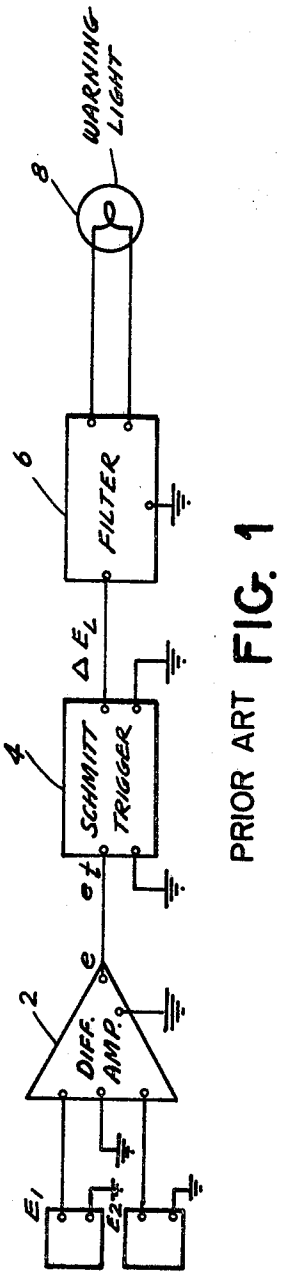
Dec. 2, 1969 J. DONIGER ETAL 3,482,234

SIGNAL COMPARATOR FOR MINIMIZING NUISANCE FAILURE ALARMS

Filed June 22, 1965 4 Sheets-Sheet 1



PRIOR ART FIG. 1

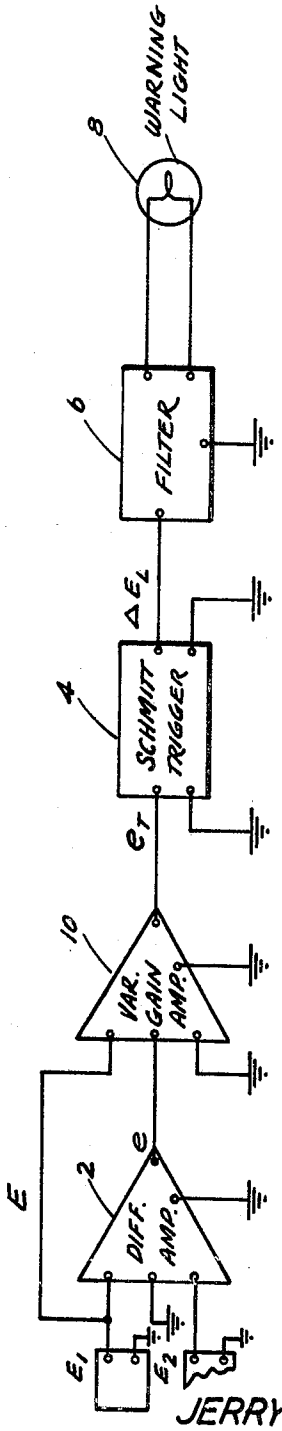
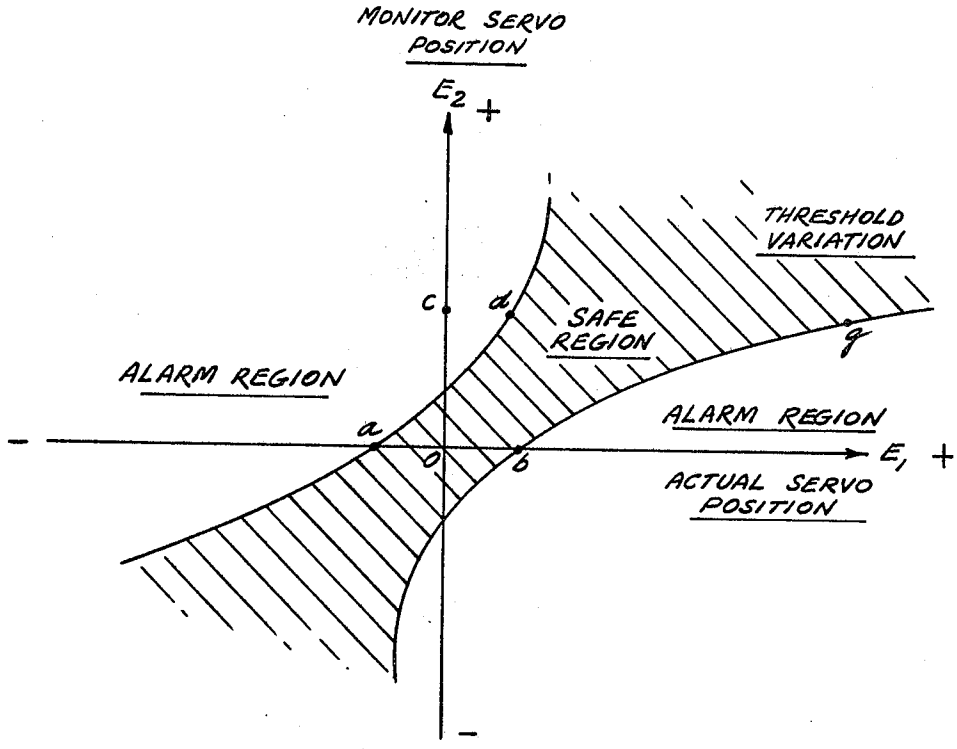


