

Dec. 25, 1951

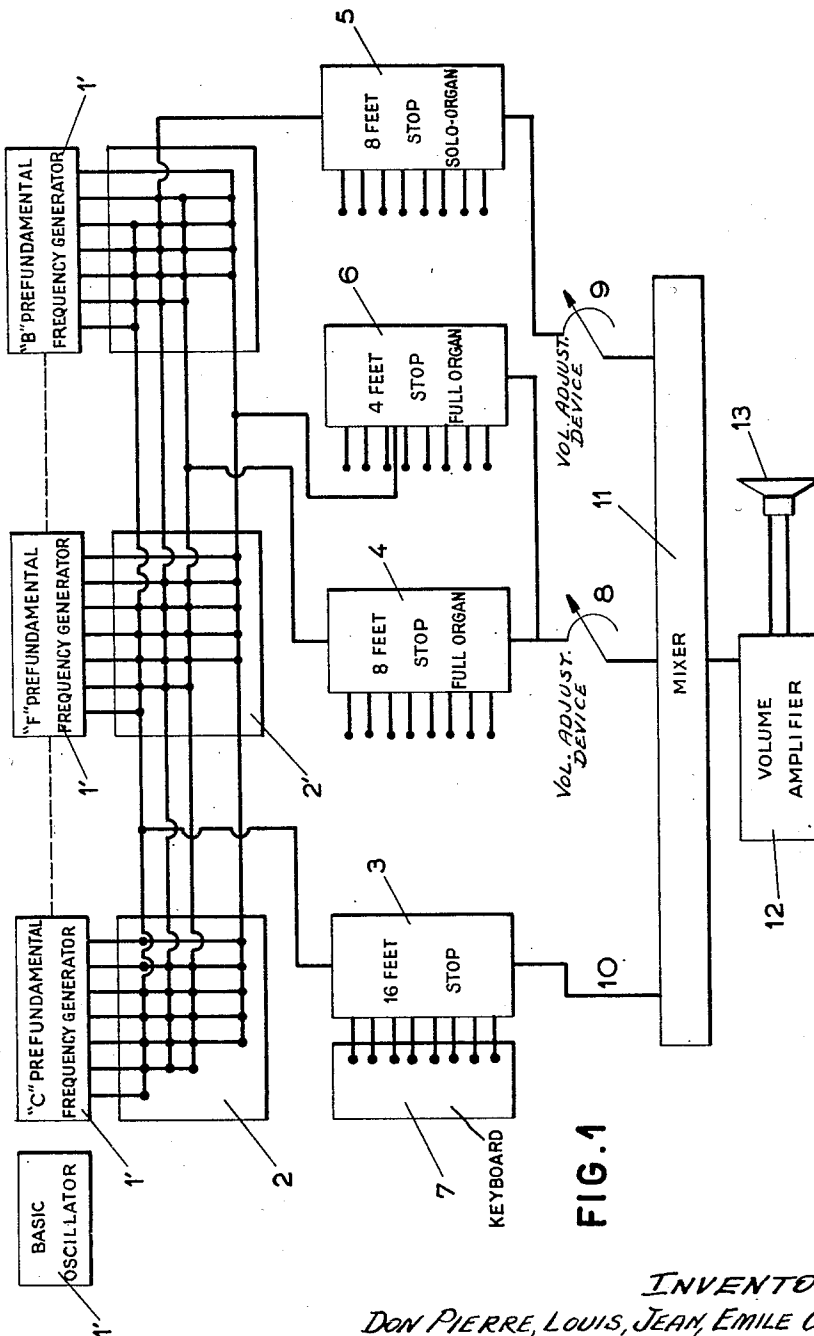
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2,580,217

