10.5.10 How does the 6L6 sound?

"6L6 = silky, clear treble combined with a well-defined, deep bass contingent ", states the advertisement. Or: *"EL-34 = delicate treble and well-defined bass and midrange."* Or: *"The 6L6 have more of a midrange tone"*. Or: *"The KT-90 will give a little more bass and treble, as compared to a EL-34."* On the other hand, we read in circuit-design textbooks that amplifier-tubes transmit their signal from 0 Hz up into ranges not measured in kHz but MHz. Osram, for example, recommends the KT-66 for radio-frequency amplifiers *"for frequencies up to 30 Mc/s"*. Much depends on the circuit the tube cooperates with, after all. In a first step, the parameters of the tube need to be taken as frequency-independent. That does not mean, however, that the whole power stage has no dependency on frequency. Also, changing tubes may well result in a different frequency response. That, however, does not allow for the conclusion that a special tube generally delivers more (or less) treble.

It is possible to investigate the behavior of a tube power separately for linear and non-linear operation, even though that is not entirely unproblematic for a guitar amplifier deliberately pushed into overdrive. But then, after all, there are guitar players who seek a sound as undistorted as possible. Also, if we focus on a system that distorts both linearly and non-linearly, we run into problems to describe it clearly (since no transfer function can be defined for such a system, amongst other reasons). In the approximately linear range, several components determine the (magnitude-) frequency response of the power stage: coupling capacitors (in combination with their load resistors), output transformer, and loudspeaker. For a guitar amplifier, we may not establish *one* frequency response of the power stage and *one* frequency response for the loudspeaker, and hope that these two diagrams would describe the overall system. For a loudspeaker fed from a stiff voltage source, we could define *one* frequency response (on axis), and for the speaker fed from a stiff current source, too – but these would be different frequency responses. For an internal impedance of 10 Ω of the amplifier, we would obtain yet another frequency response of the loudspeaker. For the power stage, the situation is similar: for an 8-Ω-load, the frequency response is different compared to a 16-Ω-load, and considering the loudspeaker loading results in different curves yet again.

One criterion in which power tubes may differ is their internal impedance. In pentodes (that are operated as such!) it is typically rather high: think 30 kΩ or so – but do keep in mind that this depends on the operating point i.e. on the bias current (Chapter 10.5.7 and 10.5.8). As the internal impedance of the tubes changes, so does the internal impedance of the amplifier. However, **negative feedback** (NFB) enters the stage at this point. For power stages with strong NFB (Chapter 10.5.6), a change in the internal impedance of the tubes has little effect on the internal impedance of the amplifier, but for power stages without NFB, these effects are considerable. Consequently, we may not conclude that characteristics found in an amp without NFB are also found in an amp that includes NFB. The higher the impedance of the amplifier output, the more resonances and treble range are emphasized. This, however, does not justify the purchase of expensive tubes (even though that may be suggested in ads): inexpensive components allow for varying the frequency response of the power stage within a broad range, as long as the linear characteristics are the issue. It may well be that a replacement tube has less gain that its predecessor – that can easily be compensated for by turning up the volume. If the power stage includes NFB, changes in the loop gain could influence the frequency response (Chapter 10.5.6), but it is easy to get a handle on this, as well – and with simple means. In linear operation, any frequency response can be achieved with any power tube; that is standard engineering-knowledge.

 Translated by Tilmann Zwicker

Things get more difficult in the non-linear range. Both phase-inverter and power stage may be overdriven. If high-gain power tubes are used, we can assume that these will distort first but if they have only a small gain, the distortion of the phase-inverter comes to the fore. Talking about power-amp distortion, we must therefore also keep the **phase-inverter** in mind. Your typical cathodyne circuit (Chapter 10.4.2) can generate up to about 40 V of voltage-amplitude, which is not enough if the grid-cathode-voltage of the power tubes is set to - 50 V. The paraphase- and long-tail-circuits, however, can easily drive the power tubes to their limit (and beyond) even for -60 V. It is necessary to always consider the power stage as a whole.