FIG. 2

INVENTORS
JERRY DONIGER
JERRY BERG
BY Herbert L. Davis
ATTORNEY



THRESHOLD VARIATION WITH INPUT SIGNAL AMPLITUDE

FIG. 3

INVENTORS
JERRY DONIGER
JERRY BERG
BY Herbert L. Davis
ATTORNEY

Dec. 2, 1969 J. DONIGER ETAL 3,482,234

SIGNAL COMPARATOR FOR MINIMIZING NUISANCE FAILURE ALARMS

Filed June 22, 1965

4 Sheets-Sheet 3

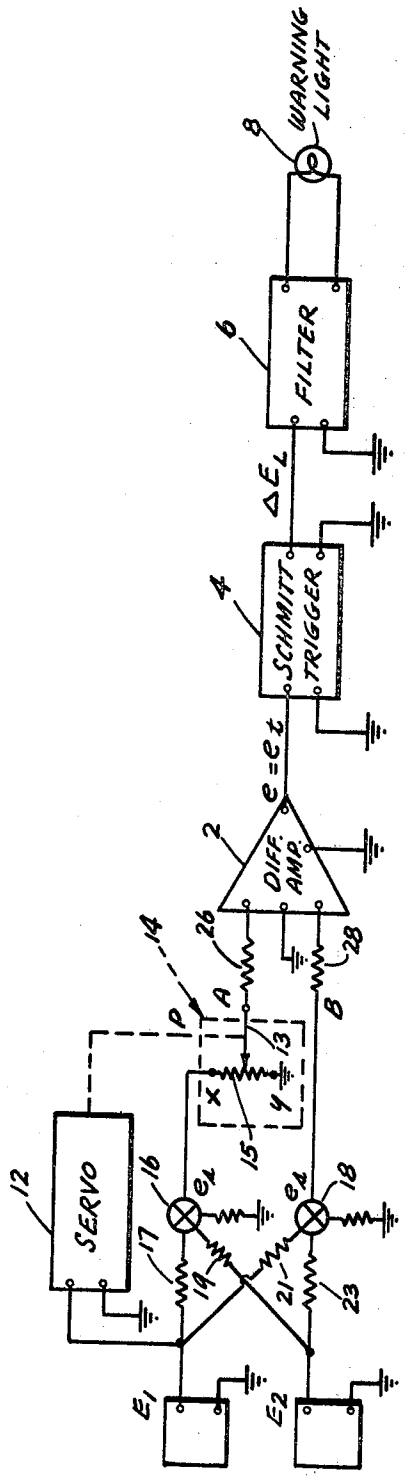


FIG. 4

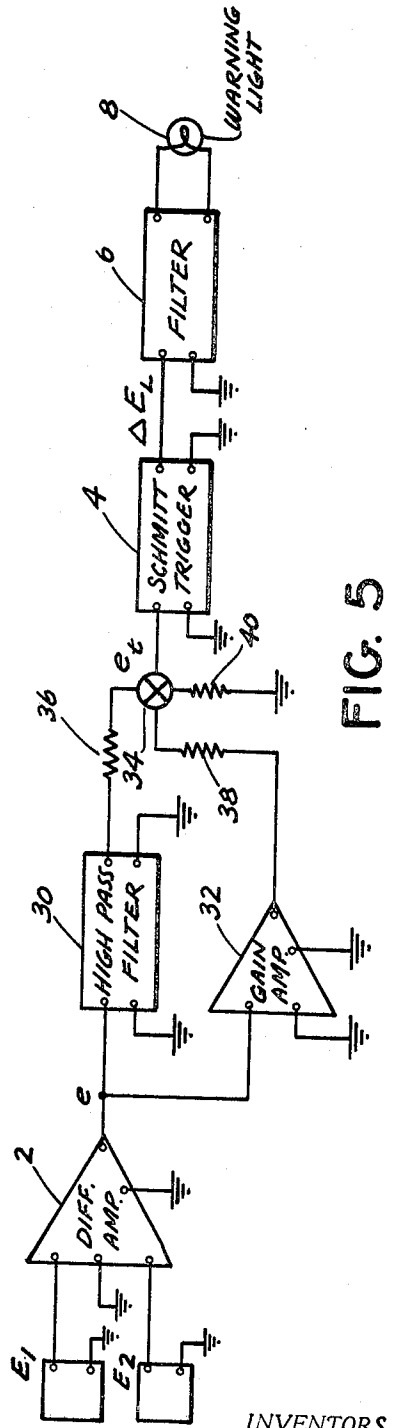


FIG. 5

INVENTORS
JERRY DONIGER
