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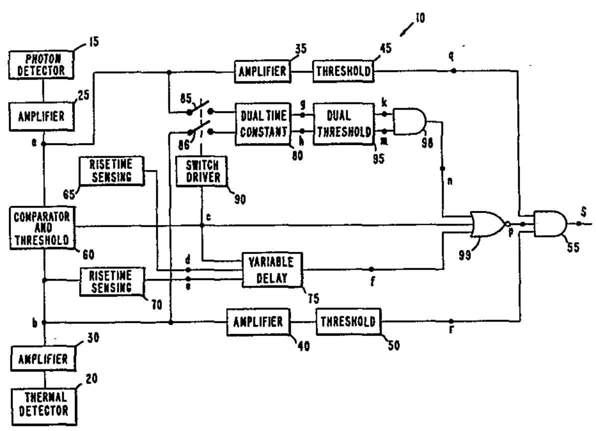
(54) **Dual spectrum fire sensor with discrimination.**

(57) A fire sensor discriminates between fires and the flash caused by a projectile piercing the wall of a protected area. The sensor system comprises first and second radiant energy detectors, each sensitive to radiation within different spectral bands. Each detector is coupled to a control signal means for generating a control signal when the radiation sensed exceeds a predetermined amplitude. A third control signal means is responsive to the first and second detectors, and is operative to generate a third control signal whenever the ratio of the amplitude of the energy sensed by the first detector to the amplitude of the energy sensed by the second detector is less than a predetermined value; not generate the third control signal whenever the ratio of amplitudes exceeds the predetermined value; and delay generation of the third control signal for a predetermined period of time after the ratio of amplitudes falls below the predetermined value. An output control signal is then generated only if all three control signals are simultaneously generated. The decay of the flash radiation is thereby electrically simulated, allowing the fire sensor to sense whether a fire develops after the flash passes.



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DUAL SPECTRUM FIRE SENSOR WITH DISCRIMINATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of devices that sense the presence of an undesirable fire or explosion within a protected area or compartment, and thereafter cause a fire suppressant to be released to extinguish the fire.

More particularly, this invention relates to a device that will distinguish a fire from the flash produced, for example, by a projectile penetrating a wall of the protected area, and release the suppressant only when it senses a fire.

2. Description of the Prior Art

There are many situations where the protection of human life requires that an area or a compartment be protected from fires. For instance, the crew and passenger compartments and the engines of aircraft are areas where a fire can quickly cause disaster. However, the fire suppressant carried on aircraft adds weight that reduces performance, and generally only the amount of suppressant necessary to extinguish expected fires is carried. The timing of the release of the suppressant is critical. If released too soon, it may be exhausted before it is really needed; if released too late, it may not be adequate to suppress the fire.

Military vehicles, such as aircraft, tanks and personnel carriers, may be vulnerable to fires caused by the entry of projectiles or flak. When a projectile or a piece of flak pierces a wall of a compartment, it causes a flash of radiant energy in the ultraviolet, the visible, and the infrared spectral regions. Prior art fire sensors, depending on their individual capabilities, would do one of two things - the fire sensor might interpret the flash as a fire and release the suppressant before the fire actually developed; or even if the fire sensor determined that the flash was not a fire, it might interpret a quickly developing fire as the continued presence of the flash, and thereby fail to release the suppressant. (In technical literature, the words "detector" and "sensor" are sometimes used synonymously. Here, "detector" refers to a radiation sensitive element that converts electromagnetic radiation to electrical signals. The word "sensor" refers to a system using at least one "detector", and which includes some other electronic apparatus to amplify or process the "detector" signals.)

The fire sensor system disclosed in U.S. Patent No. 4,206,454 to Schapira, et al is capable of sensing fires, but would also react to suppress the flash caused by a projectile penetration. The projectile flash would radiate a quick-rising short-wavelength component and a slow-rising long-wavelength component which would activate the suppressant as soon as the long-wavelength component passed the threshold level. But, such operation might be unnecessary if no fire resulted from the projectile penetration, or might occur too soon if the fire ignition was delayed, as when leaking fuel is subsequently ignited.

