

April 26, 1949.

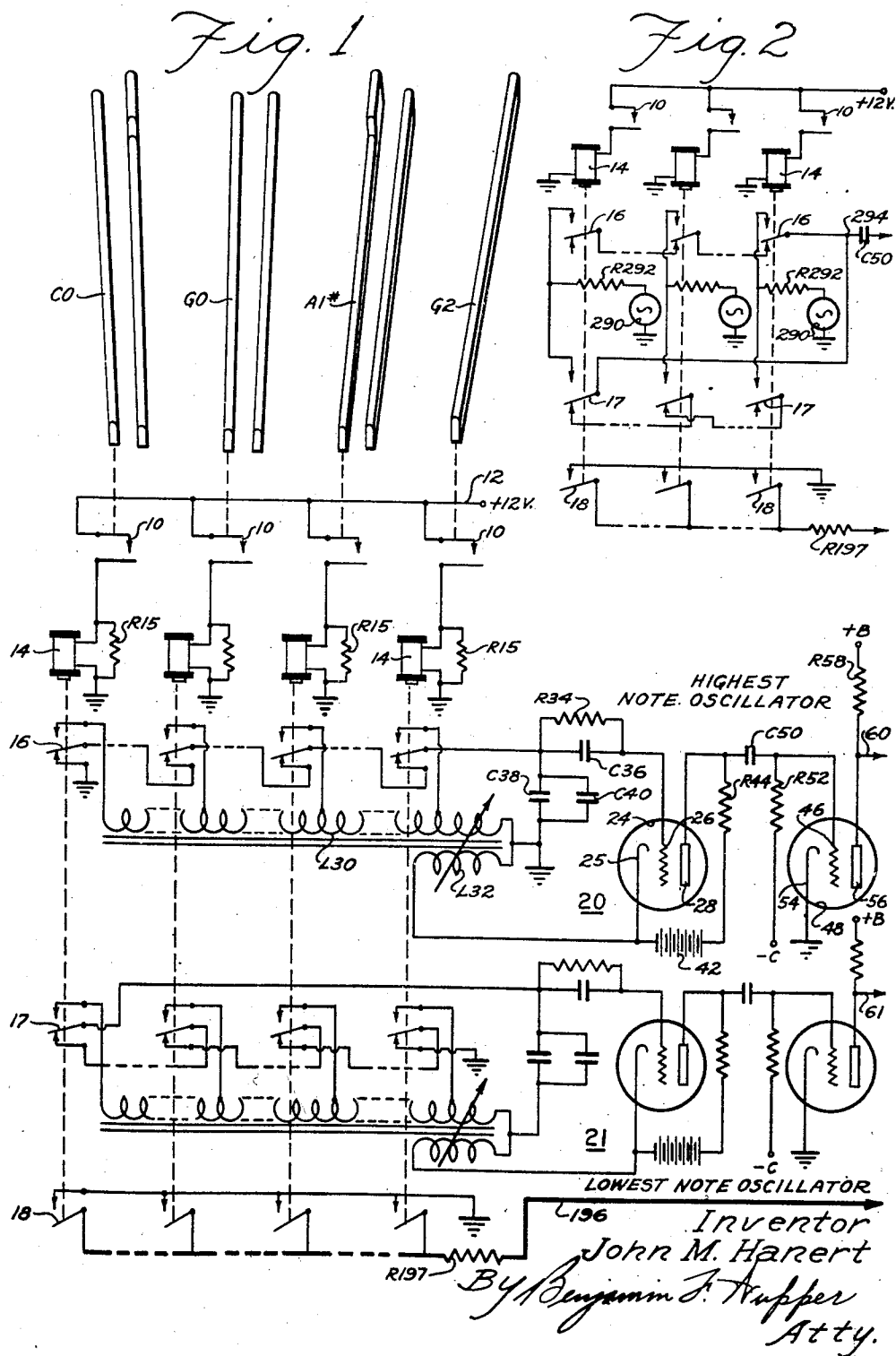
J. M. HANERT

2,468,062

ELECTRICAL MUSICAL INSTRUMENT

Filed Dec. 23, 1944

4 Sheets-Sheet 1



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ELECTRICAL MUSICAL INSTRUMENT

