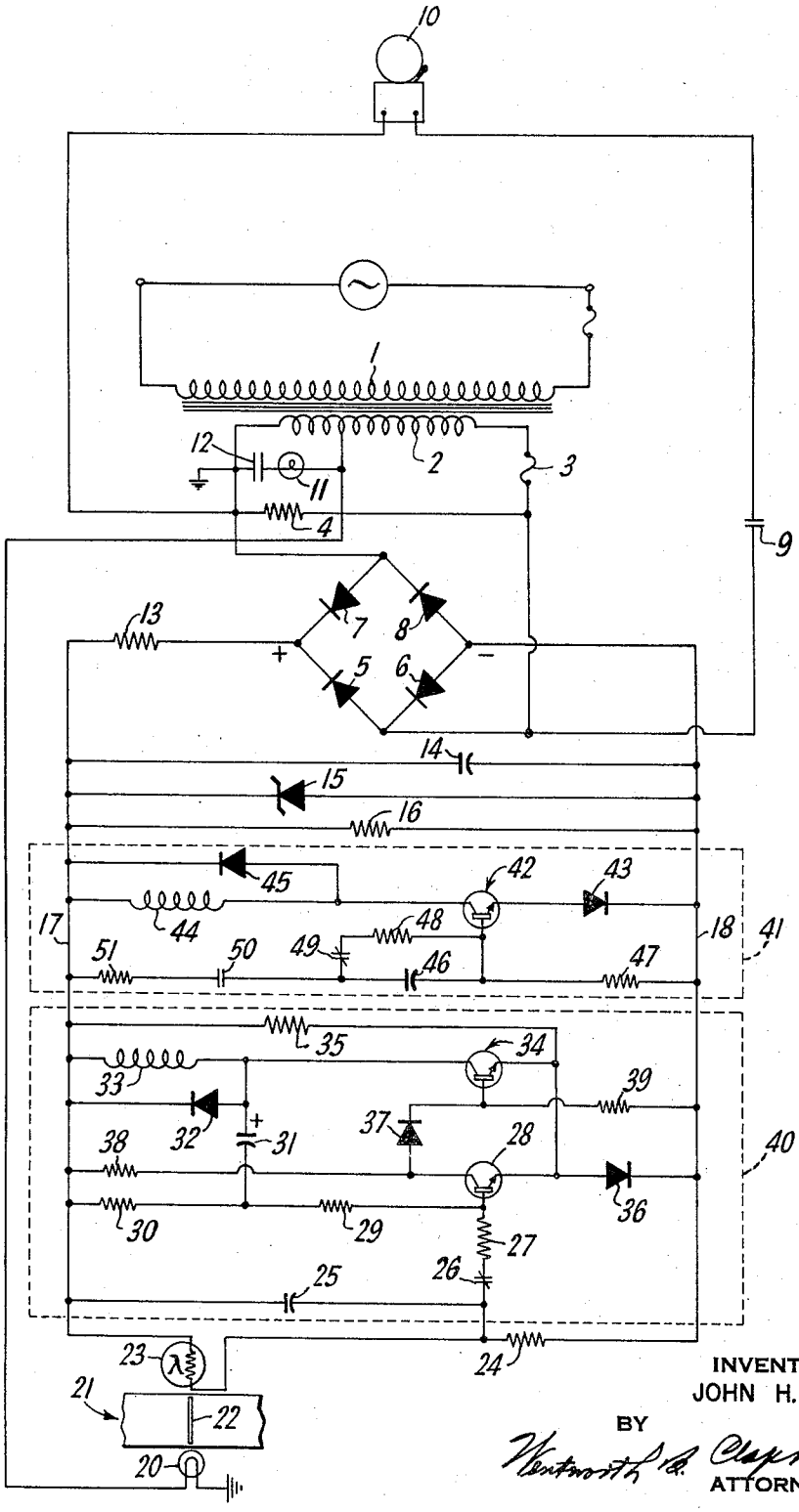
Feb. 20, 1968 J. H. DAY 3,369,810

FOUL DETECTOR

Filed Sept. 28, 1964



INVENTOR
JOHN H. DAY

BY

Wentworth & Clapham

ATTORNEY

United States Patent Office 3,369,810 Patented Feb. 20, 1968

3,369,810

FOUL DETECTOR

John Herbert Day, Shelby, Ohio, assignor to American Machine & Foundry Company, a corporation of New Jersey

