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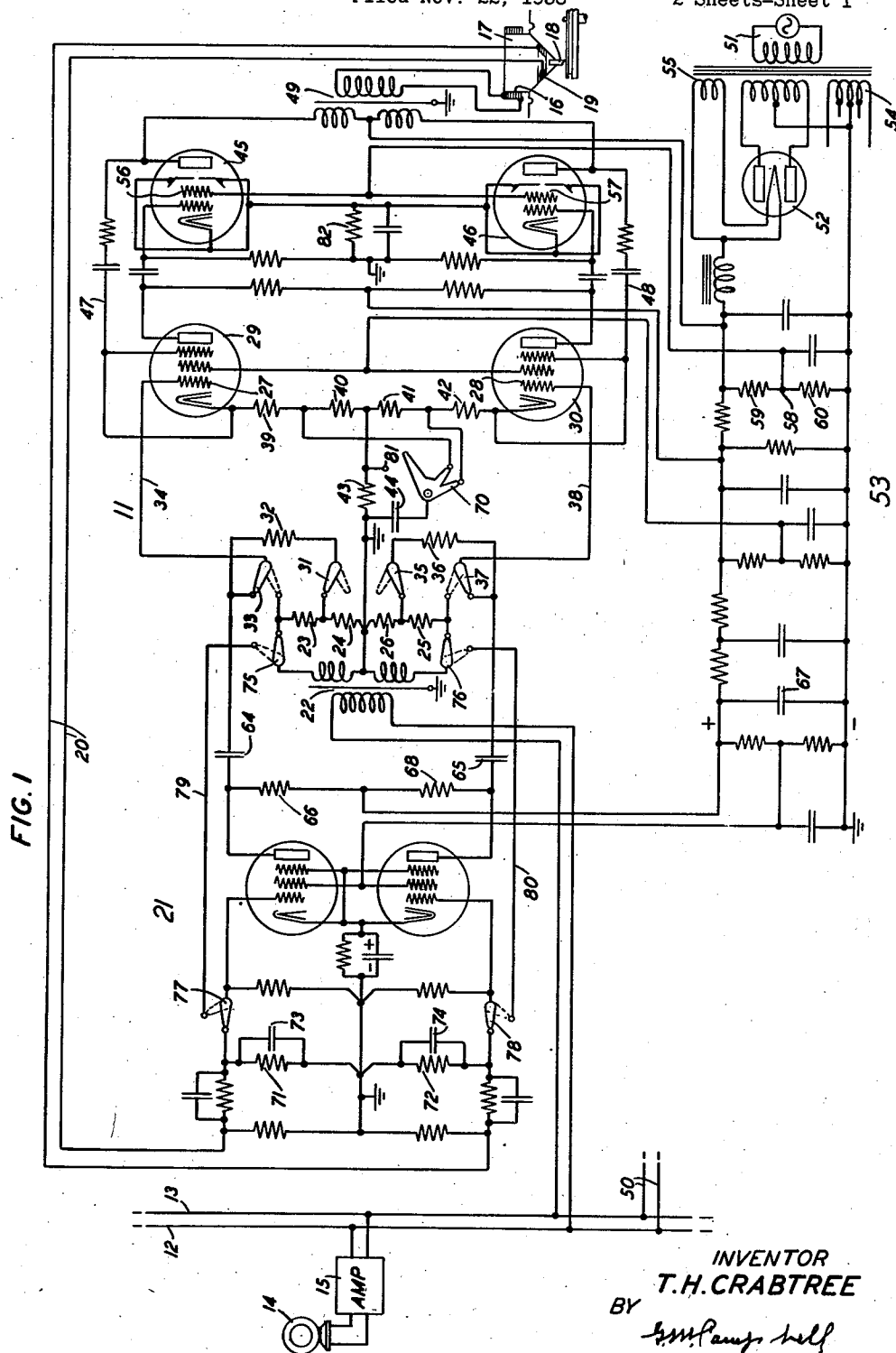
T. H. CRABTREE

