

approximation to the ideal linear shape for values of  $k$  above about 0.2. (The ideal curve would not, of course, remain linear down to  $k=0$ , for this would make it impossible to fade a programme down to zero volume. For most audio purposes, the ideal characteristic would cover about 40dB linearly, curving down to "minus infinity dB" below about  $k=0.2$ .)

Another circuit combining feedback and passive gain variation by means of a single linear pot. is shown in Fig. 14.

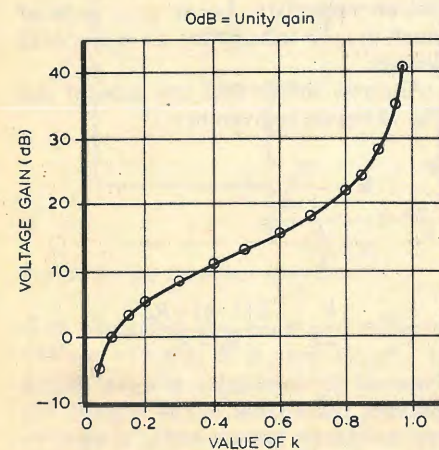


Fig. 13. Curve of circuit in Fig. 12.

This, in essence, is the circuit used by the BBC in their OBA9 outside broadcast amplifier, published in 1952. The gain is given by:-

$$\frac{V_{out}}{V_{in}} = \frac{kR + R_a}{R_a} \times \frac{R_b}{(1-k)R + R_b} \quad 3.$$

$$\text{or } \frac{V_{out}}{V_{in}} = \frac{1 + kR/R_a}{1 + (1-k)R/R_b} \quad 4.$$

The Fig. 14 circuit cannot give zero voltage gain, the gain with  $k=0$  and

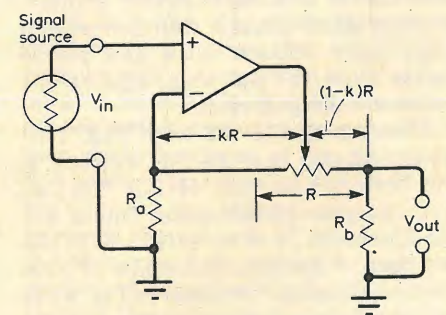


Fig. 14. Circuit providing feedback and passive control in one pot.

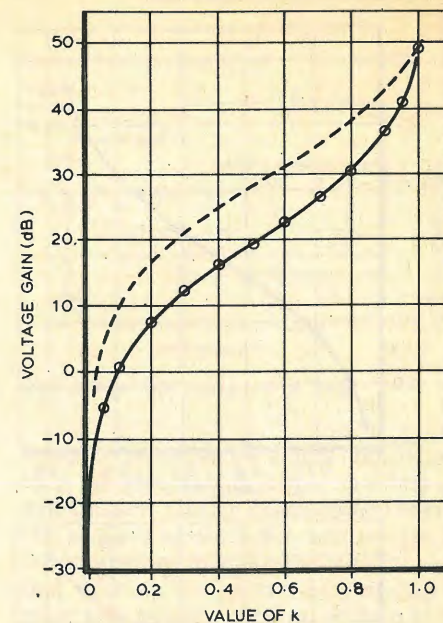
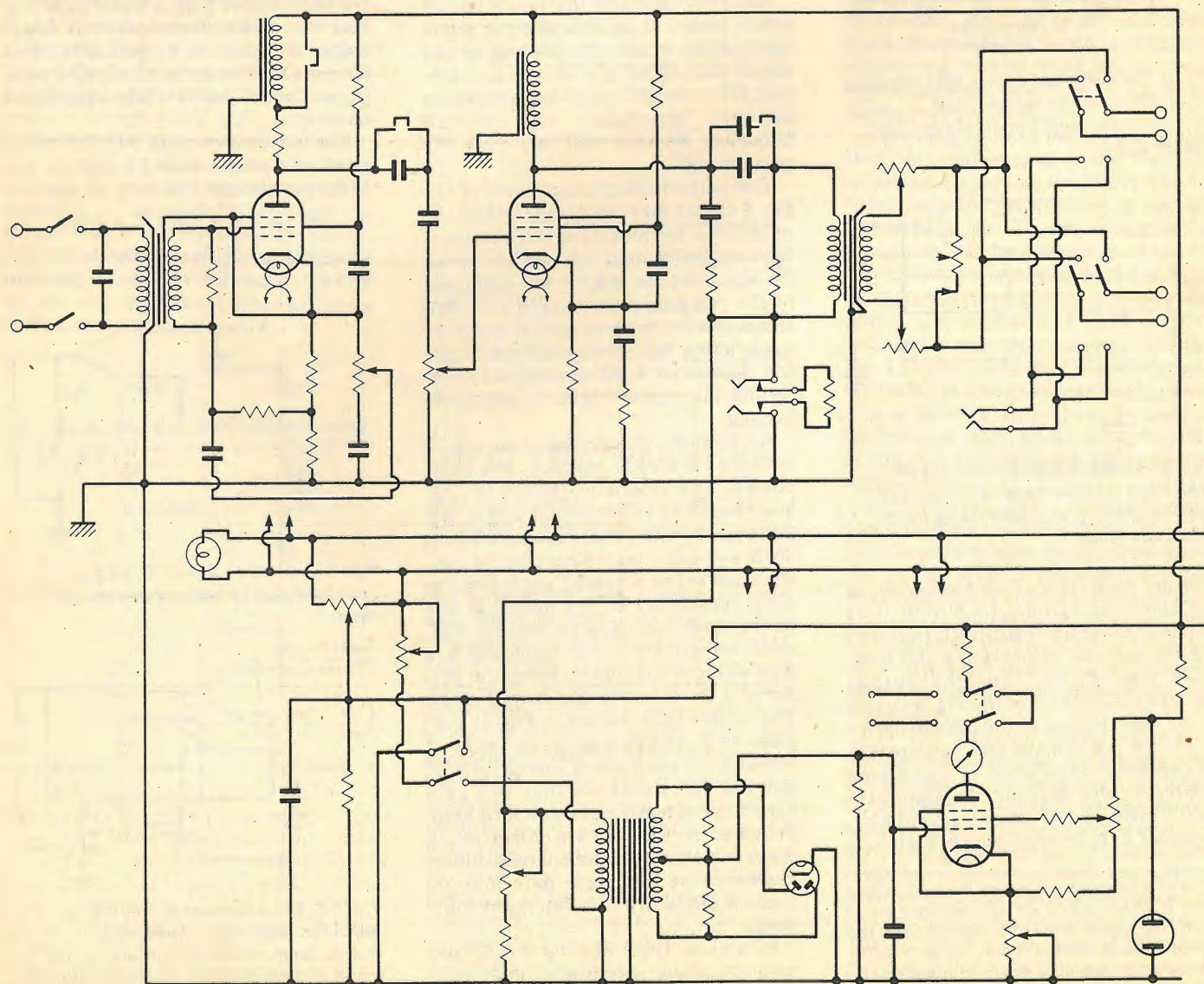