ELECTRONIC MUSICAL INSTRUMENT

Filed Feb. 21, 1950

4 Sheets-Sheet 1



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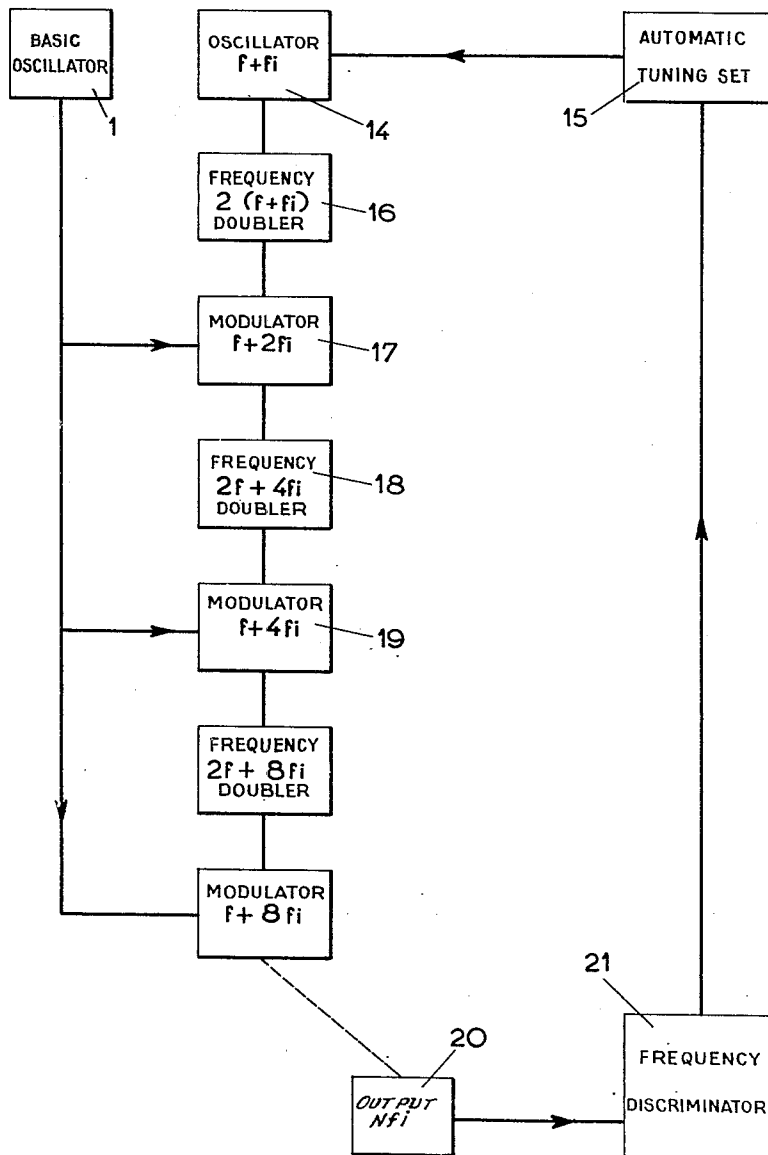
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4 Sheets-Sheet 2

FIG. 2



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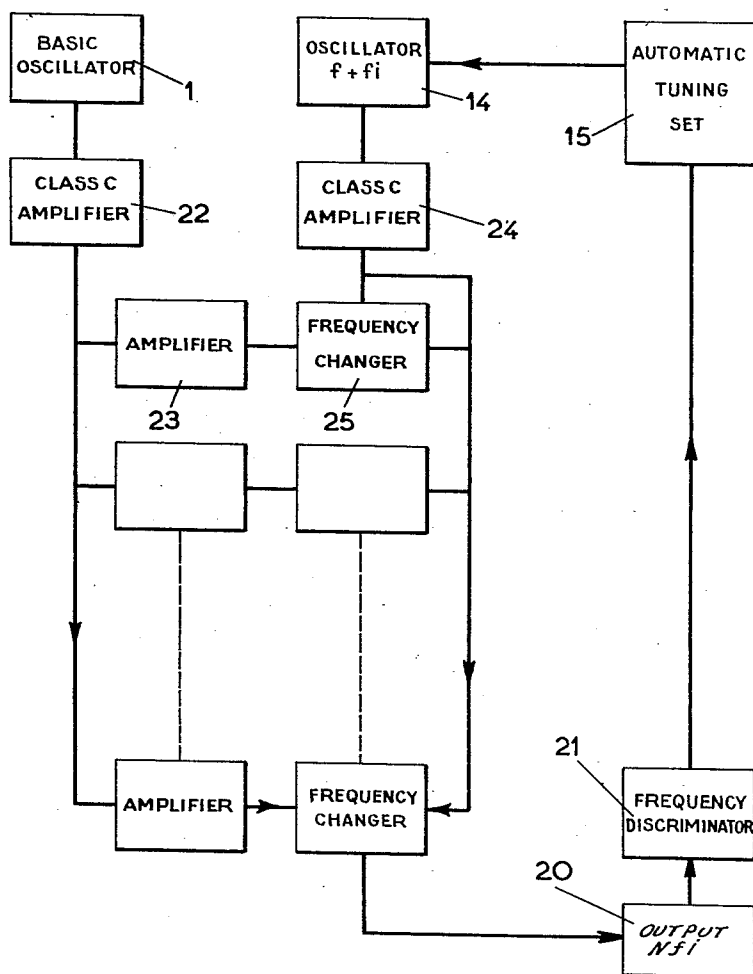
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FIG. 3



