

Sept. 5, 1944.

K. SINGER

2,357,696

SOUND RECORDING COMPRESSOR METHOD AND SYSTEM

Filed Oct. 13, 1941

2 Sheets-Sheet 1

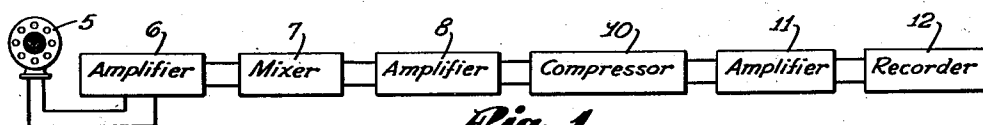


Fig. 1.

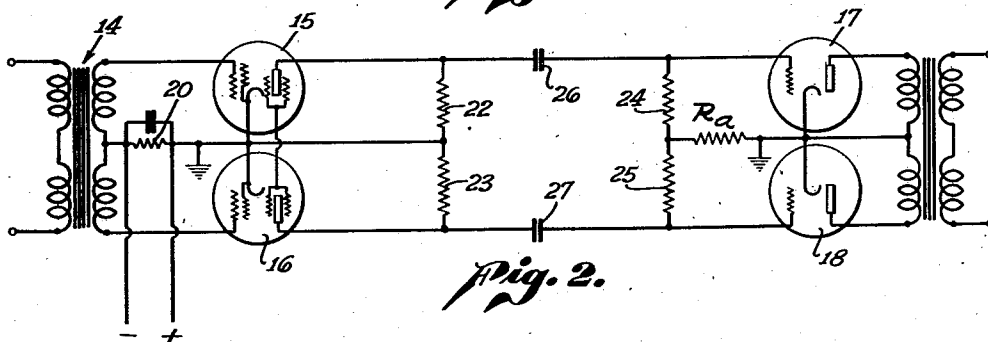


Fig. 2.

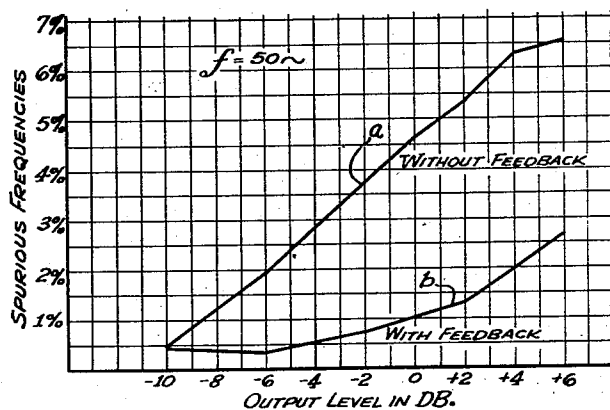


Fig. 4.

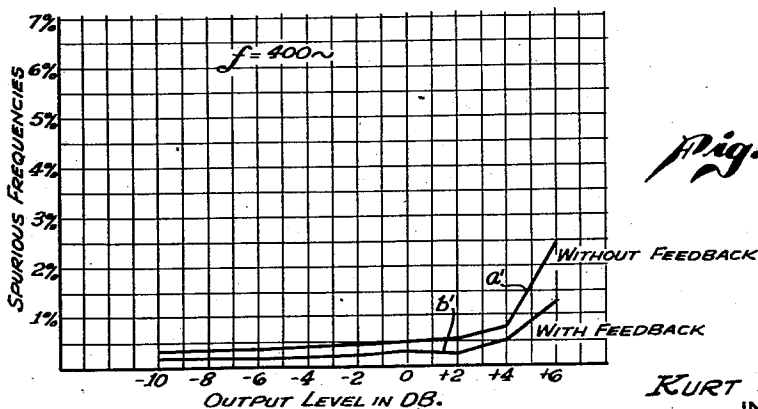


Fig. 5.

