Physics explains why rock musicians prefer valve amps

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For many guitarists, the rich, warm sound of an overdriven valve amp – think AC/DC's crunchy Marshall rhythm tones or Carlos Santana's singing Mesa Boogie-fuelled leads – can't be beaten.

But why is the valve sound so sought after? David Keeports, a physics professor from Mills College in California, looked at the science of valve amps for the journal *Physics Education*, to explain why their sound is 'better' to the ears of so many guitarists.

Professor Keeports said: "Although solid state diodes and transistors are cheaper, more practical, and technologically more advanced than glass valves, valves survive because so many guitarists are exacting about their tone, and prefer the sound a valve amp gives them."

"At its most fundamental level, this is because a moderately overdriven valve amp produces strong even harmonics, which add a sweetening complexity to a sound. An overdriven transistor amp, on the other hand creates strong odd harmonics, which can cause dissonance."

Professor Keeports explored the physics of why even harmonics enrich a sound, and why the timbre of the sound from a valve amp changes when a guitar is played more loudly.

First he ran a 200Hz sine wave – a pure wave with a single frequency– through a small Bugera hybrid amplifier, featuring a valve preamp and a solid state power amp. He tested both 'sides' of the amp; first turning up the gain knob, which controls the valve preamp while the master volume knob (controlling the solid state power amp) was set low. He then repeated the process with the preamp set low and the master turned up.

Using Logic Pro X music production software, he examined the resulting sound waves in both frequency and time domains.

Professor Keeports said: "The output from the amp showed that a moderately overdriven valve preamp produced prominent 2nd and 4th harmonics at 400 and 800 Hz, and only a very weak 3rd harmonic at 600 Hz. For the solid state power amp, this pattern was reversed. All of this behavior is consistent with the common claim about the harmonics that valve and solid state amplifiers produce. But the story is not quite so simple. Overdriving the valve preamp harder produces strong odd harmonics."

"The shift toward odd harmonics at increasing gain is a characteristic of valve amplifiers that further explains their appeal. An electric guitar player can overdrive an amp two ways: by turning up the amp's gain control, and by attacking guitar strings more strongly. Experienced guitarists don't just play their guitar – they also play the amplifier. By striking the strings harder or softer, they can change timbre along with volume."

And why does a valve amplifier behave this way?

"The simple physics of triode valve function explains everything," said Professor Keeports. "Valves have two ways to to flatten a sine wave. Overdrive a valve moderately, and it flattens just the top of the wave to make an asymmetric wave that is rich in even harmonics. Overdrive the valve harder, and it also flattens the bottom of the wave to produce a symmetric wave full of odd harmonics."

"The even harmonics provides the complex, warm, rich sound that so many guitarists desire. Add to that a valve amp's ability to produce somewhat dissonant yet driving sounds when a guitarist attacks strings harder and turns rhythm playing into lead playing, and valve function creates just the harmonics a rock guitarist needs."

More information: The warm, rich sound of valve guitar amplifiers" Keeports D 2017 *Phys. Educ*. 52 025010. iopscience.iop.org/article/10. …

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