Since 1984

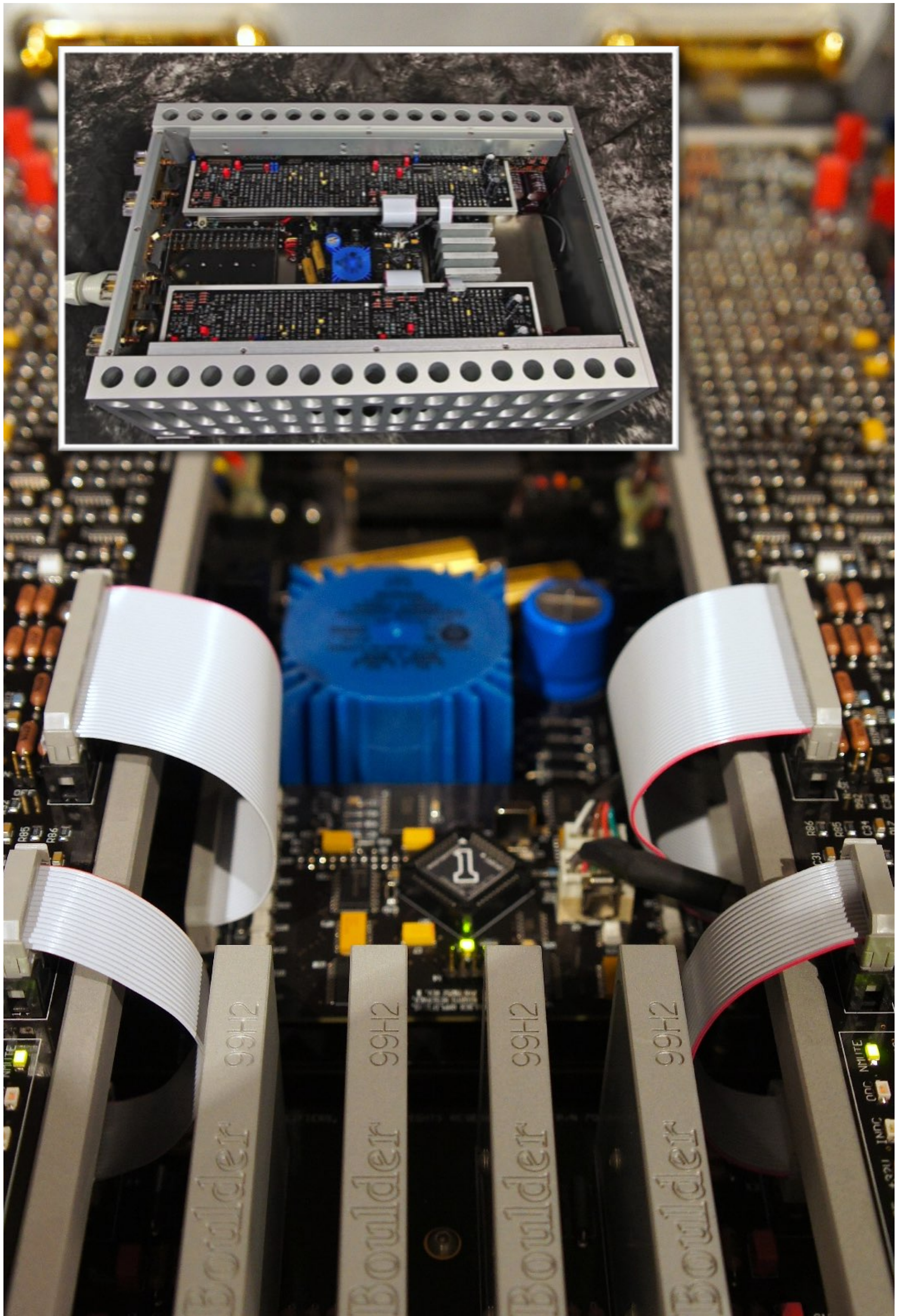
Boulder

2160

Stereo Power Amplifier

Technical Information

An introduction to the technology in the 2160 Stereo Power Amplifier. The 2160 is the second generation of 2000 Series stereo amplifier and the follow-up to the most successful product in Boulder's history.



Basic Design

The 2160 Stereo Amplifier is the second generation of 2000 level stereo power amplifier from Boulder. Following the original 2060's release, the 2000 Series stereo amplifier remained in production for over sixteen years, an unprecedented example of stability and superiority in the high-performance audio industry. Eventually, technological advancements and demand were such that a new and revised version was engineered to meet the demands of the market.

