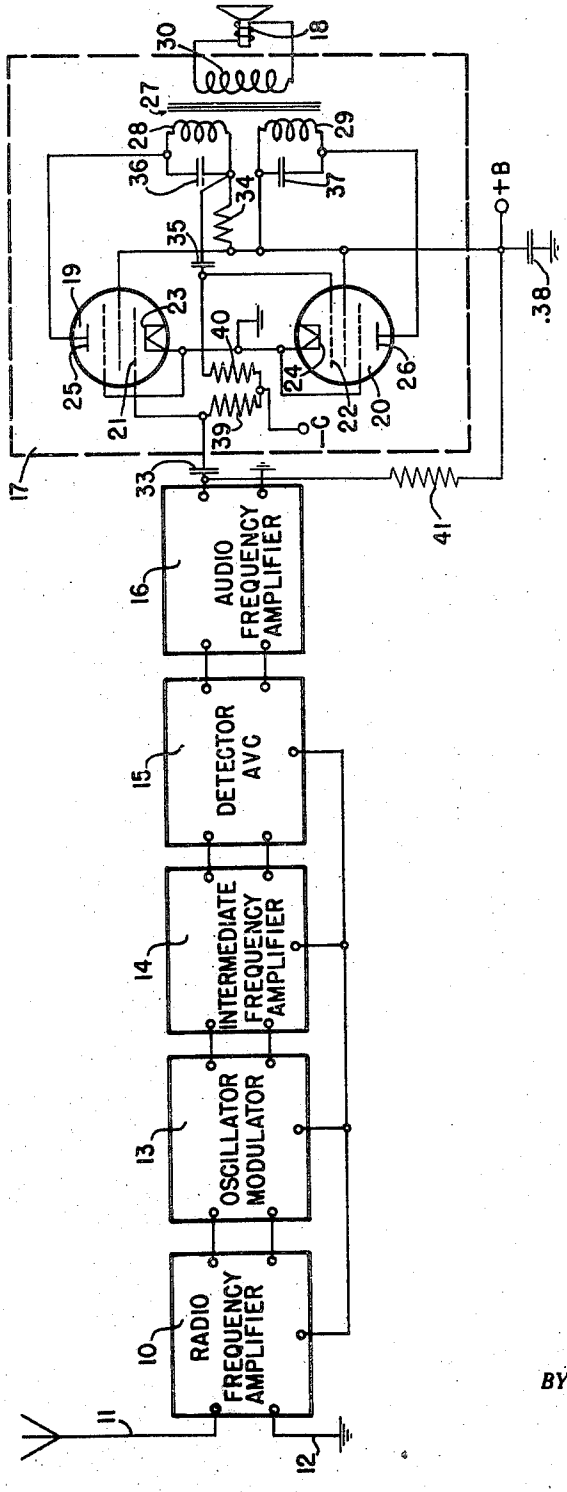
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SIGNAL-AMPLIFIER STAGE

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SIGNAL-AMPLIFIER STAGE

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This invention relates to signal-amplifier stages and, while it is of general application, it is particularly adapted to the conversion of the output from an unbalanced audio-frequency amplifier of a radio-broadcast receiver to a balanced signal for application to a sound reproducer.

It is frequently desirable in radio-broadcast receivers to utilize push-pull or balanced audio-frequency output stages for driving the sound reproducer in order to procure a maximum undistorted sound output. However, such receivers generally include a single tube unbalanced audio-frequency amplifier so that it becomes necessary to provide some means for converting the unbalanced signal output of the amplifier to a balanced signal for application to the grids of the push-pull output tubes. The simplest arrangement and that first proposed is a coupling transformer with a mid-tapped secondary winding. This arrangement has the disadvantage of relatively high cost and a non-uniform frequency-response characteristic.

A second proposal is the use of an auxiliary phase-inverter tube to develop excitation for one of the output tubes. While this arrangement is satisfactory in performance, it is expensive, involving an extra tube, an extra socket, additional circuit elements, etc., with no increase in the overall gain of the system. It has further been proposed to excite the grid of one of the push-pull tubes from a tap on the output transformer. While this arrangement involves a minimum of expense, the performance is not entirely satisfactory in several respects. In the first place, due to the variation of the magnitude and the phase angle of the primary impedance of the output transformer, including the reflected impedance of the sound reproducer over the audio-frequency range, the phase and magnitude of the inverted signal applied to the second tube varies considerably over the audio-frequency range, resulting in unbalance of the system and signal distortion. Additionally, in such an arrangement there is appreciable regeneration due to coupling between the grid of the second tube and the anode circuit of the first tube and coupling between the anode circuits of the two tubes, so that the design of the circuit to avoid oscillation becomes critical. These disadvantages are accentuated in case the output tubes are of the triode or low-impedance type.

