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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [3]: G01K 7/14

A1

(11) International Publication Number: WO 80/01317

(43) International Publication Date: 26 June 1980 (26.06.80)

(21) International Application Number: PCT/US79/01135

(22) International Filing Date: 14 December 1979 (14.12.79)

(31) Priority Application Number: 971,370

(32) Priority Date: 20 December 1978 (20.12.78)

(33) Priority Country: US

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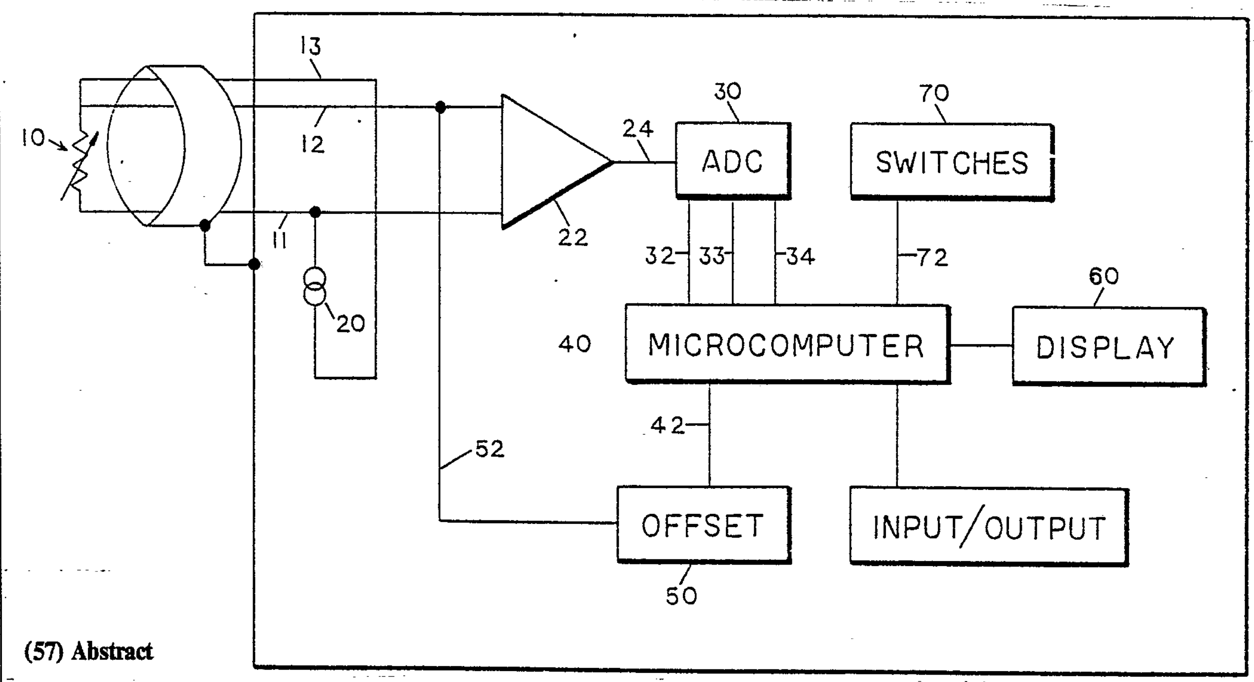
(81) Designated States: AT (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report

(54) Title: GENERAL PURPOSE ELECTRONIC THERMOMETER



(57) Abstract

An electronic thermometer comprising a platinum resistance sensor (10), a constant current source (20) which impresses a current through such sensor, an amplifier (22) which amplifies the resulting sensor voltage, and an analog to digital converter (30) which digitizes the amplifier signal and supplies the result to a microcomputer (40). The microcomputer (40) corrects for non-linearities in the resistance versus temperature relationship of the sensor and outputs to a display either: --the resulting temperature equivalent; --a calculated rate of temperature change; --a temperature equivalent representing the temperature; or --a temperature equivalent representing either the minimum or the maximum temperature measured since power has been applied to the instrument.

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GENERAL PURPOSE ELECTRONIC THERMOMETER

This invention relates generally to thermometers and improvements therein and more particularly to electronic thermometers which perform calculations or similar operations upon temperature data.

While some prior art electronic thermometers are capable of performing limited data conversions such as conversions from one temperature scale to another; while some conventional electronic thermometers allow for limited data storage and recovery such as maximum or minimum temperatures; and while certain conventional electronic thermometers have capabilities of limited data derivation such as detecting and holding in a display a temperature curve peak, none known to the inventors of the device described herein have achieved incorporation of all these capabilities in enhanced forms into a single-unit general purpose instrument.

Conventional thermometers which have selective data conversion functions either limit such conversion to two switch selectable scales or require internal hardware alterations or adjustments to achieve selection of an alternative scale.

Prior art thermometers which incorporate data recovery and derivation features fall into one of the two following categories:

--instruments which must be interfaced with ancillary equipment, either data collecting devices or data processing equipment, in order to achieve such capabilities,

--instruments with minimal data recovery or data derivation capabilities.

Devices in the former category result in elaborate and expensive thermometric systems which require sophistication on the part of the user. In addition, these instruments pose portability problems due to the bulk of such systems and are therefore unsuitable for general use. Devices in the latter category also have restricted application due to the limits of their capabilities - limits which dictate that the user make many necessary observations, comparisons, or computations in order to derive or collect commonly useful or required information. Such a requirement is wasteful of the human resource and often results in lost data due to the inability of the user to monitor the device at all times or to perform the necessary comparisons or computations in the required time or with the required accuracy.

Prior art digital electronic thermometers must either make trade-offs between precision of temperature resolution and width of range -- such trade-off being necessitated by the limits of the number of bits of resolution of the analog to digital converter used, or they must employ more sophisticated analog to digital converters the result of which is more expensive and generally less portable instruments.

The primary object of the invention described herein is to provide an electronic thermometer having improved selective data recovery, data conversion, and data derivation capabilities in an embodiment that is less expensive, more portable, more efficient, and easier for the untrained user to operate than conventional thermometric data collection and processing systems.

It is a further object of this invention to embody the above in a device incorporating high accuracy and high resolution over a wide range of measurable temperatures.

Other objects and advantages of this invention will be recognized from the following description including the specifications, claims and drawings in which:

FIG. 1 is a block diagram of the present embodiment.

FIG. 2 is a circuit diagram of the amplifier and offset circuitry.

FIG. 3 is a circuit diagram of the analog to digital converter and microcomputer circuitry.

FIG. 4 is a circuit diagram of the display and ancillary circuitry.

FIGS. 5A-B are a flow chart of an input routine comprising the routine to input data from the analog to digital converter to the microcomputer, correct the data, and update the MIN and MAX registers if appropriate.

FIGS. 6A-B are a flow chart of a routine comprising the routine determining the Latch operational mode.

FIGS. 7A-B are a flow chart of a routine comprising the routine determining the Delta T/M operational mode.

FIG. 8 is a front view of an electronic thermometer according to the preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, in the preferred embodiment, there is provided a platinum resistance sensor 10, provided with three wires 11, 12, and 13, two wires 11 and 13 being connected to a source of constant current 20, and two wires 11 and 12 being connected to an amplifier 22. The constant current source impresses a current through the sensor, the resistance of which varies in a predictable way with temperature. The resultant voltage at the sensor is transmitted to the amplifier through lines 11 and 12. The analog signal from the amplifier is carried through line 24 to a twelve-bit analog to digital converter (ADC) 30, which digitizes the signal. This digital data is presented to the microcomputer (MC) 40 through the four-bit bus 32 in the form of a sequence of binary-coded decimal (BCD) digits in response to control signals sent to the ADC by the MC through line 33.