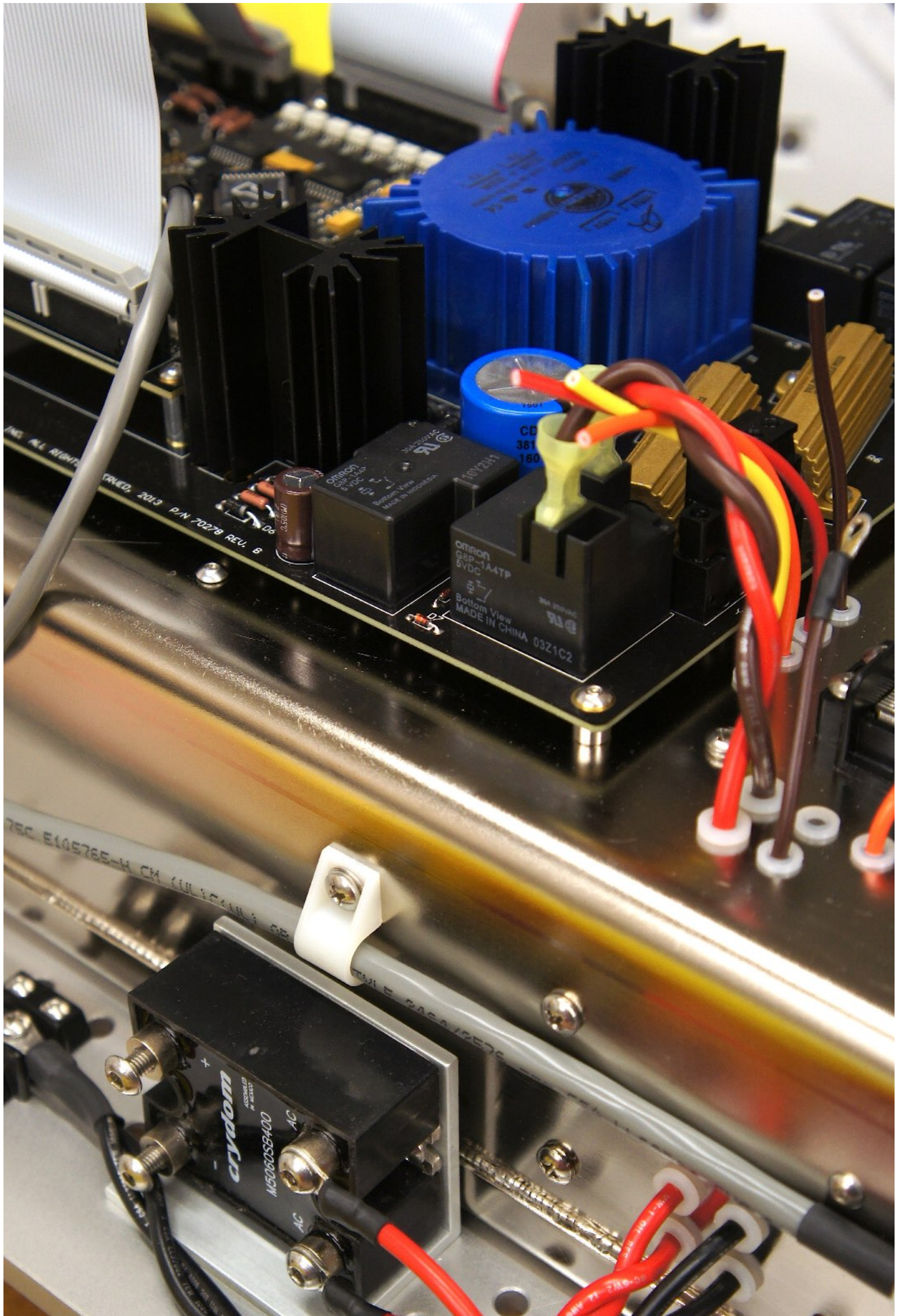
The 2160 concept was based on that of its 2060 predecessor. It is a true dual-mono design with isolated channels. The left and right channels are physically symmetrical, making each half of the amplifier sonically identical as well. All metalwork is interlocking, entirely machined from solid billet and non-resonant to eliminate microphonic resonance distortions. Physical changes to the exterior are subtle, more evolution than revolution, in order to maintain the iconic look of the 2000 Series.

Gain stages within the 2160 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 2100 power amplification. The 99H2 is a new, surface-mount design, modular, fully-discrete, extremely high-current gain stage that provides the best possible distortion figures and exceptionally low noise. The 2160's bias operation is Class A to full rated 600W output power. An analog bias circuit continually monitors the output voltage, current draw and load to adjust the bias current as necessary. If a musical peak 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 unless another transient peak is detected. This has the benefit of keeping the 2160 operating in Class A mode without the drawbacks of massive power consumption, excessive heat generation and the audible steps or "sliding" of other active bias systems.

Power output is a continuous 600 watts into an 8, 4, or 2-ohm load. Peak output will double to 1,200 watts into a 4-ohm load, and 2,400 watts into a 2-ohm load. The ability to deliver power under load contributes to unmatched control and dynamic impact during transients or dynamic swings and a sense of effortlessness during low frequency passages into any and all loads.

The 2160 is true differentially balanced from the inputs to the outputs for optimal common-mode noise cancellation in tandem with the use of the 99H2 gain stage. Lower distortion, and in particular, a lower noise floor contribute to vastly increased resolution of fine detail.

Contents



Power Supply

The 2160 incorporates two main power supplies; a massive, primary brute supply for the input and output sections and a smaller, regulated independent supply for the supervising microprocessor control section. All supplies are linear. No switching supplies are used to reduce radiated noise. Switch-mode supplies are a solution based on economy rather than performance and are avoided.

1. AC Mains

AC mains power to the 2160 is provided via a detachable 32-amp 6h, 250V IEC connector. A 32A connector was selected due the amplifier's potential to draw nearly 30A peaks 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 ideal electrical transfer. All 2160s can be built to operate at 100, 120 and 240 volts AC while still providing full rated output power.

