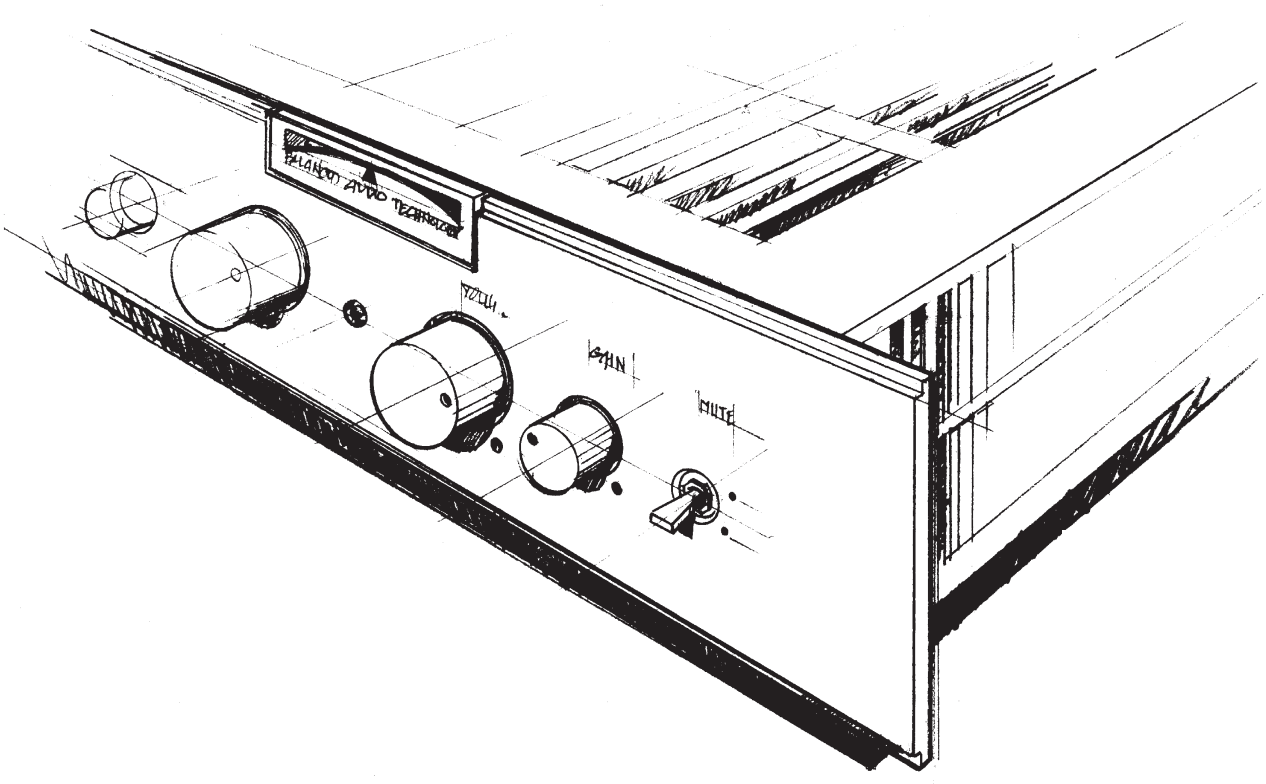
Balanced Audio Technology

VK·5

White Paper



Introduction

The purpose of this white paper is simple: while the final proof is in the listening, the design approach, philosophy, and reasoning behind the creation of a high-end instrument are extremely important. Any good equipment review allocates significant space to a discussion of these principles. Besides being educational, a description of circuit and construction *will,* to some degree*,* be helpful in predicting a device' s potential. There are, like it or not, right and wrong ways of doing things. Although there are many successful circuit topologies in existence today, a common set of rules may be applied to most of them. Following these rules will predictably result in a better or a worse sound. Every knowledgeable audiophile probably has a mental list of "good" and "bad" practices. Matching the items on this list with the VK-5' s description is, therefore, bound to generate interest.

We will not mislead you by saying that this was another "cost no object" project. There is no such thing in the real world. But here is what the VK-5 is:

It is quite possibly the best preamplifier in production today in the price range of up to many thousands of dollars.

We invite you to follow us through an educational and practical exercise. We will examine step by step what went into designing the Balanced Audio Technology VK-5. This should generate in any dedicated audiophile a high level of excitement for the considerable achievement represented by this new product.

