

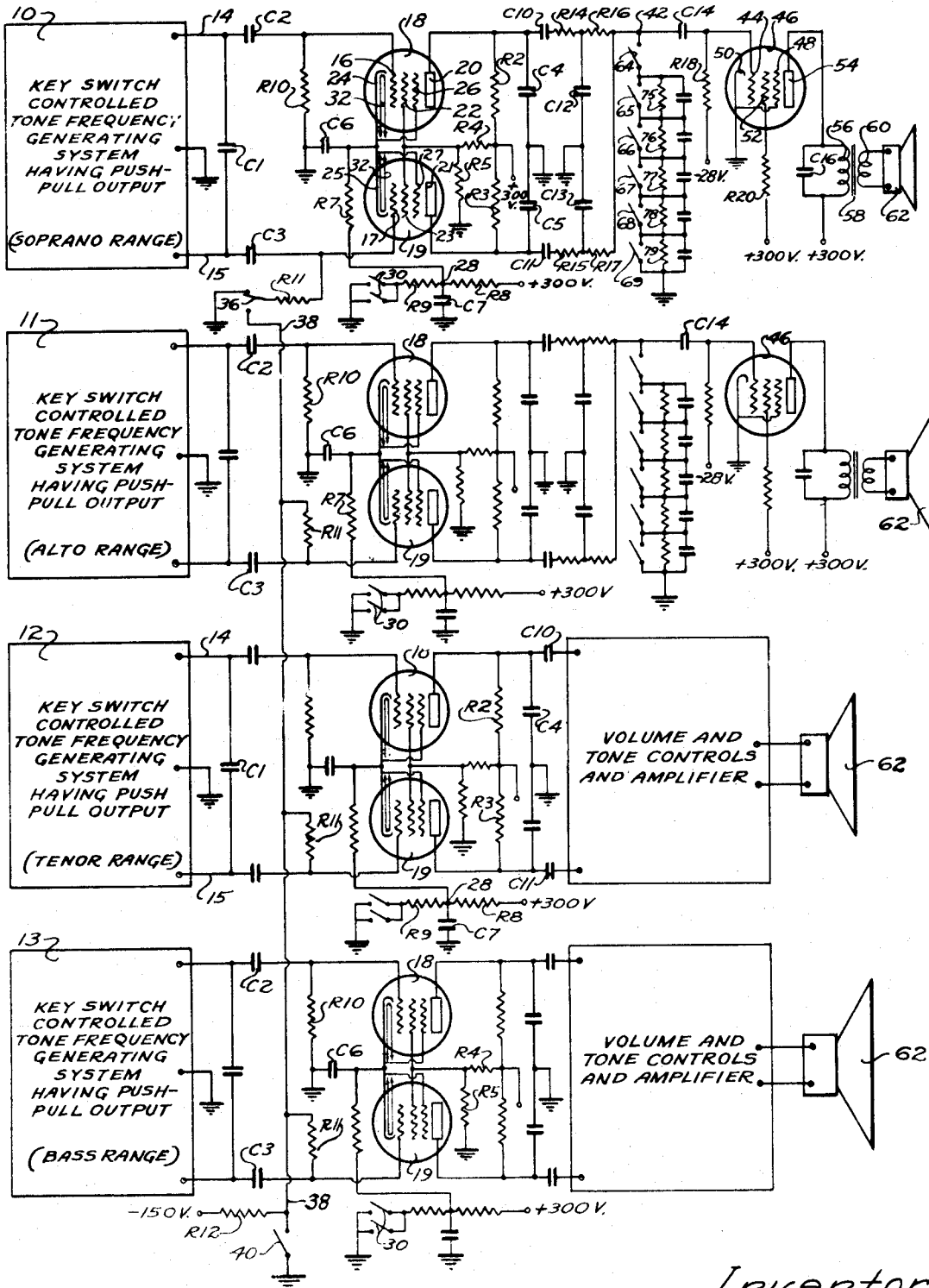
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ELECTRICAL MUSICAL INSTRUMENT

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ELECTRICAL MUSICAL INSTRUMENT

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My invention relates generally to electrical musical instruments, and more particularly to improvements in the controls therefor, whereby improved musical effects may be obtained.