2. Brute Supply

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

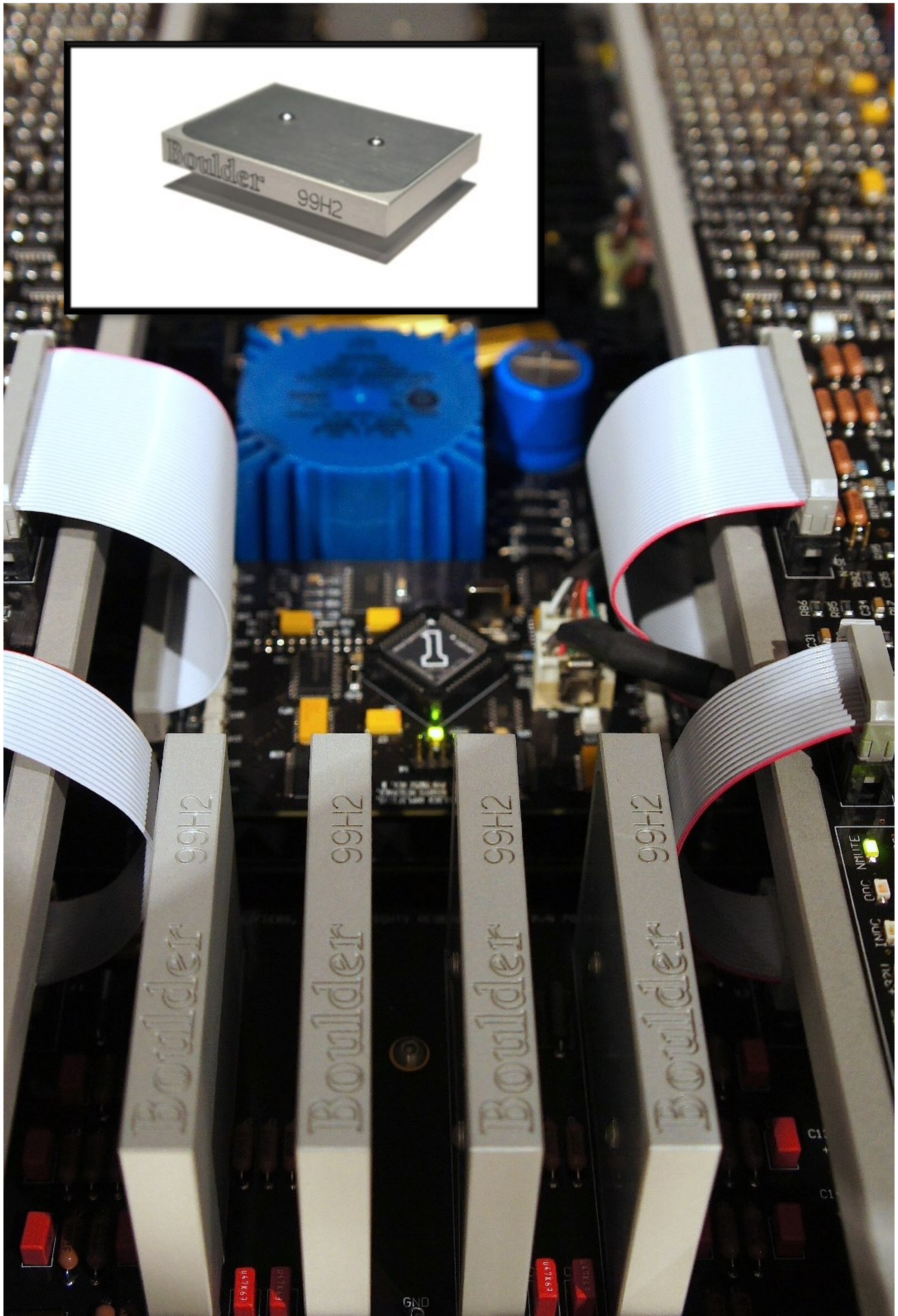
Both transformers "float" in a welded, nickel-plated, rectangular steel tube. Each transformer is isolated from the steel case so that no contact is made between the transformer and any chassis part that may transmit mechanical noise. The tube is magnetically shielded and high-mass loaded with a unique mineral, glass and epoxy resin compound to eliminate any hum or operational vibration. The complete transformer tube weighs well over 65 lbs. (30 kg).

To further prevent the transformers from buzzing or creating mechanical noise, a DC elimination circuit is utilized to block up to 3VDC from the AC mains. DC is one of the primary causes of transformer hum, thus this added circuit is essential in maintaining silent operation in any environment.

