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Olliges et al.

[11] **3,831,172**

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[54] **SOLID-STATE SOUND EFFECT GENERATING SYSTEM**

[75] Inventors: **William E. Olliges**, Arlington Heights; **Edward L. Polanek**, Glendale Heights, both of Ill.

[73] Assignee: **Universal Research Laboratories, Incorporated**, Elk Grove Village, Ill.

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[21] Appl. No.: **215,025**

[52] **U.S. Cl.**............ **340/384 E**, 273/1 E, 273/85 R, 272/14, 317/101 CC, 84/1.11, 35/12 Q

[51] **Int. Cl.** **G08b 3/00**

[58] **Field of Search**........ 340/384 E, 221, 225, 328; 272/14; 35/11, 12 Q, 12 N; 317/101 D, 101 CM, 101 CC, 101 DH; 273/1 E, 130 AB, 86 B, 85 R; 84/1.01, 1.11, 1.17, 1.19, 470

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Primary Examiner—John W. Caldwell
Assistant Examiner—William M. Wannisky
Attorney, Agent, or Firm—Fitch, Even, Tabin & Luedeka

[57] **ABSTRACT**

A solid-state sound effect generating system for selectively producing any one of a plurality of predetermined sound effects has a plurality of interchangeable plug-in printed circuit boards each having mounted thereon an electronic circuit capable of being actuated to produce an electrical output signal representative of a unique one of a group of desired sound effects, without the use of any prerecorded signals or recording medium. The circuit boards are plugged into a common control chassis which interconnects them with an audio power amplifier and loudspeaker arrangement and which further provides input terminals for external triggering signals.

