10.10 Comparative Analyses

For the most part, the chapters so far dealt with the analysis of special partial circuits. From now on we will look at guitar amps as a whole. To begin with, the large variance in old amplifiers should again be stressed: passive components could have tolerances of up to 20% or even 30%; same-type tubes vary in their transmission parameters, circuits were modified by the manufacturer without notice. Thus, Tweed Deluxe amps, for example, come within a considerable scatter range – even if they carry one and the same 5E3 designation.

10.10.1 … for they knew what they did?

An old Princeton is comprised of no more than 3 tubes, 2 transformers, 11 resistors, 10 capacitors, 2 potentiometers – and many see it as ingenious miracle work of a brilliant circuit designer whose genius-ideas to this day deny any analysis. The same holds for old Voxes, rare Parks, original JTMs, or whatever else is called up as a precious gem. Well, while it may not have been entirely trivial to develop a power amplifier, and to run a series production for it, during war- or post-war-times, this did not require superhuman ingenuity, either. In most cases, the basis was probably not much more math than $U = RI$ und $P = UI$, supplemented by the knowledge that a capacitor conducts the better the higher the frequency. Isn't this what distinguishes the circuit expert, oh dear editors of musicians' magazines? During the war the following could easily happen: a chap more or less enthusiastically joined the Royal Air Force, was really annoyed with the wireless constantly breaking down, enjoyed a surprising success after replacing a blown capacitor, was as a result promoted to technician (or even engineer) – and had laid down all the groundwork for a later career as circuit designer. Not that the actual theory was unknown: in the Langford-Smith compendium – published for the first time in 1934 – there are hundreds of pages of the basics of circuit design that to this day is worthy of being taught at university. But times were difficult and not everybody who wanted to go to college could do so. Back then, that is. That in 2007 a circuit-"expert" at a well known German musicians' magazine makes a statement along the lines of "*more than 400 V flow through such plastic stuff*" … shows a kind of congeniality, somehow ...

For the old circuits, it is impossible today to know what was the result of an intentional development towards a clear aim, and what "just happened". Presumably, the designers back in the day were not entirely sure themselves what exactly they soldered together. For one, the technical education probably left something to be desired in many cases, and the same was most likely true for the available equipment, as well. There were no PCs in 1950, and neither had "electronic calculators" been developed yet. Transistors were available merely as prototypes in R&D – the lab equipment was exclusively tube-powered. That did work pretty well for a tone-generator and an oscilloscope, but already distortion measurements posed a serious challenge. It wasn't impossible – HP (from 1939) and B&K (from 1942) offered audio measurement equipment – but it was *expensive*. For a small Brüel&Kjaer audio measuring station, even as late as 1987 one had to shell out (in €-equivalents) 13 grand for a level recorder, 8 grand for a sine-generator, 13 grand for an FFT-analyzer, 30 grand for a distortion analyzer and another 60 grand for a 1/3-octave analyzer … summed-up € 124,000.-. The two-channel version would have set you back another 21 grand, and had you decided to go for a printer … that luxury (color? Dream on, my friend: black only) would have added 14 grand more. The printer alone would have been the equivalent of three brand-new, fully gassed-up VW Beetles. At the time when the famous amp-forefathers were put together, their designers were mostly ham-radio "amateurs", just barely beyond their teens. In no way could they have afforded a full set of the wonderful light-green B&K-equipment. At best, they operated a tone-generator, an oscilloscope, and one or two "MaVoMeters" - plus a soldering iron.

