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PATENT SPECIFICATION

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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Push-Pull Amplifiers.

We, RADIO CORPORATION OF AMERICA, a Corporation organized under the laws of the State of Delaware, United States of America, of 30, Rockefeller Plaza, City and State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to push-pull amplifiers.

Amplifiers are generally required to have a predictable and substantially constant gain over a given range of frequencies. This is generally designated as the gain and frequency response of the amplifier. Since the characteristic parameters of various electronic devices employed in circuits through out the amplifier change from component to component, and also change with time and temperature, degenerative feedback is generally employed to provide for a means for controlling the gain and the frequency response of the amplifier.

The amount of degenerative feedback that can be employed in any particular amplifying system is limited by the amount of phase shift introduced into the system by various reactive components such as capacitors and transformers, etc. If the phase shift is such that instability occurs when the required amount of degenerative feedback is applied (to produce the required frequency response), the open loop (no feedback) gain and phase shift response, or the feedback network must be tailored by frequency sensitive networks to provide for the required degree of stability.

In the case of mass-produced amplifiers, such as the audio amplifiers employed in

television and radio receivers etc., these amplifiers must economically meet the required gain and frequency response limits despite the wide variety of possible different combinations of parameters of the electronic devices employed. In these mass-produced units, wherein economy is stressed, the cost of an individual component becomes a very important factor. The number of components employed must be minimized and the circuit must be designed to operate with off-the-shelf standard low-cost type components. Any frequency sensitive network employed to stabilise the closed loop operation of the amplifier must also be designed by the same criterion.

It is an object of this invention to provide means for stabilising a push-pull amplifier.

An amplifier according to the invention comprises a push-pull output stage employing a pair of amplifying transistors connected to develop an output voltage across a load in a push-pull manner, coupling means between an input circuit and the control electrodes of said amplifying transistors to drive said amplifying transistors in a push-pull manner, said transistors being connected in series arrangement whereby the emitter electrode of one of said transistors is connected to the collector electrode of the other of said transistors, with said load coupled to said emitter electrode to collector electrode connection, a degenerative feedback path coupled between the load and the input circuit, and a capacitor connected directly between the control electrodes of said pair of amplifying transistors to stabilize said amplifier against self-oscillation.

The invention itself will best be understood from the following description when read in connection with the accompanying drawing which is a schematic circuit diagram

of a push-pull amplifier according to one embodiment of the invention.

A single-ended push-pull audio amplifier circuit embodiment of the invention will be described. Referring to the drawing, input signals to be amplified are applied across the terminals 10 and are coupled through a coupling capacitor 12 to the base electrode of a preamplifier transistor 14. The transistor 14 is connected as a common emitter stage with its collector electrode connected to the negative terminal 18 of a power supply through a resistor 20 while its emitter electrode is connected to ground through a resistor 16. A biasing resistor 22 is connected between the base electrode of the transistor 14 and ground.

The collector electrode of the preamplifier transistor 14 is directly coupled to the base electrode of a driver transistor 24. The collector electrode of the driver transistor 24 is connected to the power supply terminal 18 through a primary winding 26 of a coupling transformer 28 while the emitter electrode is connected to ground through the series biasing resistors 30 and 32 and a bypass capacitor 34 connected in parallel with the resistor 32. A direct current feedback voltage developed across the parallel combination of the resistor 32 and the capacitor 34 is coupled to the base electrode of the preamplifier transistor 14 through a resistor 36. The direct current feedback through the resistor 36 effectively biases both the transistors 14 and 24 and also stabilizes their operating point for changes in temperature.

The output stage of the amplifier of the Figure is a single-ended push-pull amplifier circuit including a pair of output transistors 38 and 40. The collector electrode of the output transistor 38 is connected to a power supply terminal 42 while its emitter electrode is connected through a resistor 46 to an output terminal 48. The collector electrode of the output transistor 40 is directly connected to the output terminal 48 while its emitter electrode is connected to ground through the resistor 50. In effect, the direct current paths between the collector and emitter electrodes of the output transistors 38 and 40 are connected in series.

Series resistors 52, 54, 56 and 58 connected between the power supply terminal 42 and ground provide a biasing network for the output transistors 38 and 40. The junction of resistors 54 and 56 is connected to the output terminal 48.

The coupling transformer 28 includes two secondary windings 60 and 62 for driving the output transistors 38 and 40 respectively, in a push-pull manner. One end of the secondary winding 60 is connected to the junction of the biasing resistors 52 and 54 while the other end is connected to the base electrode of the output transistor 38 completing the

bias and input signal circuit for the transistor 38. One end of the secondary winding 62 is connected to the junction of the biasing resistors 56 and 58 while the other end is connected to the base electrode of the output transistor 40 completing the bias and input signal circuit for the transistor 40. The polarities of the secondary windings 60 and 62 are such that the signal applied to the base electrodes of the transistors 38 and 40 are 180 degrees out of phase.