4 Claims, 8 Drawing Figures

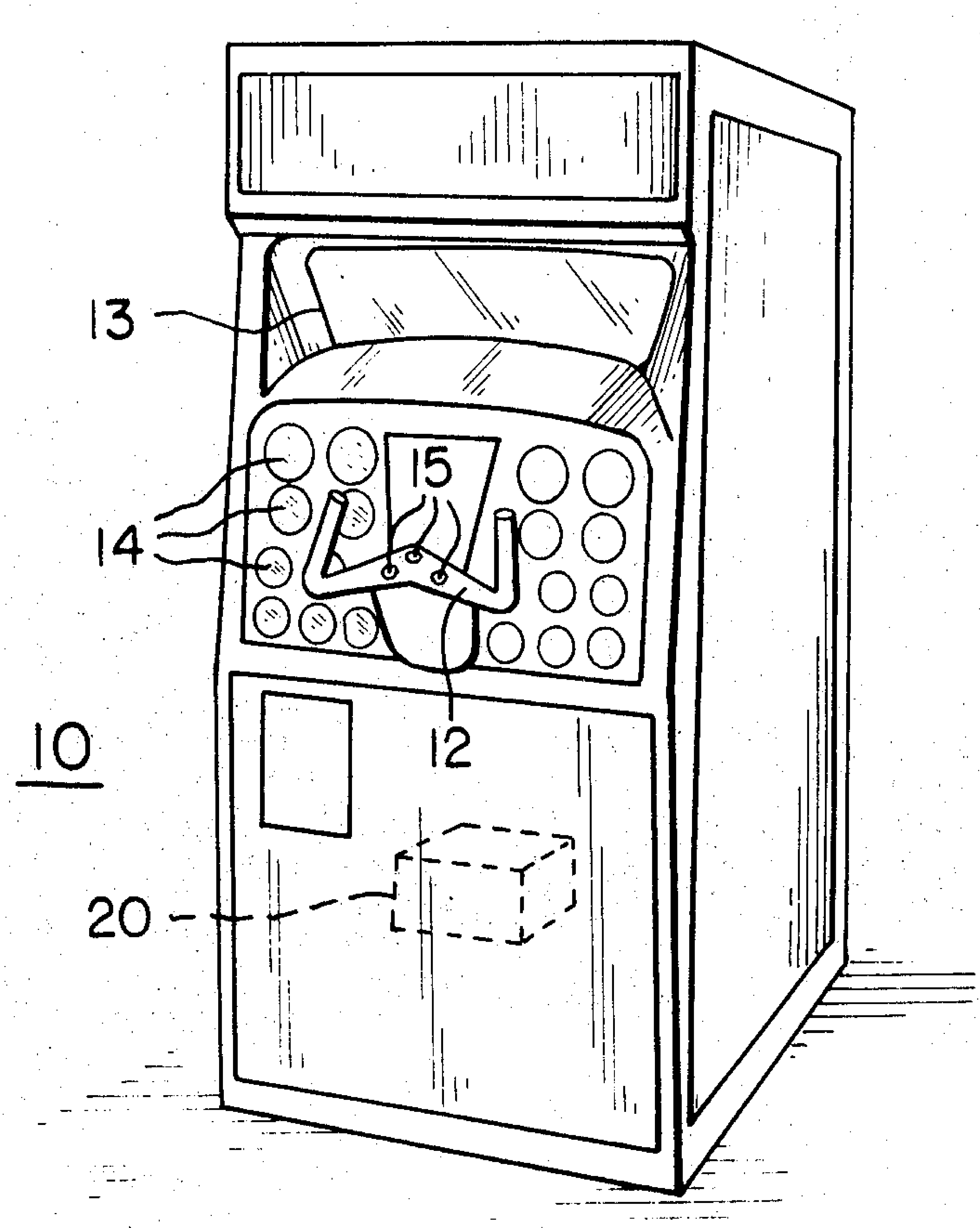


FIG. 1

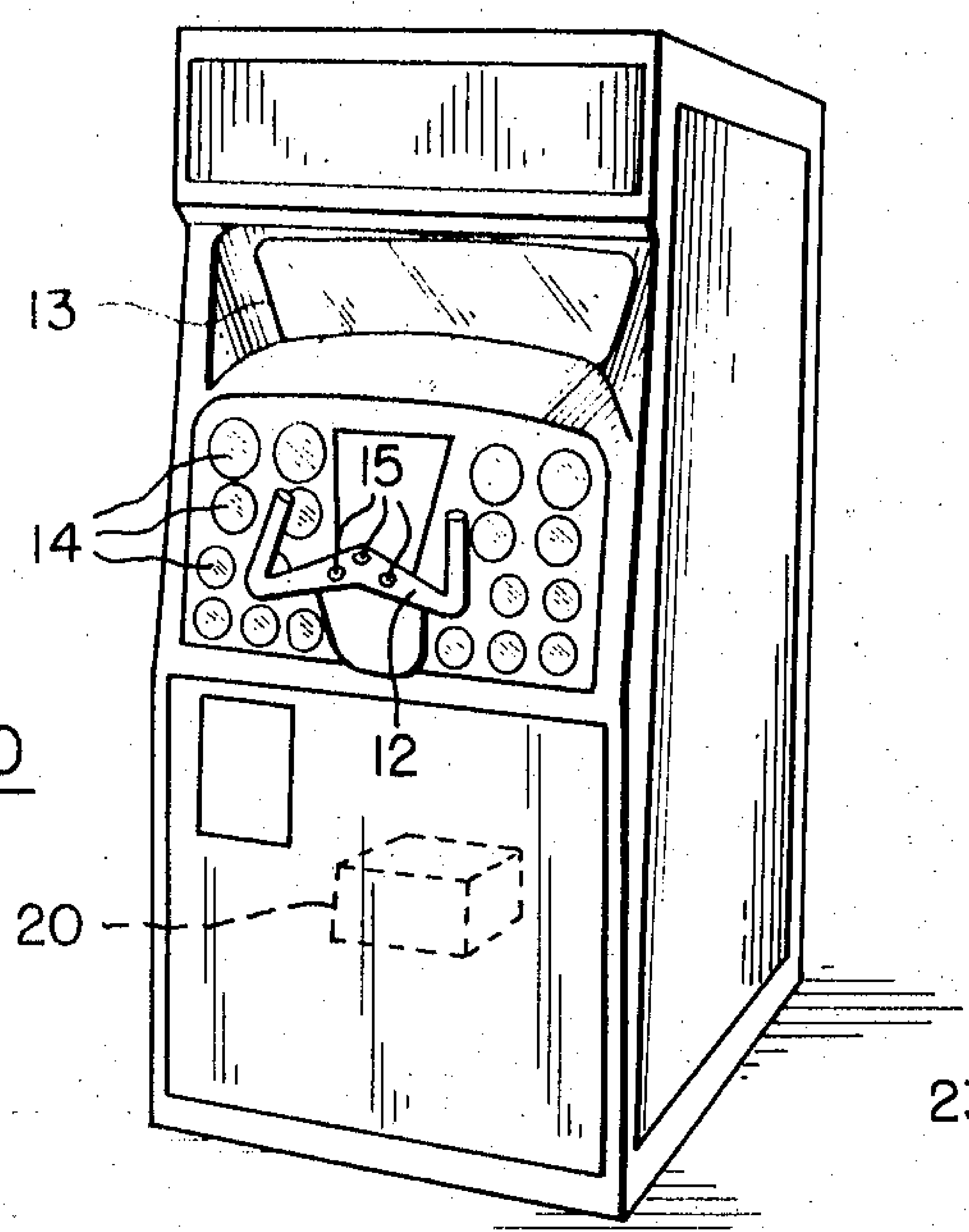
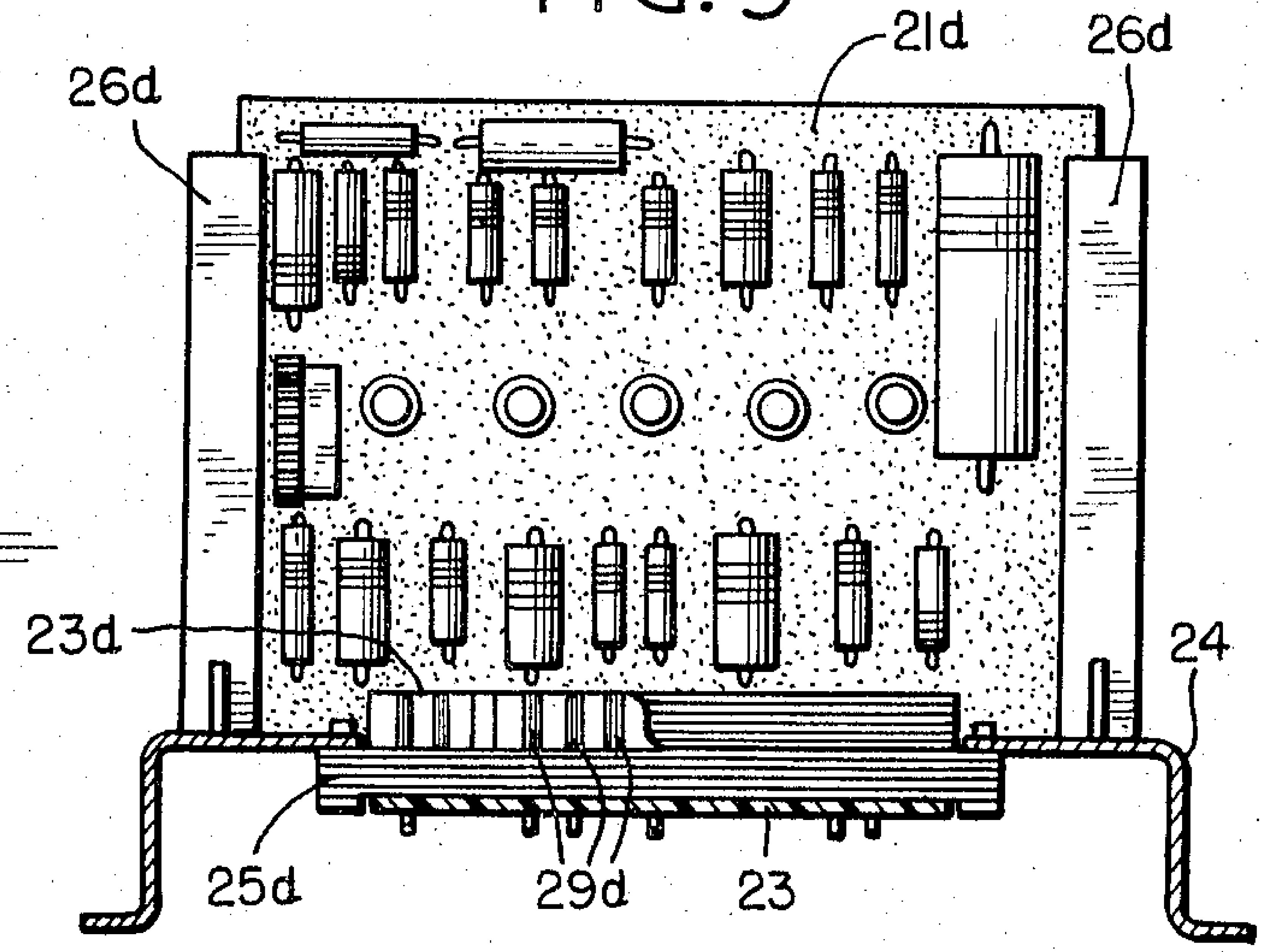


