

## **Guitar Player Nov. 1991:** Tube Mysteries Revealed. Amp guru Andy Marshall spills secrets that some manufacturers would rather you didn't know. Interviewed by Art Thompson + Tom Wheeler

**Q:** What is a vacuum tube?

**A:** It's an amplification device that can increase a guitar signal's voltage or current capacity. But that describes a transistor as well. More specifically, a tube is a "thermionic valve" that controls the flow of electrons through a vacuum. A vacuum is used so that the only significant factors operating upon the electrons are the voltages applied to the various components of the tube. A transistor is similar, except that the electrons flow through solid silicon instead of a vacuum inside a glass bottle. [*see Fig. 1*]

*Which preamp tubes are important to guitar players?*

The convention is to stick with the 12AX7-type twin-triode 9-pin design. There are several different tubes that are pin-equivalent, meaning that you can pull one out and put the other in, and while the substitution may change your sound, it will work just fine. There's a range of these—some more common, some less—that have slightly different tonal characteristics, but mostly they have different amounts of gain.

The highest-gain is the 12AX7, or 7025 [gain of 100]. The next highest and next most common is the 12AT7 [gain of 60], which was used in the phase-splitter/driver stage of most Fenders from 1963 on. There's also the 12AZ7 [gain of 60], which is very uncommon; although Fender used them on some tweed amps, you'd have a hard time finding any now. Next is the 12AY7 [gain of 44], used in the first stage of many tweed Fenders, though not in much else. The 12AU7 [gain of 19] is the lowest-gain tube in this 12-volt series and was found in some older Gibsons, in the driver stage of Hiwatts, and in Marshall Majors. [*Fig. 2 shows common names for these tubes, including their gain capabilities.*]

*How do players typically apply this knowledge?*

Preamp tubes can be changed to alter the amp's sonic character. If, for instance, your black face Fender Deluxe distorts too much, you can take out that 12AX7 in the first stage and put in a 12AT7; you'll overdrive your preamp less. If you have high-output pickups and you want a still cleaner sound from your Deluxe, take the *next* 12AX7 out and put in a 12AT7 or maybe a 12AU7 if the 12AT7 is still too much. Another popular substitution is to put a 12AX7 in place of the 12AT7 in the driver/phase-splitter position [closest to the output tubes] in a blackface or silverface Fender for more output distortion and drive. Through these methods, you can control your amp's sensitivity and gain with absolutely no chance of hurting it.

*What does the reverb tube do?*

It sends the signal to the reverb tank and actually drives a little output transformer to match the tube's output impedance to the reverb-spring driver-coil's input impedance. In this way, it's acting as a tiny power tube. There's another tube to amplify the signal coming *back* from the reverb tank so that it's equivalent in level to the guitar signal still in the amp. This is necessary because the reverb tank has incredibly high signal loss caused by converting an electrical signal to a physical motion in the spring and then converting it back to an electrical signal. [*Fig. 3 is a schematic representation of this circuitry.*]

*Describe the functional difference between preamp tubes and output tubes.*

For the most part, preamp tubes amplify the signal's voltage to get it up from the very low-level signal that the pickups supply to the relatively high level that the output stage requires. They also need to compensate for the losses in the tone-control circuitry; if you put a 10-volt signal into a typical tone-control network, you get roughly a 1-volt signal out. Preamp distortion is essentially *voltage-dependant*.

The output, or power, tubes do *not* amplify the voltage or "strength" of the signal; they merely provide the current—please don't call it "amperage"—necessary to drive the load of the output transformer. Because the signal does pass through the output tubes, they, too, affect the amplifier's sound, though more so when the amp is played at or near its power limits. Output distortion is essentially *current-dependant*.