2,266,168

AMPLIFIER

Filed Nov. 22, 1938

2 Sheets-Sheet 1



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FIG. 2

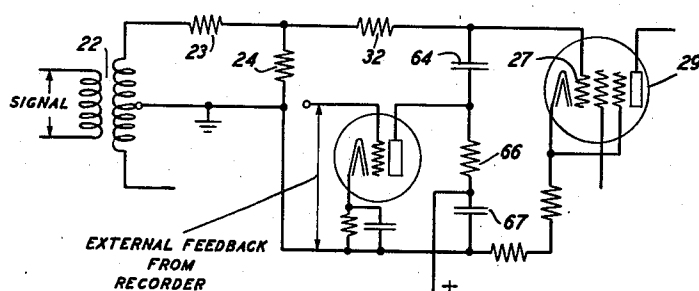
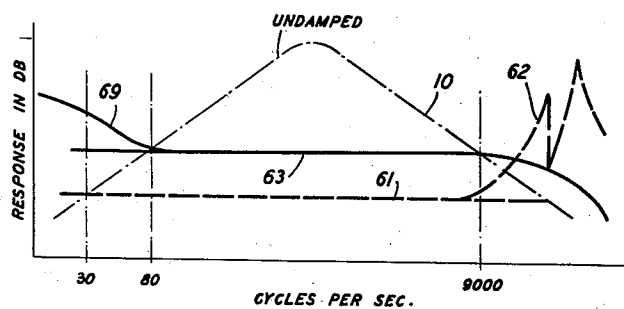


FIG. 3



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AMPLIFIER

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5 Claims. (Cl. 179-171)

This invention relates to amplifiers, particularly to amplifiers for sound recording systems and the object of the invention is an amplifier capable of use with recorders of different types.

Many of the recorders commonly used require merely that the driving amplifiers shall be capable of providing the desired output level and of transmitting a wide band of frequencies at uniform efficiency. The requirements for an amplifier to drive recorders of the feedback type are however much more stringent so that an amplifier for general recording purposes must be capable of being modified in several important respects with minimum loss of time.

According to this invention, when the amplifier is being used to drive a recorder of the negative feedback type, one or more stages may be used exclusively for amplifying the energy fed back to the input of the remaining stages on which the signals to be recorded are impressed. In this manner a very high degree of negative feedback is obtained with the result that the recorder may have a flat response over a very wide range of frequencies and amplitudes.

Switching means or strapping connections are provided in various portions of the circuit so that when the recorder to be driven is not of the feedback type, the feedback portion of the amplifier may be cut out or connected in such a manner as to increase the gain of the amplifier.

When sufficient negative feedback is used to obtain a recorder characteristic which is flat over a very wide frequency range it is very difficult to keep the phase shift around the feedback loop small enough to prevent the feedback from becoming positive at high frequencies. According to a feature of this invention, in order to increase the stability of the amplifier at high frequencies, less feedback is used than is required for producing a flat response down to the lowest frequencies in the band of interest. The low frequency deficiency is then corrected by making the signal amplifier more efficient in this portion of the range. This increased efficiency is conveniently obtained without additional circuit elements by a proper proportioning of the coupling impedances between the feedback and signal amplifiers.

Alternatively, or as an additional precaution against instability, positive feedback at frequencies above the band of interest may be decreased or eliminated by shunting the feedback path with a condenser of such small capacity as to have only slight effect on transmission within the band of interest but a relatively low impedance for the

higher frequencies which tend to produce instability.

The output stage of the amplifier preferably comprises one or more self-biased pentodes of the beam tube type. Applicant has found that with circuits commonly used for these tubes the average screen current increases considerably with increasing applied signal voltage. The resulting increase in cathode current increases the grid bias and reduces the plate current. This reduction of plate current not only reduces the output capacity of the amplifier but also results in the tube operating on a portion of its characteristic where the harmonic distortion is greater than it is for operation at maximum plate current.