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2 Sheets-Sheet 2

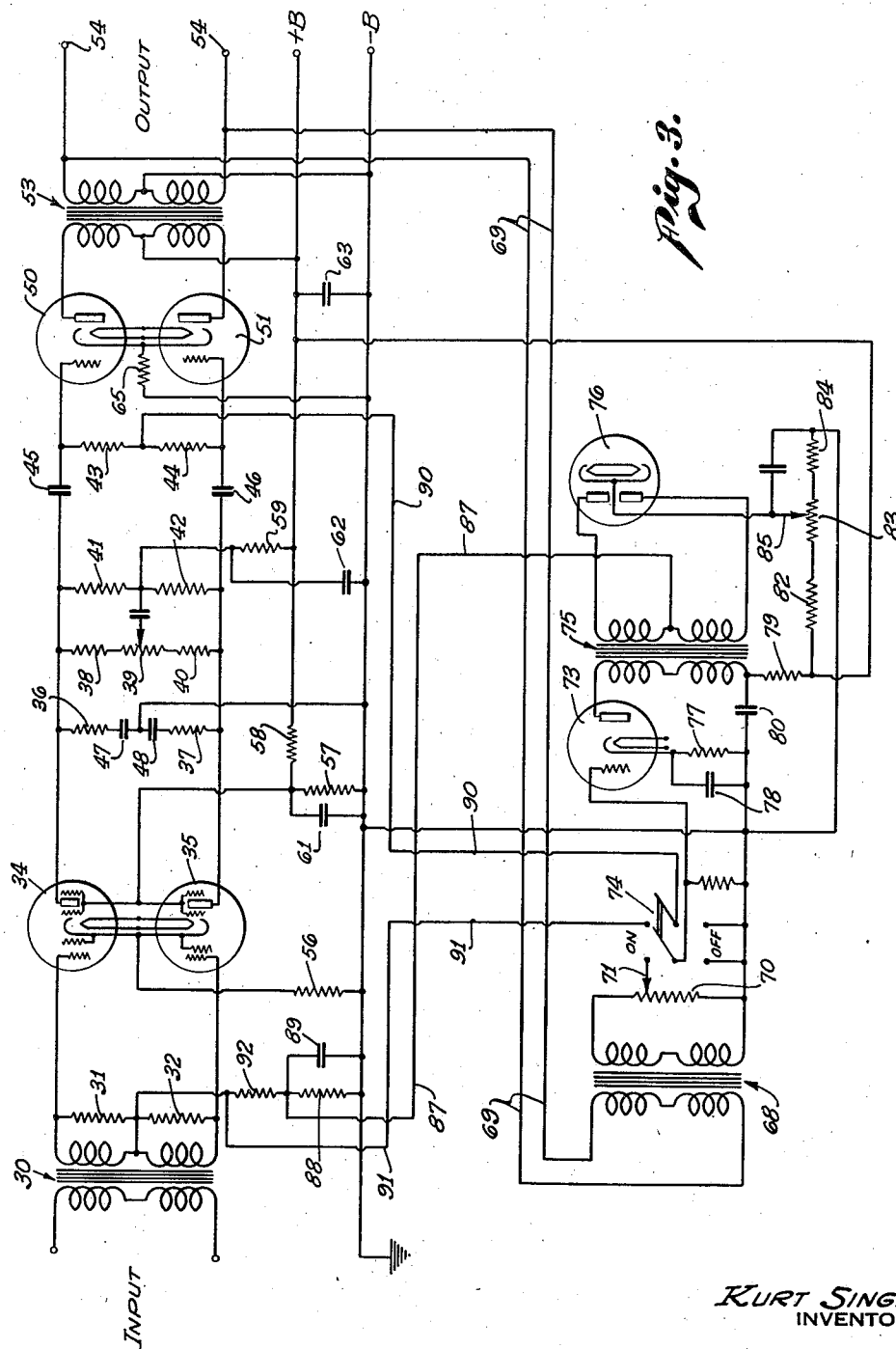


Fig. 3.

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UNITED STATES PATENT OFFICE

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SOUND RECORDING COMPRESSOR METHOD
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8 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to sound recording systems wherein automatic control of the gain or attenuation of a signal are obtained.