The fire sensor system disclosed in U.S. Patent No. 4,220,857 to Bright is likewise disadvantageous since it would interpret the projectile flash to be a fire. On impact, the projectile often releases a small amount of incendiary or produces an explosion, both of which generate a large amount of carbon dioxide as the product of combustion, even though the combustion may be very short-lived and produces no substained hydrocarbon fire. Since Bright's system responds to a situation where the non-Planckian emission of the carbon dioxide molecule at 4.4 micrometers (for example) exceeds the Planckian emission at adjacent wavelengths, a fire output signal would result. Thus, suppressant would be released to suppress a flash and explosion that would have dissipated shortly by itself.

The fire sensor system disclosed in U.S. Patent No. 4,101,767 to Lennington, et al will also have difficulty distinguishing a flash from a fire. The Lennington system is basically a single channel fire sensor (using detector 30) with a discrimination circuit (detectors 10 and 20) to prevent outputs as long as the color temperature is greater than some value (e.g. - 2400°K). This sensor system was designed specifically for the dynamics of a HEAT round attack against an armored vehicle. In this case, the long wavelength signal (4.4 micrometers) drops below the sensor threshold following the HEAT round impact before the short wavelength detectors indicate a color temperature less than the preset value. In aircraft applications, however, this is often not the case and the Lennington system may release suppressant to snuff a flash that would dissipate rapidly by itself.

SUMMARY OF THE INVENTION

The general purpose of this invention is to provide a new and improved fire sensor which overcomes the above-described disadvantages of the prior art fire sensors, and which is operable to detect the presence of a fire and cause the release of a fire suppressant.

It is also a purpose of this invention to provide a new and improved fire sensor that is capable of discriminating between a sudden flash of radiant energy and a fire that develops so soon after the flash that the fire's radiant energy might be interpreted by a detector system as a continuation of the flash.

To accomplish these purposes while overcoming the disadvantages of the prior art described above, the present invention electrically simulates what would happen optically in the event there is a flash without a subsequent fire. The timing of the release of fire suppressant does not come so soon that an occasional false alarm results (that is, suppressant is released when a flash occurs but no fire follows), but yet does not come so late that the suppressant is inadequate to extinguish a fire.

The present invention provides a three channel sensor system having a first detector capable of detecting electromagnetic energy within a first predetermined spectral band and generating a first control signal that is proportional to the amplitude of the energy it detects, and a second detector capable of detecting electromagnetic energy within a second predetermined spectral band and generating a second control signal that is proportional to the amplitude of the energy it detects. The first channel of the sensor system is responsive to the first detector and generates a third control signal whenever the first control signal exceeds a first predetermined level. The second channel of the sensor system is responsive to the second detector and generates a fourth control signal whenever the second control signal exceeds a second predetermined level. The third channel of the sensor system is responsive to both the first and second control signals and generates a fifth control signal until the difference between the amplitudes of the first and second control signals exceeds a third predetermined level. When the third level is exceeded, the third channel ceases generating the fifth control signal for a period of time which may be termed the "delay period". When the delay period has passed, the third channel will again generate the fifth control signal. The first, second, and third channels are electrically fed to an output circuit which generates an output signal only when the third, fourth, and fifth control signals are simultaneously received from the first, second, and third channels respectively. The output signal, when generated, may be further processed or used to activate electromechanical fire suppression equipment.

The length of the delay period may be determined in various ways by different types of delay circuits incorporated in the third channel. The type of delay circuit utilized may depend on the type of fire or explosion that might be expected to occur in the monitored area. A simple type of delay circuit is one that merely interrupts the generation of the fifth control signal for a predetermined period of time after the difference between the first and second control signals exceeds the third predetermined level.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a three channel sensor system according to a first embodiment of this invention.

FIG. 2 is a timing diagram showing the operation of the sensor system of FIG. 1.

FIG. 3 is a block diagram of a three channel sensor system according to a second embodiment of this invention.

