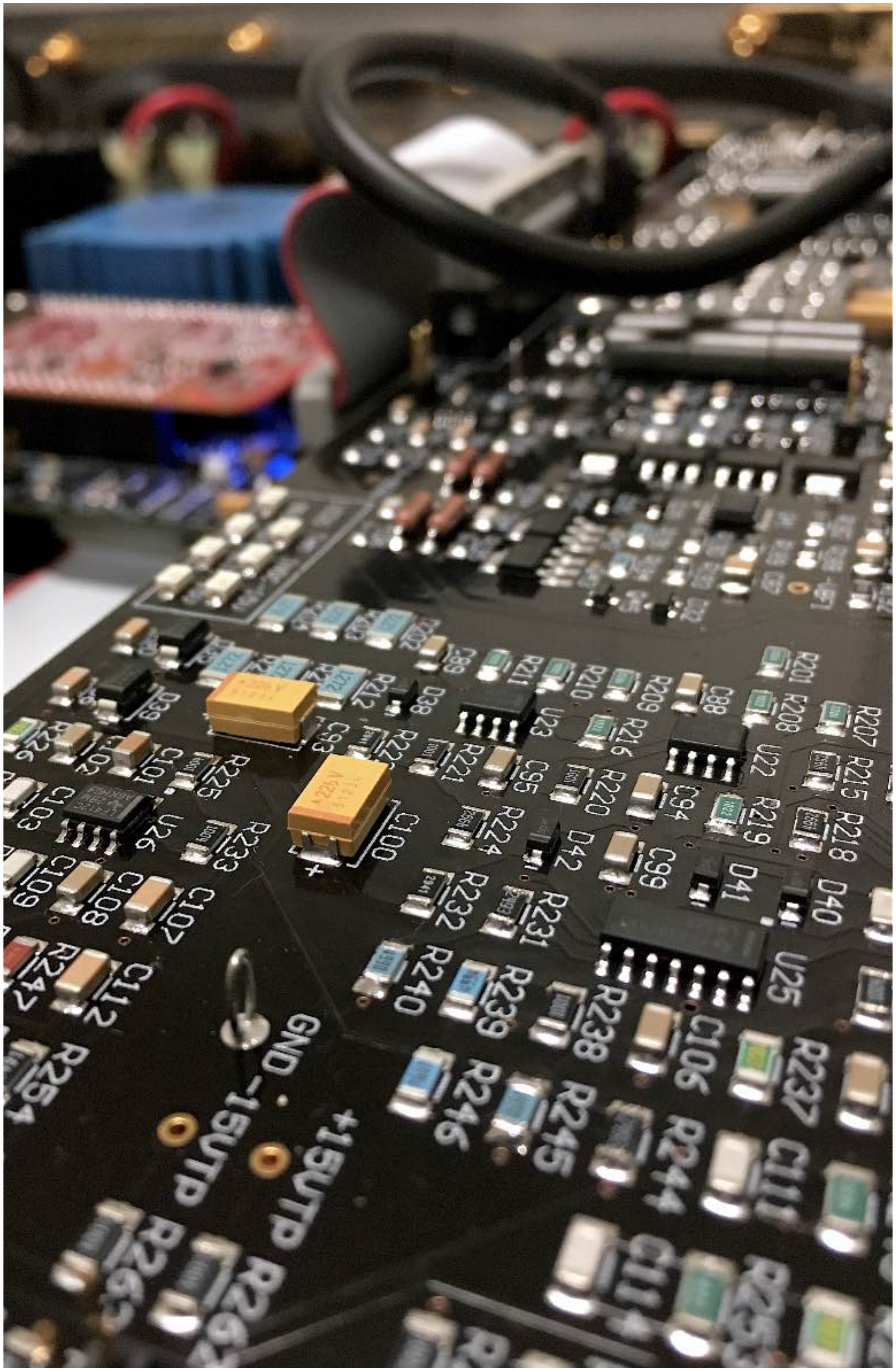
Pin 2 of the XLR input connector is positive or “hot,” and the amplifier’s overall output is non-inverting.

All transistors in the input circuit are bipolar. FET-type transistors are not used to carry audio signal because of their lower reliability and much higher sensitivity to electrostatic discharge (ESD). Bipolar devices are inherently more reliable as they aren't prone to static-related damage

In addition, bipolar amplifier stages are much more linear than FET-based stages, meaning greater fidelity to the source input signal or lower distortion.

