Oct. 26, 1937. E. S. PURINGTON 2,096,758

DYNAMIC MULTIPLIER WITH AUTOMATIC TONE FILTER

Filed April 3, 1936 3 Sheets-Sheet 1

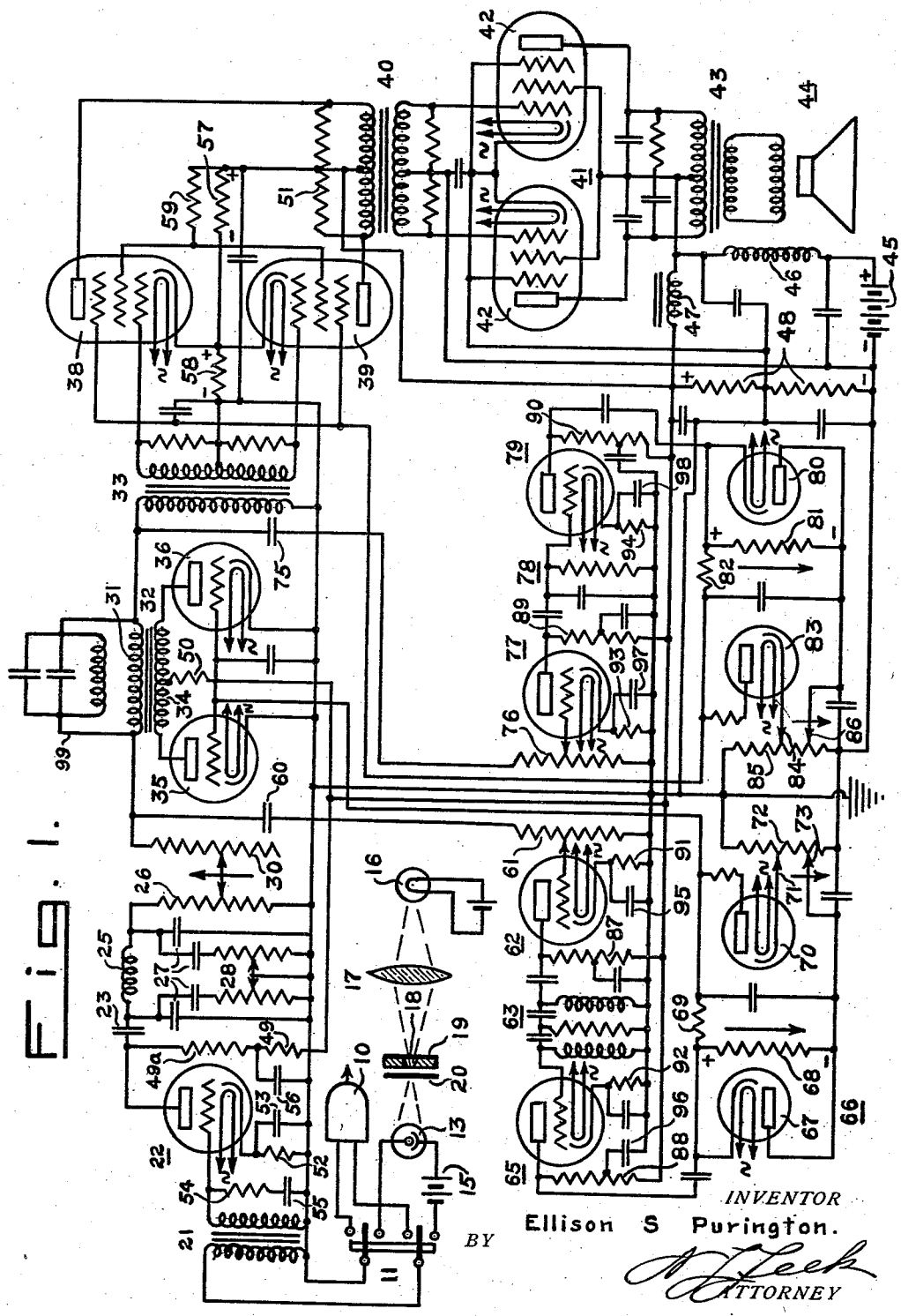


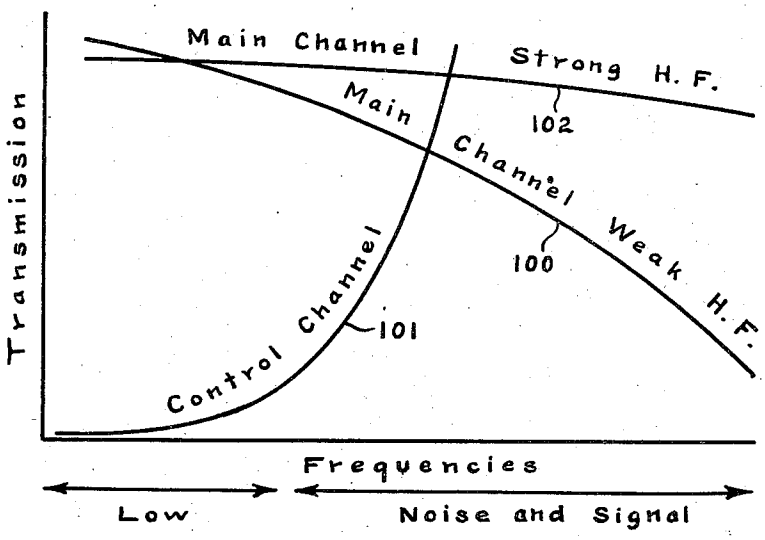
Fig. 1.

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DYNAMIC MULTIPLIER WITH AUTOMATIC TONE FILTER

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Fig. 2.