JERRY BERG
BY Herbert L. Davis
ATTORNEY

Dec. 2, 1969 J. DONIGER ETAL 3,482,234
SIGNAL COMPARATOR FOR MINIMIZING NUISANCE FAILURE ALARMS
Filed June 22, 1965
4 Sheets-Sheet 4

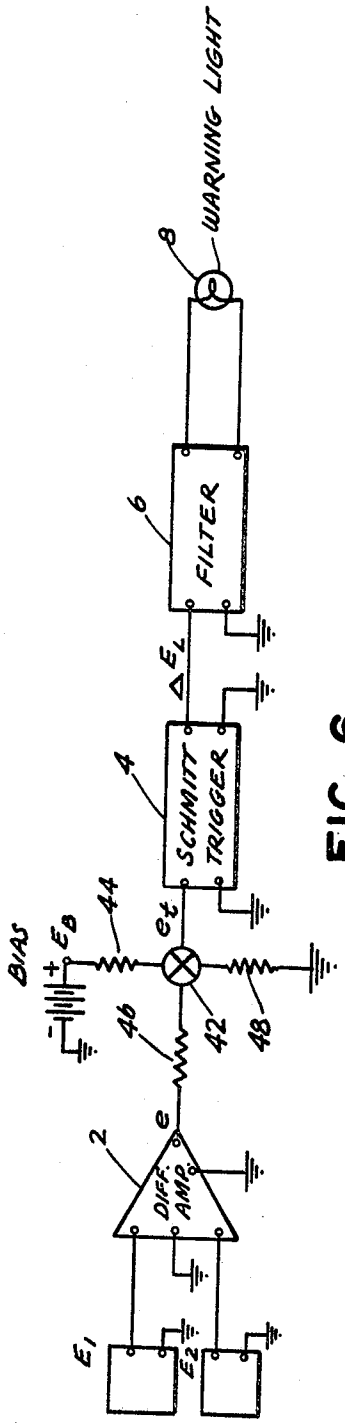


FIG. 6

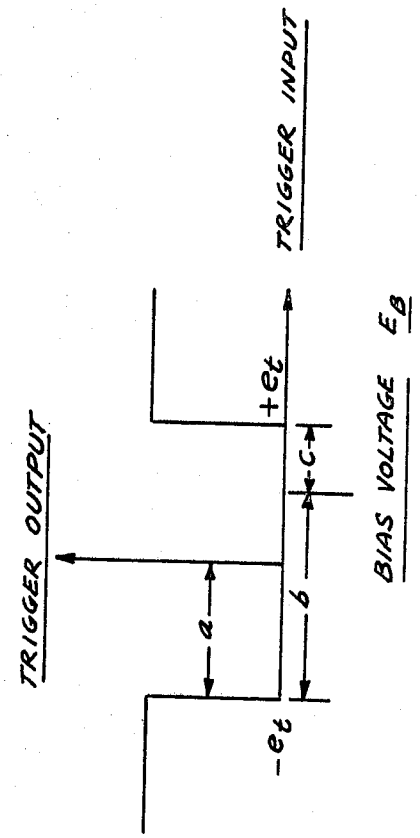


FIG. 7

INVENTORS
JERRY DONIGER
JERRY BERG
BY Herbert L. Davis
ATTORNEY

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3,482,234
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3,482,234