FIG. 3



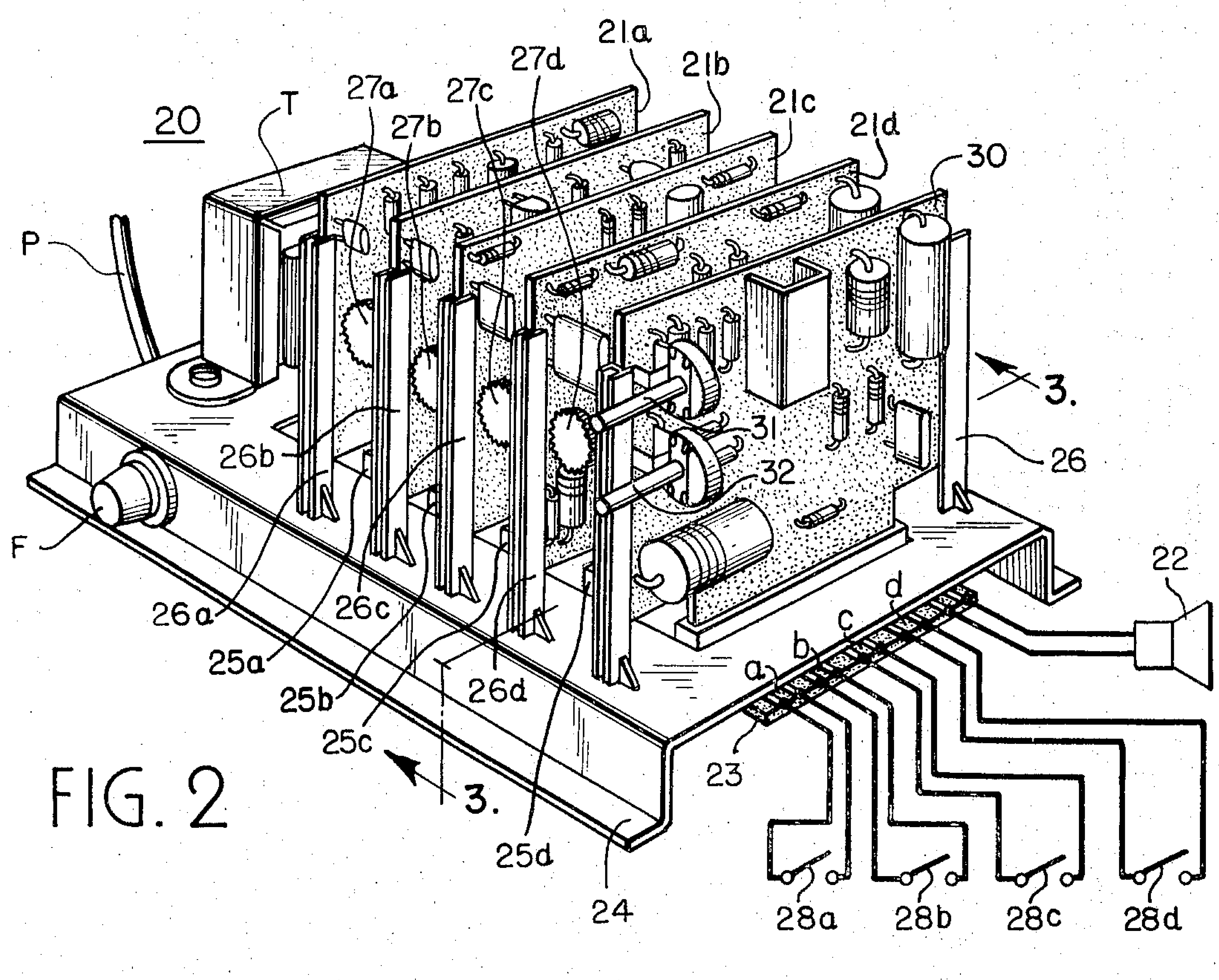


FIG. 2

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FIG. 4

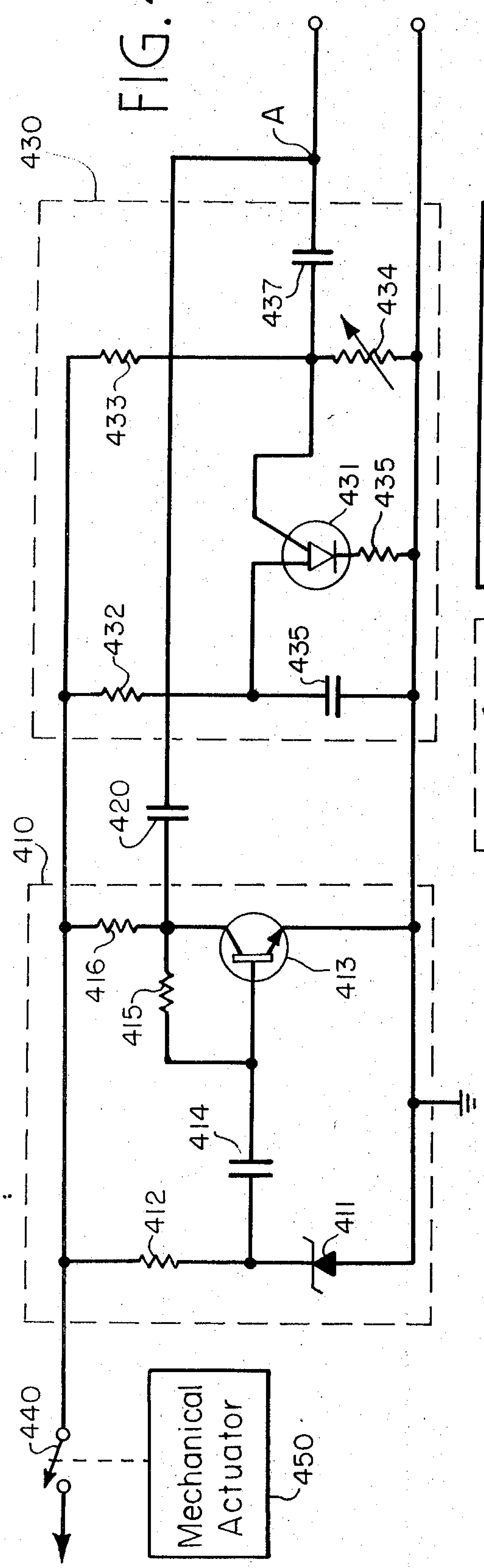
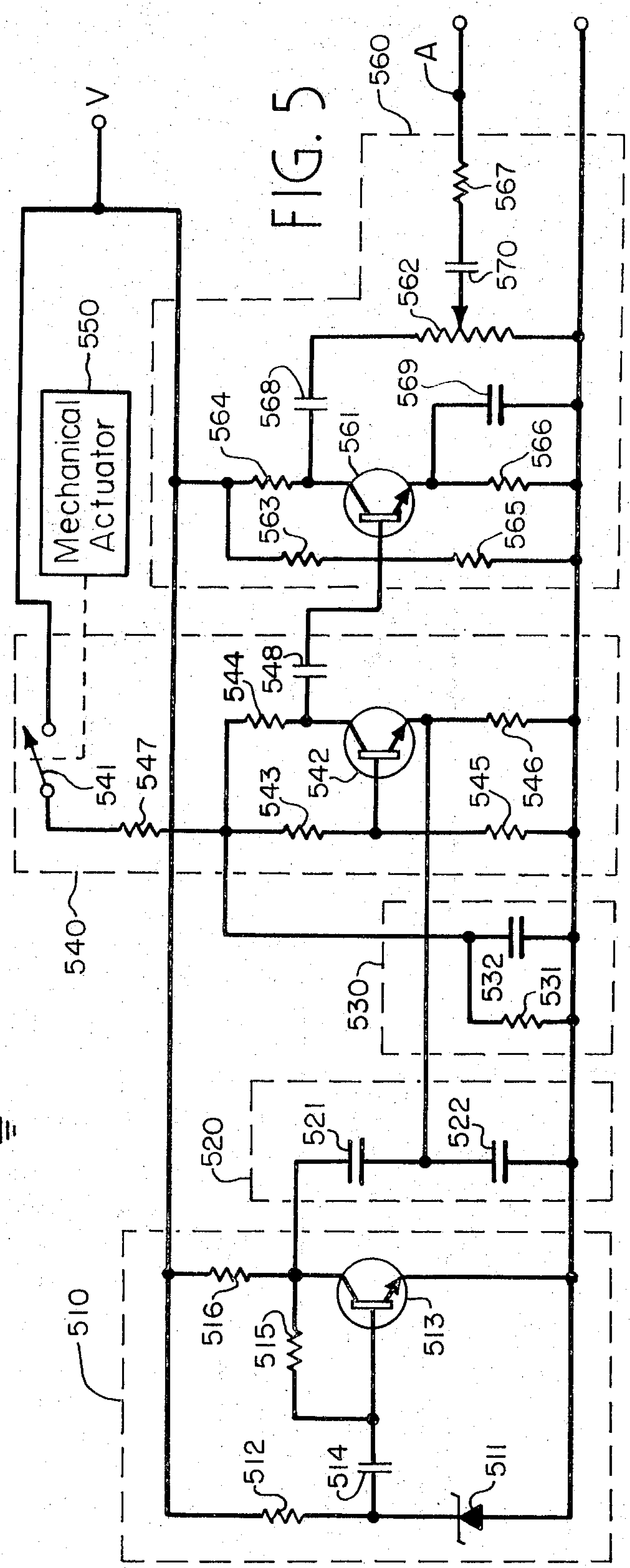
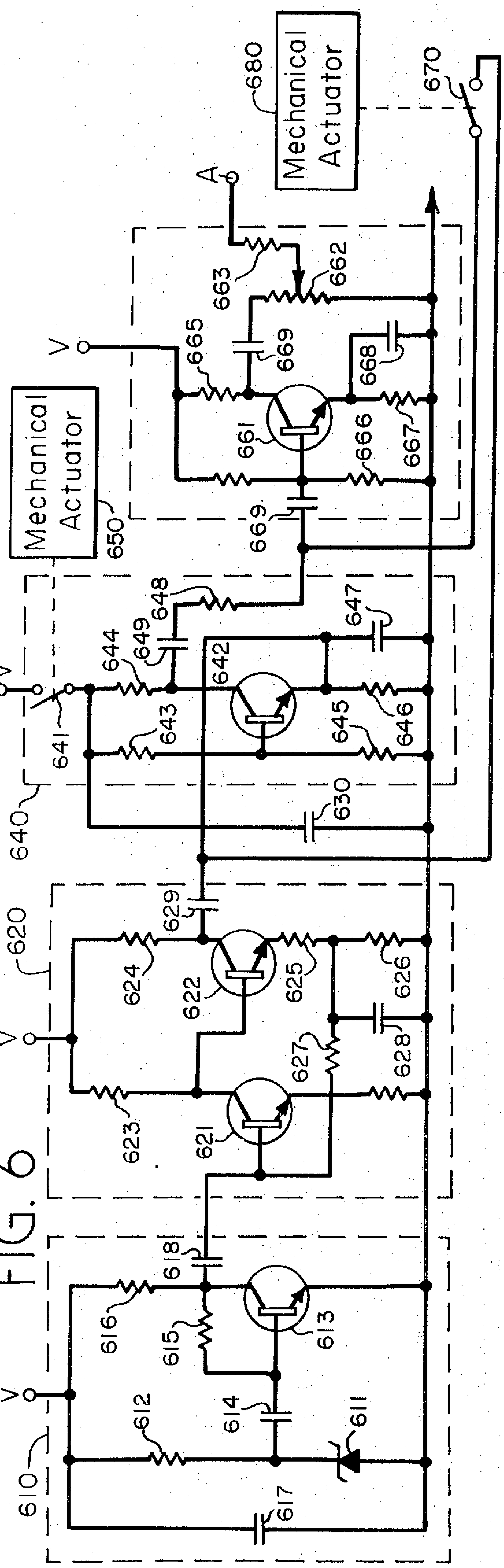


FIG. 5




Mechanical Actuator
Mechanical Actuator
V
V
V
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A