Features

First, let's consider the feature-by-feature list of what goes into the VK-5:

Signal Path:

- Fully balanced design from input to output
- Complete compatibility with single-ended systems
- Circuit topology based on True Purist approach
- All-tube design with no solid state devices in signal or regulation paths
- Unique single stage implementation with no stage-to-stage coupling (Unistage)
- Ultra short signal path
- Zero global feedback
- Plate loaded triode signal path and current/voltage regulation
- Shunt volume control
- Dual mono construction
- Custom potted oil-filled signal capacitors
- High current/low impedance design that operates tubes in the best areas of their curves
- Ability to drive loads down to 100 Ohms to full signal
- Gain adjustment controls that are outside the direct signal path
- Design based on Graceful Degradation criteria for extended performance envelope
- Separate input/output connector boards for left and right channels

With:
- No relays or switches (except for the source selector) in the signal path
- No followers or buffers in the signal path (none required)
- No plastic capacitors in the signal path
- No DC servo that degrades the signal

Power Supply:

- High-Power power supply featuring 180 Joules of high voltage energy storage
- Symmetrical positive and negative high voltage power supplies
- Low feedback vacuum tube voltage and current regulation
- Regulated DC filament supplies with soft start
- Separate DC filament supplies for regulator tubes and gain stage tubes
- Unique AC shunt voltage regulators
- Separate high quality toroidal transformers for left and right channels
- Automatic filament and plate power sequencing on turn-on
- "Sleep" mode operation at reduced filament voltage for extended tube life
- Sophisticated mute function coupled with low line voltage sensor
- Electronic over-current protection on both channels
- Conservative design margins on all components for extended life operation

Components and Construction:

- High quality parts throughout
- Extra-strong steel construction with intelligent vibration control measures
- Custom machined front panel and control knobs
- High quality printed circuit board featuring:
    - SMOBC construction
    - No tin plating on traces
    - .093" thick extra-rigid PC board material
    - Heavy 3-oz copper traces on circuit board
- Vibration node optimization with multiple PCB anchoring points
- Chassis designed to accept standard threaded cone points (spikes)
- Single-chassis design for ease of handling
- Minimal discrete wiring for optimum signal propagation
- Clean, symmetrical layout

Compare this to your mental "dream list." We are sure you will find many matches. Now try running a similar comparison on any leading contender.

This may not be as easy as it sounds. Many manufacturers intentionally gloss over some aspects of their designs and provide confusing messages about the others. Take, for example, the common claim of an all-tube signal path. Often there is no mention of a solid state current source that is an integral part of a gain stage. Needless to say, this current source *is* in the signal path. (See the Solid State Effects section).

While some of the VK-5 features are self-explanatory, others may benefit from comment.

Balanced Topology

Of course the VK-5 is balanced. 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 such 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. Roughly speaking, 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. Those who offer balanced units will price them accordingly, well outside a sane range.

Nevertheless, with several products already on the market and more coming, "balanced" is becoming a new standard. Today virtually every high-end DAC has a set of balanced outputs. The finest performance of these units will be realized with a fully balanced preamplifier.

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 amp. Different sound. Balanced clearly sounds better.

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 the music. We rejoice.

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.

When comparing specifications one must be wary of many so-called "balanced preamplifiers" on the market today. Very often such products have single-ended signal paths. While sporting XLR input and output connectors on the back panel, they still only process one half of the incoming signal. The other half is simply ignored, effectively being thrown away. Therefore, *all* the benefits of balanced topology are not present. More correctly, these designs should be called pseudo-balanced. This aspect of the design is not always clearly stated in the promotional literature. Needless to say, the VK-5 incorporates a truly and completely balanced differential topology from *all* the inputs to *all* the outputs.

...But Single-Ended Friendly

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 well designed balanced component will be *fully compatible* with single-ended pieces. Actually, all that is required to connect your favorite tuner or your older power amp to the VK-5 preamplifier is a set of inexpensive adapters. You can connect *any mix* of both balanced and unbalanced (single-ended) components to the VK-5. There is no limitation on what you can use with any particular input

or output. Balanced Audio Technology provides high quality machined virgin Teflon balanced-to-single-ended adapters for just this purpose. You will not need an expensive active converter to do this connection. While some manufacturers will require that you buy an active adapter box to connect unbalanced components to their balanced preamplifiers (at a price of well over $1000), there is no such need with the VK-5, which does all the necessary conversions internally.

Another common myth is that balanced components are noisy when used in single-ended systems. In reality, nothing in a balanced topology makes it inherently noisy. Both single-ended and balanced circuits can be designed to be either noisy or quiet. While some preamplifiers have noise problems, the VK-5 does not. Compare it to any preamplifier, single-ended or balanced, and you will be impressed with its quiet operation.

While the VK-5 will truly shine in a fully balanced system, it is, nonetheless, absolutely compatible with virtually all single-ended components found in typical high-end systems today.

Purist Bliss and Features

Every high-end designer struggles with a conflict between features and performance. Cost aside, we admit that this is not an easy choice. We know that tape monitoring loops, phase inversion and balance controls are features that affect the sound negatively. They must, because they place more components in the signal path. But will people buy products that do not have certain convenience items?