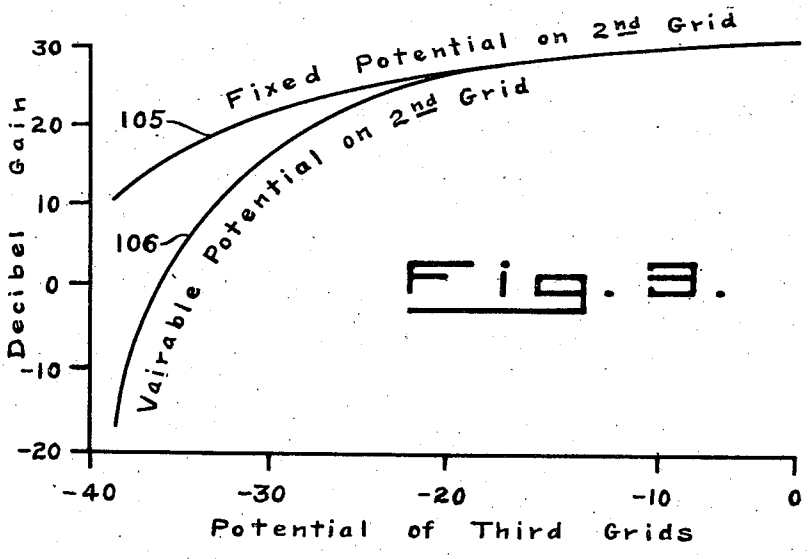


Fig. 3.

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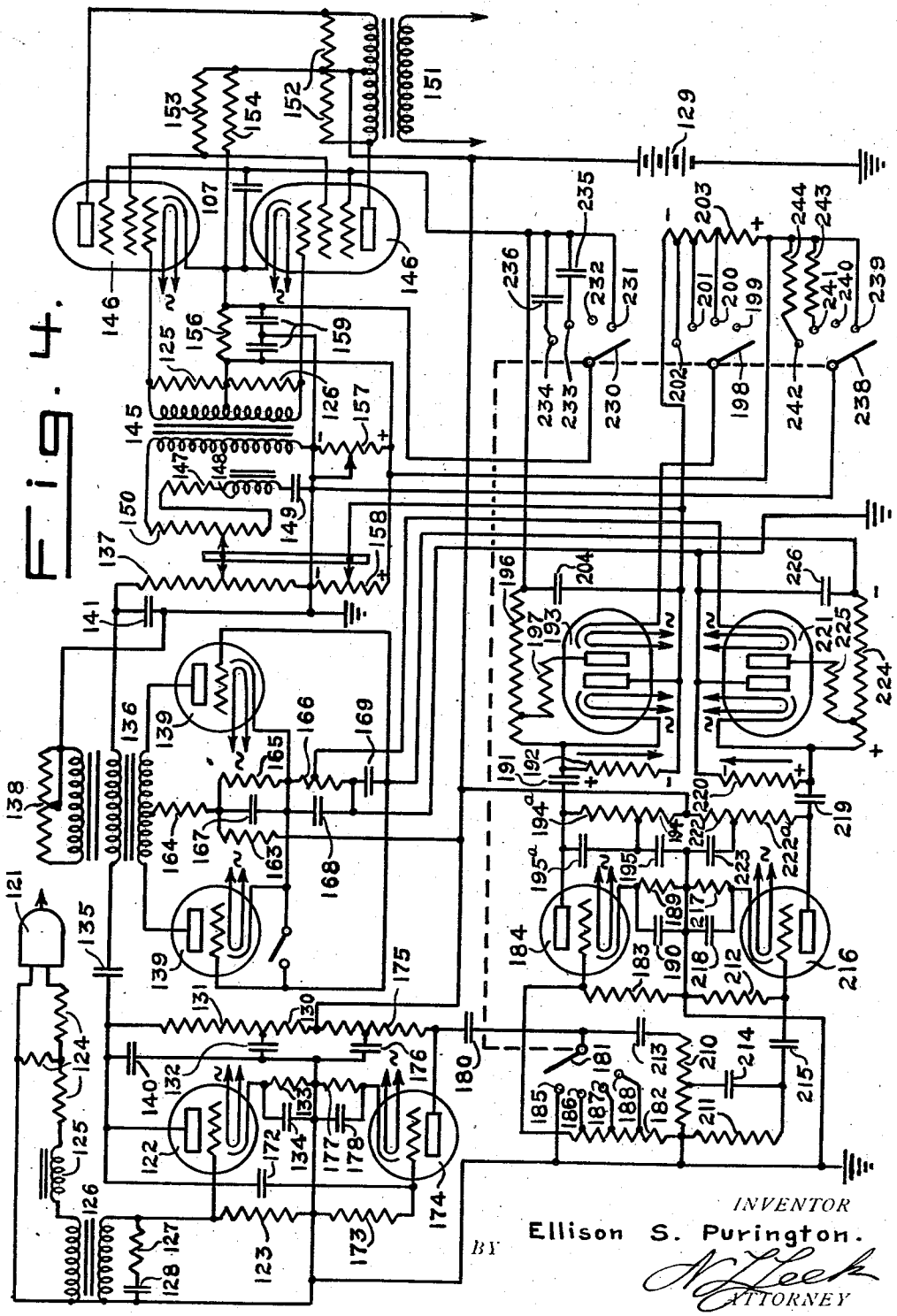
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DYNAMIC MULTIPLIER WITH AUTOMATIC TONE FILTER

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Fig. 4.



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DYNAMIC MULTIPLIER WITH AUTOMATIC TONE FILTER

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Application April 3, 1936, Serial No. 72,518

16 Claims. (Cl. 179—100.1)

This invention relates to an improved system for reproducing sound from a sound record and provides an automatic tone filter in which the impedance of an inductance arm is changed in accordance with the nature of the tone signals to be transmitted through that arm.

This invention further provides an improved method of expanding the volume output of a phonograph amplifier in accordance with the acoustic level of the tonal signals being transmitted through the amplifier.

This invention further provides a simplified control for systems of the above type.

In one embodiment an automatically variable filter device is provided which changes the relative transmission of impulses of different frequencies in accordance with the nature of those impulses.

In particular the present method accomplishes the control by including one winding of a transformer in the filter network and automatically variably loading another winding of the transformer by a balanced thermionic impedance, the value of which is determined by the recorded impulses. The balanced load permits the control to be effected without appreciable change of permeability of the core.