INVENTOR:

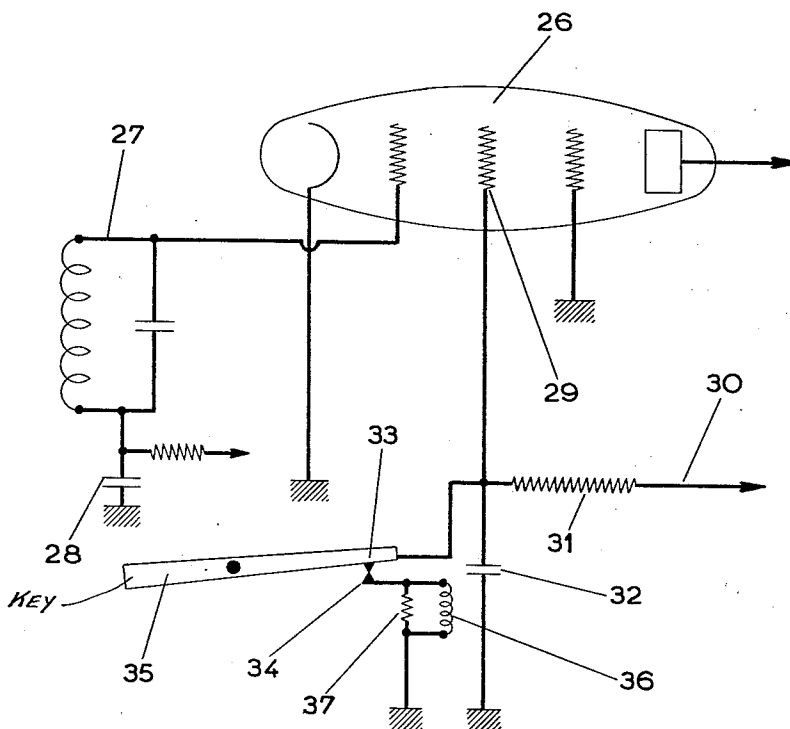
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4 Sheets-Sheet 4

FIG. 4



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UNITED STATES PATENT OFFICE

2,580,217

ELECTRONIC MUSICAL INSTRUMENT

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Paris, FranceApplication February 21, 1950, Serial No. 145,464
In France February 22, 1949

8 Claims. (Cl. 84—1.19)

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My present invention relates to an improved electronic musical instrument, and more particularly, to an electronic organ.

A wide variety of electronic musical instruments is already well-known, using either the direct emission of the notes, or beating waves. The sounds produced by such instruments, however, are often poor in timbre and particularly in the case of conventional electronic organs, the timbre lacks of the specific copiousness and softness which may be appreciated in the sounds produced by wind instruments. This is noticeable particularly with organs in which the sounds are obtained by means of phonic wheels securedly fixed for rotation to a common driving shaft. Further, the tuning of such instruments is erratic, due to the particular phase shift occurring in the elementary oscillators of the instrument or in a polyphonic instrument, for instance, which is subjected to the same requirements which are found in a pipe organ concerning the repeated tuning thereof by the player.

