HIGH, LOW AND THERMOCOUPLE BURN-OUT ALARM SYSTEM

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ABSTRACT
An alarm annunciator having hot, cold and thermocouple burn-out capability without requiring specific resistor connections for the hot and cold alarm modes of operation. An alarm burn-out switch responds to certain voltage variations in the annunciator signal translating circuitry during alarm thermocouple burn-out to provide electrical control of an alarm indicating means. The burn-out switch also serves as a constant current sink during both the hot and cold alarm modes of operation.

8 Claims, 1 Drawing Figure
FIELD OF THE INVENTION

This invention relates generally to electrical alarm systems and more particularly to an alarm annunciator for indicating hot and cold alarm conditions as well as a burn-out or open circuit alarm condition at the temperature sensing element of the system.

BACKGROUND OF THE INVENTION

Alarm annunciators have found wide-spread use in industrial process control systems wherein separate portions of stages of a control system must be maintained below or above a selected set point temperature. For example, these process control systems may include apparatus such as boilers, motors, ovens, reactors and many other types of equipment which should not be permitted to overheat during system operation. In these systems, it is common to use a temperature transducer, such as a thermocouple, which will generate a temperature responsive signal voltage. This “hot alarm” signal voltage can be processed to energize visual and/or audible alarm indicators when the temperature at the thermocouple exceeds a selected set point value. Similarly, apparatus such as distillation columns should not be permitted to fall below a given temperature, and in alarm annunciators for these control systems, “cold alarm” signals are processed to provide audible or visual alarms when the thermocouple temperature falls below a selected value. Such hot and cold alarm signals and the processing thereof to provide both hot and cold visual and audible alarms are generally well known in the process control art.

In utilizing temperature transducers in these hot or cold alarm systems, said transducers frequently undergo both thermal and mechanical fatigue which may eventually cause the transducer, such as a thermocouple, to burn-out. In the event of thermocouple burn-out, it is desirable that a burn-out or open circuit condition at the temperature transducer also generate some alarm signal which can be processed to electrically control an alarm indicator in a control room. In this manner, the control room operator can examine the operating condition of the thermocouple as well as the particular temperature condition where the thermocouple is located.

DESCRIPTION OF THE PRIOR ART

A prior art technique for insuring that an open circuit or burn-out condition at the temperature transducer of the control system will provide an alarm indication for a control room operator involves the selective connection of an input resistor to the amplifier stage driven by the temperature sensitive transducer. This input resistor will, upon the occurrence of an open circuit or burn-out alarm condition, provide the signal translating circuitry of the control system with an electrical control signal for properly energizing an alarm indicator portion of the system. The specific connection and disadvantages of such input resistor connection for the prior art alarm system identified above will be described in more detail in the following description of the operation of the present invention. From this detailed description, the significant advantages over the prior art provided by the present invention will be fully appreciated and understood.

The use of the above prior art input resistor connection to generate burn-out alarm signals had several distinct advantages. First of all, the input resistor injected noise into the input stage of the control system as well as reduced the input impedance of the system. Such reduction of input impedance increased the likelihood of DC drift and reduced the sensitivity of the control system. Furthermore, since the input resistor connection for the input amplifier stage of the system was required for cold alarm operation and not required for hot alarm operation, each prior art alarm system of the type described above had to be specified as an upscale (hot) or downscale (cold) system. Therefore, the prior art alarm system of the type described above was limited in its flexibility by requiring a particular upscale and downscale specification.

SUMMARY OF THE INVENTION

The general purpose of this invention is to provide an improved alarm annunciator having high, low and burn-out alarm capability, possessing all of the advantages of similarly employed prior art alarm annunciators while possessing none of the aforesaid disadvantages. To attain this, a unique alarm burn-out control switch is utilized and is connected to a selected node in the alarm signal translating circuitry of the annunciator. This control switch responds to a burn-out or open circuit alarm condition at the input temperature sensitive element of the annunciator to insure that an alarm indication is provided upon the occurrence of temperature transducer burn-out or open circuit conditions. It is, therefore, an object of the present invention to provide a new and improved alarm annunciator of the type described capable of operating either as an upscale or downscale alarm system without requiring separate input impedance connections for each mode of operation.

