United States Patent

[11] **3,555,167**

[72] Inventor **John W. Padalino**
Morris Plains, N.J.

[21] Appl. No. **829,472**
[22] Filed **June 2, 1969**
[45] Patented **Jan. 12, 1971**
[73] Assignee **Whippany Electronics, Inc.**
a corporation of New Jersey

[54] **MULTIVOICE CIRCUITRY WITH VIBRATO FOR ELECTRONIC MUSICAL INSTRUMENT**
21 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **84/1.19,** 84/1.25
[51] **Int. Cl.** **G10h 1/02,** G10h 1/06
[50] **Field of Search** ..... 84/1.01, 1.05, 1.11—1.13, 1.19, 1.21, 1.22, 1.24, 1.25, 1.27, (E, FB)

[56] **References Cited**

UNITED STATES PATENTS

3,049,957	8/1962	Meyer	84/1.24
3,063,324	11/1962	Campbell	84/1.01
3,097,253	7/1963	Peterson	84/1.22
3,433,880	3/1969	Southard	84/1.17

Primary Examiner—W. E. Ray
Attorneys—Clarence A. O'Brien and Harvey B. Jacobson

ABSTRACT: A sinusoidal waveform signal of audiofrequency is clipped at one or more amplitude levels to establish a plurality of signal components. Any one of the signal components, the combination of two signal components algebraically added, or the combination of three signal components algebraically added produce resultant output signals having different waveform characteristics providing selectable multivoice musical tones simulating such instruments as the flute, diapason, horn, woodwind, or full organ. The original sinusoidal signal is generated by a resonant feedback oscillator having a bias that may be varied to produce a vibrato effect in the resultant signals. Signal selection is made by a switch assembly combining different paths including a phase inverter, through which clipped signal components are conducted. The various oscillators and the phase inverter may be transistorized.