FIG. 6

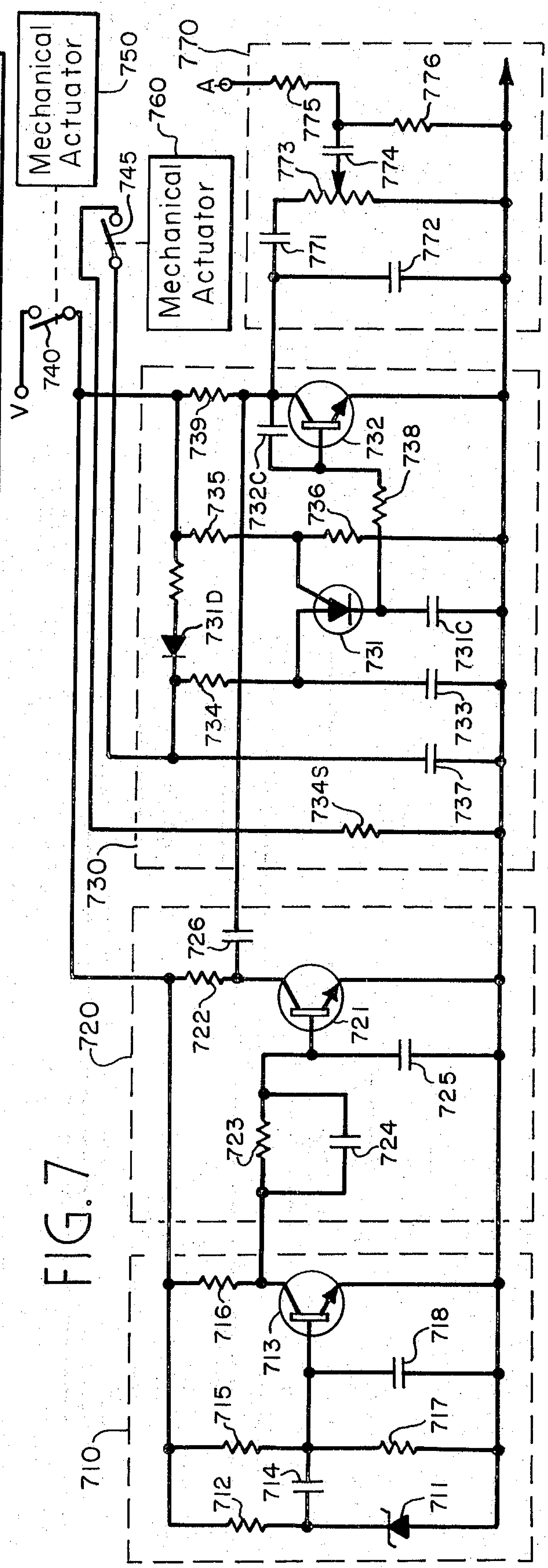
Mechanical Actuator
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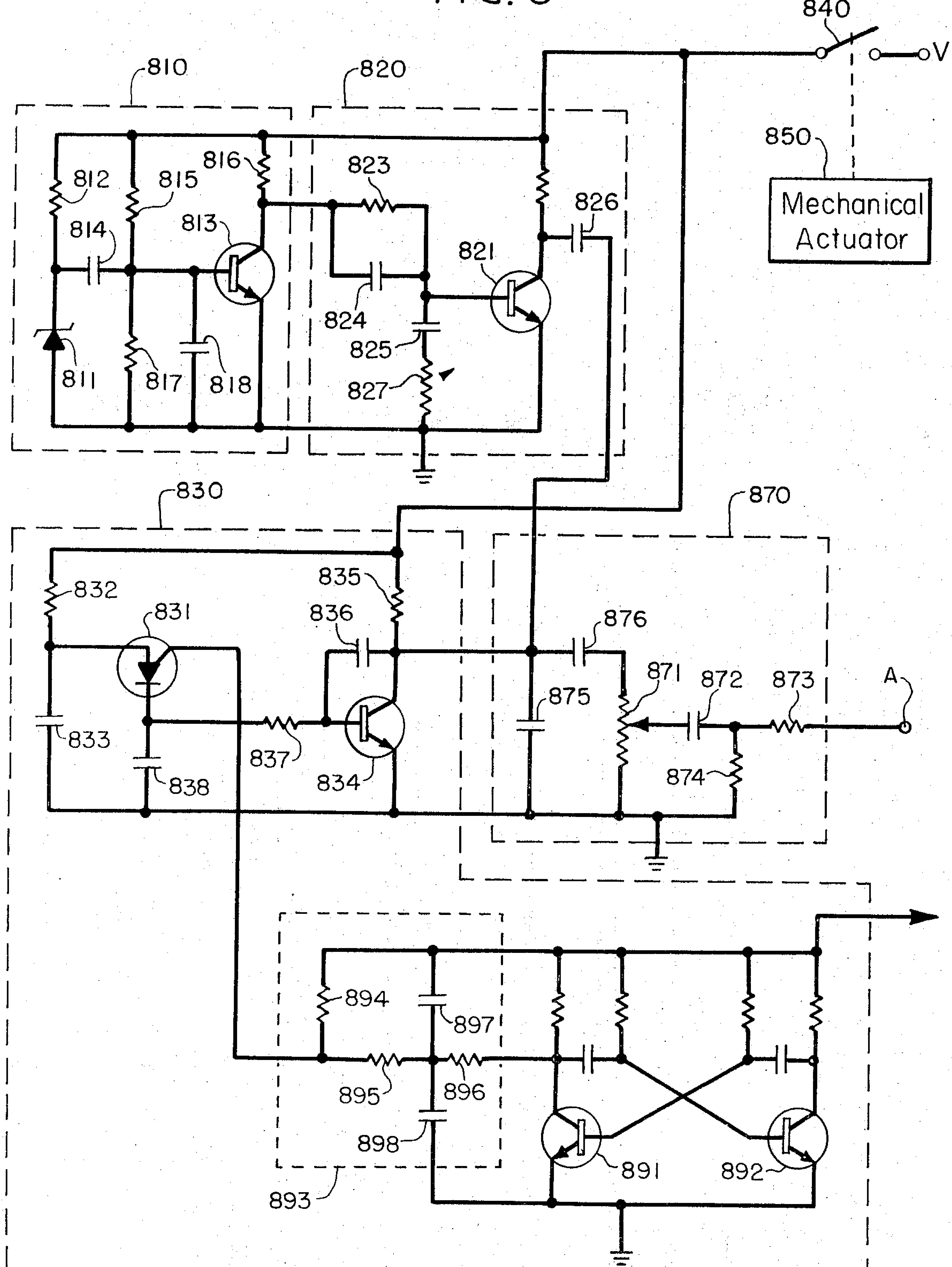
FIG. 7

FIG. 8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SOLID-STATE SOUND EFFECT GENERATING SYSTEM

The present invention relates to solid-state sound effect generating systems generally, and more particularly to such systems used in conjunction with coin-operated amusement devices in which it is desirable to accompany the occurrence of each of certain events with a corresponding predetermined sound effect.

Sound effect generating systems are widely used for various applications where it is not convenient or possible to have the actual sound. Such applications include radio and television studios, stage plays, movies, phonograph recording studios, and even as accompaniment for some live-entertainment performers. One particular application which is becoming increasingly popular is that of coin-operated amusement games of the type in which various events such as scoring or actions (e.g., motorcycles, flying airplanes, roving tanks, the firing of guns, and even the landing/docking of "spaceships") are made to seem more realistic, especially to the children who usually play them, by accompanying each event with the sound effect naturally associated therewith. Quite obviously, the more realistic the sound effects are, and the greater the number of sound effects provided in a given game, the more popular the game may become.

One method of generating realistic sound effects is to make a magnetic recording of the actual sound on a continuous-loop magnetic tape and have this tape played back whenever the event associated therewith occurs in the game. This method, of course, involves providing a magnetic play-back system, including a magnetic play-back head, amplifiers, loudspeakers, a motor system to drive the tape, and a relatively sophisticated cueing mechanism to start and stop the tape at the appropriate times. With frequent and erratic use, especially such as that to which amusement games are generally subjected, magnetic tape soon becomes noisy which detracts from the sound effect recorded thereon. In addition, dirt accumulates on the tape and tape lubrication deteriorates, both of which substantially increase the amount of wear on the recording head, thereby decreasing operating efficiency and increasing frequency of repair or replacement. Moreover, as with any device having moving parts, the cueing and drive mechanisms of magnetic tape systems are often subject to misadjustment malfunction, and eventual inoperativeness.

Another approach to the problem of providing sound effects is an electronic or mechanical approach which consists of designing a specific system for a particular application. By various switching arrangements, several sound effects are produced by a single complex circuit or device. However, not only is servicing such a system inconvenient and relatively expensive but, moreover, amusement games by their very nature are quite faddish and therefore often lose their appeal after a relatively short period of time. Consequently, with this approach, not only does the exterior physical appearance (i.e., the lights, pictures, controls, etc.) of the game become obsolete, but also the interior sound effect system as well. The cost of updating the game thus may become so prohibitive that the game may usually be scrapped instead.

It is therefore an object of the invention to provide an improved solid-state sound effect generating system.

It is another object of the invention to provide such an improved system which is highly adaptable to a coin-operated amusement game and which provides simple and inexpensive substitution of sound effects and reliable operation without cueing.

These and other objects of the invention are more particularly set forth in the following detailed description and in the accompanying drawings, of which:

FIG. 1 is a perspective view of a typical amusement game employing a preferred embodiment of the invention;

FIG. 2 is a perspective view of a sound effect generating system in accordance with a preferred embodiment of the invention which may be used with the amusement game shown in FIG. 1;

FIG. 3 is a sectional view, partially broken away, taken along line 3—3 of FIG. 2;

FIG. 4 is an electrical schematic diagram of a circuit utilized in the preferred embodiment of the invention shown in FIGS. 1 and 2 to generate the sound effect of a jet engine;

FIG. 5 is an electrical schematic diagram of a circuit utilized in the preferred embodiment of the invention shown in FIGS. 1 and 2 to generate the sound effect of gun fire;

FIG. 6 is an electrical schematic diagram of a circuit utilized in the preferred embodiment of the invention shown in FIGS. 1 and 2 to generate the sound effect of an explosion;

FIG. 7 is an electrical schematic diagram of a circuit utilized in the preferred embodiment of the invention shown in FIGS. 1 and 2 to generate the sound effect of an armored tank; and

FIG. 8 is an electrical schematic diagram of a circuit utilized in the preferred embodiment of the invention shown in FIGS. 1 and 2 to generate the sound effect of a propeller-driven airplane.

