

BAT White Paper

There is a consistent philosophy and common architecture behind every product developed by Balanced Audio Technology. You will see these common architectural elements referred to in our product descriptions. This common approach is grounded in solid engineering principles. In building a car for the ultimate in track performance, if you believe that rear wheel drive is better than front wheel drive for handling, then you build all your track cars based upon rear wheel drive architecture. Balanced Audio Technology believes that there are solid principles that lead to building a product for the ultimate in sound performance. What are these common principals or architectural elements?

Balanced Circuit Design

First and foremost, our products rely upon balanced circuit design. We staked our reputation on this architectural decision from the day that Balanced Audio Technology was founded. Electrical engineers have known for decades that given a similar implementation, a balanced circuit will always sound better than a single-ended one. Some manufacturers still claim that balanced topology is not an improvement; that "it isn't necessary". The reasons for these claims become clear once you realize that they come from the makers of single-ended products. While it is true that balanced topology requires new expertise, the main stumbling block has always been cost. When implemented incorrectly, a balanced circuit doubles the component count of a single-ended one. Many manufacturers are unable to break this cost barrier. Others are reluctant to throw away old "working" solutions.

The best way to demonstrate the improvement that balanced topology brings to audio reproduction is by setting up a good balanced system: source, preamp, power amplifier. Listen to it first and then switch into single ended-mode. Most equipment will allow you to do this by simply changing the interconnect cables or by using RCA-to-XLR adapters. You will hear an easily detectable change. Go back and forth several times – same source – same preamplifier – same power amplifier. The balanced connection always yields a more palpable and realistic sound.

Attempts have been made in various publications at explaining the sonic superiority of balanced topology. For lack of a better handle, authors concentrated on the enhanced noise immunity and high common mode rejection ratio (CMRR) of such circuits. All our experience indicates that this is a great oversimplification. Such explanations do not even begin to clarify why the *overall sound quality* improves from switching to balanced, not just the noise aspects. There is still no reliable evidence that the CMRR is *the reason* for the balanced topology's virtues in audio systems. In fact, some fine balanced amplifiers do not possess even an average CMRR, while still sounding exceptionally good.

Further references to a balanced circuit's higher RF (Radio Frequency) immunity hold even less credibility. Typical active circuits exhibit essentially no CMRR at high frequencies. RF rejection is commonly achieved through passive protection, and not through reliance on the active common mode rejection of amplification devices. Active circuits usually are unable to deal with high frequency common mode signals and simply convert them into the rectified DC-to-low-frequency byproducts. This is hardly a desirable feature, for these byproducts then appear in the sound as noise and distortion.

Then, how do we know that balanced is superior? We listen. We believe it is better to admit that we don't understand something than to provide a pseudo-scientific explanation. We build better and better balanced circuits and hear into the music ever more deeply.

Still, we believe that some explanation is required. In our opinion balanced topology simply provides a *complete signal representation*. Something magical happens when you free yourself from the limitations of the single-ended structure with its *half-signal processing*. If a one-handed craftsman can be very good, imagine what he could do with two hands.

Component Friendly Interface

A common misconception in high end audio is that balanced components are incompatible with single-ended equipment. Therefore, your investment in audio equipment is sacrificed if you move from a completely single-ended system by adding balanced components. Nothing is further from the truth. A correctly designed balanced component will be *fully compatible* with single-ended components. Indeed, many of our preamplifiers now offer single-ended input as well as single-ended output connections on the back panel. For those BAT components that use XLR connectors, all that is required to connect your single-ended component is a set of XLR to RCA input or output adapters.

Balanced Audio Technology also designs all of its products to interface seamlessly with the wide variety of audio components made, both past and present, in the marketplace. We have seen a number of manufacturers, for instance, that rely upon brutal input impedances for their power amplifiers in an attempt to lock the customer into buying a complete system from that manufacturer. We believe this is simply wrong.

BAT designs all of its power amplifiers, for example, with a component friendly input impedance of between 50k to 200k. In non-technical terms, this power amplifier input impedance is a very gentle load that can be driven by most any preamplifier or source component ever made. For example, even the kit based Dynaco PAS-3 preamplifier from the 60's would have no problem driving our reference REX II Power amplifiers or VK-655SE monoblocks.

The Low Restriction Signal Path

The circuit topology of any BAT product is consistent with our philosophy of utmost simplicity in implementing a clean, unobstructed signal path. However, the unique design of our products goes significantly beyond simply reducing the number of gain stages.