Bipolar transistors have a greater gain range and have faster operation, as input capacitance is nearly absent. Bipolar amplifier stages are also able to carry greater power and provide higher current output, both essential for high-powered amplifiers. Most importantly, the outputs of bipolar devices can have lower output impedances, meaning a vastly superior ability to drive low impedances with no reactivity (particularly frequency response) based on load.

The 1160 is a direct-coupled design with a servo eliminating DC offset voltage passed along to the inputs by the front-end source or preamplifier. This circuit is capable of nulling any DC offset up to 50 mV. Offset greater than 50mV engages a speaker-protection circuit that immediately mutes the output of the amplifier until the DC offset is corrected or removed.




## Gain Stage

### 5. 983 Gain Stage

The 1160 iproduces +26 dB of gain. The gain stages in the 1160 are Boulder's proprietary 983 gain stage, a surface-mount implemented combination of discrete and monolithic technology. The 983 is a high-current output design combining the best aspects of monolithic operational amplifier design with the high-current benefits and low distortion of discrete buffer implementation.

Two gain stages are used in the 1160, with the majority of gain (+20 dB) handled by the initial 983 stage, thus maximizing operational bandwidth. Each 983 provides input buffering, voltage gain, and fully balanced operation with a high slew rate, wide bandwidth, high current output, low distortion, and output impedance. The remaining +6 dB of gain is handled by the heatsink output stage.

Executed on the same boards as the input and protection circuits, the gain stage signal paths of the 1160 are much shorter and connectivity impedances are much more precise than comparable designs with separate assemblies for each individual circuit. These circuits are assembled in-house on Boulder's own pick-and-place machines and circuit board ovens.

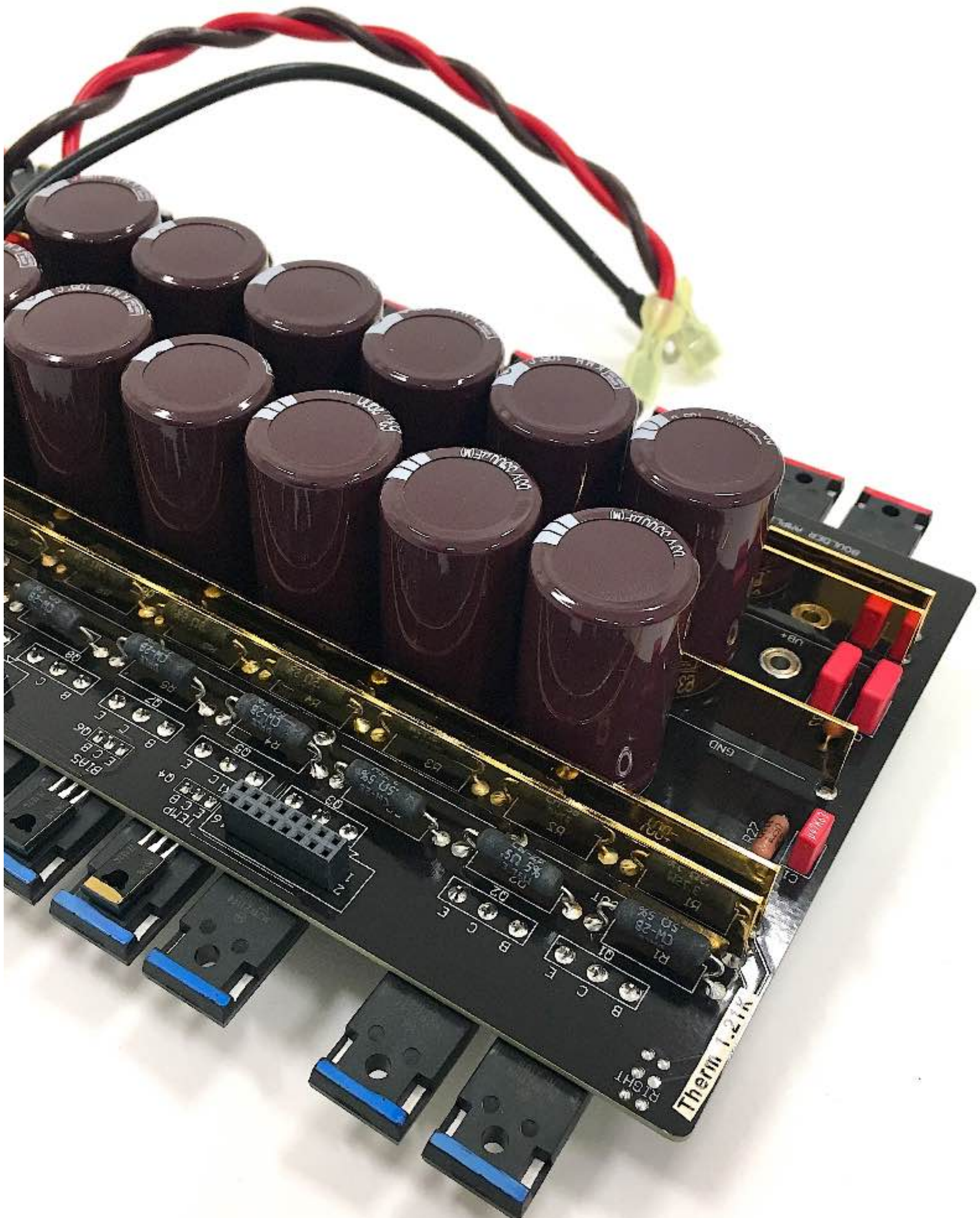
Surface mount technology allows for smaller PCB real estate (decreases PCB capacitance) as well as elimination of lead inductance and optimized ground planing. After the circuit board assemblies pass initial testing, a machined plate is screwed to the board to evenly distribute heat within the gain stage. The entire 983 circuits (one each for positive and negative halves of the waveform) are then retested.