Some companies build austere products with not much more than the volume control knob. We feel that this goes too far. After all, it is true that many features add convenience. On the other hand, the history of features in audio amplifier design is the history of sound degradation. One look at the schematics for some products makes it clear that eliminating many common features would produce a better sounding unit. Tape loops usually mean switch contacts in the very heart of the signal path. Phase inversion means more switches or, worse yet, relays.

In designing the VK-5 we kept the signal path sacred. Nothing was allowed to enter the signal path, unless it was deemed absolutely mandatory - such as the source selector switch and the volume control. But these were the only exceptions. Gain adjustment controls were allowed to exist only because they were pushed off the direct signal path. Good sound was *the* main objective. We felt that when the tradeoffs are properly understood, our customers would prefer the benefits of improved sound. They would prefer the extra short ultra-fidelity signal path. This is how we gave the Balanced Audio Technology VK-5 its uninhibited, unrestrained sound. The sound that only comes from the purist signal path. It is sacred to us.

Solid State Effects

It remains one's choice whether or not to believe that the best vacuum tube gear will always be superior to any solid state design. However, having adopted such a position, it becomes increasingly important to examine the purity of any tube circuit implementation. With very few exceptions (the mute circuit may be one example) every part of an amplifier circuit contributes something to its sound. Therefore, we made "no solid state devices under the bonnet" our ultimate goal.

On the way to this ultimate goal some compromises have to be made, based on practical and justifiable foundations. Cost is a prime example. It helps to explain why today you will probably not find a unit without any solid state devices. Although it is possible to perform all the functions of a preamplifier with vacuum tubes only, practical economy immediately rules out some solutions. A vacuum tube based mute circuit? Quite impractical!

Nonetheless, every step away from an all-tube design should be evaluated on the basis of its potential negative effect on sound. It makes sense to separate such effects into groups, depending upon the expected magnitude of the solid state signature that they will introduce. Here is the model that we followed during the development of the Balanced Audio Technology VK-5:

First order effects:

Devices directly in the signal path (gain stages, MOS signal switches, etc.)
Volume controls based on solid state devices (both bipolar and FET)

Second order effects:

Current sources used in gain stages
Voltage regulators used in plate and bias circuits

Third order effects:

Plate and bias voltage rectifiers
Reference voltage sources used in voltage and current regulators (typically zeners)

Fourth order effects:

Rectifiers and regulators in filament circuits

Arguably, non-contributing applications:

Mute circuit
LED indicators

While it is possible that different designers might reorder some of those effects, this model gives a fine approximation of the expected severity of solid state effects in a preamplifier circuit.

During the development of the VK-5, our logical and systematic approach in dealing with the tube versus solid state question was to completely eliminate *all first and second order* solid state effects. We succeeded in meeting this goal. It is our opinion that going further, into the third and fourth order effects, is uneconomical and offers diminishing sonic improvements.

We invite you to examine any other "all-tube" component on your short list from this perspective. You will be surprised. Many of them are constructed such that they suffer from the first and second order effects listed above. Could a preamplifier with an MOS transistor switch in its signal path be called "all tube?" You be the judge.

Graceful Degradation

The notion of Graceful Degradation (GD) has been around for decades. Historically it has been found in critical applications, such as aerospace, life support systems and high-reliability computers.

What is Graceful Degradation?

Every system, machine or circuit will malfunction at some point. Sometimes it is due to a component failure. Sometimes we simply ask it to do more than it was designed for. At the heart of the GD approach is the idea that except for major malfunctions, the system should not simply die, or crash, especially in a catastrophic fashion. When the electrical system on your car develops problems, you expect the car to run poorly, but not to stall completely or catch fire. You expect a well designed amplifier to go into overload softly and not clip suddenly.

It seems logical that audio circuits should be designed with Graceful Degradation in mind. Audio components are routinely pushed outside their comfort zones. Your signal can have components well beyond the "normal" 20 Hz - 20 kHz frequency range. Load resistance may be changing with frequency, dropping below the specified minimum at some point. The input signal may occasionally exceed the maximum allowable level. How will a unit that exhibits exceptional specifications under normal conditions behave in those cases? Will distortions remain constant, rise at a very gentle rate, or will they suddenly shoot up like a rocket? Will an amplifier burst into oscillation shortly after the *specified* maximum input voltage is exceeded? Will the output transformer core saturate and destroy the power tubes? What happens just below the *specified* load resistance? You want the circuit to be forgiving; with a gentle and gradual response to excessive stress.

The normal operating range should be the *minimum* acceptable level of performance. Abrupt changes in signal character suggest borderline instability and other demons lurking under the smooth surface. We wholeheartedly prefer units that do not suddenly turn and bite you, even when you push them a bit too far. We prefer products with Graceful Degradation, products like the Balanced Audio Technology VK-5.