Fig. 15. Full-line curve shows calculated performance of Fig. 14 for two values of  $R_b$ .

Fig. 16. BBC OBA8 circuit of 1939, with peak programme meter.



100% negative feedback being  $R_b/(R + R_b)$ . Though not an ideal feature, the minimum gain in the BBC design is nearly 90dB below the maximum gain, and is stated to be "effectively nil in normal conditions of use".

The full-line curve in Fig. 15 is a calculated result for the Fig. 14 circuit, using the values  $R=100k\Omega$ ,  $R_a=330\Omega$  and  $R_b=3.3k\Omega$ . For the broken-line curve,  $R_b$  was changed to  $10k\Omega$ . (The values in the BBC design were  $R=1M\Omega$ ,  $R_a=390\Omega$  and  $R_b=100k\Omega$ .)

Figure 15 shows that with an ordinary, linear  $100k\Omega$  pot. in the Fig. 14 circuit, a control law not departing by more than 2dB from the ideal linear decibel scaling is obtained over an approximately 40dB range. In the BBC design<sup>2</sup>, a stud type of  $1M\Omega$  pot. was used, giving 38 steps of 2dB each and two larger steps at the low-gain end. Of course, if the luxury of stud pots. is allowed, any of the circuits here discussed may be given whatever control law is desired.

Though there is much to be said on grounds of economy, especially in stereo systems, for using a single pot. section to vary the feedback and effect passive attenuation, the use of ganged stud type pots. to perform these operations separately gives the designer greater freedom of choice in optimizing the design in all its aspects. This technique was used in the BBC OBA8 outside broadcast amplifier, designed well over forty years ago<sup>1</sup>. Starting at the maximum-gain setting, anticlockwise rotation of the knob first simply applied increasing negative feedback to the first stage, by raising the effective value of the feedback resistance in the cathode circuit. When this purely local feedback had been increased sufficiently to give a gain reduction of 16dB, further rotation of the knob maintained this first-stage feedback constant but proceeded to insert increasing passive attenuation between the first stage and the second (output) stage. In this way the two-valve amplifier was made capable of delivering full output level to line, at low distortion (about 1%) for peak microphone input levels extending over a range of 56dB. (It is evident that the designers of this amplifier and the associated units gave high priority to keeping the number of valves used down to the absolute minimum necessary number. This is understandable enough, bearing in mind that the AC/SP3 television pentodes used were physically large and consumed four watts of heater power each. Now that high-gain devices are very small and cheap, and consume relatively tiny amounts of power, the designers of today are justified in adopting a very different outlook, often exploiting the plentifulness of gain to eliminate, or reduce the size of, transformers and also to achieve lower distortion levels in equipment of very much smaller size. Now that it has become fairly easy and cheap to obtain very low distortion