Every gain stage introduced into a circuit should perform a useful function. Unfortunately, every gain stage (be it active or passive) will also restrict the signal flow to some degree. The more restriction it imposes, the stronger the negative effects such as loss of detail, anemic bass and lackluster dynamics. Some of the elements that make the signal path more restrictive are more intuitive to understand than the others. For instance, the negative effect of a high number of gain stages is easy to understand. On the other hand, the effect of the gain stage's quiescent current, or gain stage power dissipation, is not always appreciated. In reality, however, if one asks a gain block, running at 2mA quiescent current, to deliver 1mA current to its load, then it is easy to imagine that such a weak gain block will struggle. In the same way that we do not expect a one hundred pound weight lifter to set the world record in the heavy weight category, we shouldn't expect an anemic gain stage to drive its load with ease.

Many products today, unfortunately, employ such anemic gain stages – often running at 2mA to 4mA of quiescent current. This weak design approach is easily understood once you consider that increasing the quiescent current automatically means an increase in the power required as well. This increase in power calls for bigger and more expensive power transformers and filter components.

Balanced Audio Technology's first product, the VK-5 preamplifier, contained a gain stage running at an extremely high - some might say insanely high - current of 75mA per channel. This high quiescent current allowed the VK-5i preamplifier it to drive nearly any load to high peak levels with negligible distortion. This hallmark of Balanced Audio Technology design continues today in all of our products. For example, the gain stages in the REX II preamplifier run at an astonishing 150mA per channel!

It should be more or less intuitive that the smaller the portion of current that goes toward driving the load, the more effortlessly will any gain stage perform its task. *This philosophy also allows Balanced Audio Technology to build high-power solid state amplifiers with just two gain blocks. The voltage gain stage in the VK-655SE power amplifier, for example, operates at an uncommon 250mA - eliminating the need for any extraneous and unnecessary buffers in the signal path.*

Signal stage power has been confirmed as a predictor of sonic goodness by a significant amount of experimentation performed by Balanced Audio Technology. This experimentation has provided a firm foundation for our innovative decisions, as applied to both preamplifier and power amplifier design. All BAT products employ low restriction gain stage(s). These high-power gain stages operate with uncommonly high drive capability to achieve an unprecedented level of sonic transparency. These high-power circuits also allow

us to avoid the use of popular cathode followers that further compound the sonic deficiency of many designs.

Zero Feedback Topology

There is another aspect to designing a low restriction gain stage – the elimination of negative feedback. Put simply, high feedback circuits are restrictive circuits. Empirical evidence confirms this to be the case.

In any zero-feedback configuration, the user listens to the unique voices of each individual component. These voices come through totally free and uncorrected, like solo dancers in a ballet theater. As with solo dancers, these components also must meet the most demanding performance requirements. The proper choice and application of each component are now of paramount importance. The individual parts selected for all BAT products, from the signal capacitors to the power tubes and the output transformers are well qualified for such a mission. Their characteristics are linear and well controlled. The 6C33-B output tube, for example, is an ideal vacuum tube for audio power application due to their low plate impedance and high current capability. The linear operating range for the REX II Power amplifier's oversized output transformers extend far beyond their specified output power rating.

In order to evaluate the effects of negative feedback on sound characteristics, a prototype BAT amp was equipped with feedback controls that provided an adjustment range from 3 dB to 10 dB. We soon discovered that as little as 3 dB of negative feedback was detrimental to the sound. The insertion of negative feedback generally reduces the sound stage as well as lessens the air around the reproduction of the human voice. The sound becomes constricted - no longer breathing like the live event. Thus, notwithstanding the improvements that negative feedback brings to an amplifier's measured performance, every listener preferred the zero feedback position.

Unistage™ Design - and beyond

The first look inside of any BAT components produces an immediate reaction – first, that it is built to an almost military standard of perfection – and second, that this BAT phono stage, preamplifier, or power amplifier with so many tubes or solid-state devices must be of a very complex and sophisticated design. While the latter is absolutely true, the former is not.

Simplicity of design, especially in the direct signal path, has always been the Holy Grail of the so-called Purist Approach, whose advocates like to talk about a "*direct wire with gain*" concept when describing the ultimate circuit topology. The fewer components, stages, contacts, and controls through which the signal has to propagate, the better the sound will be. If this is true, then why do so many designs employ two, three or even four gain stages and incur associated stage-to-stage coupling problems? Why is it so common to see so many relays or switches directly in the signal path?

The design of all BAT preamplifiers is unique because their signal path is so incredibly short and simple. Effectively (but not quite literally) the signal has to go through only one tube. The design is free from negative artifacts attributable to both extremes of modern preamplifier designs - passive preamplifiers on one end of the spectrum and multistage buffered active circuits on the other.