Filed Sept. 28, 1964, Ser. No. 399,515
5 Claims. (Cl. 273—50)

This invention relates to improved detecting and signalling apparatus useful, for example, for detecting and indicating infractions of the rules during the playing of a game such as bowling. The invention is particularly applicable to detection and indication of a foul by the player during rolling of a bowling ball.

The invention is particularly useful in foul detecting and signalling devices of the type in which a light beam is directed from a source of light at one side of a bowling alley across the alley at the foul line to a photoelectric transducer at the opposite side of the alley. Whenever a foul is made, as, for example, when the foot of a bowler moves through the light beam and breaks it as he rolls a ball toward the bowling pins standing at the far end of the alley, the result caused by the breaking of the beam energizes a circuit controlled by the photocell and operates a signalling device to indicate the occurrence of the foul. The signalling device may provide an audible signal, a visible signal, or both.

Though various detecting and signalling systems have been proposed by prior-art workers for bowling foul detecting and indication, and though such systems have achieved considerable success, a number of problems have been encountered which create a need for improvement. In particular, the use of electromechanical and like timing devices for controlling the indicating or signalling functions has led to undue complexity and a tendency toward unreliability and short life.

It is therefore an object of the present invention to provide a detecting and indicating system of the type described which minimizes the use of mechanical moving parts.

A further object is to devise a system in which the control and timing functions are performed by solid state devices.

A still further object is to devise a system providing visible and audible signals in response to the commission of a foul in accordance with established rules of the game.

Broadly considered, the apparatus includes a power supply, a source of light, a photocell, a monostable circuit to control a visible indication of a foul, and a separate timing circuit to control an audible indication of a foul. In accordance with established rules, it is desirable to activate a buzzer or bell for a short period after a foul, and to cause a light to glow for a longer predetermined period. The monostable circuit is used herein to control the longer period and to initiate operation of a timing circuit which, in turn, controls the shorter period.

In order that the manner in which the foregoing and other objects are attained in accordance with the invention can be understood in detail, a particularly advantageous embodiment thereof will be described with reference to the accompanying drawing which forms a part of this specification and in which the single FIGURE is a schematic diagram of a bowling foul detecting and indicating system embodying the invention.

Referring now to the drawing in detail, a conventional alternating current power transformer is employed, including a primary winding 1, which can be connected to a convenient power source, and a secondary winding 2, one end of which is connected to ground. The other end of secondary winding 2 is connected via a fuse 3 to one terminal of a resistance 4 and to the junction of the

cathode of a semiconductor diode 6 and the anode of a semiconductor diode 5, this junction being an alternating current input of a conventional bridge rectifier circuit including diodes 5 and 6, and also semiconductor diodes 7 and 8. The junction of the anode of diode 7 and the cathode of diode 8 is connected to ground. The junction of diodes 5 and 6 is also connected to one terminal of a normally open relay contact set 9, the other terminal of the contact set being connected to the energizing winding of a conventional audible signal device 10, which can be a buzzer or bell. The other terminal of signal device 10 is connected to ground. Secondary winding 2 is also provided with an intermediate tap which is connected to one terminal of the filament of a conventional incandescent lamp 11, the other terminal of which is connected to one contact of a normally open contact set 12, the other contact of contact set 12 being connected to ground.

The positive DC output terminal of the bridge rectifier circuit is at the junction of the cathodes of diodes 5 and 7, this junction being connected via current limiting resistor 13 to one terminal of a capacitor 14, the cathode of a Zener diode 15, one terminal of a resistance 16, and a conductor 17 which forms the positive DC supply line for the remaining circuitry. The negative terminal of the bridge rectifier circuit is at the junction of diodes 6 and 8, this junction being connected to the anode of Zener diode 15, the other terminals of capacitor 14 and resistance 16, and a conductor 18 which forms the negative DC supply line for the remaining circuitry.

