

[54] **MUSIC SYNTHESIZER KEYBOARD CIRCUIT**

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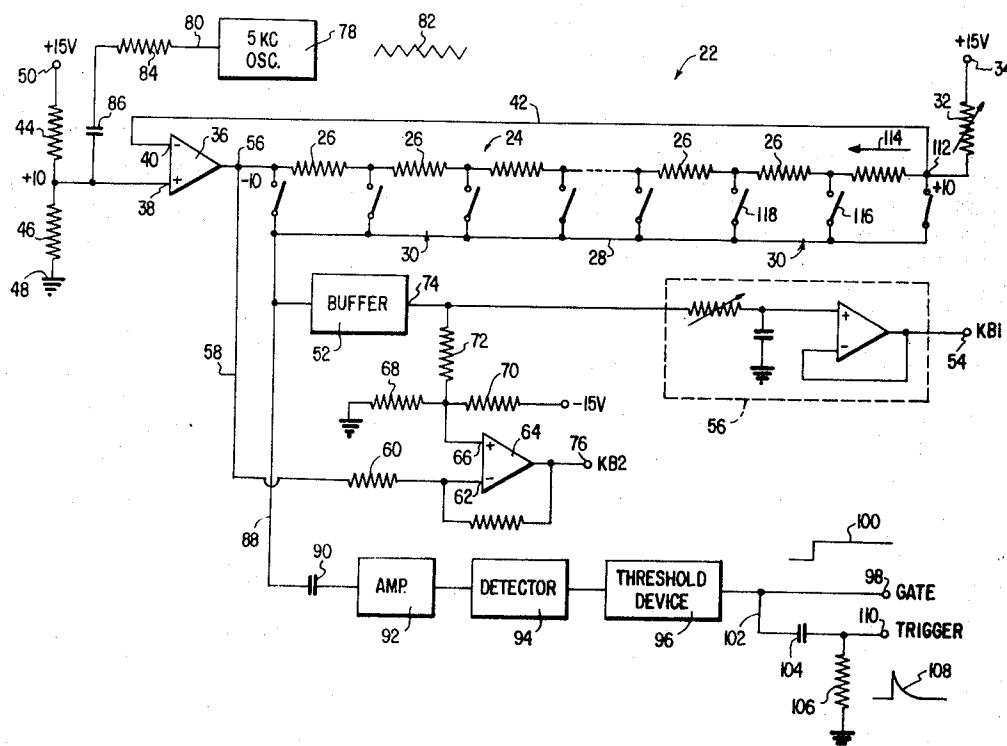
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[57] **ABSTRACT**

A keyboard circuit for an electronic music generator, such as an electronic synthesizer. The circuit makes it possible to independently control the frequencies of two voltage controlled oscillators at the same time with a single resistance string by sensing a change in potential across the entire string when a second key is depressed and summing this potential with the first note potential. Gate and trigger signals are provided for the two notes, one being generated by an AC signal superimposed on the string.