In dynamic multipliers using control upon electrodes of an amplifier device, it is desirable that the gain vary more rapidly with change of control potentials with weak signals, and less rapidly with strong signals. This is especially necessary because a greater change of decibel output is necessary to give a noticeable effect at weak volume than at strong volume. Previously this has been accomplished largely by limiting devices which cut down the effectiveness of rectification with large signal inputs. The present invention provides a simplified method in which control is effected directly upon one electrode of an amplifier, and indirectly upon another electrode in such a manner as to give increased control effect especially at low signal volumes.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Fig. 1 illustrates diagrammatically one embodiment of the invention as applied to the reproduction of sound from the sound record of a talking moving picture projector and phonograph;

Fig. 2 is a series of curves illustrating the relative frequency transmission characteristics of certain portions of the circuit shown in Fig. 1;

Fig. 3 is a series of curves showing the improvement in expansion performance in other portions of the circuit shown in Fig. 1; and

Fig. 4 shows a modified circuit arrangement according to the present invention.

Like reference characters denote like parts in the several figures of the drawings.

In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the accompanying drawings, and more particularly to Fig. 1, a phonograph pick-up 10 is shown which is connected to two contacts of a double pole double throw switch 11, the other contacts of which are connected to the circuit of a photo-electric cell 13 including battery 15. Light from a lamp 16 is focused by means of a lens 17 through an aperture 18 in an aperture plate 19 upon the sound record of a moving photographic film 20. The light which passes through this film then impinges upon the photo-electric cell 13.

The blades of the switch 11 are connected through a transformer 21 to the input circuit of a space discharge amplifier 22. The output circuit of this amplifier includes a filter network comprising a blocking condenser 23, an inductance 25, condensers 27, a double rheostat 28, and a manual volume control potentiometer 26. The double rheostat 28 constitutes a manual tone control for varying the characteristics of the filter network.

The adjustable contact of the potentiometer 26 is connected to the adjustable contact of a rheostat 30 in such a manner that they both move in unison. The rheostat 30 is connected through the primary 31 of a tone control transformer 32 to the primary of a coupling transformer 33. The secondary 34 of the tone control transformer 32 is connected to the plates of two space discharge tubes 35 and 36 by which the tone is controlled in the manner to be described. The cathodes of these tubes are grounded. The grids, during operation, are variably negative with respect to ground as will be hereinafter set forth.

The secondary of the coupling transformer 33 is connected to the first grids of two pentode expander tubes 38 and 39 which are operated as a push-pull amplifier, the output circuit of which includes the primary of a transformer 40.

The secondary of the transformer 40 is connected in the input circuit of a push-pull amplifier 41 comprising two pentode tubes 42. The output circuit of this amplifier 41 includes a transformer 43 and the moving coil of a loudspeaker 44.

A high voltage power supply battery 45 or its equivalent such as a rectifier system, is provided for supplying current to determine the potentials of the electrodes of the various space discharge devices. The field coil 46 of the loudspeaker 44, a filter choke 47, and a resistor assembly 48 are connected across the battery 45.

The positive end of the resistor assembly 48 is connected, through a feed resistor 49 and a coupling resistor 49a to the anode; of the space discharge amplifier 22, through a feed resistor 50 and windings 34 of transformer 32 to the anodes of the tubes 35 and 36, and through the primary of the transformer 40 to the anodes of the pentodes 38 and 39. The positive end of filter choke 47 is connected through the primary of the transformer 43 to the anodes of the pentodes 42.

The cathode of the amplifier 22 is connected to ground through a biasing resistor 52 and a by-pass condenser 53. A tone control resistor 54 and condenser 55 may be connected across the secondary of the transformer 21 to control the transmission characteristics thereof. A by-pass condenser 56 is connected in the output circuit of the amplifier 22 between the junction of resistor 49 and resistor 49a and ground.

The center tap of the primary of transformer 40 is connected through a bleeder resistor 57 to the cathodes of the pentodes 38 and 39 thence through a biasing resistor 58 to ground, and also through a coupling and biasing resistor 59 to the second grids of the pentodes 38 and 39. The third grids of the pentodes 38 and 39 are variably negative in accordance with the control voltage to be described.

The signal voltage is applied to the first grids of the pentodes 42. The cathodes and third grids are connected to an intermediate point on the resistor assembly 48. The second grids are connected to the positive side of choke coil 47.

For controlling the operation of the tone control tubes 35 and 36, energy is delivered from the input side of the primary winding of transformer 32, through condenser 60 to a potentiometer 61. For controlling the operation of the expander tubes 38 and 39, energy is delivered from the output side of the primary winding of transformer 32, through condenser 75 to a potentiometer 76.

For tone control purposes, the adjustable contact of potentiometer 61 is connected to the grid of an amplifier tube 62. The output circuit of this amplifier is coupled through a high-pass filter and coupling network 63 to the input circuit of a second amplifier tube 65. The output circuit of the amplifier tube 65 is coupled to a rectifier circuit 66 comprising a rectifier tube 67 and a resistor 68. The positive side of the resistor 68 is connected through a second resistor 69 to the grids of the tone control tubes 35 and 36. A limiter tube 70 is connected between the resistor 69 and the adjustable contact 71 of a potentiometer 72. The negative side of the resistor 68 is connected to a second adjustable contact 73 on the potentiometer 72 which is connected between the negative side of the battery 45 and ground.

For expansion control purposes, the adjustable contact of potentiometer 76 is connected to the grid of an amplifier tube 77. The output circuit of this amplifier is coupled by a filter and coupling circuit 78 to the input circuit of a second amplifier tube 79. The output circuit of the amplifier 79 is coupled to a rectifier circuit which includes a rectifier tube 80 and a resistor 81. The positive side of the resistor 81 is connected through a second resistor 82 to the third grids of the tubes 38 and 39. A limiter tube 83 is connected between the resistor 82 and the adjustable contact 84 of a potentiometer 85 which is connected between the negative side of the battery 45 and ground. The negative side of the resistor 81 is connected to a second adjustable contact 86 of the potentiometer 85.

