### 10.1.7 Noise, hum, microphonics

The noise of the input-amplifier tube can be modeled with good approximation by a noise-source connected in series with the tube grid and generating **white noise** with a noise-voltage density of about 5 $\text{nV}/\sqrt{\text{Hz}}$ (compare to Chapter 5.12). Note that this model does include only the stochastic component of the overall interference, and not the hum component generated by the AC-heater of the tube. Moreover, in a typical input-circuit it is not only the tube itself creating the noise: in addition, there is the grid-resistor (34 kΩ) resulting from the parallel connection of the two 68-kΩ-resistors in the input-circuit. In fact, this resistor is the actual culprit and acts as the main noise-source with a model voltage-density of no less than 24 $\text{nV}/\sqrt{\text{Hz}}$ ! Consequently, it is pointless to consider tubes with lower noise as long as we cling to the classical input-circuit. By the way: the overall noise-voltage may not be calculated by simple summation because the signals from noise-sources are not correlated. Rather, a square-root summation needs to be performed:

$$U_\Sigma = \sqrt{U_1^2 + U_2^2}; \qquad e_\Sigma = \sqrt{5^2 + 24^2}\ \text{nV}/\sqrt{\text{Hz}} = 24{,}5\ \text{nV}/\sqrt{\text{Hz}}$$

Clearly, the noise from the tube contributes almost nothing to the overall noise. However, before taking out the **grid-resistor** and connecting the pickup directly to the grid of the input tube, you should consider that this resistor does have some other jobs to do, too: it limits the grid-current and influences the non-linear distortion of the preamp-tube. Moreover, together with the input capacitance, it does form a low-pass that suppresses unwanted RF (*This is Radio Free Europe ...*). In many cases the noise generated by the grid-resistor will be less than the noise generated by the guitar circuit; the latter may certainly reach voltage-densities of 40 $\text{nV}/\sqrt{\text{Hz}}$ (or even more) in the frequency-range important for the hearing system.

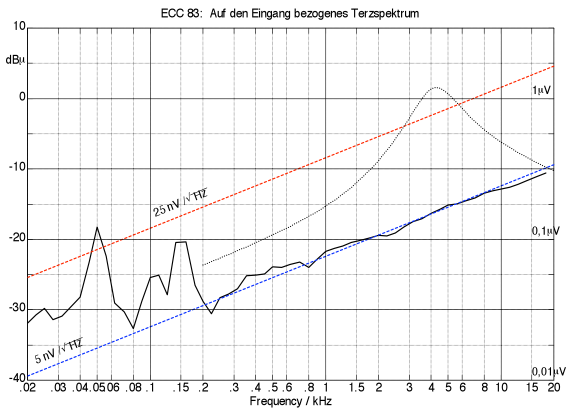


**Fig. 10.1.29**: 1/3rd-octave noise-spectrum (ECC83). The two dashed lines mark the spectrum belonging to white noise; the dotted line shows the typical noise-spectrum generated by a Stratocaster. All spectra are referenced to the tube input.

In **Fig. 10.1.29** we see the measured third-octave spectrum of an ECC83 in comparison to the theoretical characteristics. For the measurement, the grid was shorted to ground and the tube received DC-heating. Hum of around 0,1 µV is typical for simple shielding; this is much less than the interference caught by magnetic pickups. Without the grid-resistor, the tube creates – across the whole frequency-range – less noise than the pickup measured for comparison (Chapter 5.12). Including the grid-resistor, the pickup noise dominates only in the range of the pickup resonance. The third-octave levels measured at the plate are, compared to the levels given in the figure, larger by the gain factor (33,4 dB in our example). The **broadband** input-noise voltage below 20 kHz amounts to about 1 $\mu V_{eff}$ (with shorted grid); this is equivalent to a noise-voltage of about 47 $\mu V_{eff}$ at the plate.

Every guitarist can find out for him/herself which noise-source dominates in a given guitar-amp setting: just compare the noise with shorted input to the noise that occurs with the guitar plugged in and fully turned up. In case both signals are approximately equal in strength, one needs to indeed question the quality of the input tube (or that of the amplifier concept); if there is more noise with the guitar turned up, the interference is caused there. How can we achieve a **short circuit at the input**? The best way is to use a plug with both connecting pins soldered together. Alternatively, a metal potentiometer shaft (6,3 mm) or a similar short-circuit-pin could be plugged into the input jack. Or, very simple: plug in the guitar and turn the volume control (on the guitar) to “0”. Note, however, that this works only if the guitar cable actually reaches the center-tap (middle) connector of the pot (as is the case for Strats or Les Pauls with the customary circuitry). Instruments that have the pots in the so-called “reverse” connection (such as the Fender Jazz Bass) are not suitable for this approach

The second unwanted signal generated in an amplifier is **hum**. It is caused by the power system (230V/50 Hz, or 110V/60, or other voltages/frequencies depending on the country) that contaminates the more sensitive circuit sections via capacitive or inductive coupling♣. Faulty design of the layout of the ground-connection can be a reason, as well – especially in the power-rectifier circuit. In the typical tube amplifier we have relatively strong heating currents (preamps tubes: 0,3 A, power tubes 1 – 2 A) the magnetic fields of which can feed into the sensitive plate circuits. DC-heating would be an option for (the customary) indirectly heated tubes but is implemented rarely. It is not really necessary, either: using twisted wiring for the heating and a correct layout of the (electric) ground, every tube amplifier can be constructed in a sufficiently hum-free way such that – for normal use – the hum caught by the magnetic pickups of the guitar dominates.

**Microphonics** is a term characterizing the tendency of a tube to react to sound (i.e. mechanical vibrations), whether transmitted via air, or structure-borne. Combo-type amps – with loudspeaker and amplifier housed in the same cabinet – are particularly prone to associated problems. The amp may sound as if there is always a bell operating in the background, and at high volumes a howling, uncontrollable feedback may occur. The cause of microphonics is a deformation in the tube-interior, in particular in the (control) grid. The ultra-thin grid wires start to vibrate as sound impacts on the tube, and this in turn modulates the plate-current and generates interfering noises. Every tube is microphonic – but not always to the extent that problems result. Preamp tubes with their very small signal voltages should have especially low microphonics, and tubes specially selected towards this goal are available.

In an orientating **measurement**, a double-triode (12AX7) that generated a clearly ringing tone at 630 Hz when tapped was subjected to sound coming from a loudspeaker. At 130 dB SPL (a sound pressure level easily reached in a combo), an interference voltage of about 1 mV (when referenced back to the input) occurred. A 12AU7 was even considerably worse at 30 mV! Even without fully turning up an amp, such a tube will start to bring some undesirable accompaniment, and feedback whenever the amplification is high. Vibration can get to the tubes not only via air but also via the tube-socket. Consequently it is advisable to consider – at least for the preamp – mounting the respective tubes in sockets using rubber or a similar mechanical absorbent material. The latter should be able to withstand heat while not being prone to embrittlement.

♣ This happens not only at 50/60 Hz but also at the multiple frequencies, i.e. at 100/120 Hz, 150/180 Hz, etc.

 