Indeed it was possible to build an amp with only little equipment; the circuits were known. In his book about VOX, **Jim Elyea** relates that it was customary to nick left and right from the competitors. Well, he doesn't actually write "nick": *"JMI, like everyone else, borrowed literally wherever appropriate... It was not uncommon for the engineers at JMI to bring in the equipment of other manufacturers, take them apart for ideas, put them back together, and sell them in the shop"*. Ideas were "borrowed" … an approach in practice as late as 1984: just before the Frankfurt music fair, a CEO (who shall remain unnamed, as shall his company) had "his own" face plate mounted on a Japanese competitor's device, and proudly presented it at the fair as the newly developed reverb. Just to be safe, and to avoid that somebody else would nick it in turn, he took it to his hotel room every evening. '**Knowhow-Transfer**' was and is common – and not just in the Far East. Marshall's JTM is a copy of a Bassman, the tremolo-effect for guitars previously was used in organs, the VOX tone control is derived from the Gibson GA-70 (in turn inspired by the Fender Pro 5E5-A), Marshalls 18-Watt amp previously was already successful on the market as Watkins Dominator. Gibson *'disassembled every Fender-Amp'* [Elyea /Smith]. Of course these were mostly not actual 100-%-copies: one's own ingenuity has to come out somewhere. (**Fig. 10.10.1**).

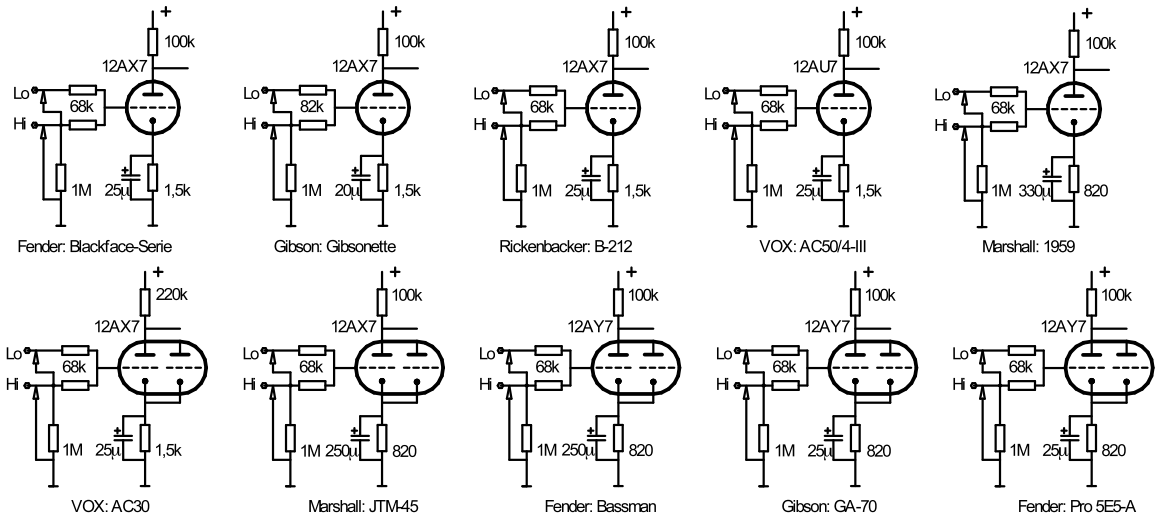

Fig. 10.10.1: Input circuits of various guitar amplifiers.

In Elyea's VOX book we repeatedly find hints that Dick Denney's prototypes were "bird's nests" – heaps of components artfully soldered together. *'Dick's working was a more organic approach, involving endless fiddling with individual parts until he got the sound he was after. He didn't care what the value of a part was; all that mattered was if it sounded right.'* Denney had a severe hearing loss but that did not get in the way. No, not because that would have put him on the same "ear-level" as his customers, but because despite the damage in his ears he was aware of what the marked demanded. He was not always aware of the inner workings of his circuits. Only when he dropped his screwdriver into the circuit (shorting two wires) did he discover that his Wurlitzer-inspired **phase modulator** also could accomplish amplitude modulation [Elyea]. Indeed, that Vib/Trem-channel ... it includes a 500-Hz-highpass followed by a further high-pass of a cutoff frequency of 8 Hz (0,8 Hz for the bass version). That's how it's done and that's how it is passed down from generation to generation. Or the **JTM-45**, Jim Marshall's holiest cow: nowadays available as reissue, but with a changed electrolytic capacitor at the cathode. Our musicians' magazine recommends: "*the 330-µF-cap should be replaced by one with 250 or 220 µF. This minimizes the bass a bit."* The explanation with a better match would have been: since it was that way in the original circuit. Let's do a simple estimate: with an internal resistance (1/*S*) and the cathode resistor of 820 Ω we get a pole-