Plate voltage is supplied to the tubes 62, 65, 77, and 79 from the positive end of the resistor assembly 48 through suitable feed resistors 87, 88, 89, and 90 respectively. The cathodes of these tubes are connected to ground through biasing resistors 91 to 94 and by-pass condensers 95—98 respectively.

It is to be understood that only the essential features of the various circuits have been set forth. The usual sources of operating potential, by-pass and blocking condensers, coupling and balancing resistors may be used in the manner well known in the art.

In the operation of the embodiment of the invention shown in Fig. 1 the energy received by the transformer 21 from either the phonograph pick-up 10 or photo-electric cell 13 passes to the amplifier 22, where it is amplified and fed through the filter network to the potentiometer 26. The double potentiometer 28 may be used as a manual tone control when desired.

Energy from the potentiometer 26 is fed through the rheostat 30, primary winding 31, and the transformer 33 to the push-pull amplifier 37. Here it is amplified and fed through the transformer 40 to the power amplifier 41, where it is further amplified and fed through the transformer 43 to the moving coil of the loudspeaker 44, where it is reproduced as speech or music in a well known manner.

For controlling the operation of the automatic variable filter some of the energy from the rheostat 30 passes through the stoppage condenser 60 to the potentiometer 61, from which any desired proportion is fed to the amplifier tube 62. Here the energy is amplified and passes through the high-pass filter 63, the high frequency component passing to the second amplifier tube 65. Here the high frequency energy is further amplified and is fed to the rectifier 67 where it is rectified and causes a current to flow through the resistor 68 in the direction of the arrow. This causes a potential difference to be built up across this resistor which is proportional to the intensity of the high frequency energy in the input signal. The positive potential produced at the upper end of the resistor 68 is applied through the resistor 69 to the grids of the filter control tubes 35 and 36.

In the absence of control signal, the tubes 35 and 36 are biased sufficiently to reduce the space currents substantially to zero, so that the secondary winding 34 is not loaded and the effect of the presence of the transformer 32 is principally the choking effect due to the actual inductance of the primary winding 31 which discri.i-

nates against the passage to transformer 33 of the higher frequency signals, such as surface noise, for example in the range of 1000 to 4000 cycles.

This discrimination against the higher tones is shown by curve 100 in Fig. 2 which shows the transmission characteristics when only weak high frequency signals are present. The curve shows the lowered transmission of the higher frequencies in the background noise range. The curve 100 represents the transmission characteristics when the needle is in the record groove in the absence of any appreciable recorded signal.

When there are recorded signals, sufficient to mask the presence of the background noises, the rectifier circuit is operated to lower the bias of the tubes 35 and 36 as already described. This decrease in bias is in accordance with the characteristics of the control channel. This in turn lowers the thermionic resistance shunted across the secondary winding 34 thus increasing the secondary loading which produces the general effect of lowering the primary equivalent impedance especially for the higher frequencies. The relative transmission of currents of different frequencies through the network in which the primary winding 31 is connected may therefore be modified by secondary thermionic impedance control.

The effect just described is depicted by the curves in Fig. 2, which show transmission characteristics relative to frequency. It has been found that the surface noises of the higher frequency range may be masked by a sufficient amount of signal in that range or by a much greater signal of lower frequency. The curve 101 shows the relative ability of currents of different frequencies to produce rectification by tube 67. The elements are suitably proportioned so that whenever a combination of lows and highs is present in sufficient amount to operate the rectifier 67, they will also be sufficiently strong to mask the surface or ground noise effects which the control channel then permits the primary winding 31 to pass.

When the combination of lows and highs is sufficiently strong so that the grid potential of the tubes 35 and 36 is equal to their cathode potential, the relative transmission of signals through the primary of transformer 32 for different frequencies is as shown by curve 102 in Fig. 2. This shows improved transmission for high frequencies over the corresponding curve 100 corresponding to weak control signals.

By this process the transmission is automatically controlled so that surface noise effects will not be transmitted to the loudspeakers unless the volume level and volume distribution is at all times such as to mask the noise effects. The constants of the circuits are preferaby so chosen that the control action will be rapid. There is no apparent loss of high tones except under conditions which would otherwise allow the passage of high tones to be accompanied by serious background disturbances. In this manner it is practicable to use a system that will transmit higher frequencies than if surface noises were suppressed by manually controlled or fixed scratch elimination.

The primary winding 31 may be shunted by a condenser, or magnetically coupled to a tuned circuit network 99 for the purposes of tuning the effective impedance of the primary winding 31, and modifying the transmission characteristics for weak signals.

It will be noted that a balanced load is placed on the secondary 34 of the transformer 32. In this way the effect on the D. C. core flux is balanced out and the load may be varied without altering the saturation of the transformer. The control is thus made rapid and distortionless.

The details of this tone control system are further explained and claimed in my co-pending application Serial No. 72,520, Patent No. 2,096,760.

With reference to the expansion operations, the first grids of the pentodes 38 and 39 are at ground potential, the cathodes are biased positively with respect to ground by the potential drop in resistor 58 through which bleeder current flows from the bleeder resistor 57 and also the space currents to the cathodes. The second grids are maintained at a positive potential by the plate battery 45 acting through the coupling resistor 59. The third grids are normally maintained at a negative potential determined by the setting of the adjustable contact 86 of the potentiometer 85.

Some of the energy which passes through the transformer 32 passes through the condenser 75 and thence through the potentiometer 76 to the amplifier tube 77. The output of this amplifier tube is further amplified by the second amplifier tube 79 and then passes to the rectifier tube 80. The rectified output of this tube passes through the resistor 81 in the direction of the arrow and thus causes a potential difference to be built up across this resistor which is proportional to the current passing through it and therefore to the signal strength.

The potential drop across the resistor 81 will decrease the negative bias on the third grids of the tubes 38 and 39 making them more positive in proportion to the increase of input signal strength. This acts directly upon the plate-cathode circuit of these tubes to increase the space current and therefore increases the amplification of this stage due to the decreased plate-cathode impedance and to increased mutual conductance of the first grid upon the plate-cathode circuit.