4 Sheets-Sheet 2

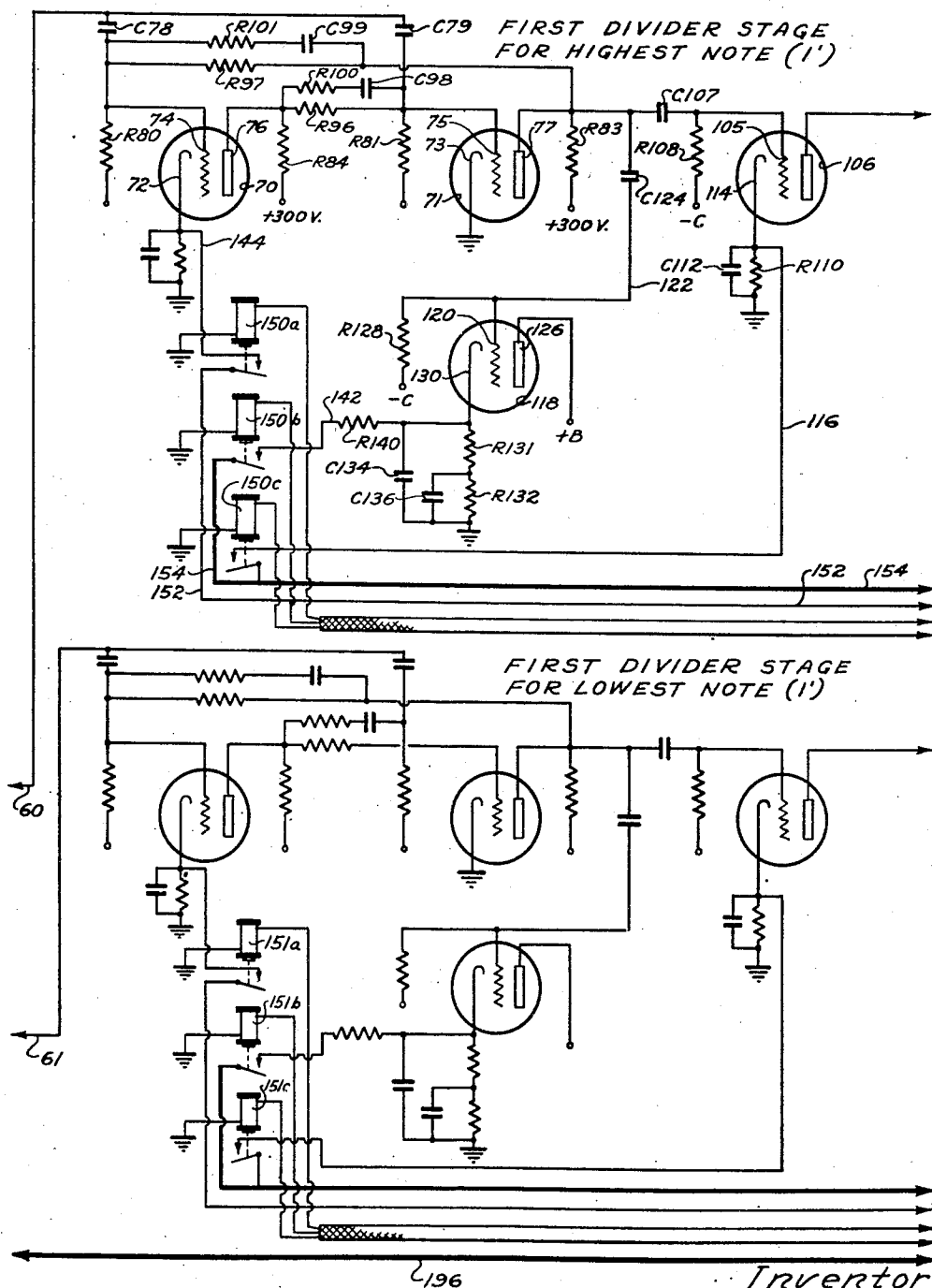


Fig. 1a

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4 Sheets-Sheet 3

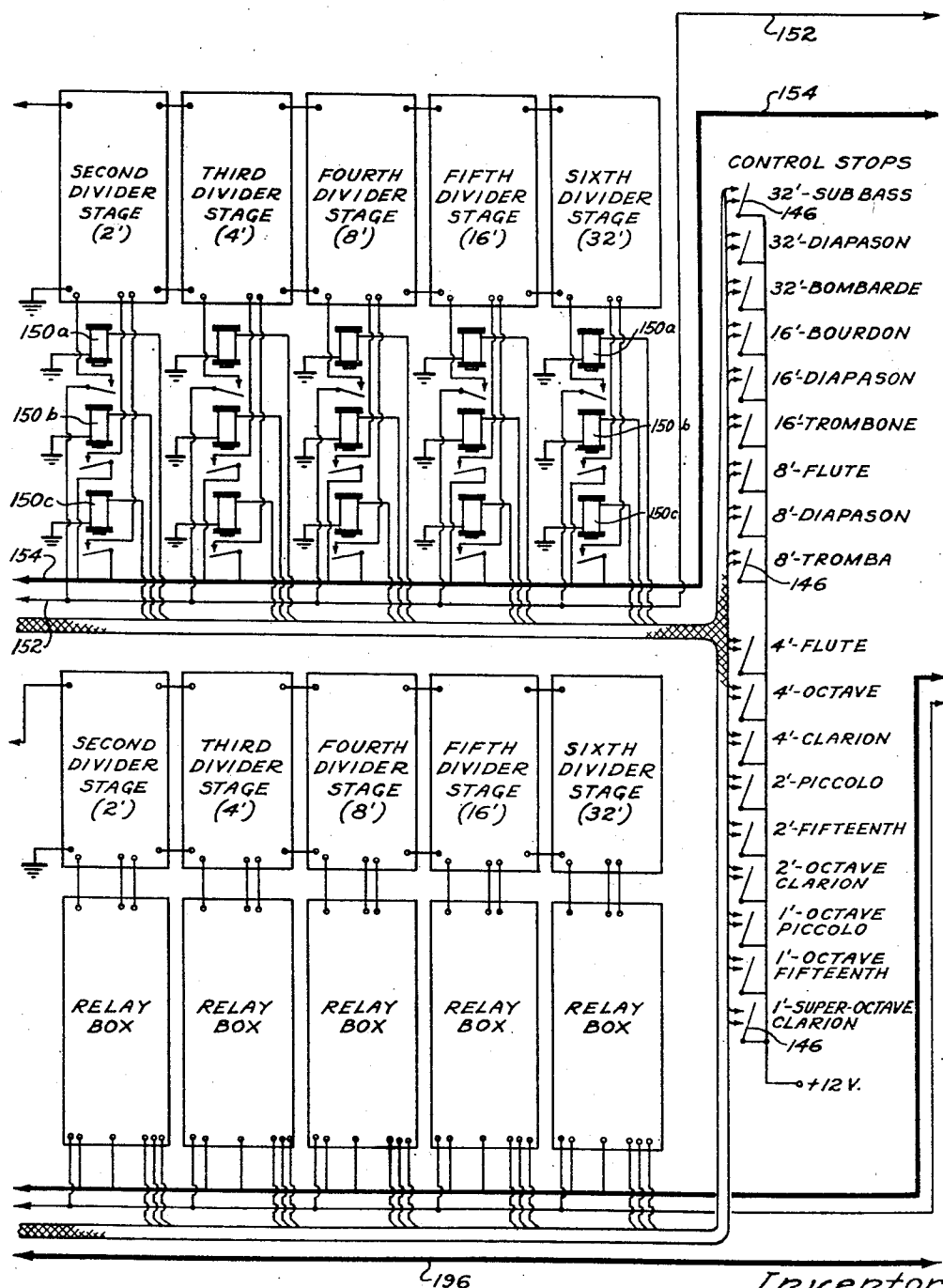


Fig. 1b

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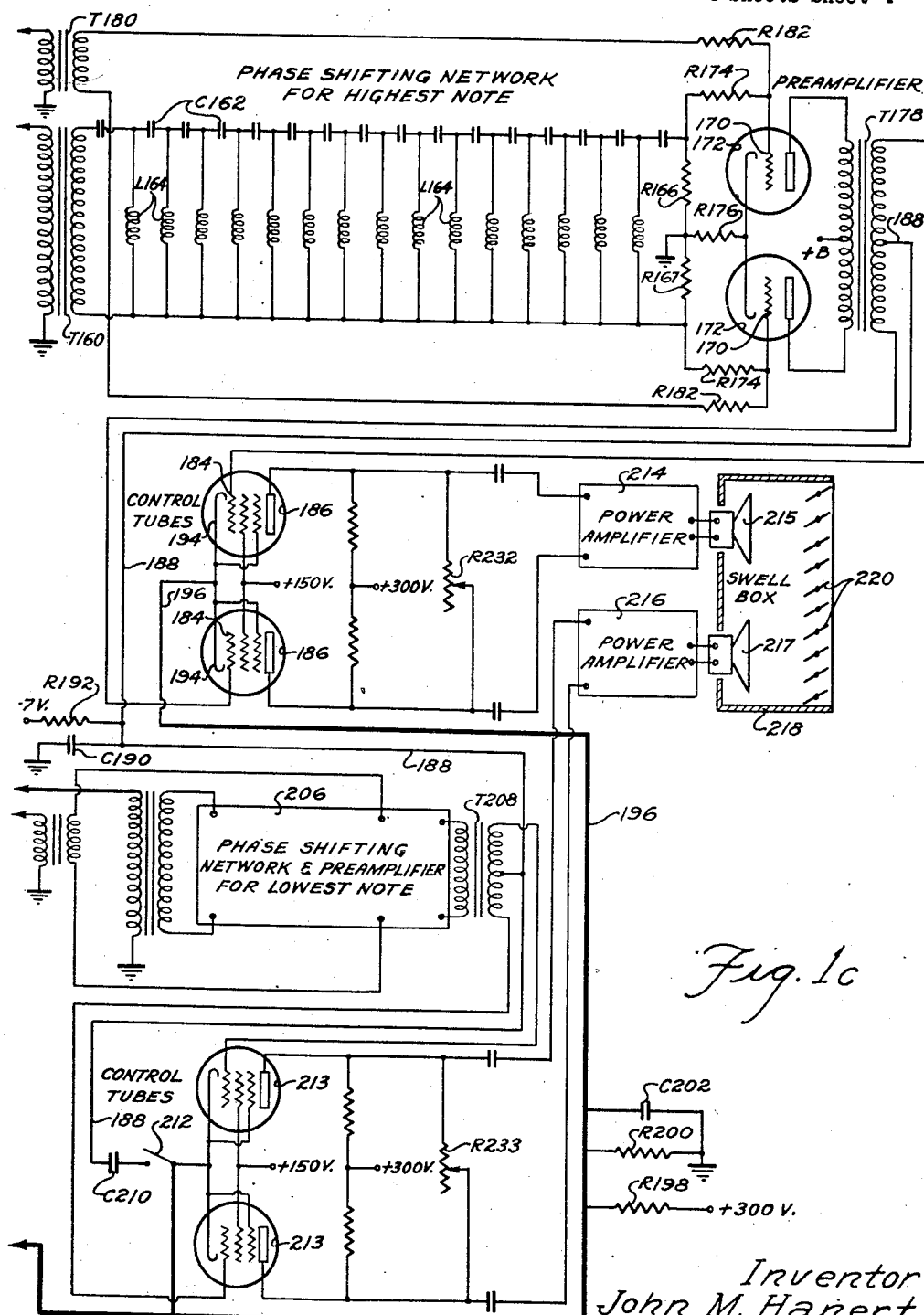


Fig. 1c

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UNITED STATES PATENT OFFICE

2,468,062

ELECTRICAL MUSICAL INSTRUMENT

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Application December 23, 1944, Serial No. 569,568

7 Claims. (Cl. 84—1.20)

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My invention relates generally to electrical musical instruments and more particularly to improvements in instruments for producing the bass tones of instruments of the organ type.

It is only the most expensive and elaborate pipe organs which have adequate pedal stops. This is due primarily to the fact that the pipes for producing bass tones are necessarily very large, require a large amount of air to cause them to speak, and are thus initially expensive, expensive to operate, and require large chambers. As a result, few pipe organs have more than two or three sets of pedal pipes. In addition, the large pipes for the bass pedals are usually of slow speech due to the time required for the building up of the acoustic wave trains in the pipes. If it were attempted to accelerate the speech of the pipes by increasing the pressure of the air supplied thereto, the quality of the tones emitted by the pipes would be undesirably altered and the pitch of the tones would not be steady. Furthermore a much larger capacity blower would be required.

In accordance with the principles of my invention these inadequacies of most pipe organs are remedied by the provision of electronic means for generating and controlling tones in the lower bass range, the apparatus being so constructed that it may be substituted for bass rank pipes or utilized as a supplement thereto, making use of the conventional stop tablets and relays of the pipe organ.