One object of the present invention is to provide means affording in an electronic musical instrument that the instantaneous frequency corresponding to any note constantly varies with respect to the true frequency of said note, thus producing sounds which are very similar to those obtained from a pipe organ.

Another object of the present invention is to provide means facilitating in an electronic musical instrument the obtainment of a wide variety of organ stops.

A further object of this invention is to provide means contributing in an electronic musical instrument, to the progressive increase in volume of the sound, when produced, while a progressive decrease thereof is achieved when the particular key corresponding to said sound is no longer depressed.

Yet another object of this invention is to provide an improved electronic musical instrument enabling a wide variety of timbres to be obtained at will.

A still further object of this invention is to provide an electronic musical instrument presenting a high stability for the mean frequency of any note, while enabling the instantaneous frequency of said note to vary slightly with respect to said mean frequency.

A further object of the present invention is to provide an improved electronic musical instrument in which a "moving harmony" effect is produced, that has a slight instability of the emitted frequency or frequencies with respect to the mean frequency of the notes.

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Other objects of the invention will be apparent from the following description of a specific diagrammatic embodiment of an electronic musical instrument in accordance with the invention.

According to the invention, the "moving harmony" effect is provided through the use of pilot oscillators from which voltages are derived having the various harmonic frequencies relating to the respective frequencies generated by said particular oscillators; said harmonic frequencies are caused to beat with the corresponding pilot frequency, thus generating the complete series of the notes to be obtained; the basic or pilot frequency oscillators further being associated with a follow-up or automatic tuning set whereby an accurate mean tuning is maintained.

According to another feature of this invention, the beat frequency generators react on the pilot oscillators through a follow-up or automatic tuning set which enables the mean stability thereof to be maintained while permitting said generators to present some independence with respect to each other.

An improved electronic musical instrument in accordance with this invention also presents a very high copiousness in timbres, due to the use of amplifiers operating according to the so-called "class C" principle.

On the other hand, the playing of the notes produces sounds which progressively increase in volume and the suppression of the notes causes a progressive decrease in said volume, thus producing an effect similar to that heard when playing a note on a pipe organ. This is obtained by controlling the unblocking of an electronic blocking tube through a circuit presenting a suitable time constant and made operative whenever the corresponding key is depressed and is also operative to modify the time of flow of the output voltage from the associated class C amplifier in each frequency cycle, said time thus varying from a zero value to a maximum value as determined when initially setting-up the instrument.

In accordance with still another feature of this invention, twelve independent pilot frequencies are used, each of which individually controls one or a plurality of beating wave generators; the frequencies of said beating waves are compared with said pilot frequencies, and said beating waves, in each octave, provide the fundamental frequencies for the related notes; on the other hand, the desired timbre is obtained by using specific amplifying means operating according to the "class C" principle, a relatively slow increase in the note volume being provided when starting through the use of a convenient time constant

circuit which enables the control electrode in the related coupling tube to be brought under potential; the flow of the current is controlled, for instance, by the depression of the corresponding organ key in a manual and/or in a pedal-board. My invention will be best understood from the following exemplary description of specific embodiments thereof, taken in conjunction with the annexed sheets of drawings, wherein some characteristic portions of the instrument are illustrated in a diagrammatic way. In the drawings:

Fig. 1 is a general basic block-diagram of an electronic musical instrument according to the invention embodied in the form of an organ;

Fig. 2 diagrammatically illustrates the elements through which the various sound frequencies are obtained;

Fig. 3 is a block-diagram showing a variation of the arrangement of Fig. 2; and

Fig. 4 illustrates in a more detailed manner the wiring diagram for the control circuit of one specific note and clearly shows the time constant means used to set up the exponential variation of the sound volume.

In order that the invention be understood more clearly, the manner in which the notes are obtained from one fundamental frequency will be disclosed first. The limitation to twelve in the number of the fundamental frequency generators results from the distribution of the notes in the commonly used scale, that is the equally tempered scale; said scale comprises seven notes, plus five sharp or flat tones. It will be appreciated, however, that a different number and/or a different distribution of the basic or pilot frequencies could be considered when using scales of any other well-known character.