### 6. Feedback Theory and Use

Correct and appropriate levels of feedback are used for achieving ideal operating parameters within the 1160, including gain determination, constant group delay across the entire bandwidth (maximally linear phase response) and bandwidth limiting.

A hallmark of Boulder designs is a thorough understanding and *proper use* of feedback. Decades ago, 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 clearly audible distortions. Designers who didn't know how to solve the problem simply tried to remove the feedback, which resulted in further compromised sound and increased distortion.

In 1984 the Boulder 500 showed the audio community, perhaps for the first time, that the proper use of feedback in tandem with proper operational amplifier design results in improved sound quality 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

Bias operation of the 1160 is Class A mode up to approximately 17 watts. Beyond 17 watts, the 1160 operates in Class AB mode. A circuit to notch out crossover distortion is implemented to maintain linear operation. The output impedance of the 1060 is effectively 0 ohms, meaning the output and electrical operation of the amplifier is non-reactive.

The voltage rails of the 1160 operate at +/-60V. Maximum power output is 300 watts into 8 ohms, with peaks of 600W and 1,200W into 4 and 2 ohms. The ability to drive a loudspeaker without dynamic limitations was one of the primary goals of the 1160. This means no increase in distortion, even during the most demanding passages or largest transient peaks, regardless of load or impedance. To meet this goal of wide dynamic range required very high voltage capability.

Starting with the microphone and throughout the entire recording and playback process, an audio signal is stored as *voltage*, not as current, thus a greater voltage potential was required to avoid any dynamic compression and allow for continuous high power output.

The complete power supply and transistor complement were designed around this 300W power output figure, regardless of impedance, guaranteeing that the 1060 will produce a minimum of the rated output power into any load.

### 7. Output Circuit and Transistors

The output section of the 1160 is comprised of 56 bipolar output devices. Bipolar devices were chosen over FET-type designs for the same reasons as the input section. Each channel amplifies both the positive and negative half of the analog waveform in a true differentially balanced design.

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

### 8. 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 its mounting tab and keeps the pressure uniform for all output devices. A special thermal transfer material between the clamp bar and the output device aids in keeping clamping pressure uniform and equal without exposing the housing of the device to potential damage in the event of over-tightening

of the screw that secures the device, leading to a cracked or broken housing. The overall benefit of this methodology is that every output device operates at a uniform and stable temperature due to the elimination of variance in clamping pressures that occur when each device is individually attached to the heatsink.

The 1160 heatsink is cut from a 25 lb. (11.3 kg) solid billet of aluminum and features Boulder's familiar digital waveform pattern on the exterior surface. Standalone fins are avoided to eliminate any resonance or ringing. Each heatsink is damped to well above the audio spectrum by securing it to chassis panels and circuitry of differing resonant frequencies. This contributes to the elimination of microphonic distortion effects that leech into the output of the amplifier by preventing any mechanical resonance from affecting the transistors that are attached to the heatsink.

In addition to complete elimination of microphonic resonances, the 1160's heatsinks were also designed for efficient heat dissipation.  Both left and right heatsinks minimize metal mass in order to reduce the amount of heat retention within the chassis. Vertical holes are drilled through the entire height of the heatsink along its length to initiate convective cooling. All heat generating components in the output section, including regulators and output transistors, are clamped to the heatsink to increase cooling efficiency and reduce the overall operating temperature of the amplifier at any power output.

