Sept. 9, 1941. K. SINGER 2,255,683

TRANSMISSION CONTROL SYSTEM

Filed March 24, 1939 2 Sheets-Sheet 1

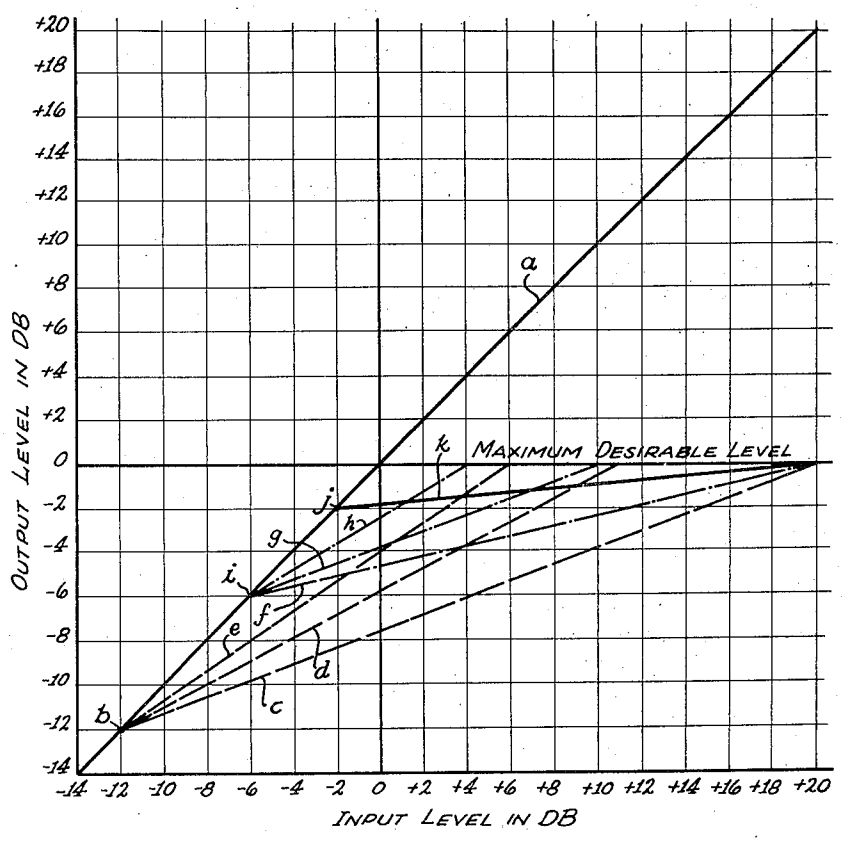


Fig. 3.

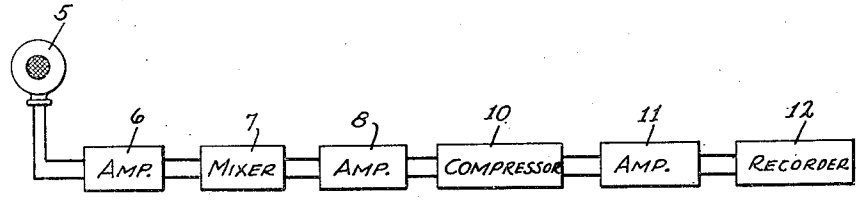


Fig. 1.

