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[54] **ALARM SYSTEM EMPLOYING PLURAL MODULES ACCOMMODATING BINARY AND ANALOG TRANSDUCERS**

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[58] **Field of Search**.....340/213.1

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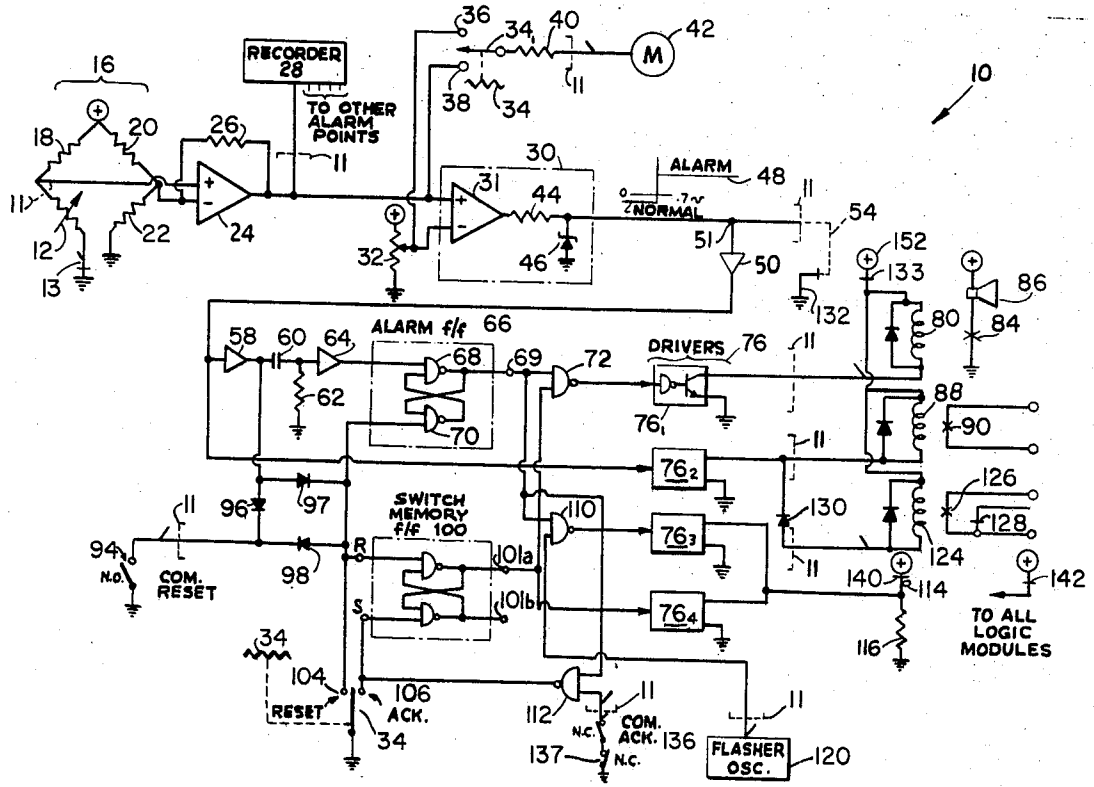
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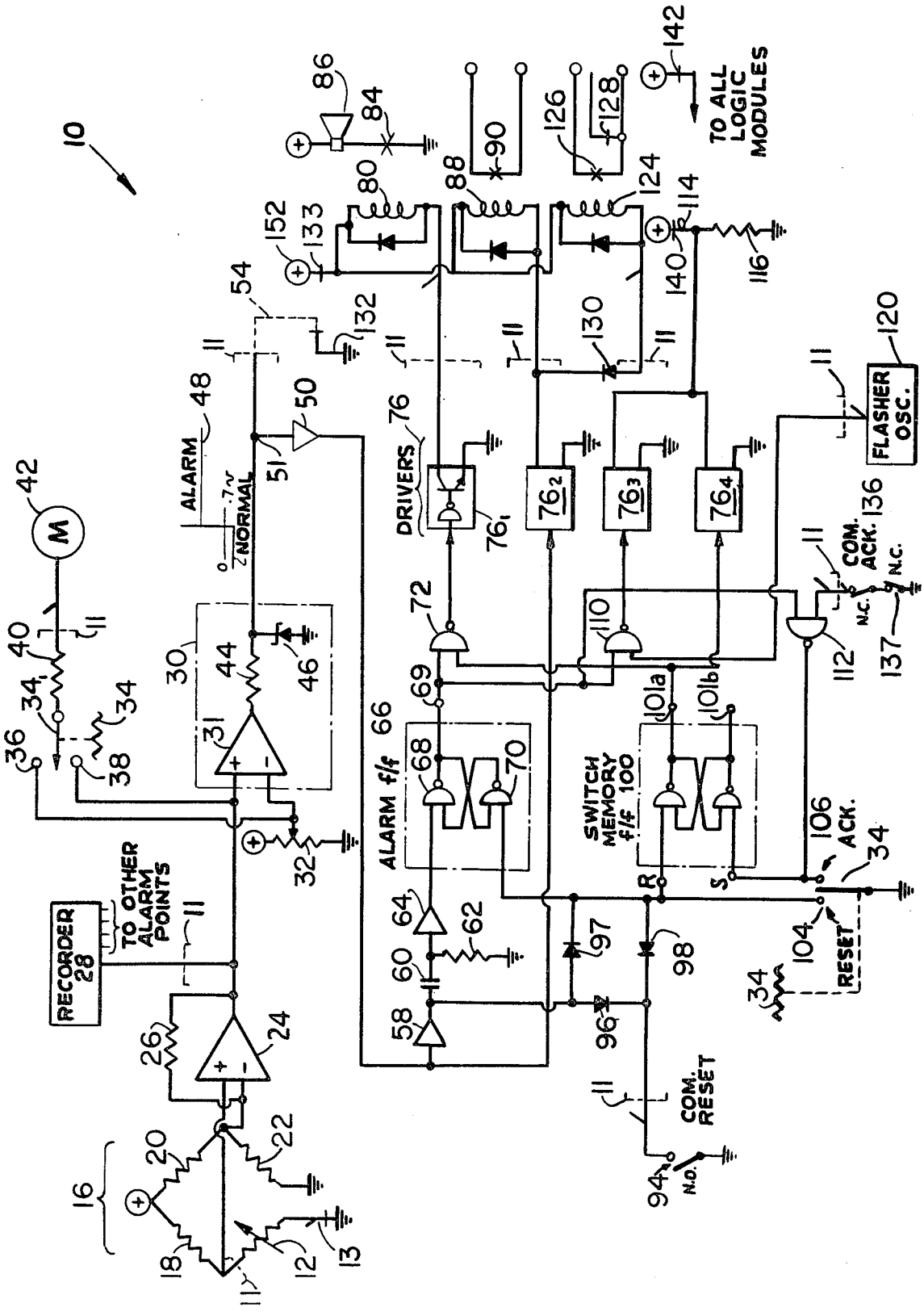
[57] **ABSTRACT**