The MC is programmed with an algorithm by which it converts the input from the ADC into a corrected BCD representation of degrees Celsius (°C.). Correction of this data - necessary due to inherent non-linearities in the variance of the resistance of the sensor with respect to temperature - is achieved by means of a table of corrections stored in the ROM of the MC. A value is stored for each ten degree C. increment of the range of the instrument and in the form of signed BCD numbers. Corrections for intermediate values are calculated by an interpolation algorithm stored in the MC's ROM. This corrected data and all other information output by the MC is displayed by means of a conventional liquid crystal display (LXD) 60.

In the present embodiment, the full-span conversion range of the ADC represents approximately four hundred °C. with a resolution of 0.1°C. Extension of this range to a span of approximately six hundred °C., with the same resolution, is effected in the following manner: referring again to FIG. 1, upon overflow, the ADC outputs to the MC an OVF signal on line 34; the MC is programmed with an algorithm by which it then sends out on line 42 a signal to the offset circuitry 50 which offsets the amplifier by inputing a voltage to the amplifier on line 52. This voltage is representative of a two hundred degrees C. subtraction. The MC is provided with an algorithm which adds this offset back to data incoming from the ADC while this offset is applied - i.e., whenever this range shift is in effect. Should this addition result in data representative of less than one hundred sixty degrees C., the MC outputs a signal to the offset circuitry to remove the offset voltage. In the event of a second OVF signal from the ADC while the offset voltage is applied, the MC responds with a routine to output a true instrument overflow indication.

All temperature data output by the MC is output in either of three temperature scales - Celsius, Fahrenheit or Kelvin - which are user selected by means of the request switches 70 of FIG. 1 which input signals to the MC through line 72. These request switches also allow the user to select any of the following operating modes or functions:

CONTINUOUS MODE: in this mode the MC inputs each conversion from the ADC, corrects the data, and outputs to the display the result approximately 1.5 times per second. Data output represents actual temperature at the sensor. In this mode the instrument functions as a thermometer.

LATCH MODE: in this mode the MC controls the following operational sequence:

(1) output to the display an acknowledgement of the request for the mode,

(2) output the initial temperature T1 recorded upon entry into the mode and save T1 for future comparisons,

(3) input each successive conversion from the ADC, output the corrected data to the display, then compare the data to T1 testing for a significant temperature change, defined in the present embodiment as greater than or equal to plus or minus 1.0°C.; if there is no significant change, continue this process, once a significant change is detected the direction of that change is noted (plus or minus),

(4) test each successive conversion from the ADC and output to the display only those temperature equivalents which represent temperatures farther removed from T1 in the direction of the previously noted significant change than the last output to the display.

In this mode, the instrument seeks the extreme of a temperature curve, and once it is detected, holds that data in the display until the mode is deselected by the user.

DELTA T/M MODE (rate of change in temperature per minute mode): in this mode the MC controls the following operational sequence:

(1) output to the display an acknowledgement of the request for the mode,

(2) output the initial temperature T1 recorded upon entry into the mode and save T1 for future calculations,

(3) from this point on, input each conversion of the ADC, correct the data input, do not output the result to the display; rather, every six seconds compare the input and corrected data to the temperature recorded at the beginning of that six second interval, calculate the relative change in temperature at the sensor during that interval, calculate from this result the relative change in temperature per minute represented by that change, and output the result of the display.

In this mode the instrument provides data concerning the relative slope of a temperature curve.

MIN RCL and MAX RCL FUNCTIONS: in all three of the aforementioned modes each input from the ADC is corrected by the MC and then compared to the temperature data stored in certain RAM registers of the MC. Data representing either a new absolute minimum or maximum recorded temperature is stored in the appropriate MIN or MAX registers, replacing any earlier stored values. At the time the instrument is powered up those registers are loaded with values which insure that the first recorded temperature will be stored in both sets of registers; therefore, at any time after power is applied the data stored in those registers represents the absolute minimum and maximum recorded temperatures.

At any time, the user can select to recall the values stored in either the MIN or MAX registers. Selection of either function results in the following MC controlled operational sequence:

(1) output to the display an indication of which data will be recalled,

(2) output to the display the data from the appropriate registers,

(3) input each successive conversion from the ADC, correct the data, and compare the result to the data in the MIN and MAX registers, update registers where appropriate, and after each such input and comparison, again output to the display the data from the requested registers.

These functions provide the instrument with the capability of data storage and selective data recovery.

DETAILED DESCRIPTION OF CIRCUIT OPERATION

Referring now to FIG. 2, operational amplifier A1, configured as a constant current source, maintains a constant current I through the sensor, resulting in a voltage V_S across the sensor. The magnitude of V_S is dependent upon the resistance R of the sensor, R being a function of the temperature of the sensor. The relationship among V_S, I, and R is given in the equation

$$V_S = I \cdot R \qquad \text{(Equation 1)}$$

The relationship between the resistance and temperature of the sensor is given by the well-known equation which takes the following general form:

$$R_T = R_0 \ (1+A \cdot T+B \cdot T^2) \qquad \text{(Equation 2)}$$

wherein;

T is the temperature in degrees Celsius

R_T is the resistance of the sensor at temperature T

R_0 is the resistance of the sensor at zero degrees Celsius

A is 3.90784×10^{-3}

B is -0.578408×10^{-6}

The aforementioned voltage V_S is impressed through buffer A2 to the amplifying circuitry comprising operational amplifiers A3 and A5 together with resistors R2, R3, R4, R5, and R7. Also impressed to the amplifying circuitry along with V_S is the zero-set nulling voltage V_Z which is determined by the voltage divider comprising resistors R8, R9, and R10 and which is supplied through the buffer A4. The function of V_Z is to null a portion of V_S in order to set the zero point of the circuitry during calibration. The operation of the amplifying circuitry is best described by the following equation:

$$V_O = -((\frac{V_S}{R2} + \frac{V_Z}{R7}) \cdot R3) \cdot -(\frac{R5}{R4}) \qquad \text{(Equation 3)}$$

wherein;

V_O is the final amplified voltage output from A5

V_S is the voltage from the sensor

V_Z is the zero-set nulling voltage

R2, R3, R4, R5, and R7 are resistors having the values given in TABLE I (page 38).

V_O (which is an analog representation of the temperature of the sensor) is applied through the current-limiting resistor R6 to the input ANI of the twelve-bit analog to digital converter IC4 of FIG. 3.

Referring now to FIG. 3, IC4, in conjunction with the required capacitors C3, C4, and C5 and the resistors R17 and R18, functions as an analog to digital converter which compares the unknown analog input V_O at ANI to a known reference voltage generated by the voltage reference IC1 and the voltage divider network comprising resistors R14, R15, and R16, the values of which are given in TABLE II (page 38). The result of this comparison is a twelve-bit digital representation of the magnitude of V_O. This digital data is output to the microcomputer IC5 as four consecutive binary coded decimal (BCD) digits upon requests received from and generated by IC5. IC5, under control of the switches S1, S2 and S3, utilizes this BCD data to generate data appropriate to user requests. For a complete description of the operation of IC5 in this respect see the descriptions and listings of the software routines given in later sections.

Capacitors C6 and C7 together with the crystal X1 in conjunction with IC5 provide the system clock. Capacitor C8 serves as a power-on reset for IC5.

Besides generating data to be output to the display as described later, IC5 also interacts with the analog circuitry to effectively increase the application range of that circuitry in the following manner: referring again to FIG. 3, when the voltage V_0 at ANI exceeds the conversion capabilities of IC4, IC4 generates and outputs to IC5 an overflow signal on the line OVF. Upon each input of BCD data from IC4, IC5 tests OVF for this signal. If this signal is present the BCD data is considered invalid by IC5 which responds as follows: IC5 either

(1) outputs a signal on $\overline{\text{OFST}}$ which results in an offset of the analog circuitry equivalent to the subtraction of 200°C. from the analog signal, and resumes accepting data from IC4, adding the "subtraction" back each time;

or (2) outputs an overflow indication to the display LXD if the analog circuitry already has this offset applied to it.