Inventor

KURT SINGER,

By Val R. Graham

Attorney

Sept. 9, 1941. K. SINGER 2,255,683

TRANSMISSION CONTROL SYSTEM

Filed March 24, 1939 2 Sheets-Sheet 2

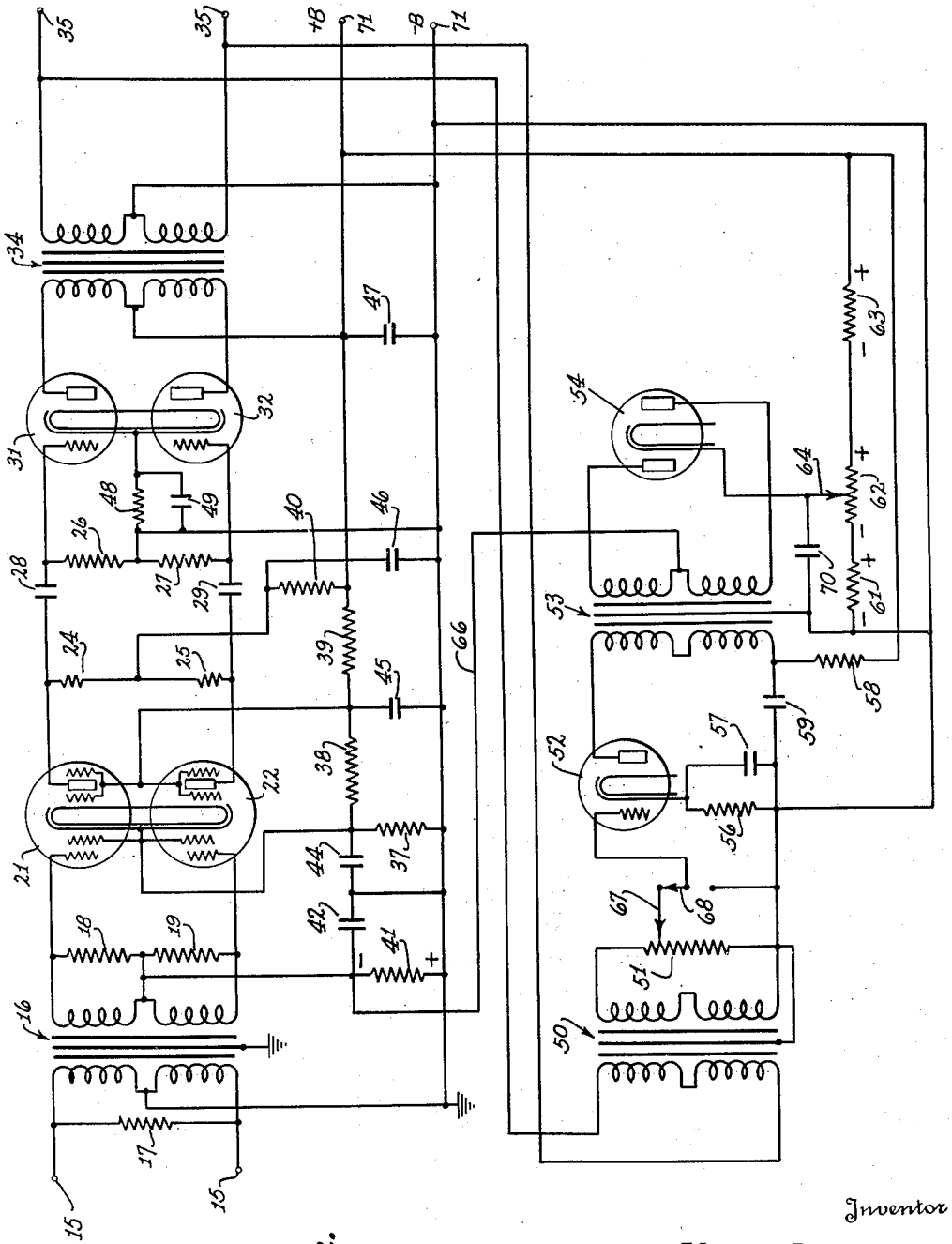


Fig. 2.

Inventor

KURT SINGER,

By Carl R. Gosham

Attorney

Patented Sept. 9, 1941

2,255,683

# UNITED STATES PATENT OFFICE

2,255,683

## TRANSMISSION CONTROL SYSTEM

Kurt Singer, Burbank, Calif., assignor to Radio Corporation of America, a corporation of Delaware

Application March 24, 1939, Serial No. 263,884

5 Claims. (Cl. 179—171)

This invention relates to current transmission systems and particularly to the automatic control of the gain or attenuation of such systems.

