

Nov. 29, 1966

T. J. GEORGE

3,288,907

ELECTRONIC MUSICAL INSTRUMENT WITH DELAYED VIBRATO

Filed May 7, 1962

2 Sheets-Sheet 1

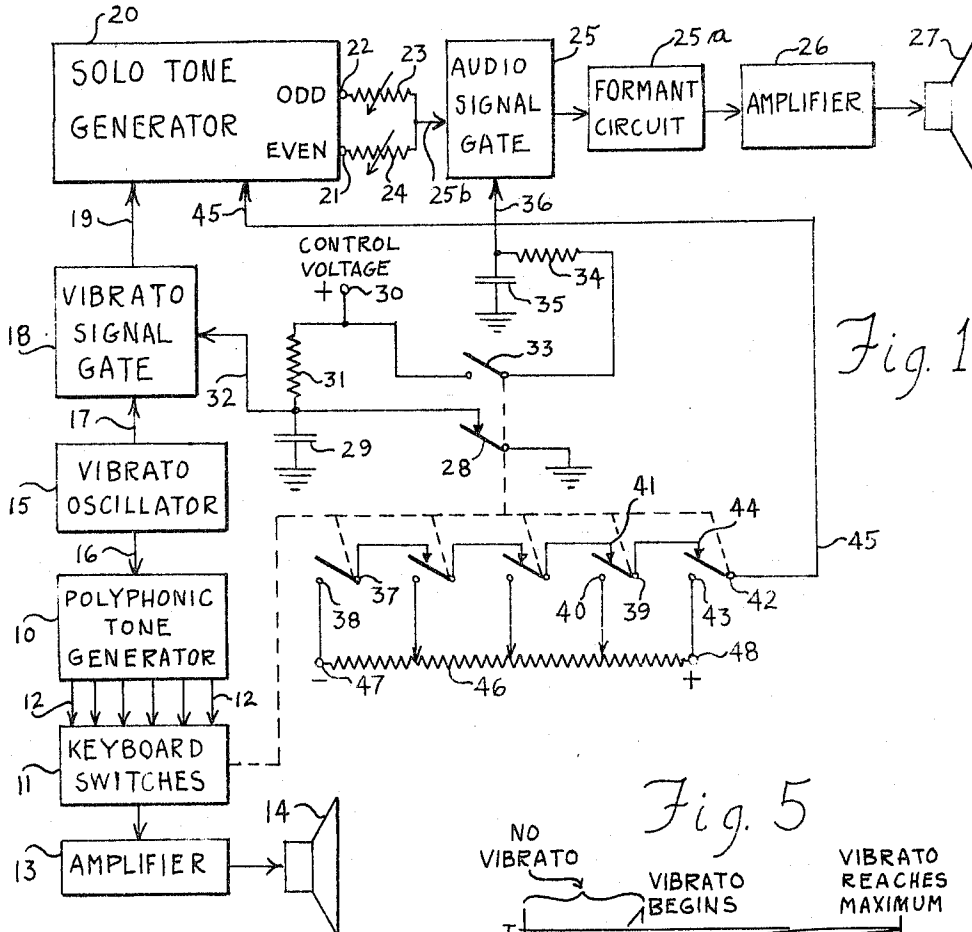


Fig. 1

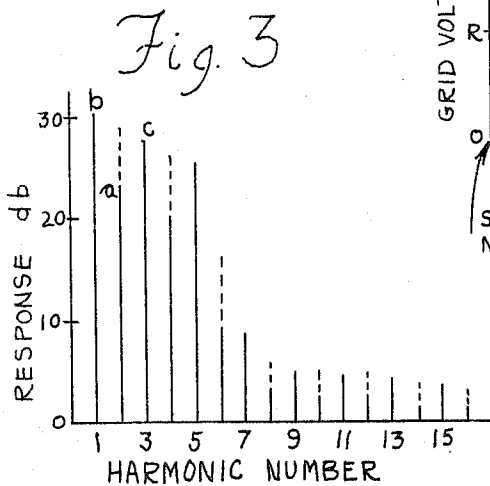


Fig. 3

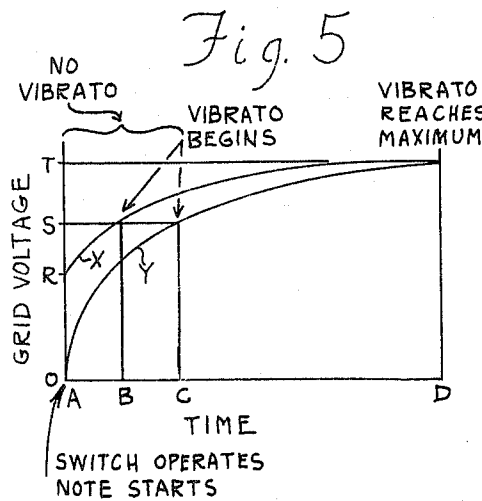


Fig. 5

INVENTOR.