It is thus the primary object of my invention to provide an improved electronic bass tone generator and control means for use in conjunction with a pipe organ, or as a supplement to other mechanical and electronic musical instruments.

Other objects will appear from the following description, reference being had to the accompanying drawings in which:

Figures 1, 1a, 1b and 1c together constitute a schematic wiring diagram of the improved instrument; and

Figure 2 is a wiring diagram of a modified form of generating and switching apparatus.

GENERAL DESCRIPTION

In general, the instrument of the invention comprises a source of relatively high frequencies of the tempered musical scale, disclosed herein as a pair of oscillators which are respectively tuned to frequencies related to those represented by the highest and lowest depressed pedals of the organ pedal clavier. Each of these oscillators is provided with a cascaded alternate impulse frequency dividing system whereby there may be generated frequencies $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$ and

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$\frac{1}{64}$ of the frequencies of its controlling oscillator. These alternate pulse frequency divider stages operate to divide the input frequency by a factor of two, substantially irrespective of any variation in frequency of the input signal.

The output signal of each of the divider stages is in the form of a rectangular or box wave and this output signal is thereafter modified to produce three different types of signal waves which are utilized for tone production. One of these modified signal waves is in the form of sharp impulse negative peaks, representing a relatively bright reed-like tone quality. The second is in the form of relatively smooth negative pulses representing a musical tone having a diapason-like tone quality. The third is in the form of a slightly modified sine wave, representing a musical tone quality similar to the bourdon, in which the fundamental is of relatively high amplitude and there are but few odd harmonics of lesser amplitude.