Output signals are developed at terminal 48 and are coupled through a coupling capacitor 64 to drive a loudspeaker 66. A resistor 68 is connected between the loudspeaker 66 and the base electrode of the driver transistor 24 to provide a degenerative feedback path for determining the gain and frequency response of the amplifier. A single capacitor 70 is connected between the base electrodes of the output transistors 38 and 40 to decrease the gain of the push-pull output stage at high frequencies to stabilize the closed loop operation of the amplifier.

In operation, the input signals that are applied across the terminals 10 are amplified by the pre-amplifier transistor 14 and the driver transistor 24 and are coupled through the coupling transformer 28 to the base electrodes of the transistors 38 and 40 as out-of phase signals to drive the output stage in a push-pull manner. For example, if the voltage applied to the base of the transistor 38 is in a direction to increase the conduction in transistor 38, the voltage applied to the base electrode of transistor 40 is in a direction to cut-off the conduction through transistor 40. With this polarity of signal the terminal 48 approaches the value of voltage at the supply point 42. On the other hand if the signals applied to the output stage are such that the transistor 40 increases in conduction while the transistor 38 decreases in conduction, the voltage at the terminal 48 approaches that of ground. The capacitance of the coupling capacitor 64 is sufficiently high to essentially present a short circuit for signal frequencies between the output terminal 48 and the loudspeaker 66.

In order to set the gain of the amplifier to be independent of the "Beta" parameters, etc. of the particular transistors employed, a degenerative feedback path (resistor 68) is provided between the driver stage and the output stage. Because of the leakage inductance of the coupling transformer 28 and the various phase shifts attributed to the reactive components within the amplifier circuit, the circuit (without the capacitor 70) has a tendency to be unstable, that is, to break into oscillation.

It was experimentally determined that the circuit of the Figure could not be economically stabilized by tailoring the degenerative feedback path by connecting a capacitor in



parallel with the resistor 68. In order to completely stabilize the amplifier for the expected wide variations in component parameters etc., the size of such a capacitor was found to be critical requiring expensive precision, low tolerance components, and therefore was not readily adaptable to low-cost production units. In addition such a capacitance in the feedback path was found to undesirably load the preamplifier transistor 14. The use of two capacitors, one connected between each base electrode of the output transistors 38 and 40 and ground to form a dominating time-constant for high-frequency response was also found to be unacceptable. The tolerance in the size of these capacitors that could be safely employed to stabilize the amplifier was also small, thereby also requiring the use of expensive low tolerance capacitors. Furthermore, the aforementioned capacitors contributed an undesirable amount of phase shift in the operation of the circuit. The use of a capacitor across the primary winding 26 was also found unacceptable since such a capacitor merely shifted the resonant peak of the coupling transformer 28 to a low frequency and would not effectively stabilize the circuit.

The single capacitor 70 connected between the base electrodes of the output transistors 38 and 40 fully stabilized the closed loop operation of the amplifying system. The capacitance value of the capacitor 70 was found to be substantially less than that required to stabilize the amplifier with separate capacitors connected between each base electrode of the output transistors 38 and 40 and ground. The value of the capacitor 70 is selected to present a high impedance to frequencies in the audio range of signals (generally 50 cycles to 15 kilocycles) and a low impedance for a range of signals beyond the audio range. As previously mentioned, the voltage applied to the base electrode of the transistors 38 and 40 and across the capacitor 70 is out-of-phase. As a result the single capacitor 70 provides a low impedance shunt to the higher range frequency signals

(beyond the audio range) being applied to the base electrodes of the transistors 38 and 40, decreasing the gain of the amplifier at the higher range frequencies while contributing a minimum of phase shift into the amplifier thereby stabilizing the closed loop operation of the amplifier. The value of the capacitor 70 is not critical, wherein a standard low-cost off-the-shelf component can be used and still sufficiently stabilize the circuit for all possible variations in component parameters.

WHAT WE CLAIM IS:—

1. An amplifier comprising a push-pull output stage employing a pair of amplifying transistors connected to develop an output voltage across a load in a push-pull manner, coupling means between an input circuit and the control electrodes of said amplifying transistors to drive said amplifying transistors in a push-pull manner, said transistors being connected in series arrangement whereby the emitter electrode of one of said transistors is connected to the collector electrode of the other of said transistors, with said load coupled to said emitter electrode to collector electrode connection, a degenerative feedback path coupled between the load and the input circuit, and a capacitor connected directly between the control electrodes of said pair of amplifying transistors to stabilize said amplifier against self-oscillation.

2. A push-pull amplifier according to claim 1 wherein the value of said capacitor is chosen so that the gain of said amplifier is substantially unaffected thereby over the audio range of 50 cycles per second to 15 kilocycles per second.

3. A push-pull amplifier substantially as herein described with reference to the accompanying drawing.

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