10.10.3 Headroom-chart

"Headroom" means drive margin i.e. "how much more gain until overdrive". The headroom-chart is the graphic representation of the frequency response of the headroom. This chart shows a frequency response for each amplifier stage – it is not "transmission frequency response" but the frequency response of the headroom relative to the drive limit (clipping) of the power-amplifier. Since this clipping is the reference, it is represented by a horizontal line at 0 dB. If, for example, the curve for the 1st stage *at a specific frequency* is indicated to be at 12 dB, then this1st stage can be driven with 12 dB more until clipping than the power amp. In other words, as the power amp goes into overdrive at this frequency, the 1st stage still has a reserve of 12 dB, or, as the 1st stage goes into overdrive, the power amp has already been pushed into overdrive by 12 dB. In **Fig. 10.10.6** we see four headroom charts. For the **Super-Reverb** (normal channel) the curve for the 2nd stage runs almost constant at -17 dB indicating that this stage starts distorting only as the power amp is already overdriven by 17 dB. Conversely, the 2nd stage of the **VOX** (AC30-TB, brilliant channel) at 100 Hz has a mere 4 dB margin, and at 1 kHz, the 2nd stage and the power amp go into overdrive at approximately the same input signal level. The drive margin of the 1st VOX-stage decreases towards low frequencies because a high-pass between 1st and 2nd stage attenuates the bass transmission.

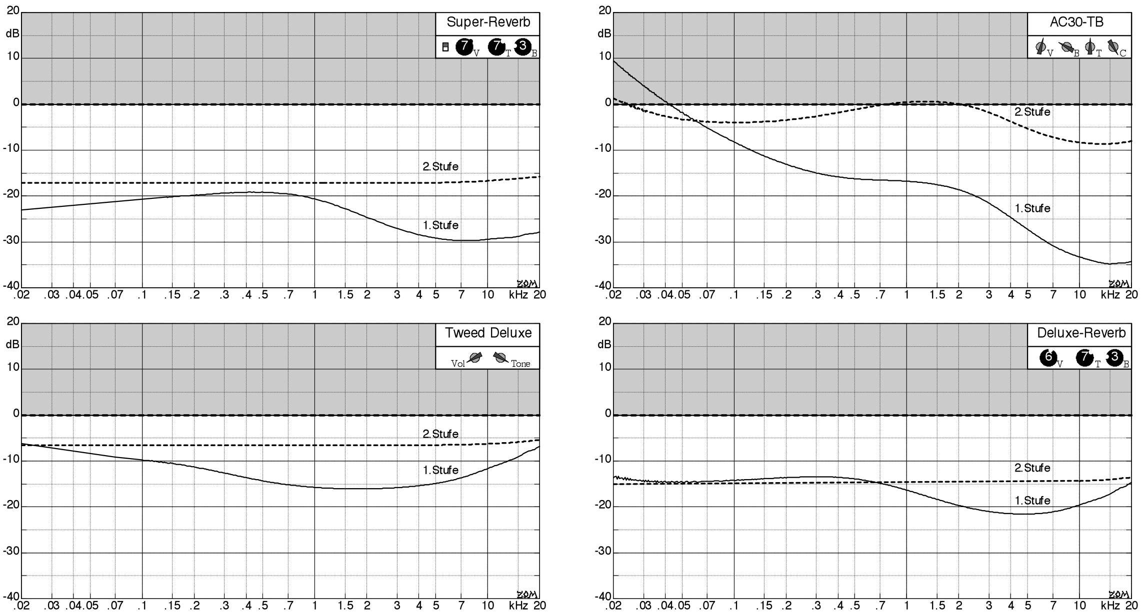


Fig. 10.10.6: Headroom-Chart for Fender Super-Reverb (AB763, upper left), VOX AC30-TB (upper right), Fender Tweed Deluxe (5E3, lower left), and Fender Deluxe-Reverb (AB763, lower right).
The higher the curve is located in the chart, the smaller the drive margin is relative of the power-amp clipping.