It is one of the principal objects of my invention to provide an electrical musical instrument with improved means for obtaining octave coupler effects.

A further object is to provide an improved electrical musical instrument having a plurality of tone generating systems under the control of a single keyboard in which means common to all or a plurality of the generating systems is provided for controlling the introduction of octave coupler tones.

A further object is to provide improved key operated switch circuits for controlling the transmission of the tone frequency signals from a generating system to the output of the instrument.

A further object is to provide an improved key operated switch for controlling the introduction of octave coupler effects and improving the tone quality of the signals produced by a generating system.

A further object is to provide an electrical musical instrument having a plurality of generating systems, each providing tone frequencies throughout a limited pitch range, and providing a signal transmission system for each generating system which is effective to attenuate frequencies other than those within the pitch range of its associated generating system.

Other objects will appear from the following description, reference being had to the accompanying drawing which shows a schematic wiring diagram of the instrument.

The invention is particularly suitable for incorporation in an electrical musical instrument of the "quartet organ" type—that is, an instrument having a generating system, an amplifying and transmission system, and a speaker for each part of the multi-part harmony music. The underlying principles of instruments of this character are disclosed in the co-pending application of Laurens Hammond, Serial No. 387,113, filed April 7, 1941.

In one form that instruments of this type may assume, there is a soprano, an alto, a tenor, and a bass oscillator, each of which may oscillate at any musical tone frequency within the range of its respective musical part, and in which the keyboard and keying system are such that a player using substantially normal playing technique in rendering multi-part harmony music will automatically cause the production of the separate

melodic parts by their respective generating, transmitting and speaker systems. Thus, in this type of instrument, the speakers may be spatially separated and the instrument may thus be used effectively for the accompaniment of multi-part harmony singing, as by quartets, choirs and congregations.

The generating systems may be of any one of a number of different well known types, (such as are shown, for example, in the following Patents to Yungblut No. 2,045,172, Hammond and Hanert application Serial No. 387,113, filed April 7, 1941, and Hanert Patent No. 2,254,284), and are therefore illustrated in the drawing as blocks. Block 10 represents the generating system for the soprano range, block 11 represents the generating system for the alto range and blocks 12 and 13 represent the generating systems for the tenor and bass ranges respectively. Each of these blocks 10 to 13 is intended to represent also the keyboard and key operated switches by which the frequency of the generating system output is controlled, it being assumed for present purposes that the outputs of the generating systems are of the push-pull type such, for example, as that disclosed in my patent application Serial No. 361,064, filed October 14, 1940.

The generating systems 10 to 13 may be similar in construction except that each will be adapted and designed to produce tones within its particular range, as for example, the soprano generator may be adapted to produce the tones A2# to G4 inclusive (233.08 to 587.33 c. p. s.); the alto generating system from the note G2 to the note D4 inclusive (196 to 587.33 c. p. s.); the tenor generating system from the note A1# to the note F3# inclusive (116.54 to 369.99 c. p. s.); and the bass generating system from the note C0 to the note D1 inclusive (32.703 to 73.416 c. p. s.).

The push-pull output of the generating system 10 is supplied through conductors 14 and 15 which are connected by a radio frequency by-pass condenser C1. The conductors 14 and 15 are connected through blocking and current limiting condensers C2 and C3 to the control grids 16 and 17 of control tubes 18 and 19 respectively.

The tubes 18 and 19 are preferably remote cut-off pentodes such as the 6K7G type. The plates 20 and 21 of these tubes are connected to a source of plate current indicated as +300 v. through load resistors R2 and R3 respectively.

The screen grids 22, 23 of the tubes 18 and 19 are connected to the potential source +300 v. through a voltage dividing network comprising resistors R4 and R5, the latter resistor connect-

ing the screen grids 22 and 23 to ground. This network is such as to maintain a voltage of +150 v. on the screen grids.