We are testing a highly praised $5000 preamplifier. Monitoring the output while increasing signal frequency, we see the sine wave suddenly change into something ugly: it takes the shape of saw teeth. "Typical," we mumble, as we count another victim of slew rate induced distortions. There is no Graceful Degradation here. This sudden change of character is typical of global-feedback designs.

With the output at 2V, we reduce the load resistance to 10K and notice the onset of clipping. At 5K it is hard to recognize the sine wave as it is clipped and distorted. So much for this unit' s buffered output.

There are no such effects in the VK-5. We observe no evidence of slew rate limiting at all. As we increase the frequency, the sinusoid gets smaller while remaining very clean. There is just a smooth first order roll-off, the way it ought to be.

We set the output to 10V and reduce load resistance to 1K. The signal remains clean, with only some drop in magnitude. As we keep lowering the load resistance to 600 Ohm, then 500, then 400 and then all the way into the totally insane area of 50 Ohm, we still see nothing but a clean wave, *gracefully* getting smaller, remaining true.

Such behavior indicates the great performance reserves the VK-5 has when handling demanding signals. We know it contributes to the free and unrestrained sound of the unit.

The unit that doesn' t fall apart under pressure. The Graceful VK-5.

The Unistage - a Model of Simplicity

The first look inside the VK-5 cabinet produces an immediate reaction - this preamplifier with ten tubes, including two large ones, must be of a very complex and sophisticated design. While the latter is absolutely true, the former is not. Despite a fairly large number of tubes, the Balanced Audio Technology VK-5 is the very model of simplicity.

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 one, two or three relays or switches directly in the signal path?

The design of the VK-5 is unique because its 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.

Passive preamps have either lackluster dynamics or very system-unfriendly input and output impedances. The low input impedance of such units chokes some signal sources. Their output impedance is usually variable and relatively high, introducing its own set of problems. The VK-5 has none of these drawbacks. Its dynamics are absolutely superb, while the input and output impedances are comfortable for other components to interface with.

Among the problems associated with multistage designs are phase shift, signal coloration and the distortion of individual stages multiplied by stage-to-stage coupling problems. Each gain stage adds its own share of undesirable effects to the signal. Phase shifts of individual stages will combine and in the best case create noticeable phase distortion, and in the worst case cause stability problems. Designs trying to eliminate stage-to-stage coupling problems (usually by removing interstage capacitors) typically employ DC servo loops or large amounts of global feedback. These servos rely on various filters to separate the DC component from the AC signal. Since no filter is ever perfect, traces of signal will be present in the DC correction voltage. This residual signal will be distorted in both frequency and time domains. When this dirty DC control voltage is later injected into the signal path, it harms the mainstream signal that is trying to get through the same stage.

The unusual design of the VK-5 Unistage allows us to avoid all these problems, while not sacrificing any aspect of performance.

Unistage. All the strong points of a single stage design with no single stage problems.

Direct?

Recently, several manufacturers have introduced and started promoting a feature called "direct" input mode. In reality this is not much more than the common "Tone Control Bypass" switch of yore. But even more revealing is the answer to the question "Why?"

Usually this feature is implemented in order to shorten the signal path under certain conditions. This is the best indication that the signal path was too long and too contaminated to begin with. Another question is: using this "direct" mode, do you really get something *direct*?

Subjecting various designs to scrutiny produces an interesting observation:

The standard signal path of the VK-5 is much shorter than the so-called "direct" modes of competing models.

As we examine the construction of one popular preamplifier in this class we find strong confirmation of this statement. First, we realize that the so-called "direct" feature is not available on all inputs. In the Balanced Audio Technology VK-5 *every source* enjoys the shortest possible treatment. Then we discover that going "direct" kills the balance control. Not so in the VK-5: since its gain controls are outside the signal path, we don't need to turn them off. They always work. There is no loss of functionality.

We then compile the list of elements that the signal has to propagate through in the "direct" mode. This is how it looks for our competitor:

1. Source selector switch
2. Series gain adjustment resistor
3. Pair of relay contacts
4. Several dozen resistors in the stepped volume attenuator
5. Equal number of soldering junctions in the attenuator
6. Cathode follower
7. Active gain stage
8. Another cathode follower
9. Output capacitor
10. Another pair of relay contacts (*phase inversion* function).

Of course, this list is *even longer* in the "normal" mode. How does a similar list look in the case of the VK-5?

1. Source selector switch
2. Single series resistor of the shunt volume control
3. Single gain stage
4. Output capacitor.

Here we see the shortest path for the cleanest possible signal. Not surprisingly, these two units demonstrate a large difference in sound quality. We have the true fusion of design philosophy and practical listening experience. They both agree: the shorter signal path is better.

Shunt Volume Control

One of the most daunting tasks of high end preamplifier design is performing the volume control function. This seemingly simple task has many pitfalls and can turn an otherwise excellent design into something mediocre. Examples abound.