The 2nd stage of Tweed **Deluxe** directly feeds the phase inverter (via a capacitor), and the headroom chart therefore runs in parallel to the horizontal power-amp-line. However, with the cathodyne-circuit of the Tweed Deluxe not having any voltage gain, there is much less margin compared to e.g. the Super-Reverb. The **Deluxe-Reverb**, on the other hand, is much closer in circuit design to the Super-Reverb than it is to its ancestor Tweed Deluxe. It does not quite reach the high margins of the Super-Reverb due to its lower supply voltage. As we change the setting of the **volume potentiometer**, it is only the curve for the 1st stage that also changes: the larger the amplification, the more this curves sinks to the bottom (= larger drive margin re the power amp). With no control located between the 2nd tube and the phase inverter, the curve for the 2nd stage cannot be changed. This is in contrast to the Fender Bassman and its Marshall-clone, the JTM-45.

For most Fender amplifiers, the tone control is located *ahead of the 2nd tube stage* – but from 1954 to 1956 some amplifiers were designed with the (in-) famous cathode-follower as 2nd stage, and the tone control *positioned behind it*. We may surmise that the RCA Receiving-Tube-Manual in its 1954 issue (RC 17) is the source; it introduces for the first time a 12AU7 with cathode-follower and *"Bass and Treble Tone-Control"*. Incidentally, the Twin (5D8) receives a very similar circuit that year, and designers at Gibson take up the same idea and include a cathode-follower into the GA70/77 (although they do change the tone control circuit). VOX, however, does not really bother with alterations and simply adopts the Gibson tone control 1:1. The cathode-follower driving the tone control is deployed in the 5D6-Bassman, as well – that amp spawned the inspiration of Marshalls Ken Bran and his JTM-45. The respective tubes are all configured in the common-plate-circuit (= **cathode-follower**) but the tubes themselves and the details of the circuits vary. RCA shows the 12AU7, Fender initially includes the 12AY7, with Gibson, VOX and Marshall, the 12AX7 is found. All amps use a double-triode, i.e. a tube containing two independent triodes within one glass container – independent but equivalent. This is actually not that advantageous because the first tube system operates on common-cathode mode (no AC at the cathode) but the second tube system operates in common-plate mode. The first tube system is to amplify the voltage, and the second should amplify the current (**Fig. 10.10.7**).

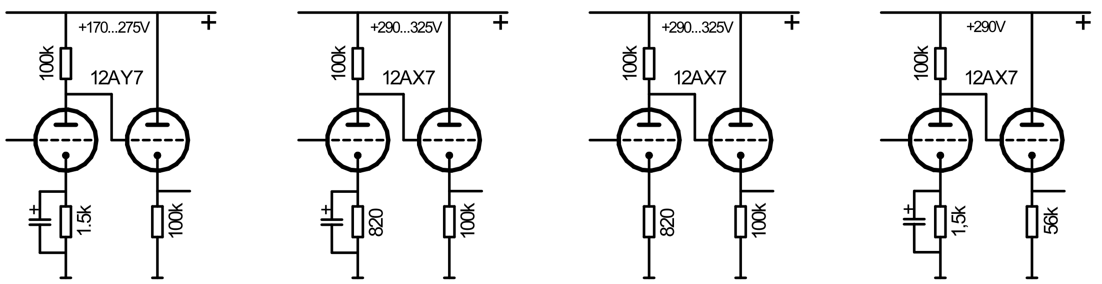


Fig. 10.10.7: Double-triode w/cathode-follower (Chapter. 10.2.2). On the right: circuit of the AC30-TB.

Fender first deploys the 12AY7 (**Fig. 10.10.8**) but then changes over to the 12AX7, the amplification of which is somewhat larger but which features less drive margin. The reason: the first tube can reduce its plate voltage (and correspondingly the output voltage) only down to about 120 V. This is what drives the second tube as it conducts. At the output we thus have available no more than about ±35 V (for modest distortion). The subsequent tone control circuit attenuates the signal by about 15 dB, and now there might not be enough signal strength left to fully drive the power amplifier.