One possibility to describe the non-linear behavior of tubes is offered via the family of output characteristics, an alternative to this would be the transfer characteristic $I_a(U_g)$. All power tubes have frequency-independent amplification parameters throughout the audio range – their maximum currents are, however, dependent on the load. Since the load impedance (i.e. the loudspeaker) is frequency-dependent, there is also a tube-specific dependency of the maximum obtainable power output. **Fig. 10.5.36** shows the output characteristics of two power tubes. For a load impedance of 2200 Ω, tube A will give more maximum power, while tube B will have a higher output power at 550 Ω. At 1100 Ω, both offer the same maximum power. In this example, the maximum power is impedance-dependent, and since the impedance is frequency-dependent, so is the maximum power. The right-hand picture indicates that for higher load impedances a current-saturation happens already at U_{g1} = -8 V – the transfer characteristic turns into the horizontal.

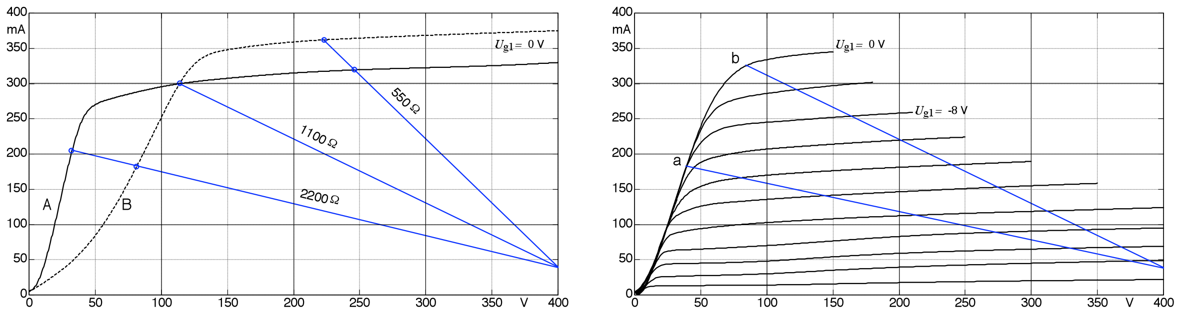

Fig. 10.5.36: Family of output characteristics: plate-current vs. plate-voltage.

Already these initial considerations show that exchanging the power tubes can change both the linear and the non-linear behavior of the power stage. Still, we may not deduce that a specific type of tube (e.g. the EL-34) has a special frequency response. Again: <u>all</u> tube parameters are frequency-<u>in</u>dependent throughout the audio range. However, cooperating with a special circuit-environment, every tube can and will result in a system that in its entirety is frequency-dependent. The number of circuit variants for power stages in guitar amplifier is not infinite, and therefore findings from the investigation of one amplifier may be applied to some other amplifiers. For example, if a special 6L6-GC sounds trebly in listening experiments with a 4-Ω-Tremolux, it is likely to sound that way in a 4-Ω-Bandmaster because the same output transformer is used in both amps. Even here, though, an imponderability remains in that the impedances of the two loudspeakers may be different, and another one in the fact that even 6L6-GC's sourced from the same manufacturer may be different. Just crowned the test-winner in a Fender-amp, one and the same 6L6-GC may disappoint completely when plugged into a Marshall. Or it may be fine – that depends on the personal taste, the musical style, the specific circuitry, the individual loudspeaker and the individual tube. Blanket-judgments such as "*the KT-66 is a HiFi-tube*" are non-sense, if they seek to refer to resistance against distortion. Because: all tubes were originally developed for HiFi, weren't they?

Fig. 10.5.37 shows the transfer characteristics of typical power tubes. These measurements can (and are supposed to) merely indicate the behavior of such curves in principle - no recommendation regarding which tube to purchase may be derived. For one, because e.g. KT-66's from two manufacturers can differ drastically, and second because even KT-66's from *one and the same* manufacturer can vary in their parameters. In order to obtain a reasonably reliable statistic, numerous tubes would have to be acquired – at more than 50 Euro per piece, this is not a really desirable undertaking.

