Bootstrapped KE 4-electret

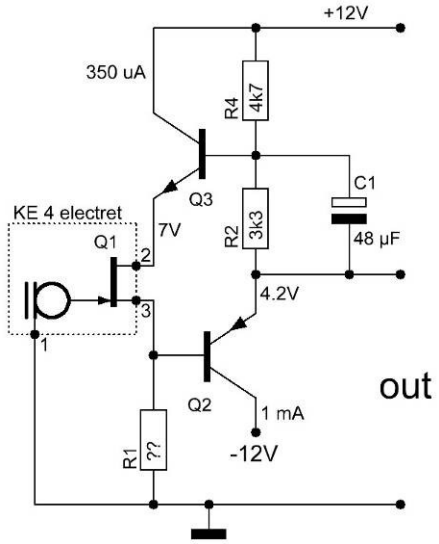
Preface

In the document: ‘Condenser microphone pre-amp with bootstrapped op amp’ on this site, bootstrapping is defended to eliminate non linear parasitic junction capacitances to avoid distortion. This robust solution is rather costly and prolix.

Investigating B&K-microphone systems, I came to a much easier design which could work fine but requires more pre-investigation in case of electrets. In particular the diverge of the parameters of the built-in FET Q1 plays tricks. This circuit will be prepared for two Sennheiser KE 4’s.

Choices of components

The (values of) the parasitic capacitances of Q1 are unknown but become less important because of the bootstrapping. However, the DC between drain and source should be large enough to keep the FET saturated. With the small FET’s used in electret microphones, the knee voltage will vary from 0.2 to 0.8 volt and the saturation current from 50 to 500 µA. The values of the components in the rest of the circuit are determined by these parameters!



Let us assume the current through Q1 is 350 µA, the average I_{DS0} of the two KE 4’s (see: ‘KE 4 van Sennheiser als meetmicrofoon’). Suppose I_c of Q2 is 1 mA.
V_{cb} of Q2 could be 3.5 volt to keep away from its knee voltage.
U_{23}, being the drain-source voltage of Q1, could be 3.5 volt, so that with R2 = 3k3 the current through Q2 should be about 1 mA. With a battery voltage of 12 volt, R4 = 4k7.

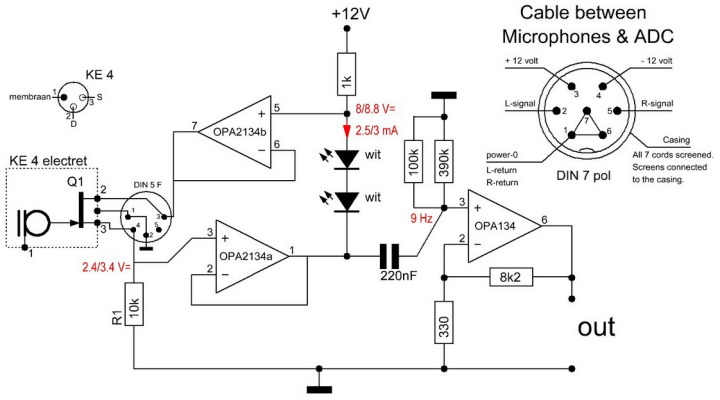
The bootstrap

The source of Q1 ‘follows’ the gate. Q2 is an emitter follower so that the AC output voltage follows the AC gate voltage.
Q3 also acts as an emitter follower so that the drain of Q1 eventually follows its gate. This means that the AC-voltage across the parasitic capacitance across gate and source as that across drain and gate will be kept naught.
The capacitance of C1 must be very large to avoid distortion (Douglas Self) or even better a bipolar type (Peter van de Willenswaard).

Conclusively

This circuit will operate with less distortion than that in the document: ‘Meet-microfoon’ (in Dutch) but it is rather sensitive to the parameters of the built-in FET of the electret. The robust but elaborate design in ‘Condenser microphone pre-amp with bootstrapped op amp’ provides by far the best results but cannot be used with a built-in FET.