20 Claims, 3 Drawing Figures



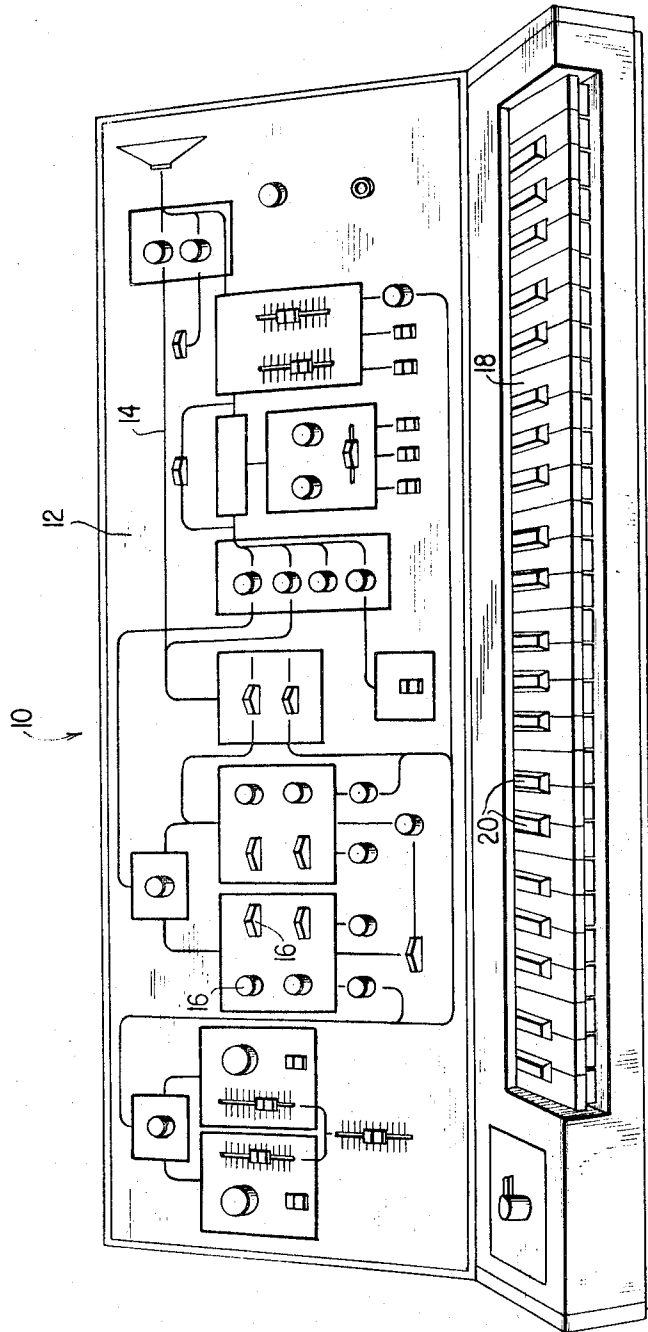


FIG. 1