At the same time this increase of potential decreases the current drawn by the second grids, thereby decreasing the potential drop through the biasing resistor 59 which increases the positive potential on the second grids. This in turn lowers the internal impedance and increases the mutual conductance of the first grids upon the anode-cathode circuit.

These two effects are in a like sense and are additive for extending the range of expansion, and increasing the expansion at low acoustical volume.

The third grid potentials are limited by the current flow through the resistor 82 so as to prevent these grids from becoming positive with respect to the cathodes.

The magnitude of the effects which are produced by this portion of the circuit are indicated in Fig. 3 which shows the gain in decibels of this amplifier stage from the grids of the tubes 38 and 39 to the grids of the tubes 48 and 49. The upper curve 105 shows the gain as a function of the potential of the third grid under conditions of a fixed potential of the second grids equal to the maximum variable potential. The lower curve 106 shows the gain as a function of the potential of the third grid when it controls the

potential of the second grid by the indirect method just described. This curve shows a greater sharpness of cut-off as well as a greater range of gain, resulting in improved expansion control and performance at weak signal values with small rectified potential.

The limiter tubes 70 and 83 function when their anodes become positive with respect to their cathodes to prevent further build up of potential on the respective control grids.

The details of operation of the pentode expander tubes are further explained and claimed in my copending application Serial No. 72,519, Patent No. 2,096,759.

In Fig. 4 is shown a system for practicing the invention, suitable for nontechnical operation, in which the controls available for adjustment are minimized by use of a gang switch which presets the controls in a best average manner for different kinds of phonograph signals.

Pick-up device 121 delivers electrical energy to operate the amplifier tube 122, which is provided with an input coupling resistor 123 connected from grid to ground. This energy is suitably treated by attenuators 124, choke 125, transformer 126, resistor 127, and condenser 128 to compensate for recording deficiencies. The attenuator 124 is preset in accordance with the design characteristics of pick-up 121, and in a coordinated design, may be omitted. Choke 125 is so proportioned as to cut down higher frequency tones which have no musical value, as for example above the order of 4000 to 5000 cycles. Resistor 127 and condenser 128 serve to relatively strengthen the lower tones to compensate for undercutting of bass notes. This is accomplished by proportioning resistor 127 and condenser 128 to load the secondary of transformer 126 for frequencies of the order of 400 cycles and over, and to produce practically no loading for frequencies of the order of 40 cycles.

These fixed adjustments are made to balance up the system tonally and as to volume, and are not an essential part of the invention.

The signal energy amplifier tube 122 is arranged as a resistance fed amplifier, with plate current supplied from a plate supply source 129 through feed resistor 130 and coupling resistor 131, with condenser 132 serving as a by-pass to ground. The space current passes from the cathode of tube 122 to ground through a resistor 133, by-passed by a condenser 134 which serves to bias the cathode positive with respect to ground. Energy amplified by tube 122 is passed through blocking condenser 135 and through the primary winding of a transformer 136, to a volume control potentiometer 137 to ground. The passage of currents from the plate of tube 122 to the volume control potentiometer 137 is influenced by the loading of the transformer primary by two secondary windings, one of which is loaded by variable resistor 138, manually controlled, and the other of which is loaded by the automatically controlled tube impedances from plate to plate of tone control tubes 139, in a manner to be described. The plate of tube 122 is by-passed to ground for high frequencies by condenser 140, and the volume control potentiometer 137 is similarly by-passed to ground by a condenser 141. These two condensers, in combination with the effective primary impedance of transformer 136, form a filter section of the low-pass type, with cut-off automatically and manually adjustable.

Energy from the potentiometer 137 is fed through a transformer 145 to the first grids of push-pull connected expander pentodes 146. Between the potentiometer 137 and the transformer 145 may be included suitable circuits for varying the fidelity of transmission in accordance with the manual adjustment of the volume control. In particular, resistor 147, choke 148, condenser 149 and potentiometer 150 may serve to discriminate somewhat against medium valued tonal frequencies when the potentiometers 137 and 150 are set for lower signal volumes.

The pentodes 146 serve to produce volume expansion in accordance with the acoustical volume output of the tube 122. The anodes of the pentodes 146 are connected to the primary windings of a transformer 151 which corresponds to the transformer 40 of Fig. 1, the secondary of which is connected to the subsequent transmission line, or amplifier stages.

The transformer 151 may be ballasted with primary resistors 152 to the mid point of which the plate supply battery 126 is connected. Potential for the second grids of pentodes 146 is supplied from the source 129 through coupling resistor 153. Bleeder current from the source 129 passes through bleeder resistor 154 to the cathodes, and thence through biasing resistor 156, which determines the bias of the first grids with respect to cathode, and through potentiometers 157 and 158 to ground. Condensers 159 may be used, if desired, to by-pass the biasing resistor 156 to ground.

The plates of the tone control tubes 139 are supplied with operating potential from source 129 through feed resistors 163 and 164. The source is also connected through bleeder resistor 165 to the cathodes, thence through biasing resistor 166 to ground. Suitable by-pass condensers 167 to 169 may be connected across the various resistors and between the grids of the tubes 139 and ground.

The gain of the amplifier stage including pentodes 146 is controlled in accordance with the voltage between the third grids and cathodes, and the transmission through primary of transformer 136 is controlled in accordance with the grid to cathode voltage of tubes 139. These voltages are automatically controlled in accordance with the signals transmitted to an amplifier-rectifier system from the plate of tube 122, through a coupling condenser 172, which impresses control signal voltage across a coupling resistor 173 connected in the input circuit of control preamplifier tube 174. The values of condenser 172 and resistor 173 are suitably proportioned with respect to each other, and with respect to the other combinations of resistors and condensers so that the expansion produced by the control channel will be in accordance with the acoustical volume instead of the electrical volume level at the output of tube 122.

The operating potential is supplied to the anode of control preamplifier tube 174 from the source 129 through feed resistor 175, by-passed by a condenser 176. The cathode is connected to ground through a biasing resistor 177 and a by-pass condenser 178.