The aforementioned offset is achieved as follows: referring again to FIG. 2, $\overline{\text{OFST}}$ is pulled low (logical "0") by IC5, which causes the transistor Q1 to actuate the relay RLY which connects the resistance determined by resistors R11 and R12 in parallel with the zero-set resistance determined by resistors R9 and R10. The result is that V_Z is changed to a new value sufficient to offset the circuitry by an amount equal to a drop of 200° C. at the sensor.

The offset, once applied, is not withdrawn by IC5 until the BCD data input from IC4 represents a temperature less than 160°C.

Referring now to FIG. 4, data output by IC5 of FIG. 3 to the display LXD is sent first to the display driver IC6 via the lines DB0 - DB7, in the form of BCD digits together with appropriate digit select signals. IC6 converts this data to the seven-segment, four-digit format required by the display.

IC9 regulates the voltage supplied to the entire circuitry. IC8 is a comparator which tests for a low-battery condition by comparing the voltage determined by the voltage input to IC9 through switch S4 and the voltage divider comprising resistors R20 and R21 (which voltage is dependent upon the state of the battery) to a reference voltage established by the voltage reference IC1 of FIG. 3 (this reference voltage is used to establish ground GND for the analog circuitry). Once the compared voltage drops below the reference voltage, the output of IC8 goes high (logical "1") and via the exclusive OR gate IC7 drives a low-battery indication on the display. The remaining gates on IC7 are used to drive the decimal point, minus sign, and most significant digit (which is a "1") of the display under control of IC5 of FIG. 3 via lines P17, P25, and P26.

FIRMWARE

Operation of the firmware will be best understood by reference to the complete listing of the routines and subroutines of instructions to follow, the flow charts of specific routines presented in FIGs. 5A-7B, and the published literature associated with the Intel 8048 microcomputer.

COMPLETE LISTING OF THE ROUTINES AND SUBROUTINES OF INSTRUCTIONS

Following is a complete assembly language listing of the program stored in the microcomputer ROM. Each page of the listing is numbered at the bottom with respect to its position in the specification as a whole. The following information is contained in the respective columns of the listing, counting columns from left to right across the page:

--column one: decimal number of each line of each page,

--column two: hexadecimal address of the ROM location in which each instruction or constant is stored,

--columns three and four: two or four character hexadecimal representation of each instruction or constant,

--column five: assembly labels,

--column six: mnemonic codes for the instructions followed by operands and labels associated with them,

--remainder of page: explanatory remarks or notes when given.

Referring now to FIG. 5, the following is a description of the operational steps of the subroutine IDATA by which data is input from the analog to digital converter (ADC) to the microcomputer (MC).

First the MC waits for the end-of-conversion signal (EOC) from the ADC (step labelled "EOC HIGH?"). Once this signal is received, the working register banks are set to appropriate initial values ("INIT REGS"). Next, the OVFL signal from the ADC is checked ("OVFL HIGH?"). If this signal is high (logical "1"), then the ADC has reached the top of its operating range. In such circumstances the MC tests its own range flag ("RNG FLG = 1?") which, when set to "1", indicates that the analog circuit has already been offset, in which case the OVFL signal from the ADC represents a true instrument overflow. In this case, the MC enters a routine which outputs an overflow signal to the display ("OVFL"). If the range flag is not high, then the MC outputs a signal to the relay and offset circuitry to apply an offset to the analog circuitry representative of a 200° C. subtraction from the signal input to the ADC, and sets the aforementioned range flag to "1" (SHIFT RNG AND SET RNG FLAG). The MC then executes a sait loop to allow time for new data to be input to the now offset analog circuitry ("WAIT"). After this wait, the MC re-enters IDATA at the beginning.

Returning now to the step labelled "OVFL HIGH?", if this signal is not high, then the MC proceeds to input the temperature data from the ADC ("INPUT T"). Next the MC checks the aforementioned range flag in order to determine whether the equivalent of 200° C. must be added to the input data ("RNG FLG = 1?"). If the range flag is high, then the MC performs the addition ("T PLUS 200 DEG."). The result is checked as to whether it represents a temperature greater than or equal to 160° C. ("RSLT$\geq$160?"). If not, the MC withdraws the offset from the analog circuit by withdrawing its signal to the relay, and clears its range flag to indicate that the offset is no longer applied ("SHIFT RNG, CLR RNG FLG"). After executing a wait loop ("WAIT") in order to allow new "non-offset" data to be input to the ADC, the MC re-enters IDATA at the beginning. If the result of the aforementioned addition does represent a temperature equal to or greater than 160° C., the MC proceeds to generate a look-up table address as described later ("GENERATE TABLE ADDR").

Returning now to the step labelled "RNG FLG = 1?", if the range flag is not "1", the MC subtracts the equivalent of 30° C. from the input data ("T MINUS 30 DEG."). This represents an unused portion of the ADC's conversion range at the bottom of that range. Since the ADC is not adequately linear in this portion of its operation, its entire operation is essentially offset by this amount. The result of this subtraction is then checked as to whether the difference is positive ("RSLT PLUS?"). If not, the MC first checks, using flags stored in a control register, as to whether IDATA was called while the instrument was operating in the LATCH mode ("LTCH LFG = 1?"). If so, the MC simply returns from IDATA: otherwise, the MC moves to a routine to output an overflow indication to the display ("OVFL"), as the data input represents a temperature below the operating range of the instrument.

Returning now to the step labelled "RSLT PLUS?", if the difference is positive, the MC proceeds to generate, using the input data, a table look-up address used to access the table of corrections for the sensor over the instrument's span ("GENERATE TABLE ADDR"). In the next step ("GET CORR L"), the correction factor from the table for the temperature at the beginning of the ten-degree Celsius chord in which the input data falls is accessed and then saved in a working register for future calculations in the step labelled "SAVE CORR 1".

Next, the table address is incremented, the correction factor for the end of the chord is accessed, and the first correction factor is subtracted from the latter ("GET CORR 2, SUBTRACT CORR 1"). Using the result of this subtraction and the relative position of the input data in the chord, the final correction factor is computed and applied to the data ("COMPUTE AND APPLY OFFSET"). The result is then stored in the registers reserved for corrected temperature equivalents ("STO RSLT IN TEMP REGS").

In the step labelled "[MIN REGS] MINUS [TEMP REGS]", the corrected data is compared to the contents of the registers in which the minimum recorded temperature is stored. If the result of the subtraction is positive, the corrected data represents a new minimum temperature and the corrected data is stored in the MIN registers ("RSLT PLUS?" and "[TEMP REGS] TO MIN REGS"). If the result is not positive, the corrected data is compared to the contents of the registers in which the maximum recorded temperature is stored ("[MAX REGS] MINUS [TEMP REGS]"). If that result is positive ("RSLT PLUS?"), no new maximum has been recorded and the MC returns from IDATA. Otherwise, the contents of the corrected temperature registers are also stored in the MAX registers ("[TEMP REGS] TO MAX REGS"), and the MC returns from IDATA.

The flow diagram given in FIG. 6 details the steps of the subroutine LATCH executed by the MC during the

LATCH operating mode.

In the first step ("REQUEST CONFLICT?"), the MC checks the status of the mode and recall requests input from the rocker switches (see FIG. 8). Since these functions are exclusive, the presence of two or more requests simultaneously represents a conflict. In this case, the MC moves to a short routine ("EXIT") which resets a special control register used by the MC to flag the current operating mode or recall being executed ("RESET CONTROL REGISTER") and then the MC returns from LATCH.

If no conflict is present, the MC outputs to the display an indication of acceptance of the LATCH request ("OUTPUT "1111""), and then inputs the initial temperature at the sensor upon mode entry ("CALL IDATA"). This initial temperature is output to the display and stored in a working register for future use ("OUTPUT T1" and "SAVE T1").