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

3. Microprocessor Supply

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



Input Stage

1. Input Circuitry and Topology

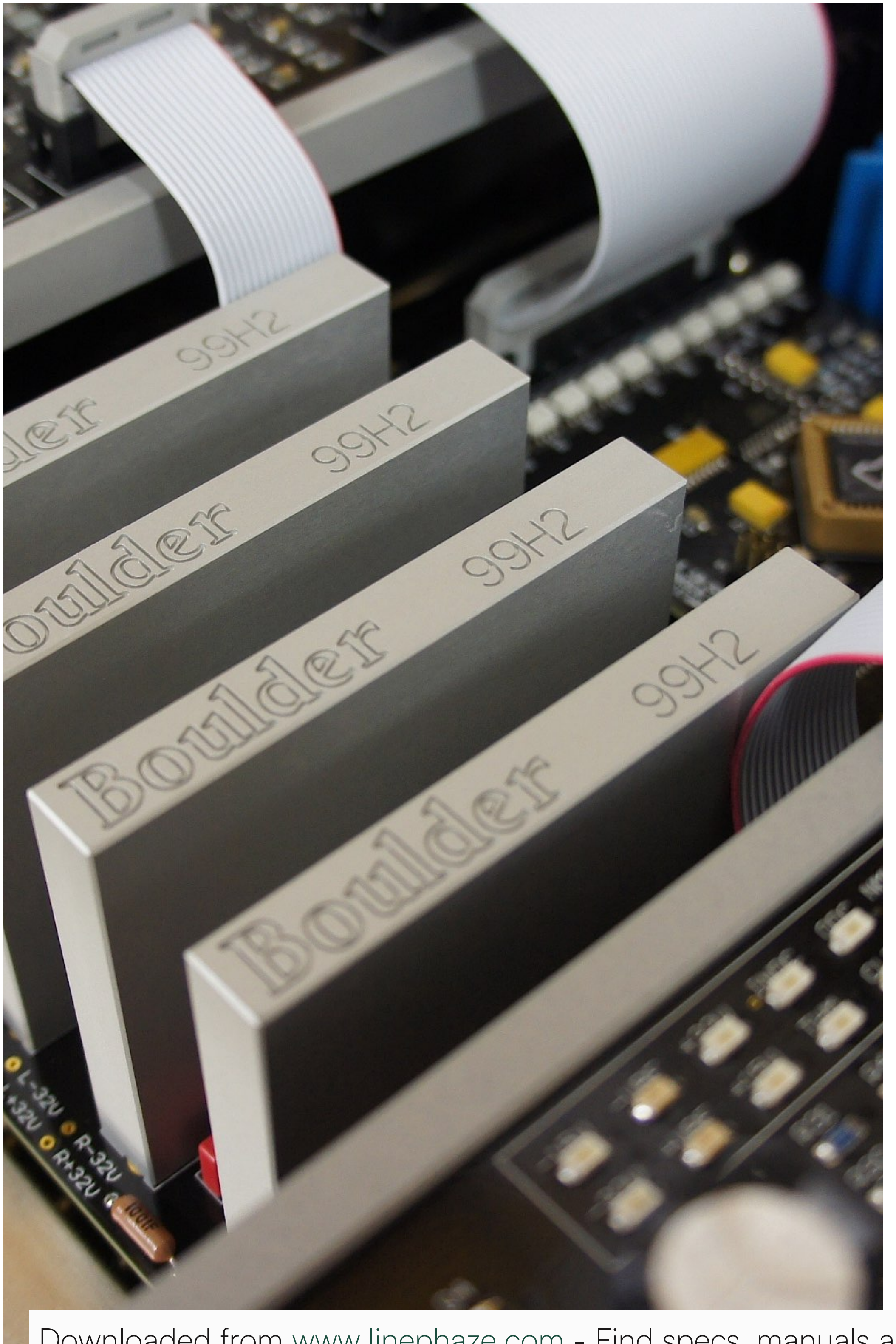
The input circuit is a true, full differentially balanced, three-stage, instrumentation-style circuit initiated with three-pin XLR connectors. This ensures that the audio signal passes from the source to the amplifier free of distortion and noise by keeping the input impedance as high as possible in comparison to the output impedance of the source. Input impedance is a tested and verified 200k ohms (100k 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 designated as positive or "hot," and the amplifier's overall output is non-inverting, meaning that a positive impulse at the input connectors will result in a positive impulse at the output terminals.

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 distortion levels. Bipolar devices are inherently more reliable as they aren't prone to static-related damage. More importantly, the circuit topologies required for FETs are awkward, with high levels of pre-distortion required to drive the outputs.

The 2160 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 that will result in 3VDC at the speaker terminals will engage a speaker-protection circuit that immediately mutes the output.



Gain Stage

1. 99H2 Gain Stage

The 2160 incorporates +26 dB of gain. The gain stages in the 2160 are Boulder's proprietary 99H2 gain stage, a proprietary, 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 design. Two gain stages are used in each 2160, 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.