We believe in a hierarchy of different volume control designs based on their sonic qualities. This hierarchy was validated by countless hours spent during listening evaluations. In these trials we used a VK-5 prototype with a modification that allowed us to replace a volume control element in a matter of seconds, so that true comparison tests could be easily performed. We extensively tested several different alternatives, including various brands of potentiometers, switches and passive components.

1. Solid state attenuators. Manufacturers use different forms of this solution with various degrees of success. Being solid state (based on FET or bipolar transistors) these attenuators do not meet our main criteria of a Purist All Tube design. No matter how you configure these attenuators (including the shorting type), they still have solid state devices directly in the signal path.

2. Conductive plastic potentiometers in a traditional signal divider mode. This decades-old configuration can be cost effective and satisfying in sound. It is user-friendly for it provides a *near-infinite resolution* volume control function. Sonic characteristics of these controls are readily apparent and depend to a large degree on the gain setting position. Typically, the lower the volume setting, the larger portion of the total potentiometer' s resistance is inserted in series with the signal, and the more noticeable is its sonic signature. Putting a substantial mass of conductive plastic in series with the signal is, unfortunately, detrimental to the sound. Therefore, this implementation is less than ideal.

3. Stepped volume controls. Gaining in popularity, these controls usually provide a noticeable improvement in sound, compared to volume control types 1 and 2.

Unfortunately, these have drawbacks as well. First, it is difficult to control the cost of this design given the large number of resistors required to implement a good balanced volume control. This forces compromise on the designer. Using the *highest* quality parts such as Vishay Bulk Metal Foil resistors, considered by many experts to be superior in their sonic characteristics, becomes cost prohibitive.

Another negative feature of this design, something that every user soon discovers, is its inability to get the volume *just right*. You are always either too low or too high. Each step is too coarse, typically from 2.5 dB to 4 dB in size. Fine resolution of the continuous volume attenuator is gone. Some makers add another control in series with the stepped one, sometimes splitting each step in two. This brings you closer to the ideal infinite resolution attenuator, but now requires that you constantly fiddle with two controls instead of one. Hardly a convenient arrangement.

More importantly, the sonic signature of this design is still very obvious. This is not surprising, since depending on the volume setting you may be listening to *up to several dozen* resistors, with just as many soldering connections inserted in series with your signal! We, therefore, kept searching for a better volume control.

4. Shunt volume control. As we replace the stepped control in the test unit with our version of the shunt attenuator, our jaws drop. Further sonic improvement of such magnitude was thought to be impossible.

The sonic superiority of this implementation is easy to understand given its *simplicity*. At any volume setting there is only one resistor in series with the signal. This finally allows us to select the highest quality resistor for the job. We go through a long list of brands and types and prefer the Vishay, a universally best choice. Highest in cost, yet with only one per phase *this is a cost effective solution*.

This volume control provides everything we were hoping for. It maintains the short signal path: only one component is in series with the signal. There are a minimum number of soldering junctions as well. This volume control has nearly infinite resolution. No relays. No additional controls to worry about. Most importantly, listening evaluations demonstrate its clear superiority over all other choices.

No Buffers or Followers

The VK-5 Unistage is not the first single stage design. You will find single stages in some of the most primitive and cheap products. It is important, therefore, to clarify the difference.

The Unistage is unique in that it is totally free from typical single stage limitations.

The VK-5 has strong output capability. Its Unistage can drive a 100 Ohm load to a full 1V signal! Not many multi-stage buffered designs can claim such power.

Buffers, while performing the useful function of lowering output impedance, also mean additional stages congesting the sound. They often rely on negative feedback to reduce their output impedance, giving rise to additional transient distortions. Wouldn' t it be better to let the gain stage perform all the necessary impedance reduction by itself? This is how the Unistage was born.

The mere presence of a buffer at the output guarantees nothing. We have tested several leading buffered preamplifiers for their ability to drive a load. They all claimed very low

output impedance, and indeed, the *small signal* measurements confirmed this. But at some point just below the minimum specified load resistance their behavior changed drastically. They usually clipped in a very sharp manner, with multitudes of harsh odd-order harmonics generated. Such behavior is typical of buffers running out of their ability to deliver current to the load. By comparison, the Unistage spectrum is still pristine much below its specified 10K minimum load. The VK-5 can supply a load current many times greater than some buffered designs. As the load impedance goes down, a predictable smooth drop in signal amplitude is all that we see. That' s all. No drama. No clipping. No buffer.

Plate Loaded Triodes

Besides eliminating buffers and stage-to-stage coupling, while providing an astonishing load drive capability, the Unistage accomplishes another task - it gets rid of cathode followers.

