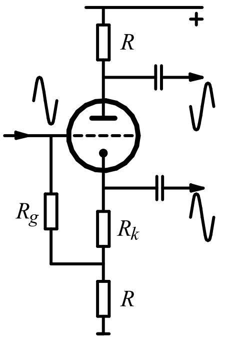
10.4.2 Cathodyne-circuit (split-load)

The cathodyne circuit takes advantage of the opposite-phase-situation of the AC-voltages at cathode- and anode. Assuming a drive situation with a grid-current of zero, the cathode-current is equal to the plate-current, and therefore voltages across equal cathode- and plate-resistors will also be of the exact same amount – irrespective of any tube variances. Textbooks on circuit design tend to explain the cathodyne configuration by separating the plate-resistance into two "exactly" equal halves that then result in the new plate-resistance and cathode-resistance, respectively. It is possible that this approach led to the designers using high-precision resistors in the cathodyne-stage. For example, the schematic for the Ampeg B-42-X specifies: *all resistors 10%* – however, the caption of the 47-kΩ-cathodyne-resistors and the subsequent 100-kΩ-load resistors reads *5%.* There were even amplifiers requiring a resistor-tolerance as low as 2% for this circuit.



$$v_A = -\frac{v_k}{1 + R_k / R} \approx -v_K$$

$$v_K = \left(1 + \frac{2R + R_i + R_k}{(R + R_k) \cdot R_i \cdot S}\right)^{-1} \approx \frac{\mu}{\mu + 3}$$

$$R_E \approx \frac{R_g}{3/\mu + R_k / R}; \qquad R_{iA} \approx R; \qquad R_{iK} \approx \frac{R + R_i}{1 + \mu}$$

Fig. 10.4.5: Cathodyne-circuit. Signals taken directly from the cathode as is typical for Fender.

In **Abb. 10.4.5** we see a guitar-amplifier-typical cathodyne-circuit. In Fender amps, both load resistors (R) normally have a value of 56 kΩ with R_k = 1.5 kΩ and a grid-resistor of 1 MΩ. Several Fender amps received this circuit in 1955 (Deluxe, Super, Pro, Bassman, Twin) but it was only about two years until the arrival of the differential amplifier (more in chapter 10.4.3). The grid-resistor R_g of the circuit in Fig. 10.4.5 is connected to the split cathode-resistor rather than to ground. This negative-feedback arrangement substantially increases the **input impedance** R_E (in the example to about 18 MΩ). It is questionable whether the designer at Fender was aware: the coupling capacitor feeding the grid is, after all, 20 nF, just as customary with 1-MΩ-inputs. The 1-MΩ-resistor is, however, not connected to ground but to an almost equally big coherent AC voltage, and thus the effective input impedance increases (bootstrap). The 10 nF and 18 MΩ component values results in a **high-pass** cutoff-frequency of 0,4 Hz – quite generous for a guitar amplifier. Gibson used, in their GA-19-RVT, a capacitor of merely 500 pF for the cathodyne input capacitor – maybe they knew more?

The **voltage gain** from grid to cathode is about $1 - 3/\mu$, with μ = open-loop gain of the tube. For the ECC83 follows, with good approximation: $v_K = 0.97$. As is typical for Fender, the amount of the plate-AC-voltage is slightly less, about $v_A = -0.945$. The **internal impedances** of both outputs are, however, highly different: at the plate we have (with good approximation) 56 kΩ (negative current-feedback at the cathode), while no more than about 1.2 kΩ are present at the cathode (cathode-follower). Amplifier tubes are often said to present *no load* to the preceding circuits, and if that were always correct, the differences between the internal impedances would be irrelevant. However, grid-currents may flow in the power tubes, and if that is the case, plate- and cathode-voltages in the cathodyne stage start to be different.

 Translated by Tilmann Zwicker

An AC-relevant plate- or cathode-load has different effects on the respective other electrode: a *cathode-loading* would increase the plate-current and thus grid-to-plate gain, while a *plate-loading* would decrease this gain. Both types of loading would however have only little impact on the grid-to-cathode gain (negative feedback). The cathodyne-stage does experience loading by the output tubes. The latter are showing a high input-impedance only as long as the power-tube grid is sufficiently negative relative to the power-tube cathode. At full drive levels, and in particular in a state of overdrive, grid-currents do flow, and the cathodyne stage operates with a non-linear load.