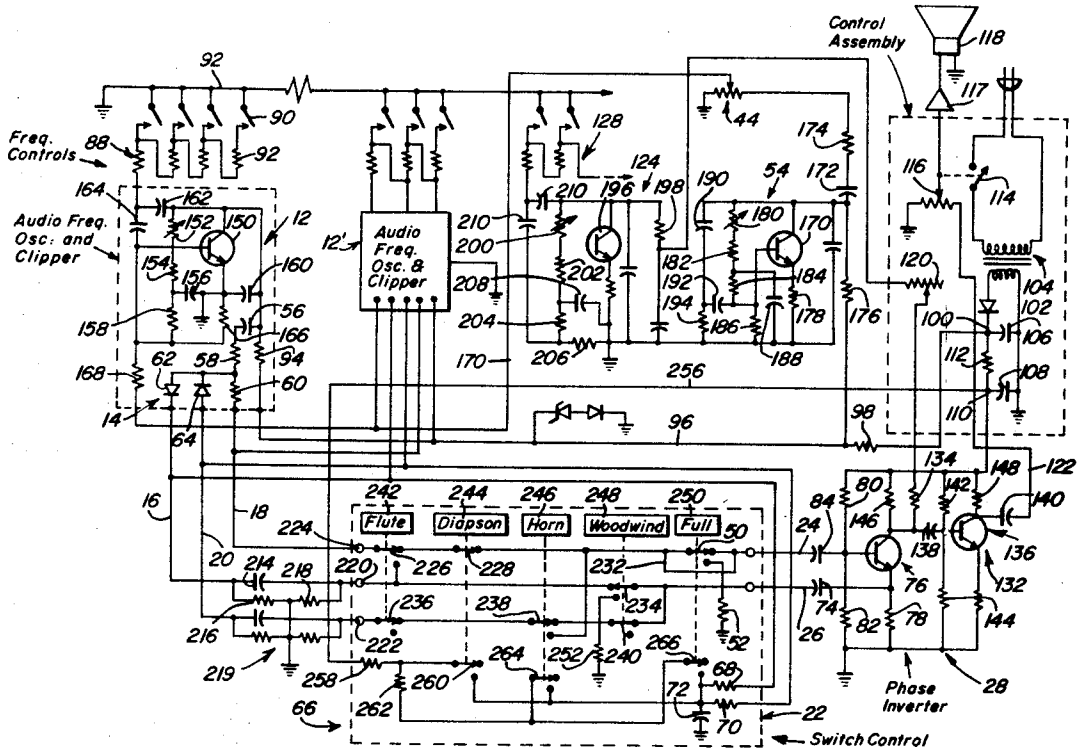


Fig. 1

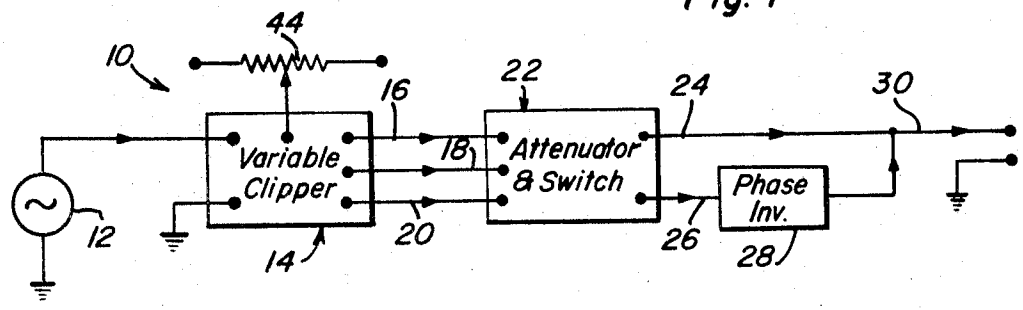


Fig. 2

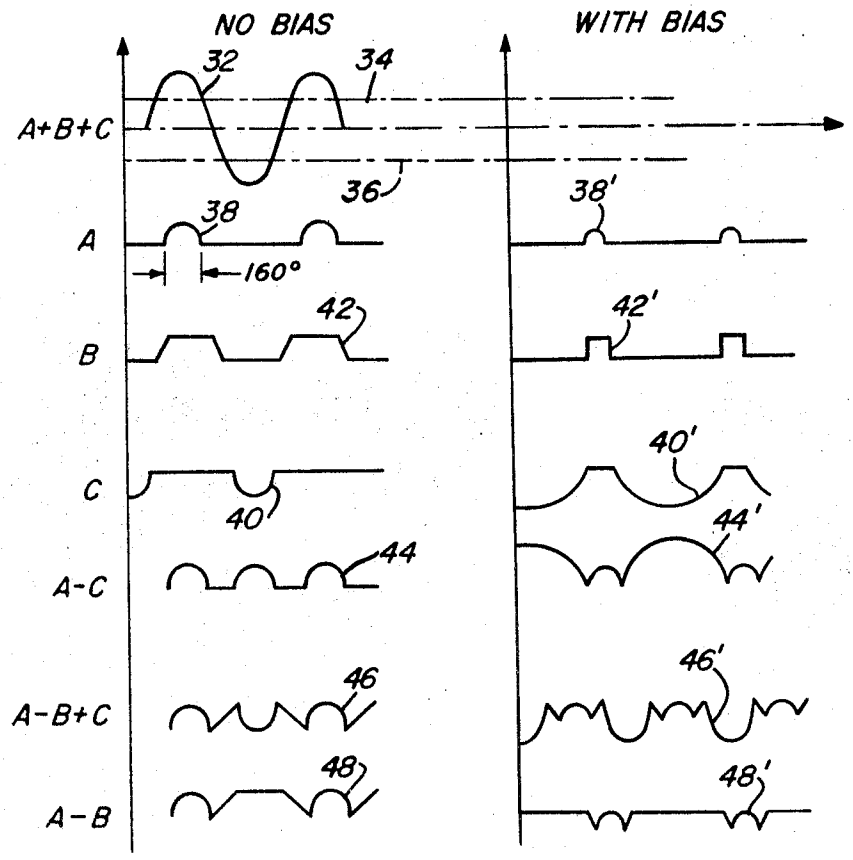
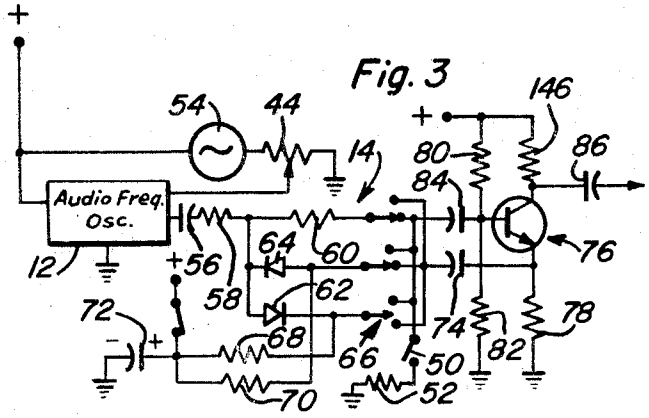


Fig. 3



John W. Padalino

INVENTOR.