Like many other experts, we at Balanced Audio Technology believe that cathode followers produce inferior sound. This seems to be true regardless of how the followers masquerade: simple followers, mu-followers, active load followers, etc. Our experience indicates that the only way to achieve good sound lies in *consistent use* of *plate loaded triode circuits*. It is pointless to argue about which topology is superior. The proof still remains in the listening. We don' t pretend to understand *completely* why plate loaded circuits are better. A matter of beliefs, perhaps, but beliefs are extremely important in amplifier design. Like Michelangelo or Picasso we discover our formulae for success by intuition, knowledge, and experimentation. But once we come across one, sometimes by reason, sometimes by chance, we don' t just cry "Eureka!" We design it in our products. And we stand by it.

While building the plate loaded triode signal path was relatively easy, we did not stop there. We have extended this approach to voltage and current regulators used in the VK-5. We believe this product to be unique in such a coherent and consistent approach to overall design. It is common practice to use cathode followers in voltage regulators. To us, this would mean a departure from the ideals of the VK-5.

Negative Feedback in Voltage Regulators

In an amplifier circuit both the power supply and control element (either tube or transistor) are connected in series with the load. This means that they both drive the load. Why then do many designers treat these two elements so differently?

The subject of global negative feedback in amplifiers has been debated for millennia. By now most designers agree that it is better to avoid, or at least to reduce the amount of, global feedback in the amplifier circuit. Many products on the market today claim to have little or no feedback. Sounds good, until you realize that the very same designers then declare that one way of further improving the sound is through very tight supply regulation (euphemism for feedback), thereby getting closer to the *ideal battery* model.

There is little argument that an ideal battery, or voltage source is, well, ideal. An ideal source would keep its voltage constant regardless of the changing load current. We must, therefore, get as close as possible to the ideal voltage source. The real question is *how* to do it.

The first popular way of doing this is through a large amount of negative feedback in the regulator circuit. Every tight voltage regulator in use today relies on global feedback to perform its function. The more feedback it has, the closer the voltage regulator is to the ideal battery model. Or is it? Take the product that has a weak raw power supply, one that drops its voltage by 20 Volts upon application of the load. Putting a voltage regulator at the output of such a supply can reduce this voltage drop by a significant amount. It is not uncommon to find a regulator that will reduce the initial 20 Volt drop to something that is hard to measure, a small fraction of a millivolt. Unfortunately, now you have 60, 80 or even 100 dB of negative feedback in the regulator and, therefore, *in the signal path*.

It should be obvious at this point, that the very same concerns that apply to high-feedback amplifiers will also be true for regulators, since *they both drive the load*. When the changing signal suddenly requires an increase in the current through the stage, the regulator must compensate for it. Unfortunately, just as in the case of the feedback-stabilized amplifier, this correction is *after the fact*. It is easy to predict that the typical regulator will have all the negative attributes of a global-feedback amplifier. In fact, it is just another such amplifier with associated transient distortions.

The conclusion should be simple: the same "less feedback is better" rule should be applied to both the amplifier circuit and the voltage source. Just as in the rest of the circuit, you shouldn' t start with a mediocre power supply and then attempt to make it "good" through tight external control. This is a sure road to disaster. Start, instead, with a different philosophy. Build a raw power supply that can easily handle your changing load currents without much voltage drop. Then, if still necessary, make it *better yet* by applying a small amount of carefully tailored feedback. You will be amazed by the results. *This is* the other, and the only right way of getting closer to the ideal battery model.

This philosophy is fully incorporated into the VK-5. To begin with, the balanced circuit topology is inherently much less demanding of a power supply. The two sides of the balanced stage generate two out-of-phase current changes that to a large degree cancel each other. Residual change in current,

something that the power supply must handle, is many times smaller than in a single-ended design. This is a good start.

The raw power supply of the VK-5 has substantially larger energy storage than virtually any other preamplifier on the market. It contains 180 Joules of high voltage storage, a figure traditionally reserved only for power amplifiers. But we didn' t want to stop there. We made a good supply much better. We created a low-feedback AC shunt regulator.

Most amplifiers have very little sensitivity to the small changes in the DC value of the supply voltage. Sound character will not be affected much when the power supply voltage changes between 300 Volts and 310 Volts, or 200 Volts and 210 Volts. The DC performance of the voltage source is not nearly as important as its AC characteristics, which are largely responsible for its sonic character. Dynamics, transient response, harmonic structure are all affected by how the power supply handles the changing (AC) voltage and current. Most regulated designs still primarily regulate the DC component of the voltage, while suffering all the drawbacks of feedback circuits. On the other hand, by relieving the voltage regulator of the need to control the DC level, we can make a very simple and effective AC regulator. We put our money where the improvement is most noticeable - in compensating AC current fluctuations on the supply rail. This improves the transient response of the circuit immediately without resorting to a monstrous hot-running traditional voltage regulator.

Of course, the regulators in the VK-5 had to be of shunt design. We strongly believe in the superiority of this *plate loaded triode circuit*. Unfortunately, standard shunt regulators have power dissipation problems. The situation is similar to Class A power amplifiers: while sounding good, they are usually both hot and heavy. Not so with our AC shunt.