The output of this tube 174 is fed through a blocking condenser 180 to a resistance coupling network to actuate the grids of expander-control amplifier tube 184 and tone-control amplifier tube 216.

The output of this tube 174 is fed through a blocking condenser 180 and a switch 181 to a resistance coupling network, comprising a tapped

resistor 182 and a fixed resistor 183 connected in parallel across the grid-cathode circuit of expander-control amplifier tube 184. The switch 181 successively engages a contact 185 connected to ground and contacts 186 to 188, connected to taps on the resistor 182. The arrangement is such that the energy supplied to the grid-cathode circuit of the tube 184 is increased as the switch 181 engages the successive contacts 188 to 186, but is zero when it engages contact 185.

The cathode of the tube 184 is connected to ground through a biasing resistor 189 and a by-pass condenser 190. The output is applied through a blocking condenser 191 to a rectifier output resistor 192, connected across one anode-cathode path of a double rectifier 193. Plate voltage is supplied to the tube 184 from the source 129 thrcugh feed resistor 194 and coupling resistor 194a. By-pass condensers 195 and 195a serve as a by-pass on feed resistor 194 and coupling resistor 194a for high frequencies. The positive end of the resistor 192 is connected through a resistor 196 to the third grids of the pentodes 146. The potential thus applied to the third grids of the pentodes 146 is limited by the second anode-cathode path of the double rectifier tube 193. For this purpose the second anode is connected through a resistor 197 to a tap on the resistor 196 and the second cathode is connected, by a switch 198 having contacts 199 to 202 to taps on a resistor 203 which is connected between the positive end and adjustable contact of the potentiometer 158. The second cathode is thus adjustably positive with respect to the first anode which is connected to the adjustable contact of the potentiometer 158. A filter and timing condenser 204 may be connected across the resistors 192 and 196 to by-pass the A. C. component of the rectified energy.

The output from the amplifier tube 174 is also impressed through a resistance capacity network, comprising resistors 210, 211, and 212 and condensers 213, 214, and 215 on the input circuit of a tone control amplifier tube 216. The cathode of this tube is connected to ground through a biasing resistor 217 and a by-pass condenser 218. The output of the amplifier tube 216 is applied through a coupling condenser 219, to a rectifier output resistor 220 connected across one anode-cathode path of a double rectifier 221. Plate voltage is supplied to the tube 216 from the source 129 through a feed resistor 222 and coupling resistor 222a, the former having a by-pass condenser 223.

The positive end of the resistor 220 is connected, through a resistor 224 to the grids of the tone control tubes 139. The potential thus applied to the grids is limited by the second anode-cathode path of the double rectifier tube 221. For this purpose the second anode is connected, through a resistor 225, to a tap on the resistor 224 and the second cathode is connected to a tap on the resistor 166 which is negative with respect to the cathodes of the tubes 139. A filter condenser 226 may be connected across the resistors 220 and 224 to by-pass the A. C. component of the rectified energy.

The timing of the expander control exercised by the control channel including the expander-control amplifier tube 184 and the rectifier 193 may be varied by a switch 230 having contacts 231 to 234. The switch blade is connected to the cathode of the expander pentodes 146. The contact 231 is connected directly to the third grids and the contacts 233 and 234 are connected to the third grids through condensers 235 and 236 respectively. When the contact 231 is closed the third grids are maintained at the cathode potential and the pentodes 146 operate as standard amplifiers. When the contacts 233 or 234 are closed the timing of the control potential on the third grids is governed by the capacities of the condensers 235 or 236.

A switch 238 is provided to vary the initial setting of the biasing potential of the cathodes of the pentodes 146 with respect to their signal grids as determined by the potentiometers 157 and 158. This switch 238 is provided with contacts 239–242 certain of which are connected to resistors 243 and 244 which are respectively connected, by the switch 238, across the potentiometers 157 and 158 for varying the effective resistance thereof.

In the operation of this embodiment, the signal energy derived from the pick-up 121 is amplified by the amplifier tube 122, passes through the filter network including the primary of the transformer 136 and is further amplified by the push-pull amplifier stage comprising the pentodes 146 after which it is applied through the transformer 151 to a utilization circuit comprising a power amplifier and a loudspeaker driven thereby.

A portion of the energy passes from the output of the amplifier tube 122 to the control pre-amplifier tube 174, thence through the resistance coupling network above described to the input circuits of the expander-control amplifier tube 184 and the tone-control amplifier tube 216. The energy is amplified by these tubes and is rectified by the double rectifiers 193 and 221 to cause a current to flow through the resistors 192 and 220 in the direction of the arrows to build up a positive potential proportional to the input energy which is applied to the third grids of the pentodes and to the grids of the tone control tubes 139, to control the expansion and tone as described in connection with Fig. 1.

In addition to control of the expansion properties in accordance with the signal characteristics at the plate of tube 122, there is an additional control by the four switches 181, 230, 238, and 198 for controlling the strength of signal to the volume control rectifier, the timing, the expander gain for weak signals, and the expander gain for strong signals. In addition there may be controls, as for example of the gain for weak signals, which vary with the setting of the manual volume control. It is understood that the four switches are mechanically connected with each other, with their blades connected to the respective switch points as indicated by the numberings.

In particular, when switch 181 is connected to contact 185, no signal is impressed upon the volume control circuit, while at the same time switch 230 is connected to contact 231 for connecting the third grids of expander tubes 146 to the cathodes, producing maximum gain irrespective of signal volume. For the next position, with contacts 186 and 232 closed, the switches may be set for average dance records; with contacts 187 and 233 closed, for average operatic records; and with contacts 188 and 234 closed, for average symphonic records. It will be understood, of course, that this classification is for illustration only, and that any desired number of switch connections may be used.