SIGNAL COMPARATOR FOR MINIMIZING NUISANCE FAILURE ALARMS

Jerry Doniger, Montvale, and Jerry Berg, Carlstadt, N.J., assignors to The Bendix Corporation, Teterboro, N.J., a corporation of Delaware

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Int. Cl. G08b 21/00; H03k 5/20; H03b 3/02
U.S. Cl. 340—248 4 Claims

ABSTRACT OF THE DISCLOSURE

A device for comparing a pair of input signals and for actuating an alarm when the difference between the input signals exceeds a predetermined threshold voltage which is provided as a function of said signals. The excessive difference signal actuates a trigger and the trigger output is filtered for applying time delay characteristics, with the time delayed output actuating the alarm.

This invention relates to signal comparators, and more particularly to signal comparators providing output signals for actuating alarm devices.

The need for high reliability aircraft performance has given rise to the development of fail-operative control equipment. This equipment includes monitoring devices in redundant systems of a type disclosed and claimed in copending U.S. application Ser. No. 318,050, filed Oct. 22, 1963, now Patent No. 3,289,193, and in copending U.S. application Ser. No. 351,426, filed Mar. 12, 1964, now Patent No. 3,431,557, both filed by Frank John Thomas and Robert Leo Worthington and assigned to the Bendix Corporation, assignee of the present invention.

The aforenoted monitoring devices include signal comparators such as those which are the subject of the present invention, and disclosed and claimed broadly in the copending U.S. application Ser. Nos. 318,050 and 351,426. These signal comparators include a differential amplifier for generating a difference signal proportional to the difference between two input signals. The difference signal is received as input to a Schmitt trigger circuit which responds thereto by providing logic output depending on the level of the difference signal relative to the trigger threshold voltage, with the logic output causing operation of a failure indicating alarm device such as a warning light when the difference signal exceeds the threshold voltage.

The present invention provides four novel variations from the aforenoted signal comparator circuit, with each variation matching threshold voltage requirements to input voltage characteristics to eliminate nuisance alarms without compromising aircraft safety.

A first form of the invention provides threshold voltage as a function of variable gain, with the gain proportional to the absolute magnitude of one of the input signals, to accommodate the condition when one input signal is voltage limited and the other is not.

A second form of the invention accommodates ratios of one threshold voltage to another in the order of 40 to 1 by adjusting the gain of the input signals through a servo driven potentiometer.

A third form of the invention varies the basic comparator configuration to obtain threshold voltages which accommodate differences in low frequency characteristics between the two input signals.

A fourth form of the invention provides for combining a bias voltage with the difference signal to provide unsymmetrical threshold voltages.

An object of this invention is to provide a signal comparator for providing an alarm output.

Another object of this invention is to provide a signal comparator which will compare input voltages to provide a difference signal for generating an alarm output when the difference signal exceeds a prescribed level.

Another object of this invention is to provide a signal comparator which will compare input voltages to provide a difference signal, and modify the difference signal to provide a threshold voltage for generating an alarm output when the threshold voltage exceeds a prescribed level, and with nuisance alarms minimized by matching threshold voltage requirements to input signal characteristics.

Another object of this invention is to compare input signals to provide a difference signal, and to modify the difference signal to provide a threshold voltage for generating an alarm output, with the threshold voltage having variable gain characteristics depending on the amplitude of one of the input signals.

Another object of this invention is to compare input signals to provide a difference signal, and to modify the difference signal to provide a threshold voltage for generating an alarm output, with the threshold voltage discriminating against low frequency differences in the input signals.

Another object of this invention is to compare input signals to provide a difference signal, and to modify the difference signal to provide a threshold voltage for generating an alarm output, with the threshold voltage depending upon gain characteristics applied to the input signals.

Another object of this invention is to compare input signals to provide a difference signal and to modify the difference signal to provide a threshold voltage for generating an alarm output with the threshold voltage having unsymmetrical characteristics.

These and other objects and features of the invention are pointed out in the following description in terms of the embodiments thereof which are shown in the accompanying drawings. It is to be understood, however, that the drawings are for the purpose of illustration only and are not a definition of the limits of the invention, reference being had to the appended claims for this purpose.