The very same philosophy of low feedback was applied to the design of the all-tube current sources used in the VK-5 gain stages. We endeavored to strike a balance between the right amount of negative feedback for good circuit performance, while avoiding omnipresent time domain distortions. We feel that we have succeeded.

Our implementation of very low feedback plate loaded voltage and current regulators perfectly complements the Unistage design. Together they develop a unique synergy that contributes to the overall excellence of the Balanced Audio Technology VK-5.

Powerful Power Supply or *Why There Is No Substitute for Cubic Inches*

Since the power supply is usually a major contributor to the overall instrument cost (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 you take the cover off a very expensive product only to find a disappointingly small power transformer of "cost effective" design and one filter capacitor serving two 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 turbocharger 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 a Ferrari 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 as little as $2, including the heat sink. On the other hand, incorporating a bigger and better power transformer, using one transformer per channel, switching to better toroidal units, beefing up the filter capacitors, could easily mean an extra $50 or more per unit.

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 a quite different approach. There you will see all the *right stuff*. It *will* have separate supplies for each channel. It *will* have good transformers, most likely toroidal. It *will* have 50 pounds 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.

The power supply of the Balanced Audio Technology VK-5 was designed to bring you much closer to this "designer-builds-it-for-himself" model. In all respects it is substantially superior to virtually anything you will see in products costing a great deal more.

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, stable, *powerful* power supply. The VK-5 power supply.

Vibration Control

Vibration control is more than simply attaching a few pieces of precut material to an instrument' s chassis. Or so it should be.

The first question that needs to be answered is: *what* are we trying to protect? Tubes *are* the components most sensitive to vibration and need to be protected first. Then, the signal capacitors. From here the sensitivity to vibration drops off quickly.

There are products on the market that literally have pounds of vibration absorber applied to the chassis elements. While there is nothing wrong with stopping the top cover from vibrating, do these designs really protect where it matters most? How do they handle the tubes?

Inside a competitor' s unit we see a large printed circuit board supporting all the sensitive components. It is roughly 11" x 17" in size and it is only bolted to the chassis *along the periphery.* As we tap on the middle of the board, near tube sockets, we hear the board rattle. This comes as no surprise, since some critical components are mounted as far as five or six inches away from the anchoring points. The rigidity of the board spanning eleven inches of free space is, therefore, insufficient to minimize the vibration. The designer tried to improve the situation by using an extra-thick .125" board material. But was this successful?

In order to intelligently compare the design of this preamp to that of the VK-5 we need to look at the equation that predicts the amplitude of vibration. Both board thickness and span play their roles. But by plugging the numbers into the equation we discover that increasing the thickness from .093" to .125" doesn' t even begin to compensate for the damaging effects of long unsupported spans. The support-to-support distances of the competitor' s unit at eleven inches simply make board vibration control impractical, case damping or not. The damping material in this preamplifier is applied where it is needed least – near the vibration *nodes*, where the vibration amplitude is approaching zero anyway. The return is minuscule. At the same time, many sensitive components, including the tubes, are located near *antinodes*, where the vibration is devastating. (A *node* is the point where the amplitude of vibration is at zero. The maximum amplitude is reached at the *antinode*. Think of two ends of a guitar string as its vibration nodes. The main antinode will be in the middle of the string.)

The VK-5 design approaches this problem in an analytical way. The central element of this approach lies in placing sensitive components as close as possible to logically distributed vibration nodes. No sensitive component in the VK-5 is more than two inches away from the nearest node. Most critical ones are within 1.5 inches or less from zero vibration points! There is no other product designed like this.

We created seventeen carefully located vibration nodes around the PC board. Then we tightly coupled them to a stable *half-inch thick* vibration-free base. This base is an integral part of the chassis, not a last minute stick-on solution. While multiple screws and stand-offs certainly add to the overall cost, our solution is extremely effective at controlling the vibrations of critical components. We literally nail the structure down to the bedrock. Building on a stable foundation is the surest way to success.

Having placed vacuum tubes next to vibration nodes, we then turned our attention to signal capacitors. Being electromechanical structures, they sense vibrations and readily convert them into unwanted electrical signals. A special fixture allowed us to listen to the sounds of different capacitors as we applied mechanical shocks to them. We found that all common plastic film parts (most famous brands included) exhibited a tremendous sensitivity to vibration and shock. These expensive parts sounded like broken microphones. In sharp contrast, our custom oil-filled capacitors had virtually no sensitivity to vibration at all. To make these parts *even better*, we decided to provide additional damping for them.

We quickly discovered, however, that a "traditional" solution of dumping a load of glue under the part, in addition to looking messy and unprofessional, did not work well. A large surface of the part is still exposed to airborne acoustical waves. The only truly acceptable approach is, therefore, to completely surround the part with vibration absorbing material. We completely encapsulated our signal capacitors with carefully selected potting compound. Tapping on these modules reveals structures totally free of vibrations.

This is intelligent vibration control the VK-5 way.

Components and Construction

All the right design decisions that we made up to this point would mean little if they were wrapped in a mediocre package. The top grade construction of the VK-5 is an integral part of its design. We believe this unit is a joy to look at, with its cover on, and especially when you take it off.

There are many misconceptions that exist in the field of high end preamplifier design. For example, we are told that you must have dual-chassis construction in a reference performance class. Isn' t it strange that many makers try to turn dual chassis into a positive attribute? They proudly display it among their "features", as if having more and more boxes in your system was better. More cables. More space required. Some vendors do not want to stop at two. If two is better than one, then three is, clearly, better than two. There are units with *four* interconnected boxes on the market. This is madness.

We feel strongly that given a choice everyone would prefer a simple and clean *single-chassis construction*. The dual-chassis design is *not* an advantage, it is simply a statement of its designer' s inability to achieve the performance goal within a single chassis.

Regardless of how many boxes you use, they must be well constructed. There should be no room for paper-thin metal, flimsy resonating structures, messy wiring and printed circuit boards that were laid out with a broom. We are amazed to see these things in products costing several thousand dollars. The VK-5 has beauty, order, symmetry, and *balance*, that immediately put it in the very top of any class. Even the circuit board traces were designed to look harmonious and elegant.

While the rubber feet that come with the unit are of a very substantial 1 1/2" size (we hesitate in calling them "standard") the user can go even further by replacing them with virtually any available spikes having standard 1/4" threads.

Orderly placement of several hundred components within a single chassis is not a trivial task. The layout of the VK-5 provides easy access to all parts for troubleshooting or service. The internal wiring is minimal and perfectly arranged. Several wires that you can see behind the front panel are *outside* the signal path and don' t affect the sound. Here again, the VK-5 sets new standards for layout that translate into improved musical sound. You can clearly see the short unobstructed signal path, engraved in the board layout, complete from input to output. It follows the lines of a well drawn schematic, with positive supply rail on top, negative on the bottom, and the heavy and stable ground in the middle. The power supply connections are not forced; they don' t "come out of nowhere". They effortlessly blend into the rest of the layout. Each channel has its own dedicated supply. Power transformers are as far away from sensitive circuits as possible. The custom-developed selector switch has wide separation between decks handling different channels. Guard runs between circuit board traces prevent signal crosstalk. Inputs and outputs for each channel are on separate boards for further separation. This is true dual mono construction at its best.

Both the material and construction of the printed circuit board affect the sound to a great degree. This is why we rejected up front the cheap tin-plated board so common among our competitors.

The VK-5 printed circuit board employs advanced SMOBC (Solder Mask Over Bare Copper) construction. The *unplated* PC board traces are then made even better through the use of super-heavy 3-oz copper. It is not uncommon to find competing products with the copper traces as thin as 1 oz and even 1/2 oz. (These numbers indicate how much copper by weight is used for every square foot of the PC board. Conductors on the 3-oz board are three times as thick as the ones on the 1-oz board. Consequently, the electrical resistance of the 3-oz PC board traces will be lower by the same factor.) Although the VK-5 printed circuit board construction carries substantially higher manufacturing cost and is, therefore, uncommon, it also puts the VK-5 in a class by itself.

Special care was taken in the choice of components. Of course, they were all selected for optimal sound. But we did not stop there. We found traditional choices in signal capacitors to be totally unacceptable. They all added typical "plastic" colorations, making the preamplifier sound artificial and electronic. We went through the extra effort of developing our own custom oil-filled capacitors – a feature found in some other unique, but ultra-expensive components. We then further improved the VK-5 by encapsulating the output modules with vibration absorbent material. We felt that these additional costs on our part would be immediately appreciated by anybody whose main interest is in sound quality, not the designer labels that a unit carries. The fact that you are able to obtain these carefully tailored custom features at a rational price represents our determination to bring an end to exorbitant high-end pricing.

Conclusions

The Balanced Audio Technology VK-5 represents a totally fresh and unconventional approach to designing and building a top-performing preamplifier. This paper, while certainly not covering *all* its design aspects, should give you a first-hand look at how we at Balanced Audio Technology approach these nontrivial tasks. We hope that you appreciate the dedication that is mandatory in such an endeavor. Breaking new ground is never easy, and doesn' t happen by chance. The VK-5 is a groundbreaking product in many respects. It meets the most stringent requirements of a true reference standard component for any system. But you need not possess a mega-dollar installation to notice the improvement that the VK-5 will bring to your enjoyment of music. Even when used in a moderately priced single-ended configuration, it will surpass virtually any other product on the market today, regardless of price. When coupled with a good balanced system it opens new horizons.

You owe it to yourself to experience the Balanced Audio Technology VK-5.

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