The suppressor grids 26, 27 of the tubes 18 and 19 are respectively connected to their cathodes 24, 25, and both are connected to ground through a cathode condenser C6. The cathodes 24, 25 are connected through a self-bias resistor R7 to a terminal 28, the potential of which is controlled by the operation of the playing keys. The terminal 28 is connected through a resistor R8 to a source of potential +300 v., and is adapted, upon closure of any one of a plurality of playing key operated switches 30, to be connected to ground through a spark suppressing resistor R9. The terminal 28 is connected to a point of fixed D. C. potential, such as ground, through an envelope controlling condenser C7.

It will be understood that there is a switch 30 operated by each of the playing keys associated with the generating system 10, the switch being preferably arranged to be operated after the playing key has operated the switch controlling the tuning of the generating system 10, in a manner similar to that disclosed in my copending application Serial No. 274,325, filed May 18, 1939, which has matured into Patent No. 2,254,284, issued September 2, 1941.

It will be understood that the cathodes 24 and 25 are normally maintained at a positive voltage of +300 v. supplied through the resistor R8, thus completely cutting off the space current through the tubes 18 and 19. The transmission of a signal through inter-electrode capacity is prevented due to the electro-static shielding effect of the screen grids 22 and 23 which are maintained at a fixed voltage of +150 v. by the voltage divider resistors R4 and R5.

Because of the relatively high positive potential upon the cathodes 24, 25 it is preferable that a separate source be provided for the heaters 32 of each of these tubes in a well known manner, and that the heater circuit be connected to the cathodes of these tubes so as to prevent large differences in potential between the cathodes and the heaters.

The grid 16 is connected to ground through a grid resistor R10, whereas the grid 17 may be connected selectively either to ground through a resistor R11 by operation of a single-pole double-throw switch 36 (when the latter is in the position it is shown in the drawing), or may be connected through a conductor 38 and a resistor R12 to a source of constant direct current potential indicated as -150 v. When the control grid 17 is connected to ground through its resistor R11, the tube 18 will operate to transmit and amplify the signal, whereas when the switch 36 is moved to a position opposite to that shown in the drawing, the control grid 17 will be maintained at a -150 v. potential, which will effectively cut off space current flow through the tube 18.

The conductor 38 may be connected to ground by closure of a switch 40. Thus, when the switch 40 is closed, the position of the switch 36 will be immaterial. The purpose of the switch 40 will hereinafter be more fully described.

The tubes 18 and 19 receive signal pulses from the generating system through current limiting condensers C2 and C3. These grid signals are relatively large (in the order of 40 peak volts), and thus cause non-linear modulation of the plate current resulting in musically desirable harmonic distortion in the output signal. On the negative swing of the grid voltage the tubes 18 and 19

closely approach cutoff, and thus, positive pulses mainly are effective to cause plate current flow, as is more fully disclosed in my co-pending application Serial No. 395,754, filed May 29, 1941. The signals supplied by the generating system 10 through the conductors 14 and 15 are preferably 180° out-of-phase, as disclosed in said application.

The tubes 18 and 19, being remote cutoff tubes, operate in a manner to suppress the sharp curvature of their input wave on the negative swing of this wave, that is, in a direction causing plate current cutoff. Thus, these tubes, while introducing desirable harmonic content into their output waves, do not introduce undesirable high frequencies which would be associated with passing through the cutoff point of a sharp cutoff tube (such as the 6J7G type).

The outputs of the tubes 18 and 19 are supplied to a common terminal 42 through condensers C10 and C11, series resistors R14, R16, R15 and R17 respectively. The junction of the resistors R14 and R16 is connected to ground through a condenser C12, while the corresponding junction between the resistors R15 and R17 is connected to ground through a condenser C13. The condensers C10 to C13 and the resistors R14 to R17 together form a filter network effective to attenuate frequencies lower than the fundamental frequency of the lowest note of the soprano part (A2#), and also to attenuate musically undesirable high frequencies (e. g. above 6000 c. p. s.)

To produce the octave coupler effect, the values of resistors R14 and R16 are made approximately one half that of the corresponding resistors R15 and R17. By making these series impedances differ from each other, exact frequency doubling is thus avoided, and the effect of the octave is produced. Every other pulse of the combined wave is smaller in amplitude, and thus the output contains a preponderance of even numbered harmonics.