An alarm system is formed of a plurality of alarm modules of similar construction, each module being connected to the output of a parameter monitoring transducer of either the continuous or discrete (e.g., switched) type. Each module includes a first portion for developing a digital signal characterizing the associated parameter as normal or off-normal. Like digital processing and output driver circuitry is included on each alarm module to provide an audio-visual alarm indication which changes stage when the alarm is acknowledged; for providing information regarding the occurrence of faults by system functions; for automatically initiating remedial action responsive to certain encountered alarm conditions; and for providing audio-visual alarm indications should an alarm signaling module be reset before the underlying alarm condition is remedied.

The module construction can provide digital and linear circuitry for accommodating both binary (on/off) and continuous, analog transducers.

13 Claims, 1 Drawing Figure




10
TO ALL LOGIC MODULES
142
86
84
90
126
128
80
88
124
114
152
133
140
116
54
132
130
120
FLASHER OSC.
ALARM
48
50
51
NORMAL
DRIVERS
76
76₁
76₂
76₃
76₄
42
M
40
34
36
38
30
44
46
31
72
69
110
112
COM. ACK.
N.C.
136
137
ALARM f/f 66
68
70
101a
101b
SWITCH MEMORY f/f 100
R
S
106
ACK.
34
RECORDER 28
TO OTHER ALARM POINTS
32
64
62
60
58
97
98
96
104
RESET
26
24
20
22
16
18
12
13
COM. RESET
94
N.O.

ALARM SYSTEM EMPLOYING PLURAL MODULES ACCOMMODATING BINARY AND ANALOG TRANSDUCERS

This invention relates to electronic instrumentation and control and, more specifically, to a modularized alarm system for providing alarm signals and control function implementation responsive to an abnormal state for one or more sensed environmental parameters.

Operative electrical or mechanical systems, e.g., a ship's propulsion and cargo processing plants, are characterized by a number of operating conditions or parameters which exhibit values between predetermined bounds when the system is operating normally. For shipboard equipment, the pressure values obtaining at selected lubrication points and in selected steam and other conduit paths, and the temperatures associated with bearings, boilers, input and output liquid and gas flows, among other data, provide useful information regarding the operational status of the vessel. It is desirable to display and record these pressure, temperature, and like parameters. Moreover, when any parameter deviates from a normal operating range, it is helpful to provide an indication that an identifiable abnormal situation exists so that an appropriate investigation and possible remedy may be instituted.

However, the monitored parameters of a subject system may, as for the shipboard application, be of diverse types, For example, relatively low temperatures may be sensed by a two terminal thermister; higher temperatures by a two or three lead resistance thermometer of markedly different impedance characteristic; pressure by a three terminal potentiometer; and various levels and the outputs of temperature and pressure switches by the presence or absence of closed switch contacts. Accordingly, prior art alarm systems have employed diverse alarm point constructions for each associated transducer; thereby incurring relatively large production and inventory costs.

Moreover, prior art alarm systems have been predominantly analog in nature, resulting in threshold and margin problems, as well as requiring relatively extensive common equipment to provide the requisite support for the structure associated with the several alarm points.

It is thus an object of the present invention to provide an improved alarm system.

More specifically, it is an object of the present invention to provide an alarm system of modular construction, the system requiring relatively little common supporting apparatus; providing outputs corresponding to visible and audible common alarm, group alarm, and control trip information; accommodating diverse transducer inputs; and which processes information on a digital basis.

The above and other objects of the present invention are realized in a specific, illustrative alarm system wherein an array of alarm point modules are employed to monitor a like array of parameter sensing transducer outputs of either the continuous or switch (on/off) type. Each module includes a first portion for generating a digital output signal to indicate the presence or absence of an alarm. For example, a low binary output from the first module portion may correspond to a normal condition. This output is produced directly by the closed contacts of a switched point, and is effected by a bridge, operational amplifier and comparator for transducers with nondiscrete outputs. Correspondingly, a relatively high voltage from the first module portion may signal the incidence of an alarm condition.

The normal, off-normal signal is then supplied to digital logic structure which includes a flip-flop for providing latching memory to retain the incidence of an alarm condition, a bistable flip-flop also being included to retain the last active state of a control switch disposed on the module. The digital logic acts through output drivers to provide an audible and visual common alarm output indication when any of the monitored conditions goes off-normal (an audible energized klaxon and a flashing light on the particular module associated with the off-normal condition); to provide output information indicating which of several functional groups has developed an alarm, and when all such alarms have begun and ended; to provide an acknowledged state where the klaxon is turned off, and where the module light is continuously on such that the alarm condition may be investigated and repaired without the relatively uncomfortable klaxon audio output; to provide a reset function whereby an alarm signaling module may be reset and wherein the entire alarm signaling cycle of operation is reinitiated if a module is prematurely reset; and wherein all modules may be simultaneously exercised by simulating an alarm condition and by resetting the modules after the simulated alarm has been removed.