The switch 181 is connected to tapped resistor 182 and grid-input resistor 183 to vary the signal

upon the grid of tube 184 without opening the circuit from grid to ground, and without modifying the energy available for actuating tube 216. The resistor-condenser network in the input circuit of tube 216 is proportioned to give additional and more abrupt discrimination against the lower frequencies, so that those tones which are most discriminated against by the primary of the transformer 136 will be most favored in producing control of the filter operation. The resistors 210 and 211 are suitably proportioned to cause control of the transformer primary impedance when higher frequency tones are sufficiently present to mask the scratch frequency tones.

The second cathode-anode branches of the tubes 193 and 221 are not used for rectification purposes, but rather to decrease the efficiency of rectification when strong signals are impressed. This action will be illustrated with reference to tube 221. The second cathode is connected to a point on the resistor 166 which is positive with respect to ground and with respect to the negative and grounded end of resistor 220. In the absence of signals, no current passes through the second anode to cathode path, because the anode is negative with respect to the cathode. When sufficiently strong signals are impressed, peaks of surges will be sufficiently great in the system to cause the second plate to become positive with respect to its cathode whereby rectified current will flow through the second plate to cathode path. This secondary flow decreases the efficiency of rectification of tube 221 and prevents further substantial increase in potential across resistance 220, thereby limiting the final potential of the grids of tubes 139 to only slightly more positive than the potential of the point on the resistance 166 to which the second cathode is connected. The sharpness and definiteness of cut-off may be increased by making the tap on resistor 224 closer to the end of the resistor which is connected to condenser 226 and by making the resistor 225 smaller.

Similar control is exercised by the second anode and cathode of tube 193, to decrease the efficiency of rectification of that tube at increased signals and to limit the potential applied to the third grids of the pentodes 146.

It will be noted that abrupt termination of rectification efficiency results when the grid potentials of tubes 139 are raised to cathode potential, due to conduction within the tubes 139 themselves, and similar results occur in tubes 146 to limit the control potential.

Tubes 193 and 221 are commercially available, type 6H6, in which two independent diodes are included in the same structure. One of the diodes is used for rectification purposes, the other is used for controlling the efficiency of rectification, giving increased efficiency of rectification for weaker signals.

It will be further observed that upon decrease in signals the condensers 226 and 169 first discharge through the grid-to-cathode path of tubes 139, and through the second anode-to-cathode path in tube 221. Thereafter the discharge path available is through resistors 224 and 220 in series. The "time constant" determined by the condensers 226 and 169, and resistances 224 and 220 in series may be of the order of .02 ohm-farad or less, but the effective time constant when the condensers are being charged will be very much less. This provides very little delay in control of the impedance of tubes 139, so that the change of transmission is very quickly accomplished.

Similar control operation is exercised by the rectifier limiter 193 and associated circuits. The timing of this circuit is controllable by switch 230 with "time constant" for example of the order of .2 ohm-farad to .02 ohm-farad for symphonic and speech purposes respectively.

In addition to timing control of the expander, the initial setting control switch 238 provides for a wider range of expansion on one type of record than on another type. Resistor units 243 and 244 serve to lower the effective resistance of the potentiometers 157 and 158 which may be varied to adjust for characteristics of different tubes 146. For example, with the switch 238 engaging contact 241 the amount of possible change of gain by tubes 146 may be 30 db, while with the switch 238 engaging contact 242 it may be 20 db, assuming volume-control set at full volume. The linking of manual volume-control setting of potentiometers 137 and 150 to the potentiometer 158 serves to reduce the initial negative bias on the third grids of the tubes 146 when the volume control is set for lower volume. This increases the amplification characteristics of the tubes for weak signals and thereby cuts down the amount of possible expansion as the general volume level is reduced so as to maintain the stray noise level in the absence of signals substantially independent of the manual control setting. In this way no signals will be lost when the reproduction is made at reduced volume.

The remaining control switch 198 is for limiting operation control, the second cathode of tube 193 being connected to the center point of the switch. The tapped resistor 203 is of relative high resistance compared with resistance of potentiometer 158. As a result, the contact points 200 to 202, connected to the tapped resistor 203, are at a potential positive with respect to the first anode of tube 193, irrespective of the setting of potentiometer 158.

It will be seen, therefore, that there is provided a phonograph circuit with a minimum of controls, namely manual volume and manual tone controls, such as would be required for a conventional type amplifier. In addition there is a signal switch which should be preset only in accordance with the type of record which is to be reproduced. Furthermore, there are suitable linkages between the manual volume-control and expander adjustments so that undesirable results are not produced when the reproduction is set for reduced volume. It will be understood that the type of circuits, the choices of adjustments to be made by the signal switch, and the linkages between the manual volume and manual tone-control circuits and the expander-control circuits as shown here are for purposes of illustration only, and that some may be dispensed with or others added as required.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but might be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. In a system for reproducing sound from a sound record, a transmission channel including a filter network and an amplifier, a transformer having a primary connected in said filter network to control the transmission characteristics

thereof, means applying a variable balanced load to the secondary of said transformer for altering the effective primary impedance, means controlling the amplification characteristics of said amplifier and a control channel energized in accordance with the applied signal, said control channel having means controlling said load and controlling the amplification characteristics of said amplifier in accordance with the impressed signal for simultaneously varying the dynamic range and the frequency distribution of the reproduced signal.

2. In a system for reproducing sound from a sound record, a signal channel comprising a filter network and an amplifier, a transformer having a primary connected in said filter network to control the transmission characteristics thereof, a pair of space discharge devices connected in balanced relation across the secondary of said transformer to variably load the same and to thereby control the effective primary impedance of the transformer, said amplifier comprising a third space discharge device and means varying the impedance of all of said space discharge devices in accordance with a characteristic of the applied signal so as to simultaneously vary the dynamic range and the frequency distribution of the reproduced signal.

3. In a system for reproducing sound from a sound record, a signal channel comprising a filter network and an amplifier, a transformer having a primary connected in said filter network to control the transmission characteristics thereof, a pair of space discharge devices connected in balanced relation across the secondary of said transformer to variably load the same and to thereby control the effective primary impedance of the transformer, said amplifier comprising a third space discharge device means deriving a control voltage from the applied signal, and means applying the control voltage to vary the grid bias on all of said space discharge devices for changing the load on said secondary and the gain ratio of said amplifier in accordance with a characteristic of the applied signal.