Thos. J. George

Nov. 29, 1966

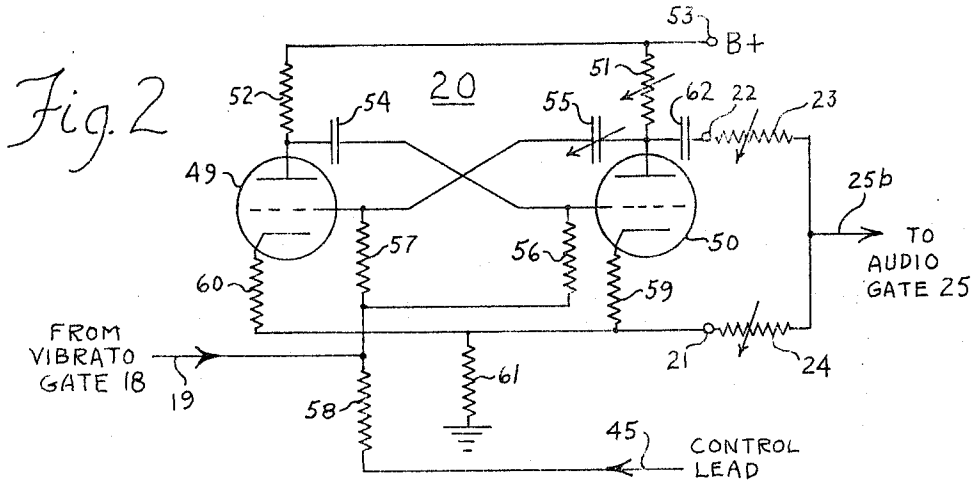
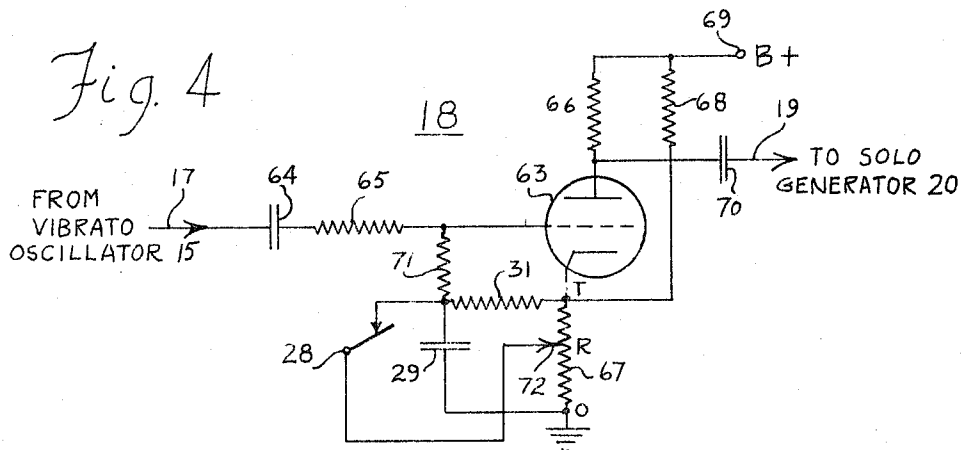
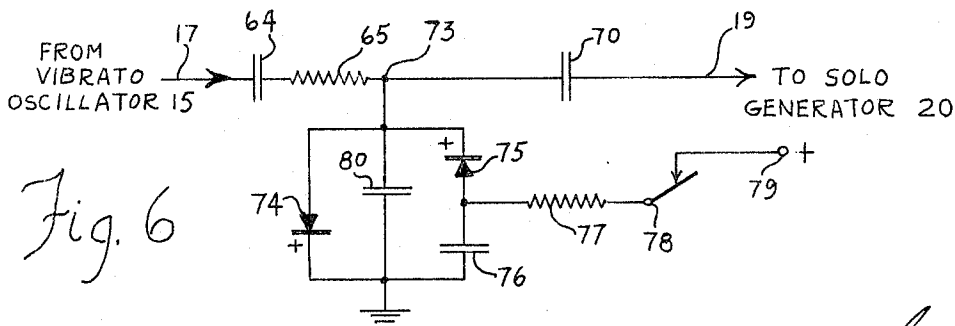
T. J. GEORGE

3,288,907

ELECTRONIC MUSICAL INSTRUMENT WITH DELAYED VIBRATO

Filed May 7, 1962

2 Sheets-Sheet 2



INVENTOR.
Thos. J. George

1

2

3,288,907

**ELECTRONIC MUSICAL INSTRUMENT WITH
DELAYED VIBRATO****Thomas J. George, Los Angeles, Calif., assignor to Ham-
mond Organ Company, Chicago, Ill., a corporation of
Delaware****Filed May 7, 1962, Ser. No. 192,922
19 Claims. (Cl. 84-1.25)**

This invention relates in general to electronic musical instruments, and more particularly to means for more accurately simulating the tonal effects of orchestral instruments, than those of the prior art.

In producing by electronic means the musical effects of orchestral instruments, it is common practice to generate by electronic means a complex tone, such as a saw tooth wave for example, and then to change the harmonic content of the original wave by means of various filters or formant circuits to provide a variety of tone colors. While this method produces pleasing musical tones, there are characteristics of orchestral instruments other than tone colors which must be more closely approximated in order to produce the experience of realism to the listener.

Orchestral reed instruments such as the oboe, clarinet, saxophone, bassoon, and English horn are widely used in all types of orchestral music. The saxophone particularly, is one of the most popular of all orchestral instruments, especially for the playing of popular music. Yet it is but poorly simulated by methods currently used in electronic musical instruments. There are a number of musical characteristics of the saxophone which help identify the instrument to the ear of the listener, and these characteristics should all be reproduced as accurately as possible, if the electronically produced sound is to closely resemble the actual instrument. The first of these is the tone color or harmonic structure of the acoustic signal heard by the listener. The second characteristic is the attack and release of the tone. The third is the manner of using the vibrato, as used by a saxophone player. And the fourth is the manner of playing instrumental solo with accompaniment, as with an orchestra, piano, or electronic organ.

The tone color has certain definite characteristics. The instrument is essentially a horn shaped instrument which is acoustically energized by a vibrating reed. It will therefore have some of the tone color of a horn. The reed is of the so called beating type which tends to generate both odd harmonics and relatively weaker even harmonics. This type of reed also produces quite strong high order harmonics. It is therefore a principal object of this disclosure to provide these tonal requirements.

The second object is to provide a gating circuit which permits the attack and release of the tone to be somewhat slower than the instantaneous attack characteristics of many electronic musical instruments.

The third object of the invention is to disclose improved means for delaying the vibrato for a short interval after the note has been started. In playing the saxophone, the performer normally starts the note without vibrato, and then as the note is held, the vibrato is started and gradually increased. This is an artistic effect which is usually repeated for each succeeding note which is played. To obtain a similar effect, certain disclosures of the prior art have employed vibrato oscillators which were normally quiescent, and which were started into oscillation each time a note was played. These have certain disadvantages which have been overcome in the present disclosure.

