

Sept. 19, 1967

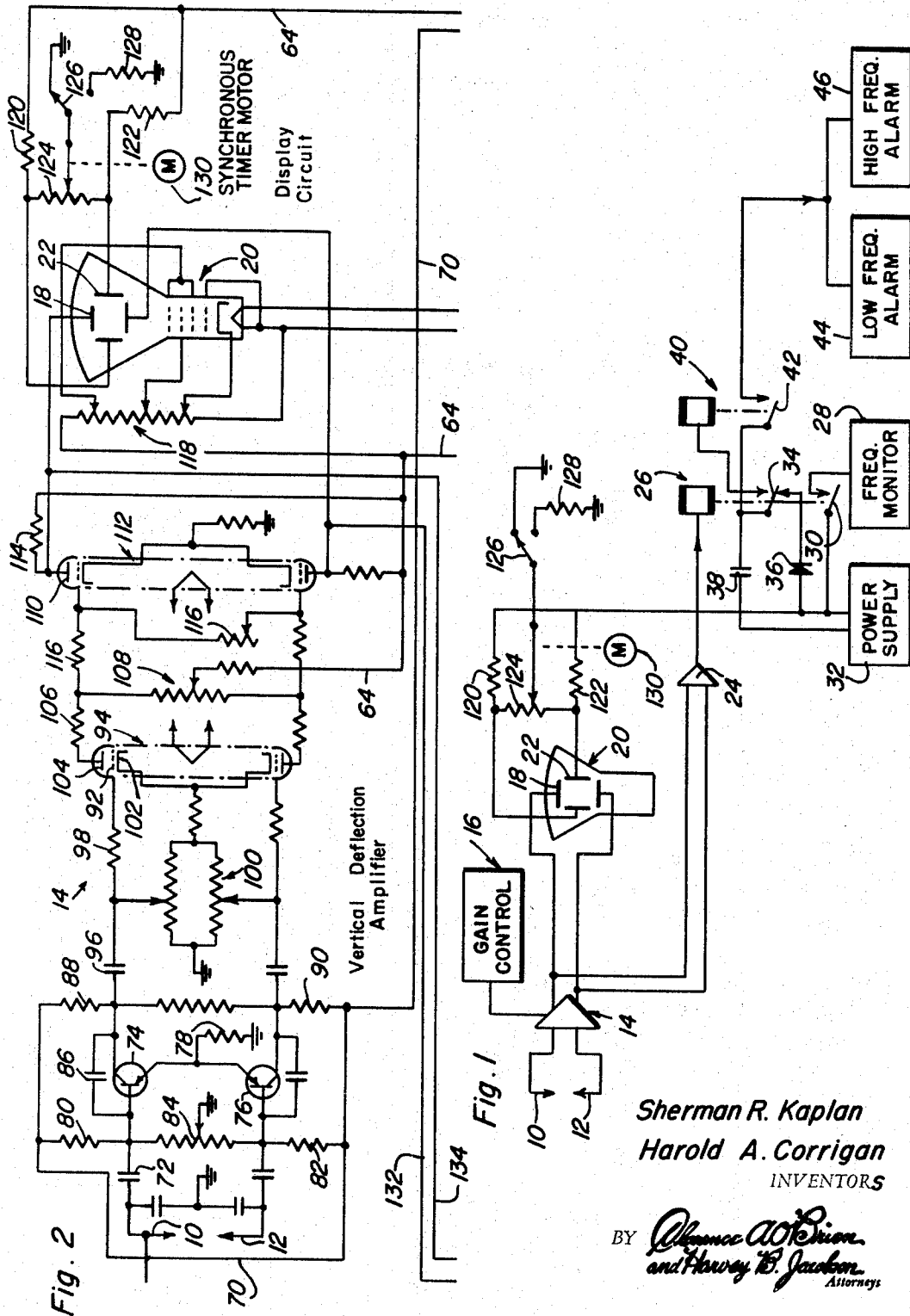
S. R. KAPLAN ET AL

3,342,176

CARDIAC MONITOR

Filed Nov. 12, 1964

2 Sheets-Sheet 1



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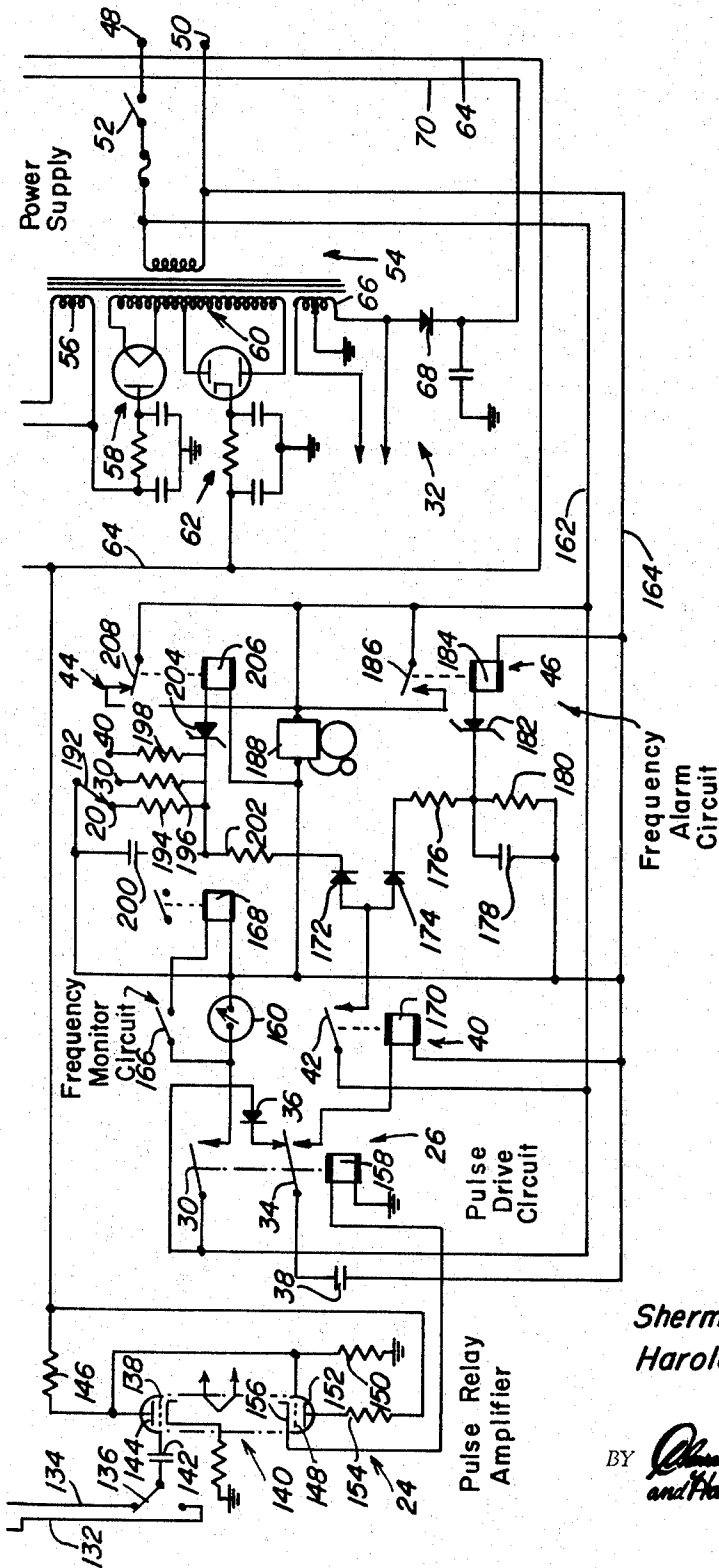
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2 Sheets-Sheet 2

Fig. 2A



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CARDIAC MONITOR

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Filed Nov. 12, 1964, Ser. No. 410,442

8 Claims. (Cl. 128-2.06)

ABSTRACT OF THE DISCLOSURE

An electronic device which simultaneously registers a patient's heartbeats on an oscilloscope and produces clicks and flashes synchronized with the heartbeats so that they may be monitored at some remote station. An alarm is also sounded at the monitoring station should the heartbeat rate become excessively high or low. A fixed electrode and an exploring electrode are attached to the patient in order to pick up the heartbeat pulses amplified and registered by the monitoring system.