BY Clarence A. O'Brien and Harvey B. Jacobson
Attorneys

PATENTED JAN 12 1971

3,555,167

SHEET 2 OF 2

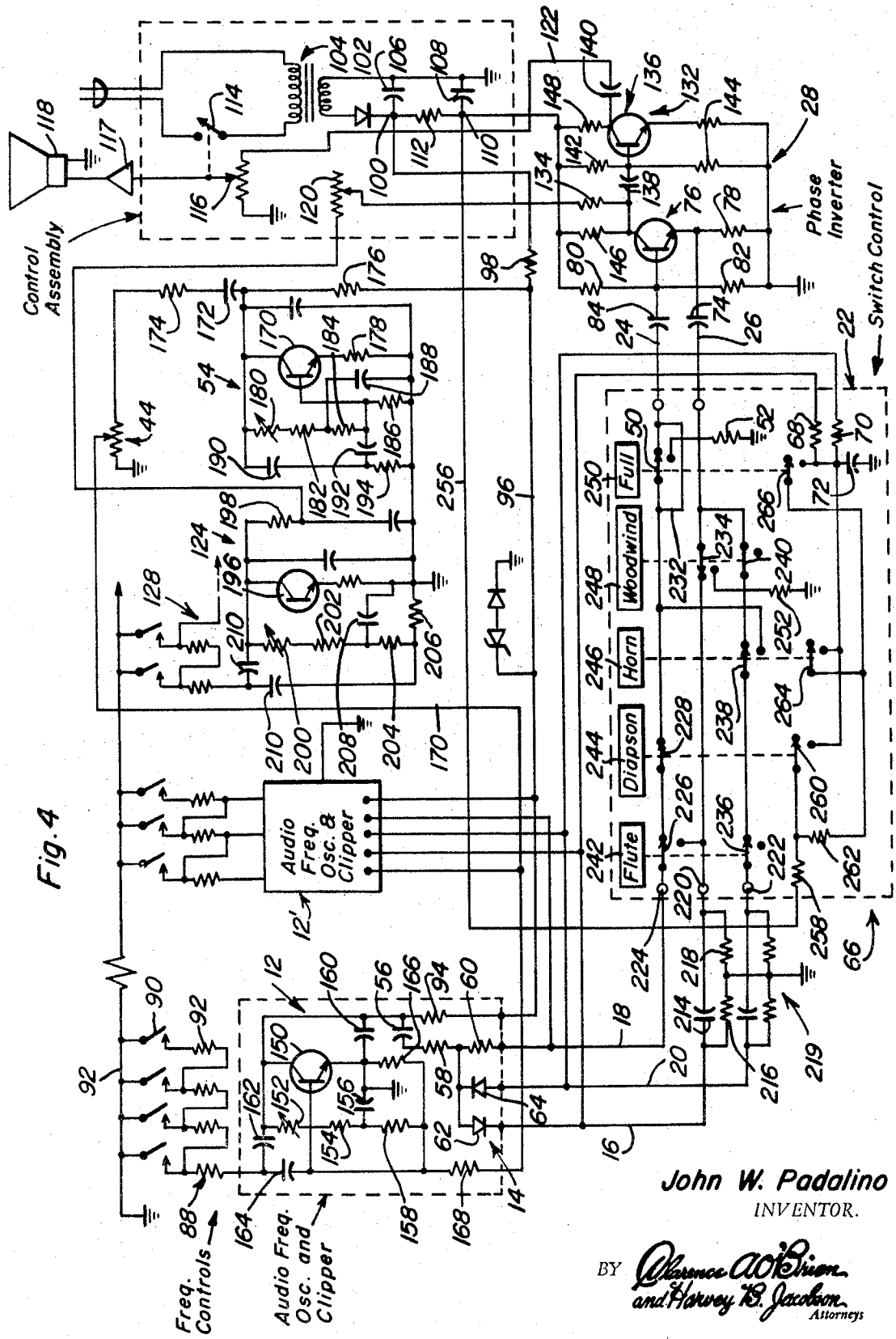


Fig. 4

John W. Padalino
INVENTOR.

