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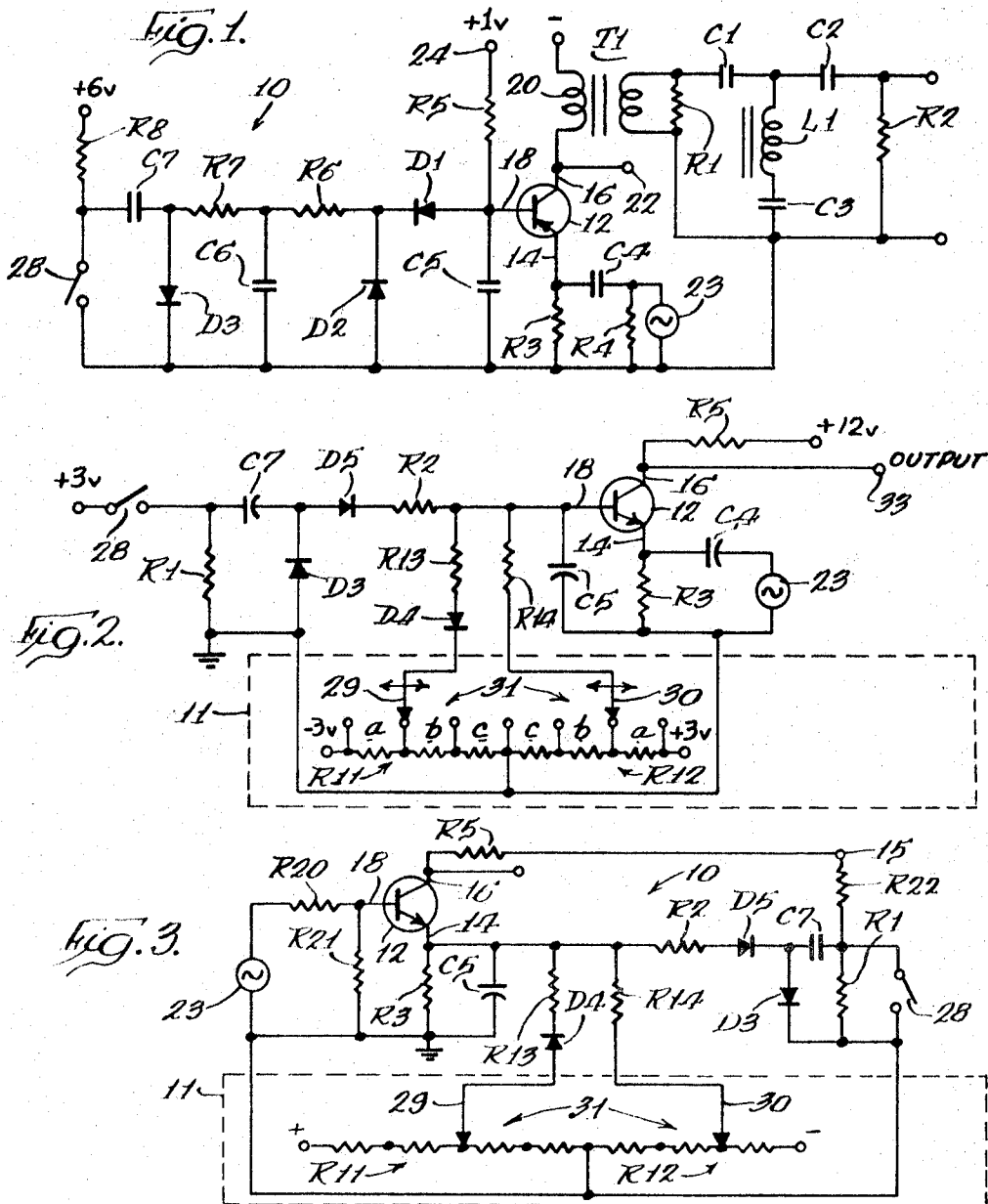
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3,465,088

MUSICAL INSTRUMENT PERCUSSIVE KEYS WITH VARIABLE SIGNAL DECAY

Filed May 31, 1966

2 Sheets-Sheet 1



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Fig. 1.

