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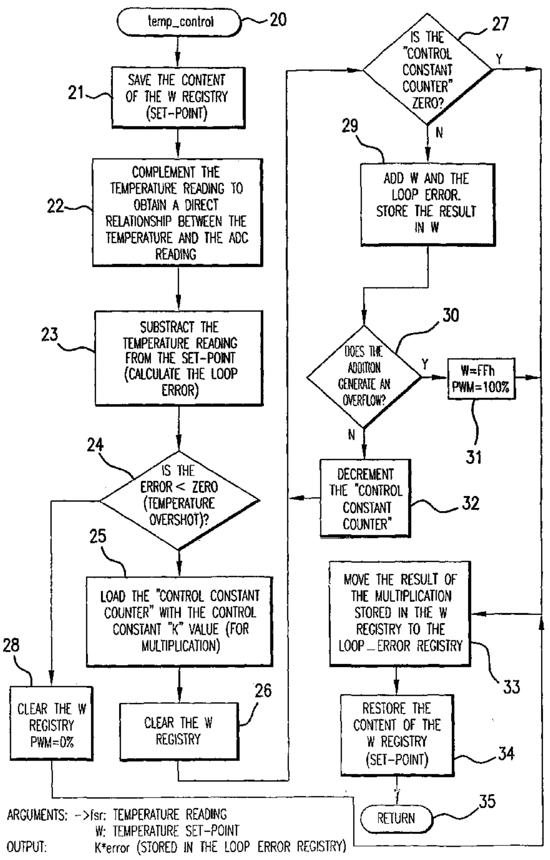
(54) Title: TEMPERATURE COMFORT DEVICE HEATER CONTROLLER METHOD AND SYSTEM



(57) Abstract: The invention relates to a method of, and system for, controlling an in-vehicle temperature comfort device heater by obtaining from a user a desired temperature setting for the comfort device and obtaining a current temperature of the comfort device, subtracting the current temperature from the desired temperature yielding a temperature difference, and multiplying this temperature difference by a numeric calibration factor to produce a PWM signal for controlling the duty cycle to the comfort device heater.

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TEMPERATURE COMFORT DEVICE HEATER CONTROLLER METHOD AND SYSTEM

FIELD OF THE INVENTION

The invention relates to a method of, and system for, controlling the temperature in heated seats, steering wheels or any in-vehicle temperature comfort device. Specifically, the present invention is directed to a method and system of continuous, proportional, closed-loop control of pulse width modulation output for control of heating elements.

APPENDIX

An Appendix is attached hereto includes 3 pages of computer program listing.

BACKGROUND OF THE INVENTION

Control of electric heaters, such as those used in heated seats, steering wheels, or other in-vehicle temperature comfort device has mainly been achieved by turning a fixed power supply on or off as needed to control the heater. Systems using this approach have a disadvantage of transmitting to the user the sensation of warming up and cooling down at or near the set-point temperature. This is often not a comfortable or desirable sensation.

Systems employing the on/off switching of the heater power supply have been developed that use extensive tables and/or curves requiring non-volatile storage to maintain data concerning the timing of the on/off switching. This is disadvantageous for several reasons. First, the non-volatile memory consumed by such systems is expensive and requires additional space and power. Second, should the contents of the memory be compromised in some way, such as partial erasure, the results may become uncomfortable for the user. Another disadvantage of such systems is that the cycling of power to the heater includes a latency period which reduces the granularity of the control of the temperature. An accuracy of approximately +/- 1° C is considered good for such heating systems.

Pulse width modulation (PWM) is used in the method and system of the present invention. PWM works by modulating the timing of the lead and trail edges of the power signal to the heater. PWM results in a relatively accurate control of a heater.

PWM has been used for heater control in fixed-location equipment, such as in the chemical industry for controlling heaters used in chemical process control. It is especially useful where precise control of temperature is desired. As yet, it has not been considered useful for controlling in-vehicle temperature comfort devices, *i.e.*, for mobile operation.

Thus, it is still desired to design a suitable heater control circuit, apparatus, and system that is capable of accurate operation in a mobile environment.

SUMMARY OF THE INVENTION

The purpose and advantages of the present invention will be set forth in and apparent from the description that follows, as well as will be learned by practice of the invention. Additional advantages of the invention may be realized and attained by the methods and systems particularly pointed out in the written description and claims hereof, as well as from the appended drawings.

The invention relates to a method of controlling temperature in a mobile comfort device which comprises: selecting a desired temperature setting for the mobile comfort device; determining a current temperature of the comfort device; comparing the desired temperature to the current temperature to detect any difference; and modifying a pulsed width modulation (PWM) signal to the comfort device based on the detected difference by an amount sufficient to change the temperature of the comfort device to the desired temperature, thus providing accurate temperature control to the device.

Generally, the PWM signal is narrowed when the desired temperature is lower than the current temperature, while the PWM signal is broadened when the desired temperature is higher than the current temperature. Advantageously, the mobile comfort device comprises an in-vehicle comfort device, such as a temperature modifiable seat or steering wheel.

In this method, the steps of obtaining the current temperature from the comfort device, comparing the desired temperature to the current temperature, and modifying the PWM signal may be repeated periodically for optimum temperature control. Also, the step of obtaining from the user the desired temperature setting for the comfort device preferably occurs asynchronously.

A default temperature setting may be provided for the comfort device and can be initially used as the desired temperature. This default temperature setting can be the last temperature previously selected for the comfort device. Also, the modifying of the PWM signal can be determined by multiplicatively combining the difference between the desired temperature and the current temperature of the comfort device with a numeric calibration factor. This numeric calibration factor is preferably a composite of two or more numeric calibration factors. Alternatively, the modifying of the PWM signal can be determined by combining the difference between the desired temperature and the current temperature of the comfort device with a numeric calibration factor. This can be accomplished by subtracting the current temperature from the desired temperature to obtain a numeric temperature difference; and multiplying the temperature difference by a numeric calibration factor to produce the PWM signal. These adjustments are made such that the temperature is sufficiently responsive so that a user does not notice when the comfort device is incorrectly controlled. The temperature controller can include one or more systems for heating, for cooling, or both.