The fourth object is to disclose means for playing the saxophone effect as a solo, since the instrument is rarely played in chords. Practically all electronic musical in-

struments are played from keyboards, and the playing technique employed requires the playing of chords in both hands. A sequence circuit is therefore disclosed herein which permits the saxophone effect to be played as a solo, while normal chord playing is simultaneously employed to provide accompaniment. And where this accompaniment is provided by the tones of an organ or piano for example, the contrast and the realism of the saxophone solo effect is very entertaining.

Other and further objects of the invention subsequently will become apparent by reference to the following description taken in connection with the accompanying drawings wherein like reference characters in the different figures indicate like elements, and in which:

FIGURE 1 is a block circuit diagram showing a preferred embodiment of the invention.

FIGURE 2 is a circuit diagram of a preferred form of variable frequency oscillator.

FIGURE 3 illustrates a harmonic analysis of a saxophone tone in accordance with the invention.

FIGURE 4 is a circuit diagram of one form of vibrato signal gating circuit, as used herein.

FIGURE 5 is a chart of voltage curves, illustrating the action of the circuit of FIGURE 4.

FIGURE 6 is a circuit diagram of an alternate form of vibrato signal gating circuit.

The electronic musical instrument illustrated in block form in FIGURE 1 is a group of interrelated parts or blocks. Most of these blocks comprise devices well known in the prior art. Where there are exceptions, circuits are given in the figures. The figure illustrates the manner in which the present invention may be employed in conjunction with any polyphonic electronic musical instrument. The tone generator 10 is shown connected to keyboard switches 11 by means of control leads 12. These switches control and direct the musical tone signals to the output amplifier 13 and speaker 14. A vibrato oscillator 15 generates a low frequency signal of about six cycles per second. This signal voltage is connected by means of lead 16 to the oscillators of the polyphonic tone generator 10. There it is used in any of various ways well known in the art to cause a periodic variation in the frequencies or amplitudes of the tone signals, to provide a musical vibrato or tremulant. The vibrato oscillator 15 may be, and for the sake of economy should be, the vibrato oscillator normally provided in the polyphonic musical instrument.

The low frequency signal from vibrato oscillator 15 is also connected, by means of lead 17, to the input of a gating circuit 18. The output signal from this gate is carried by means of lead 19 to the solo tone generator 20. In a preferred form of the invention this solo generator is a variable frequency oscillator which generates, independently, the odd harmonics, and the even harmonics of the oscillation frequency. The output signal containing even harmonics appears at terminal 21, and the output signal containing odd harmonics appears at terminal 22. These two signals are applied in selected amounts through adjustable resistors 23 and 24 via lead 25b to the audio signal gate 25, from which they pass, through formant circuit 25a, to the output amplifier 26 and speaker 27.

The vibrato signal gate 18 is normally closed and does not transmit the vibrato signal from oscillator 15 to solo generator 20, and the output signals at terminals 21 and 22 thus do not have any vibrato effect.

Upon the actuation of normally closed switch 28, a short circuit to ground is removed from capacitor 29. This permits voltage from voltage supply 30 to pass through resistor 31 and begin to charge capacitor 29. As this charge begins to rise, the rising voltage is applied over lead 32 to the vibrato gate 18. This causes the gate

to gradually open, which permits a rising vibrato signal voltage to be applied to the solo tone oscillator 20. The output signals from this oscillator will thus have a gradually increasing vibrato effect following the actuation of switch 28. Upon the restoring of switch 28, capacitor 29 is short circuited and quickly discharged. The vibrato gate 18 closes quickly, and the circuit is thus prepared so that the operation cycle just described may be immediately repeated.

As indicated by the dashed line, normally open switch 33 is ganged with switch 28, and the two switches are actuated simultaneously. When switch 33 is closed, voltage from voltage supply 30 is conducted through resistor 34 to capacitor 35, over control lead 36 to audio signal gate 25. This gate opens and conducts signals from the solo tone oscillator 20, via formant 25a to the output amplifier 26 and speaker 27. The gate does not open instantaneously, the attack of the tone being softened somewhat by the delaying action of the RC time constant of capacitor 35 and resistor 34, which may be of the order of $\frac{1}{10}$ second. The attack of the tone is thus similar to that of an orchestral reed instrument. The time delay of the start of the vibrato effect, as determined by the time constant of capacitor 29 and resistor 31, should however be considerably longer, and may be of the order of $\frac{1}{4}$ to one second, as will be described later.

The musical result of the above action is that when ganged switches 28 and 33 are operated, a musical tone is transmitted from the speaker which has a softened attack, and which in the first instant has no vibrato effect. After a brief interval the vibrato gradually appears and continues until the switches are released. When the switches are again operated the cycle of events is repeated. Thus the solo tone heard from speaker 27 is heard with softened attack and with delayed vibrato, as in the technique of playing the saxophone or other orchestral reed instrument.

In a preferred form of the invention, as indicated in FIGURE 1, the solo generator is used in conjunction with a polyphonic musical instrument having a tone generator 10, and keyboard 11. This may be any conventional musical instrument in which the notes are played by means of playing keys. The dashed lines indicate that these keys are mechanically coupled to switches 28 and 33, and also to switches 37 through 42. Switches 28 and 33 are mechanically adapted by any convenient means, to be operated when any key or combination of keys are played on keyboard 11. The means employed can be one of those shown in the Hanert Patent No. 2,937,556 or in my copending patent application Serial No. 226,085 filed September 25, 1962.