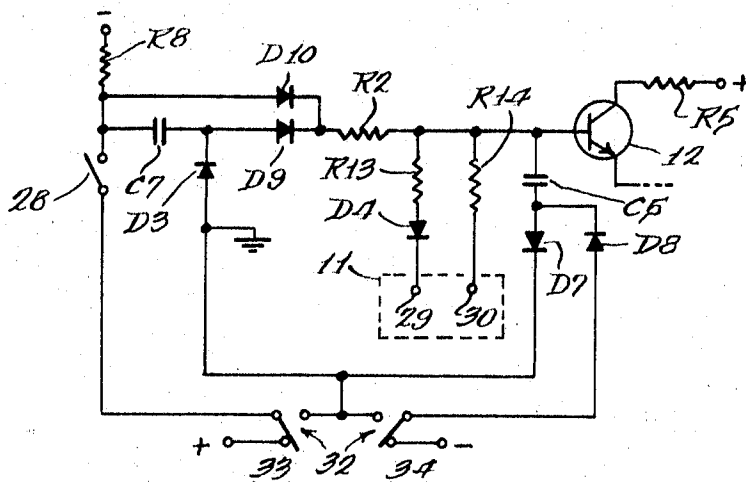
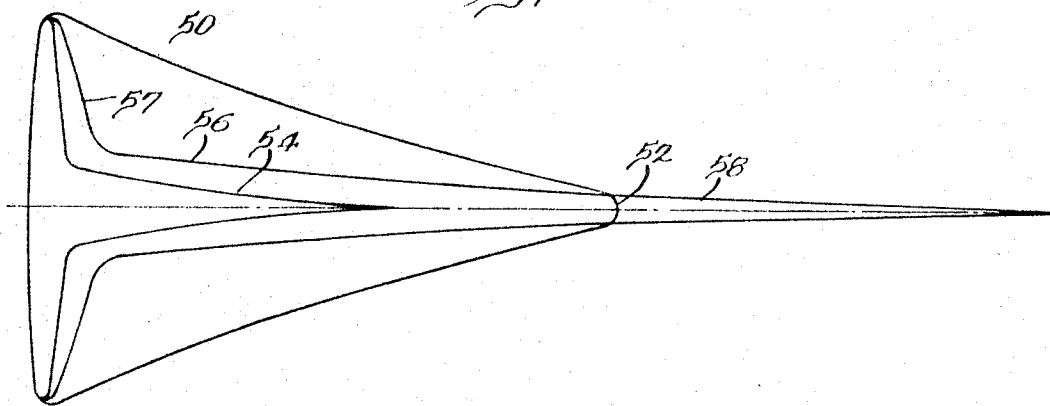


Fig. 5.



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MUSICAL INSTRUMENT PERCUSSIVE KEYER WITH VARIABLE SIGNAL DECAY

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3 Claims

ABSTRACT OF THE DISCLOSURE

A percussive keyer circuit of the general type in which conduction is normally held off by a bias potential and conduction occurs when a pulse overcomes the bias, and in which the pulse also charges a capacitor which subsequently runs down to the bias potential to produce decay of the signal. Variability in the decay is produced without appreciably disturbing the bias potential by connecting the capacitor run down path through a dynamic resistance element, the resistance of which varies with the current therethrough and varying the current therethrough by varying the voltage spread across the dynamic resistance element. Passive resistance elements and the voltages in the circuit can be chosen such that increasing or decreasing the voltage spread does not appreciably affect the potential at the circuit midpoint which serves as the bias connection.

The present invention relates in general to a percussion sustain keyer and constitutes an improvement over the keyer circuit disclosed by Milho Patent No. 3,247,306, filed Dec. 3, 1962.

This invention is for use in an electrical music instrument and more particularly it concerns keyer circuits for organs of the type having free running oscillators as opposed to systems which turn the individual oscillators on and off by operation of key contacts. The keyers provide the keyed signals with a full percussive envelope which is independent for each key tone signal source and automatic in its operation and in which the percussion sustain effect is achieved by a single key contact for each playing key.

The circuit of the invention can be used with other existing keyers to enhance their versatility.

It is a primary object of the invention to provide a circuit providing percussive effects in an electronic musical instrument which can be varied by unified control and eliminating the problems of prior percussive keyers such as lack of uniformity, thumping attack sounds, sound build-up problems and pinch off effects.

A further object is to provide an electronic musical instrument with an electronic variable impedance circuit to vary the percussive decay rate, thus allowing a choice of percussive envelopes.

A further object is to provide a novel keyer circuit for providing sustain type percussion in which the percussive envelope is never suddenly interrupted by release of a key.