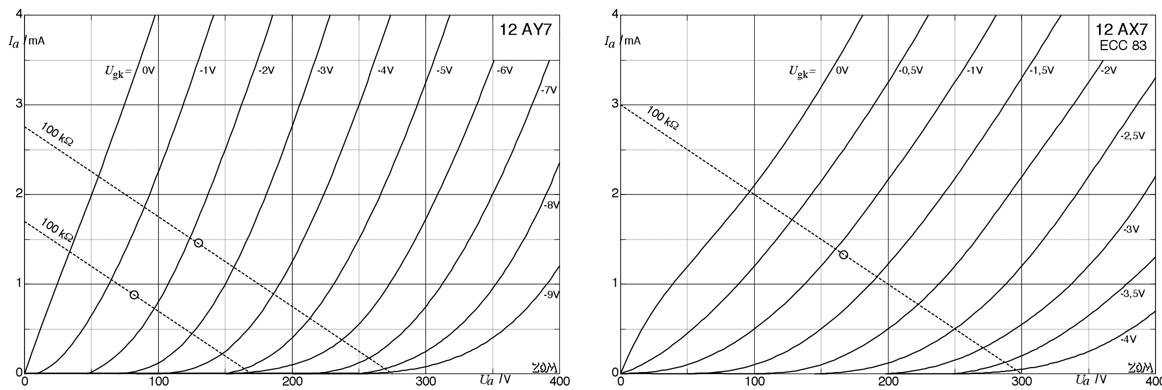


Fig. 10.10.8: Output characteristics of the double triodes used for the cathode-follower (Fender).

In the Fender amp, the cathode-follower therefore generates merely just about the voltage required to fully drive the power amplifier – that may be the reason why it is not used anymore from ca. 1960. Not so at VOX, where the cathode-follower enters the picture at the time when it is shed at Fender. VOX, however, does not "borrow" the circuit from Fender but from Gibson where the cathode-follower is first included in the GA70 and GA77♣. It receives a rather astonishing dimensioning, too: with the changeover from the 12AY7 to the 12AX7, it is not the first cathode resistor that is halved in value but the second – for whatever reason. With this resistor, the quiescent current of the second triode (**Fig. 10.10.9**) becomes large enough to cause a considerable grid current to flow, which again has consequences on the drive situation and on non-linearity (chapter 10.2.2).

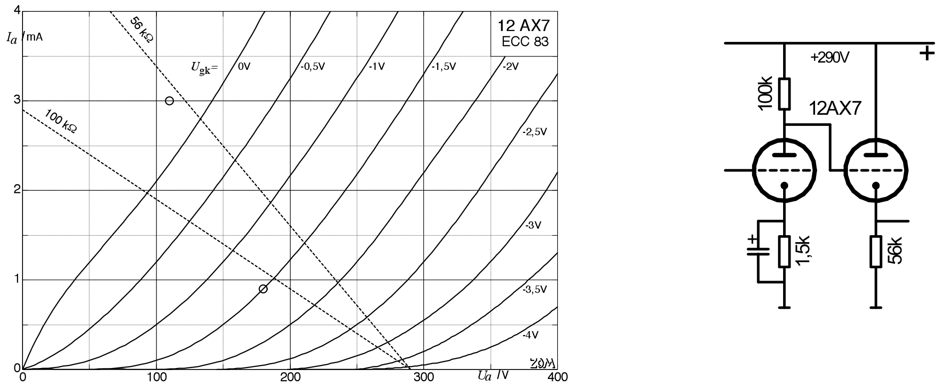


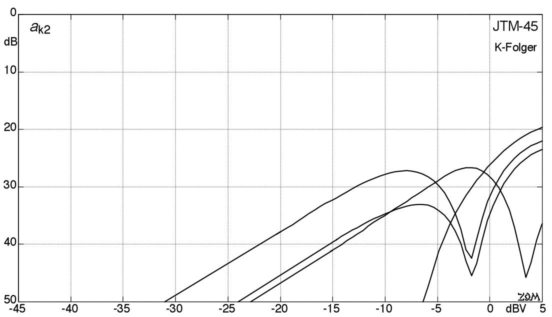
Fig. 10.10.9: Output characteristics of the double triode used in the cathode-follower (VOX AC30-TB).