*What are the most common output tubes?*

The 6L6 and EL-34 are the most common of the higher-power output tubes. The 6L6GC is one of the oldest power tubes in its class [pentode, beam power] and very common in guitar amps. It's the standard for American high-power amps from the '50s on. Jim Marshall and Ken Bran, Marshall's designer, chose EL-34s mainly because 6L6s were hard to get in the mid '60s in Great Britain, and EL-34s were more common. The two are similar, and depending on how your amp is wired, they can sometimes be interchanged with a simple bias adjustment. This does *not* mean that if you've got a stock Fender Twin, you can simply pull out your 6L6s and put in EL-34s. However, your Twin can be configured to accept either. Also, just about every 50- and 100-watt Marshall can accept 6L6s, with a minor change in the bias circuit. [Ed. Note: *The interior of an amp is loaded with dangerously high voltages, so unless you're trained in electronics, leave modifications to a technician. In addition, modifications almost invariably void warranties.*]

*How does the 6L6 sound?*

It's tight, clear, and doesn't lose its high end as much as an EL-34 when it's driven hard, which is partly why 6L6 output amplifiers seem to retain their harmonics well at high volumes. Most 6L6 output sections in classic American amps—like Fender Twins and Super Reverbs—do not have enough gain in the preamp and 12AT7 phase-splitter/driver stages to drive the output very hard. If you turn up a Twin Reverb, it distorts, but it doesn't sound like a Marshall JCM 900; it doesn't have the preamp gain. If you drive it harder, you get crystal-clear harmonics, as MESA/Boogie did in the original Mark I, when they gave the preamp an enormous amount of gain and drove the output section hard. If you compare an early MESA/Boogie to an equivalent-gain amp with EL-34s, such as a master-volume Marshall, the Boogie should retain more of its upper harmonics and high-end crispness at loud volumes.

*Some power tubes have different names, yet seem to have very similar functions.*

What started out as different countries' methods of naming tubes have become marketing devices. For instance, what is called an EL-34 in England is called a 5CA7 in the U.S.; the tubes are more or less identical. If Mullard, an English tube manufacturer no longer in business, wanted to market their EL-34s in the US in the '50s, they would label them 6CA7s. If an American company like Sylvania wanted to market their 6CA7s in England, they would label them EL-34s so that British customers would know what they were. This does not mean that a tube labeled EL-34 is necessarily English, but it does explain the background behind the nomenclature.

*What accounts for the difference in their sound?*

Manufacturing techniques and the materials used in the tube's inner components—cathode, grid, plate, etc.—affect the sound. Typically, the Sylvania 6CA7 is considered to sound a little harder and tighter than the Mullard EL-34. The Mullard EL-34s were less efficient and gave off more heat than the American-made 6CA7s. Though the two were interchangeable, the EL-34's bias was slightly different but still in the proper range to be considered a 6CA7. Two examples of players who probably used Mullards are Eric Clapton and Pete Townshend early in their careers, though this is difficult to confirm. With an EL-34, you hear a smoother, slower attack, and it saturates at lower output. To me, at lower volumes, when they're not being driven into saturation [the point at which it can't produce any more current or voltage, no matter how much is put into it], they have a little bit more “shimmer” and a little better presence, although it goes away quickly when they're driven hard, meaning that they react to how hard they're played. An American 6CA7 distorts more and doesn't react frequency-wise as much as the British tube does, though it has to be driven harder than an English EL-34 to get it to distort.

*Is the output power the same for 6L6s and EL-34s?*

They are more or less equivalent, since a pair of either can put out 45 to 60 clean watts, and if you drive them into distortion, 75 to 90 watts. But there are certain tubes with those designations that will not deliver that much power. The Russian-made 6L6 that I get from Groove Tubes for my Rock & Roll-version amps will put out about 75 *clean* watts per pair! There is also a different Russian-made 6L6 that you're lucky to get 35 watts out of a pair, and the Chinese 6L6 that I use in my blues-version amps, if you can get 50 watts out of a pair—and have them last more than a week at 50 watts—you're doing great.