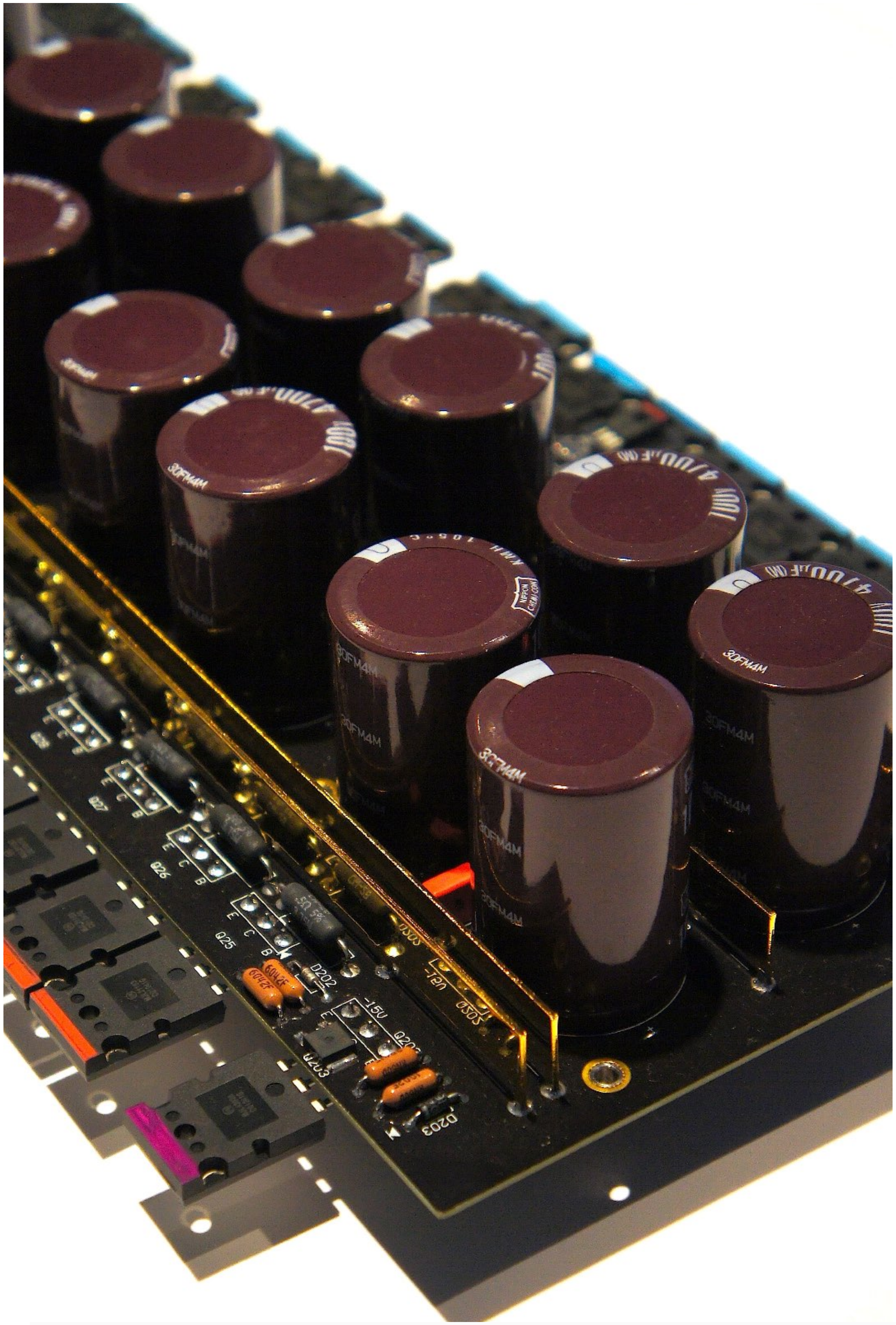
The 99H2s in the 2160 are implemented on small, surface-mount circuit boards, which are assembled in-house on Boulder's own pick-and-place machines and board ovens. Surface-mount technology allows for smaller PCB real estate (which decreases PCB capacitance) as well as elimination of lead inductance 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 plus evenly distribute and stabilize heat within the circuitry. The entire 99H2 assemblies (two each for positive and negative halves of the waveform) are then run through 19 stages of testing 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 (maximally 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. This philosophy still exists in a number of hobbyist workshops today.

In 1984 the Boulder 500 amplifier showed the audio community 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 2160 operates in full Class A bias mode to full rated output (600WPC). The output impedance of the 2160 is a specified and measured 0 ohms, meaning that the output and operation of the amplifier is non-reactive.

The voltage rails of the 2160 operate at +/-66V. Maximum power output is 600 watts into 8 ohms, with peaks of 1,200W and 2,400W into 4 and 2 ohms respectively. One of the primary goals of the 2160 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 as current. An amplifier must be able to produce a high output voltage in order to accurately recreate an audio signal, whereas current is the result of load.

The power supply and transistor complement were designed around the 600W output figure, regardless of load impedance, guaranteeing that the 2160 can produce a minimum of the rated output power into any speaker.

1. Output Circuit and Transistors

The output section of the 2160 is comprised of 80 bipolar output devices (40 per channel). Bipolar devices were chosen over FET-type designs for the same reasons as the input section. Each half of the chassis amplifies an independent channel of audio signal as expected in a true balanced, dual-mono design.

The use of a larger number of output transistors reduces the thermal cycling range required of each individual device as well as the amount of stress placed upon each device during high power handling–each transistor 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

All output devices are clamped to a non-resonant heatsink via a custom CNC machined clamp bar. This unique clamping design eliminates the individual screw-down method that secures each transistor to the heatsink via a screw and reduces long-term reliability. Clamping pressure is also uniform for all output devices. A special heat transfer material between the bar and output device keeps clamping pressure uniform 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 in clamping

pressures that occur when each device is attached to a heatsink individually and the prevention of eventual electrical failure due to a device no longer being pressed to the heatsink properly. All additional heat-radiating devices, such as regulators, have been moved to the heatsink for greater heatsinking. Overall thermal stability is increased via the use of a very high-mass heatsink.

