High-gain Audio Voltage Amplifier

*by D. Leblebici**

One of the commonly used feedback amplifier circuits is the 'feedback pair', where feedback is applied from the collector of the second transistor to the emitter of the first transistor (Fig. 1(a), ref. 1).

The feedback circuit described here is a modified form of the conventional feedback pair (Fig. 1b). Feedback is the series voltage type applied from the emitter of Tr_3 to the emitter of Tr_1. The circuit has some advantages as compared to the conventional feedback pair:

- The output as well as the input terminals of the circuit are outside the feedback loop and consequently the amount of feedback is independent of the source and load impedances.
- The input and output signals are in phase opposition and as a consequence it is possible to apply a second feedback loop (parallel voltage feedback) from the collector of Tr_3 to the base of Tr_1.

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[1]National Bureau of Standards, preferred circuit no. 201.

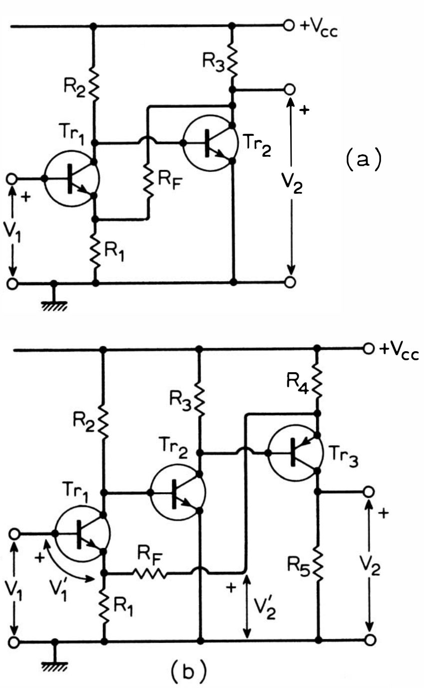

Fig. 1. Common form of feedback pair (a), and modified form (b). One advantage of the modified form is that feedback is independent of load impedance.

- The feedback voltage is taken from the emitter of Tr_3. The negative feedback acts to decrease the distortion of the voltage wave at that point. The relation between the output voltage V_2 of the amplifier and the voltage V_2' fed back can be written as

$$\frac{V_2}{V_2'} \approx \frac{R_5}{R_4}\frac{I_{e3}}{I_{e3}}$$

provided that $R \gg R_4$. For a high-gain transistor I_{c3}/I_{e3} is very close to unity. Hence

$$\frac{V_2}{V_2'} \approx \frac{R_5}{R_4}$$

This shows there is an additional and practically linear (low distortion) voltage gain of magnitude R_5/R_4 from the emitter to the collector Tr_3.

As the voltage gain from the collector of Tr_2 to the emitter of Tr_3 is approximately equal to unity, the voltage gain from the input terminal to the emitter of Tr_3 must be equal to the gain of a conventional feedback pair using the same transistors Tr_1 and Tr_2 and the same circuit components R_1, R_2, R_3 and R_F. As this gain is approximately equal to $(R_F+R_1)/R_1$ (ref. 2), the total voltage gain becomes

$$A_v = \frac{V_2}{V_1} \approx \frac{R_F+R_1}{R_1}\cdot\frac{R_5}{R_4}$$

The only drawback of the circuit is its relatively high output resistance, which is approximately equal to R_5.

Experimental circuit

The experimental circuit diagram is shown in Fig. 2. The stages are directly coupled. To stabilize the quiescent points a d.c. feedback across the first two transistors is used. A collector current of about 200 μA is chosen for Tr_1 this being the optimum collector current of transistor BC109 for minimum noise. The transistor operating points and component values have been calculated for a sufficiently high open-loop gain and as high a dynamic range as possible.

The calculated open loop gain V_2'/V_1' is 11600, a value that is sufficiently high. The additional gain provided by Tr_3 is about 10.

[2]Millmar & Holkias, 'Electronic devices and circuits', pp. 502, 3.

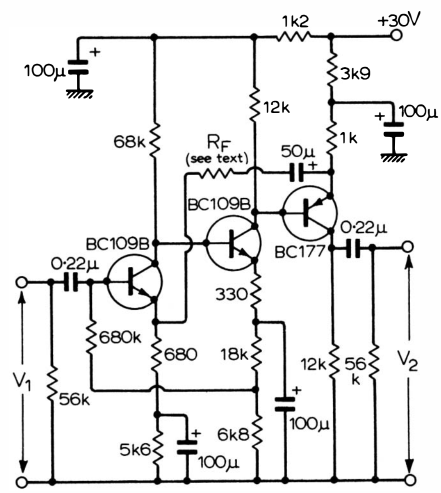

Fig. 2. Practical circuit of preamplifier with voltage gain of 100 for R_F = 5·6 kΩ or 1000 for R_F = 78 kΩ. Total harmonic distortion is 0·02% and 0·04% respectively.

The measured overall voltage gain for R_F = 5·6 kΩ was A_v = 100 (calculated value: A_v = 92) and the available maximum output swing was 18 V pk−pk (6·4 V r.m.s.). For an output voltage of 5 V r.m.s. the total measured harmonic distortion was 0·02%. For R_F = 78 kΩ the measured A_v was 1000 (calculated value: A_v = 1150). The maximum output voltage was again 18 V pk−pk and the total harmonic distortion was 0·04% (V_2 = 5 V r.m.s.). The measured lower and upper cut-off frequencies for both cases were 17 Hz and 200 kHz.

Consequently, the circuit is very convenient as a high-gain audio preamplifier. The possibility of applying a second, independent, parallel voltage feedback loop makes it possible to use the circuit as a low output impedance, moderate gain and high dynamic range booster amplifier. With frequency dependent feedback, it is also possible to use the circuit as a low distortion equalizer amplifier.