The above and other features and advantages of the present invention are realized in a specific, illustrative embodiment thereof, described in detail hereinbelow in conjunction with the accompanying drawing, which depicts an alarm system illustrating the principles of the present invention.

Referring now to the drawing, there is shown an alarm system which comprises a plurality of alarm modules 10 each associated with a parameter sensing transducer of either the continuous or switched, discrete output type. For purposes of illustration, a single module 10 is shown in detail, together with those common equipment items which are associated with that and all other modules. The apparatus associated with the module is indicated by the equipment within the dashed lines 11, while that structure beyond the dashed brackets 11 corresponds to common apparatus. Further, additional connections for the common equipment to other system modules are indicated by the branching symbol.

The alarm modules include a first portion for receiving the output of the associated transducer, and for producing a digital signal at a node point 51 which is indicative of the presence or absence of an alarm condition. More specifically, the voltage level at the point 51 will be relatively low or relatively high when the transducer is signaling a normal, or off-normal condition, respectively. The digital structure for processing the voltage level at the node 51 for producing the appropriate alarm signaling indicia is common to the modules associated with all types of transducers, and is discussed below.

Considering first transducers having a continuous output, e.g., a two terminal resistance thermometer having a resistance which monotonically increases with temperature, the transducer 12 is included in one arm

of a bridge **16** which also includes resistors **18, 20** and **22**. The transducer **12** has some resistance R0 at the low end of a desired temperature range, and a resistance R1 at the top of the temperature range. The two output signals from the bridge are supplied to a high gain difference amplifier **24** which is indicated in an operational configuration with a feedback resistor **26**.

It is desired that the output voltage from the amplifier **24** be supplied to a recorder **28** to provide a permanent record of the operation of all apparatus with an analog output, thereby providing a means for analyzing ship performance and for reconstructing power plant history if a major fault develops. This output voltage is typically constructed to some defined range required for a specific recorder **28**, e.g., zero volts to V volts. Accordingly, the resistor selection for the bridge and operational amplifier must map the transducer resistance range R0–R1 into the desired output voltage range of 0–V volts. This may be done by selecting the resistance of the resistor **20** such that the potential at the node of the resistors **20, 22** and **26** (with zero amplifier output potential) equals that at the node of the resistors **12** and **18** (Vin) at the transducer R0 value, i.e.,

$$\frac{V_{\text{Bridge}}\,x}{R_{20}+\dfrac{R_{22}R_{26}}{R_{22}+R_{26}}}\times\frac{R_{22}R_{26}}{R_{22}+R_{26}}=Vin \qquad \text{Equation (1)}$$

and for adjusting the gain G of the operational amplifier

$$G=\frac{R_{26}+\dfrac{R_{20}R_{22}}{R_{20}+R_{22}}}{\dfrac{R_{20}R_{22}}{R_{20}+R_{22}}}=\frac{V}{Vin} \qquad \text{Equation (2)}$$

to provide the output volts when the transducer **12** exhibits its R1 value.

The voltage output from the amplifier **24** is supplied as one input to a comparator **30**, e.g., as one input to a difference amplifier **31**. The other input to the comparator comprises the variable output of a potentiometer **32** which is adjusted to define the trip or alarm point for the alarm module. That is, the output of the comparator will be low (approximately 0.7 volts or one diode drop negative) when the trip point potential at the tap of the potentiometer **32** exceeds the output of the amplifier **34** to signify a normal condition; and will be high (e.g., at the zener voltage of the zener diode **46** — for example, 3–4 volts) when the output of the amplifier **24** exceeds the alarm point when the transducer **12** is thereby reporting an off-normal or alarm condition. The comparator **34** may also comprise a monolythic composite device.

