United States Patent [19]

Skolnick et al.

[11] **3,863,243**

[45] **Jan. 28, 1975**

[54] **SLEEP INHIBITING ALARM**

[75] Inventors: **Max Skolnick,** Elmont, Long Island, N.Y.; **William Steckowich,** Rutherford, N.J.

[73] Assignee: **Max Skolnick,** Elmont, L.I., N.Y.

[22] Filed: **Jan. 19, 1972**

[21] Appl. No.: **218,991**

[52] **U.S. Cl.** **340/279,** 250/336

[51] **Int. Cl.** **G08b 21/00**

[58] **Field of Search** ..... 340/279; 250/83.3, 336, 250/338, 372; 350/96 R; 351/6, 7

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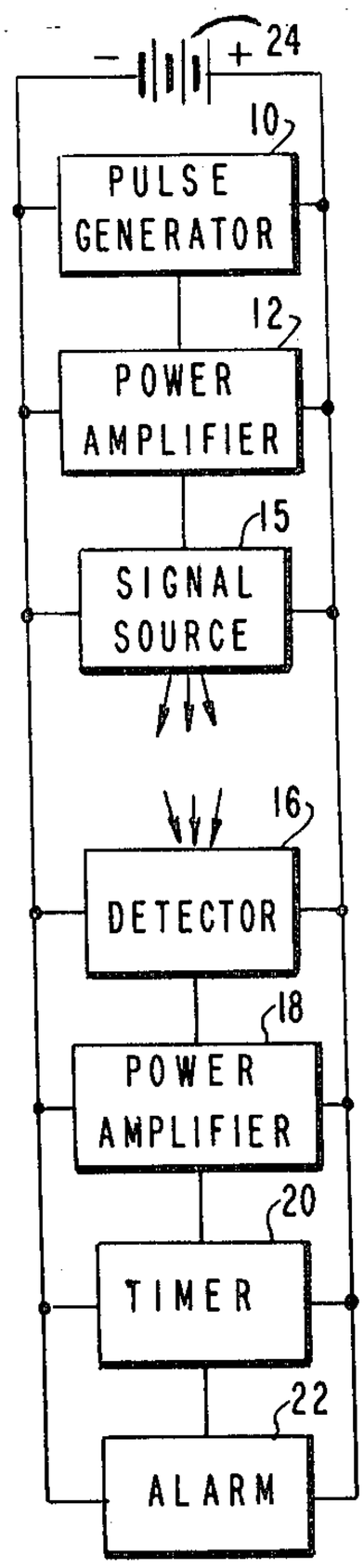
Primary Examiner—John W. Caldwell
Assistant Examiner—William M. Wannisky
Attorney, Agent, or Firm—Bierman & Bierman; Linda G. Bierman

[57] **ABSTRACT**

A method and device for detecting eye closure of an individual is provided comprising a signal source for directing signals at an individual's eye and means for detecting the said signals after reflection by the eye. An alarm system responsive to a chosen reflected signal level is also provided to alert the individual to the occurrence of an eye closed condition.