The electrical transmission portion of sound recording systems generally includes amplifiers, one unit of which may be a variable gain amplifier operating as a compressor for producing a narrow recorded range from a wider original range. The variable gain amplifiers employed are generally embodied in a push-pull arrangement to provide better transmission characteristics, a portion of the signal being amplified, rectified and used to vary the gain of the amplifiers. In the use of such push-pull compressors, it has been found that they require a very careful matching of the amplifier tubes and a careful balance of the other elements in the system such as the coupling condensers and resistors in order to prevent thump and longitudinal currents from being introduced into the signal.

The present invention is directed to a modification of the standard type of balanced compressor circuit wherein any original unbalance or any unbalance subsequently occurring during operation will not be detrimental to the transmission of the signal or cause distortion thereof during changes in gain of the variable gain amplifier. The signal is transmitted as transverse voltages, while the gain control potentials are introduced into the system as longitudinal voltages. Longitudinal voltages will be neutralized only if and when the entire circuit is balanced, and any unbalance will permit these voltages to be introduced into the signal.

The type of system to which the invention is applicable is disclosed in my Patent No. 2,255,683, of September 9, 1941.

Constant gain push-pull amplifier circuits have had incorporated therein feedback arrangements for reducing the even order distortion products developed within the amplifier tubes themselves due to differences in the plate characteristics of the tubes especially when operated to the full extent of their capacity. Such a system is disclosed in Green Patent 2,073,477, of March 9, 1937. In the present push-pull system, the variable gain tubes are operated considerably below their rated output so that the introduction and consequent elimination of the even order distortion products is of minor importance. However, it is imperative to eliminate the spurious frequencies introduced longitudinally due to insufficient filtering of the gain control potential. The filter circuit used is composed of series and shunt resistances and

shunt capacitances, and consequently the filtering efficiency is directly proportional to frequency, e. g., low frequencies, low filtering efficiency. Furthermore, as operational requirements necessitate the quickest possible response of the variable gain amplifier to control potential changes, the time constant of the filter has to be kept as low as possible. Since the time constant of the filter may be represented by $t=RC$ where R is series resistance and C , shunt capacitance, it is obvious that to keep t small, the product of RC must be small, which means that either R or C must be small. However, since the filtering efficiency is dependent upon the ratio between the series resistance to the shunt reactance, it can be seen that in order to keep the product of RC small, poor filtering efficiency at the low frequencies is unavoidable.

The present invention therefore is directed to a feedback arrangement which permits the use of the desired time constant of the control potential filter circuit together with a neutralization of the spurious frequency components thus introduced into the signal.

The principal object of the invention is to improve the operation of the automatic control of a variable gain amplifier.

Another object of the invention is to provide a feedback circuit for a push-pull variable gain amplifier which will neutralize longitudinal distortion components introduced therein.

A further object of the invention is to provide a compressor circuit in which compression or linear amplification may be selected and which will operate substantially distortionless in an unbalanced condition.

Although the novel features which are believed to be characteristic of this invention will be pointed out with particularity in the appended claims, the manner of its organization and the mode of its operation will be better understood by referring to the following description read in conjunction with the accompanying drawings forming a part thereof, in which

Fig. 1 is a block diagram of a sound recording system embodying the invention;

Fig. 2 is a schematic circuit diagram illustrating the principle of operation of the invention;

Fig. 3 is a schematic circuit diagram of a portion of the system of Fig. 1 embodying the invention; and

Figs. 4 and 5 are graphs showing the reduction of spurious frequencies by the use of the invention.

Referring now to Fig. 1, a microphone 5 feeds

a preamplifier 6 which, in turn, feeds a mixer 7, the output of which is amplified in the amplifier 8 and then impressed on a compressor unit 10. After compression, the currents are amplified in an amplifier 11 and then impressed upon a recorder 12 which may be of any type well known in the art. This of course represents only one possible use of the invention. The system just described is a general arrangement of a recording system except for the compressor 10 shown schematically in Fig. 3, and which is of the type disclosed and claimed in my above-mentioned patent.