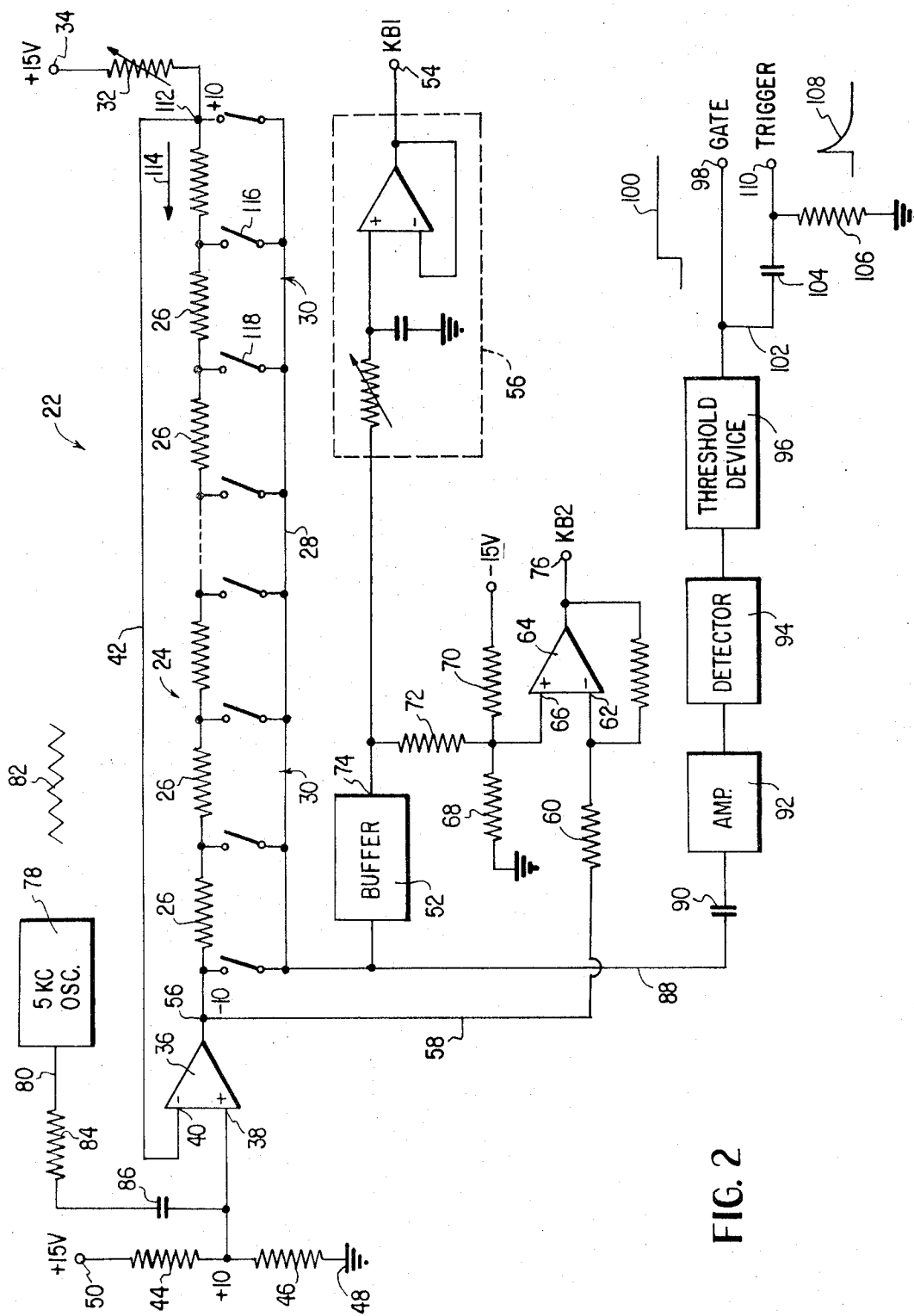
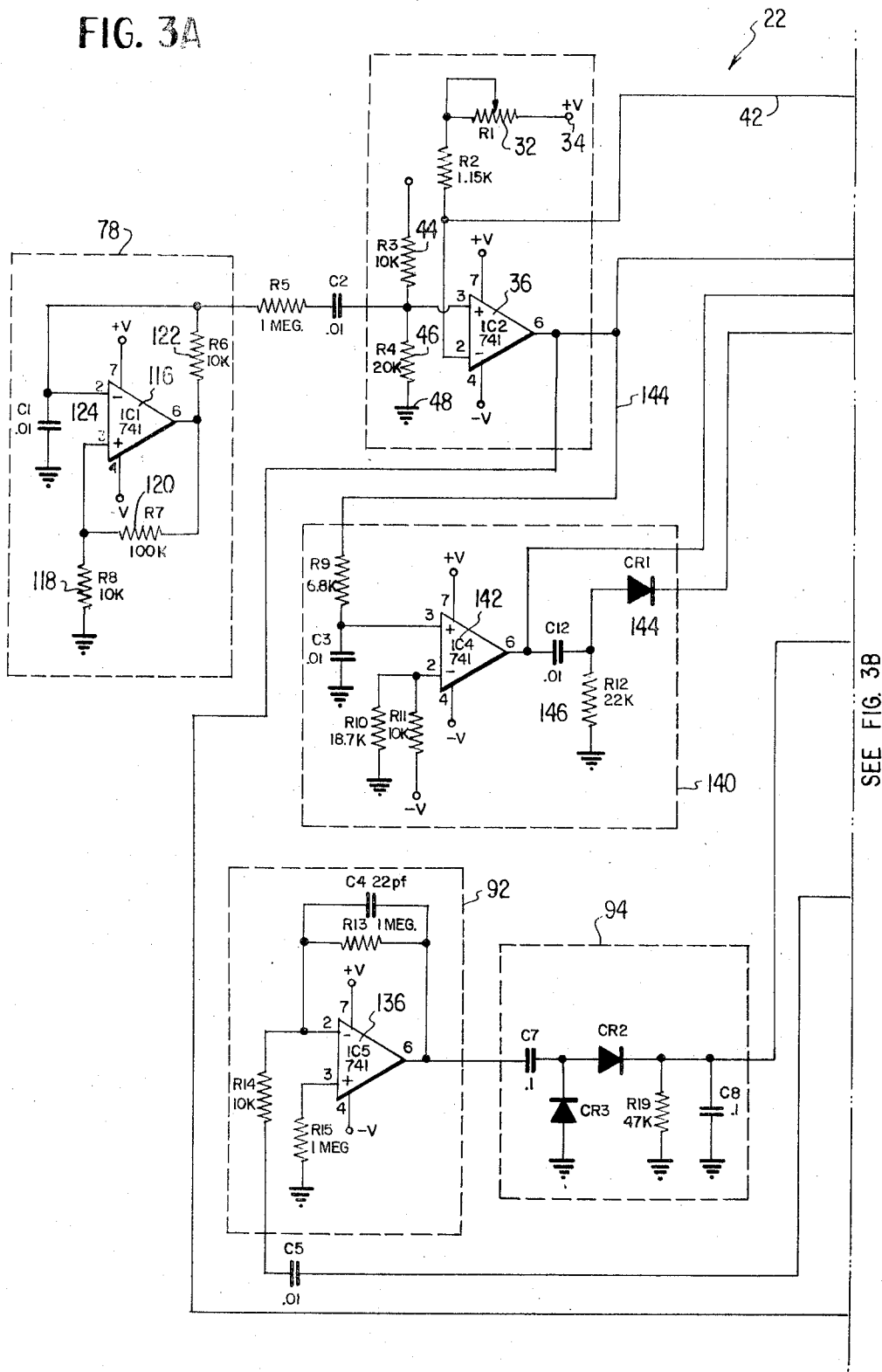