FIG. 4 is a timing diagram showing the operation of the sensor system of FIG. 3.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1, a three channel sensor system 10 has a photon detector 15 that is responsive to radiant energy within a spectral band of relatively short wavelength (0.7 to 1.2 microns, for example), and a thermal detector 20 that is responsive to a spectral band of relatively long wavelength (7 to 30 microns, for example). The analog output of each detector 15 and 20 is amplified by amplifiers 25 and 30 respectively. The outputs of amplifiers 25 and 30, which are hereinafter called nodes a and b respectively, are fed to amplifiers 35 and 40 respectively. The output of amplifier 35 is fed to a threshold device 45 having a predetermined threshold level V_{T1}. The output of amplifier 40 is fed to a threshold device 50 having a predetermined threshold level V_{T2}. The threshold devices 45 and 50 convert the respective analog outputs of amplifiers 35 and 40 to logical control signals. When the output of amplifier 35 is below the threshold level V_{T1} , the threshold device 45 will not generate a control signal (its output is a logical 0); but when the output of amplifier 35 exceeds the threshold level V_{T1} , the threshold device 45 will generate a control signal (its output is a logical 1). The threshold device 50 operates in a similar manner. The outputs of the threshold devices 45 and 50, hereinafter called nodes q and r respectively, are fed to an AND gate 55.

The outputs of amplifiers 25 and 30 are fed to a comparator-threshold circuit 60. The comparator-threshold circuit 60 generates a logical control signal only when the difference between the amplitudes of its two inputs exceeds a predetermined level.

The output of amplifier 25 is also fed to a risetime sensing circuit 65, and the output of amplifier 30 is also fed to another risetime sensing circuit 70. Each risetime sensing circuit generates an analog output that is proportional to the rate of change of its input signal. The output of risetime sensing circuit 65, hereinafter called node d, and the output of risetime sensing circuit 70, hereinafter called node e, and the output of the comparator-threshold circuit 60, hereinafter called node c, comprise the three inputs to a variable delay circuit 75. The variable delay circuit 75 generates a logical control signal for a predetermined fixed period of time after receiving control signals at all three of its input ports.

The outputs of the amplifiers 25 and 30 are also fed to a dual time-constant circuit 80 through ganged single-pole switches 85 and 86 respectively. The states of the ganged switches 85 and 86 are controlled by a switch driver 90. The switch driver 90 is controlled by the output of the comparator-threshold circuit 60. If the comparator-threshold circuit 60 generates a control signal, the switch driver 90 drives the ganged switches 85 and 86 to their closed states; if the control signal ceases to be generated, the switch driver drives the ganged switches 85 and 86 to their open states. Therefore, the dual time-constant circuit 80 receives the outputs of amplifiers 25 and 30 only if the comparator-threshold circuit 60 generates its logical control signal (i.e. - if node c is "high").

When the ganged switches 85 and 86 are closed, the dual time-constant circuit 80 is charged up by the potentials at nodes a and b. The outputs of the dual time-constant circuit 80, hereinafter called nodes g and h, are fed to a dual threshold circuit 95. The dual threshold circuit 95 converts the analog signals at nodes g and h to logical signals, hereinafter called nodes k and m. The two outputs of the dual threshold circuit 95 are fed to the input ports of an AND gate 98.

The output of the AND gate 98, hereinafter called node n, the output of the comparator-threshold circuit 60, and the output of the variable delay circuit 75, hereinafter called node f, all comprise the inputs to a NOR gate 99. The output of the NOR gate 99, hereinafter called node p, comprises the third input to the AND gate 55. The output of the AND gate 55, hereinafter called node s, is fed to electromechanical fire suppression equipment (not shown).

In most applications, a large amplitude optical signal would take longer to decay than a small amplitude optical signal. Therefore, by charging up a time constant circuit with the amplitude of the optical signal (either long wavelength or short wavelength or both), the decay of the time constant circuit can be used to model or simulate the decay of the optical signal for the case where no fire is produced.

The risetime variable delay works in a similar fashion. Few stimuli are capable of producing the fast-rising optical signals that occur when an anti-aircraft projectile penetrates the skin of an aircraft. This is especially true at the longer wavelengths. Consequently, a time constant circuit whose delay increases with rise-time of the optical signal would provide a short delay (i.e. - in the range of about 1 to 30 milliseconds) for very fast-rising signals, and would thus release suppressant at about the right time. However, for very slow risetimes, (a few tenths of a second) such as may occur when maintenance personnel are moving about, very long delays (several seconds) could be generated.