Of course, we may surmise that it is exactly this non-linearity that is required for a good guitar-sound. But then: why do Fender and Gibson not continue with the approach, why does Leo Fender try, shortly after the debut of the cathode-follower, to decrease this non-linearity via negative feedback (e.g. Super 5E4 – 5F4)? Why does it disappear from all Fender amps after about 1960? Mind you: that was still pre-CBS! In retrospect, many decisions are glorified into strokes of genius – which they probably weren't. Elyea's book on VOX can easily live with such discrepancies: on one hand Dick Denny designed that AC30 exactly according to his own ideas, on the other hand the TB-circuit (cathode-follower and tone-filter) is an exact copy of the Gibson amp. On one hand it is the EL84-power-amp that creates the sound, on the other hand the originally used EL34 was discarded not because of the sound but because it would have made the amp "two inches too tall". On one hand Dick's amp had "more clean headroom than most other amplifiers", on the other hand it featured "high harmonic content" and "plenty of even numbered harmonics". Measuring the output voltage reveals something else altogether: lots of odd-numbered harmonics (chapter 10.10.4). Besides all speculation, there is an objective reason: for full drive levels, the phase-inverter of the AC30 requires less than 10% of the voltage necessary in a Fender (EL84 vs. 6L6GC), and consequently the inferior drive situation created by the cathode-follower could be more easily tolerated compared to a Fender amp. So what about Marshall? Ken Bran does not copy the VOX approach but adopts the Fender circuit. The situation here is rather tight with regard to maintaining sufficient level so the tone stack fed by the cathode-follower is optimized to have low basic attenuation (Fig. 10.3.12). Marshall's PA-amplifiers document the fact that the cathode-follower was not regarded as a special guitar distortion device: all microphone signals – not something you would want to distort - had to pass through the cathode-follower, as well. Gibson advertised their amp (with cathode-follower) as having "unusual clear bell-like treble". What else indeed – it was 1958! Distortion was called for only later.

♣ A variant of the Gibson GA30 temporarily featured a cathode-follower, as well.

Let's speculate some more. Possibly, some designers believed that a tone filter would only work properly if driven by a (actually or only supposedly) low-impedance cathode-follower. That would explain why in the **AC-30TB** it is only the "brilliant"-channel that has the c-follower but not the "normal" – or the "Vib/Trem"-channels – the latter do not feature such a filter. Would the cathode-follower have been considered important to the sound, surely all channels would have been fed to it. Only with the **AC50** both the "brilliant"- and "normal"-channels each receive their own c-follower – because each channel has its own tone filter. In the **JTM-45**, Marshall's first amplifier, the power amp includes strong negative feedback and therefore requires a relatively high voltage to be fully driven. The preceding cathode-follower therefore had to be strongly driven and might have caused distortion. Was this intended? Apparently not, because very soon the negative feedback is reduced♣, and the c-follower distortion decreases. Is this why all over the planet the very old Marshalls are sought after most? Maybe. Or maybe not.

Both triodes (12AX7) in the c-follower of a JTM-45 (Fig. 10.10.7) need to be driven strongly and may distort. This distortion, however, is highly dependent on the individual tube, as can be seen from **Fig. 10.10.10**. In particular, the 2nd order distortion may change by a factor of more than 10 as one 12AX7 is replaced by another12AX7. Thus "the first tube is the most important"-rule (as it can be read here and there) is not correct here – it is the second tube that's important. At the same time, we must not make a connection to particularly old tubes since while these may be great, they may also be bad just as well and do not justify any surcharge. As has been shown already in Chapter 10.1, tube characteristics show different curvature and therefore give different distortion. It would be helpful if some of the "expert" writers in various magazines would for once support their monthly elaborations ("*for Marshalls from early 64 to late 65 use only Brimar tubes in the input stage*") with a measurement of the tube characteristics or distortion. It may be that in a particular specimen of a Marshall the individual Brimar 12AX7 makes for a super sound. It shall also not be questioned that a guitar player who has been writing tests and other reports eventually can judge what a good sound is. What needs to be criticized, however, is the approach to turn such insights into undocumented sweeping judgments that are incorrect in this generalization.



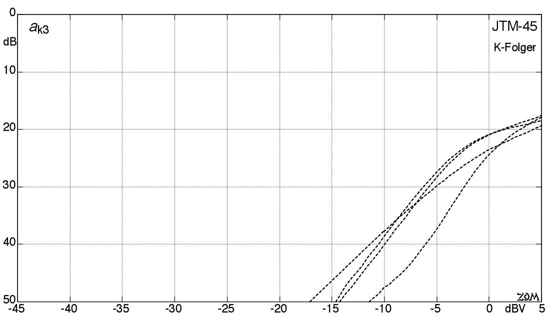


Fig. 10.10.10: JTM-45, harmonic distortion of the cathode-follower; four individual 12AX7. R_Q = 200 kΩ.

At this point, we will not continue discussing harmonic distortion of the individual amplifier stages. Details on this will be included in Chapter 10.10.4. First, the headroom-charts of a few more amplifiers need to be analyzed – these are amps in which the tone filter is not located after the input valve but immediately ahead of the phase inverter (Fender, Marshall).

♣ First taken from the 16-Ω-tap via 27 kΩ, then via 47 kΩ, finally via 100 kΩ from the 8-Ω-tap. Tubes (KT66, EL34) and primary impedance (8 kΩ, 3.4 kΩ) varied, as well.