The terminal 42 is connected to the control grid 44 of a power output pentode 46, preferably of the 6F6G type, this connection being through a current limiting condenser C14. This condenser is also made current limiting for the lowest fundamental frequency of the soprano range and is in effect an additional stage for the filtering system previously described. The value of the condenser C14 is so chosen with respect to the value of a grid resistor R18 that attenuation of frequencies lower than the fundamental frequency of the lowest note (A2#) of the soprano part is afforded. The grid resistor R18 is connected to a terminal of fixed negative biasing potential indicated as -28 v.

The suppressor grid 48 of the tube 46 is internally connected to the cathode 50 of this tube, while its screen grid 52 is connected to a fixed potential source indicated as +300 v. through a protective resistor R20. The plate 54 of the tube 46 is connected to the plate current supply source indicated as +300 v. through the primary winding 56 of an output transformer 58, the primary winding being shunted by a condenser C16. The secondary winding 60 of the output transformer 58 is connected in a suitable manner to a speaker 62. The condenser C16 functions as a further means for suppressing undesirable high frequencies (e. g. above 6000 c. p. s.) in the sound as heard from the soprano speaker.

It is to be noted that attenuation of undesirable low and high frequencies is accomplished at

a considerable number of points in the circuits between the tubes 18 and 19 and the loud speaker 52. Thus, utilizing a relatively large number of stages, the effect of a relatively sharp band-pass filter is obtained without the necessity of complicated filtering structures involving expensive iron core coils. Furthermore, the filters shown do not produce appreciable losses, which would be the case with low impedance inductance-capacity band-pass filter structures. Thus, low frequency transients which occur when playing legato from one soprano key to another are very substantially suppressed. Further low frequency suppression is afforded through speaker design and provision of a speaker baffle-board whose dimensions are inadequate to radiate efficiently, frequencies lower than 233 c. p. s. (A2#).

The volume of the output is controlled by selective operation of a plurality of switches 64 to 69. The switches 65 to 69 are respectively shunted by resistance capacity meshes 75 to 79. These meshes are of graded values so that by opening selected ones of these switches, a wide dynamic range is made available. Also, bass compensation is afforded at lower volume levels by increasing the impedance of the condenser relative to the value of the associated resistance. This bass compensation is desirable musically to produce the effect of uniform tonal response, and is necessary because of the varying frequency response of the ear at various amplitude levels.

The generating systems 11, 12 and 13 for the alto, tenor and bass parts are provided with output and control systems similar to that above described for the soprano generating system 10, it being understood, however, that the constants of the electrical elements differ to accord with the range of frequencies of the different generating systems. The various stages of the filtering system are thus made to correspond with the frequencies to be transmitted. For example, the filtering circuits for the alto output system may have the effect of a band-pass filter passing the frequencies from 196 c. p. s. to 5000 c. p. s. The filtering circuits for the tenor output system similarly may be made to pass frequencies from 116 c. p. s. to 3000 c. p. s., and the filtering circuits for the bass output system may pass frequencies from 32 c. p. s. to 1000 c. p. s. This frequency selective arrangement of the output circuits of the various parts is also carried out in the speaker and speaker baffle construction.

Thus, while the over-all acoustic output of the instrument extends throughout the complete range of the tones to be produced, (including their musically desirable harmonics), the individual output of each system is limited to its respective frequency range. Thus, undesirable keying transients as well as the undesirable high frequencies are suppressed in the individual generating and transmitting systems without affecting the frequency response of the other systems.

The fortuitous results of this arrangement which flow from utilizing a separate transmission and output system for each pitch range of tones may be readily appreciated by considering a specific example. Let us assume that incident to the operation of the key switches of the generating system 10 for the soprano range, a low frequency transient of 60 cycles is generated. The filtering system of the soprano transmission system very effectively attenuates this frequency. If the generating systems fed into a common

transmission and output system, such attenuation of the 60 cycle frequency would render the bass generating system relatively ineffective. Conversely, high frequency transients generated in the bass generating system 13 are very substantially attenuated in its transmission and output system, without in any way affecting the transmission of the desired high frequencies produced by the soprano generating system 10 and transmitted through its control, transmission, and output system.