Referring now to Fig. 2, a simple push-pull type of balanced variable gain amplifier circuit is shown wherein an input transformer 14 is connected to the grids of a pair of variable mu tubes 15 and 16, the output of which is capacitively coupled through condensers 26 and 27 and resistances 22, 23, 24 and 25 to a pair of amplifier tubes 17 and 18. The transverse signal voltages are impressed across the secondary winding of transformer 14, half of which appears across the input of each of tubes 15 and 16. The respective output voltages are impressed upon the inputs of the tubes 17 and 18 in a well known manner. In the common grid-to-cathode lead of tubes 15 and 16, a resistance 20 is shown across which are introduced the gain control voltages, these voltages comprising the grid bias and consequently varying the gain of tubes 15 and 16. There may be also introduced across this resistance an A. C. potential due to poor filtering of the control voltages or from other causes. The gain control potential together with its A. C. components is applied longitudinally to the grids of tubes 15 and 16 and consequently will appear across R_a in the common grid return circuit of tubes 17 and 18 regardless of the amount of balance existing between tubes 15 and 16 or the other circuit elements. The appearance of this spurious A. C. potential across R_a does not, of course, interfere with the transmission of the signal currents. However, there are created across resistances 24 and 25 unequal voltages in case of an unbalance of the tubes, variable amplification factors of the tubes or any unbalance caused by the other elements in the circuit such as resistances 22, 23, 24 and 25 or condensers 26 and 27. These unequal voltages are made up of signal and longitudinal voltages originating from the gain control potential. Since the signal voltages add up in the output transformer of the amplifier and since no even harmonics are being generated in the tubes because they are working below their rated capacity, this inequality of signal voltages is not harmful. However, the inequality of the longitudinal voltages produces a voltage differential across resistances 24 and 25 which is introduced into the signal at this point, as it appears across the inputs of tubes 17 and 18. Thus, any voltage variation in the gain control energy is introduced into the signal in the form of spurious, unwanted components. The present invention prevents the introduction of these components into the signal by reducing their amplitudes at the source by means of negative feedback.

Referring now to Fig. 3, which is unit 10 of Fig. 1, the input to the circuit shown is connected to the primary of a push-pull transformer 30, the secondary of which is shown shunted by resistances 31 and 32 to provide a suitable termination. The secondary of transformer 30 is connected to the control grids of variable mu tubes

34 and 35 similar to tubes 15 and 16 of Fig. 2. The plates of amplifier tubes 50 and 51 are connected to the primary of a transformer 53, the secondary of which is shown connected to output terminals 54. Initial grid bias for the variable mu tubes 34 and 35 is obtained from the voltage drop across the resistance 56 through which flow the plate and screen grid currents of tubes 34 and 35. Resistances 57 and 58 provide potential to the screen grids of tubes 34 and 35. Resistance 59 is a decoupling resistance to prevent feedback through the plate voltage supply common to tubes 34, 35, 50 and 51. Condensers 61, 62 and 63 are bypass condensers. Grid bias for tubes 50 and 51 is obtained by the plate current potential drop across the resistance 65.

The portion of the circuit just described is an amplifier, the gain of which is varied by a rectifier circuit now to be described. The voltage across the secondary of transformer 53 is impressed over conductors 69 on the control circuit including a transformer 68, the secondary of which is shunted by a potentiometer 70 having a slider 71 for varying the voltage impressed upon the grid of a triode amplifier 73. A switch 74 is provided for the purpose of disconnecting the grid of triode 73 from the potentiometer 70 and for simultaneously eliminating the feedback circuit to be described hereinafter. The output of the amplifier 73 is fed through a transformer 75 to the plates of a full-wave rectifier 76. Grid bias for the amplifier 73 is obtained from the voltage drop of its plate current across a resistance 77 shunted by a condenser 78, while a resistance 79 serves as a decoupling resistance, and a condenser 80, as a bypass condenser.

For obtaining an initial positive bias on the cathodes of rectifiers 76 with respect to its plates, a voltage divider comprising resistances 82, 83 and 84 is employed, resistance 83 being a potentiometer with an adjustable slider 85, as described in the above-mentioned patent. The rectified current from the rectifier 76 flows over a conductor 87, through a resistance 88 and thereby causes a voltage drop across this resistance, which constitutes a negative bias applied to the control grids of variable mu tubes 34 and 35. This biasing voltage varies in accordance with the voltage changes across the secondary of output transformer 53, and this varies the gain of tubes 34 and 35. Condenser 89 across resistance 88 functions as a bypass condenser for the alternating components of the rectified current and also determines, in conjunction with resistance 88, the internal resistance of the rectifier 76, and the impedance of the secondary of transformer 75, the rapidity with which voltage changes across resistance 88 can take place.