A switch **34** including a first transfer member 34_1 is included to connect either the alarm set point potential or the monitored parameter value indicating output potential from the amplifier **24** to a meter **42** via a current limiting resistor **40**. The transfer member **34** is normally biased to reside in a central rest position, and connects the alarm set point voltage to the meter **42** when pushed in contact with a terminal **36** such that system operator can see the alarm level at which he is programming the alarm module. Similarly, by urging the transfer switch member 34_1 in contact with a terminal **38**, the output of amplifier **24** is connected to the meter such that the value of the parameter under study may be viewed. Since the switch transfer member 34_1 is normally not connected to either terminal **36** or **38**, the meter **42** may be connected to all other modules having the same percentage range, e.g., temperatures of 32°–200b*L*, pressures of 0–60 p.s.i., and so forth.

Accordingly, the above-considered portion of the alarm module depicted in the drawing produces a relatively low signal at point **51** when the transducer is reporting a value less than the alarm set point dictated by the setting of the potentiometer **32**, and a relatively high potential when the transducer **12** senses a condition exceeding the value dictated by the potentiometer setting. Other continuous type analog transducers may be accommodated by simply modifying the form of the input bridge **16**. For example, a pressure transducer comprising a potentiometer having a slider member moved by a pressure responsive wiper member mechanically coupled to a bourdon tube may have its end points directly connected across the bridge energy source, or connected via a series resistor. The potentiometer tap is then connected at one input to the amplifier **24**. Further, the above-considered portion of an alarm module may provide an alarm indication when the transducer reports a value less than the setting of the trip point potentiometer **32** (a low alarm as for loss lubrication pressure) by simply reversing the input leads to the comparator **30**, or by reversing the relative position of the transducer **12** in the bridge **16**.

For transducer outputs of the switched type, the transducer output is directly connected between the point **51** and ground, as shown by the dashed normally closed transducer output **54**. Where digital logic of the current sinking type is employed, the short circuit path from the point **51** to ground, as provided by the transducer conduction path **54**, corresponds to a digital zero. When the low impedance path **54** becomes open to signal an alarm condition, the open circuit is viewed by the following digital apparatus as a binary one. Where non-current sinking logic is used, the point **51** may simply include a pull-up resistor to a voltage source. Where modules are associated with an on/off transducer output such as indicated by the dashed line **54**, the linear elements to the left of the point **51** in the drawing, i.e., the amplifier **24**, comparator **30** and their ancillary elements, may be deleted, these elements performing the binary zero (normal operating condition) current sinking function for the continuous modules.

Thus, for either analog or switched on/off transducer outputs, a low potential (digital "0") is present at the point **51** to signal a normal operating state for the parameter associated with the module, and a binary "1" voltage is present to signal an alarm state. The remaining apparatus shown in the drawing comprises digital data processing structure for appropriately reacting to the signal present at node **51**, and for responding to external commands from the operator as manifested by inputs in the form of switch closures of a common nature, or having efficacy only to one particular module.

As a first function, two particular functions are desired when an alarm condition is actually present,

these functions being operative independently of the latching alarm data processing discussed below. First, certain modules are employed to actuate a "trip contact" output (i.e., an electronic electromechanical switch) when an alarm condition is signaled, and only for the duration of the actual alarm condition. These contacts may be employed to start or stop a controlled equipment item acting either directly or via a remote relay. For example, these contacts may be employed to stop an engine if the alarm module senses a serious engine malfunction. Illustratively also, trip contacts may be employed to start an equipment item, e.g., a supplementary generator or pump if the alarm point senses that a like equipment item is overloaded.

As a second function, it is desired that a record be made of the time of occurrence and duration of alarm conditions grouped by system function. That is, all alarm modules associated with potential faults in the main engine may form one group, those associated with steam flow in the plant another group, and so forth.