Electrical current transmission systems are well known, these systems generally having a linear relationship between input and output levels. It has been found desirable, however, in certain types of transmission systems, to be able to vary the gain or attenuation of the system. This has been previously accomplished both manually and automatically in transmission systems used for sound recording, radio broadcasting, telephone communications, etc., the general purpose being, in each case, to obtain compression of a certain range of input levels into a smaller range of output levels.

Although the present invention relates to the automatic control of the gain of an amplifying system, it provides an improved method of controlling the gain changes of the system. Specifically, it permits predetermination of the rate of gain change and the selection of the input level at which such a gain change will start to occur. It thus provides greater flexibility of control than heretofore known by permitting the gain of the amplifying system to be varied at different rates over different ranges of amplitudes.

The present invention is directed to the method of and means for obtaining these controls in a novel and efficient manner. The starting point control is obtained by adjustably controlling the beginning of operation of a rectifier, while the control of the rate of gain change is accomplished by adjustably varying the gain of an amplifier feeding the rectifier.

The principal object of the invention, therefore, is to control the automatic performance of a variable gain amplifier.

Another object of the invention is to obtain with a single amplifying unit a multiplicity of operating characteristics.

A further object of the invention is to obtain with a single amplifying unit linear amplification, volume compression, volume limiting and/or any combination thereof.

A further object of the invention is to enable the point at which transition from linear amplification to volume compression, or volume limiting, and the rate at which such compression and limiting occurs, to be predetermined.

Although the novel features which are believed to be characteristic of this invention are pointed out with particularity in the claims appended herewith, 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 type of sound recording system embodying the invention;

Fig. 2 is a schematic circuit diagram of the invention; and

Fig. 3 is a graph showing the relationship between input level and output level of a compressor unit embodying the invention.

Referring now to Fig. 1, a microphone 5 feeds a pre-amplifier 6 which, in turn, feeds a mixer 7, the output of which is amplified in an 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 known in the art, this, of course, representing only one possible use of the invention. The system just described is the general arrangement of a recording system except for the compressor 10, shown schematically in Fig. 2 and which will now be referred to for a detailed description of the invention.

The input to the circuit in Fig. 2 is at terminals 15 which are connected to the primary of a push-pull transformer 16, the primaries and secondaries of which are shunted by resistances 17, 18 and 19 to provide suitable terminations. The secondary of the transformer 16 is connected to the control grids of variable mu tubes 21 and 22. The plates of tubes 21 and 22 are coupled through a capacity-resistance network comprising resistances 24, 25, 26 and 27 and condensers 28 and 29, to the grids of triode amplifier tubes 31 and 32. The plates of amplifier tubes 31 and 32 are connected to the primary of a transformer 34, the secondary of which is shown connected to output terminals 35. Grid bias for the variable mu tubes 21 and 22 is obtained from the voltage drop across a resistance 37 through which flows the plate and screen grid currents of tubes 21 and 22 and the bleeder current of a voltage divider composed of resistances 37, 38 and 39. Resistances 38 and 39 provide potential to the screen grids of tubes 21 and 22. Resistance 40 is a de-coupling resistance to prevent feedback due to a plate voltage supply common to tubes 21, 22, 31 and 32. Condensers 44, 45, 46 and 47 are bypass condensers. Grid bias for tubes 31 and 32 is obtained by their plate current potential drop across a resistance 48 shunted by a bypass condenser 49.