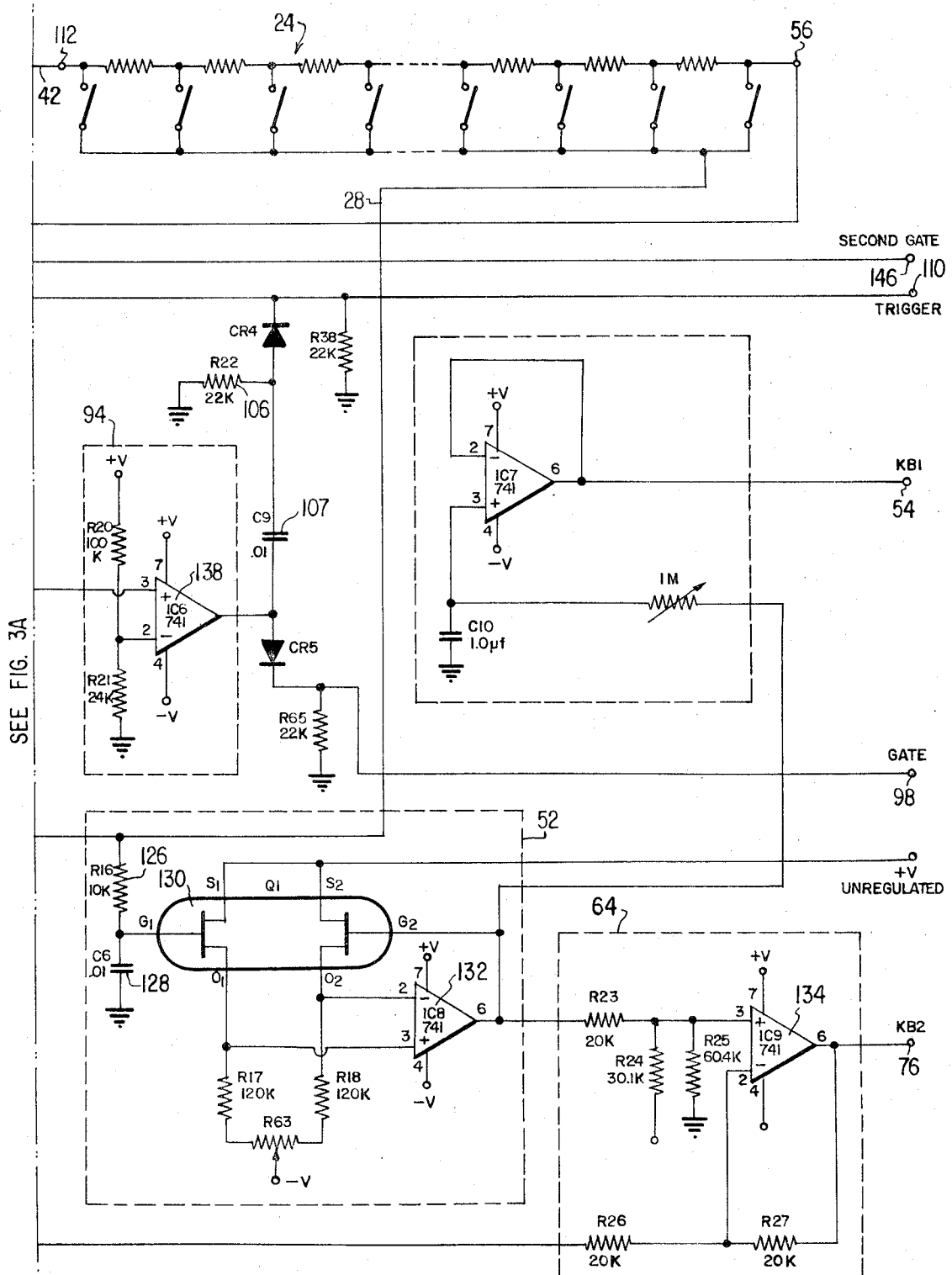
FIG. 2

FIG. 3A



SEE FIG. 3B

FIG. 3B



MUSIC SYNTHESIZER KEYBOARD CIRCUIT

This invention relates to an improved keyboard circuit and more particularly to an improved circuit for use with the keyboards of electronic music synthesizers.

Within the past several years, much interest has been shown in electronic synthesizers used by musical composers and performers to generate a variety of musical sounds. In general, these synthesizers have comprised a plurality of audio frequency oscillators whose frequencies are dependent upon control voltages which may be manually generated from a keyboard. One or more of these oscillators are conventionally operated in conjunction with other voltage controlled electrical circuits to make possible a wide variety of sounds and sound combinations. Commercially available recordings have been produced in which the music was composed with the use of an electronic synthesizer.

Pitched sounds in a synthesizer are produced by electronic oscillators. Unlike the electronic oscillators found in electronic organs, which basically are of fixed pitch, synthesizer oscillators are controllable over a large range by a control voltage. Thus, one function of a synthesizer keyboard is to provide a control voltage to a synthesizer oscillator. A second function of the keyboard is to provide a gate or trigger signal coinciding with the manual depression of a key and this trigger or gate voltage is conventionally used to set off transient controls in the synthesizer.