Another object of this invention is to provide a new and improved hot, cold and burn-out alarm annunciator having a high input impedance and maximum input sensitivity with a very low DC drift.

A further object of this invention is to provide an alarm annunciator of the type described which is adaptable to industrialized solid-state electronic circuit construction and which exhibits long-term reliability when subjected to wide ambient temperature variations and industrial environments.

A feature of this invention is the provision of an alarm annunciator of the type described which is operative with either a normally energized or normally deenergized relay output for driving visual and/or audible alarm indicators.

Another feature of this invention is the provision of an alarm annunciator having a very high and constant input impedance differential amplifier stage which is connected to a thermocouple temperature transducer. This amplifier stage provides a required high gain for the thermocouple input signals and operates with a very low DC drift.

Another feature of this invention is the provision of a solid-state current sink thermocouple burn-out control switch coupled between a relay portion of the annunciator and a selected node of the signal translating circuitry thereby. The current sink control switch responds to a predetermined voltage change at this selected node to provide a burn-out or open circuit alarm electrical condition for the annunciator. The current sink transistor simultaneously serves as a constant current sink for energizing the relay portion of the system during hot and cold alarm system operation.

These and other objects and features of this invention will become more fully apparent in the following description of a preferred embodiment of the invention as illustrated in the accompanying drawing.

DRAWINGS

A single preferred embodiment of this invention is illustrated, partially in schematic and partially in functional block diagram form, in the accompanying drawings to be further described hereinafter.

DETAILED DESCRIPTION OF THE INVENTION

The embodiment of the invention illustrated in the accompanying drawing comprises signal translating circuitry which includes a thermocouple input stage 10 whose low level output signal is amplified in a differential amplifier stage 11. The output signal of the differential amplifier stage 11 is connected to the input of the step function generator 13 which in turn provides an input control signal for the current steering gate or relay driver stage 15. An alarm burn-out control switch 17 is coupled between the relay driver stage 15 and a node 55 at the output of the differential amplifier stage 11.
Immediately below, the specific components of the preferred embodiment of the invention will be identified for stages 10, 11, 12, 13, 15 and 17, respectively. Following this description, the operation of the invention will be described in detail.

The input stage 10 includes a thermocouple 12 having one input terminal 12a thereof directly connected to the amplifier stage 11 and the other terminal 12b thereof connected to a cold junction compensating (CJC) element 14, such as a nickel wire CJC element. The cold junction compensating (CJC) element 14 is well known in the art and provides a temperature independent offset voltage at terminal 12b of the thermocouple 12 to compensate for the temperature induced voltages in the transistions of the thermocouple signal. Such voltage variations occur as a result of the temperature differential between the output terminals 12a and 12b and the input wrap around connection 12c for the thermocouple 12. The CJC element 14 is connected through a reference voltage device 20, such as a Zener diode, to ground or reference potential. The reference voltage device 20 is connected through a current limiting resistor 24 to the B+ supply voltage at terminal 25 and provides a so-called mid voltage reference potential for the alarm annunciator system. This mid voltage reference potential is between the B+ supply voltage at terminal 25 and ground potential and enables the alarm system to be operated from a single supply voltage B+. A fixed bias resistor 16 and a variable trimmer resistor 18 are serially connected as shown between the thermocouple output terminal 12b and ground potential. These resistors 16 and 18 conduct a small bleed current 30 to ground and enable the D.C. bias potential at output terminal 12b to be precisely adjusted for a given temperature.

The differential amplifier stage 11 comprises an input differential driver stage 30 which is differentially connected to an operational amplifier 56 at the input terminals 52 and 54 thereof. The differential driver 30 and the operational amplifier 56 provide the required signal gain for the alarm system. The differential driver 30 includes a pair of NPN emitter coupled transistor 32 and 34 connected to a constant current sink transistor 36 which is grounded through an emitter resistor 38. Resistors 40 and 42 provide the proper D.C. biasing for the current sink transistor 36, and a pair of transistor collector load resistors 46 and 44 are connected through a potentiometer 45 to the B+ supply voltage. The movable tap 50 on the potentiometer 45 permits fine quiescent current balance for the differentially coupled NPN transistors 30 and 34.