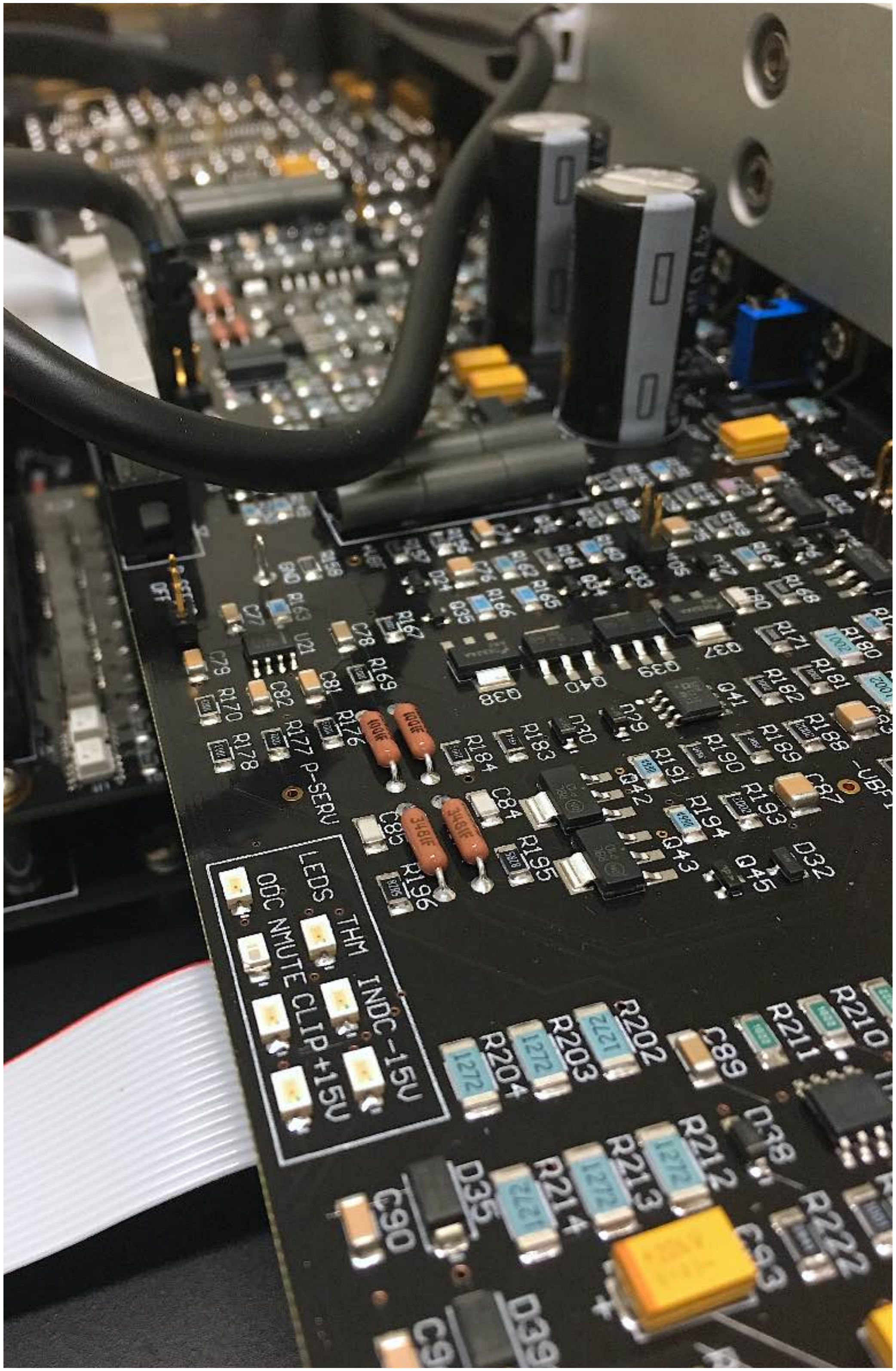
Every piece of the 1160's chassis exterior has been machined from solid billets of 6061-T6 aerospace-grade aluminum. Machining and engraving is performed in-house on Boulder's own CNC machining centers which operate at up to 90,000 RPM, and the bead-blasted finish is performed in Boulder's own proprietary blasting chamber prior to clear anodizing.

## 9. Output Terminals

Output is delivered to the loudspeakers via two pairs of custom, spade-only binding posts. Internal connection of both pairs of binding posts is parallel, so no sonic advantage exists in connecting one set over the other. A large, conductive surface area is provided to achieve the lowest contact resistance possible.