The portion of the circuit just described is an

amplifier, the gain of which is varied in a manner now to be described. The voltage across the secondary of transformer 34 is impressed on a control circuit including a transformer 50, the secondary of which is shunted by a potentiometer 51 having a slider 67 for varying the voltage impressed upon the grid of a triode amplifier 52. Switch 68 is provided for the purpose of disconnecting the grid of triode 52 from the potentiometer 51. The output of the amplifier 52 is fed through a transformer 53 to the plates of a full-wave rectifier 54. Grid bias for the amplifier 52 is obtained from the voltage drop of its plate current across a resistance 56 shunted by a condenser 57, while a resistance 58 serves as a de-coupling resistance and a condenser 59 as a bypass condenser. For obtaining an initial positive bias on the cathodes of rectifier 54 in respect to its plates, a voltage divider comprising resistances 61, 62 and 63 is employed, resistance 62 being a potentiometer with an adjustable slider 64 for the purpose to be hereinafter described.

The rectified current flows over conductor 66 through a resistance 41 and thereby causes a voltage drop across this resistance which constitutes a negative bias applied to the control grids of variable mu tubes 21 and 22. This biasing voltage varies in accordance with the voltage changes across the secondary of output transformer 34 and thus varies the gain of tubes 21 and 22. Condenser 42 has a double function; namely, it serves as a bypass condenser for the alternating current components of the rectified current and also determines, in conjunction with resistance 41, the internal resistance of the rectifier 54, and the impedance of the secondary of transformer 53, the rapidity with which voltage changes across resistance 41 can take place. This combination of resistance and capacity for the above purpose is well known in the art.

In the present invention it is possible to start variations in the gain of tubes 21 and 22 at certain predetermined input signal levels and this starting point is controlled by the setting of the variable contact 64 on resistance 62. The position of the slider 64 determines the amount of positive bias applied to the cathodes with respect to the plates of rectifier 54. As long as this positive bias is greater than, or equal to, the signal potential applied between the plates and the cathodes of rectifier 54, no rectified current will flow through resistance 41 and thus no gain change in tubes 21 and 22 will occur. As soon as the signal potential applied to the rectifier 54 exceeds the positive cathode bias, rectified current will flow through resistance 41, and gain variations of tubes 21 and 22 will take place.

Resistances 61 and 63 are used, so that the adjustable voltage range of cathode bias will be within predetermined limitations, resistance 63 limiting the maximum, and resistance 61, limiting the minimum positive bias.

It is well known that rectifiers of the type used in the invention have an inherent initial emission current, which will flow through a resistance connected between plates and cathode even when there is no signal potential applied to the plates. This condition would be met, were resistance 61 omitted and slider 64 moved completely to the negative end of potentiometer 62. This inherent initial emission current would then flow through resistance 41 and thus produce an undesirable bias on the control grids of tubes 21 and 22 and a consequent reduction of gain. This bias is undesirable because it would be subject to changes, depending upon the emission characteristics of different rectifier tubes and upon emission changes due to inherent rectifier instability. The use of resistor 61 insures the presence of a small positive bias on the cathode in respect to the plates of rectifier 54, thereby eliminating the possibility of current flow through resistor 41 unless there is a signal potential applied to the plates of rectifier 54, regardless of the position of slider 64 on potentiometer 62. Condenser 70 bypasses the resistances 61 and 62. Plate potential for the system is impressed between terminals 71 and is of a value suitable for the type of tubes and circuit shown.

Whereas it has been described above how it is possible to control the starting point of gain variations of tubes 21 and 22 by potentiometer 62, the control of the rate of this gain variation will now be explained. As the setting of slider 67 of potentiometer 51 controls the amount of signal potential applied to the grid of triode 52, which consequently determines the amount of rectified current passing through resistance 41, changes of the setting of slider 67 will result in changes of rectified current through resistance 41 for a given voltage appearing at terminals 35. It is possible, therefore, to obtain a multiplicity of rates of gain variations limited only by the available gain of the amplifier-rectifier combination 52 and 54. It will be noticed, however, that signal potential will be impressed upon the grid of tube 52 only when switch 68 is in its upper position as shown, and no potential from terminals 35 will reach the tube 52 when switch 68 is in its lower position, thus eliminating compression completely and making the amplifier 21, 22, 31 and 32 a conventional constant gain device.