BY Clarence A. O'Brien and Harvey B. Jacobson
Attorneys

MULTIVOICE CIRCUITRY WITH VIBRATO FOR ELECTRONIC MUSICAL INSTRUMENT

This invention relates to apparatus for electrically generating audio signals and more particularly to the production of selected musical tones by electronic means.

The use of audiofrequency oscillators for sine wave generators and waveform shaping circuits to produce audiofrequency tones simulating different instruments, is well known. Generally, a separate wave shaping circuit section is required for each musical instrument to be simulated. An important object of the present invention therefore is to provide a waveform generator through which audiofrequency signals having different waveform characteristics, may be produced from a sine wave signal to thereby electronically simplify the generator and make operation thereof more reliable.

In accordance with the present invention, an audiofrequency oscillator of the resonant feedback type is utilized to generate a sine wave at a selected frequency. The output of the oscillator is conducted through three different paths by a signal clipping network. The sine wave is clipped at a positive and negative level to divide it into three components respectively conducted along the three signal transmitting paths to an attenuator and switch assembly through which waveform characteristics are selected. By varying the bias applied to the oscillator, the voltage levels at which the sine wave signal is clipped may be cyclically changed to produce a vibrato effect. The three different paths through which the clipped signal components are conducted, are combined in different combinations through the selector switch assembly and fed to two output paths. One of the output paths conducts signals through a phase inverter to cause a phase shift of 180° before the signal components are algebraically added to form a selected output wave form.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIG. 1 is a schematic block diagram illustrating the principles underlying the present invention.

FIG. 2 is a graphic illustration of the signals produced in accordance with the apparatus of the present invention.

FIG. 3 is a simplified electrical circuit diagram illustrating the basic features of the present invention.

FIG. 4 is an electrical circuit diagram illustrating a specific embodiment of the present invention.

Referring now to the drawings in detail, FIG. 1 schematically illustrates the basic features of the apparatus forming the present invention, generally referred to by reference numeral **10**. The apparatus includes an oscillator **12** from which a continuous sinusoidal wave form signal is fed to a clipper network **14**. The original signal is divided amongst three signal transmitting paths **16**, **18** and **20** and fed to an attenuator and switch assembly **22**. Two output signal conducting paths **24** and **26** emerge from the switch assembly. The clipped signal components conducted through path **26** pass through a phase inverter **28** to phase shift the same 180° relative to the signal components transmitted through path **24**. The signal components are then algebraically added to produce a resultant signal in path **30** having a selected waveform characteristic.

The resultant waveforms produced by the apparatus of the present invention are particularly suited for musical organ tones. These tones originate from the aforementioned sinusoidal waveform referred to as **32** in FIG. **2**. The clipping circuit **14**, with no bias applied, is operative to clip the signal **32** at a positive level **34** and a negative level **36**. A clipped signal component **38** as shown in FIG. **2** having a conduction angle of about 160°, will then appear as a pulse conducted through path **16** while a negative-type pulse **40** is conducted through path **20**. The middle part of the sine wave **32** appears as a square waveform **42** conducted through the path **18**. If positive bias is applied to the clipping circuit **14** through bias control **44** as shown in FIG. **1**, the conductive phase for the clipped portion transmitted to path **16** is reduced to less than 160° as shown by signal pulse **38'** in FIG. **2**. The negative portion of the sinusoidal waveform conducted through path **20** will then be more than 160° as shown by **40'** while the intermediate portion will have a different duty cycle ratio than that associated with squared waveform portion **42**. By varying the bias and the output angle of conduction continuously, the squared waveform may be changed to a small conducting pulse **42'**.