 Translation into English by Tilmann Zwicker

An objective analysis of Marshall-distortion is hampered by not only *four* tone controls that need to be considered, but also by the fact that Marshalls came with two different output tubes, two different output transformers, different negative feedback, various shunt-capacitors – just to name the most important versions … there were additional issues for short time periods. **Fig. 10.10.11** shows some selected examples: on the upper left there is a standard setting matching Fig. 10.10.6. On the right we see the ancestor, on the lower left the setting for forgetful guitarists (all on 10). On the lower right there is a variant deriving its treble boost mainly from the power amp (Presence control set to 8).

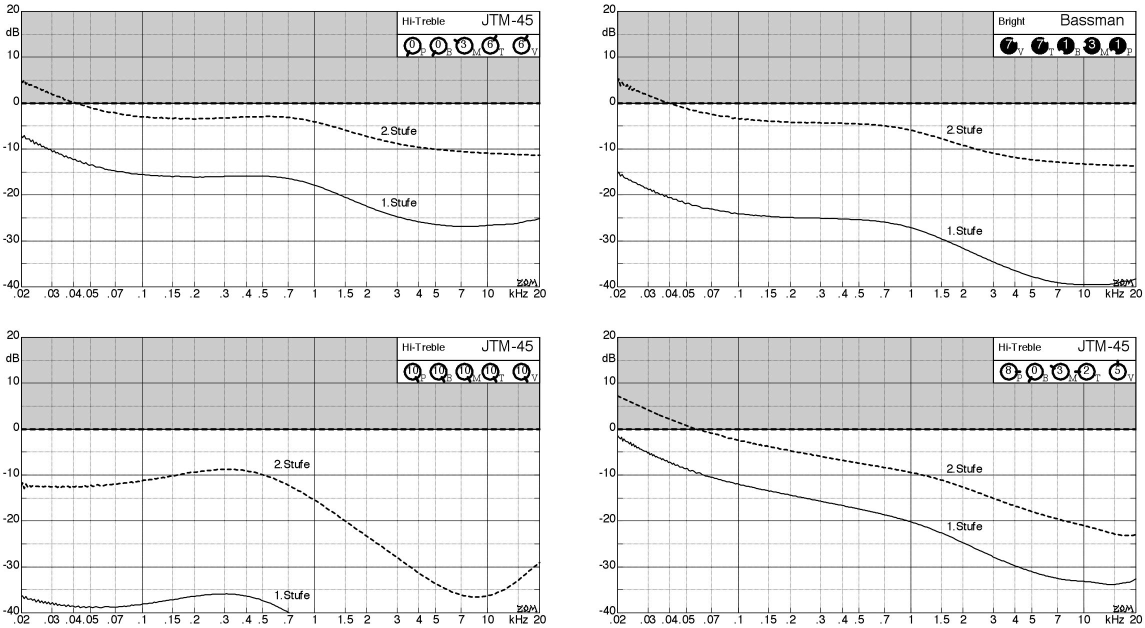


Fig. 10.10.11: JTM-45, headroom-chart. In this amp, the volume-control was not bridged by a capacitor. As a comparison, measurements of the Fender Bassman (5F6-A) are given at the upper right.

The weak dynamic range of the second amplifier stage is striking. As the tone controls are turned up, the filter attenuation drops and the second stage is given a larger dynamic range. With increasing amplification the first tube reaches a larger range (N.B.: re the power amp!). **Fig. 10.10.12** clarifies the step from the JTM-45 (KT-66) to the JTM-50 (EL34): swapping the output tubes (with bias adjustment) and the output transformer slightly reduces the gain margin for the 2nd stage. Additionally decreasing the negative feedback in the power amp cuts back drive levels to the 2nd stage and improves the dynamic range. (Supplemental info on this in chapter 10.10.4).