The tap of secondary winding 2 is also connected to one terminal of the filament of a conventional incandescent lamp 20, the other terminal of which is connected to ground. Lamp 20 is mounted at one side of the bowling alley 21 and at one end of the foul line 22 provided at the players' end of the bowling alley and beyond which a player is forbidden to pass in the act of rolling the ball down the alley. At the other end of foul line 22, a photoelectric transducer 23 is provided. Transducer 23 is advantageously a photoconductive device, the resistance of which varies in inverse proportion to the light incident thereon, the cell being provided with a light sensitive zone exposed to the radiation produced by lamp 20.

As disclosed in U.S. Patent 2,683,602, issued to R. E. Dumas et al., and U.S. Patent 3,113,774, issued to Roy E. Blewitt, Jr., the housing containing the cell 23 is constructed to shield the light sensitive zone from the effects of ambient light by providing a red filter between the cell and the portion of the bowling alley viewed by the cell. Furthermore, the housing is advantageously a tubular member having a portion extending beyond the light sensitive zone of the cell in the direction of the lamp 20, and having a small aperture therein such as to allow only the light from lamp 20 to impinge upon the light sensitive zone. This type of construction allows a reduction of the brightness of lamp 20, and prevents the lamp from being an annoying distraction to the bowler.

One terminal of cell 23 is connected to positive DC supply line 17. The other terminal is connected to one terminal of a resistance 24, to one terminal of a capacitor 25, and to one contact of a normally closed contact set 26. The other terminal of resistance 24 is connected to negative DC supply line 18, the other terminal of capacitor 25 is connected to positive DC supply line 17, and the other contact of contact set 26 is connected via a resistance 27 to the base electrode of an NPN transistor indicated at 28. The base electrode of transistor 28 is also connected via a series circuit including a resistor 29 and a resistor 30 to positive DC supply line 17. The junction of resistors 29 and 30 is connected to one terminal of a capacitor 31, the other terminal of which is connected to the anode of a semiconductor diode 32, to one terminal of

an energizing winding 33 of a conventional electromagnetic relay having a plurality of contact sets, and to the collector electrode of an NPN transistor indicated generally at 34. The cathode of diode 32 and the other terminal of winding 33 are connected to DC supply line 17. The emitter electrode of transistor 34 is connected via a resistor 35 to DC supply line 17, to the emitter of transistor 28, and to the anode of a semiconductor diode 36, the cathode of which is connected to negative DC supply line 18. The base of transistor 34 is connected to the cathode of a semi-conductor diode 37, the anode of which is connected to the collector electrode of transistor 28 and, via a resistor 38, to the positive DC supply line 17. The base electrode of transistor 34 is also connected via a resistance 39 to negative DC supply line 18. The circuitry including transistors 28 and 34 and the passive elements interconnecting these transistors and the associated DC supply lines is shown as enclosed within a dotted line and will be referred to hereafter as a monostable circuit 40, the operation and functions of which will be described in greater detail below.

A second portion of the system is shown as enclosed within a dotted line indicated at 41, and constitutes a resistance-capacitance timing circuit. Circuit 41 includes an NPN transistor indicated generally at 42, the emitter of which is connected to the anode of diode 43. The cathode of diode 43 is connected to the negative DC supply line 18. The collector electrode of transistor 42 is connected to one terminal of an energizing winding 44 of a conventional electromagnetic relay having a plurality of contact sets, and also to the anode of a semiconductor diode 45. The cathode of diode 45 and the other terminal of energizing winding 44 are connected to positive DC supply line 17. The base electrode of transistor 42 is connected to one terminal of a capacitor 46, to one terminal of a resistance 47, and to one terminal of a resistance 48. The other terminal of resistance 47 is connected to ground. The other terminal of resistance 48 is connected to one contact of a normally closed contact set 49, the other contact of which is connected to the other terminal of capacitance 46, and to one contact of a normally open contact set 50. The other contact of contact set 50 is connected via a resistance 51 to DC supply line 17.