The three basic clipped signal components **38** (A), **42** (B) and **40** (C) are fed to the switch assembly **22** so that one, two or all three of the signal components may be selectively attenuated and transmitted to one of the two output paths **24** and **26**, producing a resultant signal in path **30** which is the algebraic sum of in phase and phase shifted clipped signal components. FIG. **2** shows some examples of such resultant waveforms. Waveform **44** (A—C) is the algebraic sum of clipped signal component **38** and clipped signal component **40** phase shifted 180° by the phase inverter **28**. Signal component **42** is phase shifted 180° relative to signal components **38** and **40** all of which are algebraically added to produce the resultant wave form **46** (A—B+C). Phase shifted signal component **42** on the other hand is added only to signal component **38** to produce the resultant waveform **48** (A—B). With positive bias applied, the resultant waveforms **44** and **46** will appear as waveforms **44'** and **46'** while the resultant waveform **48** will appear as waveform **48'**. The foregoing is merely exemplary of the many combinations and waveform characteristics that may be produced in accordance with the present invention by multilevel clipping of a sinusoidal waveform and recombining clipped portions.

As shown in FIG. **3** bias may be continuously applied to the audiofrequency oscillator **12** at a vibrato rate from a bias varying control oscillator **54**. An output tone is thereby produced whose harmonic content or timber varies at a rate determined by the frequency of the oscillator **54**. The bias applied to the output of the oscillator **12** establishes the voltage levels **34** and **36** at which the sine wave output of the oscillator is clipped. The sine wave output is fed through the coupling capacitor **56** and coupling resistor **58** to the clipping circuit **14** which includes a signal transmitting resistor **60** establishing the path **18** for the signal component **42** and a pair of clipping diodes **62** and **64** connected in parallel with the resistor **60** for establishing the signal transmitting paths **16** and **20** conducting signal components **38** and **40** respectively. A bias may be applied to the clipping diodes **62** and **64** by connecting the diodes through bias resistors **68** and **70** to a source of voltage established at the positive terminal of the charge storing capacitor **72**. Thus, the clipping diodes **62** and **64** may act as series elements shunted by resistors **68** and **70** to clip and transmit the positive and negative portions **38** and **40** of the sine wave signal at levels determined by the resistance values of the bias resistors. The clipping diodes may also act as shunts for the resistor **60** to clip the positive and negative portions from the sine wave signal and transmit the center squared portion thereof through the resistor **60**.

The positive and negative clipped portions of the sine wave signal are selectively combined or individually fed through the switch assembly **66** and a signal coupling capacitor **74** as shown in FIG. **3** to the emitter of NPN type, phase inverting transistor **76**, the emitter being connected above ground by the emitter resistor **78**. Thus, the signal component supplied to the emitter of transistor **76** will produce a corresponding, in-phase output at the collector. Bias is applied to the base of transistor **76** through the voltage dividing resistors **80** and **82** so as to render the same conductive when the signal components are transmitted thereto by resistor **60** through the signal coupling capacitor **84**. The transistor **76** being connected in a common emitter arrangement, will amplify the signal input to its base, phase shifted 180°. Thus, when signals are simultaneously fed through the capacitors **74** and **84** to the transistor, a resultant signal is transmitted from the collector to the signal coupling capacitor **86** which is the algebraic sum

of the in-phase signal from capacitor **74** and the phase shifted signal passed by capacitor **84**. The gain of the signals transmitted through transistor **76** from path **16**, **18** or **20** may be regulated by an attenuator including switch **50** and grounded resistor **52**.

One specific waveform generator circuit is illustrated in FIG. **4** which includes a plurality of audiofrequency oscillators **12**, **12'** etc. Frequency selecting controls **88** are associated with each of the oscillators. The controls **88** include a plurality of frequency selecting switches **90** connected to the ground line **92** and adapted to be momentarily closed, for example, by an organ player through a keyboard arrangement. Closing of a selected switch **90** grounds one of the series connected resistors **92** and thereby selects the output frequency of the associated oscillator.

Power is supplied to each oscillator through a resistor **94** connected by conductor **96** and a voltage reducing resistor **98** to positive output terminal **100** of a power supplying rectifier which includes a rectifier diode **102** connected in series with the secondary winding of a power transformer **104** and a filter capacitor **106** connected between the output terminal **100** and the opposite terminal of the transformer secondary. The rectifier includes a second filter capacitor **108** connecting the transformer secondary to a lower potential output terminal **110** connected by voltage reducing resistor **112** to the output terminal **100**. The primary winding of the transformer **104** is connected to an available AC voltage source upon closing of the power switch **114**.