The differential operational amplifier 56 may be selected from many commercially available types of operational amplifiers, such as integrated circuit operational amplifiers, having a very high gain and which may be operated from a single voltage supply B+.

The operational amplifier 56 is connected through a decoupling resistor 58 to the single B+ supply voltage at terminal 25. Input resistor 22 and a feedback resistor 62 of the amplifier stage 11 set the gain of stage 11 as will be understood. The output terminal 55 of amplifier 56 will be alternatively referred to herein as a "selected node" of amplifier 56 within the signal translating circuitry of the alarm annunciator, and this circuit point or node is particularly identified herein because the voltage at this node is used to control both the Schmitt trigger circuit 68 as well as the alarm transducer burn-out control switch 17.

The differential operational amplifier 56 is connected through a current limiting resistor 60 to one input terminal 64 of the Schmitt trigger 68, and the other input terminal 66 of the Schmitt trigger 68 is connected via conductor 108 to a set point reference voltage, \( V_{ref, in} \), at a reference voltage generator 106. The operation of the Schmitt trigger 68 is generally well-known in the art and will not be described in detail herein. The Schmitt trigger 68 is connected with an output resistor 70 and a feedback resistor 72 in a well-known feedback circuit configuration, and a feedback capacitor 74 provides filtered Schmitt trigger action. The output node 65 of the Schmitt trigger 68 exists at one or the other of two D.C. levels, depending upon the signal condition at the input terminal 64 and 66 of the Schmitt trigger 68. If the input signal voltage at the input terminal 64 of the Schmitt trigger 68 is above the set point reference voltage, \( V_{ref, in} \), the output node 65 of the Schmitt trigger 68 will be high or at the lower of its two D.C. levels. When the input signal voltage on input terminal 64 falls below the set point reference voltage, the output voltage at the output node 65 will be driven to the lower of its two D.C. output levels.

The output voltage of the Schmitt trigger 68 is coupled through an output resistor 70 and another current setting resistor 76 to the input of the current steering gate 15. The current steering gate 15 includes a pair of emitter coupled NPN transistors 80 and 82 which are connected to the constant current thermocouple burn out control switch 17. The collectors of the NPN transistors 80 and 82 can be connected to either the relay 86 or the load resistor 84 by merely changing the positions of the reversible switches 85 and 87.

The alarm or thermocouple burn out control switch 17 includes a grounded emitter transistor 94 with a base "pull down" resistor 96 connected between the base of transistor 94 and ground potential. A current limiting resistor 98 interconnects the base of NPN transistor 94 to the previously identified selected output node 55 of the differential operational amplifier 56.

The relay 86 is energized in the absence of an alarm condition at the thermocouple 12 to maintain the switch 88 in its open position and thereby disconnect the alarm circuits 108 from B+, supply 90. When the relay 86 is deenergized, the switch 88 closes to provide an energizing D.C. supply potential to the alarm circuits 104 which may include visual and/or audible alarms. However, the relay 86 is not limited to the normally energized type, but may instead be the normally deenergized type which closes the switch 88 upon the energization thereof.

**OPERATION**

The invention will be further described hereinafter with reference to the specific circuit operation of the alarm annunciator in response to temperature induced voltage variations across the output terminals 12a and 12b of the thermocouple 12. After the alarm annunciator circuit operation is described below with reference to both hot and low alarms for temperatures above and below a set point temperature, respectively, the operation of the alarm burn-out control switch 17 will be described in detail, with emphasis on the improvement that the present invention provides over the above-described prior art alarm annunciator.