By means of the stop tablets the desired type of output signal of the various divider stages are selected, singly or in any desired combination, and transmitted to the output system of the instrument. The signals of the first mentioned type, that is, those appearing as a series of relatively sharp negative impulses are transmitted through a phase shifting network whereby the relative phases of the partials of the tone are changed to reduce the peak amplitude of the signal and thus facilitate distortionless transmission of the signal through the amplifying and speaker system. This phase shifting network eliminates the "machine gun" effect which would otherwise be produced by such series of relatively sharp impulses at very low frequencies.

The output of the phase shifting network is mixed with the other forms of signal wave in a preamplifier, and the output of the latter is amplitude controlled by a pair of push pull control pentodes. These control tubes are normally biased so as to be non-conducting but are rendered conducting by the closing of a contact upon energization of any one of the pedal controlled relays. The amplitude controlled signal is supplied to a power amplifier which is coupled to a speaker, the latter being preferably located in the organ swell box so as to have the sound output thereof controlled in part by the usual swell shutters.

It will be understood there is a system as above described for each of the oscillators, the only means common to the two systems being the contacts under the pedal controlled relays, by which

the biasing potential on the control tubes of both instruments is determined.

In Fig. 1 are shown representative pedals of a pedal clavier including pedals C0, G0, A1# and G2, the pedals C0 and G2 representing lowest and highest note pedals generally found in pipe organ pedal claviers. Each of the pedals has associated therewith a single pole single throw switch 10, one pole of which is connected to a common conductor 12 leading to a suitable source of relay operating potential such as +12 v., the other pole of each of these switches being connected to the winding of a relay 14, the circuit through the winding of the relay being completed to ground. The relays 14 are provided, instead of having the pedals directly actuate the relay switches, in order to facilitate the installation of the apparatus in a pipe organ, since the conventional pipe organ has the switch contacts 10 for controlling relays 14. These relays are rendered relatively slow-acting by the provisions of anti-spark resistors R15 in parallel with the windings thereof.

Each of the relays 14 operates single pole double throw switches 16 and 17 and shortly thereafter operates a single pole single throw switch 18. This is accomplished in the usual manner by having the contacts for switch 18 initially spaced farther apart than are the contacts for switches 16 and 17, or by equivalent armature structure whereby the armature will close switches 16 and 17 before it closes switch 18. Switches 16 and 17 control the tuning of a pair of oscillators 20 and 21 respectively for generating frequencies having a definite relationship, respectively, with the frequency represented by the highest note pedal depressed and the frequency represented by the lowest note pedal depressed. Each of the oscillators comprises a triode 24 having a cathode 25, control grid 26 and anode 28. The tuning circuit for the oscillator comprises mutually coupled inductances L30 and L32, the inductance L32 being connected between the cathode 25 and ground, while the inductance L30 has a plurality of taps corresponding in number to one less than the usual 32 pedals. Depending upon which of the switches 16 is operated a greater or lesser number of turns of L30 are connected between ground and the grid 26, this connection being through a grid resistor R34 bypassed by a capacitor C36. The capacitance portion of the tuning circuit includes a capacitor C38 and a trimming capacitor C40. Overall tuning of the range of the oscillator 20 is accomplished by adjustment of the air gap in the core common to the inductances L30 and L32.

Plate current for the triode 24 is supplied from a suitable source, indicated as a battery 42, through a plate load resistor R44, and the signal output of the oscillator is impressed upon the grid 46 of a triode 48 through a blocking condenser C50. The grid 46 is connected to a plate current cutoff negative bias potential source, indicated as -C, through a grid resistor R52, while the cathode 54 of this triode is connected to ground. The plate 56 of the triode 48 is connected to a suitable source of plate potential through a load resistor R58, while the signal output of the triode 48 is transmitted through a conductor 60.

In a similar manner the output of oscillator 21 is transmitted through a conductor 61.

The triode 48 operates as a means to rectify and increase the slope of oscillator output waves, changing the wave form into a series of relatively sharp pulses suitable for the operation of the alternate pulse dividers.

It will be noted that the connections of the switches 16 are such that when the relay 14 for the highest note pedal is operated, the remaining switches 16 are disconnected from the circuit while the operated switch 16 effects connection into the tuning circuit of a predetermined number of turns of L30 so as to cause the oscillator to operate at a frequency which bears a definite relationship to the nominal frequency of the pedal which has been depressed.

On the other hand, it will be noted that the switches 17 for the oscillator 21 are connected in such manner that the lowest depressed pedal will tune the oscillator 21 to a frequency bearing a definite relationship to the depressed pedal, while at the same time rendering ineffective all of the switches 17 associated with pedals higher than that depressed. This type of switching system and oscillator tuning means are more fully disclosed in the patent to Laurens Hammond et al. No. 2,332,076.

Alternate impulse frequency divider stages

The pulses forming the output of the triode 48 are transmitted to the first stage of a plurality of cascaded stages of alternate pulse frequency dividers. The first divider stage comprises triodes 70 and 71, the triode 70 including a cathode 72, a grid 74 and an anode 76, while the triode 71 includes a cathode 73, a grid 75 and an anode 77. Sharply peaked negative pulses constituting the output of the triode 48 are simultaneously impressed upon grids 74 and 75 through a pair of small capacitors C78 and C79, these grids being connected to ground through resistors R80 and R81 respectively. The plate 77 is connected to a suitable source of plate current, indicated as a terminal +300 v. of the power supply, through a plate load resistor R83 while the plate 76 is connected to the +300 v. terminal through a load resistor R84.

The plate 77 is coupled to the grid 74 through a feedback mesh comprising a resistance R97 which is shunted by a capacitor C99, the latter being in series with a resistor R101. In a similar manner a mesh comprising resistors R96, R100 and capacitor C98 provides a feedback circuit from the plate 76 to the grid 75.

The output of the triode 71 is supplied to the grid 105 of a rectifying triode 106 through a blocking capacitor C107. The grid 105 is negatively biased through a resistor R103 which is connected to a suitable negative terminal of the power supply, indicated as -C. The cathode of triode 106 is connected to ground through a signal derivation resistor R110 which has a filter capacitor in parallel therewith. It will be apparent that potential of the cathode 114 will be of a wave form comprising a plurality of relatively sharp positive peak impulses. Such impulses are utilized as one of the output signals of the first divider stage, such signal being transmitted through a conductor 116. This signal is very bright in tone quality, such as is characteristic of the reed and trombone families.