It is an object of the invention, therefore, to provide a new and improved signal-amplifier stage for providing a balanced audio-frequency output signal from an unbalanced audio-frequency amplifier and one which obviates one or more of the above-mentioned disadvantages of the arrangements of the prior art.

It is another object of the invention to provide a new and improved signal-amplifier stage for

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providing an audio-frequency output signal from an unbalanced audio-frequency amplifier which involves a minimum of additional circuit elements, and therefore a minimum cost, and yet provides a balanced and undistorted signal output over the audio-frequency range for which the stage is designed.

In accordance with the invention, a signal-amplifier stage comprises a pair of constant-high-impedance type vacuum tubes each having input electrodes and an associated input circuit and output electrodes and an associated output circuit. The stage also includes an output transformer including a pair of primary windings, the output circuits being connected with the windings to form a balanced output circuit. There are provided means for applying to the input circuit of one of the vacuum tubes a signal to be amplified, a resistance element in the output circuit of such one of the vacuum tubes and means for applying to the input circuit of the other of the tubes a signal derived from the resistance element. By the term "constant-high-impedance type" vacuum tube is meant a tube having a substantially constant impedance over the normal range of signal-input voltages and one which is at least several times the impedance of a simple triode vacuum tube. Well-known examples of tubes of this type are the several pentode types of vacuum tubes and the type 6L6 beam power tubes.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings while its scope will be pointed out in the appended claims.

Referring now to the drawing, the single figure is a circuit diagram, partly schematic, of a complete superheterodyne radio-broadcast receiver embodying a signal-amplifier stage of the invention.

Referring now more particularly to Fig. 1, there is represented schematically a complete carrier-signal receiver of a conventional design embodying the present invention in a preferred form. In general, the receiver includes a radio-frequency amplifier 10 having its input circuit connected to an antenna system 11, 12 and having its output circuit connected to an oscillator-modulator 13. Connected in cascade with the oscillator-modulator 13, in the order named, are an intermediate-frequency amplifier 14 of one or more stages, a detector and automatic volume control supply 15, an audio-frequency amplifier 16 of one or more stages, an audio-frequency signal-amplifier stage 17, more fully described hereinafter, and a sound reproducer 18. An automatic amplification control or A. V. C. circuit is connected between the automatic volume control supply unit 15 and the

input circuits of one or more of the tubes of the radio-frequency amplifier 10, the oscillator-modulator 13, and the intermediate-frequency amplifier 14 in conventional manner.

It will be understood that the various units just described may, with the exception of the signal-amplifier stage 17, be of a conventional construction and operation, the details of which are well known in the art, rendering detailed description thereof unnecessary. Considering briefly the operation of the receiver as a whole, and neglecting for the moment the operation of the signal amplifier 17, presently to be described, a desired carrier signal is selected and amplified by the radio-frequency amplifier 10, converted to an intermediate-frequency carrier signal in the oscillator-modulator 13, amplified in the intermediate-frequency amplifier 14, and detected by the detector of unit 15, thereby to derive the audio-frequency modulation components comprising the audio signal. The audio-frequency signal is, in turn, amplified in the audio-frequency amplifier 16, further amplified in the audio-frequency amplifier stage 17 and is reproduced by the sound reproducer 18 in a conventional manner.

The automatic amplification control or A. V. C. bias derived from the A. V. C. supply unit 15 is effective to control the amplification of one or more of the units 10, 13 and 14 in accordance with the amplitude of the received carrier signal to maintain the carrier-signal input to the detector of unit 15 within a relatively narrow range for a wide range of received signal intensities.

