Oct. 24, 1944. W. E. GILBERT 2,361,282

PUSH-PULL ELECTRON TUBE SYSTEM

Filed Nov. 13, 1941

Fig. 1.

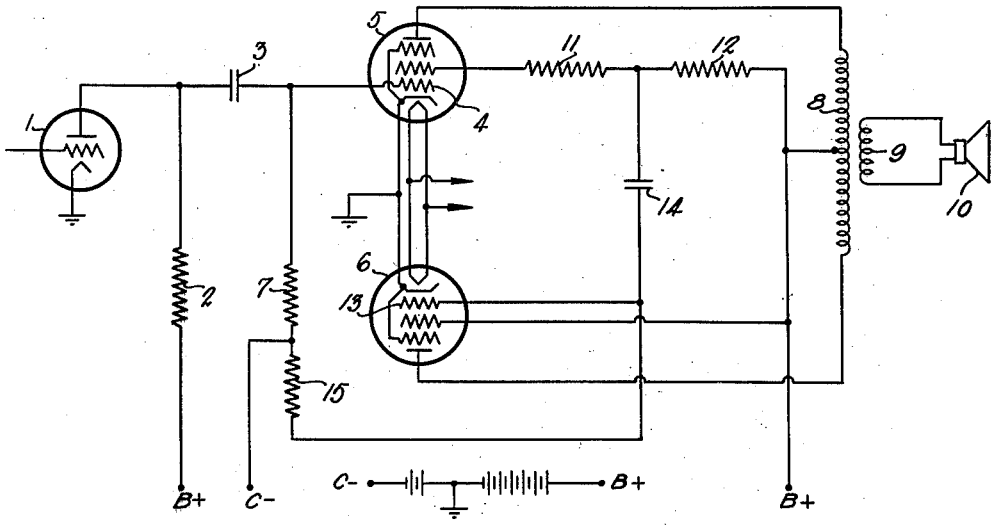
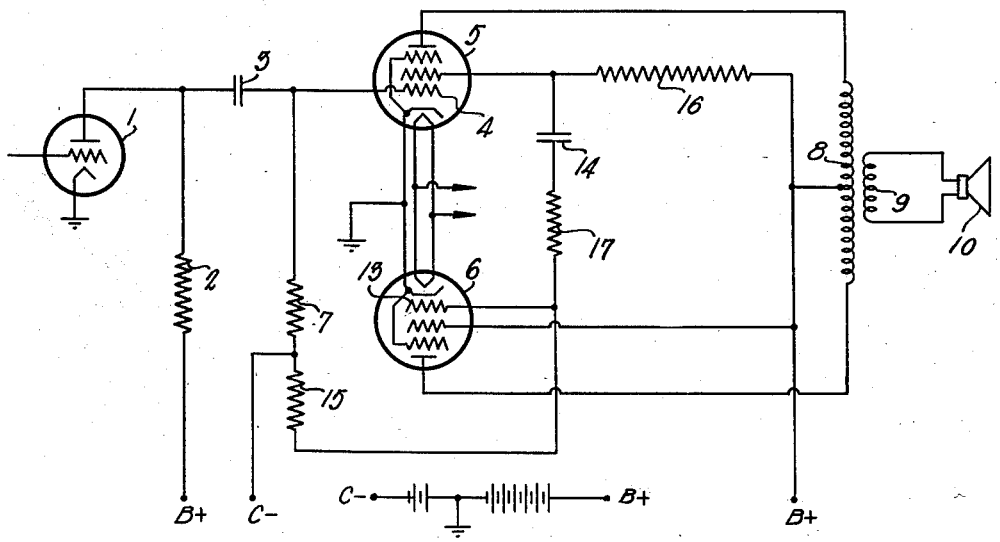



Fig. 2.




Inventor:
Walter E. Gilbert
by his Attorneys
Howson & Howson
ATTYS.

