10.6.3 Winding-capacitances & -asymmetries

In order for the push-pull power-stage to assemble the two half-waves of the signal correctly with respect to magnitude and phase, the primary windings of the transformer need to be completely similar. Which of course they are not, because they cannot be located at one and the same position on the winding-former. If first one primary winding is wound, and then the second on top of the first, the difference in wire-length is immediately apparent. Furthermore, measurements in the high-frequency range will reveal differences in the coupling- and leakage-factors, and in the winding-capacitance. To moderate these problems, the windings are subdivided (**Fig. 10.6.7**), and the subsections are alternately wound on top of each other (or next to each other in **multi-chambered** transformers).

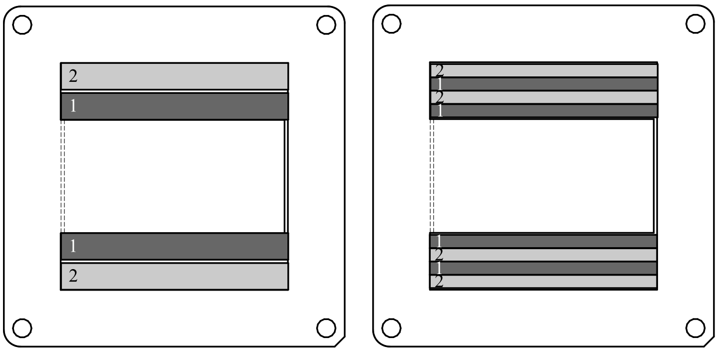

Fig. 10.6.7: Construction of the winding. In the interleaved winding (right), the sub-sections of different windings alternate. In transformers with a sophisticated build, we find multiple "nestings" of primary and secondary winding.

In the *RL*-equivalent-circuit-diagram of the transformer (Fig. 10.6.2), the relative **bandwidth** (f_H / f_T) is inverse to the leakage-**factor**; with a favorable build of the winding three frequency-decades can be covered which is sufficient even for HiFi-quality. However, the winding capacitance must not be completely ignored – in order to describe the high-frequency transmission characteristic, at least *one* capacitance is required (e.g. Fig. 10.6.3). It is this capacitance that determines (together with other parameters) the upper cutoff frequency, and it is just as important as the stray-inductance. As an example, two transformers were examined that are both offered for the **Fender Tweed Deluxe**: the 1750E from Hammond and the TAD-1839. **Fig. 10.6.8** shows the transmission frequency responses measured for loads of 8 Ω and 80 Ω at the secondary output (with a stiff current source driving *one* primary winding). Both transformers show a resonance-emphasis at high frequency: the effect of stray-inductance and winding-capacitance. Since loudspeakers do not merely represent simple ohmic resistances (Chapter 11), supplementary measurements were taken with an 80-Ω-load. This suddenly revealed serious differences, and consequently specifications at nominal load are a necessary but insufficient criterion.

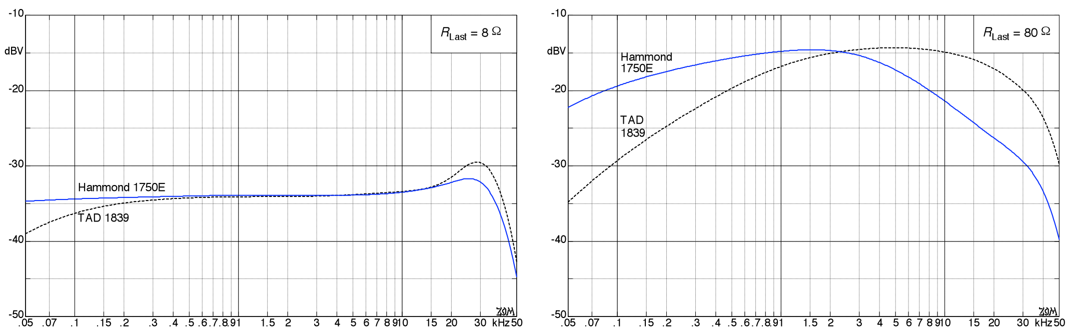

Fig. 10.6.8: Frequency response with a stiff current source (0.16 mA) driving one primary winding.