In the following disclosure, the term "stop" is intended to comprise the basic frequency of the most heavy note having a given rank in the scale. On the other hand, the term "fundamental" will be applied to frequencies having the general form $(f+2^n \cdot f_1)$, where f is the pilot frequency, i an index comprised in the range 1 to 12 inclusive; and defining the rank of any given note in the octave, f_1 the frequency of the lowermost octave in the considered organ stop, and n the rank of a given octave. Thus the frequencies for the various notes are represented generally by the expression $2^n \cdot f_1$ and are obtained by beating the prefundamental frequency with the pilot frequency f , and the harmonics of said notes having a rank p are obtained in turn by beating the frequency $p \cdot f$ with frequencies having the form $p \cdot (f+2^n \cdot f_1)$. This is true also where a prefundamental frequency is expressed by a difference instead of a sum, as is well-known in the art.

Referring now to Fig. 1, a basic or pilot oscillator generating a frequency f has been shown at 1; the oscillator 1 also generates the harmonics of said frequency f ; the generators for the prefundamental frequencies are designated 1'; the various notes in the scale are derived from said oscillators which are illustrated in a block-schematic manner in the form of rectangles each bearing the symbol for the related note. In Fig. 1, only the generators for the notes C, F and B, respectively, have been shown for the sake of clarity in the drawing. Each such oscillator gives the various octaves by generating currents having the frequencies C_0+f ; C_1+f ; $\dots$ F_0+f ; F_1+f ; F_2+f ; $\dots$ B_0+f ; $\dots$, respectively. The coupling grids in the electronic tubes associated with the various note circuits, respectively, have been diagrammatized in the drawing at 2, 2' $\dots$

and it has been assumed that the spots at the crossings of the lines in Fig. 1 correspond to a contact with a related coupling tube, and that all coupling tubes positioned along a same vertical line are fed from a same prefundamental frequency oscillator, whereas all coupling tubes represented diagrammatically along a same horizontal line have the anode circuits thereof connected in parallel.

The distribution of the organ stops is made in accordance with the fundamental frequencies. Thus an instrument has been shown having a 16-feet stop 3 at the pedal-board, an 8-feet stop 4 and a 4-feet stop 6 for the "full organ," and finally an 8-feet stop 5 for the solo-organ. Each one of said stop units or key boards in turn is fed from a related device adapted to enrich the harmonic content of the sound frequency produced, which only has been illustrated at 7 for the 16-feet stop, for the sake of clarity of the drawing.

The stops 4 and 6 for the "full organ" are controlled in volume by a volume-adjusting device 8 adapted to control the sound volume and usually called "expression pedal" as in the case of conventional pipe organs, whereas the solo organ stop 5 separately is controlled by another expression pedal 9. It has been assumed that the stops controlled from the pedal-board are not provided with volume-adjusting devices, and therefore the 16-feet stop 3 in the pedal-board has its output 10 connected directly to a mixer 11 in parallel with the signals from the expression pedals 8 and 9 for the "full organ" and for the "solo organ" respectively, and the output of the mixer 11 in turn feeds a volume amplifier 12 which supplies the loud-speakers 13 replacing the sound pipes of a conventional organ.

In order that true sinusoidal voltages be obtained, the voltage which corresponds to the frequency f and to the various harmonics thereof is fed to beating tubes with a great amplitude. For this purpose the oscillator generating the frequency f is followed by a suitable filter of well-known type providing a very pure oscillation, and then by a class C amplifier operating in a very narrow range; due to the well-known characteristics of the class C amplifiers, this amplifier provides signals containing a considerable number of harmonics, particularly the harmonics of lower rank, with a constant percentage. This feature of the invention provides for the obtention of a predetermined constant harmonics percentage from a conventional oscillator, in which the percentage in harmonics could not be defined with accuracy, should not be described arrangement be present.