Patented Oct. 24, 1944 2,361,282

# UNITED STATES PATENT OFFICE

2,361,282

## PUSH-PULL ELECTRON TUBE SYSTEM

Walter E. Gilbert, Philadelphia, Pa., assignor to Philco Radio and Television Corporation, Philadelphia, Pa., a corporation of Delaware

Application November 13, 1941, Serial No. 418,987

6 Claims. (Cl. 179—171)

This invention relates to an improved phase-inverter circuit for coupling a single-tube driver stage to a push-pull amplifier without the use of an input transformer or an additional phase-inverter tube.

In general, there are two methods of coupling a single amplifier tube with push-pull tubes, first, by means of a transformer having a center-tapped secondary winding, and second, by means of an electronic phase-inverter circuit. The first class of circuit requires the use of a transformer which, if its frequency characteristic is to be good, is an expensive piece of apparatus. As is known in the art, the second class of circuit ordinarily uses a separate phase-inverter tube, the output of the single-tube driver stage being fed directly to the grid of one of the push-pull tubes and to the grid of the other of the push-pull tubes through the phase-inverter tube. In this circuit there is substantially no gain in the inverter tube circuit, the signals applied to the grids of the push-pull tubes are substantially equal and opposite in phase, and the same phase relations are obtained as though a transformer were used. An additional tube is, therefore, introduced without resulting benefits in gain.

An improvement in inverter circuits which requires no input transformer or additional inverter tube, but in which the exciting voltage for the second push-pull tube is obtained from a screen grid of the first push-pull tube, is described fully in U. S. Patent No. 2,109,021 to E. L. Clark, issued February 22, 1938. The present invention is an improvement on the circuit therein described, and is intended to produce an even more efficient system of driving push-pull tubes.

One object of the invention, therefore, is to couple a single-tube amplifier stage with a push-pull amplifier stage without the use of a transformer or phase-inverter tube.

Another object of the invention is to balance the output of the push-pull tubes by applying voltages to their grids which are substantially equal in magnitude.

Still another object of the invention is to prevent screen current saturation of one of the push-pull tubes at the positive end of its swing.

A further object of the invention is to obtain a greater useful output from the amplifier circuit without increasing the distortion, and to obtain greater output at the same values of distortion.

Other objects of the invention will be apparent from the following description and the accompanying drawing, in which:

Fig. 1 is a diagrammatic illustration of an amplifier circuit embodying the invention; and

Fig. 2 illustrates a modified form of the invention.

Referring specifically to Fig. 1, there is shown a single driver tube 1 which may be a voltage amplifier of any suitable type, such as a triode, as illustrated, or a pentode. The anode of tube 1 is connected through a suitable resistor 2 to a source of anode supply voltage. The condenser 3 serves to couple the anode of the tube 1 to the control grid 4 of the first of the push-pull output tubes 5 and 6. The grid 4 may be connected to a source of bias voltage through a suitable high resistance 7. The anodes of the push-pull output tubes may be connected in the usual manner to the primary 8 of the output transformer, and the secondary 9 of this transformer may be connected to the load, e. g. to a loud speaker 10. The tubes 5 and 6 are both shown to be of the pentode type, although as will be explained later, it is only necessary that the tube 5 be other than a triode and this might be either a tetrode, pentode, or some other of the known multi-grid type tubes. The screen grid of the push-pull tube 5 is connected to the positive high voltage "B" supply through two resistors 11 and 12, the resistances of which are, in general, small compared to the plate resistance of the tube 5.

The signal voltage to be applied to the control grid of tube 6 is obtained at the junction of the resistors 11 and 12, the control grid 13 being connected to this junction through the coupling condenser 14. Bias voltage may be applied to the grid 13 through a resistor 15 connected to the same source of voltage used to bias the grid 4. The screen grid of the tube 6 may conveniently be connected directly to the source of positive "B" voltage.

In the operation of the amplifier circuit constructed in accordance with the invention, the signal output of tube 1 is applied, by way of the coupling condenser 3, to the control grid 4 of the pentode 5. Because there is a substantial control-grid-to-screen-grid transconductance in tubes of this character, signal current will flow not only in the anode circuit, but also in the screen circuit. And because of the presence of the serially connected load resistors 11, 12 in the said screen circuit a signal voltage will appear on the screen electrode and at the junction of the resistors 11 and 12. This voltage will, of course, be substantially 180 degrees out of phase with the control grid voltage, as is fully described in the aforementioned Clark patent.