Fig. 10.4.6 shows the time-functions of the plate- and the cathode-voltages for different drive-levels – first without the loading effect the output tubes have. Compared to the paraphase-circuit, the maximum voltages are smaller but the symmetry is better. As we include the loading by the power tubes (6V6, **Fig. 10.4.7**), the shape of the plate-voltage changes due to the grid-current-drain via the cathode – this increases the plate-current and consequently the voltage drop across the plate-resistor. In the cathode-voltage, there is practically no corresponding protrusion because the voltage gain of the cathode-follower is only marginally influenced by the plate-resistance. A typical effect found in tube amplifiers is shown in the last line of the figure: the supply-voltage decreases with increasing overdrive ("sagging"). Therefore, the minimum voltage is not constant but depends on the filter-circuit in the power-supply.

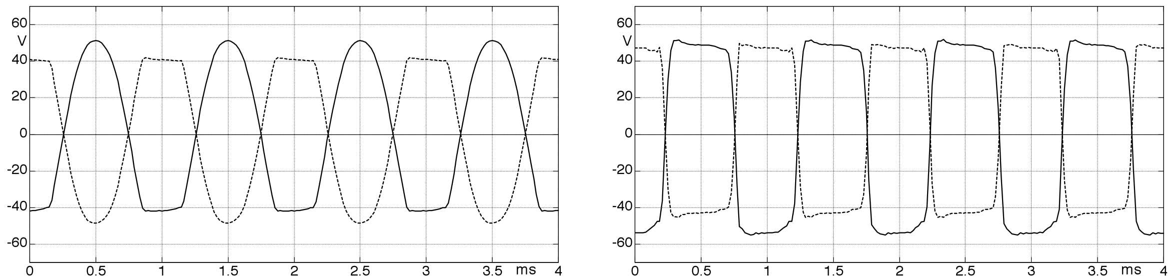


Fig. 10.4.6: Cathodyne-stage without load; AC-component. Plate-voltage (----), cathode-voltage (——).

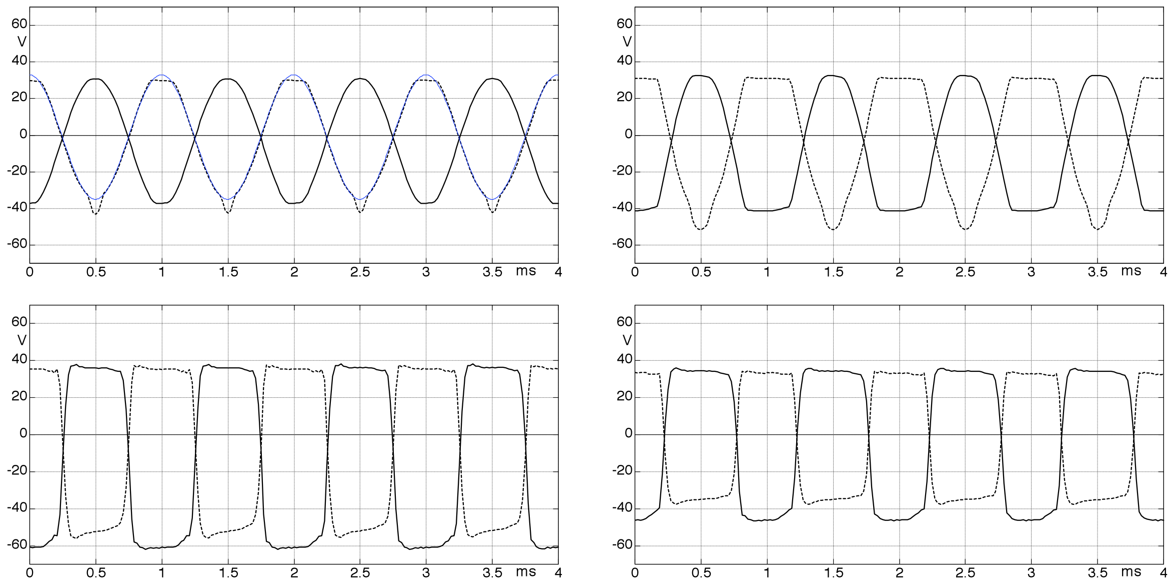


Fig. 10.4.7: Cathodyne-stage with load; AC-component. Plate-voltage (----), cathode-voltage (——).
The bottom right-hand picture shows the situation after longer-term overdrive.