**HOT ALARM MODE OF OPERATION**

For the hot alarm operation of the alarm annunciator, it is desired to provide an alarm indication when the temperature at the thermocouple 12 rises above a chosen set point temperature. The collectors of the steering gate emitter-coupled transistors 80 and 82 are directly connected, respectively, to the relay 86 and load resistor 84 for this operation, and the output of the Schmitt trigger 68 is high (using positive logic) prior to an alarm. The transistor 80 is now biased to conduction, the relay 86 is energized and the alarm switch 88 is now open. As long as the temperature at the thermocouple 12 remains below a selected set point value corresponding to the set point voltage, \( V_{set, in} \), the voltage at input terminal 64 of the Schmitt trigger 68 remains above \( V_{ref, in} \), and the Schmitt trigger 68 output voltage is high.

If now the temperature of the thermocouple 12 rises above the set point temperature and generates a corresponding decrease in the signal voltage applied to the base of the differential amplifier transistors 32, this voltage change will produce a corresponding decrease in the voltage applied to the noninverting input terminal 52 of the differential operational amplifier 56. Actually, the point 12a of the thermocouple 12 decreases toward ground potential as the thermocouple temperature increases, so that the terms "in-
crease," "decrease," "high" and "low" as used herein described the potential at a particular circuit point or node with respect to ground potential. However, when node 12a falls toward ground potential as the thermocouple temperature increases, the magnitude of the differential voltage applied to bases of transistors 32 and 34 becomes greater.

The above voltage signal deviation produces a corresponding decrease in the signal voltage at the output node 55 of the differential operational amplifier 56. This voltage change is coupled through the current limiting resistor 60 to the input terminal 64 of the Schmitt trigger 68 to trigger the latter to its low output voltage level. When the signal voltage at input terminal 64 decreases below the set point voltage at terminal 66 by a fixed amount in accordance with well known Schmitt trigger action, the Schmitt trigger 68 is driven from its high to its low D.C. output level at node 65. This voltage transition is coupled through resistors 70 and 76 to drive NPN transistor 80 nonconducting, deenergizing relay 86 and closing relay contact 88. This switching action completes a D.C. connection from the B+ power supply at terminal 90 through conductor 102 and to the visual or audible conventional alarm circuits 104. Alarm circuits 104 provide an indication for the control panel operator that the thermocouple temperature has exceeded the desired set point temperature.

COLD ALARM MODE OF OPERATION

For the cold alarm operation and with the thermocouple 12 temperature above a selected set point temperature, the output voltage of the differential operational amplifier 56 applied to input terminal 64 of the Schmitt trigger 68 is below the set point voltage, \( V_{set, low} \). Therefore, the output voltage at the output node 65 of the Schmitt trigger 68 is low, maintaining transistor 80 nonconducting and transistor 82 conducting. Since it is desired that the relay 86 be energized to hold contact 88 in its open position when the thermocouple temperature is above the set point temperature and operating in the non-alarm condition, then for this cold alarm operation it becomes necessary to interchange the collector connections of transistors 80 and 82. The positions of switches 85 and 97 in the current steering gate 15 should be reversed so that the collector of transistor 82 is now connected to the relay 86. The reference voltage, \( V_{ref} \), on conductor 110 is now higher than the base voltage of transistor 80 and the relay 86 is energized. With either transistor 80 or transistor 82 conducting as previously described, the constant current sink NPN transistor 94 provided in a set of constant current driven output relay driver or current steering stage 15, as will be seen by inspection of the drawing.

When the temperature of thermocouple 12 drops below the set point temperature, the voltage at the base of transistor 32 changes in a positive direction with respect to ground potential. This action causes the output voltage at the output node 55 of the differential operational amplifier 56 to increase, driving the input terminal 64 of the Schmitt trigger 68 above the set point reference voltage at input terminal 66. When this happens, the output D.C. voltage at the Schmitt trigger output node 65 is driven to its high D.C. level, causing the base voltage of NPN transistor 80 to override the reference voltage \( V_{ref} \) applied to NPN transistor 82. This biases transistor 82 to non-conduction, deenergizing relay 86 and allowing the open switch 88 to close and provide a source of energizing voltage for the alarm circuits 104 as previously described.

