Dec. 16, 1969 D. R. MOORE 3,484,529

ELECTRONIC MUSICAL INSTRUMENT

Filed March 28, 1967 2 Sheets-Sheet 1

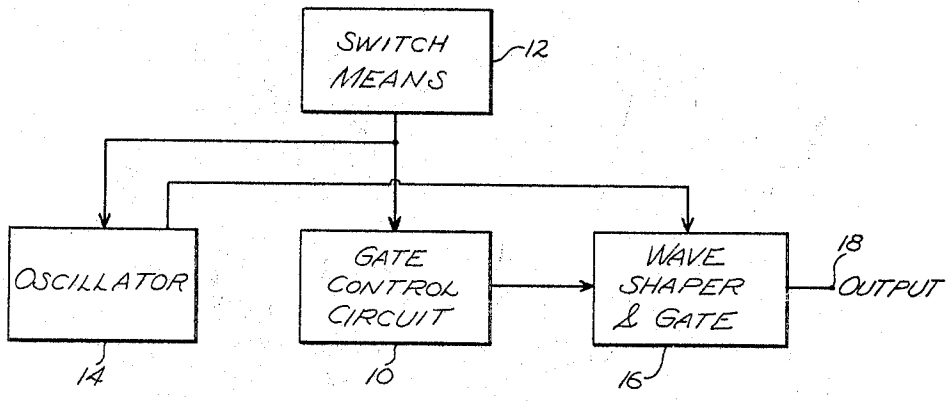


FIG. 1

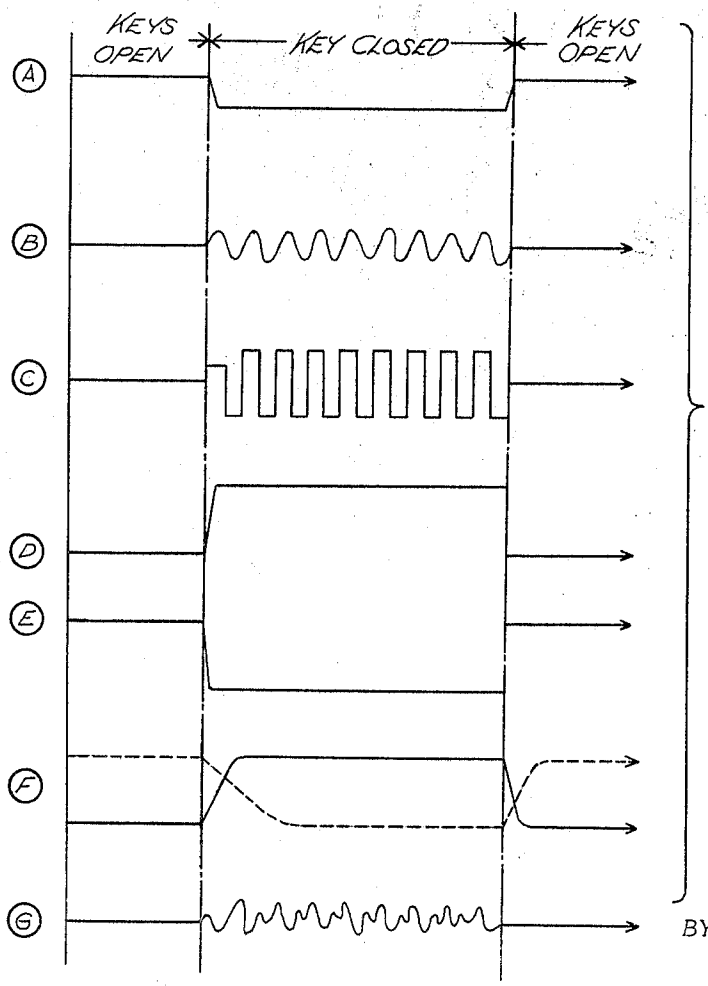


FIG. 3

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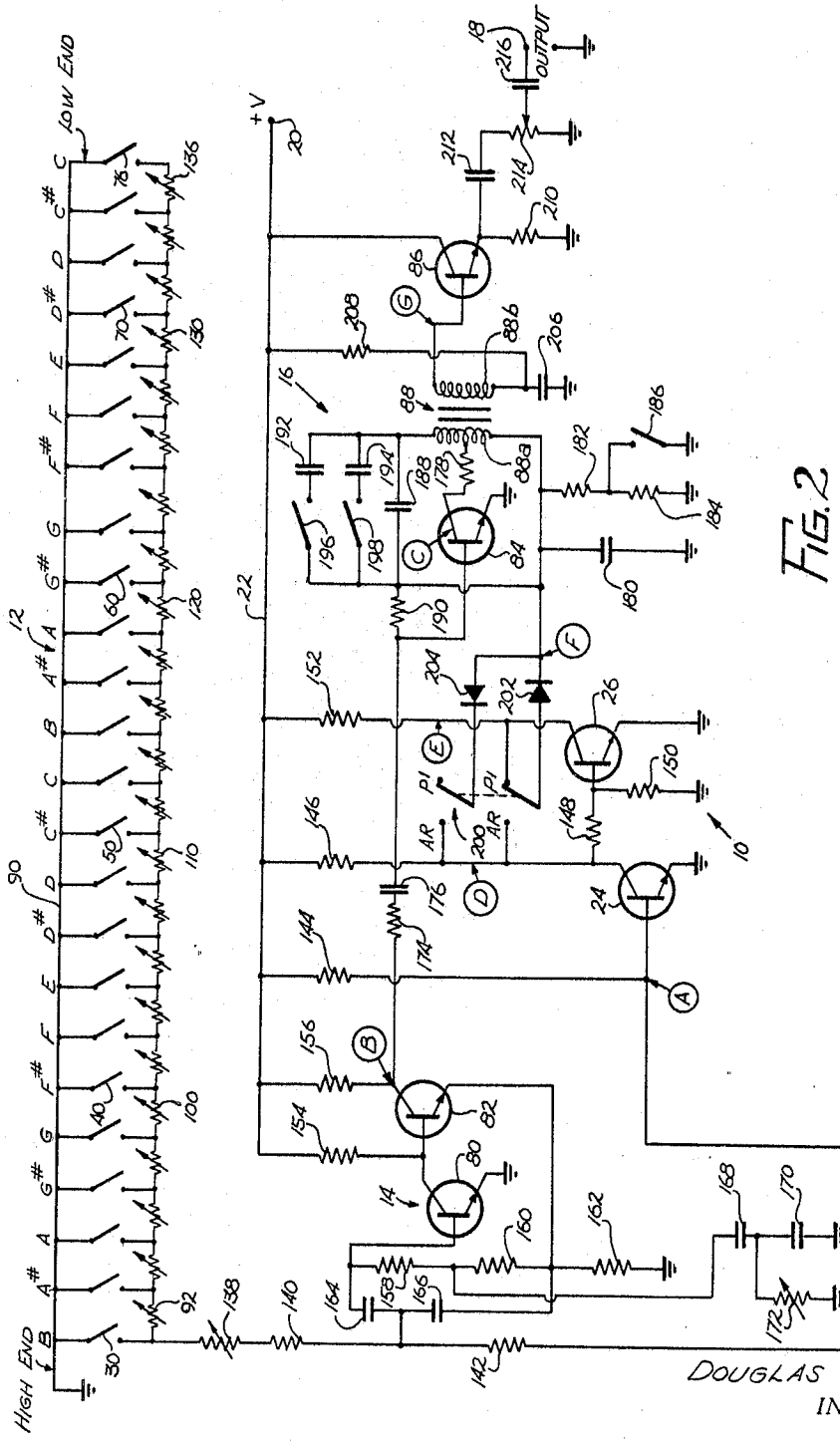


FIG. 2

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ELECTRONIC MUSICAL INSTRUMENT

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U.S. Cl. 84—1.01 10 Claims

ABSTRACT OF THE DISCLOSURE

An electronic instrument for providing string-timbre tones comprising a single oscillator whose frequency is controlled by switching of a plurality of resistors into or out of the oscillator circuit. The output of the oscillator is supplied to a gate control circuit and thence to a wave shaper and gate. The latter circuit provides at least two harmonics of the fundamental frequency generated by the oscillator.