More intelligent



With op amps it could become more simple. $V_{DS}=V_{23}$ is defined by two white LEDs. R_1 has to be experimented to get $I_D \approx 300$ uA. Q_1 will be in saturation.
The gain of the OPA134 should be about 25.
The connections of the KE 4 via the cable and two DIN-connectors ends in the die cast box on the female DIN 5 F as shown in the diagram. R1 should be

10 kΩ for I_D = 240/340 µA.
The amplification of the OPA134 should be matched to the acoustic gain of 'the other microphones': the ME6211 (-2.5 dB) on the 90°-box shows the same sensitivity on the recorder display.
C1 and R2 in the diagram with transistors has been replaced by two white LEDs (5.2 V). This means that the feed back from source to drain works from DC to AF. Thanks to the large Early Voltage of Q1 however, no instability will occur.

Distortion with Condenser microphones

The resistor across a condenser microphone capsule (in general) to bias the electronic circuit behind it, determines the distortion at the low audio frequencies! With this design the 'bias resistor' is constituted by the leakage resistor between gate and source of the little FET. (Be aware that the housing of the electret (connection 1) should be connected to ground.)
Depending on the electrets construction and the used FET, this 'bias' resistor could vary from 1 to 10 GΩ.
In Fig.5 of the article 'Electrically Manifested Distortion of Condenser Microphones in Audio Circuits' AES Vol.48 no 6 2000 June, of Holger Pastillé the distortion is shown at 140 dB!

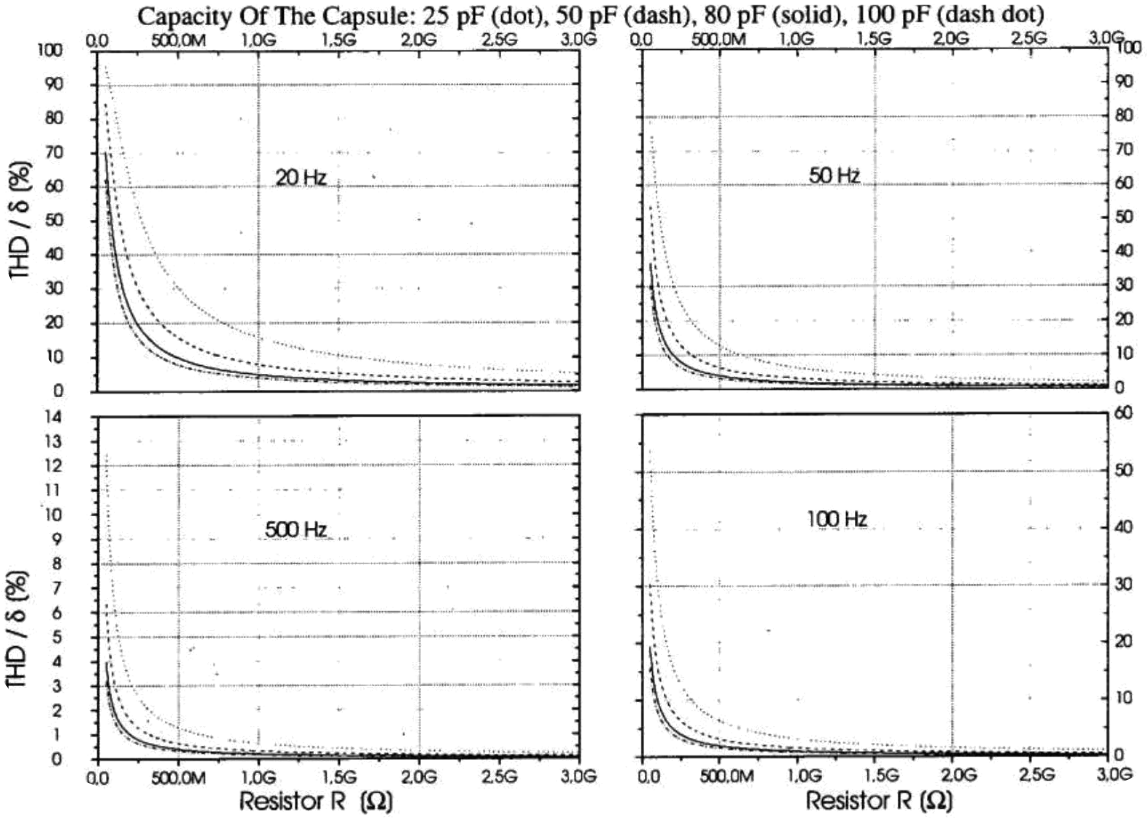


Fig. 5. Normalized nonlinearity versus resistance for four frequencies.