Thus, upon closing of the power switch **114**, a DC source of voltage is established for powering the audiofrequency oscillators as well as the other components of the generator. This DC power supply forms part of a control assembly which also includes a grounded potentiometer **116** operatively connected with power switch **114**. The resultant output signal of the waveform generator at an adjusted volume level is fed from the potentiometer through an amplifier **117** to a speaker **118**. Also associated with the control assembly, is a potentiometer **120** controlling the volume level of a bass frequency signal. The bass frequency signal is derived from an oscillator **124** having a frequency control **200**. The bass frequency signal is supplied from the oscillator **124** to an attenuating potentiometer **120**. Thus, the bass frequency signal may be superimposed upon the resultant output signal from the phase shifting transistor **76** aforementioned and fed to the base of the amplifier transistor **136** through signal coupling capacitor **138**. The amplified output signal at the collector of amplifier transistor **136** is fed to the output line **122** through signal coupling capacitor **140**. Forward bias is maintained on the base of transistor **136** through the voltage dividing resistors **142** and **144** connected between potential point **110** of the DC power supply and ground. The positive potential point **110** is also connected to the load resistors **146** and **148** establishing bias for the collectors of transistors **76** and **136**. Thus, the phase inverting transistor **76** hereinbefore described, in addition to performing a phase shifting function, also acts as a single stage driver for the output amplifier transistor **132**.

With continued reference to FIG. **4** it will be observed that each of the audiofrequency oscillators **12**, **12'**, etc. includes a NPN type transistor **150** having a grounded emitter and an output collector connected to the output signal coupling capacitor **56** and a source of DC bias from resistor **94**. Base bias is established by adjustable resistor **152** in series with resistors **154**, **158** and **166** connected between the forward bias supply and ground. Resistors **158** and **166** are shunted by capacitor **156** while the base is connected to the juncture between resistors **158** and **166**. The forward bias on the base may be positively varied varied at a vibrato rate by a signal supplied to the base through resistor **168** connected by conductor **170** to the potentiometer **44** through which the output level of the vibrato signal oscillator **54** is varied. This causes negative shift in the signal level to change the levels at which the sine wave signal is clipped.

A filter capacitor **160** is connected between the collector and emitter of transistor **150** while series connected capacitors **162** and **164** interconnect the collector and base to form a resonant feedback path. Upon closing of one of the frequency selecting switches **90**, the resonant feedback circuit is rendered operative at a selected frequency to produce a sine wave output at the collector of transistor **150**. Since the transistor is arranged in a common emitter configuration, a 180° signal phase shift occurs between the base and collector. The feedback circuit introduces an additional phase shift to make the feedback signal from the collector to the base positive. Thus, a change in base current results in an amplified change in collector current phase shifted 180°. The signal returned to the base through feedback capacitors **162** and **164** is inverted 180° to make it regenerative. The requisite phase shift occurs however at the frequency determined by the number of resistors **92** connected in series to ground.

The vibrato producing oscillator **54** is similar to the audiofrequency oscillators and accordingly includes a NPN type transistor **170** having an output collector connected to the potentiometer **44** through the signal coupling capacitor **172** and the resistor **174**. Collector bias is supplied to the transistor **170** from the DC voltage source through resistor **176**. The emitter is connected to ground through resistor **178** while base bias is established by adjustable resistor **180**, resistor **182**, resistor **184**, and resistor **186**. A resonant feedback circuit interconnects the collector and base and includes feedback capacitors **188**, **190** and **192** and ground resistor **194** establishing the output frequency of the oscillator.

The bass frequency oscillator **124** is also of the resonant feedback type and includes NPN type transistor **196** having an output collector connected to the positive voltage line **96** and to the potentiometer **120** through resistor **198**. Base bias for the transistor is established by the resistors **200**, **202**, **204** and **206**. The output frequency of the oscillator **124** is selectively established by the frequency controls **128** associated with the resonant feedback circuit which includes the filter capacitors **208**, **210** and **212** connected between the collector and the base of the transistor **196**.

