Aug. 28, 1945. T. H. PRICE 2,383,888

AMPLIFIER CIRCUIT ARRANGEMENT

Filed Feb. 2, 1942 2 Sheets-Sheet 1

Fig. 1.

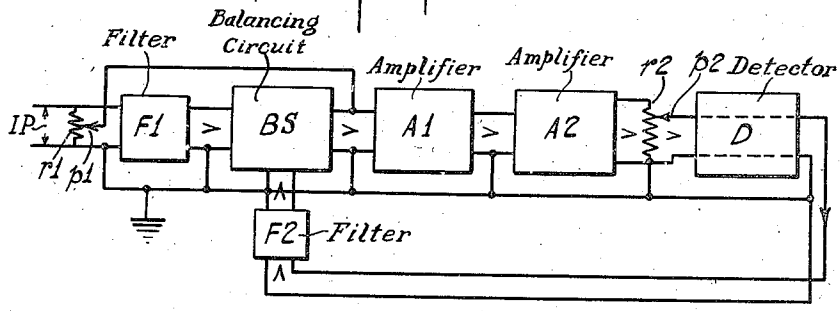


Fig. 2.

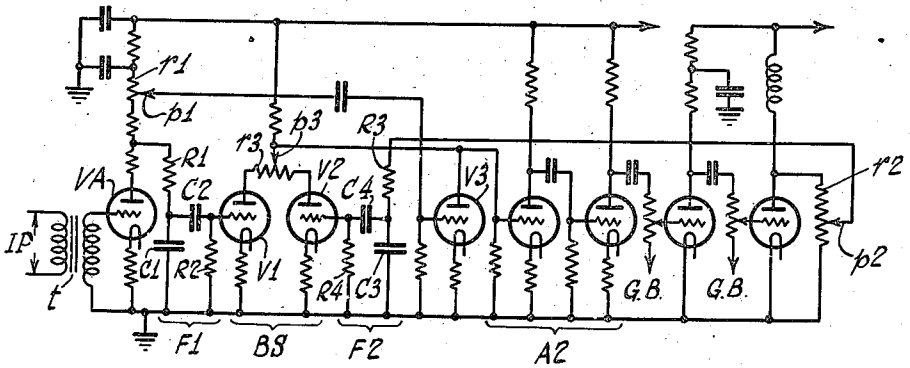
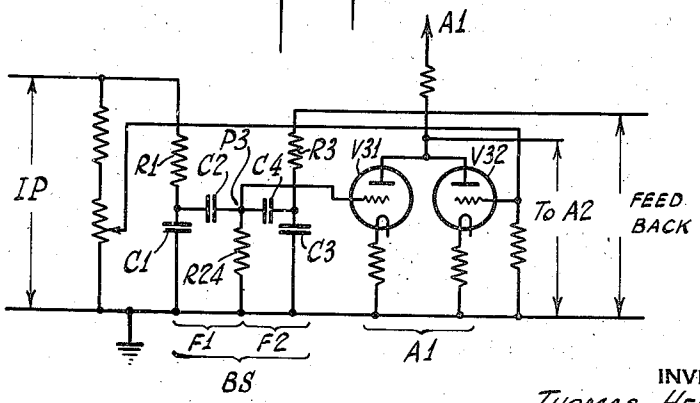


Fig. 3.



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Filed Feb. 2, 1942 2 Sheets-Sheet 2

Fig. 4.

