

July 11, 1933.

P. BORIAS

1,917,426

MULTISTAGE AMPLIFIER

Filed Feb. 17, 1928

2 Sheets-Sheet 1

Fig. 1

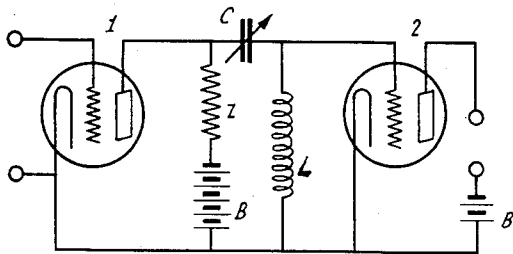


Fig. 2

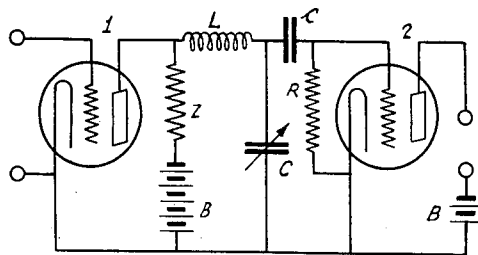


Fig. 3

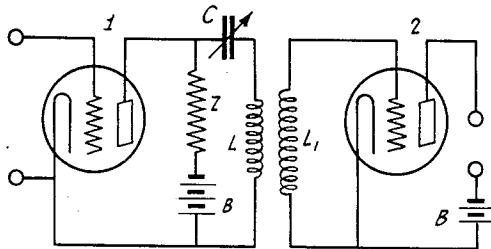


Fig. 4

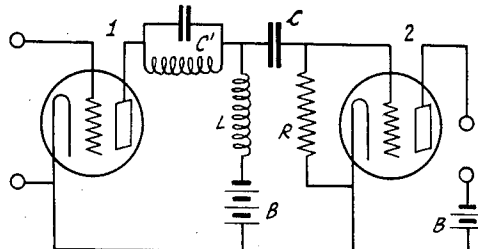


Fig. 5

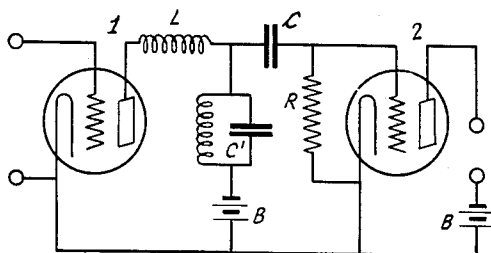
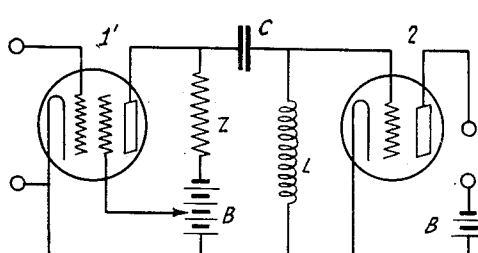