Connection options for banana plugs or bare wire are not supported. Banana plugs have been shown to decrease in spring tension over time, which in turn increases impedance through the connector and decreases reliability. Bare wire is at best a haphazard form of connection with the very real potential for shorted outputs.

At no point is the 1160 "voiced" or tuned for a specific sound or type of presentation. 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 to the greatest degree possible during engineering.




## Protection Circuitry

### 10. Monitoring and Protection

The 1160 features a complete array of protection circuits, all intended to prevent damage to either the amplifier or loudspeakers and enable quick and simple troubleshooting. All protection circuits are ARM-processor controlled.

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

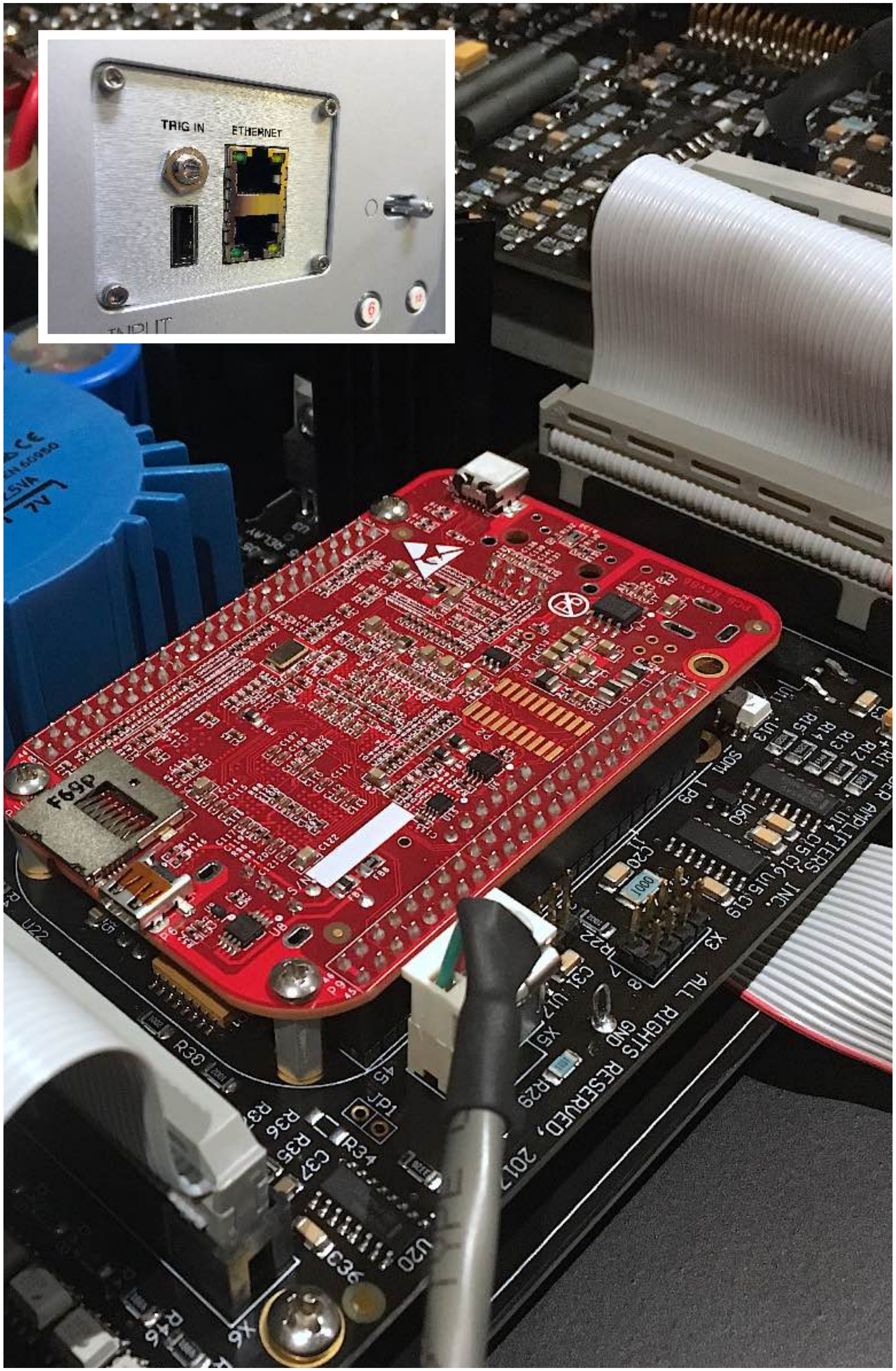
In the event that DC is present on the inputs of the 1160, a servo system will null any detected DC offset in order to prevent potentially damaging voltages from appearing at the output terminals. A secondary protection circuit will mute the amplifier if 50mV or more is detected. The amplifier will remain muted until the offset falls below 50mV, at which time it will again be nulled by the servo system.