Each 2160 heatsink is cut from an 80 lb. (36kg) solid billet of aluminum and features Boulder's familiar digital audio waveform pattern machined into the exterior surface. Extruded fins are avoided to eliminate any resonant ringing. Each heatsink is resonance damped to well above the audio spectrum by securing it to chassis panels of differing resonant frequencies. This stops microphonic distortions from leeching into the output of the amplifier by way of mechanical resonances where the output devices are attached directly to the heatsink.

In addition to complete elimination of microphonic resonances, the heatsink of the 2160 was also designed for efficient heat management. Each heatsink utilizes convection to dissipate heat generated by the amplifier while taking advantage of metal mass to retain enough heat to prevent continuous temperature fluctuations during loud and quiet passages of music. Vertical columns are drilled into the entire height 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.

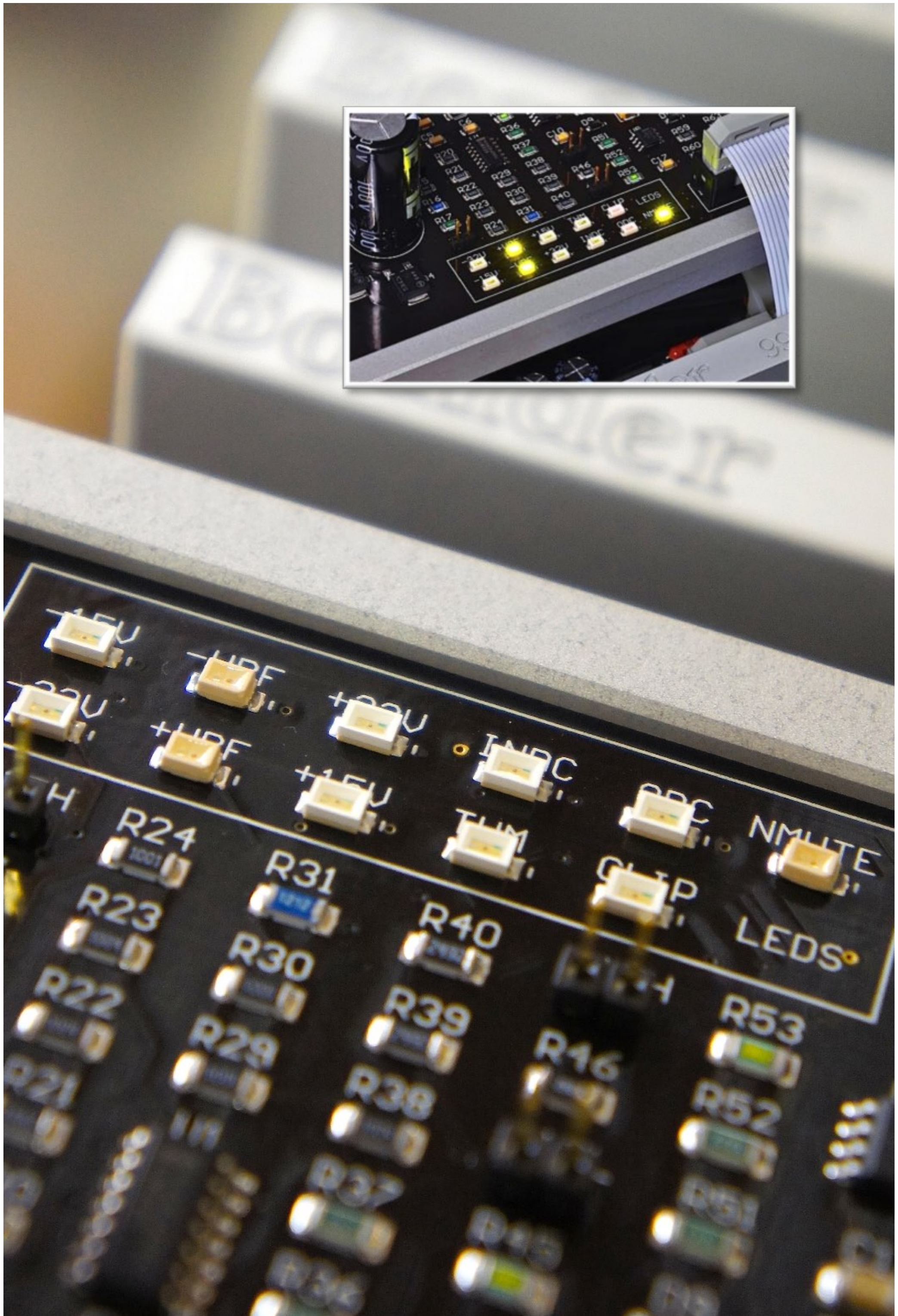
Every piece of the 2160's chassis has been machined from solid slabs of 6061-T6 aerospace-grade aluminium. Machining is performed on Boulder's own CNC machining centers that operate at speeds up to 65,000 RPM. The bead-blasted finish is applied in Boulder's own wet blasting room prior to clear anodizing.

3. Output Terminals

Output is delivered to the loudspeaker via two pairs of custom, spade-only, ¼" (6 mm) 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 surface area is provided to maintain 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, while bare wire is at best a haphazard form of connection with the very real potential for shorted outputs.

At no point is the 2160 "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 2160 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 2160 will then try to re-engage the outputs 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.