With reference to FIG. 1, there is generally shown a typical coin-operated amusement device **10** which employs a preferred embodiment of the invention symbolically shown in dashed-outline form as block **20** and discussed below in greater detail with reference to FIG. **2.** Device **10** represents any of a number of similar amusement devices in which the operator (not shown) manipulates a control member **12**, or the like, to maneuver a device (not shown) which is typically visible through a glass window **13.** Control member **12** may be used as the steering mechanism for an airplane, armored tank, motorcycle, etc., and, if desired, may further include various pushbuttons **15** for actuating breaks, accelerators, guns, sirens, etc. For example, control member **12** may represent the handlebars of a motorcycle to permit the maneuvering of a scaled-down model of a motorcycle (not shown) which is typically visible through window **13.** A roadway or obstacle course or the like (also not shown) is also commonly visible to the operator through window **13.** The typical object of the game is to maneuver the motorcycle down the roadway or through the obstacle course in such a manner as to avoid as many objects as possible at the highest possible speed. As the game progresses, the operator is rated in some manner, such as by counting the number of collisions verses distance traveled, and various scoring indicators are actuated behind window **13** and/or on the front of the game by various lights or dials symbolically represented here at **14.**

In an attempt to add realism to the game, it is quite desirable to have specific game events accompanied by corresponding predetermined sound effects. For the motorcycle game example described above, it might be desirable to incorporate sound effects of not only the motorcycle as it traverses the course, but also of the collisions when various obstacles are not avoided, police sirens when traffic laws are not obeyed, screeching tires when the brakes are applied suddenly, and the like. Similarly, in another game, where control **12** is used to represent the steering mechanism of an airplane, dials **14** the navigational instruments, and window **13** the windshield of the cockpit, the object of the game then might be to shoot down enemy planes by machine gun, drop bombs on or fire rockets at designated targets, or climb or dive to avoid enemy planes or missiles. Quite obviously, each of these events also has a very distinct sound effect which, if incorporated in the amusement game, would also add considerably to the overall realism and enjoyment of the game. In addition, it may be desirable in some games to have the scoring accompanied by the sound effect of a siren, whistle, etc.

Applicant's invention, as hereinafter described in greater detail, not only generates such sound effects electronically, but also facilitates the substitution of one sound effect for another in a very convenient and inexpensive manner so that the basic game may be changed from, for example, a "motorcycle" to a "jet plane" without replacing the entire system. Also, the same basic system parts may be manufactured and supplied for many different games.

Referring now to FIG. **2,** generally, there is shown a preferred embodiment of the invention of an improved system **20** for selectively generating a plurality of sound effects comprising a plurality of interchangeable plug-in printed circuit boards **21***a*, **21***b*, **21***c*, and **21***d*, and a non-interchangeable circuit board **30.** Each circuit board has mounted thereon an electronic circuit capable of being actuated to produce an electrical output signal representative of a unique one of the sound effects desired, as hereinafter described in greater detail. Each circuit board is further provided with a series of electrical contacts formed on a portion of its lower edge to create a plug to mate with corresponding jacks in the control chassis **24** (see FIG. **3**). Electromechanical transducer means are provided in the form of a loudspeaker **22** which is coupled to the circuits on circuit boards **21***a* – **21***d* by means of an additional circuit board or so-called "mother board" **23** mounted horizontally beneath control chassis **24.** Loud-speaker **22** is responsive to the electrical output signal from the circuits on circuit boards **21***a* – **21***d* for converting these electrical output signals into the desired sound effects. Control chassis **24** has a corresponding plurality of jacks **25***a*, **25***b*, **25***c*, and **25***d* for interchangeably receiving and supporting the edge-mounted circuit boards **21***a* – **21***d*, respectively. Mechanical reinforcement for circuit boards **21***a* – **21***d* is provided on both ends of the boards by a pair of longitudinally-grooved support members **26***a*, **26***b*, **26***c*, and **26***d*, respectively. Boards **21***a* – **21***d* are received by control chassis **24** by sliding the boards into the grooves until the plugs made with the jacks whereupon electrical contact is made with circuit board **23.** Circuit board **30** represents a non-interchangeable board which is received and supported by control chassis **24** in a similar manner and upon which is mounted electronic circuitry common to the circuits of boards **21***a* – **21***d* (e.g., additional amplification, tone control, volume control, power supply, and the like). Circuit board **23** also couples switching means, here shown as four normally open switches **21***a*, **21***b*, **21***c*, and **21***d* coupled to circuit board **23** at terminals *a*, *b*, *c*, and *d*, respectively, to the electronic circuits. Each switch is responsive to the occurrence of a specific event in the amusement game for selectively actuating the corresponding electronic circuit to thereby simultaneously accompany a particular event with its associated sound effect.

More particularly, control – **24** of system **20** includes a power cord P to connect the system to a suitable source of power such as the 110-volt AC electrical power source commonly found in most homes and office buildings. In addition, a power transformer T is provided to reduce the source voltage to that desired for the system and a fuse F is provided to guard against short circuits in the conventional manner. Circuit board **30** preferably supports the power supply circuitry, audio power amplifier circuitry, and any other auxiliary circuitry common to the circuits of circuit boards **21***a* –**21***d*. Also mounted on circuit board **30** are two controls **31** and **32** which may be used to adjust the volume and tone of the audio output signal to suit the particular application in which the illustrated embodiment of the invention is practiced. The desired output signal level of each sound effect is obtained by having individual amplitude controls **27***a*, **27***b*, **27***c*, and **27**d on circuit boards **21***a*, **21***b*, **21***c*, and **21***d*, respectively. While circuit board **30** is not made interchangeable with circuit boards **21***a* – **21***d*, it nevertheless may be made interchangeable with circuit boards similar to it but having audio power amplifier circuits of different output signal capabilities.

Thus, it may be seen that the illustrated embodiment of the invention provides for convenient interchanging of sound effects with minimal cost and delay. For example, if the circuit of board **21***a* were designed to simulate the sound of a motorcycle, in response to the contact closure of siwtch **28***a* by the depressing of the accelerator (not shown) on game **10** of FIG. **1,** and it was desired to change game **10** from that of a "motorcycle" to that of a "jet fighter," card **21***a* would be removed from control chassis **24** and a similar card (not shown) having a circuit mounted thereon for generating the sound effect of a jet engine would be substituted therefor. Circuit boards **21***b*, **21***c*, and **21***d* may also be replaced in a similar manner. Other than changing the exterior appearance of game **10,** none of the switching mechanisms, control chassis, loudspeaker, etc. would need to be replaced. Consequently, the basic structure of the game would not become obsolete and the cost of changing it to a new game would be merely that of the new plug-in circuit boards.

FIG. **3** shows the plug-in circuit board feature of the illustrated embodiment of the invention shown in FIG. **2.** The sectional view taken along line **3—3** of FIG. **2** provides a more detailed view of circuit board **21***d*, its reinforcement members **26***d*, plug portion **23***d*, control chassis **24,** jack **25***d*, and common circuit board **23.** The partially broken away portion shows in detail the electrical contacts **29***d* of plug portion **23***d*.

FIGS. 4 through 8 are each electrical schematic diagrams of circuits used to generate different sound effects. In general, each circuit comprises a random noise generator for developing an electrical signal having a random audio frequency spectrum. Filtering means are coupled to the random noise generator to obtain an audio frequency signal having a preselected frequency characteristic appropriate for the sound effect being developed. Means are coupled to the filtering means for modulating the preselected-frequency signal to produce a desired signal corresponding to the sound effect being developed. Finally, gating means are coupled to the generating means and modulating means for enabling application of the desired signal to the output of the circuit only in response to an external command or trigger signal, to thereby develop the electrical output signal representative of the predetermined sound effect desired. The external command or trigger signal may be supplied in any conventional manner and, since the particular means for supplying it forms no part of the invention, it is symbolically shown in each circuit as a block labeled "mechanical actuator." In some of the illustrated embodiments, it is desirable to include an audio preamplifier in order to obtain an output signal at an increased amplitude suitable for application to an audio power amplifier. In each embodiment, the particular type of filtering and modulation required to obtain the most accurate representation of the sound effect desired is determined empirically. In other words, a recording of the actual sound effect desired is made and then displayed graphically on an oscilliscope, oscillograph, or the like. The output of the circuit designed to develop the electrical signal representative of the recorded sound effect is also graphically displayed so that it can be compared to that of the actual sound effect and then the individual circuit components and their interconnections are adjusted to obtain the closest possible match. Alternatively, an audio spectrum analyzer may be employed in a well-known manner to analyze the components of the recorded sound, and the circuit parameters are then adjusted to produce corresponding frequency components to synthesize the sound.