THERMOCOUPLE BURN-OUT HOT ALARM MODE OF OPERATION

If the thermocouple 12 burns out during the hot alarm mode of operation described above, the base of NPN transistor 32 will become floating upon the occurrence of an open circuit condition at thermocouple 12. This causes a decrease in the collector voltage of transistor 34 due to the increase in collector current thereof. The latter voltage transition will have the same affect as that of the above-described hot alarm signal by driving the output signal of the Schmitt trigger 68 to its low D.C. voltage level and deenergizing relay 86 as previously described. This switching action occurs before the voltage at the node 55 can turn off the NPN transistor 94 and that if the system were only of the hot alarm type, the alarm burn out control switch 17 would not be required. However, the alarm annunciator of the present invention has both hot and cold alarm capability and the burn out control switch 17 works equally well during both modes of operation.

THERMOCOUPLE BURN-OUT-COLD ALARM MODE OF OPERATION

During the cold alarm mode of operation and with the set point voltage, \( V_{set, low} \), maintaining the Schmitt trigger 68 output voltage at the lower of its two D.C. levels, an open circuit or burn out condition at the thermocouple 12 will drive the operational amplifier output node 55 full negative. Thus, this voltage change at node 65 will not change the conductive state of the Schmitt trigger 68 and will not, therefore, produce a change in the conductive state of the current steering gate 78 as a result of Schmitt trigger action.

However, with the selected output node 55 at the output of the differential operational amplifier 56 connected via a base current limiting resistor 98 to the NPN current sink transistor 94, the latter transistor can be used to provide alarm burn-out or open circuit control in the following manner: When the thermocouple 12 burns out during the cold alarm mode of operation and the output of the differential operational amplifier 56 is driven full negative as determined by the voltage level of the B+ supply voltage, this negative going voltage transition will turn off the NPN transistor 94. When the transistor 94 is biased nonconducting, the current steering gate 15 is also biased nonconducting and the relay 86 is deenergized. Thus, this unique switching operation depends upon the fact that the output node 55 of the differential operational amplifier 56 is driven to its lowest positive voltage with respect to ground potential when the base of transistor 32 becomes floating for an open-circuited thermocouple condition.

In order to accomplish the same result utilizing the prior art alarm annunciator, it was necessary to connect a resistor between the base of NPN transistor 32 and the B+, power supply so that NPN transistor 32 would not be left floating during thermocouple burnout. This prior art resistor provided sufficient base current drive to the NPN transistor 32 to switch the Schmitt trigger 68 as previously described for cold alarm operation. But this resistor would either have to be specified for the prior art cold alarm mode of operation or its omission requested for the prior art hot alarm mode of operation. Other disadvantages of this input resistor connection have been previously discussed above.

It should be mentioned that the decreasing voltage at the node 55 during the hot alarm — nonburnout mode of operation is not sufficiently low to drive the NPN current sink transistor 94 to nonconduction. This output signal voltage at node 55 of the operational amplifier 56 will typically change from +12 volts to +7 volts for the hot alarm mode of operation, whereas the output node 55 will be driven down to less than 1 volt to turn the transistor 94 completely off during thermocouple burnout.

Various modifications may be made to the alarm circuitry described above without departing from the scope of this invention. For example, by making certain minor circuit modifications, a normally deenergized relay 86 can be used instead of the normally energized type described. The advantage of utilizing a normally energized relay 86 is that it enables the circuit to provide an alarm indication for power supply failure as well as the other alarm conditions previously mentioned.

I claim:

1. An alarm system for a temperature sensitive transducer subject to an open circuit condition, including in combination:
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a. alarm signal translating circuitry connected between said transducer and an alarm energizing means for providing a signal path for hot and cold alarm signals at said transducer, which signals in turn alter the conductive state of said alarm energizing means and thereby provide electrical control of visual or audible alarm indicators,
b. said signal translating circuitry including a current steering gate connected to said alarm energizing means and responsive to hot, cold and burn-out alarm signals from said temperature sensitive transducer to alter the conductive state of said alarm energizing means, and
c. an electroresponsive current switch connected between said current steering gate and a selected node in the signal path of said signal translating circuitry, said current switch responsive to a predetermined voltage change at said selected node to thereby provide a corresponding change in current flowing through said alarm energizing means and an indication of an alarm condition at said transducer.