A second type of tone quality signal is also derived from the output of the first divider stage. A triode 118 has its grid 120 connected by a conductor 122 and a blocking capacitor C124 to the anode 77 of triode 71. The anode 126 of triode 118 is connected to a suitable potential source, indicated as +B, while the grid 120 is connected to a negative potential biasing source, indicated as -C, through a resistor R128. The cathode 130 of triode 118 is connected to ground through resistors R131 and R132, these resistors having

a capacitor C134 connected in parallel therewith, and the resistor R132 having a capacitor C135 connected in parallel with it. The musical tone signal, which is of the diapason quality, is derived from the cathode 130 of the triode through a resistor R140 and a conductor 142.

A bourdon-like tone quality is derived from the cathode 72 through a conductor 144.

Tone quality selecting means

The selection of the desired tone quality or tone qualities to be transmitted to the output system of the instrument is accomplished by means of control stops (Fig. 1b) comprising a plurality of switches 146 which may be actuated in the conventional manner by tablets or stops on the console of the instrument. Each switch is adapted to energize two corresponding relays 150a, 150b, 150c and 151a, 151b or 151c, respectively for the highest note channel and the lowest note channel. There are three relays 150 for each frequency divider stage of the highest note channel as well as three relays 151 for each divider stage of the lowest note channel. The relay 150a for the first stage of the highest note channel is arranged to connect the conductor 144 to conductor 152, while relays 150b and 150c are adapted respectively to connect the signal conductors 142 and 116 to a conductor 154. The relays 150a, 150b and 150c for the first divider stage will be energized respectively by the closure of stop switches 146 for 1' octave piccolo, 1' octave fifteenth and 1' super-octave clarion. Similarly the corresponding relays for the second divider stage may be energized by closure of the switches 146 of the stops labeled 2' piccolo, 2' fifteenth and 2' octave clarion. The relays for the third divider stage are similarly operated by closure of the switches 146 associated with the tablets for the 4' flute, 4' octave and 4' clarion. The relays for the fourth divider stage are controlled by the stops identified as the 8' flute, 8' diapason, and 8' tromba. The relays for the fifth divider stage are controlled by the tablets identified as 16' bourdon, 16' diapason, and 16' trombone. The relays for the sixth divider stage are controlled by tablets indicated as 32' sub-bass, 32' diapason, and 32' bombarde.

The second to sixth divider stages for the highest note are shown in block diagram form with appropriate legends applied. Three relays 150a, 150b and 150c for each of the divider stages for the highest note are conventionally illustrated, while the corresponding relays for the divider stages for the lowest note are indicated as blocks with appropriate legends.

Each of the relays 150a of the different divider stages is adapted to connect the cathode of its associated triode 70 to the conductor 152. Relays 150b connect the cathodes of their associated rectifier triodes 118 to the signal conductor 154; while the relays 150c connect the cathodes of the rectifier triodes, such as the triode 106, to the signal conductor 154.

Phase shifting network

Since the signals transmitted through the conductor 154 have a wave form constituting a series of relatively high amplitude positive peaks, they are not transmitted efficiently, in this form, through the amplifier and speaker system. These signals are therefore transmitted through a phase shifting network to alter the phase relationship of the partials. The wave form will be altered to a shape in which the highest amplitude peak

is but a fraction of that of the input wave, without appreciably altering the amplitudes of the individual partials. The operation of this phase shifting network is more fully disclosed and claimed in my copending application Serial No. 569,569, filed December 23, 1944.

The coupling between the generating system and the phase shifting network is herein illustrated as being effected by a transformer T160, the phase shifting network comprising a plurality of sections of series capacitors C162 and shunt inductances L164. This phase shifting network terminates in resistors R166 and R167 which together form the characteristic terminating impedance for this network. The output of this phase shifting network is impressed upon the grids 170 of push pull preamplifier triodes 172, the connections to the grids being through decoupling resistors R174 respectively. The cathodes of the triodes 172 are connected to ground through biasing resistor R176 while the plates of these triodes are connected to the terminals of the primary winding of a coupling transformer T178. A center tap on this winding is connected to a suitable source of plate current, indicated as +B.

Output and amplitude control circuits

The signal conductor 152 conveys the signals from the cathode of the triode 70, and the similar triodes of the other divider stages, to a decoupling transformer T180, the output terminals of which are connected respectively through decoupling resistors R182 to the grids 170 of the triodes 172.

The terminals of the secondary of transformer T178 are connected respectively to the control grids 134 of remote cut-off control pentodes 186, while the center tap of the secondary of transformer T178 has conductor 188 connected thereto. The conductor 188 is connected to ground through a capacitor C190 and is connected to a suitable source of negative biasing voltage, indicated as -7 v., through a resistor R192. The cathodes 194 of the control pentodes 186 are connected to a conductor 196. It will be noted that the conductor 196 is adapted to be connected to ground through resistor R197 (Fig. 1) by one of the switches 18 (Fig. 1) whenever any pedal relay 14 is energized. The conductor 196 is normally maintained at a positive potential by virtue of its connection through a resistor R198 to a terminal of the power supply indicated as +300 v. and its connection to ground through a resistor R200 shunted by a capacitor C202. Resistors R198 and R200 form a voltage divider which normally maintains the potential of the cathodes 194 at such positive value that the pentodes 186 are biased beyond cutoff.

The generating system for the lowest note is in every respect similar to that above described for the highest note and corresponding parts of the generating and signal transmission system for the lowest note have reference characters applied thereto corresponding to those of the similar parts of the highest note generating and signal transmitting system. For the sake of simplicity the phase shifting network and preamplifier for the lowest note are shown as a block 206 having an output coupling transformer T208 corresponding to the transformer T178. The center tap of the secondary of transformer T208 is connected to the conductor 188 which, it will be recalled, is also connected to the center tap of the secondary of transformer T178. This conductor 188 is adapted to be connected

through a capacitor C210 (Fig. 1c) with the conductor 196 upon closure of a relay operated switch 212. The switch 212 might also be manually operated and located at the console.

The control tubes 186 for the highest note transmission system are suitably coupled to a power amplifier 214 while, in a similar manner, the corresponding control tubes 213 are suitably coupled to a power amplifier 216. The outputs of the amplifiers 214 and 216 are supplied respectively to speakers 215 and 217 which are preferably located in a chamber 218 forming the swell box of the pipe organ, or in a similar chamber in which the sound output may be controlled by a plurality of swell shutters 220 forming one side of the box or chamber. The shutters 220 are controlled from the console of the instrument in any well known manner, and thus control the acoustic output of the speakers 215 and 217, as well as the acoustic output of any organ pipes which may be located in the swell box or chamber.