Referring now more particularly to the audio-frequency amplifier stage 17 embodying the present invention, this unit includes a pair of vacuum tubes 19, 20 having input electrodes comprising control grids 21, 22 and cathodes 23, 24, respectively, and having output electrodes comprising anodes 25 and 26, respectively. The tubes 19 and 20 are of the constant-high-impedance type such as the well-known pentode type of vacuum tube. The unit also includes an output transformer 27 including a pair of primary windings 28 and 29, the output electrodes of the tubes 19 and 20 being connected with the windings 28 and 29, respectively, and a source of space current +B in a conventional manner to form a balanced output circuit. The transformer 27 is also provided with a secondary winding 30 connected to the sound reproducer 18. The transformer 27 is so designed that, when connected to the sound reproducer 18 for operation, the primary impedance of each of the windings 28 and 29 is only a small fraction of the anode-cathode impedances of the tubes 19 and 20. The screen electrodes of the tubes 19 and 20 are connected to the source +B, while the suppresser grids of the tubes 19 and 20 are connected directly to their respective cathodes in a conventional manner.

The amplifier stage 17 includes means for applying to the input circuit of one of the tubes a signal to be amplified, this means comprising a coupling condenser 33 connected between the output circuit of the audio-frequency amplifier 16 and the signal-input grid 21 of the vacuum tube 19. A resistance element 34 is included in the output circuit of the tube 19 in series with the source of anode current +B but outside of the output circuit of the vacuum tube 20. The unit 17 also includes means for applying to the input circuit of the other of the tubes a signal derived from the resistance element 34, preferably the signal developed thereacross. This means comprises a circuit including a blocking condenser 35 connected between the high signal-potential terminal of the resistor 34 and the signal-input grid 22 of the tube 20. Across the primary windings 28 and 29 are connected condensers 36 and 37, respectively, proportioned broadly to tune the primary windings to approximately the midpoint of the audio-frequency range to be translated, thereby to limit the rise in impedance of the output circuit over the high-frequency portion of the audio-frequency range. It will be understood that the source +B includes suitable filtering elements for returning the audio-frequency components to ground, such as a filter condenser 38. The source +B is also connected to supply space current to the audio-frequency amplifier 16 through a load resistor 41. A suitable grid bias is applied to the signal-input grids 21 and 22 of the tubes 19 and 20, respectively, from a source −C through grid-leak resistors 39 and 40, respectively.

Considering now the operation of the signal-amplifier stage 17 described, the signal applied to the input circuit of vacuum tube 19 is repeated by this tube in a conventional manner to develop in its output circuit including the primary winding 28 and the resistor 34 an amplified signal current. The signal voltage developed across the resistor 34 by this current is in phase opposition to the signal voltage applied to the grid 21 so that it is of the proper phase to apply to the grid 22 of the tube 20. The condenser 35 serves to apply this signal voltage to the grid 22 so that the vacuum tube 20 develops in its output circuit including the primary winding 29 a signal output of a phase reverse to that developed in the winding 28. The polarity of connections of the windings 28 and 29 are such that they have a cumulative effect in developing a signal output in the secondary winding 30 in a manner well understood in the art.

Due to the fact that the vacuum tubes 19 and 20 are of the constant-high-impedance pentode type having impedances many times as great as the primary impedance of the transformer 27 when connected to the sound reproducer 18 for operation, the output currents of these tubes are almost exactly in phase with their applied signal voltages so that the signal voltage developed across the resistor 34 is also almost exactly in phase opposition with the signal applied to the grid 21 of the tube 19. By giving to the resistance element 34 a value approximately equal to the reciprocal of the mutual conductance of the tube 19, the signal voltage developed thereacross will also be substantially equal in amplitude to the signal applied to the grid 21 so that the tubes 19 and 20 will develop balanced signal outputs and the output circuit as a whole will be accurately balanced.

Since the impedances of the tubes 19 and 20 are many times the impedance of the output circuits including the windings of the transformer 27, substantial variations in the external impedance of the tube circuits, including the impedance reflected from the sound reproducer 18, over the audio-frequency range result in inappreciable variations in the phase or magnitude of the output currents of the tubes 19 and 20. Therefore, there is a minimum of unbalance and distortion developed by the system due to variations in magnitude and phase angle of the primary impedance of the transformer 27 over the audio-frequency range. In addition, since there is no substantial variation in the current in the output circuit of the tube 19 including the resistor 34 due to voltages induced therein by the

primary winding 29, there is no appreciable regenerative coupling between the anode and grid circuits of the tube 20 so that there is no tendency of the stage to oscillate.