A further advantage of utilizing a separate transmission and output system for each of the generating systems resides in the fact that harmonic distortion in the speakers or in the amplifier tubes 46, or in both, does not have any detrimental musical effect. Such distortion does not produce cross-modulation between the voices, but results merely in adding harmonic overtones. The resulting effect is that of a slight change in tone quality, which is a distinct musical advantage, since a wide distribution of harmonic overtones is desirable when tones are sounded at high amplitude levels. By permitting harmonic distortion in the amplifier tubes and speakers, much greater acoustic output may be produced than would normally be permitted when these output tubes and speakers are operating strictly linearly as ("Class A") amplifiers. This results in great economy, especially in installations in which a very high amplitude level acoustic output is required.

In the operation of the instrument, the player will normally have the switch 36 in the position in which the resistor R11 is connected to the conductor 38 so that by closure of the switch 40, the octave coupler effect will be obtained in all four musical parts, whereas when the switch 40 is opened, the tubes 19 of all four parts will be rendered non-conducting and the octave coupler effect will be eliminated from the outputs of the four speakers. When the switch 40 is open, the player may, by operation of the switch 36, cause the soprano part alone to produce the octave coupler effect, and thus be musically differentiated from the three other voices. As a result, when using the instrument to accompany singing by large congregations, the melody or soprano part may be made to stand out over and above the other three voices because of the fact that its tonality will be more prominent through having an individual octave coupler.

By the use of the single switch 40 and the auxiliary switch 36, the player has available a means for producing marked contrast in the tone quality of the instrument as a whole, and dynamic balance or unbalance, between the various parts, may readily be controlled as desired by the player, by operation of the switches 64 to 69 of the various output systems.

As was previously pointed out, the tone generating systems 10 to 13 may be of a wide variety of types such as vacuum tube oscillators, microphone pickups from mechanical vibrators, etc. In many of these types of generators the circuits are such that when no key is depressed, the tone generators will continue in operation. It is thus important that when no keys are depressed no sound be audible from the speaker.

To accomplish this purpose, tubes 18 and 19 are cut off when no keys are depressed. A switch 30 is associated with each of the playing keys, being arranged to close whenever its key is depressed, thus changing the voltage of the terminal 28 from +300 v. (when the switch is

open), to substantially ground potential (when one of the switches 30 is closed).

Condenser C6 is made large enough with respect to self-bias resistor R7 substantially to eliminate degeneration for frequencies within the particular frequency range of the part. By so doing, low frequency transients are effectively degenerated, and thus are not sounded by the speaker. However, to produce a desirable attack and decay envelope, additional means must be provided such that the plate current does not start instantaneously upon closure of any of the switches 30, and does not cease instantaneously upon opening such switches. To accomplish this, a second time constant mesh consisting of the relatively large condenser C7, in conjunction with relatively small attack and anti-spark resistor R9, causes the potential at the junction 28 to be limited in its rate of potential decrease upon closure of switch 30. Also, the resistor R8 of relatively high value, in conjunction with the condenser C7, limits the rate at which the potential at the junction 28 rises upon opening of switch 30. Thus, the rate of decay as well as the rate of attack is controlled, but when playing legato, the potential at the junction point 28 is maintained at a fixed value. When playing legato, transients incident to suddenly changing the frequency of the generator system are greatly reduced by the filter circuits heretofore described. By making resistor R9 small and resistor R8 large, a desirable prompt attack with relatively slow decay is provided.

While I have shown and described a particular embodiment of my invention, it will be apparent to those skilled in the art that the invention may be embodied in a variety of forms. I therefore desire, by the following claims, to include within the scope of my invention all such variations and modifications by which substantially the results of the invention may be obtained through the use of substantially the same or equivalent means.