The invention also relates to a system for controlling a mobile temperature-modifying comfort device comprising: a comfort device; a microprocessor operatively connected to associated memory, a user interface and a power interface, each being electronically interconnected, with the power interface being further connected to the comfort device; and a temperature sensor and analog-digital converter (ADC) connected to the comfort device, with the ADC further connected to the microprocessor. The microprocessor and associated memory are configured so as to obtain from the user interface a desired temperature setting for the comfort device; obtain a current temperature of the comfort device from the temperature sensor and ADC; compare the desired temperature to the current temperature to determine the difference; and modify the pulsed width modulation (PWM) signal to the comfort device based on the difference so as to provide sufficient control of the temperature of the comfort device.

It is understood that both the foregoing general description and the following detailed description are exemplary and are intended to provide further explanation of the invention claimed.

BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings are included to illustrate and provide a further understanding of the method, circuit, and system of the invention. Together with the description, the drawing may help explain the principles of the invention.

FIG. 1 is a block diagram of a controller in accordance with a preferred embodiment of the invention;

FIG. 2 is a flowchart depicting a temperature-setting algorithm in accordance with a preferred embodiment of the invention; and

FIGS. 3(a) and 3(b) depict a flowchart of the interrupt service routine controlling the PWM synchronization and over-undercurrent check of an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with a preferred embodiment of the invention, a method, circuit, and system are provided to control the temperature in heated seats, steering wheels or any mobile temperature comfort device, preferably in an in-vehicle temperature control system. The use of PWM allows more accurate control of the temperature of the comfort device.

Advantageously, another embodiment of the invention involves allowing the PWM control of the comfort device to be very finely calibrated using a single calibration constant K. Use of a single calibration constant replaces the extensive tables and heating curves used in prior art comfort device controllers. This results in a great savings of potentially expensive non-volatile memory, as well as simplified recalibration.

Also, the use of PWM to control the heating process for comfort devices greatly reduces or eliminates transmittal to the user of the sensation of heating and cooling at or near the desired temperature due to the turning on and off of the heater in the prior art. With the PWM approach described herein, once the desired temperature is reached, the user will not be subjected to the constant on/off switching of existing heater controllers. The accuracy of a system employing the present invention is approximately +/- 0.1°C, which is surprisingly about ten times better than conventional on/off systems.

The block diagram of FIG. 1 depicts the control process according to an embodiment of the invention. This embodiment described below is for a seat heater, but this is for example purposes and not a limitation. Another embodiment includes a seat cooler, *i.e.*, air conditioning. Yet another embodiment encompasses a single control process capable of heating or cooling, as desired, to help maintain the same or at least substantially the same temperature depending on the season or any other form of temperature variation. Any temperature comfort device may be used.

First, the controller includes software 1 and hardware 2. The processor and associated memory, and data communication and control lines, on which the software is configured and run are not shown in FIG. 1. Any processor and associated components may be for executing the algorithm and interfacing the controller components depicted in accord with the invention.

A user initiates the control process by opting to select a temperature "set point" 3 to which the comfort device is to be heated. The selection of the set point may involve additional steps. For example, the user may be required to turn on the comfort device at the console of the vehicle prior to setting the desired temperature. The set point 3 is selected by the user in a preferred embodiment by the manipulation of a physical selector switch (not depicted). It is also possible in another embodiment that the physical selector switch is replaced by any user interface capable of allowing the user to select a set point 3.

In an embodiment that requires the user to turn on the comfort device before selecting a set point, the set point 3 is automatically set to a suitable default value at the time the controller is initialized. In one embodiment, this default value for the temperature of the comfort device is fixed in the controller at the factory. In another embodiment, the default value for the temperature of the comfort device is variable and can be set by the user. In yet another embodiment, the default value for the set point 3 is automatically set to the last temperature selected by the user.

In a preferred embodiment, the set point is a temperature in degrees (Fahrenheit or Celsius). Other embodiments may use pneumonics keyed to preset temperatures, i.e., "low heat", "medium heat", "high heat", or other ergonomic user interface devices as is well known in the art.

The set point 3 is then compared 4 to a current temperature reading obtained from the temperature sensor 10 via an analog-digital converter (ADC) 11. The comparison operation 4 is performed by subtracting the current temperature of the comfort device from the set point 3. The result is a temperature difference, referred to as an "error" or "e" in a preferred embodiment.

A numeric calibration factor "K" 5 is then used in combination with the error to calculate a PWM signal 6 to send to the power interface 7. In this way, the PWM determines the duty cycle for the power interface 7 used for the comfort device heater 8 (depicted as "seat heater" in FIG. 1.) In a preferred embodiment, the numeric calibration factor is multiplied by the error to determine the value of the PWM signal. It is not intended as a limitation that the numeric calibration factor 5 be combined with the error multiplicatively to calculate the PWM signal. Indeed, any suitable algorithm may be used to determine the PWM signal. It is not even mandatory that one numeric calibration factor be employed. For example, another embodiment may use two numeric calibration factors to achieve the same result. The choice of the particular algorithm and the use of a single numeric calibration factor in a preferred embodiment does not limit other embodiments from using other algorithms and calibration factors. The use of a single calibration factor, which may be modified in software, is advantageous over using relatively large tables and curves in non-volatile memory.

Ultimately, the calculated PWM signal determining the duty cycle is sent to the power interface 7, which drives the comfort device heater 8. The result is that the comfort device (in FIG. 1, the seat) is heated to the desired temperature 9. The temperature sensor 10 periodically monitors the comfort device temperature 9 and provides its current temperature reading, via the ADC 11, to the comparison software. This process continues while the comfort device is in use. The user does not have to change their temperature set point 3. In a preferred embodiment, the set point may be set once and forgotten by the user. Indeed, with a suitable default value, the user may never need to set the temperature of the comfort device.