In operation, when the primary winding of transformer 1 is provided with suitable alternating current voltage, the bridge rectifier circuit including diodes 5, 6, 7, and 8 provides positive DC voltage to circuits 40 and 41 and to the photoconductive cell 23. As will be recognized, the output of the bridge rectifier circuit will be full-wave pulsating direct current, the waveforms of the pulses being of erratic shape and depending upon the waveforms supplied to the primary of transformer 1 and the characteristics of that transformer. Capacitor 14 and resistance 16 are therefore provided to smooth the output of the rectifier circuit into an undulating direct current. Zener diode 15 is selected to have a breakdown voltage above the nominal direct current voltage desired between DC supply lines 17 and 18, and is provided to eliminate any excessively high voltage transients which may occur, thereby protecting any sensitive circuit elements existing in the circuitry supplied by the bridge rectifier.

It is convenient at this time to identify which of the energizing windings 33 and 44 is associated with the various normally open and normally closed contact sets. Winding 33 is the energizing winding of a relay including normally closed contact sets 26 in circuit 40 and 49 in circuit 41, and with normally open contact sets 50 in circuit 41 and 12 in the secondary of transformer 1. Thus, when winding 33 is energized, contacts 26 and 49 will open, and contact sets 50 and 12 will close. Energizing winding 44 is associated with normally open contact set 9 in series with buzzer 10.

When energized, transformer 1 also supplies lamp 20 with suitable voltage to illuminate the lamp, the light

from lamp 20 being directed to impinge upon the photosensitive zone of photoconductive cell 23. As previously described, cell 23 is in the input circuit to the monostable circuit 40. When the photoconductive area of cell 23 is provided with light from lamp 20, this being the normal condition, sufficent current flows through the circuit from positive DC supply line 17 through cell 23, the normally closed contact set 26, resistance 27, the base-emitter circuit of transistor 28, and diode 36 to negative DC supply line 18 to forward bias transistor 28, maintaining that transistor in its conductive state. As will be recognized by one skilled in the art, the emitter-collector impedance of a transistor in its conductive state is relatively low and current flow is relatively high, being limited primarily by elements external to the transistor. Thus, high current flow through the circuit from positive DC supply line 17 including resistance 38, the collector-emitter circuit of transistor 28, and diode 36 to negative line 18, the majority of the voltage between lines 17 and 18 being dropped across resistance 38. The collector of transistor 28 will therefore be at a low potential, and this potential will be conducted by diode 37 to the base of transistor 34, maintaining transistor 34 in a nonconductive state. The base of transistor 28 will also exist at a relatively low potential, and the terminal of capacitor 31 connected to the junction of resistors 29 and 30 will similarly exist at that low potential. The other terminal of capacitor 31, however, is connected to the collector of transistor 34 which, in its nonconductive condition, is at nearly supply potential. Thus, capacitor 31 will accumulate a charge with the polarity shown on the drawing through the energizing winding 33 and the circuit including resistance 29, the base-emitter circuit of transistor 28, and diode 36.

Circuit 41 in this initial stage is adapted to maintain transistor 42 in a nonconductive state. The base of transistor 42 is connected through resistor 47 to the negative supply line 18, and is isolated from the positive supply line by the normally open contact set 50.

The operation of the system advances when, in the delivery of a ball toward the bowling pins, a player commits a foul by moving his foot across the foul line so as to interrupt the passage of light from lamp 20 to cell 23. When this occurs, the resistance of cell 23 increases to a value several times its value with incident radiation. The current through the base-emitter circuit of transistor 28 diminishes with this increase of resistance, causing the transistor to become less conductive and the collector potential to increase. The increase in collector potential is conducted by diode 37 to the base of transistor 34 which now tends to become more conductive. The conduction of transistor 34 causes the potential of capacitor 31 to be reflected at base-emitter junction of transistor 28. As the potential of capacitor 31 makes the base of transistor 28 negative with respect to its emitter, the transistor is switched to a nonconductive state.