The 2160 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. In Boulder Linked systems, the amplifier will also send a message to the master component that will generate the text “AMP DC” on the display of the master unit. 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 the outputs if any DC is detected at the outputs.

All power supplies within the amplifier are continuously monitored. In the event that any supply fails, the amplifier will power down and cannot be restarted until the problematic supply is operating correctly and the fault code is cleared in order to prevent potentially damaging voltages from appearing at the output terminals. In Boulder Linked systems, this fault will send a message to the master component that will generate the text “AMP ERROR” on the display of the master unit.

A thermal protection circuit is also present. This circuit monitors the temperature of the output devices and protection is triggered when the transistor cases reach 95° C. This corresponds to approximately 80° C at the heatsink. Current output will be limited until the temperature of the output device cases again falls below 95° C, at which point normal operation will resume. In Boulder Linked systems, this fault will send a message to the master component that will generate the text “AMP HOT” on the display of the master unit.

The 2160 monitors the output signal at all times and in the event of amplifier clipping (output power capabilities have been exceeded and the audio waveform is severely distorted or “clipped”), the front panel LED will flash red to indicate the problem.

External Control

1. Boulder Link and IP Control

The 2160 has been designed to be seamlessly integrated into custom home installations as well as incorporated into systems with other legacy or current Boulder Linked products.

The Boulder Link system is a proprietary system of inter-component communication and control 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 text notices to any Boulder product with an 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.

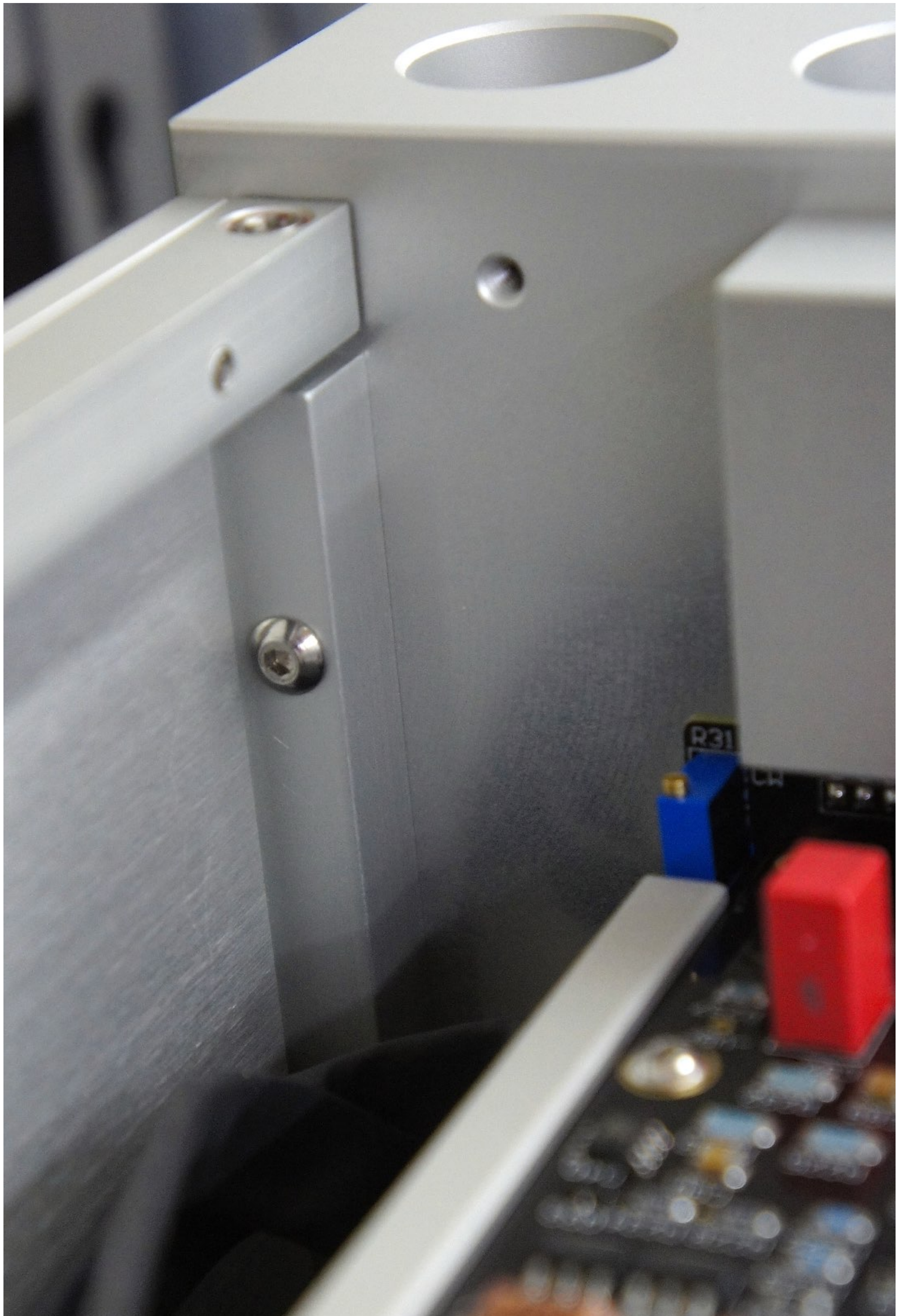
Upon power-up, a 2160 will detect any other 2100 or 3000 Series amplifiers connected via Boulder Link. It will then automatically determine the proper sequence and rate in which to turn on each amplifier so as to prevent excessive AC line current draw.