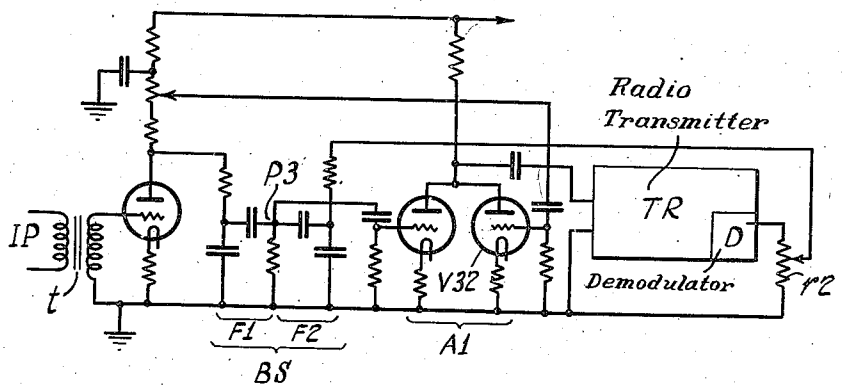
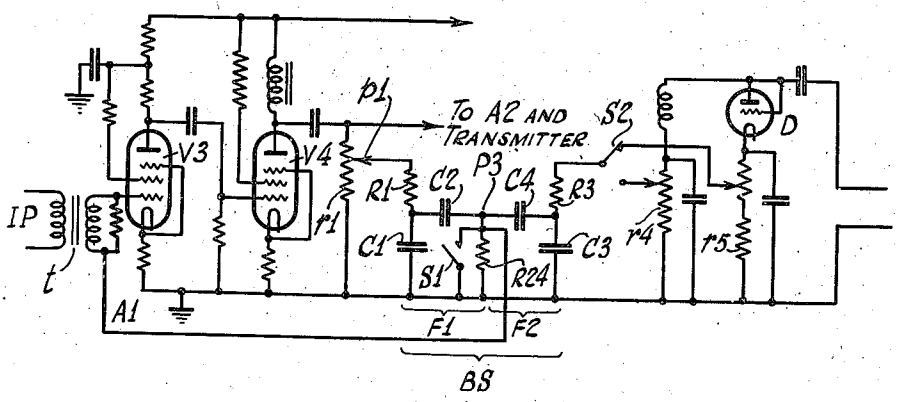


Fig. 5.



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AMPLIFIER CIRCUIT ARRANGEMENT

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5 Claims. (Cl. 179—171)

The present invention relates to amplifier circuit arrangements and provides an improved feed-back arrangement. The invention is particularly applicable to radio-telephone transmitters where it may serve for the reduction of hum caused by heating the valve filaments by alternating current or by insufficient smoothing of the anode supply. It is not, however, so limited.

As an example of the kind of difficulty which the invention may be employed to reduce or overcome, the following may be considered. One of the principal difficulties to be encountered in the application of high level negative feedback to several amplifying stages in cascade is that phase shift occurs and this increases with frequency, until at some relatively high frequency the whole system in the feedback loop oscillates or sings. There is also very often a tendency for the system to oscillate at some very low frequency. Either one or the other of these oscillations invariably sets in before some prescribed level of feedback can be achieved. The invention provides means which postpone the onset of these oscillations until the level of feedback shall be greater than the value to be adopted.

According to the invention, an amplifier system comprises at least a first and a second amplifier-stage in cascade, a source of modulating-signal energy, a first and a second filter, a balancing circuit arrangement having two input circuits, a voltage divider, associated with said source of modulating-signal energy, and including means for applying a portion of modulating-signal energy from said source to the input of said first amplifier stage, means for applying modulating-signal energy from said source to one input circuit of said balancing circuit arrangement through said first filter, means for extracting modulation signal from the output of said second amplifier stage, means for applying said extracted modulation signal to the other input circuit of said balancing circuit arrangement through said second filter, and means including said first amplifier stage for combining in correct phase for the elimination of distortion the output of said balancing circuit arrangement with the output of said first amplifier stage and for applying the combined outputs to the input of said second amplifier stage.

According to a feature of the invention, an amplifier system comprises at least a first amplifier having two input circuits and a second amplifier-stage in cascade, a source of modulating-signal energy, a first and a second filter constituted as a balancing circuit arrangement having two input circuits, a voltage divider associated with said source of modulating-signal energy and including means for applying a portion of said modulating-signal energy from said source to one input circuit of said first amplifier stage, means for applying modulating signal energy from said source to one input circuit of said balancing-circuit arrangement, means for extracting modulation signal from the output of said second amplifier stage, means for applying said extracted modulation signal to the other input circuit of said balancing-circuit arrangement, means for applying the output from said balancing-circuit arrangement to another input circuit of said first amplifier stage and means including said first amplifier stage for combining in correct phase for the elimination of distortion the output of said balancing-circuit arrangement with said portion of modulating-signal energy applied to said one input circuit of said first amplifier stage, and means for applying the energies combined in said combining means to the input of said second amplifier stage.