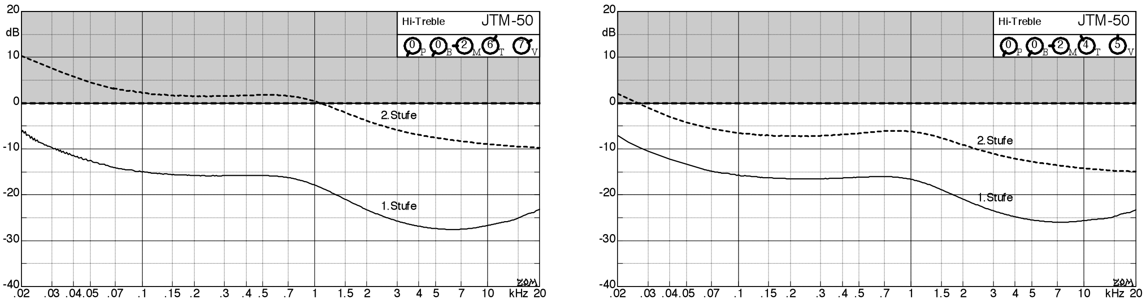


Fig. 10.10.12: JTM-50 (EL34), power-amp feedback 27 kΩ / 16 Ω (left), 100 kΩ / 8 Ω (right). Over the years the negative feedback was reduced and thus the gain margin of the 2nd stage increased.

To conclude, let us have a look at a few amplifiers without intermediate stage: in **Marshall's 18-Watt** amp (built from 1965 – 1967), the plates of the two input triodes are simply connected together which is the source of considerable preamp-distortion (L. Fender had tried this already 13 years earlier in the 5B6-Bassman). Apparently, that was not desirable (at least then!) since the 20-W-successor sums in the conventional manner. The **VOX AC15** sports a pentode in the input circuit, just like the successor **AC30/4** with 4 inputs; it is said to have been microphonic and unreliable. For this reason, there is a swap to the ECC83 in the **AC30/6** (extended to 6 inputs). There were 3 versions of this amp: Normal, Bass, Treble, and it is not yet the actual **AC30-TB** – that then finally received the distorting cathode-follower as the 2nd amplifier stage.

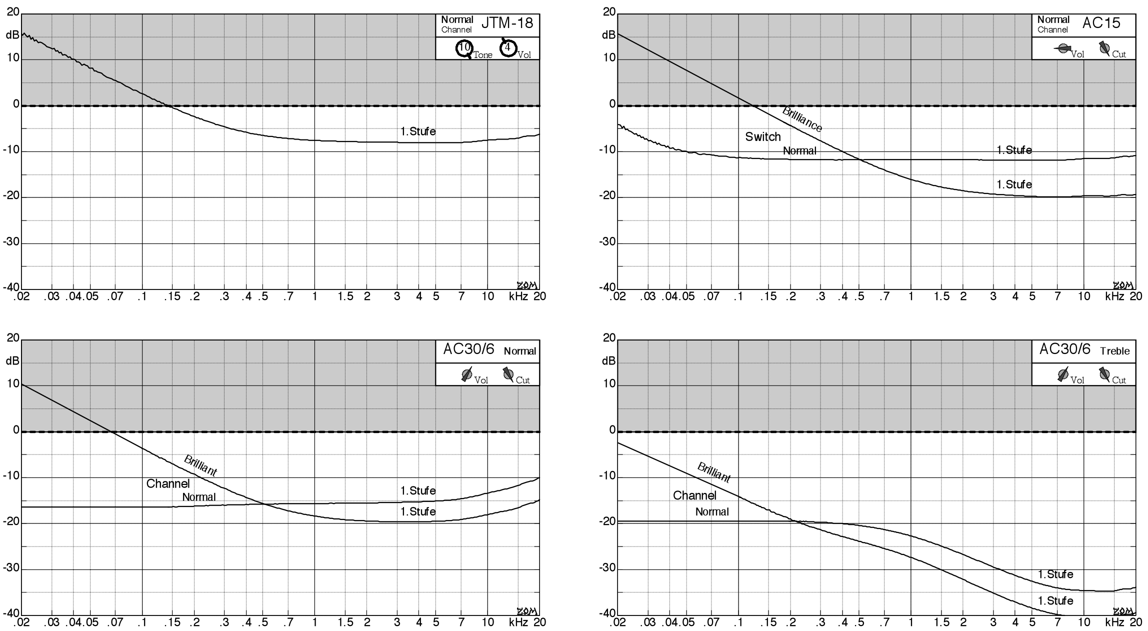
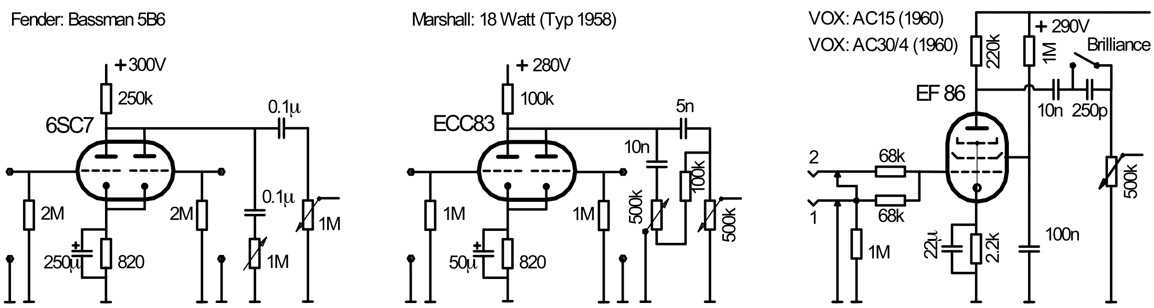