In addition to controlling the acoustic output of the instrument by means of the swell shutters 220, initial adjustment of the overall output of the control tubes 186 and 213 may be obtained by adjustment of adjustable resistors R232 and R233, respectively, for the highest and lowest notes. In lieu of placing speakers 215 and 217 in a swell chamber, separate volume controls of suitable construction, operating upon the potential of one or more of the electrodes of the control tubes 186 and 213, may be used to control the intensity of output of the instrument.

Operation

In playing the instrument the organist will operate the pedals in the usual manner. Whenever but one pedal is depressed, both oscillators 20 and 21 will be tuned to the same frequency, corresponding to sixteen times the fundamental frequency of the pitch represented by an 8' stop of the depressed pedal. When two of the pedals of the pedal clavier are simultaneously depressed, that corresponding to the highest pitch will tune the oscillator 20 to a frequency sixteen times the fundamental of the pitch represented by an 8' stop of the highest pedal depressed, while the oscillator 21 will correspondingly be tuned to a frequency sixteen times the fundamental of the pitch corresponding to the lowest pedal depressed. The output of each oscillator will be rectified and have its wave shape altered to produce a relatively sharp negative pulse suitable for the input of the first frequency divider stage coupled to the oscillator.

In describing the operation of the frequency divider stages it will be assumed that no signal is being supplied thereto by the rectifier triode 48. In this case a static condition prevails in which one or the other of the tubes 70 or 71 is conductive of plate current to an appreciably greater extent than the other. This may be understood by assuming that the potential on the plate 77 is decreased slightly. Such slight change of potential in a negative direction will also appear on the grid 74 of the triode 70 due to its connection with the plate 77 through the coupling mesh comprising resistors R97 and R101 and capacitor C99, and will also result in an increase in the potential at the plate 76 of the triode 70. Such increase in plate potential will similarly appear at the grid 75 due to its intercoupling with the plate 76 through the mesh comprising R96, R100 and C98. This increase

in the positiveness of the grid 75 will cause a further decrease in potential at the plate 77, thus supplementing the previously assumed decrease in potential at the plate 77. This cumulative decrease in potential at the plate 77 will continue until the grid 74 becomes sufficiently negative substantially to cut off the plate current in triode 70. After such limiting condition has been attained, further changes will not occur in the potentials of the electrodes in these two triodes 70 and 71, and this limiting condition will prevail for an indefinite period of time because of the direct reciprocal resistance coupling between the grids and plates of the triodes 70 and 71. Due to the symmetry of the circuits and of the characteristics of the triodes 70 and 71, it becomes a matter of chance as to which of these triodes will conduct maximum plate current in the first instance. As will be explained hereinafter, it is unimportant to predetermine which of these tubes will initially conduct the greater plate current.

The speed with which changes in potential at any of the electrodes of these triodes 70, 71 can occur due to this mutual feedback effect is limited by the shunt capacitance offered by the capacitors C78 and C79 and the interelectrode capacitance present in the triodes 70 and 71. By including capacitors C98 and C99 the effect of the shunt input capacitance is largely overcome because there is a direct low impedance connection for very high frequencies between the anode 77 of triode 71 and the grid 74 of triode 70 and also between the anode 76 and grid 75. The inclusion of these capacitors results in a substantially instantaneous mutual feedback between the triodes, which sudden change may be interpreted mathematically as being an extremely steep wave front having a Fourier harmonic series extending up to extremely high frequencies such as radio frequencies. It was found undesirable to permit this wave to contain such high frequencies, because when such was the case, radio frequency interference and spurious couplings were prevalent, thus rendering the divider unstable. By inclusion of resistors R100 and R101 in series with the capacitors C98 and C99, the rate at which such mutual feedback potential changes can occur is considerably decreased because of the time constant introduced by the resistors R100 and the capacitors C78 and C79 together with the interelectrode capacitances of the triodes 70 and 71. This decrease in the rate of change of potential substantially eliminates harmonic components of the Fourier series which lie appreciably above the super-audio range.

As pointed out heretofore, prior to the application of a negative pulse from the rectifier triode 48, one of the triodes 70, 71 will be conducting with maximum plate current and the other triode will be at substantially plate current cutoff. The series of short high amplitude negative pulses are simultaneously transmitted to the grids 74 and 75 through the small capacitors C78 and C79 whenever the oscillator 20 is in operation. Assuming that the triode 70 is drawing maximum plate current and that triode 71 is cut off, this simultaneous application of the negative pulse to the grids 74 and 75 will result in a decrease in the plate current of triode 70, thereby causing the potential on the anode 76 to increase. This positive increase in potential is transferred from the anode 76 to the grid 75 through the feedback mesh comprising R96, R100 and C98. Increase in positiveness of the grid 75 in turn re-

sults in a negative potential change at its plate 77, which negative potential change is similarly transmitted to the grid 74 through the feedback mesh comprising R97, R101 and C99. This negative change in grid potential results in a further increase in the potential at the anode 76, which change is in phase with the original positive change at the anode 76 due to the application of the negative pulse on the grid 74 from the rectifier 48. This mutual feedback action continues despite the disappearance of a signal pulse on grids 74 and 75. The action ceases when triode 71 is at substantial plate current cutoff. Due to the direct resistive coupling of the grids and anodes of the triodes 70 and 71, this cutoff condition will prevail until the rectifier 84 transmits another negative pulse to the grids 74 and 75 through the capacitors C78 and C79. By making the time constants of the feedback meshes (comprising R96, R97, C98 and C99) about eight times the time constant of the signal input circuits (comprising R30, R81, C78 and C79), the duration of the input pulses is made short by comparison with the duration of the pulses produced by the feedback meshes. This insures that the negative signal impulses will have disappeared before the feedback action is completed.

From the foregoing it is apparent that this first negative pulse from the rectifier 84 was effective to transfer the current from the previously conducting triode 70 to the previously cutoff triode 71. When the rectifier triode 48 again supplies a high amplitude negative pulse to the grids 74 and 75, triode 70 will be caused to draw maximum plate current and triode 71 will again be cut off. Thus it is seen that alternate negative pulses from the rectifier 48 are effective to cause similar changes in potential in the output circuits of the triodes 70 and 71 and thus the frequency of the plate current of either of these triodes will be one half of the input frequency. The shape of the wave in the plate circuits of triodes 70 and 71 will be substantially rectangular. The wave shape will differ slightly from a rectangle in that the positive slope is more steep than the negative slope. This is accounted for by the fact that the negative pulse input circuit has a shorter time constant than that of the feedback meshes.