According to a further feature of the invention, an amplifier system comprises at least a first and a second amplifier stage in cascade, a source of modulating-signal energy, means for applying modulating-signal energy from said source to said first amplifier stage, a first and a second filter constituted as a balancing-circuit arrangement having two input circuits, a voltage divider associated with the output circuit of said first amplifier stage and including means for applying a portion of the amplified modulating-signal energy to one input circuit of said balancing-circuit arrangement, means for extracting modulation signal from the output of said second amplifier stage, means for applying said extracted modulation signal to the other input circuit of said balancing-circuit arrangement, combining means including said first amplifier, for applying the output from said balancing-circuit arrangement to the input circuit of said first amplifier stage for combining in correct phase for the elimination of distortion the output of said balancing-circuit arrangement with the modulating-signal energy applied to the input circuit of said first amplifier stage, and means for applying energies combined in said combining means to the input of said second amplifier stage.

If there are more than two cascaded amplifier stages, the modulation signal may be extracted from the final amplifier stage. If the output of the second or final amplifier stage from which the modulation signal is extracted be modulated r-

rier, a demodulator would be included between the output circuit of said second or final amplifier stage and said second filter.

The balancing circuit may include a thermionic valve having at least two grid-electrodes, the modulating-signal energy being applied through said first filter to one of said grid-electrodes and the extracted modulation signal being applied through said second filter to another of said grid electrodes.

The combining means may include the first amplifier stage and may comprise a valve amplifier having at least a control grid and an anode, the signals to be combined being applied, respectively to the control grid and anode; or it may comprise a valve amplifier having at least a control grid, both signals to be combined being applied to the said control grid; or it may comprise a valve amplifier having at least two grids, the signals to be combined being applied one to one grid and the other to the other; or it may comprise two valve amplifiers each having at least one control grid, the signals to be combined being applied one to the control grid of one valve amplifier and the other to the control grid of the other valve amplifier.

The two filters and the balancing circuit arrangement may take other forms, for instance capacity-impedance (including capacity-inductance-resistance combinations) and their equivalents, for example piezo-electric crystal circuits.

The voltage divider may comprise a potentiometer.

The invention is illustrated in the accompanying drawings of which Figure 1 is a block diagram illustrating the basic principle of the invention, Figure 2 is a circuit diagram of the arrangement of Figure 1, Figures 3 and 5 are circuit diagrams of modified arrangements, and Figure 4 is a circuit diagram illustrating the application of the arrangement of Figure 3 to a transmitter.

In the embodiment of the invention illustrated in Figure 1 and as applied to a two stage cascaded amplifier arrangement, audio-frequency modulating-signal energy is applied over a pair of conductors IP to the two ends of a potentiometer resistor *r1* and to the input end of a first filter network F1 which may comprise resistors and condensers. A portion of the modulating-signal energy, derived from an adjustable tapping point *p1* on the potentiometer resistance, is applied to the input circuit of a first amplifier stage A1. The output of the first amplifier stage is applied to the input circuit of a second amplifier stage A2, and the output of this second amplifier stage is applied to a suitable load circuit which, for convenience may be regarded as a resistor *r2*. Amplified modulating-signal energy appears across this resistor. By means of an adjustable tapping point *p2* on this resistor a portion of the modulating-signal energy, of a desired amplitude, is applied to the input end of a second filter network F2, which, like the first filter network, may comprise resistors and condensers, and which has the same characteristic as the first filter network. The output of the first filter network F1 is applied between one grid and the cathode of an amplifier (not shown) and the output of the second filter network F2 is applied between another grid and the cathode of this amplifier, the amplifier constituting a balancing circuit BS. The balancing circuit BS must, of course, satisfy the requirement that zero output be obtained for all amplitudes and opposite phases applied to the two filters. The output of BS is applied to the first amplifier stage A1.