One of the features of the invention is that if more than one of 24 possible keys is closed, only the key corresponding to the highest note will be effective and any other depressed key will be ineffective.

This invention relates to an electronic musical instrument for providing string-timbre tones that may serve as an adjunct to a piano or other instrument, or may be used independently of any other instrument. It is particularly adapted for use as a bass adjunct with a stringed instrument and will be described in that context, although not limited thereto.

Various electronic musical instruments for providing string-timbre tones have been proposed in the past. However, these instruments have generally suffered from one or more disadvantages. For example, many of them have required a separate electronic oscillator for each tone generated, which represents a considerable cost factor when it is considered that each oscillator requires two transistors. The cost was further increased by a requirement for a separate filter for each generated tone. In addition, if two or more oscillators were energized at the same time, discordant sounds could well be produced. The cost of such instruments often ran into many hundreds of dollars.

The present invention eliminates the foregoing disadvantages by providing an instrument embodying a single oscillator, whose frequency of oscillation may be varied through a plurality of frequencies by switching one or more resistors into the oscillator circuit. A single filter is used for all of the oscillator output tones, and no discordance can result.

When any one (or more) keyboard or foot pedal switches is closed, the oscillator is energized through a gate control circuit and oscillates at a frequency determined by the amount of resistance switched into the circuit by closing of the switch. The gate control circuit also turns on a wave shaper and gate circuit when a switch energizes the gate control circuit. Means are provided in the gate control and wave shaper and gate circuits for producing either arco (sustained) or pizzicato modes of operation, and also for varying the harmonic content of the output tones to stimulate either a cello or double bass.

The invention, together with further features and advantages thereof, will be better understood from the following description, taken in conjunction with the acompanying drawings, in which:

FIGURE 1 is a simplified block diagram of an instrument embodying the invention;

FIGURE 2 is a schematic diagram of the instrument; and

FIGURE 3 is a group of waveforms useful in understanding the operation of the circuit.

The block diagram of FIGURE 1 shows a gate control circuit **10**, which is controlled by one of a plurality of switch means shown generally by a block **12**. In turn, the gate control circuit **10** controls a wave shaper and gate circuit **16** that provides an output to a terminal **18**. Whenever any one of the switch means **12** is closed, it turns on the oscillator **14**, which oscillates at a frequency determined by which of the switches is closed. The output of the oscillator **14**, which is supplied to the wave shaper and gate circuit **16**, is essentially a pure sine wave. The wave shaper serves to clip the sine wave to provide a square wave containing harmonics to provide various output timbres. As previously mentioned, either an arco or pizzicato effect can be obtained and the harmonic content of the output signal can simulate either a cello or double bass. Of course, other controls are provided to vary overall tuning of the oscillator **14** and the volume of the output signals from the wave shaper and gate **16**.

In the circuit diagram shown in FIGURE 2, a potential +V is provided to a terminal **20** connected to a potential supply line **22** which energizes the entire circuit. The gate control circuit **10** comprises a pair of NPN transistors **24** and **26**. The switches **12** shown in block form in FIGURE 1 include switches **30–76**. The oscillator **14** comprises two NPN transistors **80** and **82**, and the wave shaper and gate **16** includes NPN transistors **84** and **86** and a synthesis filter including a transformer **88** having a center-tapped primary winding **88***a* and a secondary winding **88***b*.

The switches **30–76** are normally-open, single-pole, single-throw, spring-loaded switches having their poles connected to ground through a line **90**. A plurality of impedances such as adjustable resistors **92–136** are respectively connected between the contacts of the switches **30–76**. The end of the resistor **92** is connected to the supply line **22** through a variable resistor **138**, a resistor **140**, a resistor **142** and a resistor **144**. The juncture of resistors **142** and **144** is connected to ground through a capacitor **145**. It is pointed out that if one of the switches is closed, for example, the switch **40**, and another switch such as the switch **50** is also closed, closing of the switch **50** will have no effect. Only the switch corresponding to the higher note will be effective.