The circuit loop which reverse biases transistor 28 includes the circuit from the positive terminal of capacitor 31 through the collector-emitter junction of transistor 34, emitter-base transistor 28, resistor 29, and back to the negative terminal of capacitor 31.

Also, by the conduction of transistor 34, capacitor 31 is discharged, the discharge path including positive DC line 17, the collector-emitter junction of transistor 34, diode 36, and the negative DC line 18.

The circuit including capacitor 31, resistor 29, the collector-emitter circuit of transistor 34 and the emitter-base circuit of transistor 28 forms a regenerative loop, or positive feedback loop, which is self-sustaining for so long as a source of potential is available. The potential source in the loop is capacitor 31, so it will be clear that the regeneration will continue until capacitor 31 is discharged, thus holding the circuit in this temporary, or unstable, state. It will further be seen that the value of resistor 30 must be made sufficiently large to produce the existence of a significantly long discharge cycle.

When transistor 34 becomes sufficiently conductive, current flow is provided through energizing winding 33 sufficient to energize the relay, opening contact set 26 and contact set 49 and closing contact sets 50 and 12. The normally open contact set 12, in series with lamp 11, provides a circuit for lamp 11 across a portion of secondary winding 2 of transformer 1, thereby illuminating that lamp. Lamp 11 is advantageously located so as to be obvious to the players, and may be in the mask portion of the bowling alley structure above the bowling pin area. The illumination of lamp 11 will then indicate to the players immediately that a foul has been committed, eliminating any personal judgment or doubt and terminating unnecessary discussion.

The opening of normally closed contact set 26 separates the base of transistor 28 from any further resistance changes in photocell 23 for as long as transistor 34 remains in its conductive state. When capacitor 31 has been fully discharged through the circuit described, the reverse bias potential for the emitter-base circuit of transistor 28 terminates, and the normal biasing action of resistors 30 and 29 and diode 36 will again tend to forward bias the base-emitter junction of transistor 28. Transistor 28 will then begin to conduct, this conduction tending to decrease the collector potential of transistor 28 and therefore the base potential of transistor 34. Transistor 34 then tends to be less conductive and transistor 28 is then provided with a further increasing forward bias current from DC supply line 17 through energizing winding 33, capacitor 31, resistance 29, the base-emitter junction of transistor 28, and diode 36, to the negative line 18. The diminished conduction of transistor 34 soon causes insufficient current to flow through winding 33 to maintain the relay in its energized position, and the relay de-energizes, thereby closing normally closed contact set 26 and returning the base of transistor 28 to the control of the photocell 23 which then proceeds to return the system to its normal condition in which transistor 28 is fully conductive, transistor 34 is nonconductive, and capacitor 31 is fully charged. This terminates a full cycle of operation of the monostable circuit 40.

It will be seen that a very short interruption of the light should not be allowed to cause a foul indication, such as that caused by the normal passage of a bowling ball, even at a relatively slow speed. Capacitor 25 is therefore inserted in parallel with cell 23 to absorb such short-lived interruptions.

Circuit 41 depends upon the operation of circuit 40 in that the normally open contact set 50 is operated by winding 33 in circuit 40. When the light from lamp 20 to cell 23 is interrupted and winding 33 is energized so as to close contact set 50, a charging circuit for capacitor 46 is provided, including resistance 51 and resistance 47. Current flow through resistance 47 establishes a positive potential at the base of transistor 42, placing transistor 42 in its conductive state, thereby allowing current flow through energizing winding 44 and diode 43. The relay with which winding 44 is associated is thereby energized, closing normally open contact set 9 in series with buzzer 10, allowing current flow from secondary winding 2 through the buzzer, producing an audible signal. Transistor 42 remains in its conductive state until capacitor 46 is fully charged, at which time the potential of the base of transistor 42 drops to substantially the potential of negative DC line 18, forcing transistor 42 into a nonconductive state. With transistor 42 nonconductive, current flow through winding 44 ceases and the relay is again de-energized, reopening contact set 9 and terminating the audible signal. No discharge path is provided for capacitor 46 until circuit 40 returns to its stable state, at which time normally closed contact set 49 is reclosed and capacitor 46 discharges through contact set 49 and resistance 48.