A detector D may be required, as will be seen later.

In the circuit arrangement illustrated in Figure 2, modulating-signal energy is applied, by means of a transformer *t* to the grid-cathode space of a valve amplifier VA which has, in its anode circuit, a series of resistors including potentiometer resistor *r1*. The output of the valve amplifier VA is fed to the first filter F1 which includes resistor R1 and condenser C1 in series in the anode/cathode circuit of valve-amplifier VA and condenser C2 and resistor R2 in series across condenser C1. The junction point of C2 and R2, and the junction point of C1 and R2 constitute the output terminals of the first filter F1.

(It should here be observed, that stage A1, though not necessarily the first amplifier stage in the transmitter considered as a whole, is the first amplifier stage with which the invention is directly concerned.)

The output of filter F1 is applied between the grid and cathode of one valve V1 of a balancing circuit BS.

A portion of the modulating-signal energy, derived from an adjustable tapping point *p1* on the potentiometer resistance, is applied to the input circuit of a first amplifier stage A1. The output of the first amplifier stage is applied to the input circuit of a second amplifier stage A2, and the output of this second amplifier stage is applied through further stages to a resistor *r2*. Amplified modulating-signal energy appears across this resistor. By means of an adjustable tapping point *p2* on this resistor a portion of the modulating-signal energy, of a desired amplitude, is applied to the input end of a second filter network F2 which is constructed like the first filter network and includes resistor R3 and condenser C3 in series and condenser C4 and resistor R4 in series across condenser C3. The junction point of C4 and R4, and the junction point of C3 and R4 constitute the output terminals of filter network F2. The output of filter F2 is applied between the grid and cathode of the other valve V2 of the balancing circuit BS.

The anodes of valves V1 and V2 are connected together through resistor *r3* and, by tapping point *p3* to the anode of valve V3 which constitutes the first amplifier stage and also the means for combining the forward and backward fed energies. As the anodes are joined together, and to the anode of valve V3, the only output from V1 and V2, which joins with the output of valve V3, is the difference between the forward and backward fed signals of valves V1 and V2.

If there be hum or spurious effects on the backward fed signal, this is amplified and passed on with the output of valve V3 to give the desired suppression of such hum or spurious effects. The simple and limited filtering obtained with a C and R combination has the advantage that the maximum phase shift which they produce cannot exceed 90°, whereas many types of filters produce greater phase shift. Filters or frequency discriminators having no phase shift when their filtering comes on would be the ideal, but this is impossible with present day types. The values of the resistance and capacity must be so chosen that the phase shift for the forward signal fed forward to the grid of valve V1 is equal to the phase shift experienced by the signal fed back to the grid of valve V2.

In the arrangement of Figure 3, the two filters, in addition to acting as such, act also as the balancing circuit arrangement. It will be seen that the two resistors R2 and R4, and the two valves V1 and V2, of Figure 2 are replaced by a common resistor R24. Figure 3 shows, also a modified first amplifier stage A1 wherein two valves V31 and V32 replace valve V3 of Figure 2. The portion of the modulating-signal energy which, in Figure 2, is applied to the grid of valve V3 is, in Figure 3, applied to the grid of valve V32, and the output from the balancing circuit, which in Figure 2, is obtained from point *p3* on resistor *r3* and is applied to the anode of valve V3 is, in Figure 3 obtained from point P3 and is applied to the grid of valve V31. As, in Figure 2, valve V3 served for combining or mixing the forward and backward fed energies, so, in Figure 3, valves V31 and V32, or rather their common output, serve this purpose. Apart from these differences the arrangement of Figure 3 is similar to that of Figure 2.

Figure 4, which, in all essentials connected with the invention is identical with Figure 3, indicates, that where the output from amplifier stage A1 is applied to a radio (or like carrier) transmitter TR, a demodulator, indicated at D, is fed with modulated-carrier energy where modulation signal for feed back purposes is extracted and applied to resistor *r2*.