An important feature of this invention consists in so regulating the potential applied to the screen grids of the output tubes that the screen current varies with the applied signal in such a manner that the cathode current, which is the sum of the screen and plate currents, is substantially the same for all inputs up to full signal condition.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawings in which:

Fig. 1 is a circuit diagram of an amplifier according to this invention;

Fig. 2 shows a portion of the circuit of Fig. 1 rearranged to illustrate more clearly the feature of selectively amplifying the lower frequencies; and

Fig. 3 shows the response curves of a typical feedback recorder.

In Fig. 1 the amplifier shown comprises a main amplifier 11 operating from recording bus-bars 12, 13 which are energized at a suitable level from any desired input circuit such, for example, as a pick-up microphone 14 and preliminary amplifier 15. The output of the amplifier 11 is impressed on the driving coil 16 of a disc recorder 17 which may be of the type shown in Patent 2,161,489, granted to L. Vieth et al. June 6, 1939.

The coil 16 of the recorder drives the stylus 18 to cut a record and simultaneously generates in the coil 19 a voltage proportional to the velocity of the stylus. This voltage is fed back over the conductors 20 to the input of the negative feedback amplifier 21 the output of which is impressed on the input of amplifier 11 along with the incoming signals from the recording bus-bars 12, 13 and reduces the resonant response of the recorder to a flat characteristic in the manner which is in general now well understood in the art.

Coming now to a more detailed description of the circuit, the signals from the recorder bus-bars are impressed on the primary of the transformer 22 the divided secondaries of which are shunted by resistors 23, 24 and 25, 26 respectively. The portions of the secondary potential existing across resistors 24 and 26 are impressed on the grids 27 and 28 of the push-pull tubes 29 and 30 over the circuits including switch 31, resistor 32, switch 33 and conductor 34 and switch 35, resistor 36, switch 37 and conductor 38 respectively.

The tubes 29 and 30 are self-biased by the individual resistors 39, 40 and 41, 42 and also by the common resistor 43, resistors 40, 41 and 43 being by-passed for signal currents by the condenser 44. The outputs of tubes 29 and 30 are resistance-capacity coupled in the well-known manner to the beam tubes 45 and 46 which are self-biased by the common cathode resistor 82, and the output of these latter tubes drives the recorder 17 as already explained. Internal negative feedback connections, 47 and 48 extending from the plates of tubes 45 and 46 to the cathodes of tubes 29 and 30 to reduce the noise and distortion of the amplifier and to reduce the effective output impedance of the beam tubes to a value which more nearly matches the primary impedance of the output transformer 49 in the manner well understood in the art.

Since at times other recording systems may be operating from the bus-bars 12 and 13 over circuits such as 50, it is necessary to prevent the negative feedback energy impressed on the inputs of the tubes 29 and 30 from being reflected back through the transformer 22 to the bus-bars. This is accomplished by making the value of resistors 23 and 25 of the order of ten times the value of resistors 24 and 26 so that the circuit back to the bus-bars presents a high impedance to reflected currents. While this portion of the circuit also attenuates the incoming signal, that is not a serious objection in systems of the type shown since the energy level at the bus-bars is ordinarily quite high.

The amplifier is energized from the alternating current supply 51 by means of the usual rectifier 52 and filter network 53, the tube filament circuits (not shown) being connected to suitable taps on the winding 54 of the transformer 55. It will be noted however that the screen grids 56 and 57 of the beam tubes 45 and 46 are connected to the point 58 between resistors 59 and 60 which comprise a bleeder circuit across the output of the filter 53. The manner in which these resistors are proportioned to give improved operation of the amplifier will now be described.

Applicant has found that when beam tubes or other power pentodes are operated with a given plate supply voltage into a given load impedance, there are optimum screen grid and cathode bias voltages which give maximum power output and minimum harmonic distortion. In conventional beam tube circuits however, the screen grid voltage which largely determines the plate current, falls off so much at full signal that the plate current is materially reduced thereby decreasing the output capacity and causing the tubes to operate at a point on the grid voltage-plate current characteristic, where the distortion in the output is considerably increased.