6 CONCLUDING REMARKS

It has been shown analytically that modern studio microphones with an input resistance of 3 GΩ and a small capsule capacitance have less than 0.5% electrically manifested distortion at even the highest sound pressure levels found in studios. For the reasons given (the acoustical-mechanical distortions of the capsule color the result), verification by measurement is not possible. All other sources of distortions ("clipping" and acoustical-mechanical behavior) produce higher distortions.

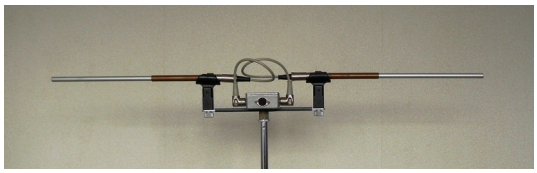
The low resistance of a traditional tube circuit design (in the area of 100 MΩ) can create distortions. If a natural recording is desired, it is suggested that for levels higher than speech or moderate music, microphones with a FET or a modern tube circuit design be used rather than a traditional vacuum tube circuit. Measuring microphones with a non-tube amplifier (input resistance approximately 20 GΩ) are practically free from electrically manifested distortions, that is, in the worst case the THD of a ½-in (12.7-mm) microphone at 10 Hz is less than 0.003%.

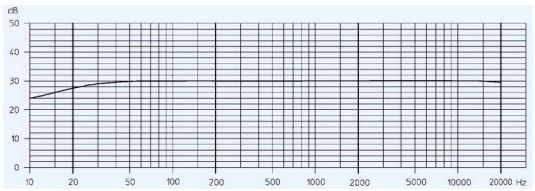
It should, of course, be remembered that the electrically manifested distortions are only one contribution to the nonlinearities of a microphone. Other causes, such as mechanical properties of the membrane, air damping, and the stiffness of the cavity, are of greater influence.

Applications

The circuit produces some subsone noise that passed the 390kΩ/220nF to the OPA134 too mutch. Enlarging the low cutoff to 9 Hz enhances the performance.
If the gain of the OPA134 will match with the recording practise will be seen later. Shouting into the microphones does not show distortion on the oscilloscope so there will be enough head-room!
With the recording of the PSO in Best at 4-22 ’23 the sensitivity of the microphones has been showed some 3 dB too large. 15 kΩ in paralel to the 8k2 in the feedback of the last op amp will be a solution.

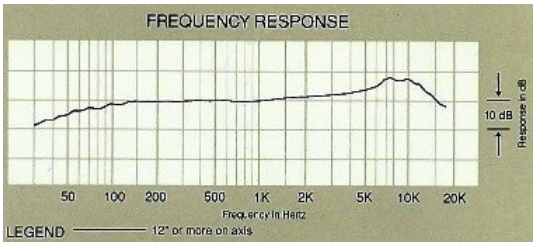
The two KE-4’s are mounted at an angle of 180° as in the photograph below:



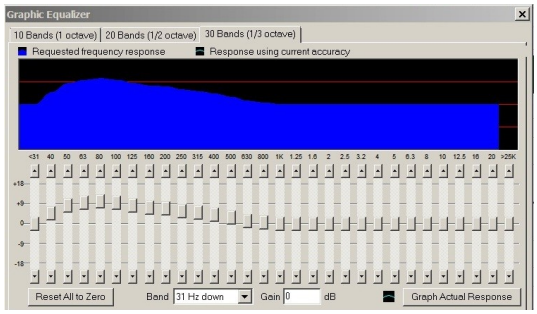


The distance between the mouths of the microphones is 83 cm.

Compaired with the 37R11’s (mounted at an angle of 90°) with 16 cm extensions:



The 37R11’s have been corrected in Adobe Edition with:



Perhaps a bit too much.

The distance between the mouths of the microphones is 47 cm.

Listening to the recordings of DISK178 and DISK177, respectively a part of Prokofjev and Kabalevsky. The differences between the two recordings is small! It took me several listening sessions before I could decide which recording is the best. Eventually listening with head-phones brought the decision:
The Kabalevsky-recording with the 37R11 cardoid’s let the instruments in the sound stage be heard more precisely and wider than the KE-4 omni’s. The KE-4 omnidirectional microphones however give a more spatial sound in a natural less wide sound stage with the instruments placed in a cloud of air. This sounds more as in reality, but the differences are small!

4-29-2023