



(86) Date de dépôt PCT/PCT Filing Date: 2000/05/15
(87) Date publication PCT/PCT Publication Date: 2000/11/23
(85) Entrée phase nationale/National Entry: 2001/11/13
(86) N° demande PCT/PCT Application No.: US 2000/013249
(87) N° publication PCT/PCT Publication No.: 2000/070415
(30) Priorité/Priority: 1999/05/14 (09/312,444) US

(51) Cl.Int.⁷/Int.Cl.⁷ G05B 9/02

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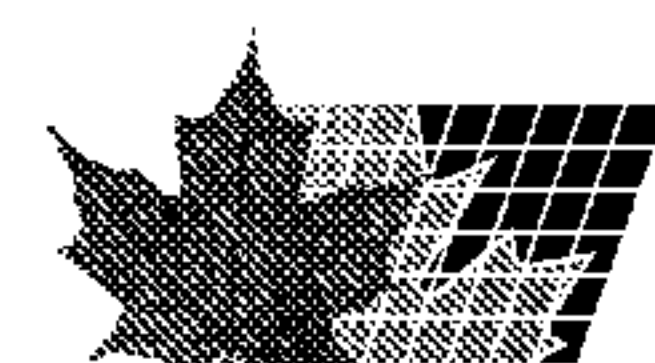
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(54) Titre : DETECTION AUTOMATIQUE DE MODE ET REJET AUTOMATIQUE DE CHANGEMENTS DE MODE
INTEMPESTIFS RESULTANT D'UNE DOUBLE UTILISATION D'UN CANAL D'ENTREE POURVU D'UN CAPTEUR
(54) Title: AUTOMATIC MODE DETECTION AND REJECTION OF INADVERTENT MODE CHANGES FROM DUAL
USE OF SENSOR INPUT CHANNEL

(57) **Abrégé/Abstract:**

A method and apparatus for control to determine the presence of a sensor or jumper on a single input channel to a micro-controller. The control process includes utilisation of a lag filter equation that allow the input channel to be utilized for two conditions, which were previously mutually exclusive. This dual use of a single micro-controller input allows communication to the micro-controller regarding first the mode in which the device is configured, and second the actual value of a condition as read by a sensor, if so configured. Additionally, the filtering provides the ability for the control to remain in a single mode of operation even if a sensor failure occurs.



**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : G05B 9/02	A1	(11) International Publication Number: WO 00/70415 (43) International Publication Date: 23 November 2000 (23.11.00)
(21) International Application Number: PCT/US00/13249 (22) International Filing Date: 15 May 2000 (15.05.00) (30) Priority Data: 09/312,444 14 May 1999 (14.05.99) US (71) Applicant: HONEYWELL INC. [US/US]; 101 Columbia Road, Morristown, NJ 07692-2245 (US). (72) Inventors: KENSOK, Timothy, J.; 4424 Camelot Drive, Minnetonka, MN 55345 (US). STOUT, Mark, E.; 18030 21st Avenue N., Plymouth, MN 55447 (US). HAMMER, Jeffrey, M.; 3393 Crystal Bay Road, Wayzata, MN 55391 (US). READIO, Philip, O.; 4183 Joppa Circle, Savage, MN 55378 (US). LENTZ, Tracy, L.; 205 Barry Avenue South #109, Wayzata, MN 55391 (US). (74) Agents: CRISS, Roger, H. et al.; Honeywell Inc. (Law Dept., Attn: A. Olinger), 101 Columbia Road, P.O. Box 2245, Morristown, NJ 07962-2245 (US).		(81) Designated State: CA. Published <i>With international search report.</i>
(54) Title: AUTOMATIC MODE DETECTION AND REJECTION OF INADVERTENT MODE CHANGES FROM DUAL USE OF SENSOR INPUT CHANNEL (57) Abstract A method and apparatus for control to determine the presence of a sensor or jumper on a single input channel to a micro-controller. The control process includes utilisation of a lag filter equation that allow the input channel to be utilized for two conditions, which were previously mutually exclusive. This dual use of a single micro-controller input allows communication to the micro-controller regarding first the mode in which the device is configured, and second the actual value of a condition as read by a sensor, if so configured. Additionally, the filtering provides the ability for the control to remain in a single mode of operation even if a sensor failure occurs.		