A short diagnosis of Fig. 10.6.8 could read: *the Hammond lacks in treble, and the TAD lacks in bass*. That is too simplified, though, and we need to dive a bit more into the details. The measurements in fact happen at a rather small primary current and, according to Fig. 10.6.6, the main inductance (see Fig. 10.6.6) is relatively small here. Also, a loudspeaker impedance of 80 Ω is, in reality, not actually reached at high frequencies. Therefore, supplementary measurements are required with loading by a real loudspeaker. These are shown in **Fig. 10.6.9**, with a **Jensen P12N** (mounted in a Deluxe-cabinet) loading the output transformer. Using a stiff current-source again reveals a slight deficiency of the TAD-transformer in the bass-region although this becomes less significant as the drive-level increases. The treble-deficiency of the Hammond-transformer remains relegated to ranges which – for a 12”-speaker transmitting frequencies up to about 5 kHz – have no practical bearing. Our revised conclusion therefore is: in the transmission range important for electric guitars, the Hammond 1750E offers a marginal advantage versus the TAD-1839 – this would possibly justify a small mark-up for the Hammond. Surprise, though: at the time of this writing (AD 2012), TAD charges a stout 86,20 Euro for the 1839 while the Hammond 1750E sets you back a mere 34,70 Euro at Tube-Town. Both TAD and Tube-Town offer a whole range of further output transformers; Chapter 10.6.5 includes corresponding measurement results.

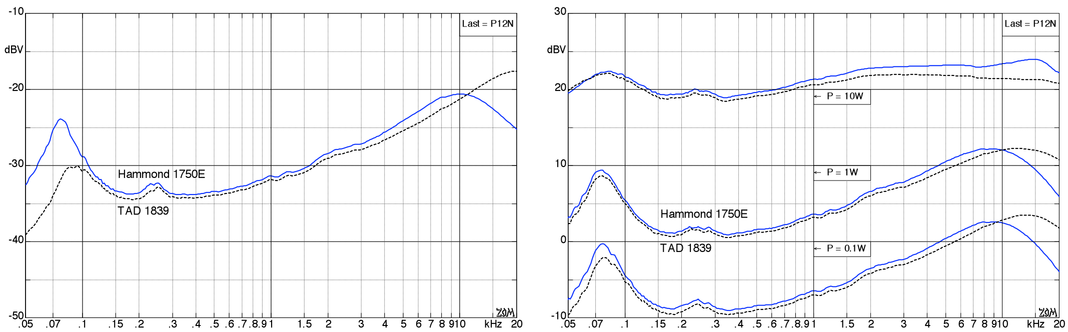

Fig. 10.6.9: Frequency responses with loudspeaker-loading: stiff current-source (left), power-stage (right). 20 dBV at 8 Ω yield => P = 12.5W, P = 10 W corresponds to a voltage level of 19 dBV. At voltage levels around 20 dB, this 6V6-GT-power-stage already shows significant non-linear distortion.

Figs. 10.6.8-9 show the transmission from *one* primary winding to the secondary winding – there are, however, *two* primary windings that feature different magnetic and capacitive coupling to the secondary side. **Fig. 10.6.10** considers this and shows both transmission functions. Again, it becomes apparent that an ECD of pure *RL*-build is not adequate, although the figure also clarifies that the differences are limited to ranges that are not relevant for guitar amplifiers.

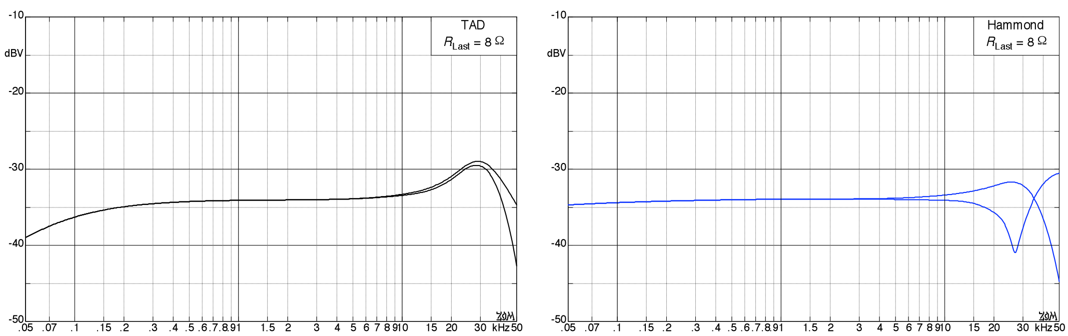

Fig. 10.6.10: Frequency responses of transmission. Primary stiff current-source; asymmetric primary windings.