Looking at the gate control circuit **10** in detail, it is seen that the base of the transistor **24** is connected to the supply line **22** through the resistor **144**, the collector of the transistor **24** is connected to the supply line **22** through a load resistor **146** and the emitter is grounded. Output is provided from the collector of the transistor **24** through a resistor **148** to the base of the transistor **26** across a resistor **150** connecting the base of the transistor **26** to ground. The collector of the transistor **26** is connected to the supply line **22** through a load resistor **152** and the emitter of the transistor **26** is grounded.

When none of the switches **30–76** is closed, the base of the transistor **24** is forward biased and the transistor **24** is conducting. Thus, the base of the transistor **26** is essentially at ground and that transistor is nonconducting. As will become apparent later, when all of the aforementioned switches are open and the transistor **24** is conducting, the oscillator **14** is inoperative and there is no output from the circuit.

Looking now at the oscillator **14**, it is seen that the collector of the transistor **80** is connected to supply line **22** through a resistor **154** and the collector of the transistor **82** is similarly connected through a resistor **156**. The collector of the transistor **80** is directly connected to the

base of the transistor **82** and the emitter of the transistor **80** is grounded. The base of the transistor **80** is connected to ground through series resistors **158**, **160**, and **162**, and the emitter of the transistor **82** is connected to the juncture of the resistors **160** and **162**. The resistors **158** and **160** are feedback resistors and, of course, the resistors **154** and **156** are load resistors. Capacitors **164** and **166** are connected in series between the base of the transistor **80** and the juncture of the resistors **160** and **162**. Capacitors **168** and **170** are connected in series between the juncture of resistors **158** and **160** in ground, and a variable resistor **172** is connected across the capacitor **170**. The variable resistor **172** serves as a fine tuning adjustment, which changes the oscillator range without changing the tone intervals.

The oscillator **14** is a modified "twin T" oscillator, whose frequency of oscillation is determined by a circuit comprising capacitors **164**, **166**, **168** and **170** and by resistors **140**, **172**, **158**, **160**, **138** and **92–136**. When any one of the resistors **92–136** is grounded, the oscillator is energized. The transistor **82** serves to isolate the output of the oscillator from the feedback components so that any loading will not change the oscillator frequency. The output of the oscillator is taken from the collector of the transistor **82** through a resistor **174** and capacitor **176** connected in series to the base of the transistor **84**. The emitter of the transistor **84** is grounded and its collector is connected through an isolating resistor **178** to the center tap of the primary **88***a* of the synthesis filter transformer **88**.

The lower end of the primary winding **88***a* is connected to ground through a capacitor **180** in parallel with series resistors **182** and **184**, with a switch **186** paralleling the resistor **184**. The DC voltage existing across the capacitor **180** controls the amplitude of the instrument output signal when the oscillator **14** is energized.

The upper end of the primary winding **88***a* of the transformer **88** is connected through a capacitor **188** to the top of the capacitor **180** and to one end of a capacitor **190**, whose other end is connected to the base of the transistor **84**. A pair of capacitors **192** and **194** are connected in parallel across the capacitor **188** through manually operable, single-pole, single-throw switches **196** and **198**, respectively. The capacitors **188**, **192**, **194** and switches **196** and **198** are also part of the synthesis filter. The positions of the poles of the switches **196** and **198** control the resonant frequency of the filter and hence the timbre of the output signal. If the switches **196** and **198** are both open, the output signal represents a cello sound, which has the highest harmonic content of any signal available from the instrument of the invention. If the switches **196** and **198** are both closed, the output signal represents the sound of a double bass, which consists primarily of the fundamental and second harmonic of the fundamental and relatively little of the third harmonic.

Before looking at the output circuitry, consider the means for providing either arco (sustained) or pizzicato output tones. The choice of which output tone is obtained is made by the setting of a double-pole, double-position switch **200**. When the switch is in the pizzicato position shown, the anode of a diode **202** is connected to the collector of the transistor **26**. The cathode of the diode **202** is connected to the top of the capacitor **180**. A second diode **204** is connected in parallel with the diode **202**, but with reverse polarity. In the pizzicato position of the switch **200**, the cathode of the diode **204** is unconnected and, thus, that diode has no effect. When the poles of the switch **200** are moved to the left (as shown in the drawing) to the arco position, both the cathode of the diode **204** and the anode of the diode **202** are connected to the collector of the transistor **24**. The operation of the foregoing portion of the circuitry will be hereinafter described with reference to waveforms shown in FIGURE 3.