Thus, the advantage of the risetime dependent delay would be an increased immunity to common false-alarm producing stimuli, whereas the amplitude dependent delay would be better able to simulate the decay of the projectile penetration and discriminate more effectively between the flash and a fire.

The operation of the sensor system of FIG. 1 is shown in the timing diagram of FIG. 2. The scenario depicted in FIG. 2 occurs when a projectile or a piece of flak bursts through the wall of an area monitored by the sensor system 10 and causes a fire. When the projectile or piece of flak pierces the wall, it causes a flash of radiant energy. The flash comprises a relatively quick-rising short-wavelength component that is detected by the photon detector 15, causing the waveform shown in FIG. 2 at node a. The flash also comprises a relatively slow-rising long-wavelength component that is detected by the thermal detector 20, causing the waveform shown in FIG. 2 at node b.

As the waveform at node a exceeds the threshold value V_{T1} at time t_1 , the signal at node q rises to a logical 1, where it remains for as long as the waveform at node a remains above the threshold value V_{T1}. As the short wavelength component of the flash continues to rise faster than the long wavelength component, the difference between their amplitudes will cause the comparator-threshold circuit 60 to generate its logical control signal at time t_2. The signal at node c will energize the switch driver 90 causing it to drive ganged switches 85 and 86 closed, thereby feeding the signals at nodes a and b to the dual time-constant circuit 80 causing the waveforms shown in FIG. 2 at nodes g and h.

When the dual time-constant circuit 80 charges up, the waveforms at nodes g and h trigger the dual threshold circuit 95 at time t_2 , generating logical control signals at nodes k and m. Since both input signals to the AND gate 98 are logical 1's, it generates a logical control signal at time t_2. The NOR gate 99 generates a logical control signal when all of its inputs are logical 0's. When the comparator-threshold circuit 60 generates its control signal at time t_2 , the NOR gate's output is inhibited, thereby inhibiting the generation of a control signal at node s.

As the relatively slow-rising long wavelength component of the flash increases, it causes the rise-time sensing circuit 70 to generate an output. At time t_3 the outputs of both risetime sensing circuits are of sufficient magnitude to turn on the variable delay circuit 75 and cause it to generate a control signal for a predetermined period of time (here t_3 to t_7). The period of time that the variable delay circuit generates its control signal should be set such that the fast risetimes caused by the penetration of anti-aircraft fire produces shorter delays than that of the amplitude variable delay circuit. Thus, the amplitude variable delay circuit would dominate in the control of the release of the suppressant for combat battle damage.

For slower risetime signals, however, the variable delay circuit 75 would be set experimentally such that delays would be incorporated to inhibit against false activation by, for example, the movement of maintenance personnel.

The slow-rising long wavelength component of the flash rises above the threshold level V_{T2} at time t_5 causing a logical 1 waveform at node r. At time t_6, the short wavelength component of the decaying flash falls off as the long wavelength component continues to rise, now due to the fire ignited by the projectile or piece of flak. The difference between their amplitudes falls below the threshold level causing the comparator-threshold circuit to cease generating a control signal, as seen at node c at time t_6. This causes the ganged switches 85 and 86 to open and the dual time-constant circuit 80 output to begin decaying. When either of the waveforms at nodes g or h decay below the threshold of the dual threshold circuit 95, one of the inputs (here node k) is removed from the AND gate 98 at time t_7 causing its output to return to a logical 0.

At time t_8 , the inputs to the NOR gate 99 will all be logical 0, and the waveform at node p will rise to a logical 1. Therefore, all three inputs to the AND gate 55 will be logical 1's and the AND gate 55 will generate an output control signal at time t_8. This control signal can be utilized to cause the release of a suppressive material to extinguish the building fire before it is out of control.

If no fire resulted from the projectile or piece of flak, the waveform at nodes a and/or b would have been below their respective threshold levels V_{T1} or V_{T2}. In that case, there would have been a logical 0 at node q and/or r, and the AND gate 55 could not have generated its output control signal at time t_8.