It is, of course, well known that the plate current in these tubes depends on the screen voltage to a greater degree than on the plate voltage and the screen grid is therefore usually connected to the voltage source through a resistor which limits

the screen current and improves the regulation. Best results are not obtained however by a very close regulation of the screen voltage for although a constant screen potential tends to maintain the plate current, the screen current at full signal is greatly increased. This results in a considerable increase in the cathode current and hence an increase in the bias on the control grid. The increased grid bias in turn will decrease the plate current at full signal and the amplifier is again operating with reduced capacity and increased harmonic distortion as in the case where the screen potential regulation is poor.

In applicant's circuit the screen grid is at the potential of the point 58 which is determined by the potential drop in resistor 59 due to the sum of the screen currents and the current in resistor 60. As the screen current increases with increasing signal the potential of point 58 will be decreased due to the larger potential drop in resistor 59 and by proper choice of the values of resistors 59 and 60 the screen potential can be made to vary in such a manner that the increase in screen current from no signal to full signal compensates for the decrease in plate current thereby keeping the cathode current and grid bias for each tube constant.

In general this involves the use of resistors low enough to pass a bleeder current which is large as compared with the screen current. For example, when using beam tubes of one well-known type with a plate voltage of about 400 volts and screen voltage of about 210 volts at no signal, resistor 59 may be 5800 ohms, resistor 60 may be 7000 ohms in which case the bleeder current is about 40 milliamperes and the total screen current of about 4 milliamperes. The procedure for determining the resistor values required in a given case is first to determine the grid bias necessary for the desired plate current at full signal with a given screen potential, then measure the cathode current and determine the screen potential which gives the same cathode current at no signal. Having determined the differences between the screen potentials and screen currents at full signal and no signal, respectively, the value of resistor 59 necessary to produce this variation is determined by dividing the difference in the screen voltages by the difference in the screen currents for the two conditions. The value of resistor 60 is then readily determined since it must be the same fraction of the total bleeder resistance that the no signal screen voltage is of the output voltage of the filter.

An amplifier regulated in this manner not only has higher maximum output capacity and lower harmonic distortion than conventional circuits but it also has a further advantage particularly in circuits using negative feedback. When a negative feedback amplifier is energized from a rectifier which has poor regulation, sudden changes in load on the rectifier set up transients in the amplifier which cause blocking and "motor-boating." The current supplied to the output stage of an amplifier comprises a very large proportion of the total load on the rectifier but in this circuit the current to the output stage is substantially constant. The output voltage of the rectifier will therefore vary only slightly for large changes in signal level and the amplifier is consequently much more stable in its operation.

In Fig. 3 of the drawings curve 10 represents a typical undamped response characteristic of a recorder of the type indicated at 17 in Fig. 1. It will be noted that such a recorder should be

of the singly resonant type preferably with the resonant peak occurring slightly above geometric mean frequency of the range of interest. If, for example, the recorder is to have a flat response for frequencies from 9000 cycles down to 30 cycles per second, this result may be obtained by using sufficient negative feedback to reduce the recorder response to the line 6. When such a large amount of feedback is used over such a wide frequency range, however, it is very difficult to prevent the feedback from becoming positive for frequencies near and beyond the upper limit of the band and hence the recorder develops an irregular rising characteristic 62 and becomes unstable at these high frequencies. The resonant frequency of the recorder is usually fixed by other considerations within the range of about 900 to 1000 cycles so that the amount of feedback used can usually be considerably less than the value corresponding to curve 61 without impairing the flat response up to the upper limiting frequency of interest. For example, in the case shown the response may be reduced only to the line 63 which is flat over the upper portion of the desired range but definitely drooping above the limiting frequency and therefore much more stable. It will be seen, however, that reducing the amount of feedback to insure stability at high frequencies also results in a drooping characteristic over the lower frequency range, such as between 80 and 30 cycles per second, which is part of the transmission band.