To summarize, all BAT preamplifiers feature a Unistage™ design that is effectively one gain block with zero global feedback. For an active preamplifier (i.e. a preamplifier with gain), this is the theoretical ideal.

Balanced Audio Technology's power amplifiers follow the same philosophy of elegant simplicity in their design. The VK-255SE and VK-655SE power amplifiers, for example, have only two gain blocks with zero global feedback in a purely symmetrical design. The theoretical ideal for any power amplifier would be to have only one gain block, but this has been achieved only with the limitation of low power output. Thus, the VK-255SE and VK-655SE are at the zenith of simplicity for any modern high-power amplifier design.

What does all this mean in practical terms? If a customer uses a BAT VK-33SE preamplifier combined with our VK-255SE power amplifier, the signal will pass through a total of three gain blocks (from start to finish) with no global feedback applied. The benefit of this approach is that it provides the ultimate simplicity of amplifying the incoming signal as few times as possible, while using no global feedback to double-back on the straight-through integrity of that signal. Imagine telling a joke to your friends and telling them to "*pass it on*".... Pass it on enough times and you won't recognize the joke. Pass the music through too many gain stages, and you'll no longer recognize the genius and beauty of your favorite recordings.

Shunt Volume Control

All Balanced Audio Technology preamplifiers employ a proprietary electronic shunt volume attenuator that offers one hundred and forty steps of 0.5 dB resolution. The series element used in this volume control is the Vishay bulk foil resistor - the most precise and low distortion resistor available. Discrete metal film resistors are used to bleed the unused signal to ground. These one hundred and forty steps give precise repeatable volume settings that sound continuous to the human ear. With a BAT preamplifier, you can always get the volume just right!

Massive Power Supply

(or why there is no substitute for cubic inches)

Since the power supply is usually a major contributor to the overall cost of a component (often as high as 30% to 50%) it is understandable, but not

excusable, that many so-called high-end products cut where it hurts. Often, when you take the cover off a very expensive product, you will find a disappointingly small power transformer of "cost effective" design and just a few small filter capacitors serving both channels. More often than not, it will be followed by a solid state voltage regulator in an attempt to make it measure tolerably, if not sound good.

Some things never lose their truthfulness. There is still no substitute for cubic inches. Yes, you can take a very small motor and put a turbo charger on it. It *will* make it better. Such a car will have a respectable top speed. Even the 0-to-60 numbers may not look too bad. Until one day you meet Lamborghini's 50th anniversary Aventador V-12 at a traffic light. Then you know it is over.

You will never find a designer who believes that a small, underpowered supply will improve the sound of an amplifier. But when the bottom line talks, they have no choice. The engine size is cut. Then the turbocharger (voltage regulator) is bolted on. When trying to sell you the virtues of a regulated supply the manufacturers usually don't mention the fact that this regulator often costs just a few dollars, including the heat sink. In addition, a voltage regulator introduces substantial negative feedback to a gain stage. On the other hand:

- i. Incorporating a bigger and better power transformer
- ii. Using one transformer per channel
- iii. Switching to better quality toroidal transformers
- iv. Encapsulating these transformers
- v. Beefing up the filter capacitors
- vi. Adding custom oil capacitors

Any of such changes could easily add substantial cost to each unit. Yet these are the very ingredients you'll find in Balanced Audio Technology's products.

It isn't at all surprising that the same designers who put a small, cheap power supply in their products will in their spare time build the "dream amplifier" for their home systems according to quite a different approach. There you will see all the *right stuff*. It *will* have separate supplies for each channel. It *will* have large high quality transformers, most likely toroidal. It *will* have a huge bank of filter capacitors. Virtually every article on improving the sound of an existing product (be it a preamplifier, power amplifier, CD player, etc.) begins with the subject of beefing up the power supply! We know why: this is the foundation for good sound.

Every Balanced Audio Technology product is designed to bring you much closer to this "designer-builds-it-for-himself" model. As experience has shown, a BAT preamplifier needs to be treated as a small power amplifier when plugged into a power-line conditioner - or in certain cases they'll not even turn on. The REX II preamplifier is an eighteen-tube two-chasse statement preamplifier that is without peer in the industry when it comes to the construction of its power supply. The Balanced Audio Technology VK-655SE monoblock power amplifiers contain 1800 joules of energy storage. Since one joule can lift a single apple

one meter off the ground, the VK-655SE contains enough stored energy to lift over a dozen bushels of apples one meter from the ground. *We call this BAT levitation! J*

A boy dancing on the deck of a ten foot boat will make it bounce - not so on a deck of an aircraft carrier. Good sound begins with a good, massive, and stable supply – a BAT power supply!