More particularly, with reference to FIG. 4, there is shown an electrical schematic diagram of a circuit which may be employed in a preferred embodiment of the invention for developing an electrical output signal at the output terminal A, in response to the application of an external command or trigger signal, representative of the sound made by a jet engine such as that used in a military fighter plane. Random noise generating means 410 for generating an electrical signal having a random audio frequency spectrum comprises a Zener or avalanche-breakdown diode 411 which is operated at a specific operating point by means of diode-biasing resistor 412 so that a white noise or "swishing" signal is generated and coupled to the base electrode of an amplifying transistor 413 by means of a coupling capacitor 414. Transistor-biasing resistors 415 and 416 are employed in a conventional manner to operate transistor 413 as a standard Class A audio amplifier.

The random-frequency audio range signal thus generated is coupled to a modulating means 430 by a filtering means in the form of a capacitor 420. The value of capacitor 420 is selected to establish a high-pass filter with a cutoff frequency of approximately 2,000 Hertz so that relatively low audio frequency signal components generated by random frequency generator 410 are not coupled to modulator 430. In this embodiment of the invention, the preselected-frequency signal of filter 420 is coupled to modulator 430 at output terminal A thereof. Modulator 430 comprises an anode-gated silicon controller rectifier (SCR) 431 which, together with biasing resistors 432, 433, 434, 435, and timing capacitor 436, operates as a relaxation oscillator with a frequency of oscillation of approximately 3,500 Hertz. The oscillating signal is coupled to output terminal A by means of a coupling capacitor 437 to thereby amplitude modulate the preselected-frequency signal also present at terminal A to produce a desired signal corresponding to the sound effect being produced. SCR-biasing resistor 434 is made adjustable to provide a pitch adjustment to simulate acceleration/deacceleration of the "jet engine."

A gating means in the form of a switch 440 is coupled to generator 410 and modulator 430 by way of the DC power supply line L leading to voltage source V. Switch 440 is responsive to an external trigger signal supplied by a mechanical actuator 450 to enable application of the desired electrical output signal to the output terminal A only in response to the external trigger signal. Thus, when mechanical actuator 450 closes switch 440, as for example when the engine-accelerator switch on the front of the "jet plane" game is depressed, voltage V is applied to generator 410 and modulator 430 so that they are both energized and thereby develop an electrical output signal representative of a predetermined sound effect (i.e., a jet engine noise) at output terminal A.

An example of one specific construction of the circuit of FIG. 4 in accordance with the preferred embodiment of the invention has been built and performed satisfactorily utilizing substantially the following circuit values and parameters:

Resistor 412	560K ohms
Resistor 415	1M ohms
Resistor 416	10M ohms
Resistor 432	1M ohms
Resistor 433	22K ohms
Resistor 434	47K ohms
Resistor 435	680 ohms
Capacitor 414	0.047 microfarad
Capacitor 420	0.0033 microfarad
Capacitor 436	0.001 microfarad
Capacitor 437	0.22 microfarad
Diode 411	1N758
Anode-gated SCR 431 (Programmable Unijunction Transistor)	2N6027(G.E.)
Transistor 413	2N3394
Supply Voltage V	+18 volts

With respect to FIG. 5, there is shown in particular an electrical schematic diagram of a solid-state electronic circuit for developing at the output terminal A of the circuit, in response to the application of an external trigger signal, an electrical output signal representative of the sound of gunfire. Random noise generating means 510 for generating an electrical signal having a random audio-frequency spectrum comprises an avalanche-breakdown or Zener diode 511, a diode-biasing resistor 512, an amplifying transistor 513, a coupling capacitor 514, and transistor-biasing resistors 515 and 516. Generator 510 operates in a manner quite similar to generator 410 of FIG. 4, although the values of the resistors and capacitors are slightly changed in order to emphasize those frequencies in the audio-frequency spectrum that comprise the frequency spectrum of the sound of gunfire.

Filtering means **520** in the form of two capacitors **521** and **522** is coupled to generating means **510** for filtering the random-frequency signal to obtain an audio-frequency signal having a preselected freqency characteristic. For this particular sound effect, gunfire, the value of capacitor **521** is selected such that more low-frequency components (e.g., below 400 Hertz) are passed than high-frequency components and the value of capacitor **522** is selected such that most of the high-frequency components are bypassed to ground.

Modulating means **530** is provided for modulating the preselected-frequency signal to produce a desired signal corresponding to the sound effect being developed. Modulator **530** comprises a timing resistor **531** and a storage capacitor **532** which cooperate with a gating means **540** to amplitude-modulate the output signal of filtering means **520**, as described below in greater detail in conjunction with the discussion of the gating means.

Gating means **540** is coupled to generating means **510** and modulating means **530** for enabling application of the desired signal to output terminal A only in response to an external trigger signal supplied by a mechanical actuator **550**. Gating means **540** comprises a mechanical momentary-contact switch **541** and a switching transistor **542** together with transistor-biasing resistors **543, 544, 545,** and **546.** Switch **541** is momentarily closed in response to the external trigger signal from mechanical actuator **550** when the associated game event occurs (e.g., a gun trigger is pulled on the front of the game). The contact closure of switch **541** applies a suitable supply voltage V to switching transistor **542** by means of resistor **547** and the transistor-biasing resistor network to bias switching transistor **542** to the conductive or ON state. Conversely, when momentary-contact switch **541** opens, switching transistor **542** immediately returns to its quiescent non-conductive or OFF state. The contact closure of switch **541** also applies voltage V to the junction of resistor **531** and capacitor **532** of modulator **530.** Without modulator **530**, the application of voltage V to switching transistor **542** would momentarily couple the signal from filtering means **520** through switching transistor **542** to the base electrode of an amplifying transistor **561** of an amplifying stage **560,** to thus produce a short burst of the preselected-frequency signal at output terminal A. With the addition of modulator **530,** however, the operation of transistor **542** is altered to amplitude-modulate the preselected-frequency signal to generate an output signal that more closely approximates the sound effect of gunfire. Instead of switching transistor **542** abruptly turning off when momentary-contact switch **541** opens, the charge stored by storage capacitor **532** discharges through switching transistor **542**, and its associated biasing network, to gradually turn off switching transistor **542** so that an exponentially diminishing amplitude results. Once again, the values of timing resistor **531** and **547** are determined empirically in order to obtain best representation of the desired signal.

In the embodiment of FIG. **5,** amplifying stage **560** is added to increase the amplitude of the desired output signal for application to a suitable loudspeaker (not shown, see FIG. **2**). In addition, a potentiometer **562** is incorporated in amplifying stage **560** to permit adjustment of the amplitude of the output signal to suit different applications.

An example of one specific construction of the circuit of FIG. **5** in accordance with the preferred embodiment of the invention has been built and performed satisfactorily utilizing substantially the following circuit values and parameters:

Resistor 512	1M ohms
Resistor 515	1M ohms
Resistor 516	10K ohms
Resistor 531	39K ohms
Resistor 543	100K ohms
Resistor 544	10K ohms
Resistor 545	22K ohms
Resistor 546	10K ohms
Resistor 547	1K ohms
Resistor 562	50K ohms
Resistor 563	270K ohms
Resistor 564	18K ohms
Resistor 565	12K ohms
Resistor 566	560 ohms
Resistor 567	22K ohms
Capacitor 514	0.22 microfarad
Capacitor 521	5 microfarads
Capacitor 522	1 microfarad
Capacitor 532	5 microfarads
Capacitor 548	0.22 microfarad
Capacitor 568	0.22 microfarad
Capacitor 569	10 microfarads
Capacitor 570	0.22 microfarad
Diode 511	1N758
Transistor 513	2N3394
Transistor 542	2N3394
Transistor 561	2N3394
Supply Voltage V	+18 volts

With reference to FIG. **6,** there is shown in particular an electrical schematic diagram of a solid-state electronic circuit for developing at the output terminal A of the circuit, in response to the application of an external trigger signal, an electrical output signal representative of the sound of an explosion. The circuit comprises noise generating means **610** for generating an electrical signal having a random audio-frequency spectrum. Generating means **610** comprises an avalanche-breakdown or Zener diode **611,** a diode-biasing resistor **612,** an amplifying transistor **613,** a coupling capacitor **614** and transistor-biasing resistors **615** and **616.** The circuit is coupled to a suitable voltage source V and operated in a manner similar to generating means **410** of FIG. **4** and **510** of FIG. **5** with the exception of a decoupling capacitor **617** which is included to filter any 60-cycle or "hum" components that may be present in voltage V.