I claim:

1. In an electrical musical instrument, the combination of a plurality of tone frequency generating systems having different tonal ranges, a separate output system for each of said generating systems, a separate signal transmitting system between each of said generating systems and its output system, each of said signal transmitting systems comprising a pair of channels connected to receive signals from their associated generating system in 180° phase relation, one of each of said pairs of channels being effective to attenuate the signal to an appreciably greater extent than the other, and means common to all of said transmission systems for rendering the attenuating channel of each of them ineffective.

2. In an electrical musical instrument, the combination of a plurality of tone frequency generating systems having different tonal ranges, a separate output system for each of said generating systems, a separate signal transmitting system between each of said generating system and its output system, each of said signal transmitting systems comprising a pair of channels connected to receive signals from their associated generating system in 180° phase relation, one of each of said pairs of channels being effective to modify the amplitude of the signal to an appreciably greater extent than the other, means common to all of said transmission systems for rendering one of the channels of each of them ineffective, and means individual to one of said

transmission systems to render its attenuating channel ineffective to transmit a signal.

3. In an electrical musical instrument, the combination of a plurality of tone frequency generating systems having different tonal ranges and each providing a push-pull output signal, a separate output system for each of said generating systems, a separate signal transmitting system between each of said generating systems and its output system, each of said signal transmitting systems comprising a pair of channels connected to receive signals from their associated generating system in substantially 180° phase relation, one of each of said pairs of channels being effective to attenuate the signal to an appreciably greater extent than the other, an electron discharge device in each of said channels, and means common to all of said transmission systems for biasing beyond cutoff the electron discharge devices in their attenuating channels thereby to render them ineffective to transmit a signal.

4. In an electrical musical instrument, the combination of a plurality of key switch controlled tone frequency generating systems having different tonal ranges, a separate output system for each of said generating systems, signal transmission controlling devices respectively connecting said generating systems with their output systems, each of said devices comprising a pair of variable mu pentodes, key controlled means for conditioning said pentodes to transmit signals from said generating systems to said output systems respectively, and means common to all of said devices and operative to cut off signal transmission through only one of the pentodes of each of said devices thereby to produce octave coupler effects in the acoustic output of all of said output systems.

5. In an electrical musical instrument, the combination of a plurality of key switch controlled tone frequency generating systems having different tonal ranges, a separate output system for each of said generating systems, signal transmission controlling devices respectively connecting said generating systems with their output systems, each of said devices comprising a pair of signal amplitude controlling circuits, key controlled means for rendering said circuits effective to transmit signals from said generating systems to said output systems respectively, a terminal forming part of one circuit of each pair, the direct current potentials on said terminals determining the amplitude of the signal transmitted by its connected circuit, two fixed potential points, and switch means for optionally connecting said terminals to either of said points.

6. In an electrical musical instrument, the combination of a plurality of key switch controlled tone frequency generating systems having different tonal ranges, a separate output system for each of said generating systems, signal transmission controlling devices respectively connecting said generating systems with their output systems, each of said devices comprising a pair of variable mu pentodes, key controlled means for biasing said pentodes to render them operative to transmit signals from said generating systems to said output systems respectively, means common to all of said devices and operative to change the bias on only one of the pentodes of each of said devices to a cutoff value.

7. In an electrical musical instrument, the combination of a plurality of key switch controlled tone frequency generating systems having

different tonal ranges, a separate output system for each of said generating systems, signal transmission controlling devices respectively connecting said generating systems with their output systems, each of said devices comprising a pair of signal transmission paths, key controlled means for rendering said paths operative to transmit signals from said generating systems to said output systems respectively, and means common to all of said devices and operative to change the signal amplitude transmission characteristics of one path only of each of said devices thereby selectively to produce octave coupler effects in the acoustic output of all of said output systems.

8. In an electrical musical instrument, the combination of a key switch controlled tone fre-

quency generator having push-pull output, an output system, a pair of electron discharge devices each having a cathode, control grid and plate, input circuits for said devices connected to receive signals in push-pull from said generator, plate circuits for said devices, said plate circuits being coupled to said output system and being effective to transmit signals to the output system at different amplitudes, key switch controlled means for changing the direct current potential on corresponding bias controlling electrodes of said devices, and optionally operable means for changing the direct current potential on the other bias controlling electrode of only one of said devices.

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