The top of the winding **88***b* of the transformer **88** is connected to the base of the transistor **86**, and the bottom of the winding is connected to ground through a capacitor **206** and to the supply line **22** through a resistor **208**. The collector of the transistor **86** is connected directly to the supply line **22**, and the emitter of the transistor is connected to ground through a resistor **210**. A capacitor **212** and a potentiometer **214** are connected in series across the resistor **210** and the output is taken from the movable arm of the potentiometer **214** and provided through a capacitor **216** to the output terminal **18**. The capacitor **212**, of course, blocks DC from the output and setting of the arm of the potentiometer **214** determines the amplitude of the output signals.

The operation of the instrument of the invention can best be understood by referring both to FIGURES 2 and 3. The curves A through G shown in FIGURE 3 correspond to the signals appearing at similarly designated points in the circuit diagram of FIGURE 2. The waveform A appears at the base of the transistor **24** in the gate control circuitry **10**. When all of the keys or switches **30–76** are open, the potential on the base of the transistor **24** is sufficient to turn that transistor on. This, in turn, lowers the potential on the base of the transistors **26** and turns that transistor off. The waveforms D and E represent the signals on the collectors of the transistors **24** and **26**.

When any one of the switches **30–76** is closed, a voltage divider is formed which lowers the potential on the base of the transistor **24** and turns that transistor off. This raises the potential on the base of the transistor **26** and turns that transistor on. As seen from waveforms D and E, the potentials on the collectors of the transistors **24** and **26**, respectively, rise and fall. It is noted that resistor **142** is larger than the sum of resistor **140** and resistors **92–136** so that any loading at the base of the transistor **24** will not cause the oscillator **14** to function.

When a switch **30–76** is closed, the oscillator **14** comprising the transistors **80** and **82** begins to function. Output of the oscillator is taken from the collector of the transistor **82** and is represented by the waveform B shown in FIGURE 3. The output of the oscillator is a fairly pure sine wave. In order to recreate a string musical sound, however, a predominance of certain harmonics are required.

As previously noted, the output of the oscillator is supplied to the base of the transistor **84**. The desired harmonics are obtained by driving the transistor **84** beyond saturation so that the sine wave input from the transistor **82** is clipped as shown by waveform C representing the signal on the collector of the transistor **84**. The square wave present on the collector of the transistor **84** contains the desired harmonics but not at the correct relative amplitudes. The adjustment of amplitudes is a function of the synthesis filter comprising the transformer **88** and the capacitors **188**, **192** and **194**. The filter is broadly resonant at the third harmonic of the center, or second, "C" provided by the instrument.

As previously mentioned, the instrument may be operated in either an arco or pizzicato mode. The mode is selected by the setting of the switch **200**. In the arco mode, when the poles of the switch **200** are moved to the left from the position shown, the capacitor **180** is connected to the collector of the transistor **24** through the diode **202**. Inasmuch as when all switches **30–76** are open, the transistor **24** is heavily conducting (as shown in waveform D), the capacitor **180** will not be charged. The purpose of the diode **202** is to isolate the timing network from the gate control network so the timing will be determined entirely by the capacitor **180**, resistors **182** and **184** and switch **186**, and not by resistors **146** or **152**. The rate at which the voltage across the capacitor **180** rises toward the supply voltage is determined by the value of the resistor **146**. Generally, this imparts a slight delay time that causes the output tone to swell to its desired amplitude and to maintain that amplitude until the switches **30–76** are all opened again. When

the switches are opened, the signal at point D goes to ground and the capacitor **180** discharges. Its discharge path is through the resistor **182** and switch **186**, and also through diode **204** and transistor **24** which is now heavily conducting.

