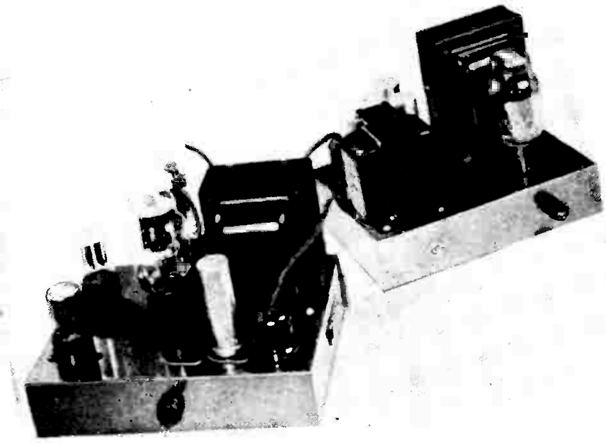

Left: Modified Williamson amplifier, featuring ultra-linear design, and power supply. (Courtesy Stancor)

An Analysis of the WILLIAMSON AMPLIFIER

by MARK VINO

AN INCREASING NUMBER of commercial audio amplifiers featuring the *Williamson* design are appearing on the market. In common with all other electronic devices these amplifiers, rugged though they may be, will require repair, and Service Men should be familiar with their circuitry.

The Williamson boom started when D. T. N. Williamson described his amplifier in the Spring of '47 in a British publication.[1] This unit, a *fixed basic gain model,* was rated at 15 watts output, and was intended to serve only as the high-level section of an audio amplifying system; that is, preamp and tone-control sections were not included. Signal input for the full 15 watts output had to be about 2 volts. Subsequent articles by Williamson described circuits for preamp and control sections; but the tag *Williamson circuit* is in general meant to refer to the original fixed gain amplifier.

The Williamson amplifier contains nothing revolutionary or tricky; it is a well-engineered, conservative circuit that takes full advantage of the progress of the audio art. It is especially suited to large-scale production because the conservatism of its design makes its quality least susceptible to the differences between laboratory and production line construction.

[1]Wireless World.

Basic Circuit Design

Williamson's original circuit, naturally, used British tubes: KT66s, L63s, and a U52 rectifier. The main differing feature, however, between British and American tubes is the physical shape, and our tubes can be, and usually are substituted in this country for the British types, with suitable changes in bias resistor values where necessary. The identifying characteristic of a Williamson amplifier is the basic circuit design illustrated in block form in Fig. 1.

A pair of push-pull output triodes form the output stage; Williamson used triode-connected pentodes. These output tubes are driven by a pair of medium mu push-pull triode voltage amplifiers, which in turn are fed by a cathode-loaded phase-splitter. The input voltage amplifier is directly coupled to the phase-splitter, eliminating the low-frequency phase shift introduced by coupling capacitors, and about 20 db of feedback is taken from the voice-coil winding, back over the entire amplifier to the cathode of the first stage. The application of this block layout to the actual circuit is shown in Fig. 2.

Although the original Williamson circuit uses pentode output tubes, the screen grids are tied to the plates, and the tubes function as triodes. The plates and screens are connected through 100-ohm stopping resistors rather than directly, but this has no significant effect on the triode characteristics.

Output Stage Characteristics

Because the output stage is operated in class *A* and not *AB,* and because the push-pull signal currents are well balanced, the common cathode resistor for the output stage bias is left unbypassed. This helps to maintain dynamic balance, and will not introduce current feedback so long as the signal voltages across the common resistor are exactly equal and out of phase. Some amplifiers, designed on the Williamson model, however, have reintroduced a cathode bypass capacitor, usually with a value of 100 mfd or so.

The potentiometer in the output stage cathode circuit of Fig. 2 varies the relative bias on each tube, so that the flow of *dc* current through each can be equalized. The simplest method of determining the correct setting is to adjust the potentiometer for zero *dc* voltage between the two output plates. Some Williamson type amplifiers eliminate this potentiometer.

In recent years a further modification of the original design of the Williamson output stage has been introduced: the so-called ultra-linear connection. In this design configuration the output tubes are operated neither as pentodes nor as triodes, but

Original Circuit's Basic Design Features . . . Characteristics of Output and Driver Stages, Phase Splitter, and the Feedback Circuit . . . Installation and Maintenance Notes

as a compromise between the two. For pentode operation the screen grids must be connected to the center tap of the output transformer; for triode operation the screen grids are connected to the top or plate end of the output transformer. For ultra-linear operation the screen grid is connected to a tap on the output transformer primary winding, in-between the two extremes, as shown in Fig. 3 (p. 61).