In addition, a thermal-protection circuit signals when the transistor cases reach 75° C. Current output will be limited until the temperature of the output device cases again falls below 75° C and normal operation resumes.

The power supply for each subsection of the amplifier is monitored by the 1160’s central 64-bit, multi-core Advanced RISC Machine (ARM) processor. The ARM processor is mounted on an isolated circuit board assembly, which is then optically isolated to prevent any radiated or conducted noise from affecting the audio portions of the amplifier.

In the event of a power supply failure, the ARM processor will immediately mute the output of the amplifier to prevent damage to the loudspeaker and illuminate a group of LEDs mounted to the output PCAs on each channel to indicate the location of the problem for service purposes.

Mains power errors occur when the AC mains voltage is too high or too low. If the AC mains voltage exceeds a predetermined limit while the 1160 is powered on, the ARM processor will mute the amplifier outputs and turn the front panel LED red as long as the over-voltage condition exists. If the mains voltage exceeds 135VAC or drops below 90VAC while the 1160 is powered on, the ARM processor will immediately turn the amplifier off and the front panel LED will blink a specific sequence to indicate the nature of the external problem. The ARM processor will then refuse to turn the amplifier on until the problem has been corrected.




# External Control

## 11. IP Control and Boulder Net

The ARM processor within the 1160 is responsible for all control circuits within the amplifier, including power on/off and two way communication with all subsections. It is also responsible for connection to outside control systems such as Savant, Crestron, and others, and providing two-way communication with these systems.

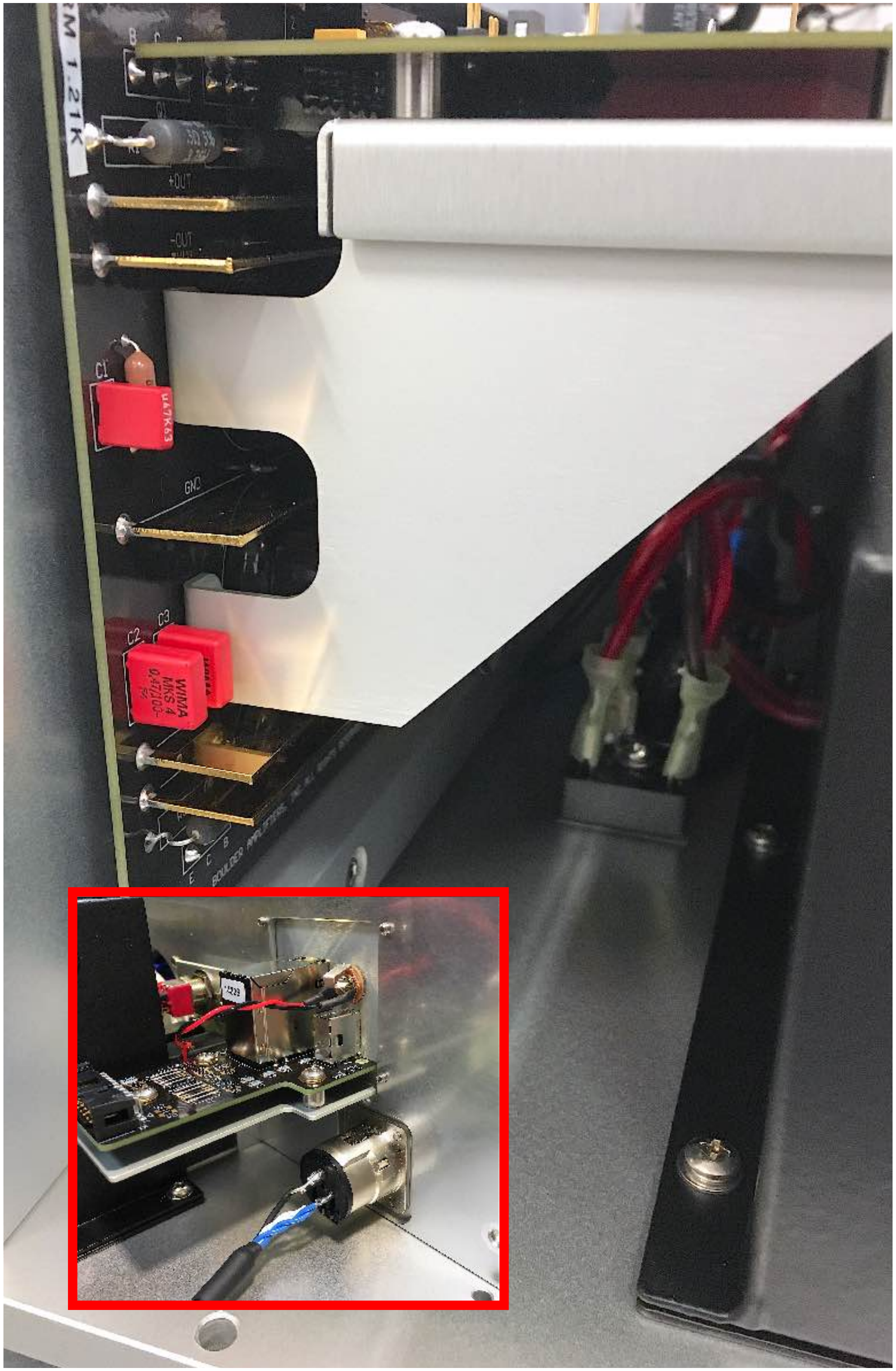
All communication with the 1160 is network IP-based and allows the amplifier to respond to commands and become a part of integrated homes or fully-automated theater systems or listening rooms. Because of this network connectivity, the 1160 can host an accessible HTML page when connected to a local area network that can be accessed by any web browser for custom setup, naming, or notification broadcasts.