A synthesizer keyboard consists of a more or less conventional mechanical key mechanism which closes one or more switches per key. A string of resistors in the keyboard forms a voltage divider with different voltages appearing at the resistor intersections. A buss bar common to all switches transmits the selected voltage through buffer circuitry to the output of the keyboard circuit where the selected voltage is conventionally used to control the oscillator pitch (frequency) and perhaps other circuit components.

Unlike an electronic organ keyboard, the keys in a synthesizer do not switch in fixed oscillators or divided down waveforms. Instead, the conventional synthesizer keyboard produces a single voltage which conventionally controls one or more oscillators in parallel. Thus, in present synthesizer constructions, only one note or fixed chord structure can be produced at any one time. In a most elementary form of synthesizer keyboard, if two or more keys are depressed at the same time, all of the keyboard circuit voltages change and none of the keys produce a correct voltage. This is conventionally remedied by driving the resistor string with a constant current source.

For example, using a positive current source, if two or more keys are depressed, the lower key produces the correct voltage since the voltage is I times NR where I is the current (constant), R the value of the individual resistors in a resistor string, and N is the number of resistors to ground below the lowest key depressed. The amount of resistance above this key is irrelevant.

Very often, a synthesizer keyboard circuit is provided with a second set of contacts which are used to generate a gate signal for controlling transients which act to modify the sound output.

The present invention provides an improved keyboard circuit which makes it possible to generate two note voltages at the same time so that two notes may be played simultaneously on the synthesizer. An addi-

tional feature of the circuit of the present invention includes an arrangement whereby gate and trigger voltages may be generated in addition to the note voltage or voltages through the use of only a single set of switches, thus eliminating the need for the conventional second set of contacts normally used to generate a gate signal.

The two note generation feature of the novel keyboard circuit of this invention is based on the recognition that, since a negative current source is used, the voltage at the low end of the resistor string is constant as long as only one key is depressed. If two keys are depressed and M resistors are shorted out, the voltage at the low end increases by I times MR when M is the number of shorted resistors, I is the constant current, and R is the value of each resistor in the string. This voltage change is directly proportional to the interval between the leftmost and rightmost depressed keys. This information, together with the value for the main keyboard voltage, is all that is necessary to produce a second control voltage corresponding to the note for the second simultaneously depressed lower key. Thus, two control voltages and two notes can be produced by a single string of resistors and one set of contacts. In the circuit, the keyboard string is driven from below with an operational amplifier as the constant source. Another operational amplifier generates the second note voltage from the main keyboard voltage and that at the lower end of the string.

The simultaneous generation of a gate or trigger signal while using only a single set of contacts is made possible by the provision of an audio oscillator, such as one operating at approximately 5 KHz. A small 5 KHz signal is injected into the resistor string by way of the constant current source. When one or more keys are depressed, this 5 KHz signal is impressed on the buss lead, where it is amplified and detected to produce a gate and a trigger.

It is therefore one object of the present invention to provide an improved musical keyboard circuit.

Another object of the present invention is to provide an improved keyboard circuit particularly adapted for use in electronic synthesizers.

Another object of the present invention is to provide an improved two note keyboard.

Another object of the present invention is to provide an improved two note keyboard and keyboard circuit particularly adapted for use in electronic synthesizers.

Another object of the present invention is to provide a keyboard circuit which generates both control and trigger voltages with only a single set of contacts.

Another object of the present invention is to provide a keyboard circuit in which the varying voltage at one end of the resistor string is used to generate a second note voltage.

Another object of the present invention is to provide a keyboard circuit in which the voltage contact is used to generate a gate and trigger voltage by way of detection of an alternating voltage signal component.

These and further objects and advantages of the invention will become more apparent upon reference to the following specification, claims, and appended drawings, wherein:

FIG. 1 is a front elevation of an electronic synthesizer incorporating the novel keyboard circuit of the present invention;

FIG. 2 is a simplified block diagram of the keyboard circuit; and

FIG. 3 is a more detailed circuit diagram of the keyboard circuit of FIG. 2.

Referring to the drawings, FIG. 1 shows an electronic synthesizer, generally indicated at 10. The synthesizer is shown, by way of example only, since it is understood that the novel keyboard circuit of the present invention is applicable to all types of electronically operated sound generators. The synthesizer 10, illustrated in FIG. 1, is of the type identified as the Sonic V manufactured by Moog Music, Inc., of Williamsville, New York. This synthesizer is constructed primarily as an educational device and includes a control panel 12 on which is printed a flow diagram 14 with component blocks spacially related to the various control knobs and buttons 16 which operate them. The synthesizer 10 is a complete sound generator incorporating its own speakers and is provided with a keyboard 18 of conventional construction containing a set of conventional keys 20. The device operates from a conventional 110 volt 60 Hz AC power supply outlet and has a four octave keyboard with 49 notes and keys (C_2 to C_6). Each of the keys operates a separate switch so that when a key is depressed, its corresponding switch is closed and a control voltage generated so that the synthesizer produces an audio note, the pitch of which is indicative of the depressed key.