To accomplish the above purposes, the signal at the node 51 is inverted by an element 50 and connected to a driver 76_2 of a driver array 76. The drivers 76 may be of any electro-mechanical or solid state configuration, e.g., comprising an inverter and an output power transistor such that a low input to a driver 76 gives rise to a low impedance conduction path from the driver output to ground. Accordingly, a high alarm potential at the point 51 generates a low potential at the output of the inverter 50 to effectively provide a ground at the output of the driver 76_2. Current then flows from a potential source 152 through normally closed contacts 133 and through coils 88 and 124, thereby closing normally open contacts 90 and 126 associated with these relays while opening normally closed contacts 128. The contacts 90 effect the trip contact function and may be used to control any auxiliary equipment item, while the contacts 126 and 128 exhibit impedance levels which provide an alarm recorder of any suitable construction with information signaling the time at which the alarm occurred, its duration, and the alarm group designation which produced the alarm. An appropriate alarm recorder for processing the information signaled by the contacts 126 and 128 is available, for example, from Marine Measurements, Inc., Berkeley Heights, N.J.

It is observed at this point that the end of the relay coil 124 remote from the positive source 152 is connected to all other modules of the particular group such that the contacts 126 and 128 are activated responsive to an alarm condition in any of these modules. However, it is desired that the trip contacts 90 be activated only responsive to an alarm condition sensed by the particular alarm module shown in detail in the drawing. Accordingly, an isolation diode 130 is employed such that the driver 76_2 activates both coils 88 and 124, but that any other driver connected to the group alarm coil 124 will activate the contacts 126 and 128 but will not energize the relay elements 88–90 by reason of the back biased diode 130.

The digital equipment of each module includes an alarm flip-flop 66 which normally resides in a reset condition when no alarm is present or has been generated since the module was last reset (manifested by relatively low potential at a flip-flop output terminal 69). The apparatus also contains a switch memory flip-flop 100 including reset and set output terminals 101*a* and 101*b*. The reset flip-flop output terminal 101*a* is relatively high when a low or ground potential was last applied to the reset input terminal, either by the second switch 34 transfer member 34_2 contacting the switch reset terminal 104 (one such switch 34 being included on each alarm module), or by a common reset switch 94 being depressed, the reset flip-flop input terminal being grounded through a diode 98.

Correspondingly, the set flip-flop 100 output 101b is high if the flip-flop set terminal was last connected to a low potential, either by the switch member 34_2 contacting the acknowledge terminal 106, or by a normally closed common acknowledged switch 136 being opened when the module was in an alarm condition such that ground was applied to the acknowledge terminal 106 via a fully enabled coincidence (e.g., NAND) gate 112.

The sequence of circuit operations which occur responsive to an alarm condition, and an operator's reaction to that condition, are as follows. The low output of the inverter 50 during the presence of an alarm causes an inverter 58 with an active (e.g., totem pole) output to become high. The positive going transient is applied to a differentiating network comprising a capacitor 60 and a resistor 62 which is sufficiently small to normally maintain the output of an inverter 64 in a high state. The positive going transient gives rise to a positive pulse across the resistor 62 thus causing output of the inverter 64 to go momentarily to the digital "0" level, thereby setting the flip-flop 66 such that a high potential appears at the flip-flop output 69 to partially enable a coincidence gate 72. If the switch-memory of flip-flop 100 resides in its reset condition with the output at 101*a* high (the normal operating condition), the gate 72 is fully enabled at the inception of an alarm thereby actuating a driver 76_1 and operating a relay 80. This closes contacts 84 and energizes a klaxton 86 which provides an audible indication that an alarm has occurred. Coincident therewith, the relatively high potential at the flip-flop output 69 partially enables a coincidence gate 110 which periodically is fully switched by the oscillatory output of an oscillator 120, a typical oscillator output frequency being in the range of 0.5–10Hz. The slowly cycling output of the gate 110 thereby periodically enables a switch 76_3 for energizing a lamp 114 associated with the alarm module at the flasher oscillator rate. A resistor 116 connects the lamp 114 to ground for a very dull glow when the lamp is off to provide an indication when the lamp has failed.