Fig. 6



INVENTOR
PAUL BORIAS
BY *Irving Adams*
ATTORNEY

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P. BORIAS

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Fig. 7

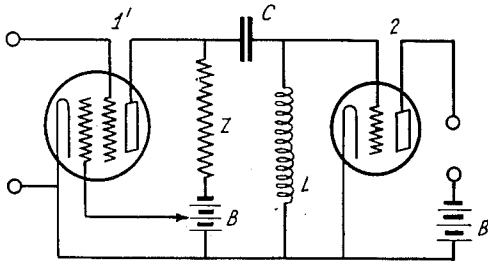


Fig. 8

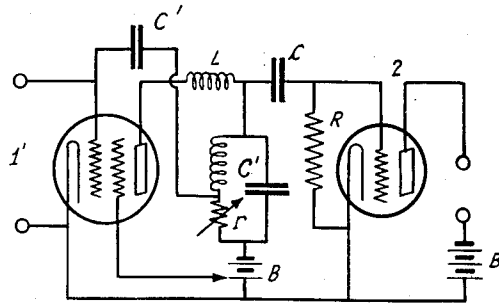


Fig. 9

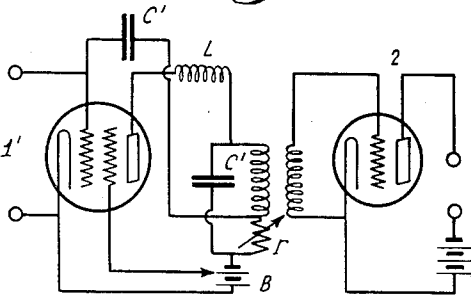


Fig. 10

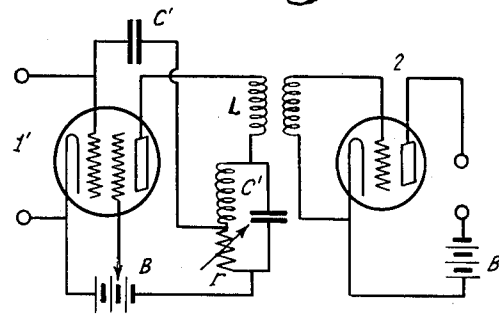


Fig. 11

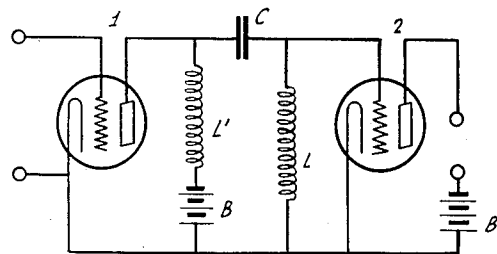
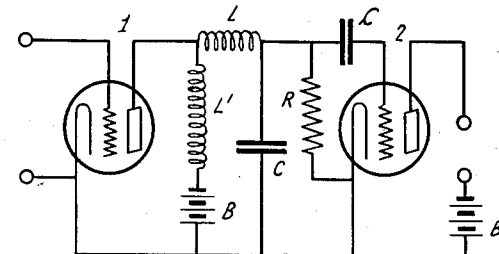


Fig. 12



INVENTOR
PAUL BORIAS
BY *John J. Adams*
ATTORNEY

UNITED STATES PATENT OFFICE

PAUL BORIAS, OF PARIS, FRANCE, ASSIGNOR TO SOCIETE FRANCAISE RADIO ELECTRIQUE, OF PARIS, FRANCE, A JOINT-STOCK COMPANY OF FRANCE

MULTISTAGE AMPLIFIER

Application filed February 17, 1928, Serial No. 254,988, and in France March 3, 1927.

The present invention relates to new methods of and arrangements for coupling multi-electrode tubes, and more particularly to radio frequency amplifiers.

5 As contrasted with arrangements known in the prior art, it offers the following advantages: absence of reaction due to the internal capacitance of the tubes, considerably higher amplification (at the same damping),
10 possibility of choosing the form of the resonant coupling so as to insure a filtering effect, regulation of selectivity independently of the amplification.

The underlying principle of the invention is as follows: whereas in the arrangements known in practice, one starts from a high frequency potential available at the plate and feeds it to the following grid either directly (resistance, choke-coil, tuned plate-circuit schemes) or indirectly by stepping it up by a tuned or non-tuned transformer (transformer coupling), according to the present invention the reactance of the plate circuit for the frequency to be received is eliminated, with the result that all reaction due to the internal capacitance of the tube is prevented, inasmuch as the plate is at an alternating current potential practically of zero value.

30 The invention, both as to its construction and mode of operation together with the objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, of which Figures 1-12 illustrate diagrammatically various forms of the invention. In all the figures similar reference characters denote similar or equivalent elements.

40 The simplest embodiment according to the present disclosure is shown by way of example in Figure 1. Referring to the illustration, 1 and 2 denote two tubes to be connected cascade-fashion, here assumed to be of the triode type, and comprising the three elements, to wit: filament, grid and plate of the usual kind. Two impedances, L and C, adjustable if desired, are connected in series, and the circuit element thus constituted is connected between the plate and

the filament of tube 1. The grid of tube 2 is connected between the two impedances above mentioned. For the working frequency the reactance of impedance L is compensated by the reactance of the impedance C. To apply to the plate of the tube the necessary direct current potential, the said plate is connected with a suitable source of potential by way of an impedance Z (resistance or self-inductance coil) which will not result in an appreciable shunt for the radio frequency current, since the branch or shunt LC forms an impedance sensibly of zero value for this current. The impedances L and C, respectively, have been indicated by the symbols usually used for self-inductance and capacitance, though it will be understood that, if desired, they could be transposed or one substituted for the other, or both be replaced by complex assemblies of capacitive and inductive elements, provided that the resultant reactances of each assembly become compensated as has been pointed out.