This invention relates to an electronic device for monitoring the heartbeat of a patient both visually and audibly.

In accordance with the present invention, the rate and rhythm of a patient's heartbeat is monitored through a pair of electrodes applied to the patient's body, the impulses so derived being displayed by an oscilloscope while at the same time, light flashes and audible clicking sounds simulate the heartbeat of the patient. Also, an alarm system is provided through which the attending personnel are alerted when the frequency of the heartbeat exceeds approximately 150 beats per minute or drops below a predetermined low rate of 20, 30 or 40 beats per minute.

It is therefore a primary object of the present invention to provide a relatively small and inexpensive cardiac monitor through which heartbeat indications may be simultaneously obtained by several different methods.

An additional object of the present invention is to provide a cardiac monitoring device having a lifesaving alarm system through which attending personnel will be immediately alerted should the heartbeat rate exceed a dangerous maximum or drop below a dangerous minimum.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIGURE 1 is a simplified schematic circuit diagram illustrating the cardiac monitoring system of the present invention.

FIGURES 2 and 2A form a complete circuit diagram of the system shown in FIGURE 1.

Referring initially to FIGURE 1, it will be observed that the cardiac monitoring system of the present invention is associated with a pair of electrodes including the diagrammatically illustrated electrode 10 adapted to be attached for example to the left arm of a patient and a second exploring electrode 12 placed either on the left leg or chest of the patient. The heartbeat impulses picked up by the electrodes are fed to a multistage, vertical deflection amplifier 14 having gain control facilities 16 so that vertical deflection signals corresponding to heartbeat pulsations may be fed to the vertical deflection plates 18 in the cathode ray tube 20 forming part of an oscilloscope display circuit. The electron beam within

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the cathode ray tube 20, will therefore be vertically deflected in accordance with the heartbeat impulses as it is horizontally swept at a constant rate by voltage applied to the horizontal deflection plates 22.

The vertical deflection signal from the amplifier 14, is also fed to a pulse relay amplifier 24 for driving a pulse relay 26 from which monitoring signals are derived and fed to a frequency monitor circuit 28. Visual and audible indication of a patient's heartbeat are thereby established by the frequency monitor circuit 28, in addition to the heart rate and rhythm registered by the oscilloscope display circuit. A monitor relay switch 30 is therefore associated with the pulse relay 26 so that it may be intermittently closed by energization of the relay 26 in order to connect the frequency monitor circuit 28 to the power supply 32. Also associated with the pulse relay 26, is a timing relay switch 34 intermittently actuated at a variable pulse rate dependent upon the pulse driving signals supplied by the pulse relay amplifier 24. One of the contacts associated with the timing switch 34, is therefore connected to the power supply 32 through a current rectifying diode 36 so that the timing capacitor 38 may be rapidly charged to its full capacity prior to the actuation of the switch 34 to its other position upon energization of the relay 26. When actuated, the switch 34 will discharge the capacitor 38 and supply a pulse of fixed duration to the alarm controlling relay 40 which will therefore be operative to intermittently close the alarm relay switch 42 at a variable rate dependent upon the rate of the patient's heartbeat being monitored, but remaining closed for periods of constant duration in order to properly operate the alarm circuit when the pulse rate or frequency of the patient's heartbeat is of such value as to require the attention of attending personnel. Closing of the alarm relay switch 42 is operative to connect the power supply to the lower frequency and high frequency sections 44 and 46 of the alarm circuit respectively operative to sound an alarm when the pulse frequency is either dangerously low or dangerously high.