A flowchart depicting a temperature setting algorithm in accordance with a preferred embodiment of the invention is shown in FIG. 2. This algorithm is executed whenever a user changes the temperature set point for the comfort device. The user first enters the new set point into the temperature control user interface 20 (referred to as "temp_control" in FIG. 2.) The current PWM is saved in memory (in the "w registry") 21.

Next, the current temperature of the comfort device is complemented to obtain a direct relationship between the temperature and the ADC reading 22. This step places the current temperature measurement on an even scale with the temperature set point for comparison. The complemented temperature reading (henceforth, "current temperature") is then subtracted from the set point temperature, to obtain the "error" 23.

If the error is a negative number 24, the current temperature is higher than the set point temperature, and a "temperature overshot" condition exists. In this case, the PWM signal in the w registry is set to zero, and execution proceeds to the step of moving the result of the multiplication stored in the w registry to the "loop_error" registry 33.

Otherwise, the "constant control counter" is loaded with the numeric calibration constant K 25. The w registry is cleared 26. Next, the error and the numeric calibration constant can be multiplied by the optionally repetitive steps of:

checking if the control constant counter is zero 27;

adding the value in w registry to the loop error registry, storing the result in the w registry 29;

checking if the addition generates a numeric overflow 30, and if so, setting the w registry to maximal value and the PWM signal to 100% 31 and proceeding to the step of moving the result of the multiplication stored in the w registry to the loop_error registry 33; and

otherwise decrementing the control constant counter 32 and repeating the steps above.

Next, the result of the multiplication stored in the w registry is moved to the loop_error registry 33, where it determines the PWM signal duty cycle to control the comfort device heater.

Finally, the w registry is restored to the set point temperature 34, and the procedure is exited 35.

FIGS. 3(a) and 3(b) depict a flowchart of the interrupt service routine controlling the PWM synchronization and over-undercurrent check of an embodiment of the current invention. In a preferred embodiment, a timer interrupt is used to periodically perform an over-undercurrent check, check the temperature of the comfort device and synchronize the PWM signal controlling the duty cycle for the heater. As those of ordinary skill in the art are well aware, the precise algorithm depicted in the flowcharts herein described may be modified or even substantially different while still accomplishing the same function. The flowcharts included and described herein are not intended to exclude other equivalent algorithms.

When the timer interrupt occurs, the interrupt service routine intreq 40 is initiated to handle the interrupt. First the TMR0 Interrupt flag is cleared 41, disabling interrupts. It is important generally in designing interrupt service routines to avoid reentrancy and other problems by first disabling further interrupts while servicing an interrupt.

Next, the w registry and status registry are backed up 42, and the TMR0 register is loaded with the PWM value from the PWM registry 43. The system is then checked to determine if the voltage is out of range 44. If so, execution proceeds to the turn the heater off step 50. Otherwise, the system is checked for an over- or undercurrent condition. If either exists, execution proceeds to the turn the heater off subroutine 50. If not, the temperature loop error is checked to see if it is zero 46, indicating that the set point temperature has been reached. If the loop error is zero, execution proceeds to the turn the heater off subroutine 50.

If the loop error is not zero, the PWM registry is subtracted from the loop error 47, and if the result is not positive 48, execution proceeds to the turn the heater off subroutine 50. Otherwise, the heater is turned on 49.

Whether the heater is now on or off, the next step is to check if the PWM period has started 51. If it has not, execution proceeds to the increment the PMW registry step 75. If the PWM period has started, it is then determined whether the heater is turned on or off 52.

If the heater is off, execution proceeds to the step of determining if the system is in an over-undercurrent off cycle 60. If the heater is on, a delay of approximately 200 milliseconds can be performed 53, to accommodate the current sensing transient. Other suitable time frames can be selected or preselected. For example, a suitable delay can be from about 100 ms to 1000 ms, preferably about 150 ms to 500 ms. The current sensing ADC channel is then selected 54, and the ADC conversion subroutine is called 55. Although not depicted in detail herein, ADC conversion subroutines are well known to those of ordinary skill in the art.

The result of the ADC conversion, the "current value," is then stored in the current registry 56. The current value is then compared with the maximum allowed value 57. If the current value exceeds the maximum allowed value, execution proceeds to the step of incrementing the current fail cycles counter 64. Otherwise, the current value is compared with the minimum allowed value 58. If the current value is lower than the minimum allowed value, execution again proceeds to the step of incrementing the current fail cycles counter 64. If the current value is in the allowable range, the current fail cycles counter is reset to zero 59, and execution proceeds to the step of incrementing the PWM registry 75.

If it was detected that the PWM period had not started, execution had proceeded to the check for the over-undercurrent off cycle step 60. If the system is not in the over-undercurrent off cycle condition, execution proceeds to the step of incrementing the PWM registry 75. If the system is in the over-undercurrent off cycle condition, the over-undercurrent off cycle counter is decremented 61. The over-undercurrent off cycle counter is then checked for a value of zero 62. If it is zero, the over-undercurrent fault flag is cleared. Whether it is zero or not, execution then proceeds to the step of incrementing the PWM registry 75.

As previously stated, if the current value exceeded the maximum allowed value, execution proceeded to the step of incrementing the current fail cycles counter 64. The current fail cycles is next checked for an overflow condition 65. If an overflow has occurred, the current fail cycles counter is set to its maximum value. Whether or not the overflow occurred, the number of current fail cycles is compared with the maximal allowed number 67. If the number of current fail cycles does not exceed the maximal allowed number, execution then proceeds to the step of incrementing the PWM registry 75.