Figure 2 shows an arrangement according to this invention which is a modification of the scheme shown in Figure 1 by the transposition or exchange of the inductive and capacitive reactances. In this case a coupling capacity c is inserted in the lead brought to the grid of tube 2, while the potential of the latter with reference to the filament is determined and governed, for instance, by means of a grid-leak resistance R.

It will be noted that, with reference to the resonant frequency, the arrangement of Figure 1 leaves a residue of amplification for the higher frequencies, but that it does not transfer the lower frequencies, whereas the scheme Figure 2 leaves a residue of amplification for the lower frequencies, while it does not transmit the higher frequencies.

The modification shown in Figure 3 has recourse to an inductive coupling for the application of the potential to the grid of tube 2, and as a result it allows of raising the potential impressed upon the grid of tube 2. Application of the variable potential to the grid of tube 2 is insured by replacing the direct connection of this grid with impedances L and C of the scheme Figure 1 by the mag-

netic induction of coil L upon a coil L' inserted in the circuit of the grid of tube 2, the said coil L' playing the part of the secondary of a transformer with an incidental stepping-up of the potential.

Primarily in the case of amplifier arrangements working at a fixed frequency, or frequencies varying only inside a narrow band, it is equally well to use, in lieu and stead of a capacity, a self-inductance coil which could be operated on a shorter wave than its own (natural) period and which, for this reason, would behave like a capacity. In this case, there would thus be two self-inductances in series, and they would have to be proportioned in such a way that operation takes place above the shortest natural wave of an inductive reactance, and below that of the longest wave corresponding to a capacitive reactance. The advantage residing in this plan is that both the very low and the very high frequencies with reference to the resonant frequency are precluded. Next, for the natural period of one of the two coils, there will occur a very appreciable reduction in amplification, especially in the case of the one inserted between the plate and the grid of the tube next above. This deformation of the resonance curve may be put to practical advantage for the purpose of providing a sort of band-filter by arranging in two successive stages the large self-inductance coil, both outside and inside the grid circuit of the second tube.

One particular embodiment of the modification employing two coils in series which is of particularly great advantage, consists in using two identical coils, the one intended to operate as a capacity being shunted by a condenser, the same being tuned to a frequency close to F, where F is the desired signal frequency to be received. For the working frequency F the stopper thus formed possesses a reactance compensating that of the other coil, and an apparent resistance equal to the ohmic resistance of the coil. Arrangements of this kind comprising coils give amplifications higher than those obtainable by the preceding schemes (Figures 1 to 3). They are schematically illustrated in Figures 4 and 5 where the same symbols designate the same elements as heretofore so that no further explanations will be required. It will be noted that these coil arrangements make it possible to dispense with the impedance Z in the preceding figures, the potential of the direct current source being applied to the plate by the coil circuit directly. Figure 4 is a scheme equivalent to Figure 1, and Figure 5 the equivalent to Figure 2, looked at from the viewpoint of arrangement respectively of the inductance and capacitive reactances with relation to the plate of the first tube and the

connection brought to the grid of the second tube.

One of the properties of the coupling system disclosed in this invention, especially when it comprises a resistance Z for direct current supply, is that it is possible to regulate the degree of selectance independently of the amplification, contrary to what is true of resonant or reaction coupling. For instance, when referring to Fig. 1, the sharpness of the resonance curve depends upon the overvoltage across the terminals of the self-inductance coil. Now, the resistance which is in series with the self-inductance coil and the capacity includes the internal impedance of the tube and the supply impedance Z which may be reduced to a resistance. The variations of the resistance Z do not influence amplification under tuned condition, though it is possible to graduate selectivity.

An improved modification of the basic idea of the invention whereby it is possible to benefit more largely from this property consists in the use of a two-grid tube or "tetrode", of the type in which two grids or auxiliary electrodes are provided at different distances between filament and plate. Figure 6 by way of example shows one form of construction of this scheme. The oscillations to be amplified are impressed upon the inner grid of the double-grid tube 1', the outer grid being raised to a certain positive potential by being connected, for example, to an intermediate point of the plate battery B. The remainder of the circuit elements of the plate and of tube 2 is identical with the denotations above given for the case of the triodes (see, for instance, Figures 1 to 3). This arrangement allows of adopting a resistance Z of high value, and therefore of securing a very flat-topped resonance curve. Moreover, the outer grid united with the plate battery constitutes an electrostatic shield between the control grid and the plate, with a further reduction of the chances of reaction. It will be understood, of course, that in the scheme shown in Figure 6, as indicated for the preceding schemes, it is possible to transpose the capacitive impedances C and the inductive impedances L, or to employ divers or complex elements (coils operating above or below their natural periods, coils with capacitance across their terminals, etc.) In Figure 7 is shown an arrangement similar to Figure 6 with the outer grid acting as the control grid in the input circuit and the inner grid being supplied with positive potential from the plate battery.