**AUTOMATIC MODE DETECTION AND REJECTION OF INADVERTENT
MODE CHANGES FROM DUAL USE OF SENSOR INPUT CHANNEL**

BACKGROUND OF THE INVENTION

5 The present invention relates to a method and apparatus for determining sensor presence and more specifically to a method and apparatus for determining if a thermoresistive sensor or jumper is present at an input terminal to a micro-controller.

 A common approach to humidity control within residential and commercial buildings has traditionally been to install a humidistat on a return air duct near the
10 furnace. A humidistat is a conventional device, commonly employing at least one micro-controller, that measures humidity and controls humidification equipment associated with the home or building.

 Associated with devices such as a humidistat, which utilizes at least one micro-controller as a part of a larger monitoring or control system, are typically several analog
15 sensors strategically mounted to provide environmental information to the monitoring or control system. These analog sensors are often monitored with an analog to digital converter, and have a micro-controller input channel dedicated to each sensor.

 Such control systems often have several discrete modes of operation that can be selected in the field by the use of removable jumpers across the various micro-controller
20 input terminals. A complex system can therefore require a large number of sensor and jumper inputs, which equates to an increase in production cost since each sensor or jumper input requires separate inputs to the micro-controller. Similarly, in devices where a sensor or jumper share the same input terminals, an indicator switch is often necessary to indicate to the micro-controller whether a sensor or a jumper is present on
25 the input terminal. The need therefore exists for an apparatus and method of control which allows various functions, such as a sensor or jumper, to share the same micro-controller input channel. Such an apparatus must also have the ability to interpret the separate information received on the common signal channel.

BRIEF SUMMARY OF THE INVENTION

30 The present invention provides a method and apparatus for enabling a single input channel to a micro-controller to operate under two distinct conditions, which were previously mutually exclusive.

In one form, the invention employs a means for determining whether a micro-controller input signal is representative of a sensor and if the sensor is operating within predetermined bounds. The invention also encompasses the monitoring of the sensor input and returning of an error state if the sensor signal exceeds the predetermined
5 bounds. In a second form, the invention employs a means for determining whether a jumper is installed across the micro-controller input channel and for returning an error state if the jumper is removed or damaged while in operation.

In the preferred form, the invention is embodied within a humidistat and employs a programmable micro-controller and a thermoresistive sensor, the
10 thermoresistive sensor operating to provide temperature information to the micro-controller via an input channel.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a block diagram of the micro-controller and associated sensing means
15 of the present invention;

Figure 2 is a flow diagram showing the preferred method and implementation of the present invention; and

Figures 3a and 3b are graphical representations of the operation of the device illustrated in Figure 1.
20

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and particularly to Figure 1, there shown is an exemplary block diagram of the micro-controller and associated sensing means of the present invention generally identified by reference numeral 10. A sensor identified by
25 reference numeral 30, along with a micro-controller 12 may operate together as part of a larger monitoring and control system. In the control system, sensor 30 may operate to obtain information about a condition to be sensed and communicate that information directly to micro-controller 12 through input channel 32. Alternatively, if sensor 30 is not required by the control system, a jumper (not shown) may be selected by a user in
30 the field to replace sensor 30 and indicate to micro-controller 12 that the sensor is not available.

For illustrative purposes, one example of a monitoring and control system may be a humidistat such as the H1008 Automatic Humidity Control manufactured by Honeywell Inc. This particular humidistat is configurable in the field, and requires either a temperature sensor or a jumper to be selected and placed across two micro-controller input terminals, one of the terminals being tied to ground or circuit common.

Although only a single sensor 30 is shown in Figure 1, such a system may also incorporate several additional sensors monitored by analog to digital converter 38 contained within micro-controller 12. If further sensors are installed, additional dedicated input channels to micro-controller 12, such as that identified by reference numeral 32, will be required. Similarly, if any of the additional sensors are removed, a jumper (not shown) may be connected between each dedicated input channel and ground or circuit common 42.

Micro-controller 12 ideally includes a current source 14, comparator 16, timer 18, read-only memory (ROM) 20, random-access memory (RAM) 22, and clock 24. In the preferred embodiment, micro-controller 12 also incorporates an internal sampling capacitor 26 and switches 28 and 40. Also in the preferred embodiment, micro-controller 12 may be a MC68HC705JJ7 or MC68HC705JP7 micro-controller as manufactured by Motorola.