Otherwise , the over-undercurrent recovery trials counter is decremented 68, and compared to zero 69. If the over-undercurrent recovery trials counter is zero, the system is turned off 73, and the overcurrent fault flag is cleared 74. Execution then proceeds to the step of incrementing the PWM registry 75. If the over-undercurrent recovery trials counter is not zero, the over-undercurrent on cycles counter is reset 70, the over-undercurrent fault flag is set 71, the over-undercurrent off cycles counter is preset, and execution then proceeds to the step of incrementing the PWM registry 75.

Finally, the w and status registries are restored 76, interrupts are enabled 77, and the interrupt service routine is exited by executing a return 78.

It will be apparent to those of ordinary skill in the art that various modifications and variations can be made in the method, circuit, and system of the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention include modifications and variations that are within the scope of the appended claims and their equivalents, and the claims are to be accorded the broadest scope consistent with the disclosure herein.

Appendix

Control routines.txt

```
; -----------------------------------------------
; interrupt service:  PWM Sync and current check
; -----------------------------------------------

                org     4
intreq:         bcf     TOIF              ; Clear tmr0 Interrupt Flag

                movwf   w_temp            ; Store the W registry
                movf    status,w
                movwf   status_temp       ; Store the Status registry
                movlw   PWM_PERIOD        ; Load tmr0
                movwf   tmr0

                btfsc   VOLTFAULT         ; voltage fault?
                goto    pwm_off           ; force heater off

                btfsc   OC_FAULT
                goto    pwm_off           ; force heater off

                movf    loop_error        ; verify if the heater should be off
                btfsc   Z
                goto    pwm_off           ; If the loop error is zero, turn off the
heater
                movf    pwm_reg,w
                subwf   loop_error,w      ; Calculate this PWM fraction state: ON or
OFF
                btfss   C
                goto    pwm_off           ; If the on time has expired, turn the
heater off
                call    heateron          ; Else, turn the heater on
                goto    currentchk        ; Check over and under-current conditions

pwm_off:        call    heateroff         ; Turn the heater off

currentchk:     movf    pwm_reg
                btfss   Z                 ; Is the PWM period starting?
                goto    pwm_end           ; No, skip the current check routine
                btfss   HEATER            ; is the heater off?
                goto    heater_off        ; Yes,
                movlw   ON_SAMPLE_DELAY
                movwf   current_set_tmr   ; wait 200us for current sampling
currentdelay:   decfsz  current_set_tmr
                goto    currentdelay
                movlw   CURSNS            ; Yes, read current channel
                call    get_ad
                movwf   current
                ;movf     current,w       ; No, check for overcurrent limit
                sublw   Ilimit_u
                btfss   C                 ; Is the current value greater than the
maximum?
                goto    current_fail      ; Yes,
                movf    current,w         ; No, check for open load
                sublw   Ilimit_l
                btfss   C                 ; Is the current value smaller than the
minimum?
                goto    ht_no_oc          ; No,
current_fail:   incf    ht_cs             ; Yes, increment the current fail cycles
counter
                btfsc   Z                 ; Does the current fail cycles overflows?
                comf    ht_cs             ; Yes, saturate it
                movlw   T_IlimON
                subwf   ht_cs,w
                btfss   C                 ; Is the number of current fail cycles
```

Control routines.txt

```
greater than the maximum allowed?
                goto    pwm_end         ; No,
                decfsz  ilim_cycles     ; Yes, decrement the number of overcurrent
protection cycles
                goto    ht_next_occ     ; If this is not the last overcurrent
protection cycle allowed,
                clrf    state           ; Else, turn off the system
                bcf     OC_FAULT        ; Clear the overcurrent fault flag
                goto    pwm_end
heater_off:     btfss   OC_FAULT        ; Is the system in the overcurrent off
cycle?
                goto    pwm_end         ; No,
                decfsz  ilim_off_pe     ; Yes, decrement the off cycles counter. Is
it zero?
                goto    pwm_end         ; No,
                bcf     OC_FAULT        ; Yes, clear the overcurrent fault flag
                goto    pwm_end
ht_no_oc:       movlw   N_Ilim          ; Reset the overcurrent number of cycles
                movwf   ilim_cycles
                clrf    ht_cs           ; Reset the overcurrent on cycles counter
                goto    pwm_end
ht_next_occ:    clrf    ht_cs           ; Reset the overcurrent on cycles counter
                bsf     OC_FAULT        ; Set the overcurrent fault flag
                movlw   T_IlimOFF       ; Preset the overcurrent off timer
                movwf   ilim_off_pe

pwm_end:        incf    pwm_reg
                movf    status_temp,w
                movwf   status          ; Restore the Status registry
                movf    w_temp,w        ; Restore the W registry
                retfie

;
; initialze: ports,ddrs,peripheral registers, ram, etc.
;
initialize:     movlw   0x20            ; clear all RAM
                movwf   fsr
clrlp:          clrf    indf            ; lower page
                bsf     fsr,7
                clrf    indf            ; upper page
                bcf     fsr,7
                incf    fsr
                btfss   fsr,7
                goto    clrlp

; entry to reinitialize ports
_init:          bsf     RP
                movlw   ddrgp_ini
                movwf   ddrgp           ; gpio data direction
                bcf     RP

                movlw   gpio_ini
                movwf   gpio            ; gpio default states

                bsf     RP
                movlw   opt_ini
                movwf   opt_reg

                movlw   adcon1_ini
                movwf   adcon1          ; flip bit 2 to set AN2,AN3 to analog in
                bcf     RP

                movlw   PWM_PERIOD      ; Load tmr0
```