Semiconductor diode 45 in parallel with energizing winding 44 and diode 32 in parallel with winding 33 are provided to absorb the inductive reflex occurring when the windings are de-energized.

In accordance with standards established by the American Bowling Congress, it is desirable to have a visible indication of a foul for approximately twelve seconds after the commission thereof, and to have an audible indication for approximately 1.5 seconds. The values of resistance 51 and capacitance 46 are therefore selected to provide approximately a 1.5-second time constant, keeping transistor 42 conductive and therefore relay winding 44 energized for that interval. Likewise, the values of capacitor 31 and resistance 30 are selected to provide approximately a 12.5-second discharge interval for capacitor 31, thereby keeping transistor 28 back-biased, transistor 34 conductive, and relay winding 33 energized for approximately the 12.5-second interval.

While one advantageous embodiment has been chosen to illustrate the invention, it will be understood by those skilled in the art that various changes and modifications can be made therein without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. In an automatic foul detecting and indicating apparatus for use with a bowling alley, the combination of visible indicating means; audible indicating means; a photoelectric transducer characterized by having a low electrical impedance condition when subjected to radiant energy and a high impedance condition when the incident radiant energy is markedly reduced; a source of radiant energy for directing radiant energy across the bowling alley to said transducer to maintain said transducer normally in said low impedance condition; first circuit means having a stable state and an unstable state, said first circuit means being connected to operate one of said indicating means when in said unstable state; a first circuit portion interconnecting said first circuit means and said transducer, said first circuit means being operative to convert from said stable state to said unstable state in response to change of said transducer from said low impedence condition to said high impedance condition and to revert to said stable state at the end of a first predetermined time interval; second circuit means connected to operate the other of said indicating means; and a second circuit portion interconnecting said first circuit means and said second circuit means, said second circuit means being responsive to change of said first circuit means from said stable state to said unstable state to operate said other indicating means for a second predetermined time interval.

2. An apparatus according to claim 1, wherein said first circuit means comprises a first transistor having a base, an emitter, and a collector; a terminal to which a source of DC voltage can be connected; a point of reference potential; switch means; a voltage divider circuit interconnecting the base electrode and said point of reference potential, said first circuit portion, including said switch means, interconnecting said photoelectric transducer, said DC supply terminal, and an intermediate point in said voltage divider circuit, said voltage divider circuit and said transducer being operative to bias said first transistor into a conductive state when said transducer is in said lower impedance state and to bias said first transistor into a nonconductive state when said transducer is in said higher impedance state; a resistance interconnecting the collector of said first transistor and said DC supply terminal; a second transistor having a base, an emitter, and a collector; a series circuit comprising a capacitor and a resistor interconnecting the collector of said second transistor and the base of said first transistor; a first electromagnetic relay including an energizing winding and a plurality of contact sets including said switch means, said energizing winding interconnecting the collector of said second transistor and said DC supply terminal, said second transistor being operative to energize said first relay in its conductive state; a charging circuit

including said energizing winding, said resistance in series circuit with said capacitor, said voltage divider circuit, and the base-emitter circuit of said transistor, said charging circuit being operative to store a charge on said capacitor when said first transistor is conductive; an asymmetrically conductive device interconnecting the collector of said first transistor and the base of said second transistor; and a resistor interconnecting the base of said second transistor and said point of reference potential; said asymmetrically conductive device and said last-mentioned resistance being operative to commutate said second transistor into a conductive state when said first transistor enters a nonconductive state, said second transistor being operative to discharge said capacitance and to become nonconductive when said capacitance has been substantially discharged.