The circuit above-described, therefore, has two variable control elements, one of which determines the point at which compression begins, or the range of compression, and the other of which determines the rate of compression. To illustrate several variations of compression characteristic curves obtainable by the use of this invention, reference is made to Fig. 3 showing a graph of the relationship between the input levels at terminals 15 and the output levels at terminals 35. It will be noted that the normal constant gain characteristic of the amplifier is shown by the 45° angle curve *a*, which condition exists when the switch lever 68 is in its lower position. For the sake of clarity, the ordinates of the graph shown in Fig. 3 have been chosen for an amplifier having zero gain at no compression. It will also be noted that for purposes of illustration the lowest input level is taken as −14 db., the maximum desirable level as 0 db., and the upper level limit as +20 db. A different maximum desirable level may be chosen than the one shown in Fig. 3 if the amplifier is used for broadcasting, telephone transmission, etc., the particular maximum desirable level shown in Fig. 3 being suitable for a film recording channel, as shown in Fig. 1. The first family of curves, illustrated by broken lines *c*, *d* and *e*, is shown beginning at a point *b* on curve *a* at a level of −12 db. It will be noted that these curves have different slopes. The point *b* or "breakaway" point is determined by the setting of slider 64, which determines when the rectifier 54 begins to function, while the slopes of the curves *c*, *d* and *e* are determined by respective settings of slider 67 varying the input level to

rectifier 54. Thus different rates of compression are obtainable over the upper amplitude range beginning at a level of −12 db., curve *c* showing that an input range of 32 db. is compressed into an output range of 12 db.; curve *d*, a range of 23 db. into 12 db.; and curve *e*, a range of 18 db. into 12 db.

Beginning at point *i* on curve *a*, a second family of three curves, illustrated by dot-and-dash lines *f*, *g* and *h* is shown, the point *i* again being determined by a certain setting of slider 64, and the slopes of the curves by certain settings of the slider 67. In this case, curve *f* shows that an input range of 26 db. is compressed into an output range of 6 db.; curve *g*, a range of 16 db. into 6 db.; and curve *h*, a range of 10 db. into 6 db.; compression beginning in each case at −6 db. Although only two breakaway points *b* and *i* and three curves from each point have been illustrated, it will be realized that substantially any breakaway point along curve *a*, as well as many rates of compression, are obtainable by different adjustments of sliders 64 and 67. Thus, a very flexible control of the compression characteristic of an amplifier is provided.

Referring again to Fig. 3, a full-line curve *k* is shown starting at a breakaway point *j* on curve *a*, this curve k illustrating that a range of input level changes amounting to 22 db. are compressed into a small range of output level changes amounting to 2 db., compression beginning at −2 db. A device which has this characteristic is commonly known as a volume limiter, while a device having any one of the characteristics shown by curves *c*, *d*, *e*, *f*, *g* and *h* is known as a volume compressor. It is, therefore, possible by a change of settings of either one or both of potentiometers 51 and 62 to obtain, with a single device, volume compressor or volume limiter characteristics.

Although the above controls are shown controlling the breakaway points and the rates of compression, it is to be understood that these controls are also applicable to an amplifier used for expansion wherein a certain range of input levels is expanded to a greater range of output levels. It is also to be understood that the amplifier-rectifier combination, which is shown connected to the output terminals 35 on Fig. 2, could be connected to the input terminals 15 instead, to produce similar results.