The particular circuitry or types of circuits that inhibit the release of a suppressnat for a period of time sufficient to allow a flash to dissipate is not limited to those shown in the embodiment of FIG. 1. Another three channel sensor system 100 is shown in FIG. 3. The sensor system 100 has a photon detector 105 and a thermal detector 110, each capable of detecting radiant energy within a certain spectral band and generating an output proportional to the amplitude of the detected radiation. Like the system of FIG. 1, the photon detector detects radiation in the 0.7 to 1.2 microns bandwidth, and the thermal detector may operate in the 7 to 30 microns bandwidth. The output of the photon detector is amplified by an amplifier 115 and the output of the thermal detector 110 is amplified by an amplifier 120.

The outputs of the amplifiers 115 and 120, hereinafter called nodes u and v respectively, are fed to the inputs of a comparator-threshold circuit 145. The comparator-threshold circuit generates a control signal at node y whenever the difference between the amplitudes of its input signals exceeds a predetermined threshold value. The outputs of the amplifiers 115 and 120 are also fed respectively to the amplifiers 125 and 130, which feed threshold circuits 135 and 140 respectively. The threshold circuit 135 generates a control signal at node w if its input exceeds a predetermined threshold value V_{T3}, and the threshold circuit 140 generates a control signal at node x if its input exceeds a predetermined threshold value V_{T4}. The outputs of the threshold circuits 135 and 140 comprise two of the inputs to an AND gate 155.

The delay function of the sensor system 100 is performed by a fixed delay circuit 150. The fixed delay circuit 150 generates a logical control signal at node z in the absence of any input signal from the comparator-threshold circuit 145. When the comparator-threshold circuit 145 generates a logical control signal, the fixed delay circuit 150 will cease generating its control signal for the duration of the input signal and for a fixed predetermined period of time (delay period) thereafter. Since the output of the fixed delay circuit 150 comprises the third input to the AND gate 155, an output control signal at node zz is inhibited for the delay period.

The operation of the sensor system 100 is shown by the timing diagram of FIG. 4 which uses the same scenario depicted in FIG. 2. When the short wavelength component of the flash rises above its threshold level V_{T3} at time t_{11}, the output of the threshold circuit 135 will rise to a logical 1 as shown at node w in FIG. 4. When the difference between the amplitudes of waveforms u and v exceeds the threshold value of the comparator-threshold circuit 145 from time t_{12} to time t_{13}, a logical 1 is generated and fed to the fixed delay circuit 150 (node y in FIG. 4). The fixed delay circuit 150 ceases generating its logical control signal at time t_{12} as shown at node z in FIG. 4, and its output remains a logical 0 until the comparator-threshold circuit 145 ceases generating its control signal at time t_{13} and for a fixed predetermined period of time thereafter (t_{13} to t_{15}).

At time t_{14} the long wavelength component of the developing fire causes the waveform at node v to exceed its threshold value V_{T4} and the threshold circuit 140 generates a logical 1. When the fixed predetermined period of time of the fixed delay circuit 150 lapses at time t_{15} , the fixed delay circuit 150 again generates a logical 1. Since all inputs to the AND gate 155 are logical 1's, the AND gate 155 generates an output control signal that may be used to release a suppressant material to extinguish the developing fire.

It is understood that the above-described embodiment is merely illustrative of the many possible specific embodiments which can represent applications of the principles of this invention. Numerous and varied other arrangements can be devised in accordance with these principles by those skilled in this art without departing from the spirit and scope of the invention.

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CLAIMS

1. A sensor system responsive to a fire or explosion comprising:

a) a first control signal means, responsive to a first radiant energy detector, for generating a first control signal when the first detector detects electromagnetic energy within a first spectral band having an amplitude greater than a first predetermined level;

b) a second control signal means, responsive to a second radiant energy detector, for generating a second control signal when the second detector detects electromagnetic energy within a second spectral band having an amplitude greater than a second predetermined level;

c) a third control signal means, responsive to the first and second radiant energy detectors, for generating a third control signal whenever the ratio of the energy detected by the first detector to the amplitude of the energy detected by the second detector exceeds a third predetermined level;

d) a fourth control signal means, responsive to the third control signal, for:

(i) generating a fourth control signal whenever the third control signal is not generated, and

(ii) not generating the fourth control signal whenever the third control signal is generated and for an additional predetermined amount of time after the third control signal is no longer generated; and

e) output gate means, responsive to the first, second, and fourth control signals, for generating an output signal only when the first, second, and fourth control signals are all simultaneously generated.