Next the MC checks as to whether the LATCH request is still valid at the switches ("LATCH VALID?"). If not, it moves to the routine EXIT: otherwise, the MC begins a comparison sequence comprising the input of new data ("CALL IDATA"), the outputting of this data to the display ("OUTPUT NEW T"), the subtraction of the new temperature data from the initial temperature data ("T1 MINUS NEW T"), a check as to whether the result is positive ("RESULT PLUS?"), setting a special change of temperature direction flat to "1" if it is; and the clearing of that flag otherwise ("SET DIR FLAG" and "CLEAR DIR FLAG"). In this sequence the MC is testing for a temperature change. In the final step of the sequence ("RESULT$\geq$1?"), the MC tests the results of the comparison as to whether a temperature change greater than or equal to 1° C. has occurred. If not, the MC re-enters the aforementioned comparison sequence.

If the change is greater than or equal to 1° C., the new temperature data is stored in designated LATCH registers ("SAVE NEW T IN LTCH REGS"). Next, the MC begins a sequence which tests for the extreme of the detected change. First, new data is input ("CALL IDATA"), then the new data is compared to the contents of the LATCH registers ("COMPARE [LTCH] REGS NEW T"). The MC then checks the change direction flag ("DIR FLAG = 1?"). If the flag is "1", indicating a positive-going change, the result of the aforementioned comparison is checked as to whether the new data is greater than the contents of the LATCH registers ("T>[LTCH] REGS?"), if so, the new data is "written into" the LATCH registers ("TEMP TO LTCH REGS"), and the new data is output to the display; otherwise, the old contents of the LATCH registers is again output to the display ("OUTPUT [LTCH] REGS").

Returning now to the step labelled "DIR FLAG = 1?", if the flag is "0", indicating a negative-going original change, the results of the earlier comparison are checked as to whether the new data represents a temperature less than that represented by the data stored in the LATCH registers ("T>[LTCH] REGS?"). If so, the new data is stored in the LATCH registers ("TEMP TO LTCH REGS") and output to the display; otherwise, the old contents of the LATCH registers is again output to the display ("OUTPUT [LTCH] REGS").

At this point, the MC checks the status of the inputs from the switches as to whether the LATCH request is still valid. If not, the MC moves to the EXIT routine and returns from the subroutine; otherwise, the MC returns to the beginning of the sequence which tests for the extreme of the temperature change.

FIG. 7 is a flow diagram giving the details of the steps executed by the MC during the rate-of-change-per-minute operating mode (subroutine $\Delta T/M$, herein referred to as DELTA T).

Referring now to that figure, as when entering the earlier-described LATCH subroutine, the MC first checks for request conflicts input from the rocker switches ("RQST CONFLICT?"). If such conflict is present, the MC moves to the EXIT routine and returns from the DELTA T subroutine; otherwise, it outputs to the display an acknowledgement of the DELTA T request ("OUTPUT "2222"") and then inputs the initial temperature data upon mode entry ("CALL IDATA"). This initial data is then output to the display ("OUTPUT T").

In the next step, the MC clears a special shift flag which is used later in the subroutine to indicate any range shift which has occurred during a call of the subroutine IDATA ("CLR SHFT FLG"). The values in registers which will be used to determine whether or not a calculated rate of temperature change results in an overflow of the instrument's calculational limits are stored in the appropriate working registers in the ensuing step (SET ΔT LIMIT REGS"). Next, a counter register which will be utilized for timing purposes is set to equal 9 ("SET CNTRL CNTR = 9?).

The last temperature data input is now stored in the DELTA T registers ("MOVE LAST T TO ΔT REGS"), to be used in later calculations as to be described. At this point, the MC checks the inputs from the switches as to whether the DELTA T request is still valid ("ΔT/M RQST VALID?"). If not, it moves to the EXIT routine and returns from the DELTA T subroutine; otherwise, the following timing loop is initiated: subroutine IDATA is called ("CALL IDATA"), the control counter is decremented ("DEC CNTRL CNTR"), and then checked as to whether it is equal to zero ("CNTR = 0?"). If not, IDATA is called again, and so on. If so, the MC begins the sequence which calculates the rate of temperature change. In the foregoing timing loop, IDATA is used as a timing device since that routine essentially counts one (two under special circumstances discussed later) EOC. As these signals occur once every .6666 seconds, accurate timing of a six-second interval is achieved by "counting" nine IDATA calls. In addition, calling IDATA insures that the MIN and MAX registers will be updated as necessary (see earlier discussion of subroutine IDATA).

The sequence of steps by which the MC calculates the rate of temperature change per minute begins with the subtraction of the data stored in the DELTA T registers at the beginning of the counting loop from the last temperature data input at the end of that loop ("T MINUS [ΔT REGS]"), in order to determine the amount of change in temperature (if any) during the period of the timing loop. Next the result is checked against the DELTA T limit registers ("RSLT MINUS [ΔT LIMIT REGS]") and the result of this comparison is then checked as to sign ("RSLT PLUS?"). If the result is positive, then the calculational limits of the instrument have been surpassed with respect to calculation of the rate of change per minute (change greater than $\pm 499°$ C. per minute). In this case, the MC moves to a routine to output an overflow indication to the display; otherwise, it continues with the calculations.

Next the shift flag is checked ("SHIFT FLAG = 1?"). If it is set to "1", then a range shift has occurred during one of the calls of IDATA in the timing loop described earlier. In this case, the timed period is equal to 6.6666 seconds rather than the desired six seconds. The MC adjusts the results of its earlier calculations by subtracting ten percent of the amount of change from those results ("ADJUST RSLT"), thereby achieving a result indicative of the amount of that change for the intended six second interval.

If the shift flag is not "1", then no adjustment of the earlier result is necessary.

In the ensuing step, the MC multiplies the amount of temperature change obtained earlier by ten ("COMPUTE ΔT/M") thereby arriving at the desired result representing the rate of change per minute, based upon the relative change for six seconds.

As all internal calculations by the MC are performed using the Celsius scale based inputs, the status of the scale requests are then checked for the presence of a Fahrenheit scale request ("F RQST?"). If such a request is present, the MC multiplies the rate of change data by 1.8 ("CONVERT TO DEG F"); otherwise, it does nothing (note: the presence of a Kelvin scale request does not require conversion as 1° K. = 1° C.).

At this point, the calculated data is output to the display ("OUTPUT ΔT/M"), after which the MC re-enters the DELTA T subroutine near the beginning of the routine (at "CLR SHIFT FLG") in preparation for the next set of calculations.