Sensor 30, ideally incorporating a voltage divider formed from resistor 34 and a negative temperature coefficient thermistor 36, operates to provide a signal indicative of a sensed condition such as temperature. It should be understood, however, that other types of sensing means may be used, and different sensors may provide information other than temperature. The present invention is therefore not to be limited to use with either an analog thermistor, a voltage divider, or a temperature sensor. Likewise, while only a single sensor 30 has been depicted in Figure 1 with micro-controller 12, it should be understood that such a showing is simplified and that in actual practice as many as two or more sensors may be used in a similar fashion.

With continued reference to Figure 1, if sensor 30 is present, micro-controller 12 will validate that a sensor is connected and operational when the resistance across thermistor 36, in the preferred embodiment, is between approximately 3,600 and 336,500 Ohms. This would correspond to a sensed temperature between -40 and 120 degrees Fahrenheit. Should a jumper (not shown) be connected instead of sensor 30

between circuit common 42 and input channel 32, micro-controller 12 will receive a signal indicating a resistance across thermistor 36 of approximately 0.5 Ohms. If neither sensor 30 nor a jumper is present, micro-controller 12 would receive a signal indicating a greater reading than the expected maximum sensor reading of 336,500
 5 Ohms. Likewise, if sensor 30 is removed after initialization of micro-controller 12, or line 32 opens, micro-controller 12 will receive a sensor signal much larger than the expected maximum.

Either sensor 30 or a jumper may be selected by an installer in the field, for connection between input channel 32 and circuit common 42. This allows input channel
 10 32 to be used to either monitor the status of the jumper (i.e. is it present or absent) or to monitor the signal transmitted from the sensor when it either has been installed. Micro-controller 12 is thus programmed to recognize the large difference in signal levels between the signal received from either the jumper or the sensor.

To extend the above concept, this invention also encompasses the situation when
 15 the sensor reading may be, under some conditions such as extremely high temperature, the same as a jumper. For example, a negative temperature coefficient thermistor, under extremely high temperatures will approach the same resistance as a short circuit, and would thus be indistinguishable from a jumper installed between circuit common 42 and input channel 32. To solve this problem, a combination of input filtering and logic may
 20 be incorporated into ROM 20.

In order to solve the above problem, ROM 20 may contain a lag filter 46 containing an equation having the following form:

$$X_{i+1} = \frac{nX_i + R + \frac{n+1}{2}}{n+1} \quad (\text{Equation 1})$$

25

Where R is defined as the current signal value on input channel 32, X_i is the previous current filter equation output, X_{i+1} is the present filter equation output, and n is the current number of the sensor reading. This particular implementation requires each of these terms to be integers, and all of the associated math to be done by integer
 30 arithmetic with simple truncation of the remainders after division. It is also

contemplated that other filter equations may be utilized in place of Equation 1, and to do so would not depart from the spirit of the invention.

Upon initialization of power to micro-controller 12, external capacitor 44 is initially discharged through switch 40 to circuit common. The signal to be received via input channel 32 is, in the preferred embodiment, continuously held on input channel 32, but may alternatively be sampled by the internal storage capacitor 26 for the duration of the sensor reading. Current source 14 then operates to charge the external capacitor 44. As the charge transfer from the current source 14 to the capacitor 44 occurs, this then results in an increasing voltage across capacitor 44, which causes comparator 16 to transition from a low state to a high state when it reaches the level of the signal sampled from input channel 32. This transition of the comparator 16 is then used to stop the operation of free-running timer 18, which contains a value proportional to the signal on input channel 32. This value is essentially a digital representation of the sensor value on input channel 32. This digital representation is then converted and stored in RAM 22 either as a temperature or as being a jumper.

After initialization of micro-controller 12, all subsequent sensor readings, and hence the values on input channel 32, are passed through the lag filter equation shown above in Equation 1 to reduce noise, the initial reading of R being used to set the operational mode indicating either sensor presence or absence. Once the mode is set, subsequent changes in the sensed value received on input channel 32 will not allow the control to shift to a new mode. The lag filter will follow the reading R , but with a lag to reduce any noise on the signal and a small offset equal to $(n+1)/2$. If the signal value on input channel 32 drops, the filter output is larger by the offset. If the signal value on input channel 32 increases, the filter output is less than the reading by the offset. Thus, if the signal value on input channel 32 goes to zero, the filter output will never actually reach zero. This prevents micro-controller 12 from interpreting the filtered reading as a jumper, which would normally read as approximately zero. Thus, if a sensor is initially present, the system will continue in normal operation should the signal value on input channel 32 suddenly drop to zero, and will not change modes. Such an event might occur if the sensor develops a short circuit, or the sensor is replaced with a jumper while in operation. Further operation of the lag filter will become apparent from the following figures and description of operation which follows.