Figure 5 illustrates a further modification. A study of Figure 4 shows that for a high level of feedback, the useful portion of the forward input signal applied to V32 is only a part of the signal developed by the first valve. But a high level of signal is required for the purpose of effecting high level feedback. In the arrangement of Figure 4 there is a sacrifice of gain, which may or may not be important.

The arrangement of Figure 5 effects an improvement in that there is no sacrifice of gain. Valves V3 and V4, shown as pentode valves, but which may be other types, amplify the input signal, and the output from V4 is passed to the second amplifier stage of the transmitter. The demodulator D receives a modulated signal from the transmitter and the extracted modulation signal of the correct phase is obtained from either resistor *r4* or resistor *r5* by means of switch S2. This signal is applied to the resistance R3 of the filter F2 which as in Figure 3 forms part of the balancing circuit. The components of the filters F1 and F2 are so chosen that, for the required level of feedback, over some given modulation frequency band, no oscillation around the amplifiers and transmitter can occur. The tapping point *p1* on resistor *r1*, connected across the output of valve V4, is adjusted so that no change of amplification of the system occurs with switch S1 open or closed; that is, the feedback is operative on only the spurious effects arising in the transmitter. The output from the filters and combining circuit is fed by way of transformer *t* from P3 whence it is applied, together with the modulating signal energy, to the grid of valve V3, constituting with valve V4 the first amplifier stage, and also serving as the mixer. It will be seen that the first amplifier stage, in this arrangement precedes the filter and balancing circuit.

The amplitude and phase of the signals applied to the balancing circuit are so adjusted that, were there no distortion of the modulating-signal energy as it passed through the amplifier stages, there would be no output from the balancing circuit. As, however, the signal energy is so distorted, the distortion signal appears in the output of the balancing circuit and is fed back to the input of the amplifier, where it is amplified (in valves V3 and V4) together with the normal modulation signal and passed on to A2. The system thus provides a high-level negative feed-back for the elimination or reduction of hum and distortion generally.

It may be observed that without the filters it would be impossible to effect high level feed-back by balancing the forward and feedback signal in a balancing stage or network. The reason for this is that when a number of valve amplifiers are connected in cascade phase shifts of the modulating signals occur in traversing the amplifiers, the phase shift being at its worst and constituting a major difficulty for frequencies below the lower limit of audio frequencies, and again beyond some relatively high value of modulating frequency or its harmonics. The result is, that at these frequencies a practical balance of the forward and feedback voltages, even with zero distortion and no spurious frequencies, is impossible owing to phase difference. In consequence of the phase shift around the amplifier stage and feedback loop, the system would oscillate around this loop before that level of feedback could be obtained which is necessary for the required attenuation of spurious effects, particularly with alternating current energising of the filaments of the amplifiers. The function of the filters is to provide high attenuation to the loop oscillation voltages which would occur without the filters, and also to provide sufficient attenuation to modulating, and harmonics of modulating, frequencies which experience such phase shifts in traversing the system that they would in the absence of filters produce undesirable effects on the frequency response and/or the distortion of the modulation signal in the output of the transmitter.

The invention is the result of considering the requirement in a complete transmitter, particularly with alternating current lighting of the filaments with the consequential need of high level feed-back to bring the hum down to acceptable values. With a transmitter consisting of several audio frequency stages and one or more stages of radio frequency amplification, the phase shift problem of the transmitter itself, and the high level of feedback required with alternating current filament lighting, together with the fact that present day filters themselves introduce some phase shift before providing great attenuation, actually results in the condition that the high level of feedback obtains only over the lower end of the audio frequency spectrum. But with simple filter networks consisting of resistance and capacity it has been demonstrated that between 30 and 40 decibels of feedback over the range of hum frequencies can be obtained when the filament energising is with 50 cycles per second current. If the level of feedback be allowed to be lower, a suitable adjustment of the filter components will effect a wider frequency range of feedback to deal with distortion over a wider band of modulating frequencies.