At the end of the listing is given a symbol table which correlates labels and their hexadecimal values. The information in columns two, three, four and six is best understood by reference to the aforementioned publications associated with the Intel 8048 microcomputer.

```
                           *****POWER-UP AND CONTROL*****
                           *
                           *
000  23 7F                          MOV A, #$7F
002  39                             OUTL P1, A
003  27                             CLR A
004  B8 28                          MOV R0, #$28
006  B9 2C                          MOV R1, #$ 2C
008  A0                             MOV @R0, A
009  A1                             MOV @R1, A
00A  18                             INC R0
00B  19                             INC R1
00C  A1                             MOV @R1, A
00D  B0 61                          MOV @R0, #$61
00F  AF                             MOV R7, A
010  AD                             MOV R5, A
011  14 84                          CALL TRVLD      BLANK DISPLAY
013  34 05                          CALL IDATA      INPUT INIT TEMP
015  0A          CKMOD              IN A, P2        INPUT REQUESTS
016  37                             CPL A
017  53 0F                          ANL A, #$0F
019  2F                             XCH A, R7
01A  53 20                          ANL A, #$20
01C  DF                             XRL A, R7
01D  AF                             MOV R7, A       SET CONTR REG
01E  12 2C                          JB0 GOLTCH      LATCH REQUEST ?
020  32 30                          JB1 GODT/M      DELTA T REQUEST?
022  52 34                          JB2 MINRCL      MIN REQUEST ?
024  72 38                          JB3 MAXRCL      MAX REQUEST ?
026  34 05                          CALL IDATA      INPUT TEMP
028  74 3D                          CALL OUT        OUTPUT TEMP
02A  04 15                          JMP CKMOD       RE-ENTER LOOP
02C  54 16       GOLTCH             CALL LATCH
02E  04 15                          JMP CKMOD
030  54 9C       GODT/M             CALL DT/M
032  04 15                          JMP CKMOD
034  BD 33       MINRCL             MOV R5, #$33    SET MODE REG
036  04 3B                          JMP INDIC
038  95          MAXRCL             CPL F0          SET FLAG = MAX
039  BD 44                          MOV R5, #$44    SET MODE REG
03B  53 03       INDIC              ANL A, #$03     REQUEST CONFLICT ?
03D  C6 41                          JZ TRVOK
03F  04 66                          JMP CMBK
```

```
00143  041  14 84  TRVOK    CALL TRVLD     DISPLAY MODE
00144  043  A5     START    CLR F1         SET SIGN FLAG
00145  044  B6 4A           JF0 PREX
00146  046  B8 29           MOV R0, #$29   SET PTR = MIN
00147  048  04 4D           JMP INFO
00148  04A  B5     PREX     CPL F1         SET SIGN FLAG
00149  04B  B8 2D           MOV R0, #$2D   SET PTR = MAX
00150  04D  B9 26  INFO     MOV R1, #$26
00151  04F  34 F4           CALL MOV01     MOVE DATA
00152  051  74 3D           CALL OUT       OUTPUT DATA
00153  053  97               CLR C
00154  054  B6 58           JF0 FLGP
00155  056  04 59           JMP INP2
00156  058  A7     FLGP     CPL C
00157  059  0A     INP2     IN A, P2       INPUT REQUESTS
00158  05A  F6 62           JC VALX
00159  05C  52 66           JB2 CMBK       JMP MIN NOT VALID
00160  05E  34 05  RPT      CALL IDATA     INPUT TEMP
00161  060  04 43           JMP START      CONTINUE MIN/MAX OUT
00162  062  72 66  VALX     JB3 CMBK       JMP MAX NOT VALID
00163  064  04 5E           JMP RPT
00164  066  54 67  CMBK     CALL EXIT      BEGIN RETURN ROUTINE
00165  068  85               CLR F0         RESET FLAG
00166  069  04 15           JMP CKMOD      RE-ENTER CONTROL LOOP
00167                  *
00168                  *
00169                  *****SUBROUTINES CPLR0, TRVLD, 3EOC,*****
00170                  *     EOCSK, EOC , SUB2B BEGIN HERE
00171                  *
00172                  *
00173  06B  97     CPLR0    CLR C
00174  06C  F0               MOV A, @R0
00175  06D  C6 7B           JZ LKHI        JMP ON ZERO BYTE
00176  06F  14 F7           CALL TCPLMT    COMPLEMENT BYTE
00177  071  A0               MOV @R0, A     STO RSLT
00178  072  18               INC R0
00179  073  F0               MOV A, @R0     GET NEXT BYTE
00180  074  03 66           ADD A, #$66
00181  076  37               CPL A
00182  077  A0     STCPL    MOV @R0, A     STO RSLT
00183  078  97               CLR C
00184  079  C8     DRET     DEC R0         RESET R0
00185  07A  83               RET
```

```
00186  07B  18      LKHI     INC R0
00187  07C  F0               MOV A, @R0
00188  07D  A7               CPL C
00189  07E  C6 79            JZ DRET
00190  080  14 F7            CALL TCPLMT      COMPLEMENT BYTE
00191  082  04 77            JMP STCPL
00192  084  B8 3E   TRVLD    MOV R0, #$3E
00193  086  FD               MOV A, R5        GET MODE
00194  087  A0               MOV @R0, A
00195  088  18               INC R0
00196  089  A0               MOV @R0, A
00197  08A  A5               CLR F1
00198  08B  B5               CPL F1           SET SIGN FLAG
00199  08C  9A DF            ANL P2, #$DF     DEC PT OFF
00200  08E  74 5C            CALL OUTC        OUTPUT MODE
00201  090  BA 01   3EOC     MOV R2, #$01     SET CTR
00202  092  14 96            CALL EOC
00203  094  BA 02   EOCSK    MOV R2, #$02
00204  096  56 9A   EOC      JT1 DECR2        JMP ON EOC HI
00205  098  04 96            JMP EOC
00206  09A  46 9E   DECR2    JNT1 DECR        JMP ON EOC LO
00207  09C  04 9A            JMP DECR2
00208  09E  EA 96   DECR     DJNZ R2, EOC     JMP R2 ≠ ZERO
00209  0A0  93               RETR
00210  0A1  14 6B   SUB2B    CALL CPLR0
00211  0A3  F6 AC            JC INCRT
00212  0A5  74 B3            CALL ADD2B       SUBTRACT BYTES
00213  0A7  F6 AB            JC SRET          JMP RSLT PLUS
00214  0A9  14 6B            CALL CPLR0
00215  0AB  83      SRET     RET
00216  0AC  14 FE   INCRT    CALL MOV10       MOVE RSLTS
00217  0AE  C8               DEC R0
00218  0AF  83               RET
00219               *
00220               *
00221               *****ROUTINE TO UPDATE MIN AND*****
00222               *     MAX REGISTERS BEGINS HERE
00223               *
00224               *
00225  0B0  C5      UPDMM    SEL RB0          REGISTER BANK
00226  0B1  FF               MOV A, R7
00227  0B2  53 FE            ANL A, #$FE      SET CONTR REG
00228  0B4  AF               MOV R7, A
```

```
0B5   14 EF   LTCHMM   CALL SETUP      LATCH UPDATE START
0B7   85               CLR F0
0B8   FF               MOV A, R7       GET MODE
0B9   12 BF            JB0 LTCHST      JMP ON LTCH RQST
0BB   14 C5            CALL CPMIN
0BD   04 CD            JMP CPMAX
0BF   B9 2E   LTCHST   MOV R1, #$2E
0C1   F2 D1            JB7 LTCHPL      JMP TEMP UP
0C3   04 D2            JMP CMPRV
0C5   B9 29   CPMIN    MOV R1, #$29    MIN UPDATE START
0C7   F1               MOV A, @R1      GET MIN
0C8   F2 D8            JB7 OLD         JMP ON MSB = 1
0CA   C9               DEC R1
0CB   04 D2            JMP CMPRV
0CD   14 EF   CPMAX    CALL SETUP      MAX UPDATE START
0CF   B9 2C            MOV R1, #$2C
0D1   95      LTCHPL   CPL F0
0D2   14 A1   CMPRV    CALL SUB2B      COMPARE VALUES
0D4   B6 D9            JF0 MORE
0D6   F6 DC            JC NEW          JMP ON NEW MIN
0D8   93      OLD      RETR
0D9   E6 DC   MORE     JNC NEW         JMP ON NEW MAX
0DB   93               RETR
0DC   FF      NEW      MOV A, R7       GET MODE
0DD   12 EB            JB0 STLTCH      JMP ON LTCH RQST
0DF   B6 E7            JF0 STMAX       JMP ON MAX FLAG
0E1   B9 29            MOV R1, #$29    READY STO MIN
0E3   B8 26   STNEW    MOV R0, #$26
0E5   24 F4            JMP MOV01       STO NEW VALUE
0E7   B9 2D   STMAX    MOV R1, #$2D    READY STO MAX
0E9   04 E3            JMP STNEW
0EB   B9 2F   STLTCH   MOV R1, #$2F    READY STO LATCH
0ED   04 E3            JMP STNEW
              *
              *
              *****SUBROUTINES SETUP, TCPLMT,*****
              *     MOV10 BEGIN HERE
              *
              *
0EF   B9 25   SETUP    MOV R1, #$25
0F1   B8 2A            MOV R0, #$2A
0F3   14 FE            CALL MOV10      RESET DATA
0F5   C8               DEC R0
```

```
0F6  93               RETR
0F7  03 66  TCPLMT    ADD A, #$66
0F9  37               CPL A
0FA  03 01            ADD A, #$01