Referring now to Figure 2, there is shown a flow chart showing the preferred method and implementation of the present invention. In this figure, as in Equation 1 above, R is defined as the current sensor output signal value or signal value on input channel 32, X_i is the previous filter output, X_{i+1} is the current filtered sensor reading, and n is the current reading number of the sensor reading.

Upon initialization or power reset 60, micro-controller 12 of Figure 1 will initially set X_i equal to the current input channel 32 signal value, R at step 62. This initial value will then be compared at decision step 64 with a predetermined minimum value. The predetermined minimum value may be chosen to be lower than the lowest possible sensor signal yet higher than zero.

Should the initial signal on input channel 32 of Figure 1 be lower than the predetermined minimum value, this would indicate that a jumper, not a sensor, is present on the input terminal at 66, and the mode for operation would be set to ignore this input channel. For example, in the humidistat example above, the micro-controller would then ignore this particular temperature sensor input channel, relying instead upon additional logic to achieve correct operation.

Even if the micro-controller interprets input channel 32 as having a jumper, the input channel is sampled for any possible change in signal level at 68. After passing subsequent input channel signal values through the lag filter equation set out in Equation 1, a new value for X_{i+1} is obtained. At decision step 70, this new value for X_{i+1} is compared again to the predetermined minimum value to detect any change in jumper status. If X_{i+1} is determined to remain below the predetermined minimum value, micro-controller 12 will validate the presence of a jumper, and return to step 66. If X_{i+1} rises above the predetermined minimum value, this then indicates to the micro-controller that an error condition has occurred and the jumper has either been removed or a portion of the circuit has opened. Error condition 72 may then be indicated to the user to require repair. Although an error condition 72 may occur, micro-controller 12 will then return to step 68 and continue to monitor the input channel signal level for subsequent changes.

Alternatively, if at decision step 64 micro-controller 12 determines that the value of X_i is greater than the predetermined minimum value, this would initially indicate that a sensor was present at 74, and this mode status would be stored in micro-controller 12.

Once again, by monitoring the signal value on input channel 32 of Figure 1, a value for X_{i+1} is obtained by passing the signal value through the lag filter equation of Equation 1 at step 76.

Once a new value for X_{i+1} has been obtained from the lag filter equation at step 76, a comparison is made at decision step 78 to determine if X_{i+1} is greater than the predetermined minimum value, yet less than a predetermined maximum sensor value. The predetermined maximum sensor value may be chosen to represent the highest possible operational output signal value from sensor 30 during normal sensor operation. If the value of X_{i+1} is within these two predetermined values, the sensor presence and operation will be validated and micro-controller operation will return to step 74. Should X_{i+1} fall outside one of the predetermined values, an error condition will ensue at step 80.

As stated previously, an error condition, such as that at step 80, may be indicated to the user to alert the user to possible sensor failure, or sensor disconnection from the input channel. In the humidistat example above, an error condition may then be indicated by the presence of a flashing light, light emitting diode (LED), or by sounding a warning tone. After error condition 80 is encountered, additional signal values may be monitored on input channel 32 of Figure 1, and resultant values for X_{i+1} may be obtained from the lag filter equation at step 76.

An additional problem is also solved with this invention. If the sensor 30 happens to be providing a zero reading when the power is interrupted to the device, the system will operate to restart in the mode indicating the presence of a jumper. It will then remain in this mode until the sensor reading increases to a level high enough to be unambiguously detected as a true sensor reading. Should this condition occur, the micro-controller 12 will then indicate an error condition, alerting the user that the system has detected an operational anomaly. If the power is cycled at the point when the sensor reading is in the normal range of operation, the system will once again recognize that a sensor is present and respond accordingly.

Referring to the graphical representations shown in Figure 3, operation of the lag filter of Equation 1 is shown for two different error conditions. In each error condition, the graphical representations are shown for an initial mode selection having an operable sensor attached to the input channel 32 of Figure 1.

In Figure 3A, the signal value 92 on input channel 32 of Figure 1 will initially follow the output value X_{i+1} of the lag filter equation to within a relatively small amount. After some period of time indicated by t_1 , a short circuit condition may occur, indicated at point 94 at which time the signal value 92 will drop to approximately zero.