Switches 37 through 42 are connected in a sequence circuit which provides a feed through connection from switch to switch. Each switch has a movable switch arm such as 39, which is connected to the normally closed contact such as 44, of the adjacent switch 42. Switch 39 has a normally open contact 40 to which contact is made when the switch is operated. Thus when switch 39 is operated a circuit is made from the contact 40 through the normally closed contact 44 of switch 42 to control lead 45. Thus, since a connection is made from each switch arm to the normally closed contact of the adjacent switch, a sequential connection can be made from lead 45 to any of the normally open contacts 38 through 43 by the operation of the appropriate switch. In the event that any two switches are operated simultaneously, such as switches 39 and 42, the switch in the sequence which is closest to the end switch and lead 45 will have precedence, and a circuit will be made to that normally open contact only, since the sequence circuit is broken below that point by the operation of the switch. Thus switch arm 42 will break with contact 44, which opens the sequence, and will make with contact 43, thus rendering switch 39 inactive.

Switches 37 through 42 are arranged to be selectively operated in sequence by the playing keys of keyboard 11,

when the instrument is played in the normal manner. Thus when any chord or combination of keys is played, the corresponding switches will operate and a circuit will be made from lead 45 to the normally open contact of that key switch which is closest in the series to switch 42. Lead 45 is connected to the last switch representing the highest musical note to be played by the instrument. Therefore the switch associated with the highest note of any chord played will be active, and all lower note switches will be inactive. The normally open contacts 38 through 43 of the sequence switches are connected to selected voltage points 47 through 48, of voltage divider 46. These voltages are used to control the oscillation frequency of solo tone generator 20 over control lead 45. This generator therefore, when properly adjusted, always plays the highest note of any chord played on keyboard 11. Since in normal playing, the highest note of the chord is the melody note, then in the device of the present disclosure, this melody note is a contrasting solo voice, having a softened attack and a delayed vibrato. Also in a preferred arrangement, the solo voice has the tone quality of a saxophone or other orchestral reed instrument, as will be subsequently described.

The solo tone generator 20 is a variable frequency balanced oscillator, of the type shown in FIGURE 2, and which is a modified form of multivibrator. The operation of this oscillator is discussed in detail in my copending patent application Serial Number 226,085 filed September 25, 1962. The circuit employs two triodes 49 and 50, having plate resistors 51 and 52 which interconnect the triode plates and the B plus supply 53. The plate of tube 49 drives the grid of tube 50 through coupling capacitor 54, and the plate of tube 50 drives the grid of tube 49 through coupling capacitor 55. Grid resistors 56 and 57 connect the grids respectively of the triodes to lead 19 from the vibrato gate, and also to control lead 45 through resistor 58. The cathode resistors 59 and 60 connect the cathodes to the output terminal 21, which is connected to ground through common resistor 61. Adjustable resistor 24 interconnects output terminal 21 and lead 25b to the audio gate. Blocking capacitor 62 interconnects the plate of triode 50 and output terminal 22. Adjustable resistor 23 interconnects output terminal 22 and lead 25b to the audio gate. Plate resistors 51 and 52 may each be 33K ohms. Grid resistors 56 and 57 may each be 560K ohms. Cathode resistors 59 and 60 may each be 3.3K ohms. Common resistor 61 may be 100K ohms, and resistor 58 may be 220K ohms. Adjustable resistors 23 and 24 may each be 1 megohm. Coupling capacitors 54 and 55 may each be .002 mfd. and capacitor 62 may be .0001 mfd.

The circuit oscillates in the manner of a multivibrator which is well known in the art, the frequency being determined principally by the values of resistors 56 and 57, and capacitors 54 and 55, and by the magnitude of the positive grid bias voltage supplied over control lead 45.

When like circuit components are matched or balanced, including the two plate resistors 51 and 52, the two grid resistors 56 and 57, the two capacitors 54 and 55, and the cathode resistors 59 and 60, the circuit has the novel capability to generate independently, the odd harmonics, and the even harmonics of the oscillation frequency. The odd harmonics appear at the plate, terminal 22, and the even harmonics at terminal 21. The simplest way of reaching circuit balance is by making one of the plate resistors 51, and one of the coupling capacitors 55, adjustable, as indicated. The odd harmonics of the oscillation frequency are cancelled out in the common cathode resistor 61 when the circuit is balanced by adjustment of these two components. It is not difficult by this means to reduce the first harmonic, for example to an amplitude more than 40 db below that of the second harmonic.

The frequency range of the oscillator is approximately three octaves, using the circuit values given above, and

depends upon the range of grid bias control voltage supplied over lead 45. When the circuit is in proper balance the waveform at terminal 22 is a rectangular wave, and the waveform at terminal 21 is a sawtooth wave. Adjustable output resistors 23 and 24 permit the relative amplitudes of the odd and the even harmonics transmitted to the audio gate over lead 25b, to be independently selected, low frequency vibrato signals are brought to the oscillator from the vibrato gate over lead 19, and cause a periodic change in oscillation frequency to provide a vibrato or tremolo effect. Although vibrato and tremolo are not musically identified, the terms are used interchangeably in this disclosure.

FIGURE 3 illustrates a harmonic analysis of a complex tone as generated in accordance with this invention. The harmonic amplitudes are shown vertically in db, and the harmonic numbers from 1 to 16 are shown horizontally. The analysis shown is that of a simulated reed tone such as a saxophone, and it will be noted that the relative amplitudes of the even harmonics, as indicated by the solid lines are generally, several db lower than the amplitudes of the adjacent odd harmonics. For example, in the case of the second harmonic the height *a*, is less than height *b* or *c*, which represent the first and third harmonics. This tone will therefore sound quite reedy to the ear, since in reed tone the odd harmonics are normally stronger than the even harmonics. Referring to FIGURES 1 and 2, the adjustable resistor 24 can be adjusted to control the amplitudes of the family of even harmonics. Thus if resistor 24 is increased to a very large value, the amplitudes of the even harmonics are greatly reduced, and if it is made infinitely large the even order harmonics disappear entirely, and the tone assumes the hollow reedy sound of the clarinet, another orchestral reed instrument. If resistor 24 is reduced in value to the point where the amplitudes of the even harmonics are approximately equal to the adjacent odd harmonics, as indicated by the dotted lines in FIGURE 3, then the waveform loses its odd harmonic character and becomes practically a sawtooth wave. This method of controlling the relative loudness of the odd and even harmonics of the tone is thus a novel and very simple way of selecting the type of reed tone desired.