0FC  57               DA A
0FD  83               RET
0FE  F1     MOV10     MOV A, @R1
0FF  A0               MOV @R0, A
100  18               INC R0
101  19               INC R1
102  F1               MOV A, @R1
103  A0               MOV @R0, A
104  83               RET
            *
            *
            *****ROUTINE TO INPUT AND LINEARIZE*****
            *    TEMP BEGINS HERE
            *
            *
105  D5     IDATA     SEL RB1          REGISTER BANK
106  56 0A  WLOOP     JT1 ENTER        JMP ON EOC HI
108  24 06            JMP WLOOP
10A  B9 20  ENTER     MOV R1, #$20     BEGIN INIT
10C  BA 04            MOV R2, #$04
10E  BB 02            MOV R3, #$02
110  BC 0F            MOV R4, #$0F
112  BD 3F            MOV R5, #$3F
114  BE 02            MOV R6, #$02
116  C5               SEL RB0          REGISTER BANK
117  FF               MOV A, R7        GET CONTR FLAGS
118  D5               SEL RB1          REGISTER BANK
119  86 29  INPT      JNI OKRGE        JMP ON NO OVF
11B  B2 25            JB5 GOOVFL       JMP ON RGE FLG HI
11D  74 F5  SHFTU     CALL SHIFT       SHIFT RANGE
11F  9A 7F            ORL P2, #$7F
121  14 94            CALL EOCSK       WAIT FOR VALID EOC
123  24 05            JMP IDATA        INPUT AGAIN
125  A5     GOOVFL    CLR F1           PREPARE FOR OVFL
126  B5               CPL F1
127  24 4B            JMP PMOVF
129  FD     OKRGE     MOV A, R5
12A  03 10            ADD A, #$10
12C  AD               MOV R5, A
```

```
00315  12D  39              OUTL P1, A        REQUEST DIGIT
00316  12E  00              NOP               WAIT
00317  12F  00              NOP
00318  130  09              IN A, P1          INPUT DIGIT
00319  131  5C              ANL A, R4
00320  132  EB 38           DJNZ, R3 PACK JMP R3 ≠ ZERO
00321  134  BB 02           MOV R3, #$02      RESET R3
00322  136  47              SWAP A
00323  137  31              XCHD A, @R1
00324  138  A1     PACK     MOV @R1, A        STO DIGIT
00325  139  EE 3C           DJNZ R6 CKDEC JMP R6 ≠ ZERO
00326  13B  19              INC R1
00327  13C  EA 29  CKDEC    DJNZ, R2 OKRGE JMP R2 ≠ ZERO
00328  13E  C5              SEL RB0           REGISTER BANK
00329  13F  FF              MOV A, R7         GET CONTR FLAGS
00330  140  D5              SEL RB1           REGISTER BANK
00331  141  B2 51           JB5 TSTRGE        JMP ON RGE FLG HI
00332  143  F1     MIN30    MOV A, @R1        BEGIN SUBTR 30 DEG
00333  144  03 97           ADD A, #$97
00334  146  57              DA A
00335  147  A1              MOV @R1, A        STO RSLT
00336  148  F6 63           JC LINR           JMP ON RSLT PLUS
00337  14A  A5              CLR F1
00338  14B  C5     PMOVF    SEL RB0           REGISTER BANK
00339  14C  FF              MOV A, R7         GET CONTR FLAGS
00340  14D  92 C9           JB4 IRETR         JMP ON LATCH OVF
00341  14F  44 6C           JMP OVFL
00342  151  F1     TSTRGE   MOV A, @R1
00343  152  03 20           ADDA, #$20        ADD 200 DEG
00344  154  A1              MOV @R1, A        STO RSLT
00345  155  03 CA           ADD A, #$CA       ABOVE 160 DEG ?
00346  157  F6 63           JC LINR           JMP ON RSLT PLUS
00347  159  74 F5  SHFTD    CALL SHIFT        SHIFT RANGE
00348  15B  8A 80           ORL P2, #$80
00349  15D  BA 01           MOV R2, #$01      PREPARE FOR EOC
00350  15F  14 96           CALL EOC          WAIT FOR VALID EOC
00351  161  24 05           JMP IDATA         INPUT AGAIN
00352  163  B8 23  LINR     MOV R0, #$23
00353  165  27              CLR A
00354  166  AB              MOV R3, A
00355  167  85              CLR F0
00356  168  F1              MOV A, @R1        GET HI BYTE
00357  169  AF              MOV R7, A         STO BYTE IN REG
```

```
16A  19                 INC R1
16B  C6 A7              JZ ADR00          JMP ON =ZERO
16D  03 AF              ADD A, #$AF       TST FOR #$51
16F  C6 B1              JZ ADR51          JMP ON = ZERO
171  FF                 MOV A, R7         GET BYTE AGAIN
172  03 F7              ADD A, #$F7       TST FOR #$09
174  C6 BC              JZ ADR09          JMP ON = ZERO
176  FF                 MOV A, R7         GET BYTE AGAIN
177  AE                 MOV R6, A         SETUP FOR TADDR
178  53 F0              ANL A, #$F0
17A  C6 85              JZ TADDR          JMP ON = ZERO
17C  47                 SWAP A
17D  AA                 MOV R2, A
17E  27                 CLR A
17F  03 06     ADD6     ADD A, #$06
181  EA 7F              DJNZ, R2 ADD6     JMP R2 ≠ ZERO
183  37                 CPL A
184  17                 INC A
185  6E        TADDR    ADD A, R6
186  AE                 MOV R6, A
187  E3                 MOVP3 A, @A       GET FIRST OFFSET
188  53 7F              ANL A, #$7F       MASK SIGN BIT
18A  A1                 MOV @R1, A        STO RSLT
18B  1E                 INC R6
18C  FE                 MOV A, R6
18D  E3                 MOVP3 A, @A       GET SECOND OFFSET
18E  F2 92              JB7 UNMSK         JMP ON SIGN BIT HI
190  24 95              JMP STO2
192  53 7F     UNMSK    ANL A, #$7F       MASK SIGN BIT
194  95                 CPL F0            SET DIR FLAG
195  A0        STO2     MOV @R0, A        STO RSLT
196  F1                 MOV A, @R1        GET FIRST OFFSET
197  C6 C6              JZ 2DIFF          JMP ON = ZERO
199  14 F7              CALL TCPLMT       COMPLEMENT OFFSET
19B  60                 ADD A, @R0        SUBTRACT OFFSET
19C  57                 DA A
19D  E6 A2              JNC DOWN          JMP ON RSLT MINUS
19F  AD        STODIF   MOV R5, A         STO RSLT
1A0  24 CA              JMP INTRP
1A2  14 F7     DOWN     CALL TCPLMT       COMPLEMENT RSLT
1A4  1B                 INC R3            SET SIGN FLG
1A5  24 9F              JMP STODIF
1A7  B1 87     ADR00    MOV @R1, #$87
1A9  19                 INC R1
```

```
00401  1AA  B1 76            MOV @R1, #$76
00402  1AC  1B               INC R3
00403  1AD  BD 11            MOV R5, #$11
00404  1AF  24 CA            JMP INTRP
00405  1B1  B1 07   ADR51    MOV @R1, #$07
00406  1B3  19               INC R1
00407  1B4  B1 00            MOV @R1, #$00
00408  1B6  1B               INC R3
00409  1B7  95               CPL F0
00410  1B8  BD 07            MOV R5, #$07
00411  1BA  24 CA            JMP INTRP
00412  1BC  B1 00   ADR09    MOV @R1, #$00
00413  1BE  19               INC R1
00414  1BF  B1 09            MOV @R1, #$09
00415  1C1  95               CPL F0
00416  1C2  BD 09            MOV R5, #$09
00417  1C4  24 CA            JMP INTRP
00418  1C6  F0      2DIFF    MOV A, @R0     GET OFFSET
00419  1C7  24 9F            JMP STODIF
00420  1C9  93      IRETR    RETR
00421  1CA  B8 20   INTRP    MOV R0, #$20
00422  1CC  BE 00            MOV R6, #$00
00423  1CE  F0               MOV A, @R0     GET LO BYTE
00424  1CF  74 BF            CALL DIVL      DIVIDE BY TEN
00425  1D1  C6 DD            JZ READY       JMP ON RSLT ZERO
00426  1D3  92 EF            JB4 USE2       JMP ON RSLT #$10
00427  1D5  AA               MOV R2, A
00428  1D6  27               CLR A
00429  1D7  6D      TIMES    ADD A, R5
00430  1D8  57               DA A
00431  1D9  EA D7            DJNZ, R2 TIMES JMP ON R2 ≠ ZERO
00432  1DB  74 BF            CALL DIVL      DIVIDE BY TEN
00433  1DD  B9 22   READY    MOV R1, #$22
00434  1DF  EB E3            DJNZ, R3 ADDDF JMP ON R3 ≠ ZERO
00435  1E1  14 F7            CALL TCPLMT    COMPLEMENT RSLT
00436  1E3  61      ADDDF    ADD A, @R1
00437  1E4  57               DA A
00438  1E5  95      OFFBR    CPL F0         CPL DIR FLG
00439  1E6  B6 FB            JF0 ADDOF
00440  1E8  C6 FB            JZ ADDOF
00441  1EA  14 F7            CALL TCPLMT    COMPLEMENT OFFSET
00442  1EC  1E               INC R6         SET RSLT FLAG
00443  1ED  24 FB            JMP ADDOF
```

```
1EF  B9 23  USE2     MOV R1, #$23
1F1  F1              MOV A, @R1
1F2  24 E5           JMP OFFBR
                *
                *
                *****SUBROUTINE MOV01 BEGINS*****
                *    HERE
                *
                *
1F4  F0     MOV01    MOV A, @R0
1F5  A1              MOV @R1, A
1F6  C8              DEC R0
1F7  C9              DEC R1
1F8  F0              MOV A, @R0
1F9  A1              MOV @R1, A
1FA  93              RETR
                *
                *
                *****INTERPOLATION ROUTINE*****
                *    CONTINUES HERE
                *
                *
1FB  60     ADDOF    ADD A, @R0
1FC  57              DA A
1FD  18              INC R0