As described in the above-mentioned patent, the above system provides a compressor circuit in which variations in the gain of tubes 34 and 35 may be controlled by the adjustment of the slider 71 on potentiometer 70, and the point at which compression occurs may be adjusted by the setting of the slider 85 on the resistance 83.

However, in the process of rectification of the signal, spurious frequency components from the rectifier 76 are applied across the resistance 88 along with the D. C. gain control voltage. It is obvious that these A. C. potentials will be introduced in the common grid-to-cathode lead and will introduce longitudinal voltages in the signal circuit, as shown in Fig. 2. If the four tubes 34, 35, 50 and 51 were perfectly balanced, and the other elements of the circuit were in balance, the

introduction of these spurious frequencies would be of no consequence in that they would not appear across the output transformer 53 although appearing across any resistance common to the respective grid return circuit of each pair of tubes. However, even though the tubes have identical characteristics when first placed in the circuit, these tubes do not maintain their balance during operation and after some use. Thus, regardless of how much care is taken to originally balance the circuit, it soon becomes unbalanced to some degree during use, thereby permitting the introduction of these spurious frequencies into the signal.

To prevent the introduction of these unwanted components, a feedback circuit has been provided from the common grid return circuit of tubes 50 and 51 to the common grid return circuit of the tubes 34 and 35 over conductors 90 and 91, through switch 74 and over a resistance 92 in series with the gain control resistance 88. Thus, the longitudinal voltages across R_a in Fig. 2 are fed back to their source of origin; namely, the common grid return resistance 88 of tubes 34 and 35, 180° out of phase to the voltages appearing across the resistance 88, thereby cancelling them to a degree depending upon their algebraic sum. The grid biasing circuit for tubes 34 and 35 is from the grids of these tubes through resistances 31 and 32 and the secondary of transformer 30 in parallel, through feedback resistance 92 (R_a of Fig. 2), resistance 88 and resistance 56, while the common grid return lead for tubes 50 and 51 is now from the grids of these tubes through resistances 43 and 44, over conductor 90, conductor 91, resistance 92, resistance 88 and resistance 65. By operation of the switch 74, however, the conductor 90 is connected to ground or minus B over conductor 94, while the slider 71 is also connected to this point. Thus, with the switch 74 in its lower position, the gain control rectifier is eliminated along with the selective feedback circuit, and the variable gain amplifier becomes a fixed gain amplifier.

In the use of such a circuit, it was found that a spurious frequency output level of -40 db. was reduced by 20 db. to -60 db. by the use of the selective feedback circuit shown, with no detrimental effects observable. By the use of such a circuit, the balancing potentiometer usually required in the grid circuit of the tubes 50 and 51 was eliminated.

Referring now to Figs. 4 and 5, in which percentage spurious frequency content is plotted against the output level in db., curve *a* of Fig. 4 shows the characteristic of the compressor without the feedback circuit, while curve *b* shows the reduction in spurious frequencies by the use of the feedback circuit at a signal frequency of fifty cycles. It is to be noted that at a 0 db. output level, the reduction is over 3½% with a compression ratio of 20 db. into 10 db. In Fig. 5, similar curves *a'* and *b'* are shown but for a signal frequency of four hundred cycles. It can be observed by comparing curves *a* and *a'* that without negative feedback the amount of spurious frequencies present with a signal of four hundred cycles is .5% as compared to 4.7% at fifty cycles at 0 db. level output. This difference in spurious frequency percentage is due to the efficiency change of the rectifier filter circuit with frequency, as mentioned above.

Thus, the use of the above-described feedback circuit permits a greater tolerance in the selection of the tubes and other circuit elements as

well as providing a variable gain amplifier with a fast-acting time constant.

Although the invention has been illustrated as embodied in a sound recording system, it is to be understood that it is also applicable to public address systems, broadcast systems, sound reproducing systems or any systems wherein a controlled transmission of currents is involved.