Plug and Play – and Easy to Use

Balanced Audio Technology is clearly focused on providing the best sound possible from all of its products. But the engineering effort doesn't stop there. Great sound with mediocre usability would be a poor recipe for a high-end audio product. Great sound with outstanding usability is our goal. BAT prides itself on engineering that is applied to making the user experience as joyfully straightforward as possible. Here are some key examples:

Automatic Bias

The advanced design of Balanced Audio Technology's tube amplifiers eliminates the traditional headache associated with most tube power amplifiers: the constant need to set and readjust the proper bias of the output tubes. A typical power amplifier will demonstrate its best performance only when the output tubes are biased optimally. Any deviation from this ideal point will result in some performance degradation, including loss of output power, increased signal distortion and reduced tube life. A small loss of power may be tolerable, but the reduced service life of an amplifier's output devices is unacceptable. It is extremely desirable, therefore, to have a power amplifier automatically adjust its output tube bias invisibly to the user, compensating for such conditions as partial mismatching or aging of tubes, as well as fluctuations in line voltage.

Unfortunately, this highly desirable feature is not found in typical commercial products. The reason for this lies in the tremendous challenge that such circuits present to their designers. Creating an automatic bias circuit that reliably and predictably controls the operating conditions of output tubes without affecting the sound in some negative way is a very serious design task. These conflicting requirements qualify the development of a sonically transparent yet robust auto bias topology as one of the most difficult areas of power amplifier design.

The VK-55, VK-55SE and REX II Power amplifier's automatic bias circuit is active in nature and should not be confused with popular (and often crude) passive self-biasing schemes that can never achieve a comparable level of performance. The "soft" low-feedback character of the BAT auto bias circuit provides the best possible combination of sonic characteristics, measured performance, and usability.

An important attribute of the Balanced Audio Technology automatic bias circuit is that it ensures that all of our vacuum tube power amplifiers sound wonderful

within the first few minutes of listening. There is a straightforward explanation for this. Most manual bias or passive self-bias circuits are adjusted for their proper bias set point with the tubes fully warmed up. As the tubes warm up, their emissions increase and the bias rises to its final value after the tubes reach their full operating temperature. During the warm-up cycle, however, the bias in traditional designs will be set too low and only gradually move upward to its appropriate set point. Depending upon tube type, this stabilization may take up to 45 minutes or even longer.

During this period of lower tube emission, the improperly biased unit will sound clinical or even unlistenable. Not so with the BAT tube amp. Its automatic bias circuit compensates for lower tube emissions during the warm-up cycle. Whether it be the VK-55, VK-55SE or REX II Power amplifier, each model will always stay within a narrow window of its optimal bias set-point, due to the sophisticated tracking inherent in their automatic bias design.

Maintaining the proper bias also contributes to prolonging the useful service life of the output tubes. The circuit ensures that plate power dissipation of the output tubes always stays at a conservative level.

In addition, automatic biasing makes changing output tubes in all BAT tube amplifiers a straightforward task. A customer simply installs a new set of tubes and turns the unit ON. The circuit automatically sets the conditions for the best operation. Individual LED indicators show the status of each output tube. Failure of any LED to turn ON indicates a problem with the corresponding tube, which may then be easily replaced. For optimal performance, matched replacement tubes provided by Balanced Audio Technology should be used.

Electronic Protection

For the REX II Power amplifier, Balanced Audio Technology extends the plug and play nature of automatic biasing even further with a novel “fuseless” protection circuit. This electronic protection circuit eliminates the power supply rail fuses to provide both a more refined sonic performance as well as a very user-friendly experience. All the user has to do in the event of an output tube being overstressed is to flip the power switch – it doesn’t get any easier than that!

No tubes to bias. No tube fuses to replace. This is the best of modern engineering applied to vacuum-tube amplifier design.

Superb User Interface

All BAT preamplifiers feature the same easy to use yet highly customizable user interface.