FIG. 2 is a simplified block diagram of the novel keyboard circuit 22 of the present invention incorporated in the synthesizer 10 of FIG. 1. The circuit comprises a resistor string 24 which is made up of 48 resistors 26 connected in series and all of the resistors 26 are of equal resistance value. Each resistor junction, as well as the two ends of the string, are connected to a buss lead 28 by respective note or key switches 30 and since there are 48 resistors, there is a total of 49 switches 30. The high end or righthand end of the resistor string 24 in FIG. 2 is connected through a variable resistor 32 to a regulated positive 15 volt terminal of a conventional regulated power supply, as indicated at 34. The low end or lefthand end of string 24 in FIG. 2 is connected to the output of an operational amplifier 36 having a positive input terminal 38 and a negative input terminal 40. The negative input terminal 40 is connected to the high end of the string by a feedback lead 42. Positive input terminal 38 is connected to a voltage divider comprising resistors 44 and 46 connected in series between ground 48 and the +15 volt regulated power supply terminal 50. Buss lead 28 is connected to the input of a buffer 52, the output of which is connected to the output terminal 54 which forms the primary or first note output KB_1 . This connection may be direct or, if desired, may be through a conventional Glissando circuit indicated by the dashed box 56. The output on lead 54 is a control voltage whose value is linearly related to the position of the depressed key and this voltage is used to control the pitch (frequency) of a first note oscillator (not shown) in a conventional manner.

As previously indicated, in conventional constructions of this type, it is possible to play only one note at a time. In the circuit illustrated in FIG. 2, it is possible to play two notes simultaneously and for this purpose the low end of string 24 at the output terminal 56 is connected by lead 58 and a resistor 60 to the negative input terminal 62 of a second operational amplifier 64. This amplifier acts as a difference amplifier and has its

positive input terminal 66 connected to a voltage divider formed by resistors 68 and 70 and is also connected through resistor 72 to the output terminal 74 of buffer 52. The output from difference amplifier 64 appearing on output lead 76 is equal to the rightmost depressed key voltage less a voltage proportional to the interval between the leftmost and rightmost depressed keys, and constitutes a second note control voltage which may be applied to a second note oscillator (not shown) in a conventional manner.

A further important feature of the present invention resides in the fact that the single set of switch contacts 30 may also be used to generate gate and trigger voltages. For this purpose, the keyboard circuit 22 includes an audio frequency oscillator 78 which, by way of example only, may be a 5 KHz oscillator producing on its output lead 80 a triangular voltage waveform of the type illustrated at 82 in FIG. 2. Lead 80 is connected through an attenuating resistor 84 and a coupling capacitor 86 to plus input terminal 38 of operational amplifier 36. In this way, a small AC signal is superimposed on the DC voltage across resistor string 24 and when a key is depressed, this small AC signal on buss lead 28 is supplied by way of an additional lead 88 and a coupling capacitor 90 to the input of an AC amplifier 92. The output of amplifier 92 feeds a detector or demodulator 94 producing a DC output which is applied to a threshold device 96 producing on its output terminal 98 a step voltage or gate voltage, such as that illustrated at 100. This gate voltage is also applied by lead 102 to a differentiator comprising capacitor 104 and resistor 106 in which the step waveform or gate waveform 100 is differentiated to produce a trigger impulse 108 at trigger output terminal 110. The gate and trigger signals may be used to control attack and decay circuits in a conventional manner.

In operation, the center of resistor string 24 is a virtual ground and the voltages adjusted so that the high end of the string at junction 112 is at +10 volts and the low end of the string at junction 56 is a -10 volts with no keys depressed. This is accomplished by establishing a voltage at the plus input of operational amplifier 36 of precisely +10 volts, and by adjusting variable resistor 32 connected to +15 volts regulated terminal 34 so that junction 56 is fixed at -10 volts. The operational amplifier 36 operates so that the resistance string 24 is in its feedback path and operates in a well known manner to energize the resistance string from its high end 112 with a constant current in the direction of the arrow indicated at 114 in FIG. 2. This current is a constant current and flows completely through the string from the high or +10 volt end 112 to the low or -10 volt end 56, and this constant current is maintained by feedback through operational amplifier 36. When one of the keys 26 of FIG. 1 is depressed, the corresponding switch 30 of FIG. 2 is closed so that the voltage appearing on buss lead 28 is determined by the potential drop, i.e., the IR drop across those resistors 26 to the left in FIG. 2 of the closed one of the switches 30. This potential is applied to the very high input impedance of buffer 52, which in turn generates at output terminal 54 a control voltage which is the main keyboard note voltage for controlling the uppermost note.