Referring now to FIGURES 2 and 2A, it will be observed that power terminals 48 and 50 may be connected to the usually available AC source of voltage so that upon closing of the switch 52, the transformer 54 in the power supply 32 will be energized. The transformer 54 includes a secondary section 56 through which AC voltage is applied to the heater element in the cathode ray tube, the voltage being rectified by the diode circuit 58 coupling the secondary section 56 to the multi-tapped secondary section 60. Also connected to the secondary section 60 is a rectifier circuit 62 supplying rectified voltage to the voltage line 64 in order to establish bias voltages on the several components of the system. A grounded, center-tapped secondary section 66 is also associated with the transformer 54 for supplying filament voltage to the several amplifier tubes of the system and is also connected through diode 68 to a rectified voltage line 70 for establishing bias voltages in the initial stage of the vertical deflection amplifier 14.

The electrodes 10 and 12 are respectively connected through coupling capacitors 72 to the bases of PNP transistors 74 and 76 in an initial differential amplifier stage, wherein a common bias on the emitters of the transistors is maintained above ground by the resistor 78. An adjustable voltage dividing network regulates the bias voltage applied to the bases of the transistors from the rectified voltage line 70, including the resistors 80, 82 and the potentiometer 84. Feedback capacitors 86 couple the bases of the transistors to the output collectors to which bias voltage is applied from line 70 through resistors 88 and 90. The signal outputs from the transistors are applied to the grids 92 of the second stage, differential amplifier

tube 94 through coupling capacitors 96 and resistors 98. An adjustable voltage dividing network 100 is utilized to regulate the relative potential differences between the grid and the cathodes 102 in the amplifier tube 94 so as to produce a balanced output signal from the plates 104. The plates are biased by the rectified voltage in line 64 through the bias resistors 106 and the potentiometer 108 regulating the relative biases applied to the plates. Rectified voltage line 64 from the power supply also applies bias voltage to the plates 110 of the third stage differential amplifier tube 112, the plates being connected to the voltage line 64 through bias resistors 114. The output signals from the second stage amplifier tube 94 are therefore supplied through coupling resistors 116 to the grids of the third stage amplifier tube 112. A control potentiometer 118 regulates the relative bias imposed on the grids from voltage line 64 through the potentiometer 108 and resistors 116 in order to control the gain of the amplifier 14. The output plates 110 of the amplifier will therefore supply and amplify heartbeat pulse signals to the vertical deflection plates 18 in the cathode ray tube 20 which is also provided with the usual grid and cathode elements interconnected through the adjustment potentiometer 118 to the voltage line 64 so as to regulate focus, brightness, astigmatism, centering, etc., in the output display of the cathode ray tube.

While the vertical deflection of the electron beam within the cathode ray tube is variable in accordance with the amplified heartbeat pulse signal supplied to the vertical deflection plates 18, a varying voltage of constant varying rate is applied to the horizontal deflecting plates 22 in order to produce a horizontal sweep of the electron beam. The display circuit is therefore also associated with a pair of resistors 120 and 122 respectively connecting the horizontal deflection plates 22 to the constant voltage line 64 from the power supply. Connected across the horizontal deflection plates 22 to predetermine the potential difference therebetween, is the resistance of a voltage dividing potentiometer 124, the wiper arm of which is electrically connected through switch 126 either directly to ground or to ground through resistor 128. The wiper arm of the potentiometer is rotated 360° at a relatively low, constant rate of speed by a synchronous timer motor 130 resulting in simultaneous increase and decrease in the respective voltages applied to the horizontal deflection plates so as to produce the aforementioned horizontal sweep of the electron beam within the cathode ray tube at a constant rate.