Each of the oscillators **12**, **12'**, etc., is provided with a clipping circuit **14** hereinbefore described in connection with FIG. **3**. Thus, three clipped signal components are fed from each clipping circuit to the switch assembly **22** through the common signal transmitting lines **16**, **18** and **20**. An RC filter network **219** including capacitor **214**, the input and output terminals of which are shunted through grounded resistors **216** and **218**, couple the signal transmitting lines **16** and **20** to two of the input terminals **220** and **222** of the switch assembly **66**, the third input terminal **224** being directly connected to the signal transmitting line **18**. The signal transmitting line **18** is interconnected with the output signal line **24** or **26** through series connected switches **226** and **228** and a bypass jumper for switch **50**. The signal transmitting line **16** is interconnected through its RC coupling network **219** and terminal **220** with the output signal line **26** through switch **234** in the switch assembly. Finally, the signal transmitting line **20** is interconnected with the output signal line **24** or **26** through its RC coupling network **219** and the switches **236**, **238** and **50** or **240** within the switch assembly.

The switches **226** and **236** are ganged and simultaneously displaceable from the operative position shown in FIG. **4** by means of a pushbutton control **242** arranged to select the waveform characteristics simulating a flute. A "diapason" pushbutton control **244** is interconnected with the switch **228** while a "horn" pushbutton control **246** is connected to the switch **238**. The switches **234** and **240** are ganged and interconnected with a "woodwind" pushbutton control **248** and a "full organ" pushbutton control **250** is connected to the switch **50**. When the switches **234** and **50** are displaced from the operative positions shown in FIG. **4**, they engage contacts connected to ground through resistors **252** and **52**.

In order to change the level of the bias applied to the signals passed through the switch assembly **66**, a positive DC voltage

line 256 connects the output terminal 110 of the power supply through resistor 258 to a switch 260 ganged with the switch 228 and through resistor 262 in series with resistor 258 to switches 264 and 266 respectively ganged with the switches 238 and 50. Thus, upon closing of any one of the switches 260, 264 and 266, a positive potential is applied through the resistors 68 and 70 to the signal transmitting lines 16 and 20.

When the control 242 is actuated, signal transmitting line 18 is disconnected from the output signal line 24 and connected to input terminal 220 and the output signal line 26. At the same time, switch 236 is displaced to an inoperative position disconnecting the signal transmitting path 20 from the circuit. Thus, a resultant output signal is produced which represents a sine wave with the negative peak portions clipped therefrom to simulate a flute.

When the control 244 is actuated, the switch 228 is displaced from its operative position so as to disconnect the signal transmitting path 18 from the circuit and at the same time switch 260 is closed in order to add DC bias to the signal components transmitted through the paths 16 and 20. Thus, in the case of the controls 242 and 244, two in-phase signals are added to form the resultant output waveform simulating a diapason quality tone. In the case of control 244, bias is added whereas in the case of control 242, no bias is added to the signal components.

When the control 246 is actuated, the switch 238 combines the signals transmitted through paths 18 and 20 and feeds them to output line 24 to be phase shifted. Bias is added to the signal component conducted through path 16 on the other hand by closing of the switch 264 and fed to output line 26. Thus, a combination of signals conducted through paths 18 and 20 are phase inverted and algebraically added to the signal conducted through path 16 to produce the resultant output waveform simulating the tones of a horn.

The tones of a woodwind are simulated by actuating the control 248 thereby disconnecting the signal paths 16 and 20 from the circuit through switches 234 and 240 and connecting the output line 26 to ground through resistor 252. The signal component 42 hereinbefore referred to in connection with FIG. 2 will then be produced as the output waveform. For full organ tone, the control 250 is actuated so that the signal components conducted through paths 16 and 20 are biased through switch 266 while switch 50 connects the signal transmitting path 18 to ground through resistor 52, for attenuation of the signal transmitted from path 16 reducing its gain. The signal components conducted through paths 16 and 20 are combined and fed to the output line 26. The signal component being conducted through path 18 is phase inverted and then algebraically added to the other two in-phase signal components. When none of the described controls are actuated, the three signal components are combined as described in connection with actuation of control 250 except that they are not attenuated in order to simulate the musical tones of a reed instrument.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

I claim:

1. A signal producing apparatus comprising means for generating a continuous signal, signal clipping means connected to said generating means for dividing the continuous signal into separate signal portions, and selectively controlled means connected to the signal clipping means for recombining different combinations of said signal portions establishing resultant signals which are different from the continuous signal.

