10.8.5.4 Tube-Screamer (Ibanez)

Whether you want to call the Tube-Screamer a distortion device, an overdrive or a treble-booster is a matter of taste – there is no fixed rule. The unit goes between guitar and amplifier, and it has 3 sections: an impedance converter consisting of a transistor, a distortion section with low-cut, and a tone filter. **Fig. 10.8.34** shows – grouped around an operational amplifier – the distortion-section components. A high-pass at the input takes care of a defined operating point – its cutoff-frequency is so low that it has no impact on the frequency response. The negative feedback circuit of the OP-amp includes the distortion-significant diodes. They have merely a negligible effect at very low signal levels; here, the circuit operates as an amplifier with a high-pass cutoff-frequency of 720 Hz. However, as soon as the voltage across the diodes becomes sufficiently large such that (relative to the potentiometer) a significant forward-current occurs, non-linear distortion starts to manifest itself, and the voltage across the potentiometer is subject to limiting. In fact, the output voltage is composed of two parts (potentiometer-voltage, and voltage across the RC two-pole), the consequence being that a part of the undistorted signal is superimposed on the distorted signal. This is a peculiarity of the Tube Screamer (and many similarly constructed devices on the market): it does not only distort but mixes in a bit of the original signal. An easier-to-interpret equivalent circuit is obtained by referencing the output voltage not to ground but to the input connection, and compensating this via adding the input voltage to the output voltage (lower part of the figure).

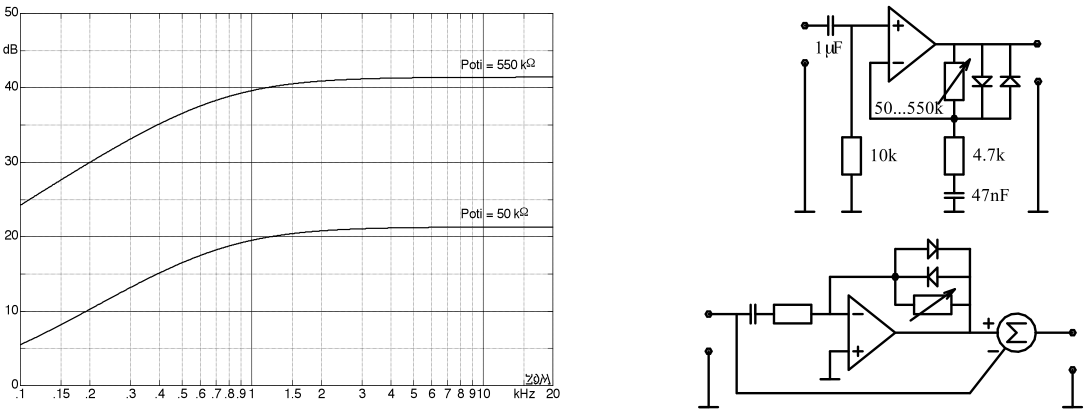

Fig. 10.8.34: Tube-Screamer: small-signal frequency-response and schematic of the distortion section.

Now, the two-part output signal becomes evident: there is the inverted input voltage, plus the (also inverted) high-pass-filtered, amplified and distorted input voltage. Of course, we arrive at the same conclusion using Kirchhoff's loop-rule, and assuming the differential input-voltage of the OP-amp as zero.

The **potentiometer** controls the basic amplification of the distortion branch, but not the amount of the distorted output signal, and not the amount of the undistorted signal, either. The balance between distorted and undistorted output signal is pre-set and cannot be changed without changing the circuit. If, for example, the amount of the distorted signal is to be enlarged, 4 diodes instead of two could be included: two each in series and the two series-circuits in an anti-parallel connection. Using one diode in one direction and two in the other direction creates an asymmetric clipping with a sound that could be considered somewhat fuller and assertive that that of a point-symmetric characteristic. Any preference will be a matter of taste and can – in case of doubt – be changed for very little money. And while we are in the process of changing diodes: a mixture of Ge- and Si-diodes can sound very attractive, and even LED's are deployed these days by Marshall (and everybody else) to achieve distortion.