The amplified heartbeat signal output from the amplifier 14 is also supplied through the lines 132 and 134 to the pulse amplifier through switch 136 as shown in FIGURE 2A connecting either line 132 or line 134 to the input grid 138 of the amplifier tube 140 through coupling capacitor 142. The plate 144 of the pulse amplifier tube is connected to the voltage line 64 through bias resistor 146. Bias is thereby applied to the grid 148 held above ground level by the resistor 150 and to the base 152 through resistor 154. Thus, the amplified heartbeat signal will be faithfully reproduced as the output from the cathode follower element 156 and applied to the pulse relay 26 in the pulse drive circuit. The relay coil 158 will accordingly be intermittently energized at a varying frequency corresponding to the patient's heartbeat being monitored and will remain energized for periods depending upon the amplitude of the amplified heartbeat signal as reflected by the electron beam trace produced in the cathode ray tube 20. This heartbeat signal may also be monitored by intermittent illumination from a neon lamp 160 connected across the AC voltage lines 162 and 164 which extend from the power supply, each time the relay monitor switch 30 is closed by energization of the relay coil 158. Also connected in parallel with the neon lamp 160, upon closing of the switch 166, is a clicking solenoid 168 operative to provide an audible clicking sound synchronized with the intermittent light flashes produced by

the neon lamp 160 indicating the rate and rhythm of the patient's heartbeat being monitored.

In view of the variable duration of the energizing periods for the monitoring relay 26, a timing relay 40 is provided as aforementioned so that the rapidly charged capacitor 38 may discharge through the relay coil 170 upon actuation of the timing relay switch 34 when the relay coil 158 is energized, the relay coil 170 then remaining energized for a predetermined constant duration. Accordingly, the alarm switch 42 will be closed by the relay coil 170 for a fixed period of time but at an intermittent rate corresponding to the heartbeat frequency of the patient being monitored. When the alarm switch 42 is closed, the AC voltage line 164 is connected in parallel to the rectifying diodes 172 and 174 in the frequency alarm circuit.

The diode 174 is connected by the voltage reducing resistor 176 to the storage capacitor 178 and to the bleed resistor 180 in parallel therewith. Accordingly, a charging circuit is completed across the AC voltage line 162 and 164 every time the alarm switch 42 is closed in order to charge the capacitor 178 at a rate controlled by the bleed resistor 180. When the charging circuit is completed by the switch 42 at a rate of approximately 150 times per minute, the capacitor 178 becomes charged to a level causing the Zener diode 182 in the high frequency section of the alarm circuit to avalanche and thereby energize the relay coil 184. Upon energization of the relay coil 184, relay switch 186 closes to connect the alarm device 188 across the AC voltage lines 162 and 164 in order to sound an alarm. It will therefore now be appreciated that closing of the alarm relay switch 42 for fixed periods is necessary in order to accurately set the high frequency section of the alarm circuit into operation when the pulse rate of the relay 26 exceeds approximately 150 pulses per minute.

While the high frequency section of the alarm circuit is operative to sound an alert should the heartbeat of the patient exceed 150 beats per minute, the low frequency section 44 of the alarm circuit may be adjustably set to operate when the frequency of the heartbeat falls below either 20, 30 or 40 beats per minute, this adjustment being achieved by movement of the switch 190 between three positions connecting the AC voltage line 164 to either resistor 194, 196 or 198. These three resistors are operative to control the rate of charge applied to the capacitor 200 connected in parallel with the bleed resistors. Accordingly, upon closing of the relay switch 42, the capacitor 200 and one of the bleed resistors are connected across the AC voltage lines 162 and 164 by means of the diode 172 and the voltage reducing resistor 202. Ordinarily, the capacitor will be charged upon closing of the relay switch 42 to a level sufficient to produce flow of energizing current through the Zener diode 204 completing an energizing circuit across the AC voltage lines through the relay coil 206 of the high frequency section of the alarm circuit. Accordingly, the relay switch 208 will be normally held open in order to open the energizing circuit for the alarm device 188. When however, the frequency of the pulse rate is too low, capacitor 200 will be discharged through one of the bleed resistors at too rapid a rate so as to reduce the charge on the capacitor below the avalanche level of the Zener diode 204. The relay coil 206 will accordingly be deenergized closing the relay switch 208 and connecting the alarm device 188 across the AC voltage lines 162 and 164. The signal frequency at which this occurs will therefore depend upon the position of the selector switch 192 in order to provide an audible alert when the heartbeat rate drops below a value deemed dangerous.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described,

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and accordingly all suitable modifications and equivalents may be resorted to falling within the scope of the invention as claimed.