In the anode circuit of said class C amplifier coupled circuits are inserted which are tuned to the various voltage components respectively and therefore provide on the one hand the fundamental frequency f and on the other hand the complete range of the harmonics thereof, which thus are separated perfectly; said various voltage components are used to feed the related harmonic amplifiers, thereby insuring an accurate separation of the harmonics, even those having a relatively high rank.

Thus, in a specific embodiment of the invention, wherein the frequency f was in the order of 50 kc., attenuations amounting to more than 40 db have been observed for the harmonics 15 and 17 respectively in a circuit tuned to the frequency of the harmonic of rank 16 (800 kc.), by using

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coils coupled at the critical value whose Q did not exceed 100.

The transfer of such relatively high frequencies is provided by applying a conventional technique, that is by means of cathode loaded separator tubes, whereby said frequencies may be distributed with low impedances.

The oscillators which generate the frequencies $(f+f_i)$ (Fig. 2) are of a design similar to that of the oscillator for the frequency f ; however, the LC circuit thereof comprises an automatic tuning or follow-up set designed to control the frequencies in the oscillators so as to produce a constant frequency difference with respect to the pilot frequency f .

Such an oscillator has been illustrated diagrammatically at 14 in Fig. 2 and the control means therefor is designated as the automatic tuning unit 15. Following the oscillator 14, a frequency multiplier 16 is provided which supplies the frequency $2(f+f_i)$. The frequency multiplier 16 is followed by a modulator 17 fed from the pilot oscillator 1 generating the pilot frequency f and this modulator 17 supplies a voltage at the frequency $(f+2f_i)$. This latter frequency in turn is doubled in a second frequency multiplier 18, thus producing the frequency $(2f+4f_i)$, and a further frequency change provided by a subsequent modulator 19 provides the frequency $(f+4f_i)$, and a further frequency change provided by a subsequent modulator 19 provides the frequency $(f+4f_i)$. This proceeding is repeated successively through a desired number of stages and at the output 20 of the arrangement a voltage having a frequency $N.f_i$ is obtained which is fed to a frequency discriminator 21 of well-known type and controls therethrough the follow-up unit or tuning set 15 which in turn controls the frequency f in the pilot oscillator 1, as previously stated.

In a variation of the above-described arrangement illustrated diagrammatically in Fig. 3 the reference numeral 1 again designates the pilot oscillator generating the pilot frequency f ; 14 is one of the oscillators providing the frequencies of the form $(f+f_i)$, 15 is the follow-up unit controlled from a frequency discriminator 21 fed by the frequency $N.f_i$ from the output 20 of the arrangement. Following the pilot oscillator 1, a class C amplifier 22 is provided supplying the prefundamental frequency f together with the harmonics thereof, as previously disclosed. Starting now from the oscillator 14, there are provided successively a class C amplifier 24 and a series of frequency changers such as 25 which finally provide the above-mentioned output frequency $N.f_i$ on the output voltage 20.

Due to that frequency $N.f_i$ on the output voltage 20 applied to the frequency discriminator 21, an efficient frequency control is provided, although actually the pilot oscillator 1 generating the frequency f is not perfectly stable, as is also the case for the oscillator 14 generating the frequency $(f+f_i)$. The discriminator 21, however, is tuned to the frequency $N.f_i$ and is stable by its nature and the possibility for the oscillator 14 of a tendency to variation in the frequency generated therefrom becomes compensated through the follow-up unit 15. The small oscillations which yet may be present with respect to the mean frequency will cause the elimination of the poor character presented by sounds which would be perfectly stable as to frequency; on the other hand, the follow-up set of automatic tuning units arrangements 15 for the various oscillators

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enable stops to be obtained the sounds of which are produced separately, as hereinabove stated, while constantly providing a predetermined mean frequency. This proceeding which is specific of this invention enables supplementarily a tremolo effect by frequency variation to be obtained merely be periodically causing some out-of-tuning of the related discriminator or discriminators.