This connection divides the load between the screen grid and plate and introduces negative feedback to the screen, permitting more power output at the same distortion, or lower distortion at the same power output. Commenting on this design change recently in an article, with the somewhat ironic title *Amplifiers and Superlatives,* Williamson pointed out that once an amplifier has, by one design or another, achieved the performance characteristics of the original circuit (less than .1% distortion at 15 watts, frequency response over the audio range uniform within .2 db, noise level 80 db below the signal output, very high damping factor, etc.), it will sound exactly like every other amplifier that has achieved or surpassed these standards. The only way such an amplifier can be improved upon is to lower the cost, size or weight without sacrificing quality. Thus the real contribution of the ultra-linear circuit was not to make the original Williamson circuit sound better, but to open the way for less expensive *Williamsons* or other *hi-fi* amplifiers. The use of the ultra-linear connection in an amplifier that has not followed the original Williamson specifications should, of course, make an audible difference.

The Driver Stage

The phase-splitter in the Williamson does not feed the output tubes directly but through a pair of push-pull drivers. These, having a common unbypassed cathode resistor, help to correct any imbalance that may be present due to imperfect operation of the phase-splitter. The benefits of push-pull operation in reducing even harmonic distortion are applied to the driver stage, which of all the voltage amplifiers must handle the highest signal voltages, and is thus most subject to harmonic distortion.

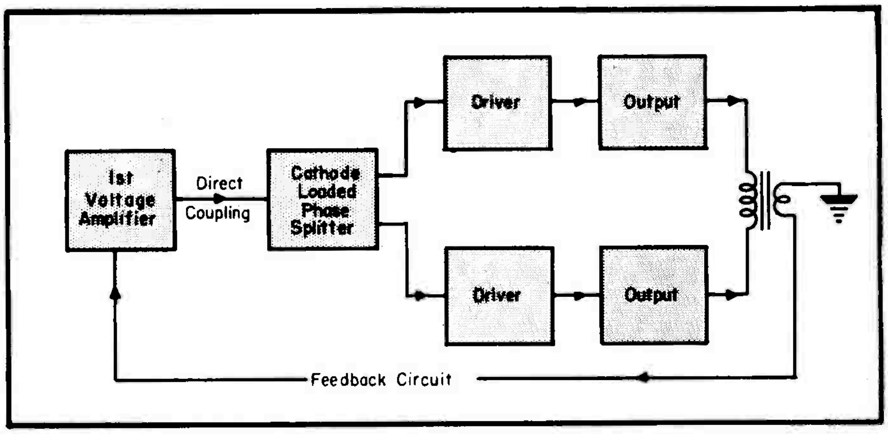

Fig. 1. Block diagram of Williamson amplifier circuit design.

The potentiometer between the plate resistors of the push-pull drivers serves to adjust signal balance. A method for making this adjustment with a pair of earphones has been outlined by Williamson and was described in a previous issue of SERVICE.[1] Some Williamson amplifier circuits, including one modified by Williamson himself, eliminate this potentiometer and connect the junction between the two plate resistors directly to *B*+, as shown in Fig. 4 (p. 61). The self-balancing characteristics inherent in the circuit, plus the stabilizing effect of the large amount of negative feedback, are relied upon for proper balance.

The Phase-Splitter

The phase-splitter is one of the distinguishing features of the Williamson circuit. The first voltage amplifier and phase-splitter are designed together, and the circuit combines cathode loading with direct coupling from plate to grid. The high *dc* positive voltage applied to the phase-splitter grid by the previous plate is counterbalanced by a slightly higher negative bias voltage derived from the large cathode resistor, and the resultant bias on the grid is about 5 volts negative. The bias voltage between grid and cathode can be measured with a *vtvm.*

Phase-Splitter Matching

Williamson has used direct coupling to reduce the low-frequency phase shift within the feedback loop. Such phase shift limits the amount of feedback that can be used without low-frequency peaking or oscillation in the form of motorboating.