Filtering means **620** is coupled to generating means **610** for filtering the random-frequency signal therefrom to obtain an audio-frequency signal having a preselected frequency characteristic for an explosive sound. For this purpose, the circuit of FIG. **6** includes a pair of transistors **621** and **622** with their respective load resistors **623** and **624.** The signal from generating means **610** is coupled to filtering means **620** by a coupling capacitor **618,** the value of which is selected to be high enough to pass essentially all of the frequency components of the signal generated by generating means **610.** A pair of emitter resistors **625** and **626** are included with transistor **622** to provide a feedback signal source. A feedback signal path is established from the junction of emitter resistors **625** and **626** through feedback resistor **627** to the base of transistor **621.** A filtering capacitor **628** is coupled from the feedback path to ground as shown to bypass to ground any AC signal components at the junction of resistors **625** and **626** so that the feedback path operates only with respect to DC signal components. In addition, the value of resistor **627** is selected low enough so that the capacitor **628** also acts to filter some of the high-frequency components from the signal applied to the base electrode of transistor **621.**

Gating means **640** is coupled to generating means **610** by way of filtering means **620** for enabling application of the desired signal to output terminal A only in response to an external trigger signal. Gating means **640** includes a momentary-contact switch **641** which is actuated by a mechanical actuator **650** in accordance with the particular game event associated with the sound effect being generated. The closing of switch **641** applies voltage source V to switching transistor **642** by way of transistor-biasing resistors **643, 644, 645,** and **646** to cause switching transistor **642** to be biased in the conductive or ON state. Voltage V is concomitantly applied to a modulating means in the form of a storage capacitor **630** so that switching transistor **642** gradually returns to its quiescent non-conductive or OFF state after momentary-contact switch **641** is opened to thus amplitude-modulate the preselected-frequency signal to produce the desired output signal in a manner very similar to that described above with reference to FIG. **5.** In other words, biasing switching transistor **642** into the conductive state enables a signal appearing at the collector of filtering transistor **622** to be applied by means of coupling capacitors **629, 649,** and **659** to the base electrode of an amplifying transistor **661** of an amplifying stage **660.** By gradually returning switching transistor **642** to the non-conductive state, via the discharging of storage capacitor **630,** the amplitude of the signal coupled therethrough is gradually diminished to obtain an output signal which more closely approximates the sound of an explosion. Amplifying stage **660** is included to provide amplification of the electrical signal representative of the explosion sound effect to a desired level which may be adjusted by means of a potentiometer **662.**

The explosion sound effect is typically desirable in connection with a game event such as when a properly aimed missile, rocket, bullet, etc., hits a target. In the event the target is missed, it is often desirable to have a sound effect that indicates this, in which case means such as a switch **670** operated by a mechanical actuator **680** may be used to bypass modulating means **630** and gating means **640** and thus couple the output signal of filtering means **620** directly to the input of amplifying means **660.**

An example of one specific construction of the circuit of FIG. **6** in accordance with the preferred embodiment of the invention has been built and found to perform satisfactorily utilizing substantially the following circuits values and parameters:

Resistor 612	180K ohms
Resistor 615	1M ohms
Resistor 616	10K ohms
Resistor 623	47K ohms
Resistor 624	10K ohms
Resistor 625	82 ohms
Resistor 626	1K ohms
Resistor 627	680 ohms
Resistor 643	100K ohms
Resistor 644	10K ohms
Resistor 645	22K ohms
Resistor 646	10K ohms
Resistor 648	1K ohms
Resistor 662	50K ohms
Resistor 663	22K ohms

-Continued

Resistor 664	270K ohms
Resistor 665	18K ohms
Resistor 666	12K ohms
Resistor 667	560 ohms
Capacitor 614	1 microfarad
Capacitor 617	100 microfarads
Capacitor 618	5 microfarads
Capacitor 628	10 microfarads
Capacitor 629	5 microfarads
Capacitor 630	5 microfarads
Capacitor 647	1 microfarad
Capacitor 649	15 microfarads
Capacitor 668	10 microfarads
Capacitor 669	0.22 microfarad
Diode 611	1N758
Transistor 613	2N3394
Transistor 621	2N3394
Transistor 622	2N3394
Transistor 642	2N3394
Transistor 661	2N3394
Supply Voltage V	+18 volts

With respect to FIG. **7,** there is shown in particular, an electrical schematic diagram in accordance with the preferred embodiment of the invention of an electronic circuit for developing at the output terminal A, in response to the application of an external trigger signal, an electrical output signal representative of the sound made by an armored tank as it travels overland. The circuit comprises noise generating means **710** for generating an electrical signal having a random audio-frequency spectrum. Generating means **610** includes an avalanche-breakdown or Zener diode **711,** a diode-biasing resistor **712,** an amplifying transistor **713,** a coupling capacitor **714** and transistor-biasing resistors **715, 716,** and **717,** and operates in a manner very similar to generators **410, 510,** and **610** of FIGS. **4, 5,** and **6,** respectively. In addition, a filtering capacitor **718** is coupled from the base of transistor **713** to ground as shown to shunt some of the high-frequency signal components (e.g., **1000** Hertz and above) to ground.

Filtering means **720** is coupled to generating means **710** for filtering the random-frequency signal to obtain an audio-frequency signal having a preselected frequency characteristic for an armored tank sound. Filtering means **720** includes an amplifying transistor **721** having a suitable load resistor **722.** The filtering to obtain the desired frequency characteristic is implemented by an RC coupling network comprising the parallel combination of a resistor **723** and a capacitor **724,** and a shunt capacitor **725** which shunts some of the high-frequency signal components (e.g., 600 Hertz and above) from the base of amplifying transistor **721** to ground.

A modulating means **730** is coupled to the output of filtering means **720** by coupling capacitor **726** for modulating the preselected-frequency signal to produce the desired signal corresponding to the sound effect of an armored tank. Modulating means **730** includes anode-gated silicon controlled rectifier (SCR) **731** and an amplifying transistor **732.** SCR **731,** in conjunction with a timing capacitor **733** and SCR-biasing resistors **734, 735,** and **736,** operates as a relaxation oscillator which, when coupled to the base of amplifying transistor **732,** amplitude-modulates the preselected-frequency signal coupled to the collector of transistor **732** (by coupling capacitor **726**) to generate the desired electrical output signal. For this circuit, the oscillating frequency of the relaxation oscillator is made equal to approximately 100 Hertz so that the oscillating signal periodically increases and decreases the amplitude of the preselected-frequency signal at the rate of 0.5 Hertz to simulate the sound of an armored tank.

At the output of modulating means **730,** an additional circuit **770** is provided for tailoring the frequency characteristic of the output signal of modulating means **730** to more closely approximate the sound of an armored tank. A relatively large-value capacitor **771** is serially connected in the main signal path and a relatively small-value capacitor **772** is connected in parallel with the main signal path so that the high-frequency (e.g., above 600 Hertz) components of the signal are bypassed to ground and only the low-frequency components are passed on to output terminal A. In addition, a potentiometer **773** is provided as shown to enable the amplitude of the output signal to be varied to suit the particular application.

In the embodiment of the invention shown in FIG. **7,** gating means in the form of a switch **740** are provided which, in response to actuation by a mechanical actuator **750,** apply a suitable voltage source V to amplifying transistors **721** and **732,** thereby enabling application of the desired output signal to output terminal A only in response to an external trigger signal. An additional mechanical actuator **760** is used to operate a switch **745** and modulating means **730** to couple an additional timing resistor **734S** and timing capacitor **737** to the SCR **731** to decrease the frequency of oscillation of the relaxation oscillator and thereby simulate the sound effect of an armored tank traveling at a slower speed.

An example of one specific construction of the circuit of FIG. 7 in accordance with the preferred embodiment of the invention has been built and performed satisfactorily utilizing substantially the following circuit values and parameters:

Resistor 712	150K ohms
Resistor 715	220K ohms
Resistor 716	12K ohms
Resistor 717	62K ohms
Resistor 722	12K ohms
Resistor 723	1M ohms
Resistor 734	1M ohms
Resistor 734S	82K ohms
Resistor 735	22K ohms
Resistor 736	22K ohms
Resistor 738	1K ohms
Resistor 739	4.7K ohms
Resistor 773	50K ohms
Resistor 775	270K ohms
Resistor 776	18K ohms
Capacitor 714	10 microfarads
Capacitor 718	1 microfarad
Capacitor 724	0.22 microfarad
Capacitor 725	0.047 microfarad
Capacitor 726	0.22 microfarad
Capacitor 731C	1 microfarad
Capacitor 732C	0.02 microfarad
Capacitor 733	0.068 microfarad
Capacitor 737	25 microfarads
Capacitor 771	10 microfarads
Capacitor 772	0.022 microfarad
Capacitor 774	15 microfarads
Diode 711	1N758
Anode-gated SCR 731 (Programmable Unijunction Transistor)	2N6027
Diode 731D	A14A
Transistor 713	2N3394
Transistor 721	2N3394
Transistor 732	2N3394
Supply Voltage V	+18 volts

With respect to FIG. **8,** there is shown in particular an electrical schematic diagram in accordance with the preferred embodiment of the invention of an electronic circuit for developing at the output terminal A, in response to the application of an external trigger signal, an electrical output signal representative of the sound of a propeller-driven airplane with an automatic "climb" and "drive" feature. The circuit comprises noise generating means **810** for generating an electrical signal having a random audio-frequency sprectrum, and operates in a manner very similar to generator **710** of FIG. **7.** Generating means **810** includes an avalanche-breakdown or Zener diode **811,** a diode-biasing resistor **812,** an amplifying transistor **813,** a coupling capacitor **814,** and biasing resistors **815, 816,** and **817.** In addition, a bypass capacitor **818** is included from the base of transistor **813** to ground in order to eliminate high-frequency components (e.g., above 1,000 Hertz) from the output signal.