The use of filters and formant circuits also aids in achieving the desired tonal characteristics. These circuits which are indicated generally by the block 25a in FIGURE 1, will not be described here since they are well known in the prior art. It is not deemed necessary to describe the audio gate 25, since gating circuits are well known in the prior art.

The vibrato signal gate 18, is shown in circuit form in FIGURE 4. A triode 63 is connected as an amplifier with the input signal to the grid brought from the vibrato oscillator over lead 17, through capacitor 64 and resistor 65. A plate resistor 66 interconnects the plate of tube 63 and the plate supply 69. This resistor may have a resistance value of 560K ohms. A cathode resistor 67 connects the cathode of the tube 63 to ground. This resistor may have a value of 50K ohms, and it has an adjustable tap 72. A cathode bias resistor 68, having a value of 100K ohms, interconnects the cathode and B plus terminal 69. The grid resistors 65 and 71 may each be one megohm, and the blocking capacitors 64 and 70 may each be .02 mfd. The timing resistor 31 which interconnects the cathode and timing capacitor 29 may be 5 megohms when capacitor 29 is .05 mfd. As described in connection with FIGURE 1, capacitor 29 is short circuited by normally closed switch 28. In FIGURE 4, this short circuit is made through a portion of resistor 67, as determined by the position of tap 72. The vibrato oscillator 15 is in continuous oscillation, and there is therefore vibrato signal voltage always present at the grid of the gate tube 63. The tube is however, normally held in a cutoff condition by means of the relatively high cathode bias voltage, as determined by re-

sistors 67 and 68, and there is therefore no output vibrato signal transmitted to the sole tone oscillator 20 over lead 19. When normally closed switch 28 is opened, upon the operation of a playing key as described earlier, voltage appearing at point T on resistor 67 begins to charge timing capacitor 29 through timing resistor 31. Resistor 71 carries this rising voltage to the grid of the tube, and the tube gradually moves from the cutoff condition and begins to amplify the incoming vibrato signal, so that an increasing vibrato signal is transmitted to sole generator 20. As earlier explained, this action causes each successive note which is played to be accompanied by a gradual buildup of vibrato effect.

Methods of the prior art have produced a somewhat similar effect by causing a vibrato oscillator to start into oscillation each time a control switch was operated. This method depends upon the oscillation buildup time of the oscillator for the vibrato delay. One such method is disclosed in the patent to Leslie, No. 2,899,644. However, it is a well known fact that it is difficult to cause a low frequency sine wave oscillator to start with any degree of reliability as to the interval of buildup time, and a patent to Fender, No. 2,817,708 attempts to remedy this difficulty by applying a transient pulse to the vibrato oscillator at the moment of operation of the control switch. Both these systems suffer in that no positive control is possible, of the interval during which the vibrato oscillation is building up, and the length of this interval is quite marginal.

The artistic use of vibrato delay in playing the saxophone and other orchestral instruments, requires that the player be able to control the interval between the start of the note and the start of the vibrato, with some degree of accuracy, for therein lies one of the means of artistic expression. In the present disclosure this delay interval is easily and accurately controlled. The curves of FIGURE 5 illustrate the manner in which the gating circuit of FIGURE 4 functions to cause vibrato delay. The ordinate O to T represents the full cathode voltage drop appearing across resistor 67. The cathode bias voltage is sufficient to hold the grid of the tube well into the grid cutoff region, when the grid is grounded to point O, the lower end of resistor 67. And when the adjustable tap 72 is set to the point O, the grid is grounded through resistor 71 and the normally closed contacts of switch 28. When tap 72 is set to point T the grid voltage is then optimum for maximum amplification of the vibrato signal. Voltage point S represents the threshold of grid voltage cutoff, and here the amplification is minimum. Thus when the grid voltage rises above point S the tube begins to conduct and to amplify the vibrato signal; when it is below point S and the tube is cutoff, and there is no vibrato output signal.

The abscissas of FIGURE 5 represent time elapsed from the operation of switch 28 at point A, until maximum vibrato is reached at point D. The ordinates represent the voltage appearing at the grid of tube 63 at any instant of that time. Curve X shows the change of voltage occurring at the grid, after the switch is opened at time A, and when the tap 72 is set to position R. It will be seen that the time from A to B is required for the grid voltage to travel from voltage R to voltage S. At voltage S the tube begins to conduct and vibrato output voltage begins, increasing until it reaches a maximum at time D. If tap 72 is set to point O, then upon the opening of switch 28 the grid voltage follows curve Y. The voltage starts from O and reaches voltage S at time C, the time interval from A to C being longer than that from A to B. If the tap is set slightly above voltage S then the note played will start with small vibrato which gradually builds up to maximum. If the tap is set to voltage T, there is no vibrato delay at all, and maximum vibrato is always present whenever any solo tone is played. Thus the position of tap 72 on resistor 67 provides a convenient means for selecting the vibrato delay

interval, or eliminating it entirely, in accordance with the artistic desires of the player.