Fig. 10.10.13: Comparison Marshall JTM-18, VOX AC15_1960, VOX AC30/6_Normal, VOX AC30/6_Treble.



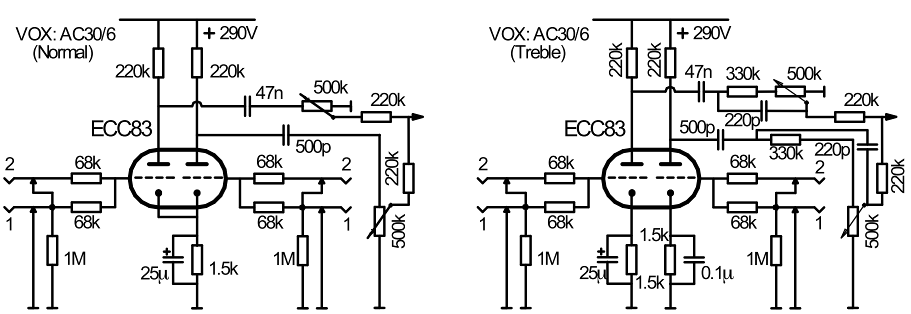


Fig. 10.10.14: Circuit diagrams of the input stages of several amplifiers.

The exact identification of **VOX**-amplifier or their channels in not entirely easy: first, there is a **Brilliance-Switch** allowing for attenuating the bass. The AC30/6 separates this switching-option into 2 channels (with two input jacks each): the **Normal-Channel** and the **Brilliant Channel** (also called Bright-Channel). Consequently, the sound-characteristics available merely as alternative switching-options in the AC15 are permanently both available in the two parallel channels. For a good measure of confusion, the AC30/6 was issues in three different model variants: Bass/Normal/Treble. "Normal" may therefore indicate the **channel** (as opposed to "Brilliant" or "Vib/Trem), or it may designate the model (as opposed to "Bass" or "Treble"). That "Bass" and "Treble" moreover characterize the tone filter controls of the AC-30TB feels somehow almost normal, again.

The **conclusion** of the headroom analysis is somewhat ambivalent: on one hand the charts reveal characteristic differences between the drive margins of various amplifiers, but then again, they do not – because the diversity of the parameters is simply too large even when setting aside the diversity of models. The unmanageable hodgepodge starts with the tubes, continues with the settings of the controls and the definition of a reference condition, and ends with the will (or lack thereof) to add another 100 diagrams to the 50 already cluttering the table. While the frequency response curves show delightfully little change when swapping one **tube** against another of the same type, the harmonic distortion can change drastically. This is true not only as we plug in a well-kept Siemens ECC83 but also as we change from one 12AX7-AC to another 12AX7-AC. The much-lauded carbon film resistors join in with a zest: some do not even fall into the 10%-tolerance range (which in itself is quite intolerable). It is annoying that a 100-kΩ-resistor in cosmetically fine condition found in a 50-yeal-old VOX measures a full 300 kΩ - but it is understandable. However, the brand-new replacement ("absolutely high-end") had 117 kΩ rather than 100 kΩ, and this caused a few not-printable eruptions. After a successful chill-down, and after arriving at the assumption that this might simply be a single out-of-the-tolerance-range case, the realization followed: all 10 carbon-composition resistors of this "High-End" batch read similarly far away from their nominal value. It is thus recommended not to interpret the diagrams shown here to the 10^{th} of a dB, but use them as an "orientation". The significant result we can retain is that the **cathode-follower** creates considerable distortion. Was this the reason why the designer of the famous AC-30TB told Jim Elyea that he in fact preferred the AC30/6 [Elyea, Section 4]?