2. The sensor system of Claim~~s~~ 1, wherein the third control signal means is generated when the amplitude of the output of the first detector exceeds the amplitude of the output of the second detector.

3. The sensor system of Claim~~s~~ 1, wherein the first spectral band is a broad spectral band within the region of 0.1 to 2.0 microns in wavelength and the second spectral band is a broad spectral band within the region of 5 to 30 microns in wavelength.

4. The sensor system of Claim~~s~~ 1, wherein the first spectral band is a broad spectral band within the region of 0.1 to 1.2 microns in wavelength and the second spectral band is a broad spectral band within the region of 2.0 to 5.0 microns in wavelength.

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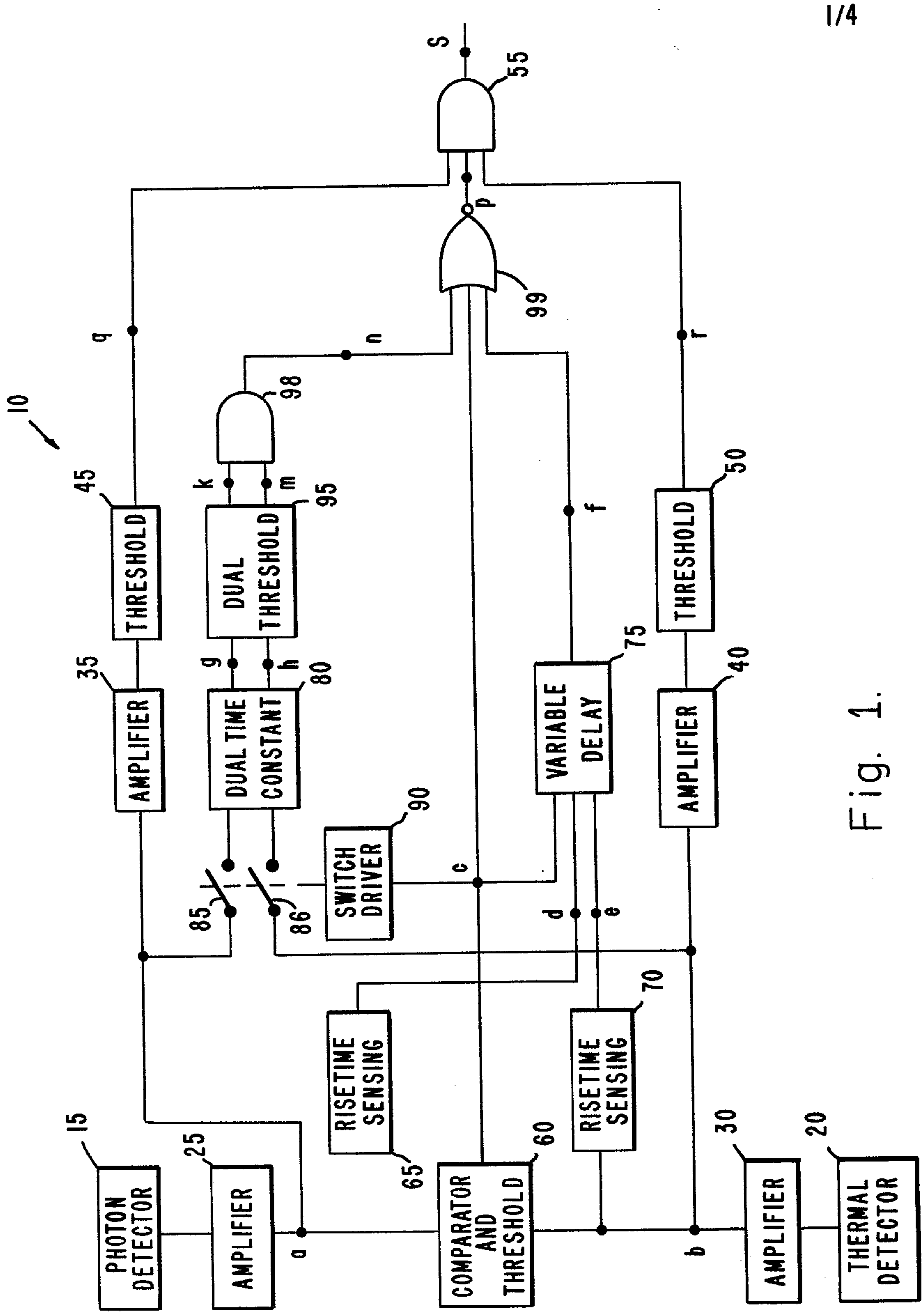
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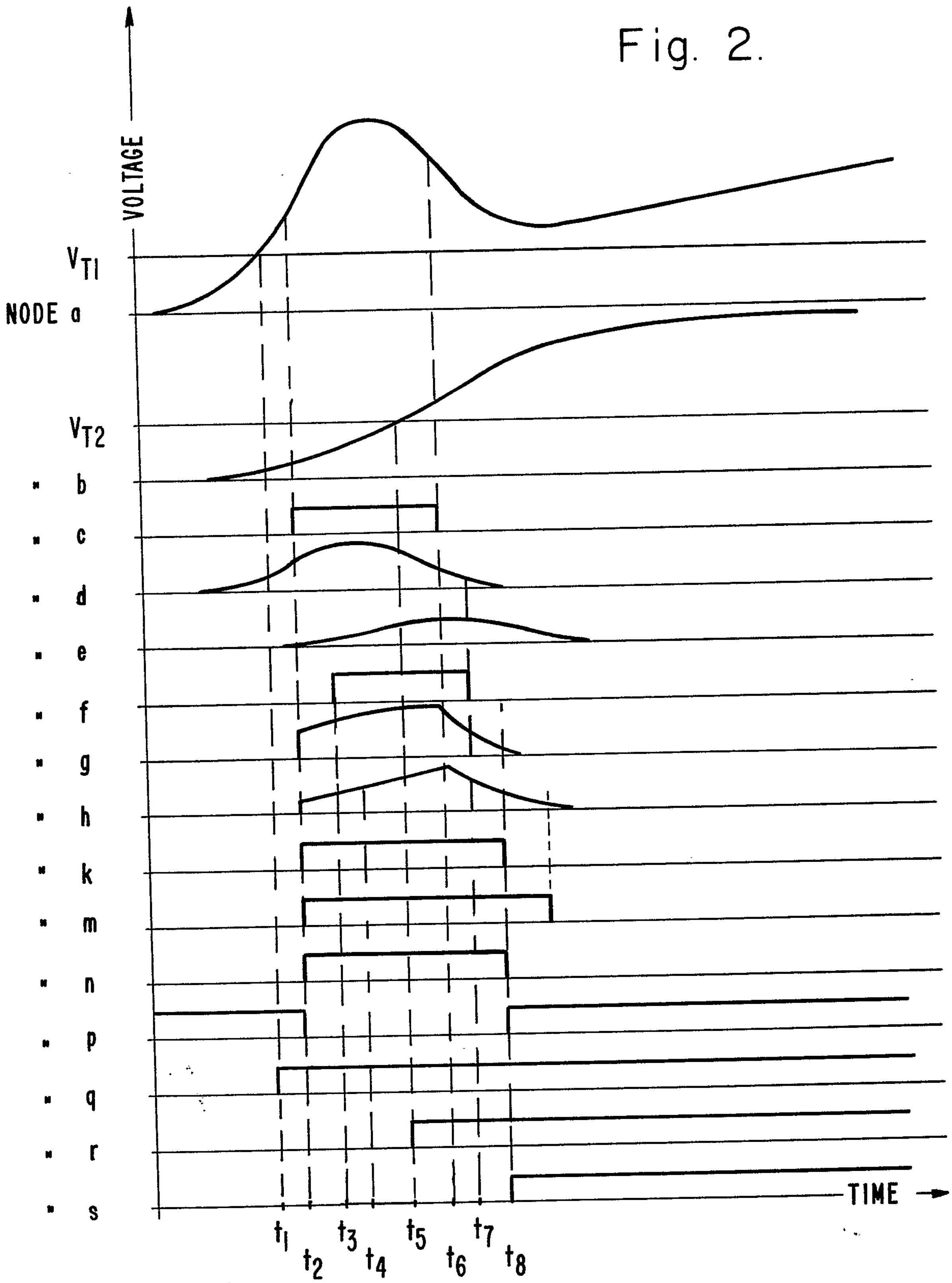
Fig. 1.