*Why do you use them?*

Because they are relatively inefficient, like the original 5881s, which were made by General Electric or Tung-Sol [a now-defunct New Jersey tube manufacturer] and used by Fender in the late-'50s Bassman. The Chinese 6L6 sounds like an original 5881 more by accident; it can't take the voltage of a 5881, which could continuously sustain 600 volts at the plates, while the Chinese 6L6 really doesn't want to see more than about 430 volts.

*What's a 5881?*

5881 is the military designation for an upgraded, sturdier 6L6. It was electronically identical, made to the same impedance, capacitance, and current capacity. You see, “6L6” is merely a specification on a sheet of paper, and anything that falls within its parameters can be called a 6L6.

*What about the 6V6?*

That's an output tube, as well, but it has a much lower plate capacity, meaning that a pair of 6V6s cannot deliver anywhere near the power that a pair of EL-34s or 6L6s can. It's more equivalent in output to the EL-84. A pair delivers between 18 and 25 watts, and they're commonly used in pairs. Just about the only amplifier that comes to mind that used *four* 6V6s was the Jim Kelley, and it was glorious; Bonnie Raitt is among the many Jim Kelley fans. It sounded like a Fender Deluxe but had twice the power. Jim went for simple, traditional preamps and just doubled the power by using four 6V6s. It's a common tube that's sought after in the realm of tweed and blackface Deluxes. Lots of players love that sound. For a good example of a tweed Deluxe sound, listen to the first few ZZ Top albums.

*You mentioned EL-84s.*

They're in the class of a 6V6. The American designation for an EL-84 is 6BQ5; it

has a 9-pin base like a 12AX7 and uses the same socket. A pair can deliver up to 20 watts if they're high-grade and set up correctly. EL-84s are most common in the smaller British Vox amps, like the AC-4, AC-15, and AC-30. They have a very sweet, smooth distortion and are favored by Brian May of Queen, among many others. Everyone's clamoring to get lower-powered amps like Fender tweed and blackface Deluxes, tweed Fender Harvards, Vox AC-30s and AC-15s, and Marshall 18- and 20-watters. MESA/Boogie uses EL-84s in the Studio .22, and Ken Fisher of Trainwreck amps uses them in some of his designs. They also showed up in some blonde Fender Tremoluxes, and Gibson built a number of amplifiers with EL-84s.

*Which tube has the most output?*

If you classify by group, the highest-power tube in a production amp is the KT-88, a beefy British version of what the Americans call a 6550. They're not *exactly* equivalent, but are more or less interchangeable. The KT-88s, which were developed by Genelex-also known as MO Valve/Gold Lion, another British company-were hand-built with little screws and nuts inside. They could take close to 900 volts on the plates continuously, and at the onset of clipping a pair can deliver over 180 watts. They're very sturdy; I've seen amps with original Genelex KT-88s that were in daily use since the late '60s, and the tubes still worked fine. This is just historical stuff, though, because they're no longer manufactured. The tooling has been bought by another company and they can be manufactured, but the price would be extremely high.

*The KT-88 has a reputation for sounding bad-any basis for that?*

No. It sounds *clean*. To drive this tube into distortion takes an astounding power supply and driver stage. They were most commonly used in Marshall Major and Sunn 2000S amps, which had ultra-linear output transformers, and the amps were designed to be clean. Many people who were used to 50- and 100-watt Marshalls bought the 200-watt Marshall Major, plugged in, and said it sounded bad because it didn't distort like they expected. It may not have been the sound they were looking for, but under no circumstances would I say that a KT-88 sounds bad.

*Is the 6550 different from the KT-88?*

Yes and no. All 6550s and KT-88s have the same pin configuration and similar bias requirements, impedance, and capacitance. The differences are in how much voltage the plates can take and, therefore, how much power they can deliver. The General Electric 6550 can "only" take about 750 volts on the plates, and a pair is good for delivering about 150 watts at the onset of clipping. Unfortunately, this tube is a little difficult to get. Another great 6550 was the American-made Tung-Sol. It could only take about 730 volts, and a pair was good for about 120 watts, but they had a relatively warm sound for a 6550. Going further down the scale are the very warm-sounding Chinese 6550s and KT-88s, which are perfectly good tubes but don't really want to see more than about 620 volts. They are good for about 90 to 100 watts a pair at these voltages. Last of all is the now-extinct Sylvania 6550. This was the same tube they sold as a 6CA7, and while it was a perfectly good 6CA7, it was a pretty wimpy 6550. It was only good for about 525 volts and put out about 75 watts a pair.