When an operator hears the klaxton he approaches the alarm system and notes which of the possibly several hundred alarm modules have flashing lamps. This provides information indicative of the ship's fault condition(s). He also acknowledges the alarm, either by moving the switch 34_2 to the acknowledge position in contact with the terminal 106, or by opening the common acknowledge switch 136. Operation of either switch produces a ground at the set input of the switch memory flip-flop 100, thereby providing relatively low and high voltages at the flip-flop outputs 101*a* and 101*b*. The low potential at the terminal 101*a* disables the gate 72, thereby disabling the driver 76_1 and opening the contacts 84 to shut off the howling klaxon. The low potential at the terminal 101*a* also activates the

driver 76_4 for maintaining the lamp 114 in the illuminated state. Thus, the identity of the alarm condition is preserved and the operator may acknowledge the alarm before he examines the modules for the alarm condition information. This may be important where a remote acknowledged switch is employed (e.g., as a switch 137 which is located at some remote point such that the klaxon can be disabled for the comfort of other personnel.)

The operator then proceeds to repair the condition which caused the alarm, or to satisfy himself that the alarm condition has abated. As an aid, he may move the switch 34_1 member to the terminal 38 to obtain a reading of the value of the parameter associated with that module at the meter 42.

When satisfied that the alarm condition has abated, the operator resets the module, either by connecting the switch members 34_2 and 104 on the module or by depressing the normally open common reset switch 94 which is connected in like fashion to all alarm modules (as is the common acknowledge switch). While one of these reset switches is in the reset position, ground is applied to the reset input of flip-flop 100 to restore the output potential at the point 101*a* to the normally high state thereby resetting this flip-flop to the quiescent operating condition such that any subsequent alarms produced by the transducer associated with depicted module will energize the klaxon, and do all other operations discussed above.

Further, the output of the inverter 58 is connected by either active reset switch to ground via one of the diodes 96 or 97 depending upon which switch 94 or 34_2 was employed to effect the reset function. This impresses a low potential on the output of the inverter 58. If, as was contemplated by the operator, the alarm condition has disappeared, the normal low potential state persists at the output of the inverter 58, and no further system action occurs when either reset switch is released. That is, the output of inverter 58 was low when a reset switch was activated, and remains low when this switch is released.

However, if the alarm condition is still present when either reset switch was activated, a relatively high potential persists at the output of the inverter 58 such that a positive going input is impressed upon the differentiator capacitor 60 when a grounding reset switch is released. Accordingly, the module operates in the manner described above to initiate a complete alarm indicating audio-visual cycle of operation.

Thus, the module of the drawing has been shown by the above to digitally process the binary alarm indication at the point 51 for providing all required audio-visual indications, and for providing output control and metering contact closures in a reliable, repeatable, digital manner.

It is desirable that a mechanism be employed to test the alarm modules to assure that each module is in working order, and will function to report an actual alarm condition should one occur. To this end, a test switch is employed and includes normally closed contacts 132 in one arm of the bridge of each module (or in series with the input of an on/off module), and a normally closed contact 133 connecting the relay coils to the source 152. In the test mode, the contacts 132-133 are opened thereby supplying one bridge node with the full source potential (or ground to exercise a low alarm) to simulate an alarm condition which is then processed in the above-described manner to assure that all parts of the module are working. The contacts 133 are opened in the test module such that a testing cycle does not operate the klaxon, alarm recorder, or trip relays.

Finally, normally closed contacts 140 and 142 are employed to selectively remove power from groups of modules to implement a rest condition, e.g., a docked vessel condition wherein certain equipment items are turned off and might therefore generate what would be interpreted as alarm conditions. The contacts 140 and 142 may be opened by energizing an appropriate relay coil before the monitored equipment is turned off, or automatically turned off by implementing this function as part of the serviced equipment.