It should be noted that the closure of one switch 30 corresponding to the depression of one key of the keyboard does not change the potential along the string 24 since the high impedance of buffer amplifier 52 draws

negligible current. It is a feature of the present invention that two notes can be played simultaneously by the depression of two different keys 30 of the keyboard 18. Assume, by way of example only, that a first key of the keyboard is depressed to close switch 116 of the switch set 30. This produces a voltage on buss lead 28 which is proportional to the voltage drop across the resistor in FIG. 2 between switch 116 and the top end 112 of the resistor string. This signal passes through buffer 52 and appears at the first keyboard note signal on output lead 54. If a second key is depressed to the left of switch 116 and a second switch 30 is closed, such as by way of example only, if switch 118 of the set 30 is closed simultaneously with switch 116, the circuit of FIG. 2 will produce the above-described first note at output 54 and a second note corresponding to the closure of second switch 118 at the second output terminal 76. Since the potential on the buss is proportional to the IR drop across the one resistor above switch 116, this voltage applied to the buffer 52 and appearing at the output terminal 54 is not affected by the closure of an additional switch 118. However, with the two switches closed, one of the resistors, i.e., the resistor between switches 116 and 118, is shorted out through those switches. The shorting out of one of the resistors 116 changes the potential drop across the entire resistor string in an amount proportional to the number of shorted resistors. That is, with a constant current through the resistor string, the total potential drop from the high to the low end of the string is reduced in an amount proportional to the number of shorted resistors. Since the high end 112 is fixed at +10 volts, this change in potential across the string is reflected in a rise in potential at the low end 56 of the string so that junction 56 becomes positive with respect to its original -10 volt level by an amount proportional to the number of resistors that are shorted out between the two closed switches 116 and 118. This rise in potential is applied as an inverting input to the difference amplifier 64. The other input to this amplifier at the input terminal 66 is proportional to the main key note signal on buss 28 and by summing these two signals, the output at output terminal 76 is a DC potential which is equal to (a) the potential drop across the resistors to the right of the highermost key depressed minus (b) the current I times the number of resistors shorted out. It is readily apparent that the difference of these two is a signal corresponding to the second key, i.e., key 18 in the example given, so that the output at terminal 76 is a voltage modified by the potential drop across the number of resistors shorted to the left of the primary higher key.

A second feature of the invention is the use of a single set of contacts or a single set of switches 30 to produce the gate and trigger outputs at terminals 98 and 100. This is done by superimposing on the DC potential across resistor string 24 from DC potential terminal 34 a small AC signal derived from oscillator 78. The oscillator output is heavily attenuated in resistor 84 and applied to the string through coupling capacitor 86 and operational amplifier 36. When one of the switches 30 is closed, this superimposed AC signal appears along with the DC potential on buss lead 28. The AC signal is applied to AC amplifier 92, where, since it is originally quite small, it is heavily amplified. The amplified AC output is detected or demodulated in detector 34 to provide a DC output from this detector proportional to the AC amplitude into amplifier 92. The detected or

DC output from detector 94 is applied to the threshold device 96 which produces the step voltage 100 with the step or increase in voltage coinciding with the depression of one of the keys 30. This may be used as a step gate at output 98 to actuate suitable attack and decay circuits or may be differentiated and supplied to terminal 110 as a trigger output. Suitable low pass filtering circuits may be provided as desired in the buffer 52 and operational amplifier 64 to insure that the small AC signal superimposed on the DC signal does not reach the DC output terminals 54 and 76.

FIG. 3 is a detailed circuit diagram of the keyboard circuit 22 of FIG. 2 with like parts bearing like reference numerals. The circuit is preferably of integrated and printed circuit construction on the oscillator 78 in FIG. 3 takes the form of a multivibrator including integrated circuit 116, resistors 118, 120, and 122, and capacitor 124. The buss lead 28 connected to the switches for resistors string 24 feeds a signal to the buffer 52 which includes a low pass filter comprising a resistor 126 and capacitor 128. The buffer is a sample-and-hold, very high input impedance, unity gain buffer and comprises a pair of FET transistors 130 and integrated circuit 132. The buffer supplies a DC output to one input of difference amplifier 64 which includes an integrated circuit 134. The other input to the difference amplifier 64 is by way of lead 58 from the low end 56 of the resistor string. Buss lead 28 is also connected through coupling capacitor 90 to the input of AC amplifier 92 including integrated circuit 136. The AC amplifier produces a highly amplified AC output which is demodulated in detector 94 and applied to threshold device 96 which, in the preferred embodiment, takes the form of a voltage comparator including integrated circuit 138. The output from this circuit appears as a gate signal on output lead 98. It is also applied through the differentiator comprising resistor 106 and capacitor 107 as a trigger signal to output terminal 110.