The balance between the plate and cathode resistors of the phase-splitter determines the signal balance of this stage's output. Therefore, when replacing either of these resistors, a high quality unit, whose value is matched to its mate *with an ohmmeter,* must be used. All of the paired plate and grid resistors following the phase-splitter are preferably matched in this way, but matching is especially important in the case of the components of the phase-splitter itself.

Negative-voltage feedback is taken from the voice-coil to the input stage

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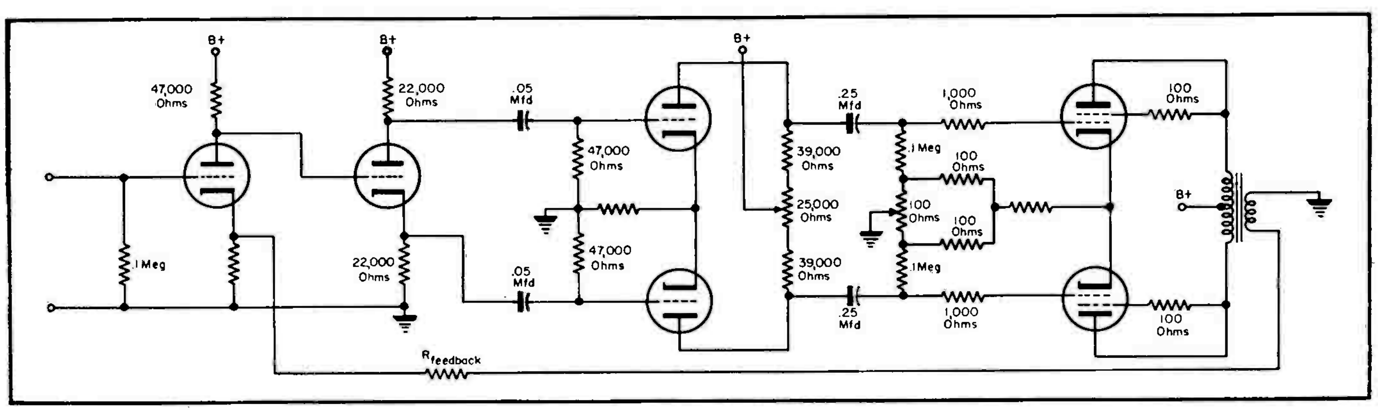
Fig. 2. Simplified schematic of Williamson amplifier, showing some of the values used in the original circuit. Bias resistor values are determined by the tubes used.



Williamson Amplifier

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cathode, as illustrated in Fig. 5. Twenty db or more of feedback is applied; therefore the voltage gain of the amplifier is reduced at least 90%. If the polarity of the feedback leads is reversed, the amplifier will oscillate instead of suffering a reduction of gain; this means that the wrong side of the voice coil has been grounded. The large amount of feedback can only be used in conjunction with a high quality output tranformer, and when a compromise is made in the choice of the output transformer the amount of feedback may have to be reduced by increasing the value of the feedback resistor, R_3.

Another possible source of phase shift within the feedback loop is insufficient capacitance for the coupling capacitors. If the latter are replaced, substitute values cannot be chosen at random from the shelf. The replace-

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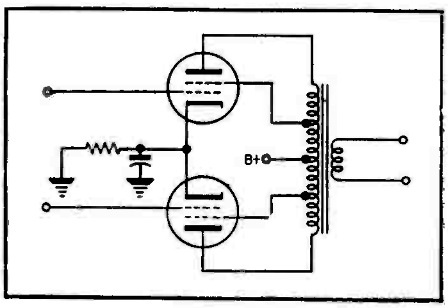


Fig. 3. Ultra-linear output circuit, in which the screen grids are connected to neither the center-tap nor plate end of the output transformer, but to a point intermediate between the two. The output tubes operate with characteristics which are in-between those of triodes and those of pentodes.