The shining light on the 6550/KT-88 horizon is a new tube called the KT-90 or KT-99. It's made in Yugoslavia and is easily the equivalent of the GE 6550, only it has a very warm, smooth sound like a great big EL-34. I am designing one of my new amplifiers to use it. I can get a solid 150 watts from a pair by putting about 720 volts on the plates.

They are available from several tube houses. They are not fat like a 6550, but look more like a longer, pointy EL-34 with very thick glass. They can be put in just about any amp that takes 6550s, KT-88s, or 6CA7s, with a bit of a bias modification [*see your tech for details*]. Guitar players will love them, but they are probably a bit too soft-sounding for most bass players, so I doubt we'll be seeing many Ampeg SVTs outfitted with them. I am very excited about this tube.

*Describe a rectifier.*

A rectifier is a tube or solid-state device that permits electricity to flow in only one direction. They are used in all AC [alternating current] driven amplifiers. Any amp that plugs into the wall has a rectifier, which converts the AC coming out of the power transformer into DC [direct current]. Tubes require DC voltages to operate. [*Fig. 4 shows the difference between tube-style and solid-state rectifiers.*]

*What happens when you replace a solid-state rectifier with a tube rectifier?*

Assuming the amp can do it, it reduces the efficiency, and the voltage to the tubes drops. The solid-state rectifier gives off less energy as heat, so more of the voltage that goes into it comes out of it as usable DC electricity. The tube rectifier, on the other hand, gives off a lot more energy as heat, and as the amplifier gets louder and more current is drawn from it, the tube rectifier becomes less efficient and gives off still *more* energy as heat, causing a loss of transient response and an overall compression of the signal. A sharp pick attack immediately requires more current from the power supply, and the rectifier tube cannot respond as quickly as the solid-state device. So with the tube rectifier, the transients go down and pick attack is reduced, but it tends to be somewhat warmer and smoother than the sound from an amp with a solid-state rectifier. A term you hear is that a tube rectifier has more *sag*, or compression.

*What is bias?*

On their way from the cathode to the plate, the electrons inside the tube go through a component called the control grid. Bias is a constant DC voltage applied to that grid, and it regulates the current flow from the cathode to the plate; this then determines how hard the tube is going to work, which affects its performance, sound, and life expectancy. For any given class of amplifier-A,B,AB,etc.-and any given individual tube at any given plate voltage, there is an ideal bias voltage. It can be determined mathematically, although it's usually derived by testing under use with an oscilloscope and an oscillator, or with a current meter.

There are three categories of amplifier bias schemes: self-adjusting cathode, adjustable grid, and non-adjustable grid. Examples of amps in the self-adjusting category are tweed Fender Deluxes, old Marshall 20-watt amps, Vox AC-30s, and many early Ampegs and Gibsons. These tend to have a smoother, more compressed sound. Almost all amps over 20 watts are of the adjustable-grid-bias type. These amps allow a tech to easily adjust the bias voltage to suit the tubes. By far the least common category is the non-adjustable-grid bias. With these amps, the bias voltage is set at the factory to a theoretical optimum. The only significant proponent of the non-adjustable bias is MESA/Boogie, and as long as you buy their tubes, it works just fine.