8 Claims, 5 Drawing Figures



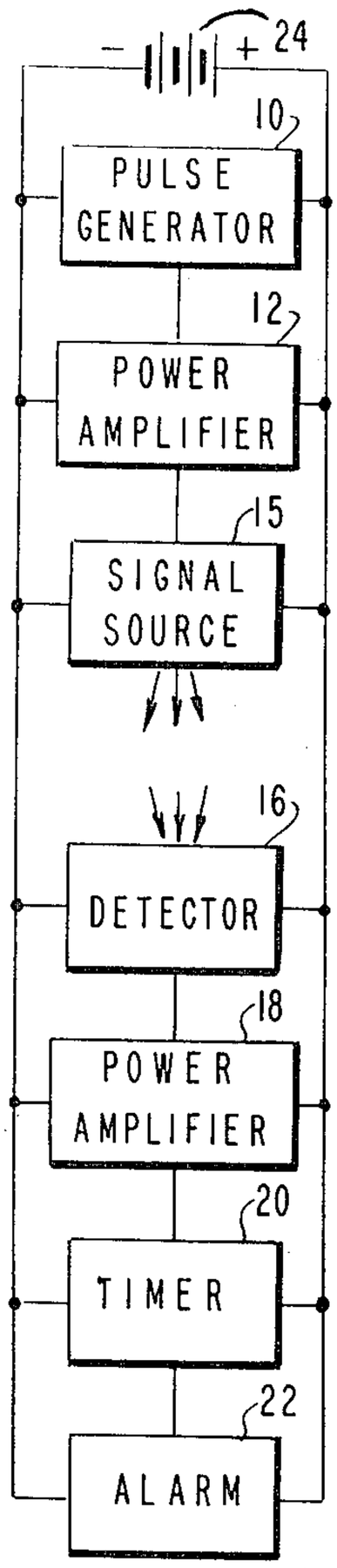


FIG. 1

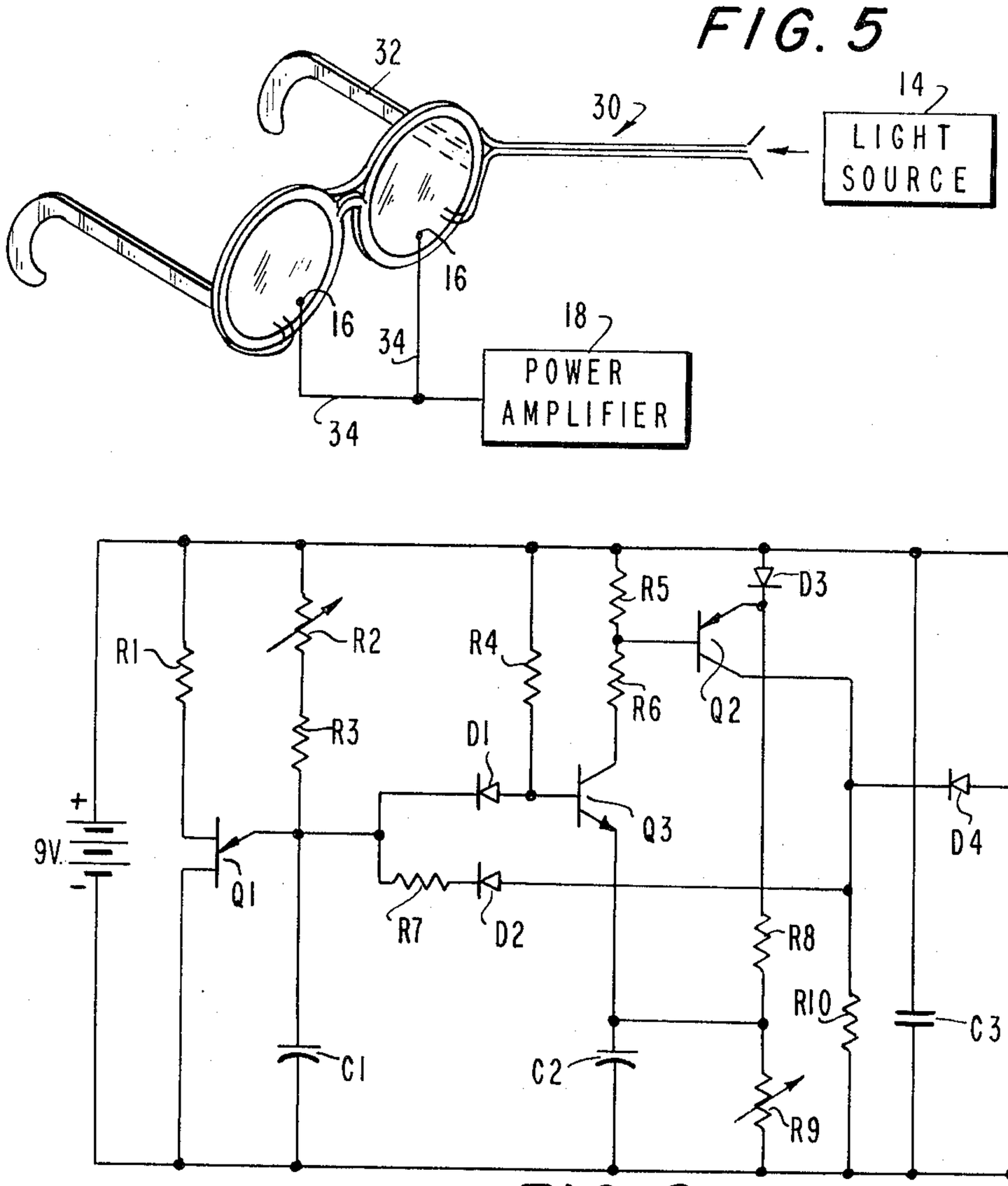


FIG. 2

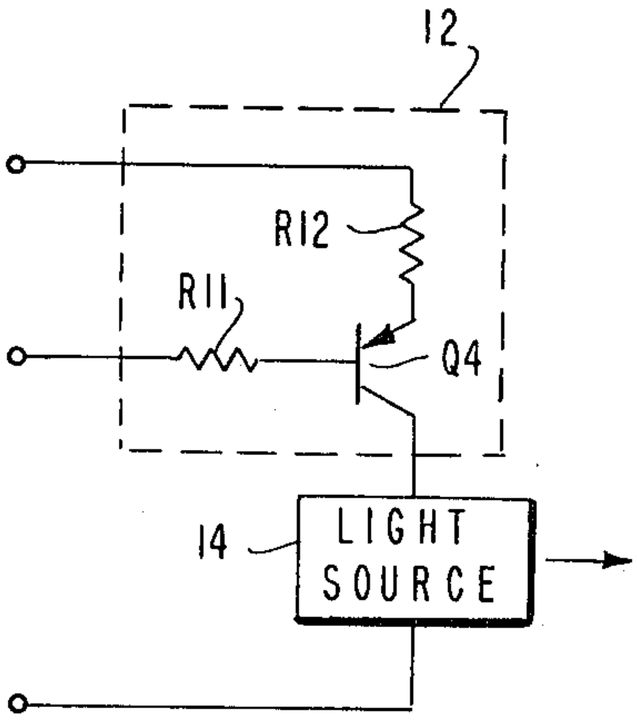


FIG. 3

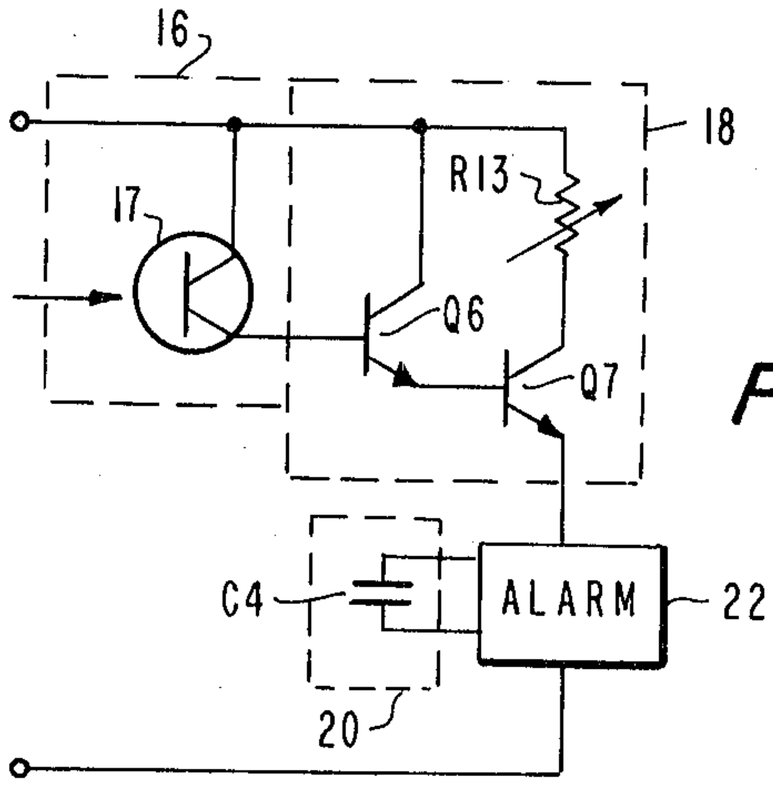


FIG. 4

FIG. 5

SLEEP INHIBITING ALARM

This invention relates to a method and apparatus for controlling an electric device by eyelid movement and more particularly to a method and device which indicates eye closure.