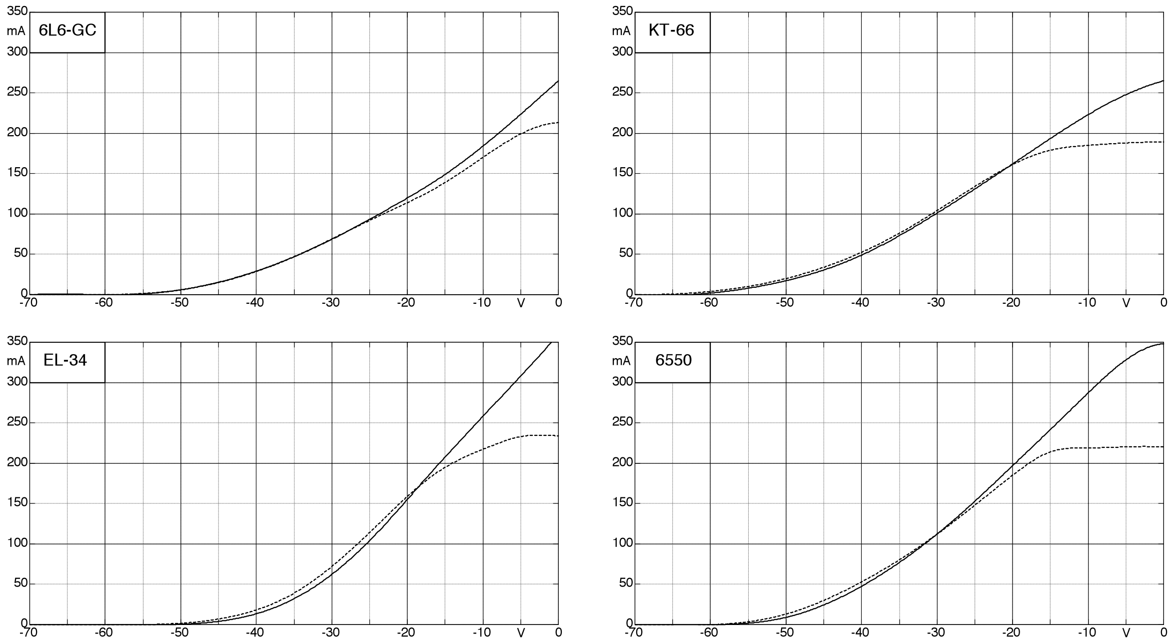

Fig. 10.5.37: Difference in the transfer behavior (measurements), ohmic load 8 Ω (——), 16 Ω (----). M50A.

The measurements were done using a TAD M50A output transformer and an ohmic load-impedance. The differences in the gain (large with the EL34, smaller with the 6L6-GC and the KT-66) are obvious, which is not surprising: the datasheets show the same under the entry "transconductance". We find large maximum currents for the EL34 and the 6550, allowing for inferences regarding loudness, and we see similar curves with the 6L6-GC for both 8Ω and 16Ω, but larger differences between the two load conditions in the 6550. Taking the frequency response of a specific speaker as a basis, we can deduce basic sound-variations from the difference in the respective two curves for each tube. Both curves similar = load-independent, stiff current-source; pronounced differences = less power at a higher-impedance load i.e. less treble. For such statements we certainly need to look into the linear behavior, too; it is only with such an overall consideration that we arrive at a reliable conclusion.

Can these measurements support the notion that an EL34 will distort rather early while the 6550 remains "solid and clean", as Pittman writes in his Tube Amp Book? Before diving into the slightly different 16-Ω-curves, lets first linger and check Pittman's bias-voltages: -50 V for the EL34, and -68 V for the 6550. That does, however, not match Fig. 10.5.37, at all! What could A.P.'s approach have been here? Probably, his reference amplifier works with a higher supply voltage than the one used for the above measurements. An increased voltage at the screen grid could explain a more negative control-grid-voltage, however: how generally valid are Pittman's statements then? His subjective evaluation of the sound shall not be put into question, but his GT-Electronics-Dual-75-Amp is not really that ubiquitous, and at -50 V (EL34) it is not set typically, either. As Pittman notes a few pages later: in a 50-W-Marshall there'd be -43 … -40 V.