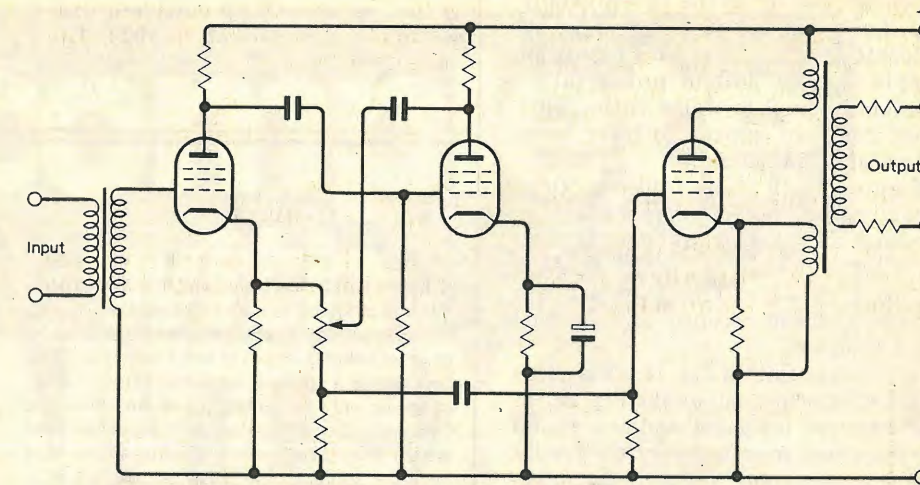


Fig. 17. BBC OBA9 circuit, designed in 1952.

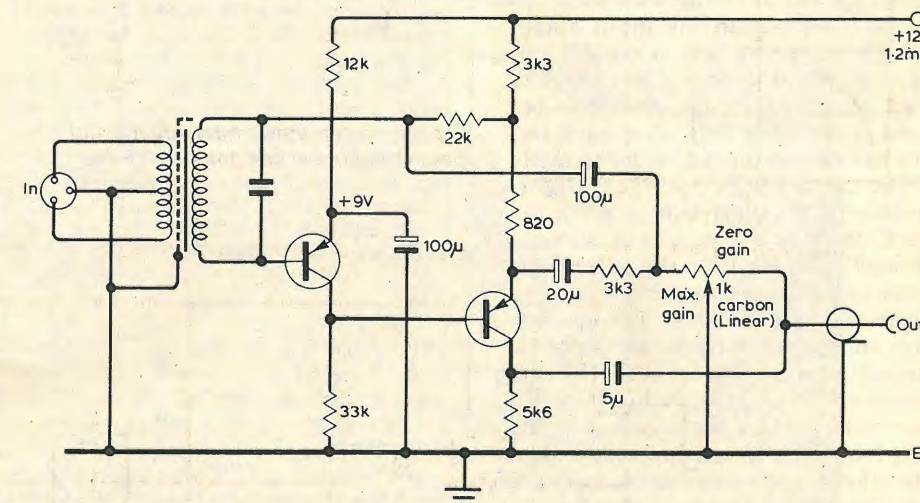


Fig. 18. Author's design of 1961.

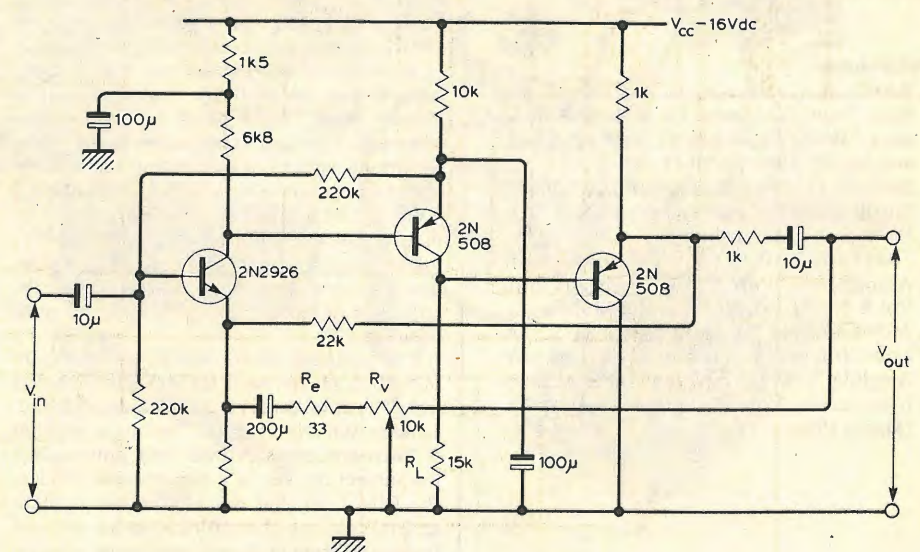


Fig. 19. Circuit by McWhorter of 1966.

levels, there is little argument for doing otherwise, whereas when the OBA8 was designed, lower distortion would have meant more valves, higher power consumption and shorter operating time on standby batteries. The designers were therefore justified in making the distortion just comfortably low enough, but no less, though they were doubtless

quite capable at that time of achieving much lower distortion levels had this been thought desirable. In most circumstances of use, it is doubtful whether the subjective quality of the OBA8 could be distinguished from that of the best modern equipment. The weakest feature of the design is that the secondary of the input transformer,