A further object is to provide an electronic musical instrument with an electronic variable impedance keyer that will produce, control, and achieve a desired envelope of tonal intensity.

A further object of the invention is to provide a novel keyer circuit in which a switch is provided to render the percussive circuit ineffective and make the output either that of a sustain type keyer or dependent on manual keying.

Other objects and advantages will become apparent from the following description, reference being had to the

accompanying drawing, wherein common reference numerals are used to designate the same element in all the figures.

In the drawings:

FIG. 1 is a schematic diagram of a percussive circuit of the prior art;

FIG. 2 is a schematic diagram of a percussive circuit illustrating the invention;

FIG. 3 is a schematic diagram of a modification of FIG. 2;

FIG. 4 is a schematic diagram of a modification of FIG. 2; and

FIG. 5 is a waveform diagram of the percussion envelopes of the circuits of FIGS. 1 and 2.

FIG. 1 is a schematic diagram of the prior art disclosed by Milho Patent No. 3,247,306. The keyer circuit is indicated generally by the reference numeral 10. It comprises a transistor 12 of the PNP type having an emitter circuit 14, collector circuit 16 and a base circuit 18. The collector circuit 16 is connected through the primary 20 of an output transformer T1 to a source of negative potential. A lead 22 connects the primary 20 to a similar collector circuit of each of a plurality of other keyers which feed transformer T1. The output of the transformer T1 is applied through a suitable output system to a loud speaker or similar transducer.

A resistor R1 is connected across the secondary output of transformer T1 which acts as a mixer and provides a voltage gain while a low frequency transient filter comprising capacitors C1, C2 and C3 and inductance L1 serves to filter the output of transformer T1. A resistor R2 is also connected across the output of transformer T1. The emitter circuit 14 and transistor 12 are also connected through a low frequency transient filter comprising resistors R3 and R4 and a capacitor C4 to a tone signal source 23 to ground. A similar signal source is provided for the other keyers feeding transformer T1 over lead 22.

The base circuit 18 and the transistor 12 are connected through a resistor R5 to a source 24 of approximately one volt positive potential. The base circuit is also connected to a large capacitor C5 and to one terminal of a diode D1 poled to pass current when the base circuit 18 is positive with respect to the other terminal of diode D1. The other terminal of diode D1 is connected to a diode D2 poled in the reverse direction and connected in shunt with capacitor C5. Diode D1 is also connected through series connected resistors R6 and R7 and through a diode D3 poled in the same direction as diode D1 to ground.

The junction of resistors R6 and R7 is connected to ground through capacitor C6 and the junction of resistor R7 and diode D3 is connected to one terminal of a keying capacitor C7. The other terminal of capacitor C7 is connected through a resistor R8 to source 26 of about six volts positive potential so that capacitor C7 is normally charged to this value. One playing key 28 of the organ is adapted when operated to connect the junction of resistor R8 and capacitor C7 to ground.

In operation, the purpose of the keyer circuit 10 of FIG. 1 is to reproduce in an organ a response similar to that experienced in playing a percussive instrument. Therefore the circuit must cycle in an appropriate mode when triggered. Key 28 is a manual key switch to a common bus. R8, C7 and D3 comprise the only active circuit until the key switch is closed. R8 determines the charging rate of C7 limiting the speed of sound reiteration. Once the key switch 28 is closed, C7 transfers its charge through D2, R7, 12, C5 and R3. The capacitor C7 discharges a negative voltage through transistor 12 causing base to emitter current in the transistor for the first time. The base current is required to turn on collector to emitter

current, causing the generator tone appearing on R3 to be amplified and sent via C1 to the speaker system.

Note that once the operator closes switch 28, he is at the mercy of the circuit in so far as tonal results, or stating it differently, the problem of controlling the discharge of C7 determines the operating cycle of transistor 12. The circuit output is shown in FIG. 5, envelope 50. To this point this is prior art.

Now, attention should be directed to transistor 12 and means to change its output such as varying the tonal range time, initial signal attack time, and rate of signal decay from the composite envelope viewpoint.

The circuit in FIG. 2 is representative of the percussive keyer of the present invention. To obtain various keyer sustain times, R13 and D4 are added to each keyer circuit and connected to one lead 29 of unitary type control switch 31. R14 is connected to unitary switch lead 30 controlling a voltage opposite that on unitary switch 29. Transistors 12, D4, R13 and R14 represent the only shunt resistance to any positive charge placed on C5. The dynamic resistance of the silicon diode D4 is approximately that determined by the following formula:

$$r_d \cong \frac{nKT}{qI_f}$$

where

n =a constant (varies between 1 and 2)

I_f =diode forward current

$K=1.38 \times 10^{-23}$ watt-seconds/° K.