The harmonic analysis of a rectangular wave shows that it comprises a fundamental of given amplitude plus a third harmonic of one third of the amplitude of the fundamental, a fifth harmonic of one fifth the amplitude of the fundamental etc.

The rate at which the input pulses are supplied is immaterial to the frequency dividing operation. By using relatively small capacitors the frequency range over which these frequency dividers will operate successfully may extend over the entire audio frequency band. In the embodiment of the invention disclosed herein, the divider stages are required to divide over a range of only 32 semitone intervals, slightly more than two and one half octaves, so that no difficulty whatsoever is experienced in having the frequency divider stages consistently and accurately divide their input frequencies by 2. The inclusion of the series resistors R100 and R101 serves to decouple the input grid circuits from the output feedback meshes, and thus renders the circuit more stable in operation and less sensitive to the exact values of the input capacitors C78 and C79. The resistors R100 and R101, together with the feedback meshes comprising C98, C99, R96 and R97 determine the upper frequency limit to which

the divider functions in a stable manner. These time constants should be small in comparison with the time required for one cycle of the highest audio frequency (e. g. 1568 c. p. s.) which is to be generated by the oscillator 20.

Since the output of the triodes 71 is of generally rectangular wave shape it is necessary to rectify this wave and to change the negative portion of this wave into relatively sharp negative pulses, for reliable operation of the second divider stage. The rectifier triode 108 which may be considered as part of the first divider stage performs this function as well as providing a suitable reed quality signal wave to the conductor 116. Thus the triode 108 performs the double function of providing a suitable input signal for the second divider stage as well as providing a tonally suitable output signal for reed and trombone-like tones. A somewhat similar but less bright tone quality is derived from the rectifier triode 118, due to the filtering action of the mesh R131, R132, R140, C134 and C136 connected to the cathode 130 of this triode. The signal derived from the cathode 72 through the conductor 144 is a symmetrical wave having well rounded peaks and troughs, and as previously pointed out, represents tones of the bourdon type, namely tones having a strong fundamental and a relatively weak series of odd harmonics only.

The organist will operate one or more of the stop control switches 146 and thereby transmit to the coupling transformers T109 or T180 or both, the desired tone qualities and octave coupler effects. Since the bourdon type tone qualities derived from the cathodes of the triode 70 of the various divider stages is initially of a smoothly undulating character, it is not usually necessary to shift the phases of the partials and therefore these tone signals are transmitted directly to the grids 173 of the preamplifier triodes. As previously pointed out, the relatively high peak amplitude pulses derived from the cathodes of the rectifier triodes 108 and 109 would tend to overload the amplifier and speaker system, since these wave forms represent a phase relationship of the partials in which their peak amplitudes coincide. By means of the phase shifting network, the peak amplitudes of the various partials are variously displaced so that the peak amplitude in a single cycle of the fundamental is reduced to approximately one third of the original peak amplitude of the signal, and the "machine gun" effect is removed.

Whenever one of the pedal control relays 14 is energized, it closes its associated switch 18. The grid bias on the remote cutoff control pentodes 186 and 213 is normally sufficient to cut off these tubes due to the application of a positive voltage to the cathodes of these pentodes by means of the voltage divider mesh comprising R198 and R200. Thus, when one of the switches 18 is closed, it connects the cathodes of these control pentodes 186 and 213 to ground, rendering these tubes conductive with a prompt attack. When it is desired to have the intensity envelopes of the signals of such form that the attack is relatively slow, the switch 212 (Fig. 1c) is closed, whereupon the lowering of the potentials of the cathodes of the control pentodes 186 and 213 is accompanied in the first instance by the corresponding lowering of the potentials on the grids of these control pentodes. However, after a short time, as the capacitor C210 becomes charged, the grids of these pentodes become in-

creasingly positive with respect to their cathodes, and they commence conducting the signals on their grids with gradually increasing amplitude, producing the effect of slow tonal attack. When a pedal is released its relay 14 operates first to open its switch 18 and immediately thereafter to operate its switches 16 and 17. The opening of switch 18, by disconnecting the cathodes of the control tubes 196 and 213 from ground, permits their potential to rise rapidly to cut-off potential, the rate of potential rise being determined by the values of R198, R200 and C202. Thus the tone will have decayed substantially to zero intensity by the time that switches 16 and 17 are operated to change the frequency of oscillation of the oscillators 20 and 21.

Since the apparatus employs conventional organ controls, it may be considered as an integral part of the pipe organ, not requiring the organist to learn any new technique of registration. The only control in the apparatus disclosed herein which could not be accomplished by the usual pipe organ controls is that of producing slow or fast attack at will, by operation of the switch 212.

While the use of the variable frequency oscillators, whose frequencies are controlled by the lowest and highest depressed pedals has manifold advantages, there are some instances in which other forms of generators may be coupled to the divider stages in place of the variable frequency oscillators. For example, in adapting the invention to an electric organ of the type shown in the patent to Laurens Hammond, No. 1,956,350, it would be unnecessary to provide two oscillators, but instead the various frequencies supplied to the frequency divider stages could be obtained from the phonic wheel generators present in this type of organ. A circuit suitable for utilization of such generators as the sources of the various frequencies required is shown in Fig. 2, in which figure circuit elements corresponding to those previously described bear corresponding reference characters.

In Fig. 2 the pedal energized relays operate single pole double throw switches 16 for selecting the generator related to the pitch of the highest pedal depressed and single pole double throw switches 17 for selecting the generator related to the pitch of the lowest pedal depressed. In this figure the generators 290 are utilized as the frequency sources. The three generators 290 conventionally illustrated are representative of the 32 semitone generators which would be utilized for supplying the frequencies for the 32 pedal notes. These generators will generate frequencies at the various semitone intervals from 523.25 c. p. s. to 3135.96 c. p. s. The generators 290 are respectively coupled to the upper contacts of switches 16 and 17 through resistors R292. Switches 16 are so connected in series that operation of any switch 16 renders ineffective the switches 16 of lower pitch, and thus the switches 16 control the transmission to the output conductor 294 of a frequency related to the highest depressed pedal. The switches 17 are connected in series in an opposite manner so that the lowest pitch switch 17 which is operated determines which of the generators 290 shall be connected to the output conductor 294. The output conductor 294 transmits a signal through capacitor C50 to the pulse sharpening and rectifying triode 48 previously described, and this pulse is then utilized for controlling the frequency of operation

of the cascaded alternate pulse frequency divider stages, all in the manner previously described.