 Translated into English by Tilmann Zwicker

In **Fig. 10.8.35** we see the time function of the OP-amp output voltages for three different drive-levels. The clearly recognizable phase-shift is not the result of the high-pass at the input but that of the 4.7-kΩ-47-nF-two-pole. The right-hand picture shows a type of distortion that should be avoided at all cost: a piercing-through to the opposite voltage limit. The exact reason (latch-up?) will not be discussed here, but if this happens, another OP-amp-type needs to be brought in. The curves shown here were measured using a TL-072 that – being a FET-OP-amp) apparently is susceptible to such effects. In defense of this actually very good analog IC it should be said that this effect happens only at rather high drive-levels. But if it indeed happens, the sound is so horrible that it probably is usable only as a special effect.

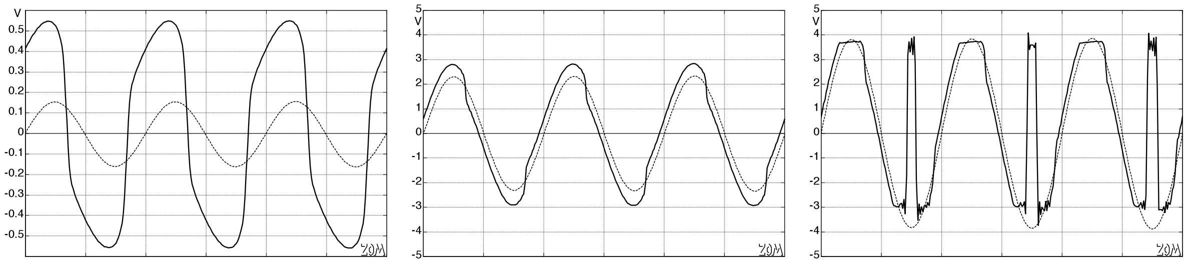

Fig. 10.8.35: Time function for different drive-levels (f = 500 Hz). U_{Batt} = 9V.

In his Gitarre&Bass-article (11/01 – recommended reading!), B.C. Meiser lists several OP-amp types suitable for the operation in the Tube Screamer (e.g. the NE 5532). He also points to the fact that the NJM 4558 is not suitable. A fundamental problem of all pedal-type devices is the requirement that they have to run off small battery-voltages. For the TL-072, the recommended supply voltage is 30 V; in the Tube-Screamer it has to make do with a meager 9 V – and even this only for a fresh battery. The manufacturers do allow for smaller operating voltages, but they do not specify which parameters will then deteriorate. If the specified operating-voltage for the LM1458 is 10…36 V, 9 V is simply too little. The NJM4558 is supposed work from 8 V – but how well will it do the job? In some data sheets we find: use from 12 V. For the Texas RC4558 we read: from 10 V. With regard to the slew-rate, the data given are: for the NJM 4558 = 1V/µs, for the RC 4558 = 0.5 V/µs, and for the MC 4558 = 1.5 V/µs. All these values are specified for 30 V supply voltage and not for 9 V. Trial and error is the only way to find out how well (or how poorly) an OP-amp performs at 9 V; the data sheets give too little information on this. Also, we need to consider that distortion – as it is practiced in the Tube-Screamer – originally was seen as off-limits by the manufacturers. Word has gotten out only rather late that an OP-amp needs to sound good also when overdriven. So: try out some OP-amps – these ICs don't cost a lot.

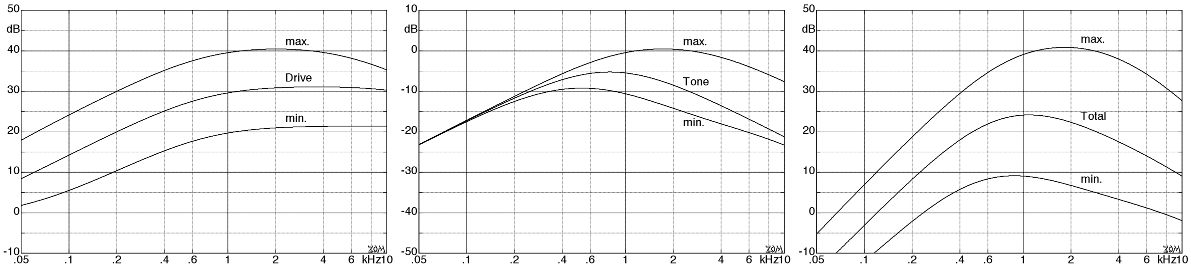

Fig. 10.8.36: Tube-Screamer-frequency responses: distortion unit, sound filter. Overall circuit. The transfer function of the sound filter is easily calculated by Y-delta-transforming the OP-amp input circuit.