T =absolute temperature (° K.=° C.+273)

$q=1.6 \times 10^{-19}$ coulombs

Therefore the shunt resistance of C5 can be varied by changing the diode forward current with unitary switch 31. The change in diode forward current must be accomplished such that the voltage at the junction of R13 and R14 will not vary. Thus any reference voltage on the base of transistor 12 will be stable during quiescent conditions and any positive charge on C5 can discharge to the same stable voltage.

The sustain-time remote control circuit 11 is at a distance from keyer circuit 10. Transistor 12 is of the NPN type.

In operation, C5 of FIG. 2 assists the initial discharge of C7 by sustaining the positive voltage at the base of transistor 12. It should be stated that the value and ratios of capacitors C7 and C5 is stringent in obtaining uniformity of repetitive percussive output of transistor 12. Modification of the desired ratio gives crescendo or decrescendo in reiteration. The discharge path of C5 initially is through transistor 12 and R3 and subsequently the major part is through R13 and R14. Note that transistor 12 is of the NPN type and responsive to the positive voltage placed on the base. Change of the base voltage 18 dictates its performance.

Changing the decay rate of C5 must be done without disturbing the general forward voltage or bias of the transistor 12. D5, R11, R12 are quite important in changing the decay rate of this forward bias of transistor 12. Note that R11 and R12 work together as shown in FIG. 2. By varying the current through D4, the result is to cause an apparent change in resistance without any transfer of voltage to the discharge path of C5. Any voltage change made to vary the shunt resistance of C5 must not reflect any change in the average conduction of transistor 12 to avoid undesired effects such as pinch off.

In listening to the composite output of the keyer, the total ring time of the signal required to faithfully reproduce a given percussive instrument must be considered. A piano will normally have short ring time or sustain time as compared to the characteristically long ring time of a chime. Most simple keyer circuits fall short in performance of this nature.

C4 has considerable importance that is not apparent on initial investigation. The composite output of transistor 12

must appropriately provide various levels of signal strength especially at the start of operation. C4 is chosen in value to determine the initial strike amplitude as compared to the main body of the envelope. For example, if preference is desired for a metallic percussive instrument, the capacitor is twice the value it should be for a string percussive instrument. R3 also plays an important role but usually this resistance is determined for other criteria such as the amount of power taken from tone generator 23 and maximum signal gain expected of transistor 12. It should be noted that R2 is determined by the rise time or speed of attack expected from the keyer 10. C5 is placed directly on the base of transistor 12 to provide the maximum signal gain from the keyer circuit.

The keyer 10 has a common base configuration of such low AC impedance on the base that the most severe variations of beta of transistor 12 will not be noticeable at the output with a given signal amplitude.

Summarizing, the operation of the circuit of FIG. 2 is similar to that of FIG. 1 except for the fact that the decay time of capacitor C5 is varied by the remote circuit 11 which controls the sustain time for the output 33. Unitary switch 31 acts in opposition to provide desired, opposite polarity voltages to switch contacts 29 and 30. It is by this means that the effective resistance loading of the decay circuit is varied.

Curves 54 and 56 of FIG. 5 show the percussion envelopes, amplitude vs. time, for medium sustain and long sustain, respectively, of the circuit of FIG. 2. The difference between the two outputs shown is that the effective resistance loading in the decay circuit has been varied by unitary switch 31 changing the resistance in the base circuit of transistor 12. The effective resistance loading is greater for the long sustain of curve 56. The bias voltage in the keyer circuit, that is, the voltage at the base of transistor 12 is maintained constant.

The difference between the prior art of FIG. 1 and the circuit of FIG. 2, curves 50 and 54, 56, respectively, is that the envelope of curve 50 decays to zero amplitude linearly, but experiences a pinch off effect as the envelope collapses at 52. The percussive envelopes 54, 56 decay at a rapid rate and then over a much longer period of time on the order of twelve times the initial envelope period of decay to zero amplitude at a linear rate with no envelope collapse. It is by this means that pinch off effect is avoided.