Control routines.txt

```
                movwf   tmr0

                movlw   intcon_ini
                movwf   intcon

; initialize thermistor fault timer
                movlw   T_FAULTTHERM
                movwf   fault_tmr

; preset current limit variables
                movlw   N_Ilim
                movwf   ilim_cycles
                movlw   T_IlimON
                movwf   ht_cs
                movlw   T_IlimOFF
                movwf   ilim_off_pe
                movlw   I_Off
                movwf   current
                bsf     GIE
                return

;--------------------------------
; Temperature control sub-routine
;--------------------------------

temp_control:   movwf   w_temp2         ; Save the content of W registry
                comf    indf,w          ; Invert the "inverse realationship" between
temp and voltage on the NTC
                                        ; To a direct one
                subwf   w_temp2,w       ; Calculate the error
                btfss   C               ; Test if the error is negative (overshoot)

                goto    neg_error       ; If the error is negative, turn off the
heater
                movwf   loop_error
                movlw   CONTROL_K
                movwf   k_counter
                clrw
                movf    k_counter,f
mult_loop:      btfsc   Z               ; Multiply the error by the control constant
K
                goto    end_mult
                addwf   loop_error,w
                btfsc   C
                goto    error_ovf       ; If the error is too high, set the PWM to
100%
                decf    k_counter,f
                goto    mult_loop
end_mult:       movwf   loop_error
                movf    w_temp2,w       ; Restore the content of the w registry
                return
```

THE CLAIMS

What is claimed is:

1. A method of controlling temperature in a mobile comfort device which comprises:

selecting a desired temperature setting for the mobile comfort device;

determining a current temperature of the comfort device;

comparing the desired temperature to the current temperature to detect any difference; and

modifying a pulsed width modulation (PWM) signal to the comfort device based on the detected difference by an amount sufficient to change the temperature of the comfort device to the desired temperature, thus providing accurate temperature control to the device.

2. The method according to claim 1, wherein the PWM signal is narrowed when the desired temperature is lower than the current temperature.

3. The method according to claim 1, wherein the PWM signal is broadened when the desired temperature is higher than the current temperature.

4. The method according to claim 1, wherein the mobile comfort device comprises an in-vehicle comfort device.

5. The method according to claim 1, wherein the in-vehicle comfort device comprises a temperature modifiable seat or steering wheel.

6. The method according to claim 1, wherein the steps of obtaining the current temperature from the comfort device, comparing the desired temperature to the current temperature, and modifying the PWM signal are repeated periodically.

7. The method according to claim 1, wherein the step of obtaining from the user the desired temperature setting for the comfort device occurs asynchronously.

8. The method according to claim 1, wherein a default temperature setting is provided for the comfort device and is initially used as the desired temperature.

9. The method according to claim 8, wherein the default temperature setting is selectable to a desired value.

10. The method according to claim 9, wherein the default temperature setting is the last temperature previously selected for the comfort device.

11. The method according to claim 1, wherein the modifying of the PWM signal is determined by multiplicatively combining the difference between the desired temperature and the current temperature of the comfort device with a numeric calibration factor.

12. The method according to claim 11, wherein the numeric calibration factor is a composite of two or more numeric calibration factors.

13. The method according to claim 1, wherein modifying of the PWM signal is determined by combining the difference between the desired temperature and the current temperature of the comfort device with a numeric calibration factor.

14. The method according to claim 1 which further comprises:

subtracting the current temperature from the desired temperature to obtain a numeric temperature difference; and

multiplying the temperature difference by a numeric calibration factor to produce the PWM signal.

15. The method according to claim 14,wherein the control of the temperature is sufficiently responsive such that a user does not notice that when the comfort device is incorrectly controlled.

16. The method of claim 1, wherein the temperature control comprises heating.

17. A system for controlling a mobile temperature-modifying comfort device comprising:

a comfort device;

a microprocessor operatively connected to associated memory, a user interface and a power interface, each being electronically interconnected, with the power interface being further connected to the comfort device;

a temperature sensor and analog-digital converter (ADC) connected to the comfort device, with the ADC further connected to the microprocessor;

wherein the microprocessor and associated memory are configured so as to

obtain from the user interface a desired temperature setting for the comfort device;

obtain a current temperature of the comfort device from the temperature sensor and ADC;

compare the desired temperature to the current temperature to determine the difference; and

modify the pulsed width modulation (PWM) signal to the comfort device based on the difference so as to provide sufficient control of the temperature of the comfort device.

18. The system according to claim 17, wherein the microprocessor steps of:

obtaining a current temperature of the comfort device from the temperature sensor and ADC;

comparing the desired temperature to the current temperature; and

modifying the PWM signal;

are repeated periodically.