By utilizing the frequency generating system of Fig. 2 a reduction in the cost of the instrument may be effected in some instances, especially those in which the generators 290 form a regular part of the instrument. This system also presents the advantage that the pedal controlled bass tones will be exact sub-multiples of the frequencies produced by the generators 290. There will thus be no possibility of beating of the harmonics of the pedal tones with the frequencies derived directly from the generators 290.

While I have shown and described particular embodiments of the invention, it will be apparent to those skilled in the art that numerous modifications and variations may be made in the form and construction thereof, without departing from the more fundamental principles of the invention. I therefore desire, by the following claims, to include within the scope of my invention all such similar and modified forms of the apparatus disclosed, by which substantially the results of the invention may be obtained by substantially the same or equivalent means.

I claim:

1. In an electrical musical instrument for producing organ bass tones and having an amplifier and electroacoustic translating means, said instrument having a pedal clavier, the combination of two generating systems, each comprising an oscillator and a cascaded series of alternate pulse responsive frequency divider stages; a switch for each of the pedals of the clavier and respectively opened by the pedals, a relay for each pedal, circuits respectively completed by the switches to energize associated relays, switch and circuit, means respectively rendered operative by the relays and effective to tune one of said oscillators to a frequency related to the pitch of the highest operated pedal of said clavier, switch and circuit means respectively rendered operative by the relays and effective to tune the other oscillator to a frequency related to the pitch of the lowest operated pedal of said clavier, each of said divider stages providing a plurality of different wave form output signals, and selectively operable remotely controlled means for causing the transmission to said amplifier of any one or a plurality of the output signals from said divider stages.

2. The combination set forth in claim 1 in which the amplifier is normally ineffective to transmit the signals, and in which there is a means operable by any one of the pedal controlled relays to render the amplifier effective to transmit the signals after the oscillators have been tuned by the relay controlled switch and circuit means.

3. In an electrical musical instrument for producing the pedal tones of an organ and comprising an amplifier, the combination of a pedal clavier, a relay for each of the pedals of said clavier, each of said relays being energized upon depression of its associated pedal and operating three switches, a pair of oscillators, means controlled by the first of said relay switches to tune one of said oscillators to a frequency related to the pitch of the highest of a plurality of depressed pedals, means operated by the second of said relay switches to tune the other oscillator to the frequency related to the pitch of the lowest of a plurality of depressed pedals, a circuit completed by the operation of the third relay switch to render the amplifier effective, a plurality of

cascaded alternate pulse responsive frequency divider stages connected to each of said oscillators, means for deriving from each of said divider stages output signals of different predetermined wave forms, and stop controlled relay operated switch means for selectively transmitting the output signals of said frequency divider stages to the amplifier.

4. In an electrical musical instrument including an amplifier for producing the pedal tones of an organ, the combination of a clavier comprising a plurality of pedals, a plurality of relays, each including three switches respectively operated upon depression of the pedals, a pair of oscillators, means controlled by the first of said switches to tune one of said oscillators to a frequency related to the pitch of the highest of a plurality of depressed pedals, means operated by the second of said switches to tune the other oscillator to the frequency related to the pitch of the lowest of a plurality of depressed pedals, a circuit completed by the operation of the third switch to render the amplifier effective, a plurality of cascaded alternate pulse responsive frequency divider stages connected to each of said oscillators, means for deriving from each of said divider stages an output signal of predetermined wave form, and remotely controlled stop switch means for selectively transmitting the output signals of said frequency divider stages to the amplifier.

5. In an electrical generator of bass tones for a pipe organ having a pedal clavier and a shutter controlled swell box, the combination of a pair of oscillators capable of being tuned through a range of semitone intervals of extent as great as that of the pedal clavier of the organ, the pedal clavier of the organ comprising a plurality of pedals, a switch operable by each pedal, a plurality of relays respectively controlled by the pedal switches, means controlled by said relays for tuning one of said oscillators to a frequency related to the pitch of the highest pedal and tuning the other oscillator to a frequency related to the pitch of the lowest of two or more simultaneously depressed pedals, a multistage cascaded frequency divider system for each of said oscillators to provide frequencies which are submultiples of the frequencies respectively generated by said oscillator, an amplifying system for each frequency divider system, selectively operable remotely controlled means for coupling the various stages of each frequency divider system to its associated amplifying system, a loudspeaker for each amplifying system, said loudspeakers being located in the organ swell box,

and means operated by said relays for controlling the gain of both of the amplifying systems.

6. In an electrical musical instrument particularly adapted for supplementing the tonal output of a pipe organ equipped with a shutter control swell box by providing adequate bass tones, the combination of a pair of electronic oscillators, a pedal clavier comprising a plurality of pedals, means controlled by said pedals for tuning one of said oscillators to a frequency related to that of the highest of two or more simultaneously depressed pedals and tuning the other oscillator to a frequency related to that of the lowest of a plurality of simultaneously depressed pedals, a pair of multi-stage frequency dividers respectively coupled to said oscillators to successively divide by two the frequencies generated by the oscillators; two amplifying systems respectively associated with said frequency dividers, selectively operable means for coupling the outputs of predetermined stages of said frequency dividers to their respective amplifying systems, a pair of loudspeakers respectively coupled to said amplifying systems and located in the pipe organ swell chamber, and common means operated upon the depression of any one of the pedals to increase the gain of both of said amplifying systems.

7. In an electrical musical instrument having a bass tone generating system providing output signals of two different tone qualities, the first of the output signals comprising a fundamental frequency and a series of harmonics of high amplitude relative to the fundamental in which the peak amplitudes of the partials are substantially coincident, and the second signal comprising a fundamental frequency and relatively few harmonics of relatively low amplitude, an amplifying system, means for impressing the second signal directly upon the input of the amplifying system, and a frequency responsive phase distorting network forming a transmission line for impressing the first signal upon the amplifying system.

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