The present invention is primarily a safety device to be used to arouse a vehicle operator who is becoming drowsy at the controls of his vehicle. In 1969, according to the National Safety Council, out of 60,000 traffic fatalities, 15,000 of them were directly attributable to drivers becoming drowsy and/or falling asleep at the wheel. With this fact in mind, the need for an effective safety device to eliminate this problem is obvious. Heretofore no device has been able to accomplish this purpose. Such a device would of necessity have to be not only completely harmless to the driver, but also be non-distracting to allow uninterrupted vehicle operation. Several attempts at devising such a device have been made, each ending in failure due to one reason or another. Until the invention herein described, no safe, effective and convenient method of arousing a sleepy driver has been developed.

In accordance with the present invention, apparatus is provided for generating and transmitting a signal onto the surface of an individual's eye, along with a signal detector positioned to receive the reflected signal. There have been a number of attempts to construct operational devices. However, devices of the type encompassed by this invention have attempted to operate on the theory that there is no reflection from the eyelid (U.S. Pat. No. Re. 24,197) or an assumed difference in reflection intensities between the pupil and the white portion of the eye. Most prior art devices tend not to work properly, as in U.S. Pat. No. Re. 24,197 or tend to accidental activation due to minor movements of the eye. It has been discovered that there is a significant variation in reflection intensity between the eyelid and eyeball, and that this difference can be effectively utilized to provide a device which is not subject to accidental activation due to minor eye movement. For instance, when the eye is open, most of the signal will be absorbed by the eyeball, only a small portion being reflected. When the eye is closed, a greater portion of the signal is reflected by the eyelid as compared to the eyeball.

The signal can be in any detectable form. However, there are certain medical, toxicological or oculogical limitations in signal form. For instance, the signal cannot be damaging to the eye, nor should it be annoying or distracting in any way. In addition, it should be of a character which will minimize accidental activation of the detector due to spurious signals. One way this can be achieved is by making the detector, the sensing circuitry, or both, responsive only to a selected signal band width. Of course the signal source will generate signals within the detectable band width. In order to further minimize these difficulties, two types of sources prove most effective: electromagnetic or sonic waves. Electromagnetic waves of certain frequencies, either non-polarized light in the upper reaches of the visible spectrum, infrared polarized light, or near-infrared frequencies have proven acceptable. Of course sonic waves at frequencies and intensities harmless to tissue, preferably outside the audible range, may also be used if desired.

An alarm is connected to the sensor circuitry adapted to respond to a selected signal level to indicate when

the eye is closed. A timer or delay may be incorporated into the sensor circuitry which will permit an indicator, such as an alarm, to be activated when the eyelid has been closed for a preselected length of time.

The source and detector of the instant invention can be placed anywhere which will permit adequate detection and will not obstruct the eyes. A most practical position is on a pair of eyeglass frames, with or without prescription lenses, to be worn by the user.

In its preferred form, the apparatus of the invention includes a power source for energizing the signal source. The signal source has means for adjusting the frequency and the pulse width of the signal. When the apparatus is to be used by a vehicle operator, this component is contained either permanently in the vehicle or is portable. The power source may be a battery, either that of the vehicle or an internal battery pack may be provided, if desired. A convenient means of accomplishing connection with the vehicle battery in the portable form of the apparatus is to utilize the cigarette lighter socket. Alternatively, the entire signal source may be built into the dashboard of the car with a permanent battery connection.

The detection arrangement can be set up to monitor either a single eye of the individual, or both eyes simultaneously. Monitoring both eyes simultaneously is preferable for more accurate detection.

The device has many uses which will be apparent to one skilled in the art. Although the description is primarily directed to alerting a drowsing vehicle operator, it is understood that many other uses exist, such as electrically monitoring hospitalized patients who require close surveillance.

The drawings herein depict a preferred embodiment, wherein like numerals refer to like parts.

FIG. **1** is a block diagram functionally showing the parts of a preferred form of the apparatus and their relationship;

FIG. **2** is a circuit diagram of a pulse generator, used in the system of FIG. **1**;

FIG. **3** is a circuit diagram of the power amplifier for the light source used in the system of FIG. **1**;

FIG. **4** is a circuit diagram of the detector, power amplifier for an alarm, a timer and the alarm, also used in the system shown in FIG. **1**; and

FIG. **5** is an isometric view of an eyeglass frame with source and detector.