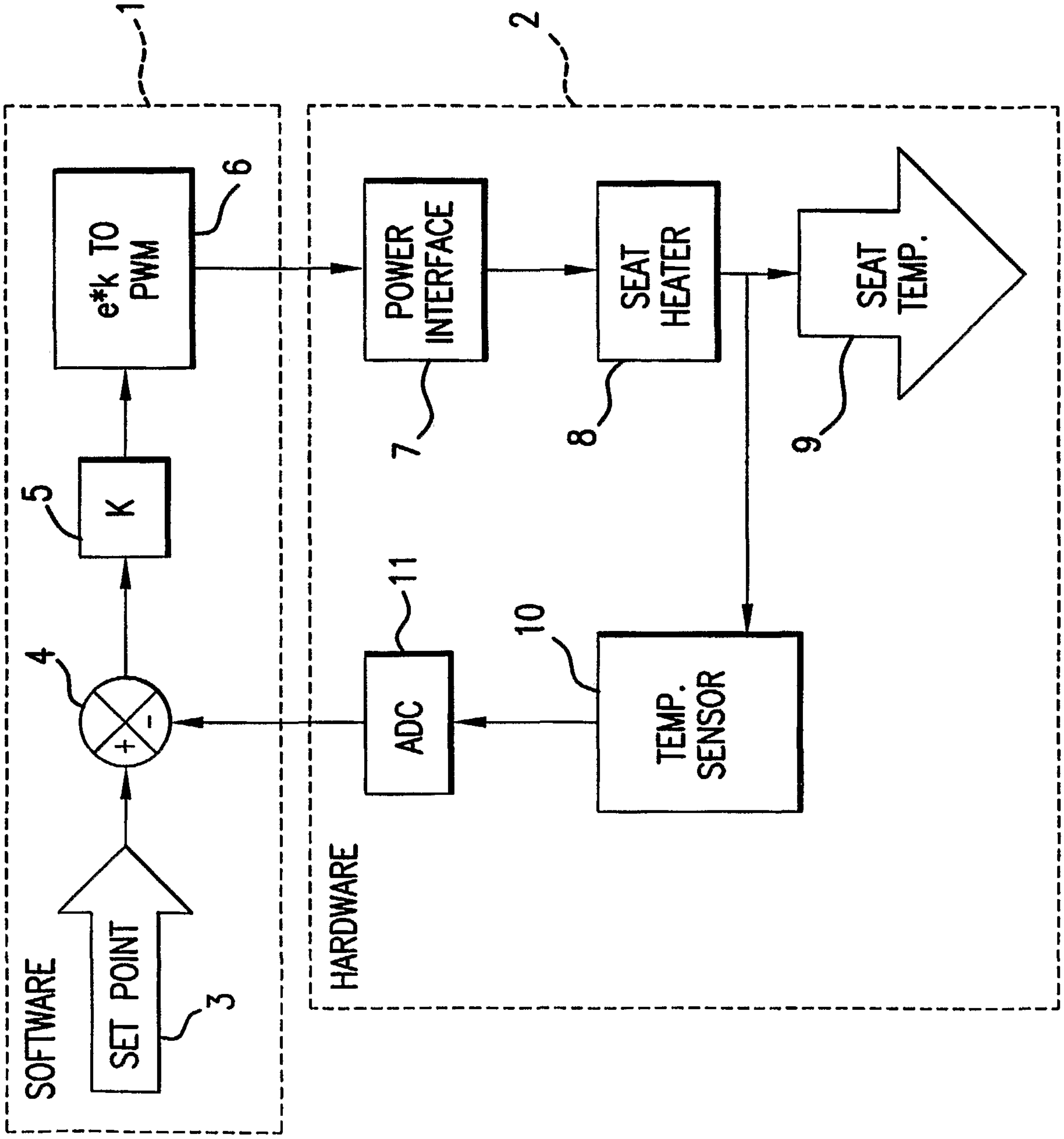
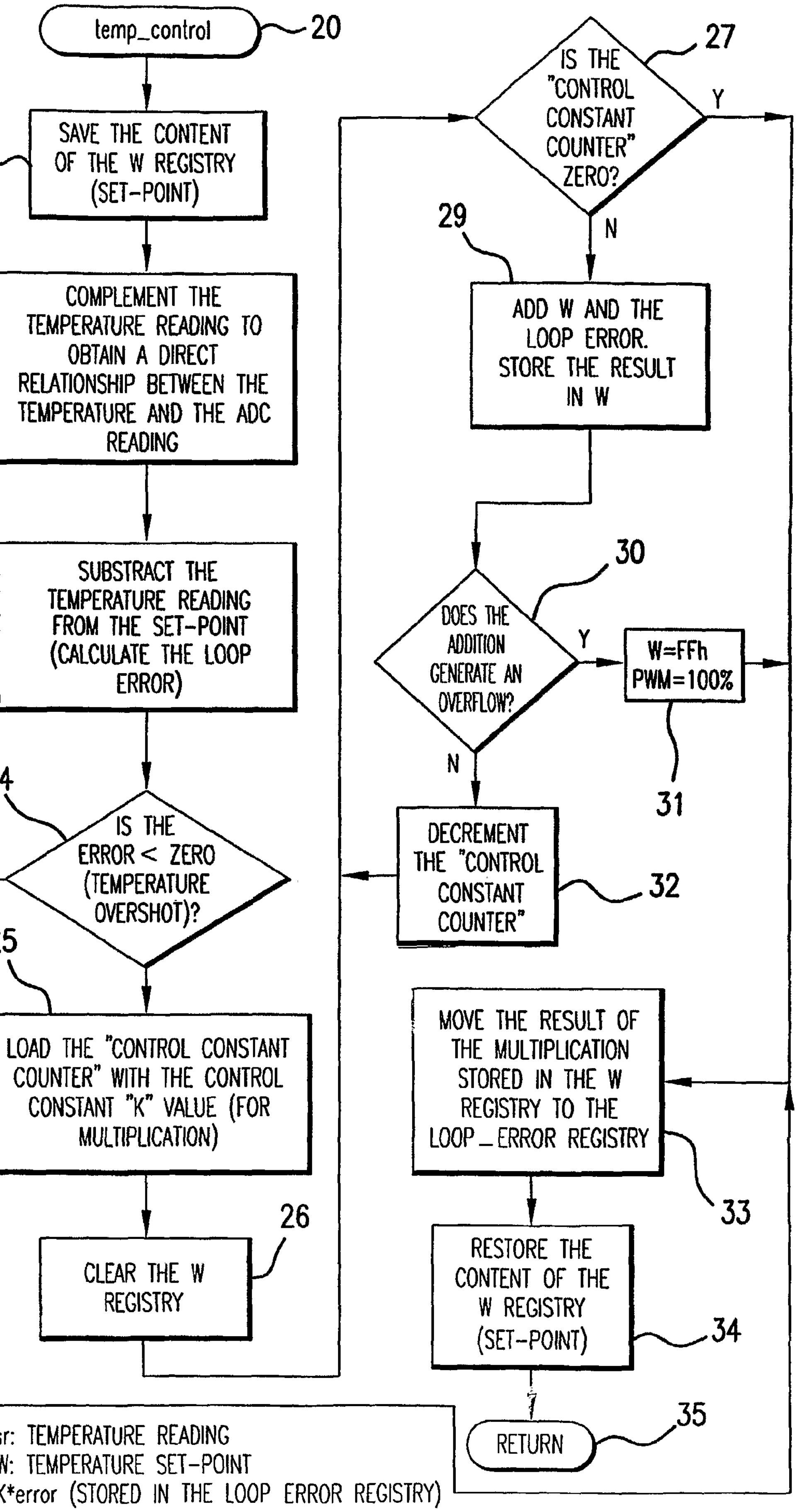