2. The alarm system defined in claim 1 wherein said current steering gate includes first and second emitter coupled transistors connected to said first and second emitter coupled transistors connectable to receive hot and cold alarm signals from said signal translating circuitry and the other of said first and second emitter coupled transistors connected to a reference potential, whereby the connections of said first and second emitter coupled transistors to said hot and cold alarm signals and said reference potential, respectively, are interchangeable for the hot and cold alarm operations of said system.

3. The alarm system defined in claim 2 wherein said signal translating circuitry includes a differential amplifier means connected to said temperature sensitive transducer and further connected to said selected node to generate said predetermined voltage change at said selected node necessary to drive said burnout control switch means nonconducing upon the occurrence of an open circuit condition at said transducer, said differential amplifier means operative to amplify both increasing and decreasing cold and hot alarm signals, respectively, for controlling the conductive state of said steering gate without affecting the conductive state of said burnout control switch means in the absence of an open circuit condition at said transducer.

4. The alarm circuitry defined in claim 3 wherein said signal translating circuitry further includes step function generating means interconnected between said differential amplifier means and said current steering gate, said step function generating means connected to receive a set point reference voltage in addition to hot and cold alarm signals from said differential amplifier means for generating predetermined step functions to drive said current steering gate to predetermined states of conduction and to thereby control said alarm energizing means in response to both hot and cold alarm signals amplified in said signal translating circuitry.

5. Alarm condition responsive circuitry, including in combination:
a. amplifier means responsive to an open circuit or burnout alarm condition to provide a predetermined voltage change at the output terminal thereof,
b. current switch means including a transistor connected to both said output terminal of said amplifier means and to an alarm energizing means and responsive to said predetermined voltage change for altering the electrical signal condition at said alarm energizing means, thereby providing an alarm indication of said open circuit or burnout alarm condition, whereby said transistor serves as a source of substantially constant current for said alarm energizing means during normal non-alarm operation of said circuitry and interrupts current flowing through said alarm energizing means in response to said predetermined voltage change at the output of said amplifier means.

6. Circuitry defined in claim 5 wherein:
a. said amplifier means includes a differential amplifier connected to a thermocouple and responsive to both normal temperature induced voltage changes at said thermocouple and burnout or open circuit conditions at said thermocouple to provide an output alarm signal voltage at the output terminal thereof, and
b. a current steering gate coupled to said differential amplifier and further connected between said current switch means and said alarm energizing means, said current steering gate conducting current through said alarm energizing means during the nonalarm operation of said circuitry and interrupting current flowing through said alarm energizing means during alarm conditions to thereby provide electrical control of alarm indicators controlled by said alarm energizing means.

7. Circuitry defined in claim 6 wherein:
a. said alarm energizing means is a relay, said circuitry further including
b. a Schmitt trigger interconnected between said current steering gate and the output of said differential amplifier and responsive to signal voltage changes thereof for controlling the conductive state of said current steering gate, and thereby controlling the energization of said relay, and
c. means for applying predetermined reference voltages to both said current steering gate and to said Schmitt trigger to establish the level of switching wherein in accordance with the set point temperature control of said alarm circuitry.

8. An alarm system having high, low and thermocouple burnout alarm capability, including in combination:
a. alarm signal translating circuitry connected between a temperature sensitive transducer and an alarm energizing means for providing a signal path for hot and cold alarm signals at said transducer, said signals being operative to alter the conductive state of said alarm energizing means and providing electrical control of visual or audible alarm indicators, said signal translating circuitry including amplifying means providing an output signal changing in a first direction in response to a temperature alarm condition at said transducer and changing in a second direction in response to a burn-out or open circuit condition at said transducer, and
b. a bypass signal path connected in parallel with a portion of said translating circuitry and between an output node of said amplifying means and the current path for said alarm energizing means, said bypass signal path including a current switch in said current path of said alarm energizing means and responsive to said signal change in a second direction for interrupting the current flow through said alarm energizing means, whereby signal changes in both said first and second directions at said output node of said amplifying means are operable to alter the conductive state of said alarm energizing means and provide alarm indications for both temperature and open circuit alarm conditions at said transducer.