In the circuit of Fig. 1 condensers 64 and 65 in the output of the feedback amplifier 21 are of such capacity that their impedances for all frequencies in the transmission band are low as compared with the impedances of resistors 24, 32 and 26, 36 shunting the inputs to the tubes 29 and 30 of the main amplifier 11. Under this condition as is well understood in the art, the transmission characteristic of the coupling between the feedback amplifier 21 and the main amplifier 11 will be substantially flat over the transmission band. The condensers 64 and 65, however, as will be seen more clearly from Fig. 2, are also parts of shunt paths across the inputs of tubes 29 and 30 of amplifier 11. Condenser 64, resistor 66 and condenser 67 of the rectifier filter network form a path from the grid 27 of tube 29 to the grounded cathode and similarly condenser 65, resistor 68 and condenser 67 from a path across the input of tube 30.

Condensers 64 and 65 will ordinarily be of the order of .02 microfarad and condenser 67 of the order of 8 microfarads so that the impedance of condenser 67 is negligible as compared with the other elements of the shunt paths. A signal impressed on the primary of transformer 22 will produce a potential across resistors 24 and 26 and these potentials are impressed on the shunt paths referred to above through resistors 32 and 36, respectively. Since the impedance of the condensers 64 and 65 increases with decreasing frequency the proportion of the signal potential applied to the grids of the tubes 29 and 30 will be progressively greater as the frequency decreases and the signal path will have a rising low frequency characteristic as indicated by the curve 69 in Fig. 3.

By proper choice of the values of the condenser and resistors this increase in the efficiency of transmission may be made of the proper magnitude to compensate substantially for the drooping characteristic of the undamped recorder at these frequencies so that as shown the flat re-

sponse with feedback is extended down to the lowest frequency of interest. It will be clear from the foregoing explanation that this required correction at low frequencies may be obtained without impairing the feedback circuit transmission characteristic by using coupling condensers 64 and 65 of such capacity that their impedances over the frequency range in which compensation is required is greater than the impedance of resistor 66 shunting the feedback amplifier to give increased signal transmission at low frequencies but less than the impedance of resistors 32 and 24 to keep the feedback transmission substantially constant.

If for any reason it is impractical to make the amplifier sufficiently stable at high frequencies by reducing the amount of negative feedback used and compensating for a drooping characteristic in the manner just described, the resistors 71, 72 in the input of the feedback amplifier may be shunted by condensers 73, 74 of the order of .001 mfd. to .006 mfd. capacity. Such condensers are of such high impedance as to have a very small effect on transmission for frequencies within the band of interest but low enough in impedance, for frequencies above the transmission band where the feedback is positive, to reduce transmission around the feedback loop to a level which does not make the amplifier unstable.

When the recorder to be driven is not of the feedback type the feedback amplifier may be readily disconnected by operating switches 33, 31, 35 and 37 to their dotted positions. In this case energy cannot be fed back to the bus-bars and the full potential across the secondaries of transformer 22 may therefore be impressed directly on the grids of tubes 29 and 30 through the switches 33 and 37. A part or all of the increased over-all gain due to the elimination of external feedback and to the use of the full voltage across the secondaries of transformer 22 may be utilized, if desired, to reduce distortion by increasing the internal negative feedback in the amplifier 11. The switch 70 in the position shown connects the cathode resistors 39 and 42 to ground through condenser 44 thereby bypassing the signal currents around resistors 40, 41 and 43 and leaving only resistors 39 and 42 effective to impress negative feedback voltages on the grids of tubes 29 and 30. By closing the switch 70 on contact 81 only resistor 43 is bypassed and the alternating potentials developed across resistors 40 and 41 are also impressed on the grids of tubes 29 and 30 thereby increasing the negative feedback and correspondingly reducing the over-all noise and distortion.