SOFTWARE
SET POINT
3
4
+
-
5
K
e*k TO PWM
6
1
2
HARDWARE
POWER INTERFACE
7
SEAT HEATER
8
SEAT TEMP.
9
TEMP. SENSOR
10
ADC
11

FIG.1

FIG.2



ARGUMENTS: ->fsr: TEMPERATURE READING
W: TEMPERATURE SET-POINT
OUTPUT: K*error (STORED IN THE LOOP ERROR REGISTRY)

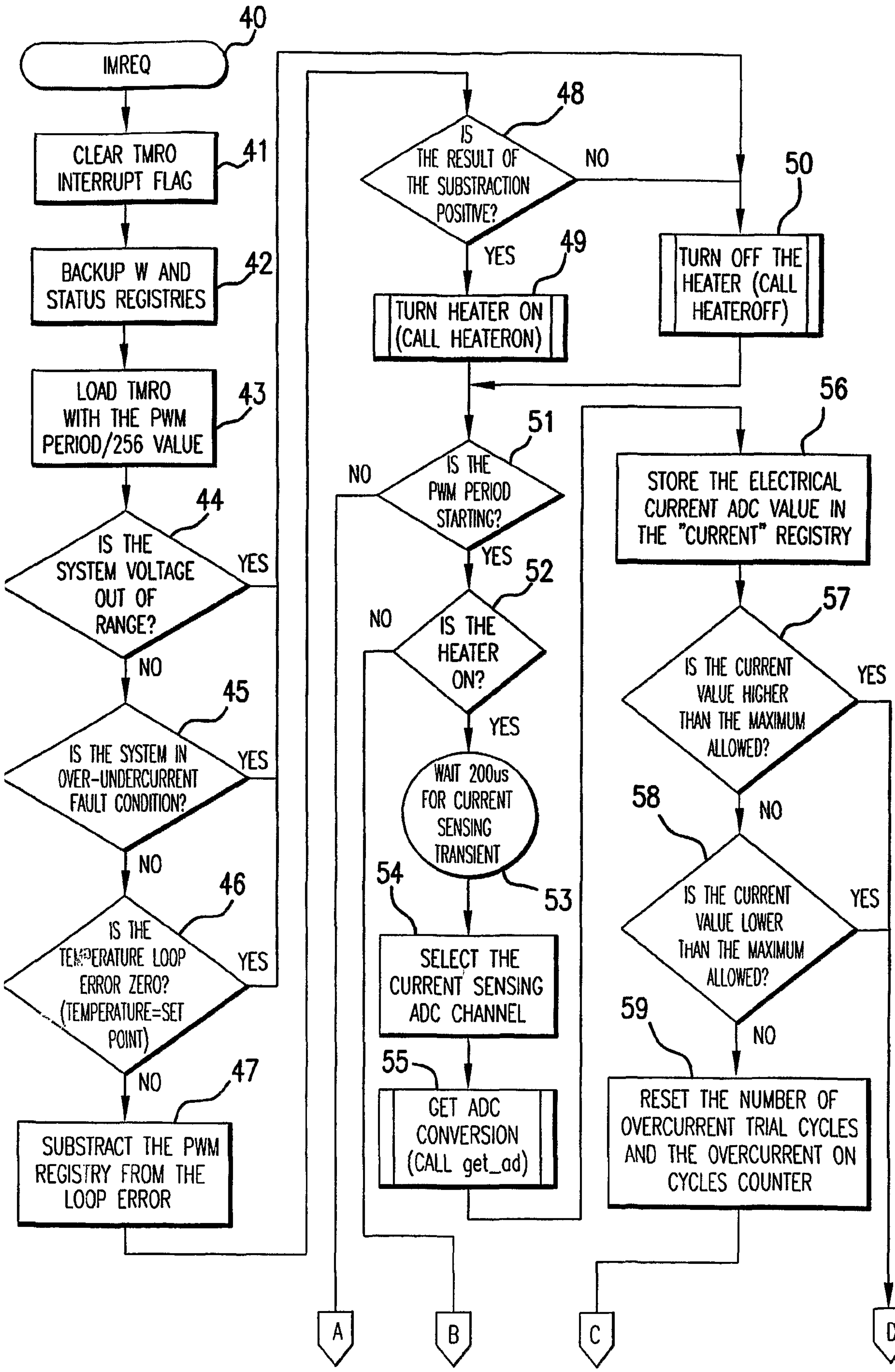
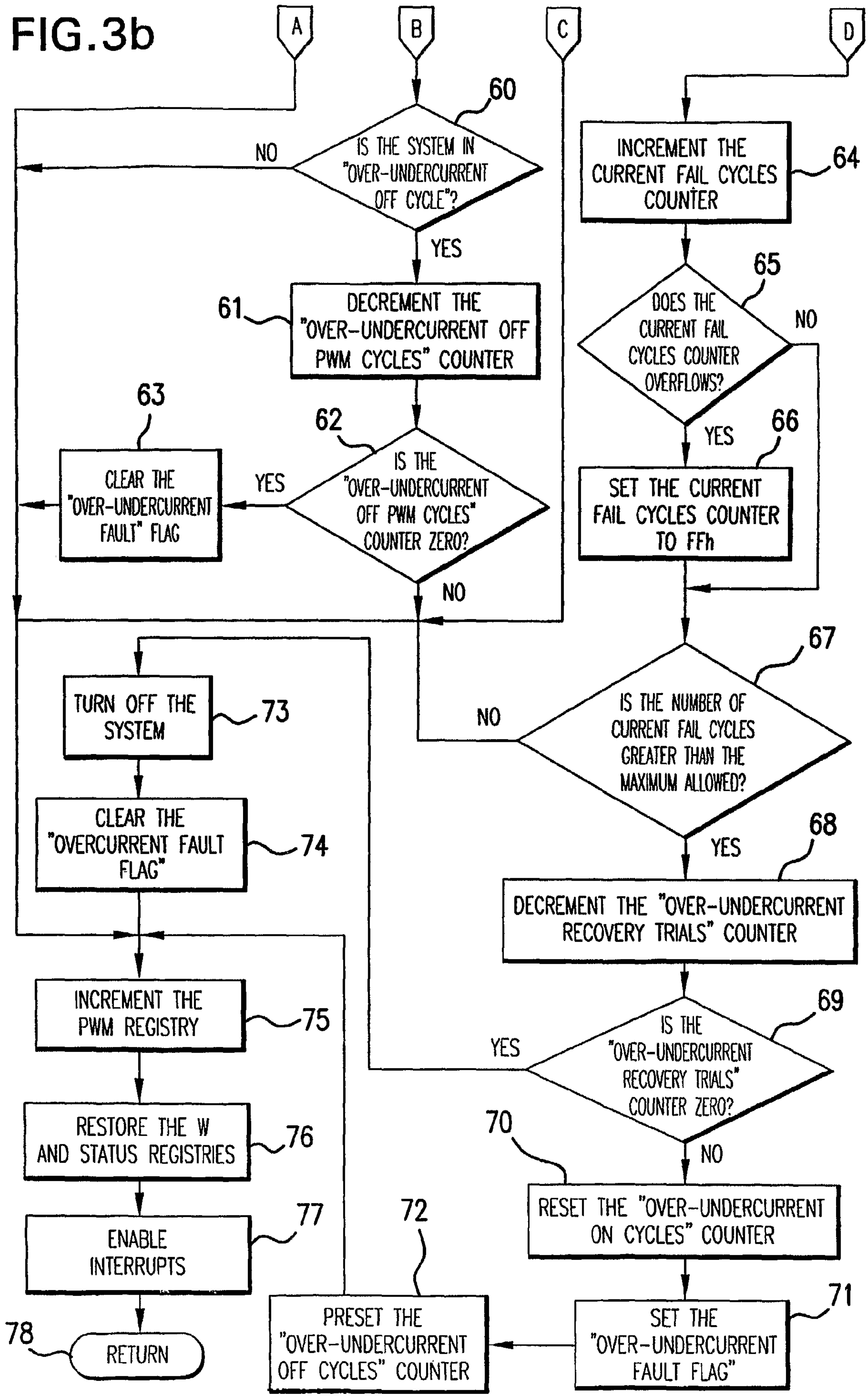