- 10 The harmonic amplifiers in accordance with this invention using electronic tubes connected according to the class C principle finally produce a series of peaks of sinusoids which, when developed in a Fourier series as a function of the operative angle θ of the amplifier provides broadly the value

$$\frac{4\theta}{\pi}$$

- 20 for the amplitude of the harmonics, whatever rank they may have, which value does not depend upon n , if n and θ are maintained sufficiently small. Consequently variations in the voltages of the prefundamental frequencies do not affect the sound timber, and the various harmonics may be added easily to each other while providing a constant amplitude.

- As a result of this manner of obtaining the harmonic frequencies, any predetermined timber may be conserved throughout the complete musical range of the instrument; a suitable adjustment made at will by the player, in a well-known manner, enables said player, either to cause the instrument to produce specific timbers, or to use preset timbers which for instance will correspond to the conventional timbers in an organ, such as salicional, oboe, flute, etc.

- Fig. 4 illustrates the arrangement in accordance with this invention whereby the sound volume is caused to increase progressively and to decrease progressively without the timber being changed when a key is depressed in the manual or in the pedal-board. This arrangement further provides for the suppression of any knocks which often are heard when a sound or note is emitted or suppressed.

- In this Fig. 4, the coupling tube 26 has been shown in the form of a pentode, by way of example only, without any limitative intention of the invention, since any other electronic tube may be used provided said tube comprises an electrode whose potential is adapted to control the duration of flow of the output potential in any period.

- The grid circuit 27 for the coupling tube 26 is tuned to one of the fundamental frequencies, that frequency obviously being chosen which corresponds to the rank of the related note in the scale, and the grid electrode is returned at 28 to a negative potential of high value thereby causing the tube 26 to operate well beyond cut-off, so as to provide for the operation as class C amplifier with narrow range of operation in any cycle.

- The screen grid 29 of the electronic tube 26 is brought to a suitable potential from the H. T. supply source 30 for the apparatus through a resistance 31 associated with a condenser 32 which is connected to the ground through contacts 33—34, the contact 33 being attached to the key 35 for the corresponding note, and an impedance coupling 36—37 is inserted between the contact 34 and the ground. The resistance 37 of said coupling is provided to adjust the time constant of the just described circuit to the desired value. Under these conditions, the screen

grid 29 is brought to ground potential through the contacts 33—34 and the aforesaid coupling 36—37, which can be assumed to have a negligible resistance; thus the tube 26 normally is blocked. Whenever the key 35 is depressed, however, the potential applied to the screen grid 29 exponentially increases according to a law which is a function of the values for the resistance 31 and the condenser 32 respectively, as is well-known in the art, and thus the operative range of the tube 26 also varies from zero to the maximum value which has been preset at the initial adjustment of the assembly. When the player releases the key 35, then the condenser 32 slowly is discharged into the impedance coupling 36—37. The characteristics of the time constant circuit are set from the resistance 37 of the impedance coupling in order to prevent the formation of spurious oscillations. As a result of this arrangement, the sound volume decreases and no knock is heard when the particular key is operated.

Furthermore, the arrangement is such that the key has a zero potential and that a contact must be broken in order that the note be played. Of course, a plurality of such contacts may be connected in series in an obvious manner to provide for the various combinations of stops which are characteristic of an organ.

While the present invention has been described in connection with the specific application thereof, to an electronic organ, it is to be clearly understood, however, that it could be applied to any other musical instrument, such as for instance an instrument producing continuous sounds, without such applications departing from the general scope of the invention, which, therefore, I do not intend to be limited more than comprised within the scope of the appended claims.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent, is:

What I claim is:

1. Electronic musical instrument provided with operating keys, comprising: a first oscillator generating a predetermined fixed pilot frequency, a series of frequency generators in a number of equal to the number of notes in the scale and each generating a related prefundamental frequency; a plurality of series of frequency changing means each associated with a corresponding one of said prefundamental frequency generators, each series generating respectively second frequencies equal to the sum of a corresponding even harmonic of the related frequency for the related note in the lowermost octave and of said pilot frequency; first means for causing said prefundamental and said second frequencies to beat with said pilot frequency; a plurality of key-operated means for operating corresponding ones of said first means; a series of discriminators each connected to a related one of said frequency changing means generating an harmonic of high rank of the corresponding note and each tuned to said pilot frequency; and means for applying the output of said discriminators to the related one of said prefundamental frequency generators, respectively.