In the pizzicato mode of operation, the switch **200** is in the position shown. The capacitor **180** is connected through the diode **202** and the switch **200** to the collector of the transistor **26**. Thus, before any one of the switches **30–76** is closed, the collector of the transistor **26** is essentially at the supply potential (waveform E) and the capacitor **180** is charged up to that level, as shown by the dashed curve in waveform F. When a key is closed, the capacitor **180** is prevented from discharging through the transistor **26** and must discharge through the resistors **182** and **184**, or through the resistor **182** and the switch **186**. Whether the switch **186** is open or closed determines which of two discharge rates the capacitor **180** will have. If the switch is closed, the discharge rate of the capacitor will, of course, be faster than if the switch is open. When the switches **30–76** are once again all opened, the capacitor **180** is recharged through the diode **202** as shown in waveform F. Waveform G is an idealized output waveform which shows that the arco output signal amplitude is dependent on the amplitude of the DC signal at point F. The transistor **84** is energized by a signal only when the oscillator **14** is functioning in response to one of the switches **30–76** being closed. The waveform G most closely resembles the output in the arco mode of operation. It is understood that in the pizzicato mode the signal would start at full amplitude and decay rapidly to zero. It is also pointed out that in the pizzicato mode the fundamental frequency decays more rapidly than the harmonic frequencies as is true in a stringed instrument.

It is now apparent that the instrument of the invention embodies a number of advantages not present in prior art devices. First, from the point of view of cost advantage, it eliminates the use of a separate oscillator for each tone to be generated and the use of a separate filter for each tone. A single oscillator and a single filter system are used for the generation of all tones. Second, only one set of switches is required to control the frequency of the oscillator and to provide a DC control voltage that initiates and terminates production of an output tone. Third, it eliminates any possibility of discordant output tones occurring, which has previously been possible when two or more keyboard switches are simultaneously closed.

It is apparent that many changes and modifications may be made to the musical instrument of the invention as disclosed in the single embodiment described herein without departing from the true spirit and scope of the invention.

What is claimed is:

1. An electronic musical instrument comprising:
potential supply means;
a plurality of variable impedances;
a plurality of first switch means for connecting selected ones of said plurality of impedances between said potential supply means and ground; and
a multi-staged transistorized oscillator having a circuit for determining frequency of oscillation, said circuit including a variable resistance coupling said oscillator to said plurality of impedances, grounding of different ones of said impedances varying said frequency of oscillation and energizing said oscillator.

2. An electronic musical instrument comprising:
potential supply means;
a plurality of impedances;
a plurality of first switch means for connecting selected ones of said plurality of impedances between said potential supply means and ground;
an oscillator having a circuit for determining frequency of oscillation, said circuit including said plurality of impedances, grounding of different ones of said impedances varying said frequency of oscillation and energizing said oscillator; and
a gate circuit connected to said plurality of first switch means, a wave shaper circuit connected to said oscillator and to said gate circuit, and output circuitry connected to said wave shaper circuit.

3. The instrument defined by claim **1**, wherein said plurality of impedances comprise a plurality of impedances connected in series, and said first switch means are manually operable and are respectively connected between adjacent ones of said impedances and ground.

4. The instrument defined by claim **2**, wherein said plurality of impedances comprise a plurality of impedances connected in series, and said first switch means are manually operable and are respectively connected between adjacent ones of said impedances and ground.

5. The instrument defined by claim **2**, wherein said oscillator produces a sine wave output, and said wave circuit includes means from providing at least one harmonic of said sine wave output in the wave shaper output.

6. The instrument defined by claim **5**, wherein said wave shaper circuit contains means for selectively providing output signals representing tones having different timbres.

7. The instrument defined by claim **5**, wherein said gate circuit contains second switch means for selectively providing sustained mode and pizzicato mode output tones from said wave shaper circuit.

8. The instrument defined by claim **7**, wherein amplitude of said wave shaper output is controlled by a charge across capacitor means therein.

9. The instrument defined by claim **8**, wherein in sustained mode, said capacitor means is charged through said second switch means while said oscillator is energized and discharged while said oscillator is de-energized.

10. The instrument defined by claim **8**, wherein, in pizzicato mode, said capacitor means is charged through said second switch means while said oscillator is de-energized and discharged while said oscillator is energized.

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U.S. Cl. X.R.

84—1.24; 331—113, 142