5 Due to the small offset inherent in the lag filter equation, the output value 90 will decrease but remain slightly above zero, thus preventing the filtered reading from being mistaken for a jumper, which would read as approximately zero. Also shown in Figure 3A is one example of a predetermined minimum input signal level, indicated by horizontal line 104. The actual predetermined minimum input signal level may be
10 chosen depending on the operating characteristics of the sensor used. Once the filter output drops below this line, an error condition is realized, and the user is alerted to this anomaly.

Likewise, as shown in Figure 3B, the signal value 96 on input channel 32 of Figure 1 will approximately match that of the lag filter equation output 98 value until an
15 open circuit error condition is realized at some time t_3 . As the input channel signal value 96 approaches a very large value, indicative of open air resistance, the lag filter equation output value 98 will steadily increase, yet remain slightly lower than the input channel signal 96. Thus, the filter output is once again less than the input channel signal 96 by the offset factored into the lag filter equation. A predetermined maximum output
20 value has also been indicated on Figure 3B as horizontal line 102. This maximum output value may also be chosen depending on the sensor employed. Once the filter output has risen above the predetermined maximum value 102, an error condition is indicated and the user is alerted.

In summary, the foregoing has been a description of a novel and unobvious
25 method and apparatus for determining sensor presence at an input terminal to a micro-controller. This description is meant to provide examples, not limitations. The applicants define their invention through the claims appended hereto.

CLAIMS

The embodiments of the invention in which an exclusive property right is claimed are defined as follows:

- 5 1. A method for selecting the operational mode of a micro-controller, comprising the steps of:
 - a) initializing the micro-controller;
 - b) monitoring at least one input channel to obtain a first measured variable;
 - 10 c) applying the first measured variable to a filter to obtain a filter output;
 - d) comparing the filter output to at least one predetermined value; and
 - e) selecting a mode of operation based upon the comparison of the filter output and the at least one predetermined value.
- 15 2. The method for selecting the operational mode of a micro-controller of claim 1 further comprising the step of:
 - b₂) setting the initial output of the filter equal to the first measured variable.
- 20 3. The method for selecting the operational mode of a micro-controller of claim 2 further comprising the step of:
 - d₂) comparing the filter output to a second predetermined value; and
 - d₃) determining whether the filter output falls between the first predetermined value and the second predetermined value.
- 25 4. The method for selecting the operational mode of a micro-controller of claim 3 further comprising the step of:
 - f) returning an error signal if the filter output is outside said first or second predetermined values.
- 30 5. The method for selecting the operational mode of a micro-controller of claim 1 further comprising:

f) monitoring the at least one input channel to obtain a second measured variable;

g) applying the second measured variable to a filter to obtain a second filter output;

5 h) comparing the second filter output to the at least one predetermined value; and

i) returning an error signal if the second filter output is less than the at least one predetermined value.

10 6. A micro-controller input monitoring apparatus for monitoring and determining sensor presence, comprising;

a capacitor for receiving and storing an electrical charge;

a current source, the current source providing the electrical charge to said capacitor;

15 a micro-controller comprising:

at least one input channel operable to receive an input signal;

a comparator having first and second inputs and at least one

output, the first input connected to the input channel, the

second input connected to the current source;

20 a timer connected to the output of the comparator, said

comparator operating to trigger said timer when a

predetermined condition exists on said first and second

inputs;

memory connected to the timer for receiving and storing a time

25 value; and

a filter connected to the memory for operating on the stored time value,

the filter operable to produce a first output if a sensor is

connected to said input channel and a second output if a jumper is

connected to said input channel.

7. The micro-controller input monitoring apparatus of claim 6 wherein the filter is operable to produce a third output if a sensor or jumper is not connected to said input channel.

5

8. A micro-controller input monitoring apparatus comprising:

a micro-controller having at least one input channel, the at least one input channel capable of receiving an input signal;

a filter connected to the input channel for processing the input signal, said filter comprising:

10

a comparator, the comparator comparing the input signal to a predetermined value;

a means for producing a first output signal if a sensor is attached to the at least one input channel;

15

a means for producing a second output signal if a jumper is attached to the at least one input channel; and

a means for returning an error condition if the input signal falls outside a predetermined value.

20

9. The micro-controller input monitoring apparatus of claim 8 wherein the micro-controller input monitoring apparatus further comprises:

a means for producing a third output signal if a sensor or jumper is not connected to said input channel.