The signal-amplifier stage of the invention also has the characteristic of greatly reducing or eliminating in the output circuit hum voltages introduced from the power supply circuit. For example, assuming that a 120-cycle hum voltage e_{38} appears across the filter condenser 38, the portion of such voltage applied to the grid of the tube 19 may be represented by the expression:

$$e_{g19}=e_{38}\left[\frac{\frac{R_{39}R_p}{R_{39}+R_p}}{R_{41}+\frac{R_{39}R_p}{R_{39}+R_p}}\right]$$

Since the hum voltage on the grid of the tube 20 is the algebraic sum of that across the resistor 34 and that across the condenser 38 and since that across the resistor 34 is equal and opposite to e_{g19}, as explained above for signal voltages, the circuit constants of the amplifier stage may be proportioned in accordance with the above equation to make e_{g19} one-half of the hum voltage e_{38} so that the hum voltage applied to the grid of the tube 20 is also one-half of the hum voltage and of the same phase. As a result, the hum voltages in the output circuits of the tubes 19 and 20 balance out in transformer 27 and are suppressed from the voice-coil circuit of the sound reproducer 18. Such suppression is, of course, independent of any residual hum in the voice-coil circuit due to an imperfectly compensated sound reproducer.

While it will be understood that the signal-amplifier stage of the invention may incorporate a wide range of circuit designs, there follows the values of the principal circuit elements of a particular signal-amplifier stage embodying the invention which provided satisfactory operation:

Tubes 19 and 20: Type 6K6
Anode-cathode resistance: 68,000 ohms
Mutual conductance: 2,300 micromhos
Impedance of each of windings 28 and 29, loaded: Approx. 12,000 ohms
Resistance 34: 470 ohms
Condensers 36, 37: 0.003 microfarad
Coupling condensers 33, 35: 0.05 microfarad
Resistors 39, 40: 0.5 megohm
Resistor 41: 0.22 megohm

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of the invention.

What is claimed as new is:

1. A signal-amplifier stage comprising, a pair of constant-high-impedance vacuum tubes of the pentode type each having a cathode, a plate, a control grid, a screen grid and a suppressor electrode, said suppressor electrode being connected to said cathode, a source of potential, means for applying said source of potential between said cathodes and said screen grids of said tubes, a balanced output circuit including a transformer having a pair of primary windings and a resistance element, the impedances of said primary windings being small compared to the plate-cathode impedances of said tubes, one of said primary windings being connected in series with said resistance element and said source of potential between said cathode and said plate of one of said tubes, the other of said primary windings being connected in series with said source of potential between said cathode and said plate of the other of said tubes, coupling means for applying a signal to be amplified between said cathode and said control grid of said one vacuum tube, said one vacuum tube providing an output across said one primary winding and said resistance element which varies linearly with the signal applied to said one vacuum tube, and coupling means for applying the signal developed across said resistance element between said cathode and said control grid of said other of said tubes.

2. A signal-amplifier stage in accordance with claim 1 in which said resistance element and said coupling means provide hum components of the signals produced in said output circuit by said tubes which are substantially the same and are balanced out in said output circuit.

3. A signal-amplifier stage comprising, a pair of constant-high-impedance vacuum tubes each having a cathode, an anode, a control grid, a screen grid and an electrode positioned adjacent said anode which is electrically connected to said cathode, a source of potential, means for applying said source of potential between said cathodes and said screen grids of said tubes, a balanced output circuit including a transformer having a pair of primary windings and a resistance element, the impedances of said primary windings being small compared to the anode-cathode impedances of said tubes, one of said primary windings being connected in series with said resistance element and said source of potential between said cathode and said anode of one of said tubes, the other of said primary windings being connected in series with said source of potential between said cathode and said anode of the other of said tubes, coupling means for applying a signal to be amplified between said cathode and said control grid of said one vacuum tube, said one vacuum tube providing an output across said one primary winding and said resistance element which varies linearly with the signal applied to said one vacuum tube, the value of said resistance element being substantially equal to the reciprocal of the mutual conductance of said one tube so that the signal developed thereacross is substantially the same as the signal to be amplified, and coupling means for applying the signal developed across said resistance element between said cathode and said control grid of said other of said tubes.

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