The out-of-phase voltage appearing at the junction of resistors 11 and 12 is applied, by way of the coupling condenser 14, to the control grid 13 of the second or dependent push-pull tube 6. By proper selection of the values of resistors 11 and 12, particularly the latter, and by use of tubes having suitable characteristics, the voltage applied to the grid 13 may be made substantially equal in value to that applied to the grid 4, and the outputs of tubes 5 and 6 will, therefore, be substantially equal and 180 degrees out of phase, and proper push-pull operation will be obtained. In one particular embodiment of the invention, the driver tube was a 7C6; the push-pull tubes were 7B5's; the resistors 7 and 15 were each 470,000 ohms; the resistors 11 and 12 were 10,000 and 6600 ohms respectively; and the condenser 14 was .006 mf.

While tubes 5 and 6 are illustrated as pentodes, the tube 6 may be a triode, omitting merely the suppressor grid and screen grid connections, while the tube 5 may be a tetrode, omitting the suppressor grid connection. Obviously, any other form of tube may be employed in which a suitable auxiliary electrode is provided. It is to be understood, of course, that if the tubes are of a different type, e. g. one a triode and the other a pentode, the characteristics should be matched such that they will give satisfactory push-pull operation.

Although resistors 11 and 12 are shown as separate resistances, it will be understood that they constitute an impedance having an intermediate tap point.

In the form of invention shown in Fig. 2 similar reference characters denote parts equivalent to those of Fig. 1. In this modification the resistor 16 has a value approximately equal to the sum of resistors 11 and 12 in Fig. 1, and the reduced voltage is obtained by the voltage divider consisting of resistors 17 and resistor 15. It is apparent that the resistor 16 has the same D. C. voltage drop thereacross as the sum of the voltages across resistors 11 and 12 of Fig. 1, and that the A. C. voltage appearing on the screen grid of tube 5 is properly reduced by the voltage divider effect of resistors 17 and 15, and applied to tube 6. It may also be found advantageous to use an iron core choke instead of the resistor 16. The same swing may then be obtained while using a higher D. C. screen voltage, due to the lower voltage drop of the choke as compared to the resistor 16, and even greater output may be obtained. The same applies to the resistors 11 and 12 of Fig. 1.

In operation, the circuit herein described has the advantage over the circuit shown in the aforementioned Clark patent in that there is no tendency on the part of the screen circuit of the first push-pull tube 5 to swing beyond the linear portion of its operating characteristic. The addition of the resistor 11 (or the use of the relatively large impedance 16) lowers the voltage applied to the screen grid but substantially increases the range and linearity of its characteristic. The resulting lower screen voltage, due to the use of the resistor 11, will reduce very slightly the output of tube 5, but the improved linearity of the screen circuit substantially increases the available output from the dependent tube 6. In one embodiment the net result of the use of this invention was an increase in overall output of approximately 10% at 10% distortion, and an increase in overall output of 30% at the maximum usable output of the circuit.

It will be apparent that the invention is capable of further embodiments or modifications and is not limited to the particular embodiments illustrated.

I claim:

1. An amplifier circuit, comprising a pair of pentode electron tubes arranged for push-pull operation, a driver tube therefor, means connecting the control grid of the first of said pentode tubes to the output circuit of said driver tube, an impedance in the screen grid circuit of the first pentode, and means connecting the control grid of the second of said pentode tubes to an intermediate point of said impedance, the portion of the impedance between said intermediate point and the screen grid of the first pentode substantially reducing the voltage on said screen grid and allowing the screen grid a greater positive voltage swing, thereby permitting the derivation of a greater driving voltage for the control grid of the second pentode without exceeding the limits of permissible distortion.