1FE  B9 25           MOV R1, #$25
200  A1              MOV @R1, A
201  19              INC R1
202  F0              MOV A, @R0
203  F6 0D           JC CARR1
205  EE 0A           DJNZ, R6 STOH JMP ON R6 ≠ ZERO
207  03 99           ADD A, #$99
209  57              DA A
20A  A1     STOH     MOV @R1, A     STO RSLT
20B  04 B0           JMP UPDMM      EXIT INPUT ROUTINE
20D  EE 11  CARR1    DJNZ, R6 INCTH JMP ON R6 ≠ ZERO
20F  44 0A           JMP STOH
211  03 01  INCTH    ADD A, #$01    INC HI BYTE
213  57              DA A
214  44 0A           JMP STOH
                *
                *
                *****LATCH ROUTINE STARTS HERE*****
```

```
00487                     *
00488                     *
00489  216  54 60  LATCH        CALL MMCK       REQUEST CONFLICT ?
00490  218  BD 11               MOV R5, #$11    SET MODE REG
00491  21A  14 84               CALL TRVLD      DISPLAY MODE
00492  21C  34 05               CALL IDATA      INPUT TEMP
00493  21E  74 3D               CALL OUT        OUTPUT TEMP
00494  220  B8 26               MOV R0, #$26
00495  222  B9 2F               MOV R1, #$2F
00496  224  34 F4               CALL MOV01      TEMP TO LTCH REGS
00497  226  0A     SIGCK        IN A, P2        INPUT REQUESTS
00498  227  12 67               JB0 EXIT        JMP LTCH NOT VALID
00499  229  34 05               CALL IDATA      INPUT NEXT TEMP
00500  22B  74 3D               CALL OUT        OUTPUT TEMP
00501  22D  B9 25               MOV R1, #$25
00502  22F  B8 30               MOV R0, #$30
00503  231  14 FE               CALL MOV10      STO NEW TEMP
00504  233  C8                  DEC R0
00505  234  B9 2E               MOV R1, #$2E
00506  236  14 A1               CALL SUB2B      START SIGNIF TEST
00507  238  FF                  MOV A, R7       GET CONTR REG
00508  239  E6 3F               JNC UPWRD       JMP RSLT MINUS
00509  23B  53 7F               ANL A, #$7F     SET LTCH DIR FLG
00510  23D  44 41               JMP SIG
00511  23F  43 80  UPWRD        ORL A, #$80     SET LTCH DIR FLG
00512  241  17     SIG          INC A           RESET LTCH FLG
00513  242  AF                  MOV R7, A
00514  243  F0                  MOV A, @R0
00515  244  03 EF               ADD A, #$EF     GREATER THAN/=#$10 ?
00516  246  F6 4C               JC SIGYS        JMP IF YES
00517  248  18                  INC R0
00518  249  F0                  MOV A, @R0      GET HI BYTE
00519  24A  C6 26               JZ SIGCK        JMP ON ZERO BYTE
00520  24C  14 B5  SIGYS        CALL LTCHMM     UPDATE LTCH REGS
00521  24E  34 05  ROLL         CALL IDATA      INPUT NEW TEMP
00522  250  1F                  INC R7          RESET LTCH FLG
00523  251  14 B5               CALL LTCHMM     UPDATE LTCH REGS
00524  253  B8 2F               MOV R0, #$2F
00525  255  B9 26               MOV R1, #$26
00526  257  34 F4               CALL MOV01
00527  259  74 3D               CALL OUT        OUTPUT LATCH REGS
00528  25B  0A                  IN A, P2        INPUT REQUESTS
00529  25C  12 67               JB0 EXIT        JMP LTCH NOT VALID
```

```
00530  25E  44 4E           JMP ROLL        REPEAT
00531                *
00532                *
00533                *****SUBROUTINE MMCK AND ROUTINES
00534                *     DECRT AND EXIT BEGIN HERE
00535                *
00536                *
00537  260  53 0C    MMCK   ANL A, #$0C     MASK CONTR FLAGS
00538  262  C6 6B           JZ RQOK         JMP NO CONFLICT
00539  264  C7       DECRT  MOV A, PSW
00540  265  07              DEC A
00541  266  D7              MOV PSW, A      DEC STK PTR
00542  267  FF       EXIT   MOV A, R7       GET CONTR REG
00543  268  53 20           ANL A, #$20     RESET CONTR REG
00544  26A  AF              MOV R7, A
00545  26B  93       RQOK   RETR
00546                *
00547                *
00548                *****OVERFLOW ROUTINE BEGINS HERE*****
00549                *
00550                *
00551  26C  C5       OVFL   SEL RB0         REGISTER BANK
00552  26D  23 99           MOV A, #$99
00553  26F  76 75           JF1 HIGH        JMP ON PLUS FLG
00554  271  B8 29           MOV R0, #$29
00555  273  44 77           JMP DBLST
00556  275  B8 2D    HIGH   MOV R0, #$2D
00557  277  A0       DBLST  MOV @R0, A
00558  278  C8              DEC R0
00559  279  A0              MOV @R0, A
00560  27A  FF              MOV A, R7       GET CONTR FLAGS
00561  27B  52 8D           JB2 ORET        JMP ON MIN FLG
00562  27D  72 8D           JB3 ORET        JMP ON MAX FLG
00563  27F  B8 26    CPOVF  MOV R0, #$26    BEGIN OUTPUT NINES
00564  281  23 99           MOV A, #$99
00565  283  A0              MOV @R0, A
00566  284  C8              DEC R0
00567  285  A0              MOV @R0, A
00568  286  74 3D           CALL OUT        OUTPUT NINES
00569  288  FF              MOV A, R7       GET CONTR FLGS
00570  289  12 8E           JB0 LLOOP       JMP ON LTCH FLG
00571  28B  32 98           JB1 WTRET       JMP ON DELTA T FLG
00572  28D  93       ORET   RETR
```

```
28E  43 10  LLOOP   ORL A, #$10       SET OVF FLG
290  AF             MOV R7, A
291  0A             IN A, P2          INPUT REQUESTS
292  12 64          JB0 DECRT         JMP ON LTCH NOT VALID
294  34 05          CALL IDATA        INPUT TEMP
296  44 7F          JMP CPOVF         OUTPUT NINES AGAIN
298  14 90  WTRET   CALL 3EOC         SKIP THREE EOCS
29A  44 64          JMP DECRT
            *
            *
            *****DELTA T / M ROUTINE BEGINS HERE*****
            *
            *
29C  54 60  DT/M    CALL MMCK         REQUEST CONFLICT ?
29E  BD 22          MOV R5, #$22      SET MODE REG
2A0  14 84          CALL TRVLD        DISPLAY MODE
2A2  34 05          CALL IDATA        INPUT INIT TEMP
2A4  74 3D          CALL OUT          OUTPUT INIT TEMP
2A6  FF     REGO    MOV A, R7         GET CONTR FLAGS
2A7  53 BF          ANL A, #$BF       CLR SHFT FLG
2A9  AF             MOV R7, A
2AA  B8 38          MOV R0, #$38
2AC  B0 00          MOV @R0, #$00     LOAD OVF VAL LO
2AE  18             INC R0
2AF  B0 05          MOV @R0, #$05     LOAD OVF VAL HI
2B1  BA 09          MOV R2, #$09      LOAD TIMER REG
2B3  B8 32          MOV R0, #$32
2B5  B9 25          MOV R1, #$25
2B7  14 FE          CALL MOV10        SAVE INIT TEMP
2B9  0A     COUNT   IN A, P2          INPUT REQUESTS
2BA  32 67          JB1 EXIT          JMP ON DT/M NOT VALID
2BC  34 05          CALL IDATA        INPUT TEMP
2BE  EA B9          DJNZ, R2 COUNT JMP ON R2 ≠ ZERO
2C0  B8 32          MOV R0, #$32
2C2  B9 25          MOV R1, #$25
2C4  14 A1          CALL SUB2B        COMPUTE DELTA T
2C6  A5             CLR F1
2C7  E6 CA          JNC FLGOK         JMP ON MINUS RSLT
2C9  B5             CPL F1
2CA  B8 38  FLGOK   MOV R0, #$38
2CC  B9 32          MOV R1, #$32
2CE  14 A1          CALL SUB2B        CK FOR OVFL
2D0  E6 D4          JNC CKR7          JMP ON MINUS RSLT
```

```
2D2  54 7F           CALL CPOVF
2D4  FF     CKR7     MOV A, R7       GET CONTR FLAGS
2D5  D2 F1           JB6 ADJST       JMP ON SHFT FLG HI
2D7  F1     RIGHT    MOV A, @R1      START COMP DT/M
2D8  47              SWAP A
2D9  A1              MOV @R1, A
2DA  C9              DEC R1
2DB  F1              MOV A, @R1
2DC  47              SWAP A
2DD  A1              MOV @R1, A
2DE  27              CLR A
2DF  31              XCHD A, @R1
2E0  19              INC R1
2E1  31              XCHD A, @R1
2E2  C9              DEC R1
2E3  36 E7           JT0 DTOUT       JMP ON NO F RQST
2E5  74 CF           CALL 1*8R1      CONVERT TO DEGS F
2E7  B8 3E  DTOUT    MOV R0, #$3E
2E9  14 FE           CALL MOV10
2EB  8A 20           ORL P2, #$20    DECIMAL POINT ON
2ED  74 5C           CALL OUTC       OUTPUT DT/M
2EF  44 A6           JMP REGO        RE-ENTER ROUTINE
2F1  B8 32  ADJST    MOV R0, #$32
2F3  74 E3           CALL DIV10      COMPUTE ERROR
2F5  B8 34           MOV R0, #$34
2F7  B9 32           MOV R1, #$32
2F9  14 A1           CALL SUB2B      SUBTRACT ERROR
2FB  18              INC R0
2FC  34 F4           CALL MOV01      RSLT TO DT/M REGS
2FE  19              INC R1
2FF  44 D7           JMP RIGHT
                     *
                     *
                     *****TABLE OF CORRECTIONS*****
                     *    TYPICAL VALUES
                     *    PROBE DEPENDENT
                     *
                     *
301  76     TABLE                    -190 C
302  65
303  54
304  47
305  36                              -150 C
```