Although the gating circuit of FIGURE 4 uses a vacuum tube, and is arranged to amplify, other gate circuits may be used which employ other types of conductive devices, and which do not amplify. For example, a so-called grid controlled rectifier may be used, or a transistor may replace the vacuum tube. A multi-electrode vacuum tube may be employed instead of a triode, or a diode may be used with some saving in cost. A diode gating circuit such as is shown in FIGURE 6, may be used to interconnect the vibrato oscillator 15 and the solo generator 20, instead of the gating circuit of FIGURE 4. The input lead 17 is connected through series resistor 65, to the output lead 19, at point 73. Capacitors 64 and 70 serve as blocking capacitors, as in FIGURE 4. Point 73 is connected through a shunt path to ground, through a variable resistance network comprising diodes 74 and 75. Diode 74 is connected between point 73 and ground, with the cathode terminal to ground. Diode 75 and timing capacitor 76, which may be .25 mfd., are connected in series between terminal 73 and ground, with the cathode of the diode connected to terminal 73. A 2 megohm resistor 77 interconnects the junction of the diode and the capacitor, with a normally closed switch 78. The other terminal of the switch is connected to a positive voltage source 79 of approximately 100 volts. As long as the switch is closed current flows from source 79, through resistor 77, and through the two diodes in series. This forms a low resistance shunt from point 73 to ground, thus preventing vibrato signal from lead 17 from reaching lead 19. Voltage from source 79 holds capacitor 76 in a charged condition, as long as switch 78 remains closed so that the voltage across the capacitor 76 corresponds to that which is required to render the diodes 74 and 75 conductive. The switch is adapted to be opened by any playing key of keyboard 11, in the manner previously described in relation to switch 28. When switch 78 is opened, the voltage supply 79 is disconnected from resistor 77, and the charge on capacitor 76 begins to discharge through the two diodes in series so that as the voltage across the capacitor 76 decreases the diodes 74 and 75 are gradually rendered non-conductive. As the charge dissipates the resistance between point 73 and ground begins to rise, and the vibrato signal voltage transmitted to solo generator 20 over lead 19 begins to rise, accompanied by an increasing vibrato effect in the tones from the solo generator. A certain amount of distortion of the vibrato signal waveform takes place due to the nonlinear characteristics of the diodes, and capacitor 80, which may be .1 mfd., is connected from point 73 to ground to minimize this effect. Diode 74 may be replaced by a resistor of approximately one-half megohm, and the circuit will still provide a vibrato delay, but the degree of control is somewhat reduced.

As indicated in the block diagram of FIGURE 1, it is desirable to employ one output amplifier and speaker for the tones from the polyphonic generator, and a separate amplifier and speaker for the solo generator. One amplifier and speaker may of course be used for the two tone sources, but the separate speaker systems are highly desirable. The very purpose of the invention is an improvement in the realism of simulation of saxophone and other orchestral instruments. Hence the elimination of a point source of sound is indicated, and the use of the second speaker system definitely improves the effect of realism. This is probably due to the fact that this three dimensional acoustic effect more nearly resembles that of an actual orchestra, where the various instruments are separated in space.

The fact that the vibrato oscillator is in continuous oscillation makes it possible when desired, to use vibrato with the polyhydic generator 10 only, or with the solo generator 20 only, or with both generators simultaneously. In the present disclosure the delayed vibrato signal from

vibrato gate 18 has been applied to the solo tone generator 20 only, and not to the polyphonic generator 10. However it is obvious that it could be applied to both generators simultaneously, or to the polyphonic generator only, if so desired.

While I have described and illustrated certain preferred embodiments of the invention, it will be apparent to those skilled in the art that variations of the specific structures and circuits shown may be employed without departing from the broader aspects of the invention. For example a piano can be used to provide the accompaniment chords instead of an organ. I therefore desire, by the following claims, to include within the scope of the invention all such similar and modified forms of the circuits and apparatus disclosed herein, by which substantially the results of the invention may be obtained, using substantially the same or equivalent means.

The claims are as follows:

1. In an electronic musical instrument having a tone generator and a playing key for controlling the output of the generator, means for providing a delayed vibrato effect comprising a source of continuous vibrato signal voltage, a circuit means coupling said source to said tone generator for affecting the output tone of said generator at a vibrato rate, said circuit means including a normally inactive conductive device, a control switch adapted to be operated by said playing key, a control circuit coupled to said conductive device for rendering it active, said control circuit including said switch and said control circuit including means for providing a selected time delay in the rendering active of said conductive device.

2. In an electronic musical instrument having a keyboard and switching means adapted to be operated by the keys of said keyboard, means for providing a delayed vibrato effect comprising at least one tone generator, a source of continuous vibrato signal voltage, normally inactive coupling means interconnecting said source and said tone generator and adapted to transmit said vibrato signal to said tone generator to affect the frequency thereof when said coupling means is active, control circuit means including said switching means and adapted to render said coupling means active, adjustable time delay means coupled to said control circuit for establishing the rate at which said coupling means is rendered active, said time delay means including an adjustable resistance and a capacitor.

3. In an electronic musical instrument having a first tone generator, a vibrato oscillator and means for selectively applying vibrato signal to said first tone generator, and at least one playing key adapted to control the output tones of said first tone generator, the combination comprising a second tone generator having a vibrato control point, a switch having two terminals and adapted to be operated by said playing key, a normally quiescent gate circuit comprising an electronic conductive device having an input terminal, a control terminal, and an output terminal, a source of control voltage, circuit means connected to said input terminal and adapted to receive signals from said vibrato oscillator, circuit means interconnecting said output terminal and said vibrator control point, circuit means including a time delay means interconnecting said control terminal and one terminal of said switch, circuit means interconnecting the other terminal of said switch and said source of control voltage, whereby a delayed vibrato signal is applied to said second tone generator upon operation of said playing key, regardless of the presence or absence of vibrato effect in said first tone generator.

4. In an electronic device to simulate a saxophone effect, an output system, a source of potential, a solo tone generator comprising a balanced multivibrator, said multivibrator comprising two amplifying devices having a common resistance in series with said source of potential, a first terminal connected to one of said devices, a second terminal connected to one end of said resistance, an

output terminal, first adjustable coupling means interconnecting said first terminal and said output terminal, second adjustable coupling means interconnecting said second terminal and said output terminal, a first normally inactive gate circuit interconnecting said output terminal and said output system, a source of continuous vibrato signal voltage, circuit means interconnecting said vibrato signal source and said multivibrator comprising a second normally inactive gate circuit, a playing key, two switches adapted to be operated substantially simultaneously by said key, a source of control voltage, circuit means interconnecting said first gate circuit and said source of control voltage including one of said switches and a first time delay means, circuit means interconnecting said second gate circuit and said source of control voltage including the other of said switches and a second time delay means.