Ethernet connection options have also been made available that will allow IP (Internet protocol) control of amplifier turn-on and turn-off as well as all system commands.

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

In highly complex custom installations, discrete coding options are available from the Boulder factory to facilitate individual commands and control of each Boulder product for use with these outside control systems.

In addition, a 12V trigger via a 1/8” mini-jack connector is available on the rear panel of the amplifier to control the standby function of the amplifier in a 12V trigger-based system, such as those from surround sound processors. When a continuous 12V DC signal is present at the amplifier’s trigger connector, the amplifier will turn on. When the 12V signal is absent, the amplifier will revert to standby mode.



Mechanical Design

The mechanical design of the 2160 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 2160 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 mechanical and electrical isolation.

1. PCB Mounting

All circuit boards within the amplifier are slid into machined frames custom 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 damping foam material is then sandwiched between the circuit board and the frame assembly in order to damp any vibration, either air- or chassis-borne, and eliminate any microphonic distortions.

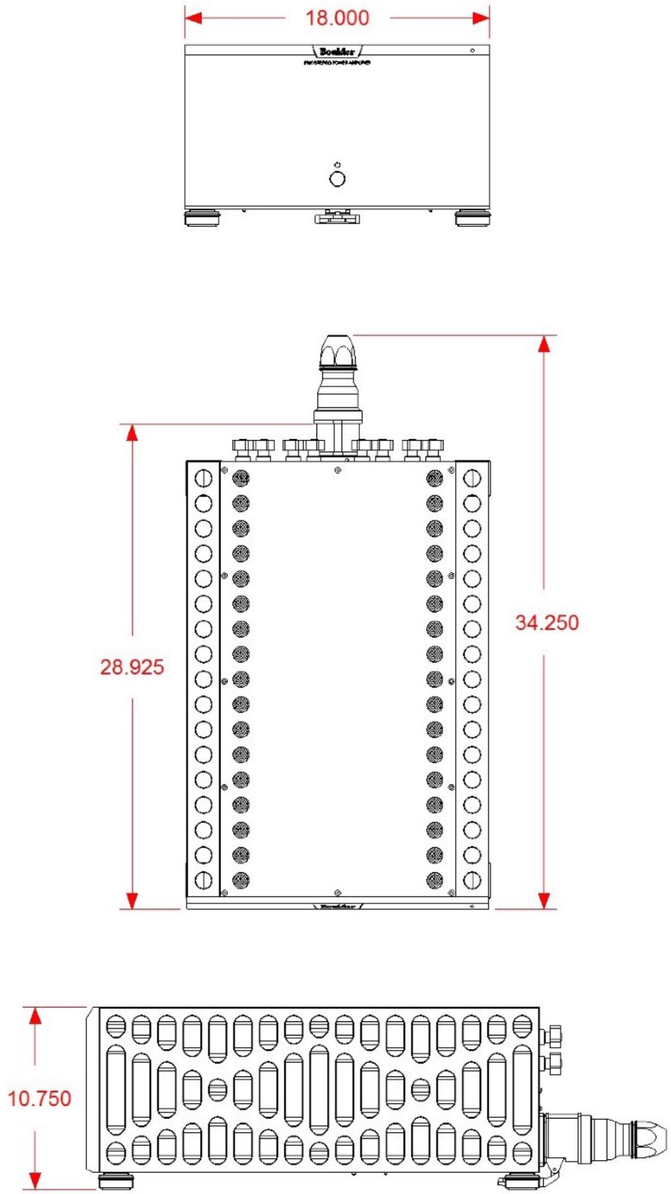
2. Interlocking Structure and Damping System

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 its underside. 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 performs the dual function of providing ideal shielding as well as keeping the top cover tight and rattle-free. Once in place, the top cover is held in place via stainless steel screws that are counter-sunk into the top cover.

The chassis is supported on multi-layer feet comprised of a four-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. Dimensions



2. 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	600W
Continuous Power, 4Ω	600W
Continuous Power, 2Ω	600W
Peak Power, 8Ω	600W
Peak Power, 4Ω	1,200W
Peak Power, 2Ω	2,400W
Magnitude Response, 20 Hz to 20 kHz	+0.00, -0.04dB
Magnitude Response, -3dB at	0.015 Hz, 200 kHz
Voltage Gain	+26dB
Signal to Noise Ratio (re: 500W/8Ω)	-135dB, Unweighted, 20 to 22 kHz
Input Impedance	Balanced: 200kΩ
Common Mode Rejection (Balanced Only)	60Hz: 90dB, 10kHz: 70dB
Crosstalk, L to R or R to L	None
Input	3-pin Balanced XLR, Pin 2 Hot
Output Connectors	2 Sets 0.25" (6mm) Wingscrews
Power Requirements	100/120/200/240 VAC, 50-60Hz 240W Nominal 5000W at Maximum Output

All specifications measured at 240VAC mains power

Boulder Amplifiers
3235 Prairie Avenue
Boulder, CO 80301
Tel: 303-449-8220
e-mail: sales@boulderamp.com
web: www.boulderamp.com