Blackie Pagano

Rectifiers: Tube vs. Solidstate

By David Jung

Rectifiers. We've heard mention of them, whether solidstate or tube. But what do they actually do?

Rectifiers are one of the most misunderstood components in an amplifier. Basically, they convert incoming AC voltage to the usable DC current that makes your amp tick.

In the golden era of amplification, tubes were used for this job. But in the late-'60s and early-'70s, demand for louder amps drove builders to use silicon diodes, then solidstate rectifiers began showing up in guitar and bass amps.

Since then, manufacturers have gone back and forth between tube and solidstate rectifiers. There are pros and cons to both. But what are they? And how do they affect your tone? I sat with rectifier raconteur Blackie Pagano to find out!

So, what is rectification?

The simple explanation is that you have wall voltage going into an amplifier. That alternating-current (AC) voltage hits an amplifier's transformer, which splits it into multiple voltages that are sent to the components of the amp. Coming off the transformer, these voltages are all still AC. Your amp needs direct current (DC) to function, and the rectifier takes AC voltage and turns it into DC voltage.

Early on in amplification, they didn't have any choices. Silicon diodes had not been invented, so early amplifiers used tubes to do the job, which was fine when you didn't need a lot of power. But as time went on, rock and roll acts started drawing bigger crowds and amp manufacturers had to figure out how to get more bang out of their equipment.

At first, they added rectifiers and power tubes; you'd see amps with two, three, four rectifier tubes. But all those tubes required more power, so you had to use larger transformers, and more of them. It was an inefficient system, and there's a limit to how much current a tube rectifier can handle. Each has its design maximum, and early tubes were rated fairly low.

The difference between a 30-watt amplifier and a 100-watt amplifier in terms of current demand is huge, and all that extra current is being drawn through the power supply. Once silicon-based solidstate components were invented and they figured they could rectify with them, they made silicon-based rectifiers. Unlike a tube, solidstate rectifiers don't require a heater – they need no energy to work, they're a chemical connection that chops the signal similarly to the way a tube rectifier would.

What were the first amps to use solidstate rectifiers?

The first *popular* amps to use them were Marshall, and they have a characteristic sound. When you crank a Marshall, it's heavy rock, right? It's aggressive. And part of that sound is coming from the solidstate rectifier.

So what's the downside?

Well, unlike tube rectifiers, solidstate diodes generate noise. This noise is in a band way above our hearing, but it affects the audible signal with a certain harshness we hear. Whether that's a downside depends on personal taste. Everything sounds like what it's made of. So in a tube rectifier, you're getting a tube voicing. And everything coming out of your transformer is going through – and being rectified by – that tube. So everything moving forward from there – filter caps, choke, etc. – are all going to have a tube-rectified signal coming in that sounds different from a silicon-rectified signal.

Even though silicon diodes are doing the same job as tubes, the physical connection is completely different. With diodes, your signal passes right through them, and the chemical connection transforms the signal.

With tubes, there's no actual contact between the signal and the tube's internal elements. They're isolated. Second, tubes have internal impedance, which makes them "slower" and leads to more voltage drop.

Are there specific tubes that make better rectifiers?

5Y3, 5AR4, and 5U4 are the most common. In order of their ratings, 5Y3 was the earliest and has the lowest ratings, 5U4 was the next stage of development and had a bit higher rating, and then the 5AR4 (also known as GZ34) came last and has the highest rating. They have roughly the same pin-out, which means you could swap them with each other. But you can't switch them around without knowing what's going on with the rest of your amp, because their ratings are different.

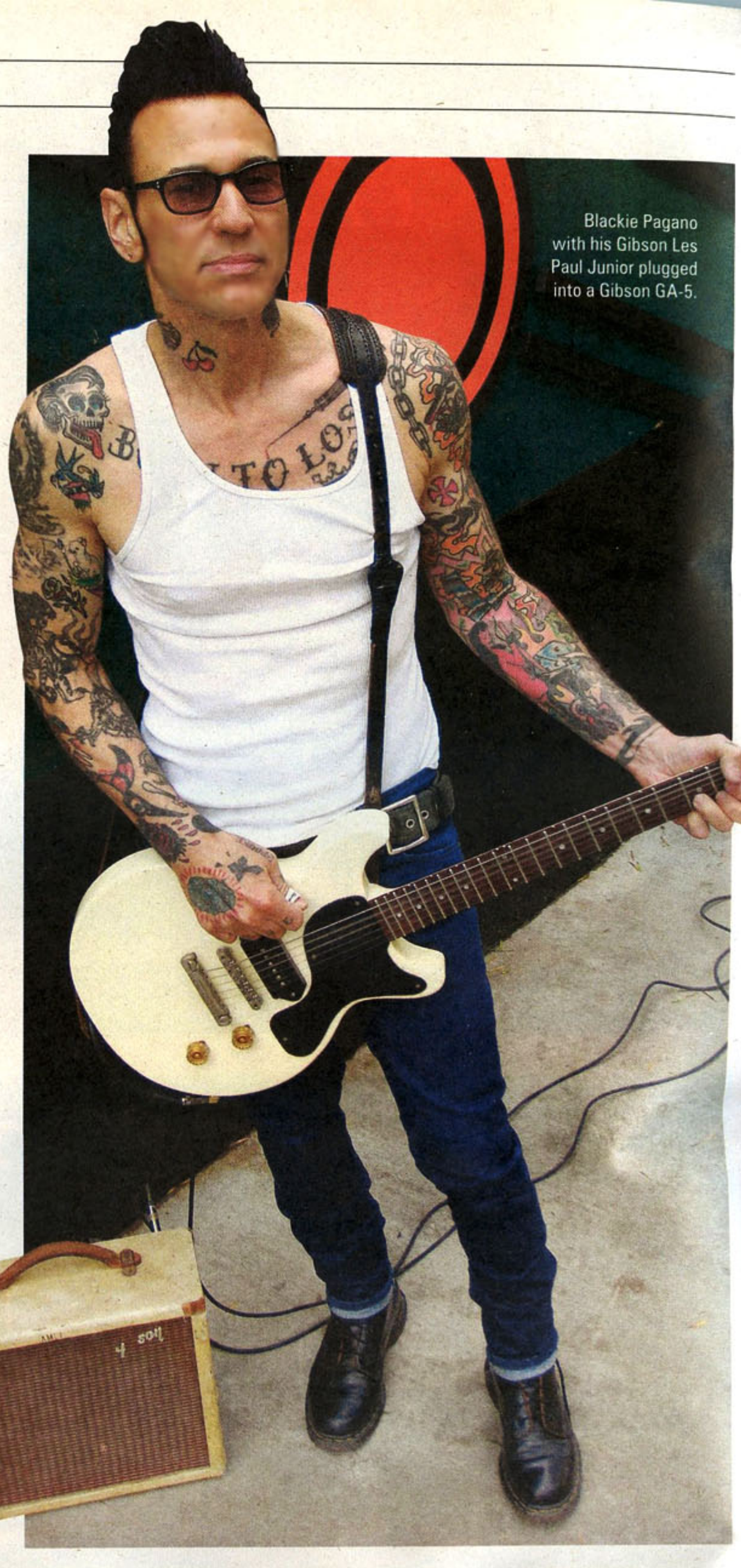
I always stress that – *do not* take out one rectifier and drop in another without knowing exactly what you're doing!