5. In an electronic musical instrument having a tone generator for generating a reed-like tone, the combination comprising an output system, a balanced multivibrator including two electron amplifying devices each having a control electrode, mutually regenerative reactive feedback paths interconnecting said devices, said paths including one fixed capacitor and one adjustable balancing capacitor, a source of potential, a load resistor for each device coupling each said device to said source of potential, one of said resistors being an adjustable balancing resistor, a third load resistor common to both said devices and coupled to said source of potential, a frequency control terminal for said multivibrator, a first resistor coupling said control terminal to one of said control electrodes, a second resistor coupling said control terminal to the other of said control electrodes, a source of vibrato signal voltage connected to said control terminal, circuit means connected to said control terminal for applying selected voltages to said terminal corresponding to the notes of a musical scale, a first output terminal connected to said common load resistor, a second output terminal connected to one of said other load resistors, an impedance interconnecting said output terminals, circuit means interconnecting said impedance and said output system.

6. In a musical instrument having a plurality of playing keys and a plurality of switches selectively operable by at least some of said keys and a control switch operable by any of said keys, the combination comprising an output system, a source of vibrato signal voltage, a variable frequency solo tone generator having a frequency control terminal, said generator having a first output terminal for deriving signals containing substantially only odd harmonics and a second output terminal for deriving signals containing substantially only even harmonics, circuit means coupling said output terminals to said output system, a normally inactive gate circuit having a gate input terminal, a gate output terminal, and a gate control terminal, circuit means coupled to said gate input terminal and adapted to receive signals from said source of vibrato signal source, circuit means coupling said gate output terminal to said frequency control terminal, a source of control voltage, circuit means including said control switch and a time delay means coupling said gate control terminal to said source of control voltage, said time delay means including resistance and reactance, a source of potential and a voltage divider connected thereto, said voltage divider having a plurality of adjustable taps, a plurality of individual circuit means interconnecting said plurality of taps and said plurality of switches, said switches as a group having a single output point, circuit means interconnecting said output point and said frequency control terminal.

7. In an electronic musical instrument having at least one playing key and a first tone generator and first output system adapted to reproduce the tone signals from said generator, the combination for producing a delayed vibrato effect comprising, a solo tone generator having a frequency control terminal, a source of continuous vibrato signal voltage, a normally inactive gate circuit having a

control point and an output point, a switch adapted to be operated by said playing key, a source of control voltage, circuit means interconnecting said vibrato signal source and said gate for transmitting vibrato signals to said gate, circuit means interconnecting said output point and said frequency control terminal, circuit means including said switch and a time delay means interconnecting said source of control voltage and said control point, a second output system, circuit means connected to the input of said second output system and adapted to receive signals from said solo tone generator.

8. In an electronic musical instrument having at least one playing key and a first tone generator and first output system adapted to reproduce tones from said generator, the combination comprising a second output system, a solo tone generator having a frequency control terminal, a source of continuous vibrato signal voltage, a first normally inactive electronic gate circuit having an input terminal, an output terminal, and a control terminal, circuit means connected to said input terminal and adapted to receive signals from said source of vibrato voltage, circuit means interconnecting said output terminal and said frequency control terminal, a second normally inactive electronic gate circuit having an input point, an output point and a control point, circuit means connected to said input point and adapted to receive signals from said solo tone generator, circuit means connecting said output point to said second output system, switching means adapted to be operated by said playing key, a source of control voltage, individual circuit means including time delay means and said switching means interconnecting said source of control voltage with said control point and said control terminal.

9. In an electronic musical instrument having a plurality of playing keys and a solo tone generator for generating a tone signal of complex waveform, the combination comprising adjustable impedance means coupled to said tone generator for controlling the relative amplitudes of the odd harmonics and the even harmonics of said tone signal waveform, a low frequency generator for continuously generating for controlling the relative amplitudes of the circuit interconnecting said low frequency generator and said solo tone generator, means actuated by at least one of said playing keys for gradually rendering said gating circuit operable to transmit an increasing amplitude of said vibrato signals from said low frequency generator to said solo tone generator to provide a vibrato effect in said tone signal waveform.

10. A musical instrument in accordance with the combination set forth in claim 9, in which said solo tone generator is a variable frequency oscillator having a frequency control terminal and in which there are a plurality of keying switches operable selectively by said playing keys, said switches being connected to selected voltage supply points and being connected in a sequence circuit having a single output terminal, circuit means for controlling the frequency of said oscillator interconnecting said single output terminal and said oscillator frequency control terminal.

11. In an electronic musical instrument for playing chords having a continuous vibrato effect and solo tones having a delayed vibrato effect, a keyboard, a polyphonic tone generator, a solo tone generator, a vibrato oscillator which is in continuous oscillation, first circuit means interconnecting said oscillator and said polyphonic generator, second circuit means interconnecting said oscillator and said solo generator, said second circuit means comprising a normally inactive gate circuit, means including a time delay device coupled to said gate circuit and operable from said keyboard for rendering said gate circuit active to provide a delayed vibrato effect in the tones of said solo generator.