2. The combination of claim 1 wherein said continuous signal is a sinusoidal waveform.

3. The combination of claim 2 wherein said portions of the continuous signal are amplitude clipped components of the sinusoidal waveform

4. The combination of claim 3 including bias means for varying the conduction angle of the continuous signal from which each of said signal portions is clipped.

5. The combination of claim 4 wherein said selectively controlled means includes phase shifting means for inverting at least one of said signal portions, and a switching control device interconnected with the signal clipping means and the phase shifting means for algebraically adding selected in-phase signal portions from the signal clipping means and signal portions inverted by the phase shifting means.

6. The combination of claim 5 wherein said generating means includes at least one resonant feedback oscillator and control means connected to the oscillator for changing the frequency of the continuous signal.

7. The combination of claim 1 including bias means for varying the phase of the continuous signal from which each of said signal portions is clipped.

8. The combination of claim 1 wherein said selectively controlled means includes phase shifting means for inverting at least one of said signal portions, and a switching control device interconnected with the signal clipping means and the phase shifting means for algebraically adding selected in phase signal portions from the signal clipping means and signal portions inverted by the phase shifting means.

9. The combination of claim 1 wherein said generating means includes at least one resonant feedback oscillator and control means connected to the oscillator for changing the frequency of the continuous signal.

10. The combination of claim 1 wherein said generating means includes an audiofrequency oscillator having a sinusoidal waveform output.

11. The combination of claim 10 wherein said selectively controlled means includes phase shifting means for inverting the signal portions, attenuating means connected to the signal clipping means for varying the gain of selected signal portions transmitted through the phase shifting means and in bypass relation thereto, switch means connected to the attenuating means and the phase shifting means for selecting the signal portions regulated by the attenuating means, and means for algebraically adding the selected signal portions transmitted through and bypassing the phase shifting means to produce said resultant signals.

12. The combination of claim 11 wherein said resultant signals simulate the tones of different musical instruments.

13. The combination of claim 1 wherein said selectively controlled means includes phase shifting means for inverting the signal portions, attenuating means connected to the signal clipping means for varying the gain of selected signal portions transmitted through the phase shifting means and in bypass relation thereto, switch means connected to the attenuating means and the phase shifting means for selecting the signal portions regulated by the attenuating means, and means for algebraically adding the selected signal portions transmitted through and bypassing the phase shifting means to produce said resultant signals.

14. The combination of claim 1 wherein said resultant signals simulate the tones of different musical instruments.

15. The combination of claim 14 including vibrato means for varying the phase of the continuous signal from which each of said signal portions is clipped.

16. In combination with a source of voltage, an audiofrequency oscillator connected to said source and having a sinusoidal waveform output, a clipping circuit network connected to said oscillator establishing a plurality of signal transmitting paths through which clipped signal portions of said output are conducted, bias control means connected to the source for establishing signal levels at which the output is clipped, a selector switch assembly connected to the clipping circuit network and the bias control means for selecting at least two of the signal transmitting paths, and a phase inverting

circuit connected to the switch assembly for combining at least two of the clipped portions of the output conducted through the selected signal transmitting paths in phase shifted relation to each other.

17. The combination of claim 16 wherein the clipping circuit network includes a pair of clipping diodes and a signal transmitting resistor connected in parallel to the oscillator to establish said signal transmitting paths, said bias control means being connected in shunt relation to the clipping diodes.

18. The combination of claim 17 wherein said oscillator includes a current control device having input, output and control terminals, a regenerative feedback circuit interconnecting the output and control terminals for sustaining the sinusoidal output at a predetermined frequency, frequency control means connected to the feedback circuit for selecting said frequency, and bias means connected to the control electrode for establishing the phases of the output from which the signal portions are clipped.

19. The combination of claim 18 including vibrato producing means connected to the bias means for cyclically varying the phases of the clipped signal portions.

20. The combination of claim 16 wherein said oscillator includes a current control device having input, output and control terminals, a regenerative feedback circuit interconnecting the output and control terminals for sustaining the sinusoidal output at a predetermined frequency, frequency control means connected to the feedback circuit for selecting said frequency, and bias means connected to the control electrode for establishing the phases of the output from which the signal portions are clipped.

21. The combination of claim 20 including vibrato producing means connected to the bias means for cyclically varying the phases of the clipped signal portions.