2. A phase inverter system for audio amplifiers and the like, comprising an input stage having an unbalanced output circuit, an output stage including an independent space discharge device and a dependent space discharge device, said devices having their output circuits connected in balanced relation, means for coupling the output circuit of said input stage to the input circuit of said independent device, an auxiliary electrode disposed in the space current path of said independent device, a source of D. C. supply voltage, a connection between the cathode element of said independent device and the negative terminal of said source, a pair of resistors connected in series between said auxiliary electrode and the positive terminal of said source, and means for deriving the signal voltage developed across one of said resistors and for applying said signal voltage to the input circuit of said dependent device, the resistance of said one resistor being selected to provide an input signal for said dependent tube which is approximately equal in magnitude to the signal applied to said independent tube, the resistance of the other resistor being sufficient, when taken in combination with said one resistor, to insure substantially linear operation of the auxiliary electrode circuit within the desired operating range.

3. A phase inverter system for a push-pull amplifier, comprising a pair of space discharge devices, each having an anode, a cathode, and a control element, and at least the first of said devices having an auxiliary electrode interposed between the control and anode elements, a load circuit connecting the anodes of said devices in push-pull relation, connections for applying an input signal to the control element of said first device, an auxiliary circuit interconnecting the auxiliary electrode of said first device with the cathode of said first device and including a source of direct current, said auxiliary circuit including an impedance connected between the said auxiliary electrode of said first device and the positive terminal of said source of direct current, said impedance being of such magnitude that the signal voltage developed thereacross is substantially greater than the signal voltage applied to the control element of said first device, and also of such magnitude as to insure substantially linear operation of said auxiliary circuit within the desired operating range, and means for deriving from said auxiliary circuit a signal voltage less than the total signal voltage developed across said impedance, but otherwise corresponding

thereto, and for impressing said derived signal voltage upon the control element of the second space discharge device.

4. A phase inverter system for a push-pull amplifier, comprising a pair of space discharge devices, each having an anode, a cathode, and a control element, and at least the first of said devices having an auxiliary electrode interposed between the control and anode elements, a load circuit connecting the anodes of said devices in push-pull relation, connections for applying an input signal to the control element of said first device, an auxiliary circuit interconnecting the auxiliary electrode of said first device with the cathode of said first device and including a source of direct current, said auxiliary circuit including an impedance connected between the said auxiliary electrode of said first device and the positive terminal of said source of direct current, said impedance being of such magnitude that the signal voltage developed thereacross is substantially greater than the signal voltage applied to the control element of said first device, and also of such magnitude as to insure substantially linear operation of said auxiliary circuit within the desired operating range, and a connection from a predetermined intermediate point of said impedance to the control element of the second space discharge device for supplying thereto a portion only of the signal voltage across said impedance, said intermediate point being so chosen that the said portion is substantially equal to the signal voltage applied to the control element of said first device.

5. A phase inverter system for a push-pull amplifier, comprising a pair of space discharge devices, each having an anode, a cathode, and a control grid, and at least the first of said devices having a screen element interposed between the control grid and anode, a load circuit connecting the anodes of said devices in push-pull relation, connections for applying an input signal to the control grid of said first device, an auxiliary circuit interconnecting the screen element of said first device with the cathode of said first device and including a source of direct current, said auxiliary circuit including an impedance connected between the screen element of said first device and the positive terminal of said source of direct current, said impedance being of such magnitude that the signal voltage developed thereacross is substantially greater than the signal voltage applied to the control grid of said first device, an auxiliary circuit interconnecting the auxiliary electrode of said first device with the cathode of said first device and including a source of direct current, said auxiliary circuit including a connection from a predetermined intermediate point of said impedance to the control grid of the second space discharge device for supplying thereto a portion only of the signal voltage across said impedance, said intermediate point being so chosen that the said portion is substantially equal to the signal voltage applied to the control grid of said first device.

6. A phase inverter system for a push-pull amplifier, comprising a pair of space discharge devices, each having an anode, a cathode, and a control element, and at least the first of said devices having an auxiliary element interposed between the control and anode elements, a load circuit connecting the anodes of said devices in push-pull relation, connections for applying an input signal to the control element of said first device, an impedance connected between the said auxiliary element of said first device and the positive terminal of a source current, said impedance being of such magnitude that the signal voltage developed thereacross is substantially greater than the signal voltage applied to the control element of said first device, and a voltage divider for applying to the control element of the second space discharge device a portion only of the signal voltage across said impedance, said portion being substantially equal to the signal voltage applied to the control element of said first device.

WALTER E. GILBERT.