You’ll find any of our preamplifiers straightforward to use right out of the box. They are also just as straightforward to customize. Here are some of the many useful features:

- i. Name your sources: For example, choose THTR for home theater playback.*
- ii. Fix your volume: Choose the THTR input and fix its volume at unity gain to allow easy master control of your home theater system from your preamp processor remote.*
- iii. Implement a fixed level offset by source: This will allow all your sources to play at the same volume-level based on the display readout.*
- iv. Implement a left vs. right channel balance adjustment: This would allow you to compensate for an older tuner that has a slightly weaker output from one of its channels.*
- v. Set a maximum volume: to prevent a toddler from blowing out your speakers with a quick spin of the volume knob.*
- vi. Choose your preferred style of volume readout: from absolute counts (0-140) to decibel readings with respect to either unity gain or maximum gain.*
- vii. Change phase for any one source: to correct for sources whose outputs are out of phase by design.*
- viii. Switch to mono: to play back that old mono 78rpm recording without any phase modulation artifacts from your stereo cartridge.*
- ix. Turn off the display: or dim it to your satisfaction*
- x. Change volume: Every step will be 0.5db so that you'll always get the exact volume needed to make each recording sound its best.*
- xi. Fade the volume: if - for example - your phone rings. When you're off the phone, fade back up to your prior volume level with just one touch of the remote.*
- xii. Turn the preamp off/on or switch sources: to show that this functionality is complete.*

This is simply an exceptional user interface, proving that great sound and thoughtful design can be combined in one great product – from Balanced Audio Technology.

Components and Construction

It should be clear that Balanced Audio Technology relies upon a firm engineering foundation to design each of its products. Execution - from circuit layout to component choice and vibration control are also critical in ensuring that each design performs to the highest level. The Bugatti Veyron does not achieve a

speed of over 250mph by using off the shelf tires. Balanced Audio Technology, similarly, does not break the high end sound barrier by cavalierly choosing available components. Here are but a few of many examples:

- a. The toroidal transformers used in the VK-255SE, VK-655SE and REX II Power amplifiers are all encapsulated in deep drawn aluminum cans. To provide maximum vibration control, each transformer is sealed with epoxy. This epoxy sealing requires seven layers of application to produce the final product. The external surface of each can is powder coated for maximum durability.
- b. Only the highest quality Vishay Bulk Foil resistors are used in the most critical location for the electronic shunt volume control of every BAT preamplifier. Since BAT's designs are fully balanced, there are four Vishay bulk foil resistors required for each preamplifier. Each Vishay Bulk Foil resistor is one thousand times as costly as the typical metal film resistor.
- c. The VK-53SE preamplifier as well as the and REX II Control Module and Power Module use a five pound control plate for mounting the main printed circuit board.
- d. All preamplifier and phono stage chassis incorporate a hidden third mount that allows any user to install a three point mounting for threaded isolation points.
- e. Custom oil-filled signal capacitors are employed as BAT found the traditional choices in signal capacitors to be unacceptable. The typical poly cap added a "plastic" coloration that made our components sound artificial and electronic.
- f. All SE and REX II preamplifiers now incorporate custom output transformers that are shielded to provide maximum noise immunity.
- g. The circuit layout of every Balanced Audio Technology product is meticulously done. When you remove the top (or bottom) cover of any BAT product, you can be extraordinarily proud of the meticulous craftsmanship.

These are but a few of the many examples of the excellence in execution that are a part of every Balanced Audio Technology product.

Upgrade Path

Balanced Audio Technology strives for excellence in the support of our customers by being accessible on the phone for advice, as well as turning around any upgrades or repairs quickly and professionally. Part of that excellence also involves designing in an appropriate upgrade path for our models. Here are some examples of that upgrade path:

- a. Every stereo amplifier that BAT has ever made can be upgraded to a monoblock amplifier.
- b. With the recent introduction of the VK-53SE preamplifier, VK-52SE owners will be please to know that they can avail themselves of a full upgrade.
- c. Similarly, the REX preamplifier can be fully upgraded to the REX II preamplifier.

There are always times when Balanced Audio Technology creates an architectural step change in its product line. This architectural step change occurs when fundamental engineering changes are required to move to the next generation of performance. For example, after the VK-50SE preamplifier was introduced - for eight years it would be upgradeable to our flagship VK-51SE preamplifier. The introduction of the VK-52SE and REX II preamplifiers, however, made this upgrade path from the VK-50SE/VK-51SE series no longer viable.

Put simply, there are few companies in the industry that work harder to maintain a logical upgrade path for their customers.

Conclusion

Balanced Audio Technology applies a refreshing yet “out of the box” approach to high-end component design. Innovative engineering brings the customer easy to use products that offer novel advancements such as automatic biasing and “fuseless” electronic protection. The BAT hallmark of an elegant signal path combined with a massive power supply yields a signature sound that is free-breathing and true. These elements combined with Balanced Audio Technology’s meticulous construction and stellar customer support should make BAT your go-to choice for high-end audio.