2. Electronic musical instrument provided with operating keys, comprising: a first oscillator generating a fixed pilot frequency; a series of frequency generators in a number equal to the number of notes in a scale and each generating a second frequency which includes the frequency for the related note in the lowermost octave in

the instrument plus said pilot frequency; a plurality of series of frequency changing means, each series being associated with a corresponding one of said frequency generators and generating respectively third frequencies equal to the sum of a corresponding even harmonic of said frequency for the related note and of said pilot frequency; first means for causing said second and said third frequencies to beat with said pilot frequency; a plurality of key-operated means for operating desired ones of said first means; a series of frequency discriminators each connected to a related one of said frequency changing means generating an harmonic of high rank of the corresponding note and each tuned to said pilot frequency; and means for applying the output of said discriminators to the related one of said second frequency generators, respectively.

3. In an electronic musical instrument according to claim 1, said frequency changing means in each series comprising in cascade: a frequency doubler fed from the related prefundamental frequency generator; a modulator fed both by said frequency doubler and said pilot oscillator; and series of frequency doublers and modulators in series, each frequency doubler being fed by the next preceding modulator and each modulator being fed both by the next preceding frequency doubler and said pilot oscillator.

4. In an electronic musical instrument according to claim 1, said frequency changing means in each series comprising: a first class C amplifier fed by said pilot oscillator; a second class C amplifier fed by the related prefundamental frequency generator; and a plurality of amplifiers and frequency multipliers connected together respectively, said amplifiers being fed in parallel from said first class C amplifier, and said frequency multipliers being fed in parallel from said second class C amplifier.

5. Electronic musical instrument provided with operating keys, comprising: a first oscillator generating a fixed pilot frequency; a series of frequency generators in a number equal to the number of notes in the scale and each generating a related prefundamental frequency; a plurality of series of frequency changing means, each series being associated with one of said prefundamental frequency generators and generating respectively second frequencies equal to the sum of a corresponding even harmonic of the related frequency for the corresponding note in the heaviest octave in said instrument and of said pilot frequency; first means for causing said prefundamental and said second frequencies to beat with said pilot frequency; a plurality of key-operated means for operating corresponding ones of said first means; a plurality of class C amplifiers operating in a narrow amplitude range; second means controlled from the player for connecting a desired number of said class C amplifiers to the output of said first means; mixing means; and third means responsive both to the operation of said key-operated means and to said second means, for feeding to said mixing means, in desired manners and amounts, the output of said first means and the output of desired ones of said class C amplifiers.

6. In an electronic musical instrument according to claim 1, including a coupling tube associated with each key, for each one of said tubes: a grid in said tube adapted to control the operation thereof; means for applying a positive potential to said grid; a time constant circuit inserted in said last-mentioned means; means for

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connecting said grid to ground potential; a self inserted in said connecting means; and normally closed contact means in said connecting means, responsive to the operation of the related key.

7. In an electronic musical instrument according to claim 1, including a coupling tube associated with each key, respectively, for each one of said tubes: a grid in said tube adapted to control the operation thereof; means for applying a positive potential to said grid; a resistance inserted in said last-mentioned means; a condenser connected across said grid and ground; first contact means attached to said key and connected to said grid; second contact means normally engaging said first contact means; means for connecting said second contact means to ground; and a self inserted in said last-mentioned connecting means.

8. In an electronic musical instrument according to claim 1, including a coupling tube associated with each key, respectively, for each one of said tubes: a grid in said tube adapted to control the operation thereof; means for applying a

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positive potential to said grid; a resistance inserted in said last-mentioned means; a condenser connected across said grid and ground; first contact means attached to said key and connected to said grid; second contact means normally engaging electrically said first contact means; means for connecting said contact means with ground; a self inserted in said last-mentioned connecting means; and an adjustable resistance connected across said self.

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EMILE COLOMBANI.

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