FIG. 3 shows a circuit not previously described, namely, a second note trigger circuit, generally indicated at 140. This circuit comprises a voltage comparator including an integrated circuit 142 having one input connected to a reference level and its other input connected through lead 144 to the low end 56 of the resistor string. A rise in potential at the resistor string with the closing of the second key is sensed by the voltage comparator 142 and applied as a second note gate signal to output terminal 146. This second note gate signal is in all respects identical to the first note gate signal appearing at output lead 98 with the exception that it occurs in response to closure of the second switch and the accompanying rise in potential at the low end 56 of the resistor string. It too is differentiated by a capacitor 144 and resistor 146 for use as a second note trigger output at terminal 110.

It is apparent from the above that the present invention provides an improved keyboard circuit and particularly a keyboard circuit of simplified and inexpensive construction and yet one which makes possible the simultaneous playing of two notes from the keyboard using only a single resistor string. Also provided in the circuit is a suitable AC oscillator for superimposing on the keyboard controlled DC signal an AC signal so that a single switch set may be used to generate both the DC control voltage and gate or trigger impulses. Also provided in the circuit is a second gate/trigger for generating gate and trigger signals coincident with the depres-

sion of a second key or production of the second note. All this is made possible in a circuit through the addition of a few simple solid state components and all these features are provided in a circuit which includes only a single resistance string and a single set of contacts which substantially reduces the cost and complexity of the keyboard circuit. While described in conjunction with a specific synthesizer keyboard arrangement, it is apparent that the novel keyboard circuit of the present invention may be used with all types of electronic instruments in which control voltages are generated by the depression of a key and the invention is not limited to a specific synthesizer arrangement.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. A keyboard circuit comprising a multiplicity of series-connected resistors, or a resistance string, means coupled to said string for supplying it with a constant current, a buss lead, a set of switches coupling said buss lead to spaced points along said string, a first note output coupled to said buss lead, and a second note output coupled to one end of said string.
2. A circuit according to claim 1 wherein said string comprises a series of equal resistance elements.
3. A circuit according to claim 1 wherein said buss lead is coupled to said first note output by a buffer.
4. A circuit according to claim 3 wherein said buffer comprises a high input impedance sample-hold circuit.
5. A circuit according to claim 1 wherein said constant current means comprises an operational amplifier, said string being coupled in the feedback circuit of said amplifier.
6. A circuit according to claim 5 wherein said second note output is coupled to the low potential end of said string.
7. A circuit according to claim 1 including a difference circuit having its output coupled to said second note output, a first input of said difference circuit being coupled to said one end of said string and a second input of said difference circuit being coupled to said

buss lead.

8. A circuit according to claim 7 wherein said difference circuit comprises a difference amplifier.

9. A keyboard circuit comprising a resistance string, a constant current source coupled to said string, a buss lead, a set of keyboard switches coupling said buss lead to spaced points along said string, a DC output coupled to said buss lead, means coupled to said string for superimposing an AC signal on said string, and a transient control output coupled to said buss lead.

10. A circuit according to claim 9 wherein said transient control output comprises a gate output.

11. A circuit according to claim 9 wherein said transient control output comprises a trigger output.

12. A circuit according to claim 9 including an AC amplifier and demodulator coupling said buss lead to said transient control output.

13. A keyboard circuit comprising a resistance string, a constant current source coupled to said string, a buss lead, a set of keyboard switches coupling said buss lead to spaced points along said string, a buffer coupled to said buss lead, a first note output coupled to said buffer, a difference amplifier having first and second inputs, said first input being coupled to the output of said buffer and said second input being coupled to one end of said string, and a second note output coupled to the output of said difference amplifier.

14. A circuit according to claim 13 including a Glissando circuit coupling said buffer to said first note output.

15. A circuit according to claim 13 including a first note transient control output coupled to said buss lead.

16. A circuit according to claim 15 including an audio frequency oscillator coupled to said string, said first transient control output being coupled to said buss lead through an AC amplifier, a detector and a threshold device.

17. A circuit according to claim 15 including a second note transient control output coupled to said end of said string.

18. A circuit according to claim 17 including a voltage comparator coupling said second note transient control output to said end of said string.

19. A circuit according to claim 13 and further including an electronic synthesizer having a keyboard with a separate key for each of said switches.

20. Apparatus according to claim 19 wherein said synthesizer has a four octave keyboard with 49 keys.

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