As shown in the block diagram of FIG. **1**, pulse generator **10** is connected with power amplifier **12** which, in turn, is connected to signal source **15**. Signal source **15** directs a signal to the eye surface of an individual. A detector **16** is placed to intercept the signal as shown in FIG. **5**. The output of the detector **16** is proportional to the received intensity, and this output is fed into a power amplifier **18**. Power amplifier **18** amplifies the signal which is then fed to a timer **20**. An alarm **22** is connected to the output of timer **20** and is activated only when an output from the timer occurs. Timer **20** is included in the circuit to provide means for discrimination between a blink and longer duration eye closure conditions. The timer is activated by the initial input from power amplifier **18**, but will not pass the signal on to alarm **22** until a selected time interval has elapsed. In this manner, normal blinking will not activate the alarm.

The entire system is energized by a battery **24**, each component being connected across it positive and neg-

ative terminals. Battery **24** can be either a vehicle battery or a portable battery pack. Alarm **22** can be any type conventionally known but is preferably audible. Each component mentioned above will be more fully described hereinafter.

FIG. **2** is a circuit diagram of pulse generator **10.** Capacitor C_1 (6.8 mfd) is normally charging at a rate determined by the combined resistance of resistor R_3 (100 K) and variable resistor R_2 (7.5 K) which are placed in series. When capacitor C_1 has charged to a sufficient potential, a unijunction transistor Q_1, such as General Electric 2N1671, becomes operable and discharges the capacitor C_1. Resistor R_1 is used to load the transistor Q_1 circuit to permit capacitor C_1 to discharge through transistor Q_1. Therefore, this portion of the circuit determines the R-C time constant according to adjustment of R, thus setting the frequency of the output pulse in the range from 100 KHz to 1 MHz.

Transistor Q_2 (such as Motorola 2N334) and Q_3 (such as Motorola 2N4409 or 2N4410) are biased into operation when the voltage at the emitter of Q_1 is greater than the voltage at the emitter of Q_3. This biasing takes place by means of diode D_1, such as Fairchild FDH600, and resistor R_4 (1 MEG). Resistors R_5 (6.5 K) and R_6 (12 K) perform the double function of biasing Q_2 and limiting the current through transistor Q_3. Transistor Q_3 is connected to a capacitor C_2 (200 mfd) which is in parallel with variable resistor R_9 (5 K). By adjusting the resistance of R_9, the discharging time of C_2 is varied. The emitter of Q_3 is connected to this parallel circuit through resistor R_8 (3.7 K). Thus C_1, R_8 and R_9 establish the on-off time of transistors Q_2 and Q_3 and establish the pulse width of the output signal of the generator.

The output of transistor Q_1 is in saw-tooth wave form and is compensated by the feedback current from the output of the collector of transistor Q_2 through diode D_2 (such as Fairchild FDH600) and resistor R_7 (1 MEG) to the emitter of transistor Q_1. This is done in order to prevent the setting of resistor R_9 which controls the discharging time of C_2 from effecting the charging time of C_1 and thus changing the frequency. The feedback from transistor Q_2 is equal to the current fed into the base of transistor Q_3 at the switching point. These circuits can be utilized to vary the pulse width over a wide range while having no effect upon the frequency of the output signal.

Diode D_3 (such as Fairchild FDH600) is provided to prevent any current flow from the emitter of Q_2 to the positive pole of the battery.

Diode D_1 (such as Fairchild FDH600) prevents any negative current flow through transistor Q_3, which because of the sawtooth cycle draws current through resistor R_4 thus driving the base of transistor Q_3 positive. Capacitor C_3 (200 mfd) is provided to prevent any extraneous pulses from affecting the power supply. Resistor R_{10} (4.3 K) is a load resistor which functions to establish a positive going pulse and diode D_3 (such as Fairchild FDH600) is utilized to block any negative return into the positive battery lead.

This variable pulse generator is utilized to generate a pulse of the desired frequency and pulse width to the power amplifier **12** which in turn energizes the signal source **15,** which in this case is light source **14.** The correct adjustment of this generator will enable the light source to emit light of sufficient intensity and at a frequency which is non-distracting to the vehicle operator. At the same time, the pulse width of the light source output can be controlled to minimize the probability of accidentally activating the detector **16.** Detector **16,** of course, will be selected to be responsive to the incident light frequency and preferably only to light of the particular frequency emitted.