3. An apparatus according to claim 2, wherein said second circuit means comprises a third transistor having a base, an emitter, and a collector; a second asymmetrically conductive device interconnecting the emitter of said third transistor and said point of reference potential; a second electromagnetic relay having an energizing winding and at least one contact set, said energizing winding being connected between the collector of said third transistor and said DC supply terminal; said contact sets including a normally open contact set operative to close when said first relay is energized and a normally closed contact set operative to open when said first relay is energized; a second capacitor; resistance means operative to bias said third transistor into a normally nonconductive state; and a charging circuit for said capacitor including said normally open contact set, said third transistor, and said second asymmetrically conductive device, said charging circuit being operative when said normally open contact set is closed to pass current to said second capacitor to bias said third transistor into a conductive state and to energize said second relay, said at least one contact set of said second relay being operative when said relay is energized to actuate said other one of said visible signal means and said audible signals means, said third transistor being responsive to the accumulation of a substantially full charge on said second capacitor to return to said nonconductive state.

4. An apparatus according to claim 1 and wherein said first circuit means further comprises first semiconductor circuit means having at least three electrodes including a control electrode, said first semiconductor circuit means being operative to conduct current when said photoelectric transducer is in said low impedance state, said first semiconductor circuit means being responsive to an impedance change in said photoelectric transducer from said low to said high impedance condition to diminish conduction through said first semiconductor means; capacitance means; charging circuit means including said control electrode and one other electrode of said first semiconductor circuit means to store a charge in said capacitance means when said first semiconductor means is conductive; second semiconductor circuit means having at least three electrodes including a control electrode, said second semiconductor means being responsive to a decrease in conduction through said first semiconductor circuit means to increase conduction through said second semiconductor circuit means, said first and second semiconductor circuit means and said capacitance means being operative as a positive feedback circuit to terminate conduction through said first semiconductor circuit means and enhance conduction through said second semiconductor circuit means, said last-mentioned conditions existing as said unstable state until said capacitance means has lost said stored charge.

5. In an automatic foul detecting and indicating apparatus for use with a bowling alley, the combination of visible signal means; a first electromagnetic relay having an energizing winding, a normally open contact set, and a normally closed contact set, said normally open contact set being connected to energize said visible signal means when said relay is energized; a photoelectric transducer characterized by having a low electrical impedance condition when subjected to radiant energy and a high impedance condition when the incident radiant energy is markedly reduced; a source of radiant energy for directing radiant energy across the bowling alley to said transducer to maintain said transducer normally in said low impedance condition; a terminal to which a source of DC voltage can be supplied; a point of reference potential; a first transistor having a base and emitter, and a collector, said first transistor being responsive to current flow established from its base to its emitter to conduct current from its collector to its emitter, and responsive to current flow from its emitter to its base to terminate current conduction via the collector and emitter; a first asymmetrically conductive device interconnecting the emitter of said first transistor and said point of reference potential; a voltage divider circuit interconnecting the base of said first transistor and said DC supply terminal; a resistance connected in series circuit relation with said transducer, said normally closed contact set, the base-emitter circuit of said first transistor, and said asymmetrically conductive device between said DC supply terminal and said point of reference potential, said series circuit being operative to establish sufficient current flow from the base to the emitter of said first transistor to place the same in a fully conductive state when said transducer is in said low impedance condition; a second transistor having a base, an emitter, and a collector, the emitter of said second transistor being connected to the emitter of said first transistor, and said energizing winding of said relay being connected between the collector of said second transistor and said DC supply terminal; a second asymmetrically conductive device connected between the collector of said first transistor and the base of said second transistor; a capacitor connected between the collector of said second transistor and an intermediate point of said voltage divider circuit, said capacitor being operative to accumulate a charge when said first transistor is fully conductive; said first transistor being operative to diminish conduction in response to a change of said transducer to its high impedance state; diminished conduction of said first transistor causing said second transistor to become conductive and provide a discharge path for said capacitor through the collector-emitter circuit of said second transistor to further diminish conduction of said first transistor, and said second transistor being operative to energize the energizing winding of said relay until said capacitor is fully discharged; audible signal means; a circuit means having a second electromagnetic relay having an energizing winding, and a normally open contact set, said normally open contact set being connected to permit energization of said audible signal means when said second relay is energized, said second circuit means being responsive to energization of said first electromagnetic relay to operate said audible signal means for a second predetermined time interval.

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ANTON O. OECHSLE, *Primary Examiner.*