12. In an electronic musical instrument adapted to play chord tones having a continuous vibrato effect and reed-like solo tone having a delayed vibrato effect, the com-

bination comprising, a polyphonic tone generator, a solo tone generator, a plurality of playing keys, a source of continuous vibrato signals, a first output system and a second output system, said first output system adapted to reproduce chord tones from said polyphonic generator under the control of at least some of said playing keys, said solo tone generator comprising a balanced multivibrator having two amplifying devices and a common load resistor, a first put terminal connected to one of said amplifying devices, a second output terminal connected to said common load resistor, circuit means interconnecting said first output terminal and said second output system for delivering an output signal of substantially rectangular waveform to said system, circuit means interconnecting said second output terminal and said second output system for delivering an output signal of substantially saw-tooth waveform to said system, circuit means interconnecting said source of vibrato signals and said polyphonic generator, control circuit means interconnecting said source of vibrato signals and said multivibrator, said control circuit means comprising a normally inactive gate circuit, switching means operable by at least one of said playing keys, means including said switching means and a time delay means for rendering said gate circuit active, said time delay means including both resistance and reactance.

13. In an electronic device to simulate a saxophone effect and having a plurality of playing keys and an output system, a source of potential, a solo tone generator for generating independently the odd harmonics and the even harmonics of the generator frequency comprising a balanced multivibrator, said multivibrator having two amplifying devices and a load impedance common to both said devices, said common load impedance connected to said source of potential, a first output point connected to one of said amplifying devices, a second output point connected to one terminal of said common load impedance, an output terminal, adjustable impedance means interconnecting said first output point and said output terminal, adjustable impedance means interconnecting said second output point and said output terminal, circuit means including a formant circuit interconnecting said output terminal and said output system, a source of continuous vibrato signals, circuit means including a normally inactive gate circuit connected to said multivibrator and adapted to receive signals from said source of vibrato signals, a switching device adapted to be operated by at least one of said playing keys, circuit means including said switching device and a time delay device for rendering said gate circuit active upon the operation of said key.

14. In an electronic musical system for producing musical tone effects and having a plurality of playing keys and a control switch adapted to be operated by at least one of said keys, means for producing a delayed vibrato effect comprising in combination, a tone generator for generating a plurality of musical tone signals, a plurality of switches adapted to be selectively operated by said keys, said plurality of switches being coupled to said tone generator for controlling the musical tone signals, a normally inactive vibrato control circuit means coupled to said system to impart a vibrato effect to said musical tones when said control circuit means is active, said control circuit means including a source of continuous vibrato signal voltage, means coupled to said vibrato control circuit means including said control switch and a time delay means for rendering said vibrato control circuit means active upon the operation of one of said playing keys,

an output amplifier and speaker coupled to said system for reproducing said musical tones with delayed vibrato effect.

15. The combination as set forth in claim 1 wherein said conductive device is connected in series between said vibrato signal source and said tone generator.

16. The combination as set forth in claim 1 wherein said conductive device is connected in shunt with said vibrato signal source.

17. The combination as set forth in claim 16 wherein the resistance of said conductive device is altered following the operation of said playing key.

18. In an electronic musical instrument having a tone generator and at least one playing key for controlling the tones of said generator, means for producing a delayed vibrato effect having an adjustable delay interval comprising in combination, a source of continuous vibrato signals, a gate circuit interconnecting said vibrato signal source and said tone generator for affecting the tones of said generator when said gate circuit is active, said gate circuit comprising an electronic amplifying device, normally held in an active condition by means of a bias of one polarity, control circuit means connected to said gate circuit and actuated by said playing key for applying to said gate circuit a control voltage of effective polarity opposite to said bias, to render said gate circuit active after a delay interval, means coupled to said control circuit for selecting a desired control voltage to provide a desired delay interval.

19. In an electronic musical instrument having a tone generator and at least one playing key for controlling the tones of said generator, means for producing a delayed vibrato effect having an adjustable delay interval comprising in combination, a source of continuous vibrato signals, a gate circuit interconnecting said vibrato signal source and said tone generator for affecting the tones of said generator at a vibrato rate when said gate circuit is active, said gate circuit comprising an electronic amplifying device normally held in an inactive condition by means of a bias voltage, control circuit means including a time delay means connected to said gate circuit and actuated by said playing key for applying to said gate circuit a delayed control voltage, to render said gate circuit active after a delay interval, said time delay means comprising a selected capacitor and an adjustable resistor.

References Cited by the Examiner

UNITED STATES PATENTS

2,496,224	1/1950	Long	84—1.25 X
2,542,065	2/1951	Van Wye	84—1.17
2,811,069	10/1957	Faulkner	84—1.25 X
2,897,361	7/1959	Schreiber	84—1.26
2,899,644	8/1959	Leslie	331—49
2,918,576	12/1959	Munch	84—1.26 X
2,933,699	4/1960	Bonham	84—1.25 X
3,038,364	6/1962	Bergman	84—1.24
3,051,032	8/1962	Hanert	84—1.19

OTHER REFERENCES

Dorf: *Electronic Musical Instruments* (textbook), Radio Magazines, Inc., 1954, ML-1092-D57, pages 115, 116, 122, 123, 141, 142, 151 and 152 relied on.

ARTHUR GAUSS, *Primary Examiner*.

GEORGE N. WESTBY, *Examiner*.

E. DREYFUS, I. C. EDELL, J. BUSCH,
Assistant Examiners,

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,288,907

November 29, 1966

Thomas J. George

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 35, for "grides" read -- grids --;
column 5, line 8, for "selected," read -- selected. --;
same line 8, for "low" read -- Low --; column 5, line 12,
for "identified" read -- identical --; column 6, lines 2 and
10, for "sole", each occurrence, read -- solo --; line 15,
for "vibrate" read -- vibrato --; line 52, strike out "and",
first occurrence; column 7, line 73, for "polyhydric" read --
polyphonic --; column 8, line 60, for "vibrator" read --
vibrato --; column 10, line 41, strike out "generator for
controlling the relative amplitudes of the" and insert
instead -- generating vibrato signals, a normally
inoperative gating --; column 11, line 9, for "put" read
-- output --; column 12, line 22, for "active" read --
inactive --.

Signed and sealed this 19th day of September 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents