The VAC iQ Intelligent Continuous Automatic Bias System

Guaranteeing unparalleled fidelity in vacuum tube components

By Kevin Hayes

The VAC iQ System of intelligent continuous automatic bias (patent pending) is the result of 18 years of research and development by the engineers at VAC and represents the first time in history that each tube in the output stage of a vacuum tube amplifier is held at the optimal bias point (quiescent current) at all times, regardless of how loudly or softly the music is playing.

The result is sound that is always the best it can be, reduced distortion and noise, and elimination of tube failure drama, all without any effort by the user.

The VAC iQ Intelligent Continuous Automatic Bias System is, to put it mildly, a very big deal. It is found in the new VAC Statement 450 iQ Monoblock.

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Background

When one "sets the bias" of an amplifier, one is adjusting the quiescent current of the output tube; audiophiles generally call this the idle current, while engineers note it as "Iq" (I standing for current, q for quiescent). It is the Iq that sets the operating mode (Class A, AB, or B) of a given output stage. A typical Iq for a KT88 tube would be 60 milliamperes, and listing tests have shown that variations of as little as 1 milliampere are audible.

In prior state-of-the-art, output tube Iq is set by one of two approaches, known by as "fixed bias" and "cathode bias" (also known as "self bias" and sometimes incorrectly called "automatic bias" or "auto bias"). In this former approach, a negative voltage (relative to the cathode voltage), which may be adjustable in spite of the name "fixed", is applied to the control grid of the tube; the more negative the voltage, the lower the Iq. In cathode bias, the grid is held at DC ground potential and the cathode of the tube returns to ground through a large resistance, such that the current flowing through the tube causes the cathode to rise to a positive voltage relative to the grid, such that the grid again is negative with respect to the cathode. Cathode bias has something of a self-centering action but is far too weak to establish and maintain precise Iq.

If Iq is set too low, sound quality suffers. If Iq is set too high, the chance of "run away" tube failure is increased. Between these two points, variations of 2% are distinctly audible.

Operation

If tubes were perfectly stable devices, one could set the bias once and never think of it again. In practice, the Iq of a tube varies with warm-up, with power line voltage, with the temperature of the output transformer, with age, with the volume of music being played through it, and randomly. Some of the variations are minor, and some happen over long periods of time, but one way or another, Iq should be watched and adjusted, both as a matter of sound quality and reliability.

The Difficulty

At first, this would seem like an easy problem to solve: just have an automatic circuit keep measuring the DC and adjust it all the time. The problem is that no conventional technique allows for this because of a characteristic of the tube called the "rectification effect". Even though a vacuum tube is much more linear than a transistor, it is not perfectly linear, and that small nonlinearity causes part of the audio signal to appear as a DC component when you try to measure Iq while music is playing. This is the rectification effect, and it is inherent in all existing amplifying devices (tube and transistor) to some degree and is quite extreme whenever a tube reaches cut-off, as happens in all Class AB and Class B amplifiers as well as when an amplifier reaches it maximum power output (i.e., when it "clips").

Many approaches were explored at VAC. One of the most appealing at first blush was to measure the DC plus audio signal and then subtract the measured audio signal from it, on the theory the (DC + AC) – AC = DC. As it turns out, this does not work due to the fact that musical waveforms are asymmetrical, and the location of the waveform's true zero crossing, which is lost when the DC is removed, changes the measured RMS value of the energy present.

Other Approaches / Prior Art

Some other approaches to automatic bias have been tried, and there are some amplifiers that do not have bias adjustments and thus seems automatic. The most prominent of these are now briefly summarized.

1) Cathode bias. As previously noted, cathode bias provides some inherent correction, steering the Iq toward a desired point, but without the strength of action and precision needed. There is a second problem caused by the bypass capacitor which must by used around the cathode resistor, which is that it is charged up by any present rectification effect. The result is that when the amplifier enters Class AB operation or is clipped, the capacitor charges to a higher voltage; the bias voltage rises and the Iq is reduced, driving the amplifier toward Class B operation, and in some cases, beyond, with very high resulting distortion. Under some circumstances, the amplifier will produce high distortion for several seconds after it exits clipping.

2) Some designers have placed a constant current source in place of a cathode bias's cathode resistor. Unfortunately, cathode current must vary for amplification to take place, and in the end, the same basic problem with rectification effect occurs.

3) Some designers run their output stage very close to Class B, with Iq in the 10-20 milliampere range. Part of the theory here is that even if the tube drifts, it is unlikely to drift so far as to cause a catastrophic tube failure. Of course, operation isn't really optimized, and Class B operation has some significant sonic penalties. In some amplifiers, massive amounts of negative feedback are used to lower measured distortion; in others, things like DC restorers and other older techniques are applied in attempt to reduce the distortion somewhat, to small effect.

4) A few manufacturers use an active circuit, usually a "set and hold" logic controller, to set bias during the amplifier's turn-on cycle, and then hold that setting thereafter. The problem, as anyone who has adjusted a tube amplifier knows, is that a tube's idle current changes a lot within the first half hour of operation. Thus, an amplifier that employs this type of "automatic self-regulation" is guaranteed never to be operating optimally. Due to this fact, additional protection circuits are added to detect tubes that run away due to the lack of continuous automatic bias optimization.

5) As a side note, in the world of solid-state amplifiers, one often encounters adaptive sliding bias schemes. In such cases, the designer is not attempting to hold an optimal, steady Iq, but rather is intentionally varying it, trying to prevent cut-off from occurring for more than a fraction of a second at a time, effectively keeping the amplifier as close to a Class B Iq as possible while still being able to claim some sort of Class A operation. This is altogether different than the intention or operation of the VAC circuit.

The VAC iQ Intelligent Continuous Automatic Bias System
After sixteen years of research, VAC reached the conclusion that is was not mathematically possible to achieve an automatic bias circuit that was theoretically precise. It was at that point that a new insight arose, giving rise to a new heuristic approach. Two additional years of research, modeling, experimentation, and testing proved that VAC's heuristic approach results in an underlying Iq in each tube that is always within 1% of the set target Iq under all conditions, from silent passages to the most explosive and sustained musical peaks, and in the process, ensures that the individual tubes as well as the overall output stage are always delivering optimal performance.

The VAC iQ Continuous Automatic Bias System (patent pending) is a true breakthrough in power amplifier design. It is not inexpensive, but, once heard, it is indispensable.

What Else Does It Do?
In addition to guaranteeing unparalleled fidelity, the VAC iQ System greatly enhances the reliability of the amplifier in several ways.

First, "run away" tube failures are eliminated. Run away tubes arise from one of two mechanisms. The first is a "gassy" tube, the Iq of which tends to rise on its own until it goes into positive thermal feedback; the VAC iQ System prevents that cycle from ever starting. Interestingly, through observation of the operation of the VAC iQ circuit, it has been revealed that such tubes actually tend to be relatively "cold" tubes, which users ordinarily "crank up" thorough bias adjustment.

The second run away mode occurs when a tube is set to run at a relatively high iQ and then randomly drifts a bit higher or becomes physically hotter through sustained loud musical passages. The VAC iQ circuit detects any move to a higher iQ and automatically corrects for it, and once again, the run away cycle is never allowed to start.

As part of its operation, the VAC iQ System can tell when a tube is becoming weak and notifies the user that it should be replaced when convenient, while still making the best of its remaining life.

Lastly, it is always possible for a mechanical break to occur within a tube, resulting in an internal short circuit. No adjustment of bias can fix this, so if this occurs, the VAC iQ System automatically shuts off the high voltage power supply within a fraction of a second, long before a conventional fuse could blow, and illuminates a red LED to indicate which tube has failed.

Summary
The VAC iQ Intelligent Continuous Automatic Bias System advantages:

- Always the best sound

-No user adjustment

- Supreme reliability

-Longer tube life

-Indication of weak tubes

-Automatic protection from and indication of failed tubes

Final Note
The principles of the VAC circuit are applicable to solid-state devices as well as vacuum tubes. Development and licensing of these applications will be considered.

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