What is claimed as new is as follows:

1. In a system for monitoring the heartbeats of a patient to whom electrodes are applied for receiving pulse signals, a display device having a pair of perpendicular deflecting elements, amplifying means connecting one of said deflecting elements to the electrodes, constant voltage varying means connected to the other deflecting element for visual display of a varying voltage applied to said one deflecting element by the amplifying means, and pulse indicating means connected to the amplifying means for energization at a variable frequency and pulse duration corresponding respectively to the frequency and amplitude of said varying voltage.

2. The combination of claim 1 wherein said constant voltage varying means comprises a rectified source of constant voltage, voltage dividing means connected to said source for establishing a predetermined potential difference between two points, potentiometer means connected between said two points for regulating the relative voltages at said points between minimum and maximum values, and a timer device connected to said potentiometer means for varying the relative voltages at a constant rate of speed.

3. The combination of claim 2 including alarm means operatively connected to said pulse indicating means for establishing an alerting signal in response to minimum and maximum values of said variable frequency.

4. The combination of claim 3 wherein said alarm means comprises timing means operatively connected to the pulse indicating means energized for a fixed period of time in response to energization of the pulse indicating means, a pair of charging circuits connected to said timing means for charging during said fixed periods of time at a rate dependent upon said variable frequency of the pulse indicating means, high frequency sensing means operatively connected to one of said charging circuits for energization in response to charging thereof at a rate exceeding said maximum frequency value, low frequency sensing means operatively connected to the other of said charging circuits for energization in response to charging thereof at a rate exceeding said low frequency value, and a common alerting device connected to said high and low frequency sensing means for operation in response to energization of one of the sensing means or deenergization of the other sensing means.

5. The combination of claim 1 including alarm means operatively connected to said pulse indicating means for establishing an alerting signal in response to minimum and maximum values of said variable frequency.

6. In a system for monitoring the heartbeats of a patient to whom electrodes are applied for receiving pulse signals, a display device having two pairs of deflecting

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elements, amplifying means connecting one pair of said deflecting elements to the electrodes, and constant voltage varying means connected to the other pair of said deflecting elements for visual display of a varying voltage applied to said one deflecting element by the amplifying means, said constant voltage varying means comprising a rectified source of constant voltage, voltage dividing means connected to said source for establishing a predetermined potential difference between said deflecting elements of the other pair, potentiometer means connected between said deflecting elements for regulating the relative voltages thereon between minimum and maximum values, and a timer device connected to said potentiometer means for varying the relative voltages at a constant rate of speed.

7. In a system for monitoring the heartbeats of a patient to whom electrodes are applied for receiving pulse signals, a display device having a pair of deflecting elements, amplifying means connecting one of said deflecting elements to the electrodes for establishing a voltage varying at the frequency of said pulse signals, constant voltage varying means connected to the other deflecting element for visual display of said varying voltage applied to said one deflecting element by the amplifying means, and alarm means operatively connected to said amplifying means for establishing an alerting signal in response to minimum and maximum frequency values of said varying voltage.

8. The combination of claim 7 wherein said alarm means comprises timing means operatively connected to the amplifying means energized for fixed periods of time in response to said pulse signals, a pair of charging circuits connected to said timing means for charging during said fixed periods of time at a rate dependent upon the frequency of said varying voltage, high frequency sensing means operatively connected to one of said charging circuits for energization in response to charging thereof at a rate exceeding said maximum frequency value, low frequency sensing means operatively connected to the other of said charging circuits for energization in response to charging thereof at a rate exceeding said low frequency value, and a common alerting device connected to said high and lower frequency sensing means for operation in response to energization of one of the sensing means or deenergization of the other sensing means.

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