frequency of 2 Hz (330-µF), and 2,7 Hz (220 µF) respectively. For a more exact calculation we would have to consider the plate resistor, as well … however: is that really necessary? How relevant is the operation at 2 Hz in a guitar amp? We might look into the issue of transient phenomena – had not our author in the expert journal written in another passage that jumper wire would sounds differently compared to stranded wire, and that silver wire had a *"cruel"* sound. Here we touch the world of HiFi, where wire with blue insulation sounds more airy, while wire with brown insulation sounds somehow … shitty. Side-note: for electrolytic capacitors, the exact capacitance was never really of much importance – it is not uncommon to find tolerances of e.g. +50/-20% printed on the housing.

So, how did that **250-µF-cathode-cap** arrive? That's truly difficult to assess and we can only speculate. The circuit of Leo Fender's very first Bassman (5A6) is shrouded in time and mystery – it seems nobody has actually seen a drawing of this circuit[⊗]. In any case, the closely related Pro Amp (allegedly delivered with the very first P-Basses since the Bassman Amp was not ready yet) had double-triodes (6SC7) with joint cathodes in the input circuits, and it included normal 25-µF-caps. The second variant Bassman (of which the circuit diagram 5B6 *is* available) also featured the same-type double-triode with joint cathodes, but sported the infamous 250-µF-biggie – almost as big as the power-supply filter cap. Why was that? Some thoughts about that:

1. While in the active channel (of the two-channel input configuration) the signal from grid to plate is inverted, it also reaches the anode via the other channel (2nd half of the tube). This common-grid signal path is non-inverting such that in the plate two out-of-phase signal are summed and thus there will be an attenuating effect. However this happens only at very low frequencies since the route via the cathode is a low-pass. With 25 µF a loss of 3 dB would have occurred at 2 Hz – more than adequate even for a bass guitar, and not really any reason to up the cap by a factor of 10.
2. The big cap was supposed to eliminate hum induced by the tube heater. That may actually be a possible reason – however the Pro Amp did quite well with 25 µF at the cathode.
3. A bass amp needs to operate at low frequencies. O.k. – but as much as 250µF? Both output transformer and speaker are far from able to carry such infrasound to any extent.
4. Someone in logistics misread Leo's handwriting and accidentally ordered 1000 pieces of 250-µF caps instead of 25 µF. Hm … maybe not.

The mystery remains – from other angles as well: why does Leo keep the 250 µF as he switches to the 12AY7? Now he's got a modern double-triode with totally separate systems, but still he maintains the big 250-µF cap in the Bassman. He holds on to it for years – until the completely redesigned 6G6-Bassman, when suddenly the "small" 25-µF cap suffices. Just as it suffices in the Deluxe, but there it had held its own from the very start (5D3). Same as for the Pro (5D5), as mentioned above, and for the Super (5D4). They all got by with 25 µF. Only the Bassman features the 250 µF. It's a bass amp, after all, so let's accept it. Next, however, Marshall's Ken Bran copies the Bassman and it becomes a guitar amp – and naturally keeps the 250-µF-cathode cap. Since then, all Bluesbreaker imitators adamantly insist on that cap … most likely because, now as it was then, they may not always exactly know what they are doing. Because the cutoff frequency is so excessively low, we could look for other criteria: for example for transient phenomena that play a role as the tube is overdriven. Still, no find – Marshall will use the 820-Ω-resistor for the two cathodes

[⊗] The circuit „Old Bassman" or even „5A6" found on the internet at the time of this writing can NOT be a Bassman but is highly likely to be a Dual Professional in view of the two speakers, the dual output transformers, the three inputs, and two volume controls (contrasting a single speaker, one output transformer, two inputs and one volume control on the Bassman).