What could happen?

Well, the tubes handle different amounts of current. An amp with a high current demand needs a 5AR4, but if you try a 5Y3 to lower the power, thinking you want to drop the output and get more breakup at lower volume, if the current demand is too high or the capacitance at the other end of the amp is too big and draws too much current, it'll blow the rectifier. Now, we could run a lesser designated tube beyond its design maximum. Or suppose an amp is designed for a 5Y3 and we want more juice, so we put in a 5AR4... Well, because there's a good deal less voltage draw through a 5AR4 – the voltages at the other side are going to be higher.

Is that a bad thing? Not necessarily. But it's a bad thing if we don't know what's going on. The bias could be off, you could be pushing the tubes beyond their designed maximums, etc. We're dealing with devices that have very specific ratings, and you don't want to play games with them unless you know what you're doing.

The other thing that can happen – and this is super-important – all tubes glow, and what you see is not part of the tube's function, it's the heater wire – the filament – and it's purpose is to get everything hot so the tube will function. Tubes in guitar amps won't function unless they're hot. And that heater winding is the highest-current component of the amplifier. Different rectifier tubes draw different fila-



Blackie Pagano with his Gibson Les Paul Junior plugged into a Gibson GA-5.

ment currents, and they can be vastly different.

The 5U4 for example draws three amperes of filament current. The 5AR4, which is actually rated higher for current output, draws two amps of filament current. That's a 30 percent difference, and one ampere is a lot of current!

So, if we're swapping a 5AR4 to a 5U4 to get less power, we want more voltage drop and a slower power supply with more internal impedance, lower voltages throughout the amp so we can get more distortion at a lower volume – we may be making demands the power transformer can't supply. If the power transformer can only supply two amps of current and we're asking it to supply three by plugging in a different tube with a different current demand, it's likely to fail, especially if it's really old!

What did they do to make solidstate rectifiers less noisy?

Again, the noise they make is above the audible frequency, in the megahertz range. But it modulates signal. So they came up with 20 schemes in the last 20 years to filter it, all of which have a sonic signature – *everything* in an audio circuit has a sonic signature. Your ears catch every nuance, even if you don't realize it.

Fairly recently, a new type of diode was invented, called "fast recovery epitaxial diodes" or FREDS. They started in hi-fi; the cutting edge of amp design is always high-end audio, and a few guitar-amp companies are using FREDs.

Soundwise, what are the main differences?

Some would say the tube rectifier is a bit sweeter at low volume, but slower and squishier when turned up, while solidstate is a bit edgier and more aggressive at higher volumes.

Is that where the term "tube sag" comes from?

Yes, from when you turn up an amp from the 1940s or '50s, lay into a chord, and there's that slight delay where it feels like the amp is straining to keep up. That's when current demand coming through the tube exceeds its ability to supply it. So you get a little bit of compression. The signal kind of sucks out a bit, and if it's just doing it a little bit, it's a very desirable sound.

There are a lot of things that affect tube sag – filtration, the power supply, the size of the caps, etc. But generally speaking, the rectifier tube is the main element.

Is it possible to take a solidstate amplifier and turn it into a tube-rectified amp, or vice versa?

Yes. Power-supply wise, if you know what you're doing, you can do some neat tricks. There are voltage drops, and you might lose a watt or two going from solidstate to tube, but it's a fairly simple procedure that can have profound impact on the tone of an amp.

Tubes versus solidstate, your personal preference?

Tough question. If I was playing in a heavy rock band at clubs, I'd want a solidstate rectifier for the response and attack. But for small amps, tubes are the way to go.

There are good heavy-rock amps that use tube rectification – a Mesa Boogie or two that have three tube rectifiers to handle the current draw of the amplifier... But in my experience, no one uses those. I see those amps in here a fair amount and when I do, they're always switched to the silicon-diode side.

Why do you think that is?

Those are high-gain amps, and those high-gain sounds are always purveyed better with a little extra aggression. Silicon diodes work there.

David Jung is a professional writer/screenwriter and vintage guitar enthusiast living in Los Angeles, where he hangs with some of the best amp techs and collectors in town. **VG**