When the recorder used is not of the feedback type and more gain is required than can be obtained satisfactorily in the amplifier 11, the feedback amplifier 21 may be used in the signal circuit. In this case switches 33 and 37 are left in the positions shown, switches 31, 35 and 75 to 78 are moved to their dotted positions and switch 70 is operated to either position in accordance with the gain and distortion requirements of the particular case as described above. Signals applied to the transformer 22 are then fed over conductors 79, 80 to the input of amplifier 11 through switches 33 and 37.

It will therefore be seen that this amplifier is well adapted for use as a general purpose recording amplifier and that the circuit may be readily changed to meet the requirements of recorders of different types. While the inven-

tion has been described for purpose of illustration with reference to a particular circuit it will be understood that it may be modified in various ways within the scope of the following claims.

What is claimed is:

1. In an amplifying system, a source of signals, a resonant receiving device, a signal amplifier connecting the source to the device, means for generating a voltage proportional to the response of the device, a feedback circuit including an amplifier for impressing the voltage on the input of the amplifier to make the response of the device uniform over a predetermined frequency range and a condenser coupling the feedback amplifier to the signal amplifier and forming with the output of the feedback amplifier a shunt across the input of the signal amplifier, the capacity of the condenser being proportioned with respect to the impedance of the input of the signal amplifier and the output of the feedback amplifier so as to give a flat frequency transmission characteristic in the feedback circuit and a non-linear frequency transmission characteristic through the signal amplifier to compensate for the characteristic of the receiving device below the frequency range in which the response is made uniform by the feedback circuit.

2. An amplifying system comprising a source of signal currents, a receiving device, a signal amplifier having an input circuit connected to said source and an output circuit connected to the receiving device, a second amplifier having an input circuit and an output circuit connected to the input of the signal amplifier, means for selectively connecting the input of the second amplifier either to the receiving device to feed back to the signal amplifier a voltage proportional to the response of the device to reduce the distortion in the output of the device or between the source of signal currents and the signal amplifier to increase the gain of the system, and means for producing negative feedback in the signal amplifier to utilize the increased gain of the system to reduce the distortion in the signal amplifier.

3. In an amplifying system, a source of current, a resonant receiving device, an amplifier having an input circuit connected to the source and an output circuit connected to the device, means associated with the device for generating electric currents of an amplitude varying with the response of the device, a negative feedback circuit connecting said means to the input of the

amplifier for reducing the resonant response of the device to a flat characteristic over a predetermined frequency range, said circuit including reactive elements of such value that the feedback becomes positive for frequencies above said range and tends to cause instability in the operation of the amplifier, and a condenser connected across the feedback circuit of such small capacity as to have only slight effect on the transmission of frequencies within the range of resonant response of the device, but to substantially reduce transmission of the frequencies tending to cause instability.

4. In an amplifying system, a source of signal currents, a resonant receiving device, an amplifier having an input circuit connected to the source and an output circuit connected to the device, means associated with the device for generating electric currents of an amplitude varying with the response of the device, a circuit conducting the generated currents to the input of the amplifier in phase opposition to the signal currents and producing the maximum negative feedback action consistent with stable operation whereby the resonant response of the device is reduced to a substantially flat characteristic over a frequency range extending from a frequency within the band to be transmitted up to the upper limit of the band, means in said circuit for reducing transmission for frequencies above said range and coupling elements between the circuit and the amplifier having a flat transmission characteristic for the generated currents for selectively increasing the transmission through the amplifier for currents from the source of frequencies below said range and producing a flat characteristic down to the lower limit of the band.

5. In an amplifying system, a source of signal currents, bus-bars connected to said source for distributing the currents, a signal amplifier having input and output circuits, a connecting circuit between the bus-bars and the input circuit and a feedback circuit connected to the input circuit and carrying currents varying in amplitude with the output of the amplifier, said connecting circuit having a shunt impedance and a high series impedance connecting a small portion of the shunt impedance across the input of the amplifier, whereby said connecting circuit presents a high impedance between the feedback circuit and the bus-bars.

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