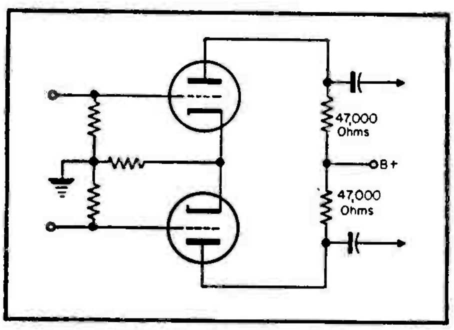
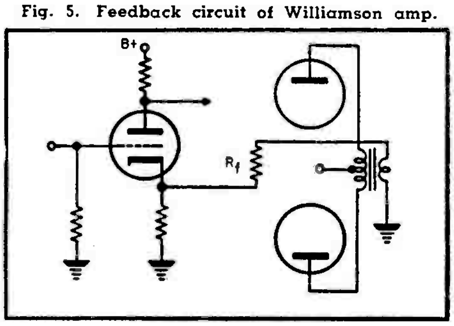
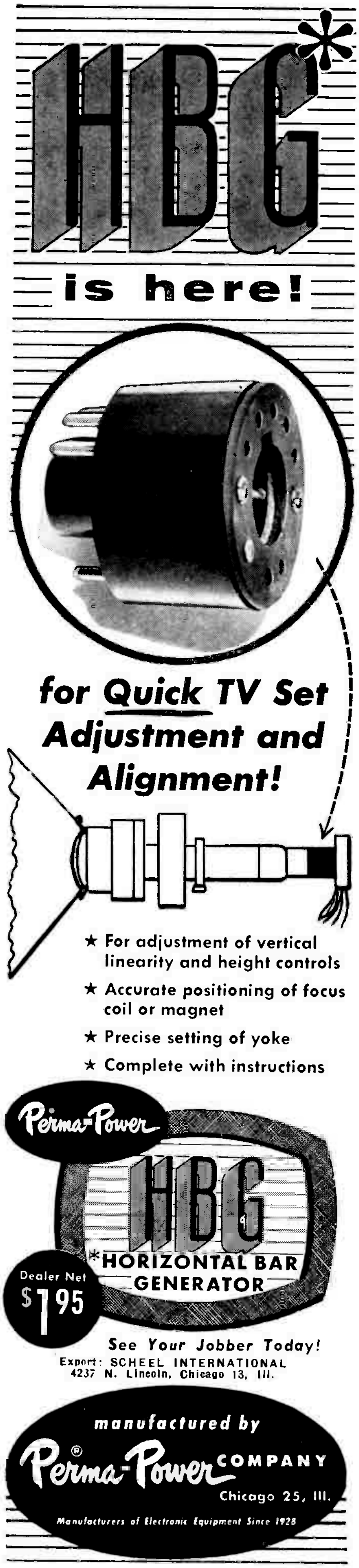


Fig. 4. Driver circuit, with potentiometer of Fig. 2 eliminated.

Fig. 5. Feedback circuit of Williamson amp.





Williamson Amplifier

(*Continued from page* 61)

ment must have as high a capacitance as the original, because insufficient capacitance may introduce motor-boating.

The Power Supply

The Williamson power supply is conventional, and in the original uses two chokes, one high current unit for the output stage, and one low current unit for the voltage amplifiers. The $B+$ voltage of the original amplifier, with KT66 output tubes, is 450.

Performance

The complete amplifier should perform so well that it does not influence the character of the reproduced sound to any audible degree. The quality of the system should be entirely dependent upon the associated loudspeaker pickup, and other components.

There is no special characteristic of this amplifier that requires special matching characteristics of the components with which it works; a good speaker system connected to the correct impedance voice-coil terminals, and a good preamp and control amplifier with standard high-impedance or cathode-follower output, is all that is required. There is often a certain advantage to having the high-level power amplifier as a separate fixed gain unit; the heavy chassis can be mounted on the cabinet floor, away from the control panel.

[1]Vino, Mark. *The Maintenance of Hi-Fi Audio Systems*, SERVICE; Oct., 1953.

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AD CAMPAIGN REVIEW

At an ad-campaign session in office of Ray L. Triplett, prexy of Triplett Electrical Instrument Co., where new program for '54 was discussed. Kneeling, left to right: Burton Browne, head of agency handling account; Lynn C. Wimmer, BBA public relations department; Cleon Triplett, manager of plant 2; Norman A. Triplett, sales manager; Ray L. Triplett, and (back to camera) Robert E. Abbott, BBA creative chief. Standing, left to right: Arden R. Baker, Triplett ad manager; James P. Cody, assistant to Browne; W. Ropp Triplett, vice president and assistant to president and M. Morris Triplett, chief engineer.

"Oh, boy! JENSEN NEEDLES"