What I claim as my invention is:

1. A compressor circuit comprising a balanced amplifier circuit, a rectifier, means for connecting a common input portion of said amplifier circuit to said rectifier, a timing filter connected in said last mentioned means, the output of said rectifier varying the gain of the amplifiers in said amplifier circuit, at a rate determined by said timing filter, and a feedback circuit independent of said gain varying rectifier circuit and connected adjacent said first-mentioned means for neutralizing the spurious frequency components introduced from said rectifier circuit and not eliminated by said timing filter.

2. A compressor circuit comprising a balanced variable gain amplifier for transmitting signal currents, a rectifier for rectifying a portion of said signal currents, means for impressing the output of said rectifier on the common grid return of said balanced variable gain amplifier to vary the gain thereof, a timing filter for determining the rate at which the output of said rectifier varies the gain of said variable gain amplifier, and an independent feedback circuit from the output of said balanced variable gain amplifier to said common grid return at a point adjacent the point of connection of said first-mentioned means for neutralizing spurious frequency components in the output circuit of said rectifier not eliminated by said timing filter.

3. A compressor circuit comprising a balanced transmission circuit for signal currents, a rectifier, means for feeding back from the output circuit of said balanced transmission circuit to a common portion of the input circuit thereof through said rectifier a portion of said signal currents for controlling the amplitude of said signal currents, a timing filter in the output of said rectifier for regulating the rate of controlling the amplitude of said signal currents, said timing filter permitting the introduction of certain frequency components into said transmission circuit from the output circuit of said rectifier, and means for feeding back from a common portion of the output circuit of said balanced transmission circuit to said common portion of the input thereof another portion of the currents transmitted by said transmission circuit for neutralizing said certain frequency components introduced from the output circuit of said rectifier.

4. A compressor circuit in accordance with claim 3 in which means are provided for eliminating at will both of said feedback circuits for converting said compressor circuit into a circuit having a linear relationship between the input and output voltages thereof.

5. The method of eliminating the spurious frequency components in the output of a rectifier controlling the gain control potential of a push-pull variable gain amplifier to provide a predetermined rate of action of said control potential comprising rectifying a portion of the signal transmitted by said variable gain amplifier, said rectified current containing certain spurious frequency components, and reintroducing into the gain control circuit of said amplifier from the common output portion thereof voltages corre-

sponding in frequency to said spurious frequency components but in reverse phase to the first introduction thereof into said gain control circuit.

6. An electrical signal transmission circuit comprising a variable gain push-pull stage of amplification, a second push-pull stage of amplification connected to said first stage of amplification, a rectifier, means for connecting the output of said second stage with the input of said rectifier, means for connecting the output of said rectifier to certain gain control elements in the common portion of the input circuit of said first stage, and means for connecting the common grid return of said second stage with certain other gain control elements and said first-mentioned gain control element of said first stage of amplification for neutralizing certain frequency components introduced into said variable gain stage of amplification from the output circuit of said rectifier.

7. An electrical signal transmission circuit comprising a variable gain push-pull stage of amplification, a second push-pull stage of amplification connected to said first stage of amplification, a rectifier, means for connecting the output of said second stage with the input of said rectifier, means for connecting the output of said

rectifier to certain gain control elements in the common portion of the input circuit of said first stage of amplification, said last-mentioned means introducing longitudinally into said amplification stages spurious frequencies, said frequencies being normally balanced out of the signals being transmitted by said transmission circuit when said amplification stages are in balance, and means for feeding back in opposite phase from a point on the common portion of the input circuit of said second stage of amplification said spurious longitudinal frequencies to said gain control elements and to another gain control element in the common portion of the input circuit of said first stage of amplification to eliminate from said control grids said spurious frequencies.

8. The method of obtaining a predetermined compressor action in a variable gain amplifier comprising rectifying a portion of the signal being transmitted, controlling the gain of said variable gain amplifier at a predetermined rate, said rate providing insufficient filtering of certain frequency components in the output current of said rectifier, and re-introducing into said rectifier output circuit similar frequency components in phase opposition.

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