4. A system for reproducing sound from a sound record comprising a transmission channel having a filter network and an amplifier, a variable impedance device included in said filter network and adapted to change the transmission characteristics thereof, said amplifier comprising a multi-grid space discharge device having a signal grid and a plurality of control grids at least one of which is positively biased, means applying the signal voltage from the output circuit of said filter to said signal grid, means applying a control voltage to both of said control grids so as to control the impedance of said tube thereby in the same sense, and means responsive to the applied signal for varying the impedance of said variable impedance device and for producing said control voltage.

5. In a system for reproducing sound from a sound record, a signal channel including a nonlinear amplifier adapted to expand the dynamic range of the signal, a manual volume control for adjusting the volume of the reproduced signal and means for changing the amount of expansion produced by said amplifier, said last means being mechanically linked to said manual volume control so as to reduce the expansion when the volume control is set for a lower volume.

6. A system for reproducing sound from a sound record comprising a variable filter and an amplifier adapted to expand the dynamic range of the reproduced sound, a control channel connected to control the amount of expansion produced by said amplifier, means energizing said control channel in accordance with the signal energy, adjusting means for variably adjusting the proportion of the signal energy applied to the control channel, a second adjusting means for adjusting the timing of the control action, a third adjusting means for adjusting the amplifier gain for weak signals and a fourth adjusting means for adjusting the amplifier gain for strong signals and means operating all of said adjusting means in unison for presetting the amplifier for a plurality of different types of records.

7. A system for reproducing sound from a sound record comprising a variable filter and an amplifier adapted to expand the dynamic range of the reproduced sound, a control channel connected to control the amount of expansion produced by said amplifier, means energizing said control channel in accordance with the signal energy, adjusting means for variably adjusting the proportion of the signal energy applied to the control channel, other adjusting means for adjusting the amplifier characteristics, and means operating all of said adjusting means in unison for presetting the amplifier for a plurality of different types of records.

8. A system for reproducing sound from a sound record comprising a variable filter and an amplifier adapted to expand the dynamic range of the reproduced sound, a control channel connected to control the amount of expansion produced by said amplifier, means energizing said control channel in accordance with the signal energy, means for adjusting the control action, means for adjusting the expansion, means for adjusting the amplification, and means operating all of said adjusting means in unison.

9. A system for reproducing sound from a sound record comprising a variable filter and an amplifier adapted to expand the dynamic range of the reproduced sound, a control channel connected to control the amount of expansion produced by said amplifier, means energizing said control channel in accordance with the signal energy, adjusting means for variably adjusting the proportion of the signal energy applied to the control channel, a second adjusting means for adjusting the timing of the control action, a third adjusting means for adjusting the amplifier gain for weak signals and a fourth adjusting means for adjusting the amplifier gain for strong signals.

10. A system for reproducing sound from a sound record comprising a variable filter and an amplifier adapted to expand the dynamic range of the reproduced sound, a control channel connected to control the amount of expansion produced by said amplifier, means energizing said control channel in accordance with the signal energy, adjusting means for variably adjusting the proportion of the signal energy applied to the control channel and other adjusting means for adjusting the amplifier characteristics.

11. In a system for recording or reproducing sound, a signal channel including an amplifier adapted to expand the dynamic range of the reproduced signal, a control channel therefor, means supplying said control channel with a portion of the sound energy and a rectifier in said control channel, means utilizing said rectifier for producing a control voltage varying in accordance with the applied signal and means for decreasing the efficiency of rectification in said rectifier when the control voltage produced thereby

exceeds a predetermined value, and means utilizing said control voltage to vary the amplification characteristics of said amplifier.

12. In a system for recording or reproducing sound, a signal channel including an amplifier adapted to expand the dynamic range of the reproduced signals, a control channel therefor, means supplying said control channel with a portion of the sound energy and a double rectifier in said control channel having two anode-cathode paths, means utilizing one of said anode-cathode paths for producing a control voltage varying in accordance with the applied signal and means utilizing the other of said anode-cathode paths for decreasing the efficiency of rectification in said first path when the control voltage produced thereby exceeds a predetermined value and means utilizing said control voltage to vary the amplification characteristics of said amplifier.

13. In a system for recording or reproducing sound, a signal channel including a variable impedance device, a control channel having a rectifier connected to produce a control voltage, and means decreasing the efficiency of rectification when the control voltage exceeds a predetermined value, and means utilizing the control voltage to vary the impedance of said variable impedance device.

14. In a system for recording or reproducing sound, a signal channel having a variable impedance device, a control channel having a double rectifier with two anode-cathode paths, means utilizing one of said paths for producing a control voltage, means utilizing the other of said paths to decrease the efficiency of rectification in said first path when the control voltage exceeds a predetermined value, and means utilizing said control voltage to vary the impedance of said device.

15. In a system for reproducing sound from a sound record, a signal channel including an amplifier tube having a negatively biased control grid, means adjusting said bias to vary the amplification characteristics of the tube, a manual volume control for adjusting the volume of the reproduced signal, and means interconnecting the bias adjusting means and the manual volume control so as to decrease said bias when the volume control is set for lower volume whereby the stray noise level is maintained substantially independent of the volume control setting.

16. In a system for reproducing sound from a sound record, a transmission channel including a filter network and an amplifier, a transformer having a primary connected in said filter network to control the transmission characteristics thereof, means applying a variable balanced load to the secondary of said transformer for altering the effective primary impedance thereof, said amplifier comprising a multi-grid space discharge device having a signal grid and a plurality of control grids, at least one of which is positively biased, means applying the signal voltage from the output circuit of said filter to said signal grid, means applying a control voltage to both of said control grids so as to control the impedance of said tube in the same sense and means responsive to the applied signal for controlling said load and for producing said control voltage for simultaneously varying the dynamic range and the frequency distribution of the reproduced signal.

ELLISON S. PURINGTON.