In the drawings, wherein corresponding numerals indicate corresponding parts:

FIGURE 1 is a block diagram of the basic signal comparator disclosed and broadly claimed in the copending U.S. application Ser. Nos. 318,050 and 351,426.

FIGURE 2 is a block diagram of the basic comparator shown in FIGURE 1 modified as in the first form of the invention.

FIGURE 3 is a graphical representation of the variation of threshold voltage with input signal amplitude as shown in the form of the invention of FIGURE 2.

FIGURE 4 is a block diagram of the basic comparator of FIGURE 1 modified as in the second form of the invention.

FIGURE 5 is a block diagram of the basic comparator of FIGURE 1 modified as in the third form of the invention.

FIGURE 6 is a block diagram of the basic comparator of FIGURE 1 modified as in the fourth form of the invention.

FIGURE 7 is a graphical representation of trigger voltage output and input, effected by a bias voltage being combined with the difference signal, as in the fourth form of the invention.

BASIC SIGNAL COMPARATOR

The basic signal comparator disclosed and broadly claimed in copending application Ser. Nos. 318,050 and 351,426 is shown in FIGURE 1 including a differential amplifier **2** to provide a difference signal e which is received by a Schmitt trigger **4**, with Schmitt trigger **4** providing a change in output ΔE_L which may be coupled through a filter **6** to a device such as a warning light **8**, providing signals indicating a system failure when difference signal e has exceeded a predetermined level.

Input voltages E_1 and E_2 are received and compared by differential amplifier **2** to provide difference signal e which is received as an input by Schmitt trigger **4**. Schmitt trigger **4** is arranged to provide an output voltage when difference signal e is below a fixed threshold level e_t. When difference signal e is above threshold level e_t, Schmitt trigger **4** is switched to a null state. The change in output ΔE_L of Schmitt trigger **4** is thus dependent upon the level of difference signal e relative to threshold level e_t, and is coupled to filter **6** which is a resistance-capacitance network filtering ΔE_L so that an alarm voltage, which may be coupled to warning light **8**, is effective only after a definite time interval.

FIRST FORM OF THE INVENTION

The first form of the present invention provides a variation in the basic comparator configuration of FIGURE 1 to accommodate unmatched characteristics of input voltages E_1 and E_2. Such a situation might arise, for example, if E_1 is voltage limited so as to indicate the position of a servo that is torque saturable, and E_2 is employed to indicate the position of a monitor servo which does not sense load torque. Under these conditions, the difference between E_1 and E_2 might be sufficient to exceed threshold voltage e_t of Schmitt trigger **4** so that nuisance alarms will be generated which are not really indicative of a system malfunction.

In such a servo system the requirement of the monitor servo may be to disregard conditions of torque saturation. In order to eliminate nuisance signals, the magnitude of difference signal e must be increased as a function of the amplitude of input voltage E_1. The means for accomplishing this is shown in FIGURE 2. A variable gain amplifier **10**, which may be of a type to provide gain control as shown and described in Basic Theory and Application of Transistors, Department of the Army Technical Manual TM 11-690, Chapter 8, Sec. 2, pp. 155-158, March 1959, is interposed between differential amplifier **2** and Schmitt trigger **4** to receive difference signal e. Also coupled as input to variable gain amplifier **10** is the absolute value of input voltage E_1, designated as E, to provide the gain of variable gain amplifier **10** as a function of e. Since threshold level e_t of Schmitt trigger **4** is fixed, the magnitude of difference signal e which is required to reach threshold level e_t is a function of the gain of amplifier **10**;

$$e=E_1-E_2$$

$$e_t=ef[(E)]$$

An example of the relationship that threshold voltage e_t has with input voltages E_1 and E_2 is shown with reference to the graphical representation of FIGURE 3, which provides E_1 along the abscissa and E_2 along the ordinate thereof, whereby E_1 is the voltage representing actual servo position and E_2 is the voltage representing monitor servo position.

The sectioned area of the graphical representation of FIGURE 3 is the area of signal variation which will not cause an alarm. This area increases as the input signal is increased. If E_2 is zero, for example, then E_1 can vary between $+b$ and $-a$ without causing an alarm. If E_2 has a value of c, then E_1 can vary between d and g without causing an alarm. Ratios of one threshold voltage to another, in the nature of 3 or 4 to 1 are required in most automatic pilot systems, and may be provided by modifying the basic comparator circuit shown in FIGURE 1 with variable gain amplifier **10** shown in FIGURE 2.