The 1160 has also been designed to operate seamlessly with other current Boulder components via the Boulder Net system. Boulder Net is a continuously self-monitoring system that keeps track of individual interconnected networked Boulder components and all of their associated setup parameters, names, zones of operation, and protection circuits.

The Boulder Net system is a proprietary system of inter-component communication specific to Boulder products for control, setup, and multiple zone function distribution. It is an IP-based communication system that enables a user to setup and control the system and initiate power-up, power off, input selection, unit naming and location, user preferences and adjustments, volume and streaming commands, as well as transmit any protection or warning notices to any Boulder product with an alpha-numeric display or a mobile device running the Boulder Net system application. In this way, localized system integration and control can be achieved without the need for, or independently of, a whole-home integration system.

As all Boulder Net commands are IP-based and built around the JSON (JavaScript Object Notation) protocol, they can also be seamlessly integrated into 3rd party networked control systems.

12V trigger compatibility is supported via a 1/8” minijack connection on the rear panel of the 1160 that allows the amplifier to be turned on and off by any source (SSP, preamplifier, etc.) or controller that features a 12V trigger output. Both continuous and pulse trigger systems are supported.




## Mechanical Design

The mechanical design of the 1160 was constructed to eliminate mechanical resonances and provide effective heat dissipation. All casework was designed on advanced 3D CAD systems and machining tolerances are held to within 5/10,000 or 1/1,000 of an inch, depending on the application of the metalwork.

The 1160 is the first Boulder product to feature radiused corner edges and features a unique front panel design displaying the topographical mapping of Flagstaff Mountain to the west of Boulder, Colorado.

Every piece of the 1160's casework has been machined from solid billets of 6061-T6 aerospace-grade aluminium. Machining is performed on Boulder's own CNC machining centers which operate up to 90,000 RPM. Metalwork is then spin-brushed and sanded prior to bead-blasting. The bead-blasted finish is performed in Boulder's own custom built and proprietary blasting chamber and then clear anodized using Bouder's own anodizing recipe to maintain color and texture consistency from batch to batch.

The entire exterior chassis of the 1160 is mechanically damped, either via the use of direct application of damping materials (such as the top cover) or by adjoining one subassembly to another in order to raise the resonant frequency of the compound assembly to well above the audio domain.

All brute power supply transformers are potted, floated, enclosed in a welded steel enclosure, and DC filtered to eliminate mechanical resonances. The smaller microprocessor transformers are potted and located on a separate PCB to prevent mechanical vibration from affecting the amplifier's output.

### 12. PCB Mounting

All circuit boards within the amplifier are screwed directly to mounting plates designed specifically for each circuit PCB. No long spans of PCB are left open to prevent board flex or "trampolining" so as to prevent solder joints from weakening or breaking during rough transportation or handling. A non-conductive foam damping material is then sandwiched between the circuit board and the mounting plate in order to prevent any vibration, either air- or chassis-borne, from inducing any microphonic distortions.