connected in parallel, and then again also for single-cathode operation. Shouldn't they have brought in 1600 Ω for the latter? No, they didn't. Not that Fender looks much better: they change from the 12AY7 to the 12AX7 without matching the cathode resistor although these are quite different tubes. Who cares, as long as the contraption doesn't go up in flames. The RCA-Receiving-Tube-Manual recommends 1,5 kΩ as cathode resistor for the 12AX7 (at 300V/100kΩ) – that may have been the starting point for it all, and that was then somehow copied, and copied again, and again …

With respect to the design approach of early guitar amplifiers, the VOX book gives interesting insights: *1935 for the first time an effort was made to do more than amplify the signal of an electric guitar. Rather, the idea was to alter the tone, both making the electric guitar a different instrument, not just a louder guitar, and also making the amplifier itself an important part of the sound [Elyea]*. Some manufacturers, however, arrived at this realization only much later: *In late 1957, it was a natural to apply the Hi-Fi designation to the new amplifier (VOX AC2/30)*. Similarly, Dave Funk reports about the early Bassman: *Everything was very technical, hi-fi, and by the book.* The first guitar amps either included no possibility at all to influence the sound, or merely included a primitive tone control to attenuate the treble range. Dick Denney's **VOX AC15** followed this design approach, as well, and was supposed to reproduce as "**HiFi-like**" as possible. At first, the "Normal" channel sported merely a control to diminish the treble. The lower cutoff frequency of lower than 20 Hz was determined by the values of the coupling capacitors, while the upper cutoff frequency of about 17 kHz resulted from unavoidable stray capacitances. This configuration would have done a good job in a music box, as well. It was only the power amp that refused the trend – to include negative feedback. Apparently the amp worked better without it, as had the amps of Fender, Gibson, and many more. Indeed, dispensing with negative feedback was not an invention that VOX came up with. To have a 500-Hz-highpass in the Vib/Trem-channel be followed by a further 0,8 Hz high-pass – well, that actually may be "VOX-typical".

In **Fig. 10.10.2** we see the frequency responses of two Bassman amps (are these then 'Bassmen'?) from input to the second stage. Compared to the fundamental of the (regular) lowest string of an electric bass (E_1 = 41.2 Hz), the 5B6 appears quite a bit 'oversized'. For the later 5F6-A, the lower cutoff frequency even depends on the position of the volume control of the "other" channel, which would appear to push the significance of the lower frequency limit even further into the background.

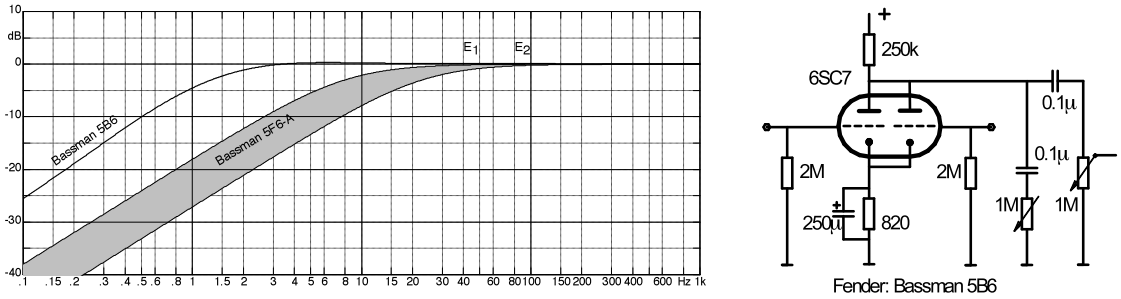

Fig. 10.10.2: Frequency responses of two Fender Bassman amps. String-fundamental: Bass (E1), guitar (E2).

Thus we shouldn't look for reasons that never existed. Much resulted from circumstances that cannot clearly be seen anymore today, or happened due to pure chance and by accident.

(Translator's note: at this point Manfred Zollner makes a comparison to processes which may have influenced how literature was written. As an example, he relates to the well-known poem "**Der Erlkönig**" written in 1782 by famous German poet Johann Wolfgang von Goethe. Since this passage "works" only in German, it was not translated and is not included here – please see the German version of this book if you are interested.)