The initial rapid rate or steep slope portion 57 is determined by the emitter components while the decay to zero amplitude or shallower slope portion 58 is controlled by the base components of the circuit 10. The waveforms 54 and 56 are particularly useful in reproducing metallic percussive sounds. However, the keyer circuit is also capable of reproducing string percussion sounds having a substantially uniform slope without a pinch off effect.

Component specifications for the schematic circuit of FIG. 2 are as follows:

C4	-----mfd	100
C5	-----mfd	33
C7	-----mfd	33
R1	-----ohms	1000
R2	-----do	390
R3	-----do	2200
R5	-----do	680
R11a	-----do	100
R11b	-----do	50
R11c	-----do	25
R12a	-----do	100
R12b	-----do	50
R12c	-----do	25
D3	-----	1N462
D4	-----	1N462
D5	-----	1N462
Transistor 12	-----	2N2926

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The circuit of FIG. 3 represents a common-emitter percussion keyer similar to the common-base keyer of FIG. 2. The concept is the same as that shown in FIG. 2, but the inputs to the transistor 12 have been changed to supply voltages of a single polarity represented at 15, thus resulting in a cheaper power supply. The tonal input to the transistor 12 is applied at the base 18. The tonal input 23 provides in input impedance on the order of ten times greater than that provided at the emitter 14 of the transistor 12. This increase in impedance results in a more economical tone generator. Transistor 12 is keyed at the emitter 14 through switch 28 and capacitor C7.

FIG. 4 shows further additions to the keyer circuit 10 in which the operator has the option of having a percussive keyer or a straight DC keyer with or without sustain time. Switch 32 provides the required positive voltage for diode D8 which shunts any charge from capacitor C5. Diodes D7 and D8 can be reversed biased by the negative section 34 of switch 32, and with these diodes basically open, capacitor C5 cannot accept any charge. Switch 28 represents an individual note switch in the manual of the organ. Once again switch 32 is unitary in use and multiple keyer circuits can be attached to a single switch as 32.

The operation of the device of FIG. 4 is similar to that of FIG. 2. Leads 29 and 30 lead to the remote circuit 11 which controls the output sustain time. In addition, switch 32 permits percussive or direct DC keying to be selected. Moreover, resistor R2 can be altered to determine attack time for a given note. Scaling this resistor to varying pitches can enhance the tone especially of the extreme ends of the manual.

In summary, applicant has invented a means of applying two voltages to a keying circuit in such a way as to change the effective resistance loading in the decay circuit and thereby vary the decay rate without actually changing the potential toward which the note is decaying. This avoids, for example, a pinch off effect which occurs when the note is decaying toward a point far below audibility and also avoids upsetting bias voltages in the keyer. Presumably this invention can be applied to any keying circuit of this general type.

Various modifications may be made in the invention without departing from the spirit and scope thereof and it is desired therefore that only such limitations shall be placed thereon as imposed by the prior art and are set forth in the appended claims.

I claim:

1. In a musical instrument variable decay percussion keyer circuit for connecting a tone signal source to an output system upon the actuation of a playing key individual to the signal source, an electronic variable impedance device, circuit means including said variable im-

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pedance device for connecting said source to said output system, means normally applying a bias of a certain sense and potential to the variable impedance device to render said circuit means ineffective to conduct said signal to said output system, means including a playing key for applying a pulse of opposite sense and appropriate potential to said variable impedance device to overcome said bias and render said circuit means effective to conduct the tone signal to the output system, a decay circuit connected to the variable impedance device to render the variable impedance device gradually nonconductive at a controlled and selected rate after the variable impedance device has been rendered conductive by the application of said pulse thereto while maintaining a substantially constant bias at the variable impedance device when said variable impedance device is biased nonconductive, said decay circuit comprising means connected to a pair of potential sources of opposite sense to apply selected opposing balanced potentials to said variable impedance device, one of the last said potentials having the sense of said bias potential and the other of the last of said potentials having the sense of said conducting potential, a resistor between the potential source having the conducting potential sense and said variable impedance device, and a resistor and a dynamic resistance element in series between the potential source having the bias potential sense and said variable impedance device, said dynamic resistance element having the characteristic that its effective conductance is dependent upon the value of the current therethrough.

2. The keyer circuit called for in claim 1 in which the dynamic resistance element is polarized such that an increase in the potential difference between the said opposing potentials reduces the resistance of said dynamic resistance element.

3. The keyer circuit called for in claim 2 in which said dynamic resistance element is a diode.

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