Means **820** are coupled to the generating means at the collector of amplifying transistor **813** for filtering the random-frequency signal to provide an audio-frequency signal having a preselected frequency characteristic for a propeller-driven airplane sound. Filtering means **820** includes an amplifying transistor **821** and a suitable load resistor **822.** Filtering is accomplished by a serially-connected RC coupling circuit comprising the parallel combination of a resistor **823** and a capacitor **824** together with a shunt-connected RC network comprising the series combination of a capacitor **825** and a variable resistor **827.** By making resistor **827** variable, some tone adjustment is provided.

Means **830** are coupled to filtering means **820** for modulating the preselected-frequency signal to produce a desired signal corresponding to the sound of a propeller-driven airplane. Modulating means **830** includes an anode-gated silicon controlled rectifier (SCR) **831** with its associated biasing resistor **832** and timing capacitor **833** which together operate as a relaxation oscillator. Modulating means **830** further comprises an amplifying transistor **834,** a load resistor **835,** and a feedback capacitor **836.** The cathode of SCR **831** is coupled to the base of amplifying transistor **834** by a coupling resistor **837** to provide an amplified oscillating modulating signal at the collector of amplifying transistor **834.** By making the frequency of oscillation equal to an audio frequency of approximately 300 Hertz and combining this signal with the output signal from filtering means **820** (at the collector of amplifying transistor **834**), the resulting amplitude-modulated electrical signal is highly representative of the sound of a propeller-driven airplane engine. Moreover, by varying the rate of oscillation of the relaxation oscillator at a rather slow rate (e.g., one-third Hertz), the sound effect thus generated closely resembles that of a propeller-driven airplane which is climbing and diving.

To develop the climbing and diving feature, modulating means **830** further comprises a free-running multivibrator including multivibrator transistors **891** and **892** which are operated in a conventional manner and timed to oscillate at the desired repetition rate (e.g., one-third Hertz). By coupling the collector of multivibrator transistor **891** to the anode gate of SCR **831** by means of a filter network **893,** the biasing of SCR **831** is varied at the repetition rate of the multivibrator to thereby vary the frequency of oscillation of the relaxation oscillator. Filter network **893** changes the pulse-train signal developed by the multivibrator to a sine-wave signal suitable for application to the gate of SCR **831.**

The output signals from filtering means **820** and modulating means **830** are combined in an output network **870** which provides some additional tailoring of the frequency response of the output signal and, by means of a potentiometer **871**, enables adjustment of the output signal level. The particular values of the capacitors and resistors used in output means **870**, as well as many of the others in the respective circuits, have been determined empirically to obtain the closest approximation of the sound effect desired, and may, of course, be modified for other applications.

In the schematic diagram shown in FIG. **8**, gating means in the form of a switch **840** are provided which, in response to actuation by a mechanical actuator **850**, apply a suitable voltage source V to amplifying transistor **813**, **821**, and **834** thereby enabling application of the desired output signal to output terminal A only in response to an external trigger signal.

An example of one specific construction of the circuit of FIG. **8** in accordance with the preferred embodiment of the invention has been built and performed satisfactorily utilizing substantially the following circuit values and parameters:

Resistor 812	150K ohms
Resistor 815	220K ohms
Resistor 816	12K ohms
Resistor 817	6.2K ohms
Resistor 822	12K ohms
Resistor 823	1M ohms
Resistor 827	10K ohms
Resistor 832	1M ohms
Resistor 835	47K ohms
Resistor 837	1K ohms
Resistor 871	50K ohms
Resistor 873	22K ohms
Resistor 874	18K ohms
Resistor 894	47K ohms
Resistor 895	10K ohms
Resistor 896	47K ohms
Capacitor 814	10 microfarads
Capacitor 818	0.47 microfarad
Capacitor 824	0.22 microfarad
Capacitor 825	0.1 microfarad
Capacitor 826	0.22 microfarad
Capacitor 833	0.01 microfarad
Capacitor 836	0.022 microfarad
Capacitor 838	0.47 microfarad
Capacitor 872	0.01 microfarad
Capacitor 875	0.022 microfarad
Capacitor 876	0.22 microfarad
Capacitor 897	50 microfarads
Capacitor 898	50 microfarads
Diode 811	1N758
Anode-gated SCR 831 (Programmable Unijunction Transistor)	2N6027
Transistor 813	2N3394
Transistor 821	2N3394
Transistor 834	2N3394
Transistor 891	2N3394
Transistor 892	2N3394
Supply Voltage	+18 volts

Thus, there has been shown and described a new and improved solid-state sound effect generating system which is highly adaptable to a coin-operated amusement game. A game constructed with the system of the invention may be easily and economically converted to a different, more popular game by simply "facelifting" the exterior and substituting new circuit boards with the desired new sound effects. The invention also provides for easy servicing. Should a board become defective, it can be replaced immediately thus avoiding costly replacement of the entire system. Moreover, with the increased speed of repairs afforded by the ease of circuit board replacement, less time, and therefore revenue, is lost while the game is "out of order." The invention also provides an improved cueing capability in that a given sound effect may be instantly stopped, started, loudened, softened, or have its pitch changed at any time during the operation of the game. The system of the invention has improved flexibility in that any number of desired sound effects may be incorporated, in any desired combination, with minimum cost and inconvenience. By having the main amplifier circuitry on a separate circuit board, the power output capability of the system may be changed to suit the particular application simply by substituting different-power amplifier boards. Other sound effects may be generated by a system in accordance with the invention by using an audio-frequency spectrum analyzer to analyze a recording of the actual sound desired to be generated to ascertain the approximate frequency composition thereof and then employ the principles of the invention to construct the appropriate circuit.

It will, of course, be understood that modifications of the present invention, in its various aspects, will be apparent to those skilled in the art, some being apparent only after study, and others being merely matters of routine electronic design. As such, the scope of the invention should not be limited by the particular embodiment and specific construction herein described, but should be defined only by the appended claims, and equivalents thereof.

Various features of the invention are set forth in the following claims.

What is claimed is:

1. In combination with an audio-visual amusement device of the type in which specific events are each accompanied by a corresponding predetermined sound effect, an improved system for selectively generating a plurality of said sound effects, comprising:

a plurality of interchangeable plug-in printed circuit boards each having mounted thereon a solid-state electronic circuit capable of being actuated to independently develop an electrical output signal representative of a unique one of said sound effects;

each said electrical circuit comprising a random noise generator for developing an electrical signal having a random audio frequency spectrum, filtering means coupled to said random noise generator for obtaining an audio frequency signal having a preselected frequency characteristic, and means for modulating said preselected frequency signal to thereby develop said output signal;

electromechanical transducer means coupled to said circuits and responsive to said electrical output signal for converting said output signal into said sound effect;

a control chassis having a corresponding plurality of jacks for interchangeably receiving and supporting said circuit boards, said chassis further having means for electrically interconnecting said received circuit boards;

and switching means coupled to said electronic circuits and responsive to the occurrence of any of said events for selectively actuating the corresponding electronic circuit to thereby simultaneously accompany a particular event with its associated sound effect.

2. An electronic sound-generating system for selectively generating a plurality of sound effects, and adapted for use with an audio-visual amusement device of the type in which specific events are each accompanied by a corresponding predetermined sound effect, comprising:

a plurality of interchangeable plug-in printed circuit boards each having mounted thereon a solid-state electronic circuit capable of being actuated to independently develop an electrical output signal representative of a unique one of said sound effects;

each said electrical circuit comprising a random noise generator for developing an electrical signal having a random audio frequency spectrum, filtering means coupled to said random noise generator for obtaining an audio frequency signal having a preselected frequency characteristic, and means for modulating said preselected frequency signal to there by develop said output signal;

electromechanical transducer means coupled to said circuits and responsive to said electrical output signal for converting said output signal into said sound effect;

a control chassis having a corresponding plurality of jacks for interchangeably receiving and supporting said circuit boards, said chassis further having means for electrically interconnecting said received circuit boards;

and switching means coupled to said electronic circuits and responsive to the occurrence of any of said events for selectively actuating the corresponding electronic circuit to thereby simultaneously accompany a particular event with its associated sound effect.

3. A circuit according to claim **1,** in which said modulating means comprise an anode-gated silicon-controlled rectifier operated as a relaxation oscillator to modulate the amplitude of said preselected-frequency signal at a predetermined audio-frequency repetition rate.

4. A circuit according to claim **3,** in which said modulating means further comprises a free-running monostable multivibrator coupled to said relaxation oscillator to vary the frequency of oscillation of said oscillator at a predetermined rate.

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