I claim:

1. An electrical current transmission system having input terminals and output terminals, an electrical current amplifier intermediate said input and output terminals, said amplifier having a normally constant gain, a second amplifier connected to the output of said first-mentioned amplifier and having a constant gain, a potential source for the anodes of said amplifiers, a rectifier connected to said second amplifier, means for connecting the output of said rectifier to said first-mentioned amplifier, the output of said rectifier varying the gain of said first-mentioned amplifier, means for initially biasing said rectifier at a predetermined negative value for selectively determining when said rectifier begins to vary the gain of said first-mentioned amplifier, means for obtaining said rectifier bias from said potential source, and means for adjusting the input level to said second amplifier for selectively determining the rate at which said rectifier varies the gain of said first-mentioned amplifier, said means for initially biasing said rectifier for selectively determining the point at which said rectifier varies the gain of said amplifier comprising a variable potentiometer having a fixed section and a variable section, said fixed section preventing the flow of initial inherent emission current in said rectifier at no signal input.

2. An amplifying system comprising a pair of variable mu tubes connected in push-pull, said tubes having normally a constant gain characteristic, a second amplifier having a constant gain characteristic, a high potential source for the anodes for said tubes, means for connecting the output of said push-pull tubes to the input of said second amplifier, a rectifier connected to the output of said second amplifier, means for connecting said rectifier to said push-pull tubes, the output of said rectifier varying the gain characteristic of said push-pull tubes, a combination fixed and adjusable potentiometer connected across said potential source for selectively determining the point at which said rectifier begins to vary the gain of said push-pull tubes, a variable potentiometer connected in the input circuit of said second amplifier for selectively determining the rate of variation of the gain of said push-pull tubes by said rectifier and means for eliminating at will the operation of said second amplifier.

3. An amplifying system comprising a pair of variable mu tubes connected in push-pull, said tubes having normally a constant gain characteristic, a second amplifier having a constant gain characteristic, a potential source for the anodes for said tubes, means for connecting the output of said push-pull tubes to the input of said second amplifier, a rectifier connected to the output of said second amplifier, means for connecting said rectifier to said push-pull tubes, the output of said rectifier varying the gain characteristic of said push-pull tubes, a combination fixed and adjustable potentiometer connected across said potential source for selectively determining the point at which said rectifier begins to vary the gain of said push-pull tubes, a variable potentiometer connected in the input circuit of said second amplifier for selectively determining the rate of variation of the gain of said push-pull tubes by said rectifier, and means for eliminating at will the operation of said second amplifier, one fixed section of said potentiometer for selectively determining the point at which said rectifier begins to vary the gain of said push-pull tubes maintaining said rectifier negatively biased to prevent the flow of initial inherent emission current in said rectifier at times of no signal input thereto while another fixed section of said potentiometer limits the application of positive bias applicable to said rectifier.

4. An electrical current transmission system comprising an amplifier having a plurality of pairs of electron devices connected in push-pull and in a series relationship, a constant gain amplifier connected to the output of said first-mentioned amplifier, a potentiometer in the input of said last-mentioned amplifier for selectively determining the amplitude impressed on said second amplifier, means in the input of said second amplifier for short-circuiting said input circuit, a rectifier intermediate the output of said second-mentioned amplifier and the input of said first-mentioned amplifier, means for varying the bias impressed on said rectifier, said means comprising a biasing potentiometer variable between predetermined limits, and fixed

means in the biasing circuit of said rectifier for preventing the flow of initial inherent emission current in said rectifier at times of no input to said rectifier, said potentimeter determining the amount of positive bias potential impressable upon said rectifier.

5. An electrical compressor circuit comprising a normally constant gain amplifier having input, output and biasing circuits, a second constant gain amplifier connected to the output of said first-mentioned amplifier, a rectifier connected intermediate the output of said second amplifier and the input of said first amplifier, the input level to said second amplifier determining the gain of said first-mentioned amplifier over a predetermined range of input levels to said second amplifier, a potential source for the anodes of all of said amplifiers, and means for obtaining from said potential source a biasing potential for said rectifier, said last-mentioned means including a potentiometer connected across said potential source, said potentiometer having an adjustable portion to vary the bias potential on said rectifier, a fixed portion to limit the minimum bias potential applicable to said rectifier and a second fixed portion to limit the maximum bias potential applicable to said rectifier.

KURT SINGER.