40
IMREQ
CLEAR TMRO INTERRUPT FLAG
41
BACKUP W AND STATUS REGISTRIES
42
LOAD TMRO WITH THE PWM PERIOD/256 VALUE
43
IS THE SYSTEM VOLTAGE OUT OF RANGE?
44
YES
NO
IS THE SYSTEM IN OVER-UNDERCURRENT FAULT CONDITION?
45
YES
NO
IS THE TEMPERATURE LOOP ERROR ZERO? (TEMPERATURE=SET POINT)
46
YES
NO
SUBSTRACT THE PWM REGISTRY FROM THE LOOP ERROR
47
IS THE RESULT OF THE SUBSTRACTION POSITIVE?
48
NO
YES
TURN HEATER ON (CALL HEATERON)
49
TURN OFF THE HEATER (CALL HEATEROFF)
50
IS THE PWM PERIOD STARTING?
51
NO
YES
IS THE HEATER ON?
52
NO
YES
WAIT 200us FOR CURRENT SENSING TRANSIENT
53
SELECT THE CURRENT SENSING ADC CHANNEL
54
GET ADC CONVERSION (CALL get_ad)
55
STORE THE ELECTRICAL CURRENT ADC VALUE IN THE "CURRENT" REGISTRY
56
IS THE CURRENT VALUE HIGHER THAN THE MAXIMUM ALLOWED?
57
YES
NO
IS THE CURRENT VALUE LOWER THAN THE MAXIMUM ALLOWED?
58
YES
NO
RESET THE NUMBER OF OVERCURRENT TRIAL CYCLES AND THE OVERCURRENT ON CYCLES COUNTER
59
A
B
C
D

FIG.3a

FIG.3b


A
B
C
D
60
IS THE SYSTEM IN "OVER-UNDERCURRENT OFF CYCLE"?
NO
YES
61
DECREMENT THE "OVER-UNDERCURRENT OFF PWM CYCLES" COUNTER
62
IS THE "OVER-UNDERCURRENT OFF PWM CYCLES" COUNTER ZERO?
YES
63
CLEAR THE "OVER-UNDERCURRENT FAULT" FLAG
NO
64
INCREMENT THE CURRENT FAIL CYCLES COUNTER
65
DOES THE CURRENT FAIL CYCLES COUNTER OVERFLOWS?
NO
YES
66
SET THE CURRENT FAIL CYCLES COUNTER TO FFh
67
IS THE NUMBER OF CURRENT FAIL CYCLES GREATER THAN THE MAXIMUM ALLOWED?
NO
YES
68
DECREMENT THE "OVER-UNDERCURRENT RECOVERY TRIALS" COUNTER
69
IS THE "OVER-UNDERCURRENT RECOVERY TRIALS" COUNTER ZERO?
YES
NO
70
RESET THE "OVER-UNDERCURRENT ON CYCLES" COUNTER
71
SET THE "OVER-UNDERCURRENT FAULT FLAG"
72
PRESET THE "OVER-UNDERCURRENT OFF CYCLES" COUNTER
73
TURN OFF THE SYSTEM
74
CLEAR THE "OVERCURRENT FAULT FLAG"
75
INCREMENT THE PWM REGISTRY
76
RESTORE THE W AND STATUS REGISTRIES
77
ENABLE INTERRUPTS
78
RETURN