The battery is shown as 9 volts in FIG. **2.** It is to be understood that a normal 12 volt automobile battery has a minimum output voltage of 9 v. Appropriate voltage control may be provided by voltage regulation if necessary. Alternatively, any source level may be used provided circuit components are adjusted accordingly.

FIG. **3** shows a circuit diagram of the power amplifier used to energize the light source **14.** Power is provided from the same parallel circuit from the battery which energizes the pulse generator. Transistor Q_4 (such as Motorola M901) is used to drive light source **14.** Resistor R_{11} (5 K) is connected to diode D_4 in the pulse generator **10.** The voltage drop across resistor R_{11}, when a negative going pulse is received, is sufficient to bias transistor Q_4 into conduction. Resistor R_{12} (10 ohms) is provided to limit the current load across transistor Q_4 when it is conducting.

FIG. **4** shows a circuit diagram of the detector, power amplifier, timer and alarm. This circuit is also connected in parallel with the power source. A detector **16,** in this case a photo cell **17,** is used to sense reflected light of a selected frequency. Transistor Q_6 (such as Motorola QN4409) and transistor Q_7 (such as Motorola 2N3055) are utilized in series with photo cell **17** to amplify the detected signal. Variable resistor R_{13} (5 K) is utilized to properly bias transistor Q_7. Alarm **22** is disposed between transistor Q_7 and the negative lead from the battery so as to be energized when necessary.

The pulse generator is adjusted so that the light transmitted from the light source has sufficient intensity to reflect a selected quantity off an eyelid. The frequency may be chosen to give maximum reflection by the eyelid to increase the difference in reflection intensity between the eyelid and the eyeball.

Small frequency adjustments may be made for each individual by simply operating the apparatus in the eye closed position. However, high frequencies, generally toward the end of the visible spectrum, can be used.

The instant apparatus turns off the light source when a positive going pulse is received at the base of transistor Q_4 from pulse generator **10.** Should the pulse generator fail to operate, transistor Q_4 is normally biased "on" from resistor R_{10} which will allow constant light emittance at a brighter than normal intensity, as a safety feature.

The frequency output of pulse generator **10** has been described above. Preferably, the frequency chosen is considerably less than the time it takes to complete one blink. Under normal circumstances, the frequency output of the pulse generator should be at least 4 cps. and preferably, greater than 8 cps.

The reason for utilizing cyclic on-off times for the light source can be understood by reference to the alarm **22** and its associated timer **20.** Timer **20** consists of a capacitor C_4 which must reach a selected charge level before alarm **22** becomes operative. Each successive negative going pulse from pulse generator **10** adds to the voltage buildup across capacitor C_4. A resistor, if necessary, can be provided in series with capacitor C_4 which together form an RC circuit having a time con-

stant directly proportional to the circuit values of these two parameters. To build up sufficient charge on capacitor c_4 to operate the alarm, the negative going pulses must occur with sufficient regularity. In addition, the eyelid must be closed for the detector to receive a sufficient reflected signal intensity during this time interval so that the current to capacitor C_4 generates a sufficient voltage drop across the capacitor to add to whatever voltage level is already present. The R of the alarm will bleed off charges from extraneous blinks.

It can readily be appreciated that by setting the pulse generator frequency and the time constant of the timer **20** at a selected level, the voltage pulses to capacitor C_4 will occur with a frequency sufficient to build up a charge to operate alarm **22** when the eyelid is closed. As an example, if the eyelid is closed for a time duration longer than a normal blink, and the pulse generator generates a positive going pulse ten times a second, and if the RC time constant is equal to this time duration, a sufficient charge will be built up on the capacitor to cause alarm **22** to operate. Of course, the above assumes that the output of detector **16** will be sufficient to bias transistor Q_6 and Q_7 into a sufficiently conductive state to achieve a full charge. If the output of detector **16** is too low, little or no buildup of charge on capacitor C_4 will occur since an insufficient biasing voltage will be applied to transistors Q_6 and Q_7.