SECOND FORM OF THE INVENTION

While the first form of the invention provides for threshold voltage ratios of 3 or 4 to 1, it is recognized that occasions may arise when threshold voltage ratios in the order of 40 to 1 are required. Such a situation will come into existence when voltages which are proportional to altitudes over a range of zero to 2,500 feet are used as inputs to differential amplifier **2**.

The configuration shown in FIGURE 4 accommodates such a condition. Input voltage E_1, for example, may drive a servo **12** which positions, through suitable mechanical means, an arm **13** of a potentiometer **14** to points x and y on potentiometer resistor **15** providing voltages proportional to the altitude represented by E_1. E_1 and E_2 may be compared at points **16** and **18** through summing resistors **17** and **19** and **21** and **23** respectively, to provide summation voltage e_s at points **16** and **18**. Voltage e_s generated at point **16** is applied across potentiometer **14** to a gain adjusting resistor **26** designated as A. The signal generated at summation point **18** is applied directly to a gain adjusting resistor **28** designated as B. Differential amplifier **2** combines these gain adjusted voltages to provide difference signal e, which may be algebraically represented in terms of the gain resistors **26**(A) and **28**(B) and the setting of potentiometer **14** designated as **P**.

$$e=Ae_s-Be_sf(P)$$

If difference signal e is also threshold voltage e_t of Schmitt trigger **4**, then when potentiometer **14** is in position X shown in FIGURE 4, voltage e_s required to reach threshold voltage e_t is;

$$e_s=\frac{e_t}{A+B}$$

When potentiometer **14** is in position Y shown in FIGURE 4, then voltage e_s required to reach threshold voltage e_t of Schmitt FIGURE 4 is;

$$e_s=\frac{e_t}{A}$$

Since gain adjustment resistors **26** and **28** control the parameters A and B in the aforenoted equations, a wide range of threshold voltage ratios can be thus implemented.

THIRD FORM OF THE INVENTION

The third form of the present invention accommodates the condition when input voltages E_1 and E_2 have the same high frequency characteristics, but not the same very low frequency or steady state characteristics. If a component of voltage E_1 for example, is generated by an integration device, then the direct current or steady state level of E_1 may differ considerably from that of E_2. It may be desirable that this diffeernce between input voltages does not cause an alarm signal.

In order to compensate for this condition, the basic comparator shown in FIGURE 1 has been modified to that shown in FIGURE 5. A high pass filter **30** has been interposed between differential amplifier **2** and Schmitt trigger

4. Any steady state differences inherent in difference signal e are completely rejected by high pass filter **30** before reaching Schmitt trigger **4**.

The use of high pass filter **30**, however, also prevents difference signals e having excessively large steady state characteristics from being transmitted to Schmitt trigger **4**. Since large steady state differences may indicate a failure condition, it is desirable to have such differences indicated and processed through the comparator to provide an alarm. This is achieved by providing an override gain circuit **32**, which may be a conventional type constant gain amplifier, to bypass filter **30** in the event that difference signals e having large steady state differences are generated. By including override gain circuit **32** in the basic comparator configuration, large differences between input voltages E_1 and E_2 may be indicated which come about as a result of uncontrolled gyro or integrator drifting in a monitoring system.

The outputs of high pass filter **30** and of override gain circuit **32**, are combined at point **34** through summing resistors **36** and **38** respectively. The signal at point **34**, grounded through resistor **40**, represents threshold voltage e_t required to actuate Schmitt trigger **4** to provide output ΔE_L.

FOURTH FORM OF THE INVENTION

The fourth variation of the basic comparator configuration shown in FIGURE 1 provides for a possible requirement that threshold voltage e_t required to actuate Schmitt trigger **4** be unsymmetrical in order that large voltage differences of one polarity or phase, and small voltage differences of the opposite polarity or phase may be detected.

This result is accomplished, as shown in FIGURE 6, by combining a bias voltage E_B with difference signal e at point **42** through resistors **44** and **46** respectively to provide a summation voltage grounded through a resistor **48**. The signal at summation point **42** represents threshold voltage e_t.