### 13. Interlocking Structure and Damping System

All chassis parts are interlocking and are attached via stainless steel screws and threaded inserts to prevent corrosion in harsh or salt air environments. The interlocking chassis component design has been utilized to eliminate any effect chassis resonances may have on the audio signal by raising the overall harmonic resonance of the chassis above the audio bandwidth when bolted together. The heatsinks contain no fins or resonant tongs that might ring and thus modulate the audio signal passing through the output transistors passing through them.

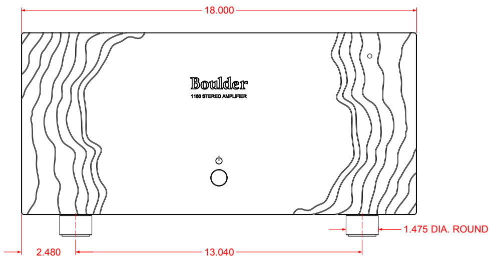
The top cover is damped by way of a die-cut sheet of pliant damping

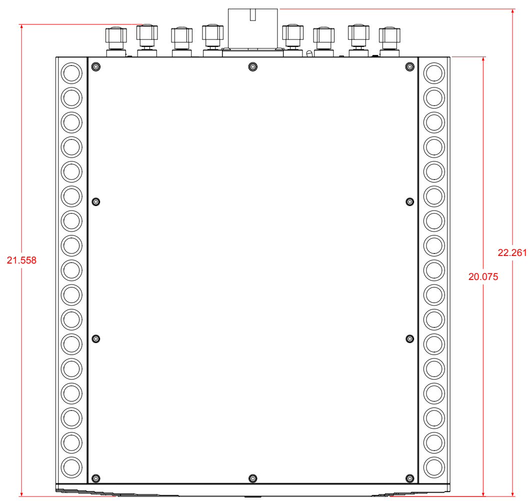
material compressed between the top cover and a stainless steel plate screwed to the underside of the cover. The layer of self-adhesive and elastic aircraft damping material is sandwiched between the top cover and stainless steel plate to form a complete constrained layer damping system itself rather than a plate with damping material attached to it. The top cover assembly is then bolted to the heatsinks, front panel, and rear panel to prevent any rattling or vibration when installed.

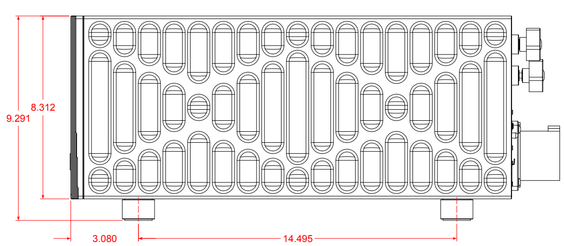
The complete amplifier chassis is supported on four feet comprised of a three-layer system of damping and shock absorption. Each foot is made of a machined and bead-blasted cylinder that incorporates two layers of damping material (one firmer and one softer) in a constrained layer damped arrangement, isolating the amplifier from any direct coupling of the chassis to the surface on which it is placed. This eliminates any need for specialty racks, shelves, or accessory isolation devices in most installations.

The front panel button is cut from solid bar stock stainless steel. It is then machined to shape and hand-polished to a mirror finish in a nine-step process that is much more durable and corrosion-proof when compared to simple plated or plastic solutions.

## 15. Dimensions




# Specifications

## 16. Technical Specifications

| | |
|---|---|
| THD at Continuous Power, 20 Hz to 2 kHz | 0.001% |
| THD at Continuous Power, at 20 kHz | 0.005% |
| Continuous Power, 8Ω | 300W |
| Continuous Power, 4Ω | 300W |
| Continuous Power, 2Ω | 300W |
| Peak Power, 8Ω | 300W |
| Peak Power, 4Ω | 600W |
| Peak Power, 2Ω | 1,200W |
| Frequency Response | -3 dB @ 0.015 Hz, 150 kHz |
| Magnitude Response, 20 Hz to 20 kHz | +0.00, -0.04 dB |
| Magnitude Response, -3 dB at | 0.015 Hz, 150 kHz |
| Voltage Gain | 26 dB |
| Signal to Noise Ratio (re: 500W/8Ω) | -127 dB, unweighted, 20 to 22 kHz |
| Input Impedance | Balanced: 100kΩ, unbalanced 50kΩ |
| Crosstalk, L to R or R to L | Greater than 120 dB |
| 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 6mm/0.25” Wingscrews |
| Power Requirements | 100/120/200/240 VAC, 50-60Hz |
| Power Consumption | 240W Nominal, 3,000W at Maximum Output |

*All specifications measured at 120VAC mains power*

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