It is to be understood that the above-described arrangement is merely illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention. For example, the elements 58-60-62-66 may be replaced with other alternating current coupled flip-flop structures such as a D-type, or edge triggered flip-flops. Also, the rest functions may be effected by appropriately injecting or withdrawing current in the bridges of selected modules.

What is claimed is:

1. In combination in an alarm system for providing an indication of off-normal conditions for the values of an array of parameters sensed by an array of transducers, a plurality of alarm modules each including means connected to a different transducer for producing a digital signal characterizing the operational state of the parameter sensed by the associated transducer, transition responsive bistable alarm memory means connected to said digital signal producing means for preserving the incidence of an off-normal condition, a reset-acknowledge switch, switch bistable memory means having input control terminals connected to said reset-acknowledge switch, said switch bistable means assuming a stable state dependent upon the last actuated condition of said reset-acknowledge switch of said module to its reset or acknowledge state, common alarm signaling means, and coincidence logic means responsive to the outputs of said alarm bistable memory means and said switch bistable memory means for selectively energizing said common alarm signaling means.

2. A combination as in claim 1 further comprising trip switching means, group alarm switching means, means included on a plurality of said modules for selectively energizing said group alarm switching means, and means including a diode on one of said modules for energizing said group alarm switching means and for energizing said trip switching means.

3. A combination as in claim 1 further comprising a flasher oscillator connected to said alarm modules, each of said modules including a lamp, first driver means including coincidence means connected to said flasher oscillator and to said alarm bistable memory means, and additional means connected to said switch bistable memory means for illuminating said lamp.

4. A combination as in claim 1 further comprising common acknowledge means and common reset means connected to said switch memory means of said modules.

5. A combination as in claim 1 wherein said common reset means includes a common reset switch, and wherein each of said modules include diode means connecting the input of said transition responsive bistable means and said switch memory means to said common reset switch.

6. A combination as in claim 4 wherein said common acknowledge means includes a common acknowledge switch, and wherein each of said modules includes coincidence means having inputs connected to said common acknowledge switch and said alarm bistable means, and an output connected to said switch memory means.

7. A combination as in claim 1 wherein said digital signal producing in at least some of said modules means includes an operational amplifier connected to an associated transducer for mapping said transducer variations into a predetermined voltage range, a trip point potentiometer, and comparator means connected to said operational amplifier and to said trip point potentiometer for providing said digital signal depending upon the polarity of the input voltage difference impressed thereon.

8. A combination as in claim 1 further comprising means for triggering said transition responsive bistable alarm memory means responsive to said alarm memory means being reset while an alarm condition persists.

9. A combination as in claim 8 wherein said transition responsive bistable alarm means includes driver means with active output means and alternating current coupling means, and means for fixing the input to said alternating-current coupling means responsive to a reset operation.

10. A combination as in claim 1 further comprising test means for simultaneously simulating alarm conditions in each of said modules.

11. A combination as in claim 1 further comprising rest means for selectively inhibiting alarm indications from modules associated with off-line equipment.

12. A combination as in claim 7, further comprising test means for simultaneously simulating alarm conditions in said modules, said test means for said some modules comprising normally closed switch means connected in said operation amplifier-transducer voltage mapping circuitry, and means for opening said normally closed contacts for providing an alarm simulating condition.

13. A combination as in claim 1, wherein said digital signal producing means in at least some of said modules includes voltage divider means, linear operational amplifier means for providing an analog voltage, a comparator connected to said amplifier for producing an output alarm signaling digital signal, set point voltage supplying means connected to an input of said comparator, output display means, and transfer switch means ganged with said reset-acknowledge switch, for selectively connecting a measure of said amplifier output voltage or said set point voltage to said output display means.

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