The technique of combining bias voltage E_B with difference signal e results in a shift in the original symmetrical threshold voltage to an unysmmetrical value as may be seen by the graphical representation of FIGURE 7. In reference to FIGURE 7, the total input voltage increment from one threshold point to the other remains the same although each threshold signal is not symmetrical with the other. As an example, a equals normal symmetrical threshold and b and c are the unsymmetrical thresholds. Although $b+c$ equals $2a$, b and c are not equal to each other.

SUMMARY

In summation, therefore, the means embodied in the present invention limits the basic comparator configuration disclosed and broadly claimed in U.S. application Ser. Nos. 318,050 and 351,426, so that nuisance alarms generated due to differences in input voltage characteristics may be minimized. It is important to note that the novel embodiments of the present invention accomplish this task without effecting the safety of the aircraft utilizing the system.

In reference to the figures included herein, and the descriptions thereof, it may be seen that the means employed to minimize nuisance alarms is based on matching the threshold voltage of the triggering device providing the alarm output to common characteristics of the input voltages. This is accomplish in the several forms of the invention whereby the gain of the threshold voltage is made proportional to the magnitude of one of the input voltages; the gain of the input signals is adjusted to accommodate large threshold voltage ratios; filters are provided to accommodate differences in low frequency characteristics between the two input signals; and a bias voltage is utilized to provide an unsymmetrical threshold voltage.

The above modifications, combined with the basic signal comparator system, provide a highly useful means for providing warning signal alarms and at the same time provide limitations which optimize the system so as to eliminate nuisance alarms. Such a device is of extreme importance and should enjoy a wide use on modern aircraft in applications embodying fail operative control equipment.

We claim:

1. In a device of a type including means for receiving first and second input signals, means for comparing said signals to provide a difference signal, a trigger circuit having an output, said trigger circuit being responsive to the difference signal to produce a change in said output when said difference signal exceeds a predetermined level, and means responsive to said change in output to actuate an alarm; the improvement comprising means for modifying said difference signal to provide a threshold voltage, said means including a filter for extracting low frequency components from said difference signal to provide a filtered signal, an amplifier responsive to said difference signal for increasing the gain thereof to provide an amplified signal, means to combine said filtered signal and said amplified signal to provide said threshold voltage, said trigger circuit having said output being responsive to a predetermined level of said threshold voltage to provide said change in output, and means responsive to said change in output to actuate said alarm.

2. A device for providing an output to actuate an alarm comprising means for providing first and second input signals, means for comparing said signals to provide a difference signal, means for modifying said difference signal to provide a threshold voltage having unsymmetrical characteristics, a trigger circuit having an output, said trigger circuit being responsive to the unsymmetrical threshold voltage to produce a change in said output when said unsymmetrical threshold voltage exceeds a predetermined level, filtering means for applying time relay characteristics to said change in output and means responsive to said time delayed change in output to actuate the alarm.

3. In a device of a type including means for receiving first and second input signals, means for comparing said signals to provide a difference signal, a trigger circuit having an output, said trigger circuit being responsive to the difference signal to produce a change in said output when said difference signal exceeds a predetermined level, and means responsive to said change in output to actuate an alarm; the improvement comprising means for modifying said difference signal to provide a threshold voltage, said means including means for providing a bias signal, means for combining the bias signal with said difference signal to provide an unsymmetrical threshold voltage, said trigger circuit having said output being responsive to a predetermined level of said unsymmetrical threshold voltage to provide said change in output, and means responsive to said change in output to actuate said alarm.

4. In a device of a type including means for receiving first and second input signals, means for comparing said signals to provide a difference signal, a trigger circuit having an output, said trigger circuit being responsive to the difference signal to product a change in output when said difference signal exceeds a predetermined level, and means responsive to said change in output to actuate an alarm; the improvement comprising means for modifying said input signals to provide a modified difference signal including means for combining said first and second input signals to provide first and second summation signals, a servo actuated by said first input signal, a potentiometer positioned by said servo and responsive to said first summation signal to provide a signal proportional to said first input signal, means to adjust the gain of said proportional signal to provide a third signal, means to adjust the gain of said second summation signal to provide a fourth signal, means to combine said third and fourth signals to provide said modified difference signal, said trigger circuit having said output being responsive to a

predetermined level of said modified difference signal to provide said change in output and means responsive to said change in output to actuate said alarm.

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JOHN W. CALDWELL, Primary Examiner

DANIEL MYER, Assistant Examiner

U.S. Cl. X.R.

307—235; 328—148