The invention is susceptible of modification. Thus one loop, incorporating all, or a large number, of the stages of a transmitter, which introduce mains hum, and a feed-back circuit both as above described may be so arranged as to provide a high level of feed-back, with its concomitant narrow frequency band of feed-back. A sec-

ond loop may be used, incorporating fewer stages and preferably (though not necessarily) the later stages and a feed-back circuit as above described so designed as to give a wider effective frequency band of feed-back. With such an arrangement the necessary effective feed-back for the provision of a carrier substantially free from hum and a modulation of high fidelity is obtained. The width of frequency band of feed-back may of course be controlled by suitable choice of the electrical dimensions of the elements of the filters.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed I declare that what I claim is:

1. An amplifier system comprising at least a first and a second amplifier stage in cascade, a source of modulating-signal energy, a first and a second filter, a balancing circuit arrangement having two input circuits, a voltage divider associated with said source of modulating-signal energy and including means for applying a portion of modulating-signal energy from said source to the input of said first amplifier stage, means for applying modulating-signal energy from said source to one input circuit of said balancing circuit arrangement through said first filter, means for extracting modulation signal from the output of said second amplifier stage, means for applying said extracted modulation signal to the other input circuit of said balancing circuit arrangement through said second filter, and means including said first amplifier stage for combining in correct phase for the elimination of distortion the output of said balancing circuit arrangement with the output of said first amplifier stage and for applying the combined outputs to the input of said second amplifier stage.

2. An amplifier system comprising at least a first amplifier having two input circuits and a second amplifier stage in cascade, a source of modulating-signal energy, a first and a second filter constituted as a balancing-circuit arrangement having two input circuits, a voltage divider associated with said source of modulating-signal energy and including means for applying a portion of said modulating-signal energy from said source to one input circuit of said first amplifier stage, means for applying modulating signal energy from said source to one input circuit of said balancing-circuit arrangement, means for extracting modulation signal from the output of said second amplifier stage, means for applying said extracted modulation signal to the other input circuit of said balancing-circuit arrangement, means for applying the output from said balancing-circuit arrangement to another input circuit of said first amplifier stage and means including said first amplifier stage for combining in correct phase for the elimination of distortion the output of said balancing-circuit arrangement with said portion of modulating-signal energy applied to said one input circuit of said first amplifier stage, and means for applying the energies combined in said combining means to the input of said second amplifier stage.

3. An amplifier system comprising at least a first and a second amplifier stage in cascade, a source of modulating-signal energy, means for applying modulating signal energy from said source to said first amplifier stage, a first and a second filter constituted as a balancing circuit arrangement having two input circuits, a voltage divider associated with the output circuit of said first amplifier stage and including means for applying a portion of the amplified modulating-signal energy to one input circuit of said balancing-circuit arrangement, means for extracting modulation signal from the output of said second amplifier stage, means for applying said extracted modulation signal to the other input circuit of said balancing circuit arrangement, combining means including said first amplifier for applying the output from said balancing-circuit arrangement to the input circuit of said first amplifier stage for combining in correct phase for the elimination of distortion the output of said balancing-circuit arrangement with the modulating-signal energy applied to the input circuit of said first amplifier stage, and means for applying energies combined in said combining means to the input of said second amplifier stage.

4. A method of amplifying signals to eliminate distortion which includes amplifying the signals, subjecting a portion of the signals to separate amplification, phase shifting the separately amplified signals, combining the phase shifted signals with the first amplified signals, deriving a portion of the combined signals, and combining the last portion with the separately amplified signals.

5. A method of amplifying signals without distortion which includes the steps of subjecting the original signals to a predetermined phase shift, subjecting a predetermined portion of the original signals to a separate phase shift equal to the first phase shift, amplifying the two phase shifted signals in such relative amplitude and phases that in the absence of distortion of the original signals the output is zero, and balancing the last-named amplified signals against the said predetermined portion of the signals thereby to eliminate any distortion in the original signals.

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