Also, another striking aspect in the Tube Amp Book: two tubes (6L6-OS vs. 6L6-B) differ slightly in their distortion: "The 6L6-OS clips a little sooner". Every single tube is, however, also selected according to its distortion characteristic and designated with numbers: 1 – 3 = early distortion, 4 – 7 = normal distortion, 8 – 10 = late distortion. This is because of unavoidable scatter in manufacturing even tubes of *one and the same* type will have different data. Now, does a 6L6-OS with a rating of 10 still distort earlier than a 6L6-B with a rating of 1?? As commendable as Aspen Pittmans's approach towards quantification is, one has to get lost in this vast desert: the circuits are different, and so are the output transformers, the loudspeakers, the tubes – and in any case on top of that the subjective expectations, as well. In a Marshall, Pittman opines, the 6550 sounds *"loud and crunchy"*. If you don't favor that, you change the circuit to install EL34's, because that tube sounds *"smoother, with warmer distortion"*. Turning over a page or two, we also read that the EL-34 may sound *"gritty and a little squashy"*, and the 6550 may sound *"fat and clean"*. Or it may sound *"extremely harsh"*, as we read in publications from German authors. We however also find the latter attesting the EL34 a "*warm sound*" which doesn't really fit "*gritty*". On the other hand, German advertisement has the EL34 giving a "dynamic attack", while the US-colleagues arrive at the verdict: *"The EL-34-setup seemed to lack dynamics"*. For the 6L6-GC, evaluations stretch from "*a fat, more mid-rangy singing distortion sound*" to "*more unstable and mushy*".

In fact, it is not only purposeful but imperative to judge the tone of a sound source according to auditory criteria. Measurements are (hopefully) precise and objective, but they are not necessarily directly linked to our subjectively perception. That's why we carry out auditory experiments. If both too much and too little dynamics are attested to the EL34, several reasons are conceivable. Different amps may have been used, or different music played, or just different EL34's may have found their way into the experiment. Indeed, it seems that everything that sports a glass cylinder of 8 – 9 cm length and 33 mm diameter may call itself EL34. Tube retailers do not angrily send back to the manufacturer all rejects that fail the specifications in the Philips-/Siemens-/Mullard-datasheets, but sell this junk – with a markup – as *"specially selected"* merchandise. Which isn't totally inaccurate, either, somehow. Why didn't others think of that? "*For a premium of an additional 500 Euro you can get a selected TV-set the right-hand screen-half of which remains dark.*" Wouldn't that be a cool idea? It is, for amplifier tubes. It is even legal, because today your EL34 is not just designated as such but it's now called EL-34-SVT, EL-34-Cz, EL-34B-STR, EL-34C, or EL-34R, etc. – and any notice of defects can be averted. That does not mean that none of these tubes meet the specifications; some even exceed it – but some will remain 20% below the given current specification. Others may reach the specified current but fail regarding the transconductance. Apparently, the scatter is big enough for Groove-Tubes to designate one of ten (!) subgroups to each tube. These 10 subgroups will have to be significantly different, too – otherwise e.g. three groups would have been sufficient. Now lets consider, on top of this, that the power tubes are fed by driver-tubes the data of which are also subject to a noticeable spread. Furthermore, the power is supplied from circuits including rectifier tubes that may by called (despite individual "selection") rejects (see Chapter 10.7.4). In view of all this the question "*what does the 6L6 sound like*" can only be answered with a sobering "beats me – no clue – not a hunch". Sorry, folks, thou ask'st the wrong man.

"...I have to point out that my experiments trying to map the sonic differences between various tube-types to sound-files did not meet satisfactory results. The recording/reproduction-process minimizes the differences to a minimum such that almost nothing remains of the described differences. We can hardly conclude anything comparable to what is experienced as a difference when playing." (Gitarre&Bass 6/09).