FIG. **5** depicts the preferred arrangement of the signal source and detector on an eyeglass frame **32.** A remote light source **14** is provided to radiate light energy into a bundle of optical fibers **30.** The bundle **30** is split such that it has ends at each corner of the eyeglass frame **32.** Light is thus transmitted to the surface of the individual's eyes. Fiber optics are utilized to prevent the individual from being annoyed by the heat generated by the light source. In addition no lens is necessary as the light is columnized by the use of the fiber optic bundle for easier detection. Detectors **16, 16** are placed at the bottom of the frames adjacent to the end of the fiber optics bundle **30.** The detectors are electronically connected by means of wires **34,34** to the power amplifier **18.** In operation, when the eyelid is closed, the light from light source **14** conducted through fiber optics bundle **30** will be reflected from the individual's eyelids and sensed by detectors **16,16.** The detectors will then emit an electrical signal conducted by means of wires **34,34** to power amplifier **18,** which will in turn, if the duration of the signal from the detector is longer than a predetermined time interval, activate the alarm.

It is to be understood that modifications may be made which are not specifically described herein but which will be readily apparent to those skilled in the art. It is intended to cover all such modifications which fall within the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. An apparatus for detecting eye closure of an individual comprising:

a signal source for generating and transmitting a signal into the individual's eye;

a power source for energizing said signal source;

means for detecting the difference in reflected signal intensity between the signal reflected by the opened eye of the individual and the higher signal intensity reflected by the eyelid of the individual when the eye is closed, comprising a photosensitive signal generator;

said signal source comprising a pulse generator to generate a signal; an amplifier to amplify said signal and a light energized by said signal;

said pulse generator comprising means for generating a sawtooth pulse at a desired frequency;

means for varying the width of the generated pulse and means for compensating said generating means so as to eliminate the dependency of frequency upon said pulse width varying means;

said generating means comprising a unijunction transistor and a capacitor, said capacitor being connected between the emitter of said transistor and the negative lead of said power source such that upon charging to the activation voltage of said transistor said transistor is activated to discharge said capacitor, and means for varying the charging time of said capacitor;

an alarm activated by said reflected higher intensity signal.

2. The apparatus according to claim **1** wherein said pulse width varying means comprises;

a second transistor biased by said capacitor to operate when the bias voltage is less than the voltage at the emitter of said second capacitor,

means for adjusting the voltage at the emitter of said second transistor, and

a third transistor biased by said second transistor to operate whenever said second transistor is operable such that the signal output at the collector of said third transistor has a pulse width dependent upon said adjusting means.

3. The apparatus according to claim **2** wherein said adjusting means comprises a second capacitor and a variable resistor in parallel with said second capacitor.

4. The apparatus according to claim **2** wherein said compensating means comprises:

a feedback circuit for connecting the collector of said third transistor to the first capacitor such that the charging time of said first capacitor is independent of the charging time of said second capacitor.

5. The apparatus in accordance with claim **2** wherein the input of said amplifier is connected to the collector of said third transistor and wherein said light is connected to the output of said amplifier.

6. The method of detecting eye closure of an individual comprising:

energizing a light to emit a light ray pulse of a particular frequency and pulse width, amplifying said pulse and energizing said light with the signal output from said amplifier converting a constant direct current into a pulsed signal of designated frequency and varying the width of said pulse without changing the frequency of said signal;

directing said light to the individual's eye;

detecting the reflected signal from the eye in both the open and closed position of the eye, and providing an alarm responsive to the signal reflected when said eye is in said closed position;

the step of converting a constant direct current comprises the steps of charging a capacitor, biasing a transistor to operate when the capacitor is fully charged to discharge said capacitor, adjusting resistance to vary the charging time of said capacitor and biasing a second transistor to operate during the time the capacitor is charging.

7. The method in accordance with claim 6 wherein the step of varying the pulse width comprises:

charging a second capacitor when said second transistor is operational,

varying the discharging time of said second capacitor by means of an adjustable resistor,

controlling the emitter voltage on a third transistor in accordance with the discharging time of said second capacitor such that the output pulse at the collector of said third transistor has the frequency determined by the charging time of said first capacitor and a pulse width determined by the discharging time of said second capacitor.

8. The method according to claim 7 wherein the step of varying the pulse width further comprising compensating the bias of said second transistor to keep the charging time of said first capacitor independent of the discharging time of said second capacitor.

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