Finally, although the amplification figures attainable by the aid of the present disclosures are far higher than those obtained by the conventional forms of arrangement, whereby it is made possible to design efficient amplifiers free from retro-action, it will be

noted that the invention is particularly suited to the use of regeneration. Indeed, by the addition of regenerative couplings, it is feasible to insure considerable amplification figures, far higher, at any rate, than those obtainable in the usual regenerative circuit arrangements, in the presence of equal damping. Moreover, the use of regeneration does not increase the chances of self-excitation in the schemes according to the present invention, whereas the dangers from this source are quite considerable in the customary schemes.

The adoption of regenerative coupling in circuit arrangements according to this invention, as will be understood, is capable of a great number of modifications. All that is necessary with that end in view is to take off at a convenient point of the circuits a portion of the amplified potential having convenient size and phase, and to apply the same to the input circuit of one of the amplifier tubes. The necessary conditions as hereinbefore set forth according to this invention are realized by adopting the following scheme:

The potential to be fed back, if taken off simply at one of the coupling impedances (say, inductance coil L of the arrangements illustrated in Figures 1, 2 and 3) must be fed back not to the grid of the tube in whose plate circuit the impedance in question is included, but rather to the grid of the tube next below supposed to be coupled with the tube in question in one of the ways adapted to preserve phase coincidence between the grid potential and the plate current of the tube (for instance, resistance-coupling arrangements or arrangements according to this invention).

It is generally preferable to practice reaction in the same tube. For this object, one efficient scheme consists in adopting one of the arrangements of this invention comprising a complex impedance (self-inductance and capacity in parallel), to insert in the branch containing the self-inductance coil a series resistance r , and to feed back to the grid of the particular tube in whose plate circuit is included the said impedance, the potential taken off across the terminals of the said resistance, with the interposition, if necessary, of such capacities as may be required so as to prevent the short-circuiting of the sources, or the application of undesirable direct current potentials to the grid. Regulation of the feed-back may be effected by the adjustment of the said resistance or else by

the setting of the rheostat controlling the heating of the tube.

Figures 8, 9 and 10 of the accompanying drawing illustrate various embodiments of the scheme before described, there having been chosen, by way of example, the case of a two-grid tube indicated at 1', each of the said figures showing a modification for the connection of tube 2, the coupling means being insured either by capacity or else by induction with one or the other of the coupling coils. The symbols and reference numerals are the same as before. As will be understood it is possible to combine the elementary arrangements before disclosed with other modifications.

According to other modifications, the present invention also allows to insure a reduction in the disturbances reaching the receiver in the shape of aperiodic shocks. This end is realized by employing as the impedance for the direct current supply of the plate a self-inductance coil in the circuit arrangements shown in Figures 1 to 3, the result being arrangements of the kind illustrated in Figures 11 and 12. The impulse due to a shock will cause the tube 1 to oscillate at a frequency (corresponding to the constants of the circuit L'/CL) which differs from that for which maximum amplification is obtained, and in this manner it is easier to distinguish the signals from the strays.

Although the invention has been stated to be especially useful for the amplification of radio frequency currents, it will be obvious that it is equally well applicable to tuned radio frequency amplifiers.

Having thus described the nature of my invention, I claim:

In combination a vacuum tube having a cathode, inner grid, outer grid and an anode, an input circuit including the cathode and said outer grid, an output circuit comprising the anode, a resistance having a high value, a current source and said cathode all in series, means for connecting said inner grid to said current source, a second vacuum tube having input and output circuits, said input circuit including a reactance adapted to act as a coupling device between said first mentioned tube output circuit and said second mentioned tube input circuit, means for connecting the cathode of said first mentioned tube to one end of said coupling device and means comprising another reactance for connecting the anode of said first mentioned tube to the other end of said coupling device.

PAUL BORIAS.