*Is a bias adjustment necessary when substituting one type of output tube for another?*

Over 90% of the time the answer is yes, but it's difficult for the musician to judge. It's best to consult the manufacturer or a knowledgeable tech. Take Groove Tubes: They

group tubes by bias requirement. If you buy a set of 6L6s in Groove Tubes' H-5 [H is GT's hardness/bias rating] and your tech sets the bias correctly, then as long as you buy the same tube in H-5, you don't have to touch the bias. But if you put in H-8s, you need a bias adjustment. Now, the fact that some amps don't *have* an "adjustable" bias doesn't mean that it doesn't need adjustment by a qualified tech anyway; it's just that some manufacturers have decided that as long as the bias falls within a certain range, everything is cool.

*Some amps have a switch for triode or pentode operation.*

Those are two methods of operating a 5-component tube. Until the 1930s, all audio-output tubes were triodes. The audio pentode was developed for more efficiency. You cannot take a triode [3-component] tube and operate it as a pentode [5-component] tube, but a pentode *can* operate as a triode by applying the appropriate voltages to the components. By switching a pentode tube to triode mode, it becomes less efficient. Typically, its output power drops by approximately one-half, and you lose highs because the impedance of the tube changes and the output transformer is subjected to a higher constant current. Power triodes also tend to have slower attack and sound more like what we associate with "Class A" operation. So when you switch from pentode to triode, you're going to drop power, lose highs, usually have a smoother, more cello-like sound, and get fewer harsh, odd-order harmonics in the distortion. [Fig. 5 shows the differences in wiring for pentode or triode operation.]

*It sounds as if you almost get two different amps when you switch from pentode to triode.*

Yes. It doesn't just lower the power—it's a different sound; it responds differently. Another good way of lowering the power to get output distortion at a lower volume is to pull out two of the power tubes in a four-tube amp, one from each side. It does change the impedance that the transformer sees, and I've heard arguments that it's a good way to blow a transformer, but I disagree. The way you blow a transformer is by overheating its core, and if you have a transformer rated for 100 watts and you give it 50, even with an impedance mismatch you're not going to overheat it.

*One argument against removing two tubes is that because of the way tubes age, when you put the four tubes back into service the once-matched quartet is then mismatched.*

This is quite true, and if you're a perfectionist, you would time-share the tubes so that they age equally.

*What are matched tubes, anyway?*

Any time a signal is simultaneously shared by two or more tubes, as in multiple-tube output sections, the tubes must be amplifying at the same level, or they will be "fighting" each other. Depending on how mismatched the tubes are, this will reduce efficiency, degrade the musicality and smoothness of the sound, and bastardize the natural overtone series by suppressing certain harmonics and increasing others. There are cases where people intentionally use mismatched tubes to obtain a grungier, more primitive tone. It's like people intentionally recording with very old strings or blown speakers. It's uncommon, but sometimes you want the effect.

*What is a microphonic tube?*

If a preamp tube has something rattling around inside the glass bottle, it can change the tube's amplification factor. If the component is moving enough to actually superimpose its *own* signal, or resonant frequency, on the signal you're playing, it feeds back, or

becomes microphonic. In less extreme cases you have to excite the tube with you signal, like if you get this squeal every time you play A on the first string at the 5<sup>th</sup> fret. If the tube itself is *extremely* microphonic, it may feed back on its own, without any input at all. People usually don't notice the problem until they turn on the amp and it goes *woooo*. Then they tap the tubes until the culprit squeals, and they replace it. But really, any tube is technically microphonic to one extent or another, because it is a physical structure with little spirals of wire and pieces of metal inside; the question becomes, is it microphonic enough to bring forth audible feedback in the circuit?

*Can you have microphonic output tubes?*

Yes, but they don't usually cause feedback, because there's little or no voltage amplification in the output stage. If you get half a volt of signal, it's hardly noticeable. A microphonic output tube usually shows itself as a rattle when you thump the amp, or perhaps at certain notes you hear something that sounds like a couple of BBs in a jar. Not all microphonics are caused by tubes themselves, just about 95% of them. Capacitors in the signal path are occasionally microphonic. I've seen extreme cases where one of the decoupling capacitors causes a squeal, and if you touch the body of the cap it sounds like a bass drum coming out of the speaker.