Fig. 2.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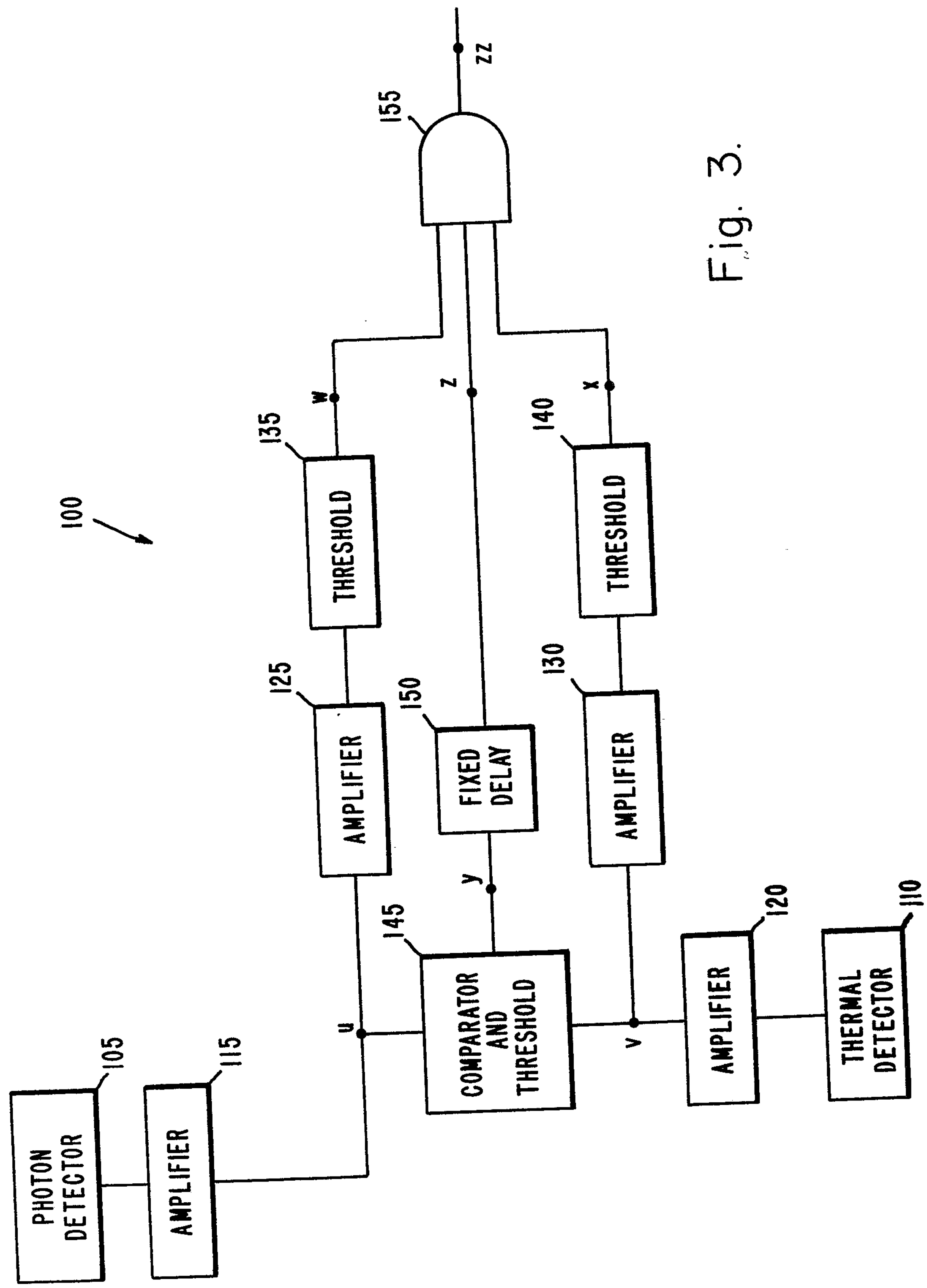
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Fig. 3.

Fig. 4.