00659	306	25	
00660	307	15	
00661	308	07	
00662	309	00	
00663	30A	89	-100 C
00664	30B	97	
00665	30C	A3	
00666	30D	A9	
00667	30E	B4	
00668	30F	B8	-50 C
00669	310	C4	
00670	311	C8	
00671	312	D4	
00672	313	D7	
00673	314	E1	0 C
00674	315	E4	
00675	316	E7	
00676	317	F0	
00677	318	F2	
00678	319	F3	50 C
00679	31A	F4	
00680	31B	F5	
00681	31C	F6	
00682	31D	F7	
00683	31E	F7	100 C
00684	31F	F7	
00685	320	F6	
00686	321	F5	
00687	322	F3	
00688	323	F1	150 C
00689	324	F0	
00690	325	E8	
00691	326	E7	
00692	327	E4	
00693	328	E2	200 C
00694	329	D9	
00695	32A	D5	
00696	32B	D2	
00697	32C	C8	
00698	32D	C3	250 C
00699	32E	B8	
00700	32F	B4	
00701	330	A7	

```
00702  331  A1
00703  332  95                                         300 C
00704  333  87
00705  334  00
00706  335  07
00707  336  14
00708  337  23                                         350 C
00709  338  32
00710  339  42
00711  33A  52
00712  33B  63
00713  33C  72                                         400 C
00714                 *
00715                 *
00716                 *****OUTPUT ROUTINES OUT, OUTC,*****
00717                 *    OUTF, OUTK BEGIN HERE
00718                 *
00719                 *
00720  33D  D5        OUT      SEL RB1           REGISTER BANK
00721  33E  B8 3E              MOV R0, #$3E
00722  340  B9 25              MOV R1, #$25
00723  342  14 FE              CALL MOV10        TEMP TO OUTPUT REGS
00724  344  9A DF              ANL P2, #$DF      DECIMAL POINT OFF
00725  346  F2 5C              JB7 OUTC          JMP ON MSD NINE
00726  348  8A 20              ORL P2, #$20      DECIMAL POINT ON
00727  34A  A5                 CLR F1            CLR SIGN FLG
00728  34B  03 80              ADD A, #$80       MINUS 200 DEG
00729  34D  57                 DA A
00730  34E  A0                 MOV @R0, A
00731  34F  C8                 DEC R0
00732  350  B5                 CPL F1            SET SIGN FLG PLUS
00733  351  F6 56              JC SCALE          JMP ON RSLT PLUS
00734  353  14 6B              CALL CPLR0        COMPLEMENT RSLT
00735  355  B5                 CPL F1            SET SIGN FLG MINUS
00736  356  0A        SCALE    IN A, P2          INPUT REQUESTS
00737  357  37                 CPL A
00738  358  92 9F              JB4 OUTK          DEG K RQST ?
00739  35A  26 84              JNT0 OUTF         DEG F RQST ?
00740  35C  D5        OUTC     SEL RB1           REGISTER BANK
00741  35D  B8 3E              MOV R0, #$3E
00742  35F  BB 08              MOV R3, #$08
00743  361  BC 02              MOV R4, #$02
00744  363  BA 02     CNT2     MOV R2, #$02
```

```
00745  365  27     DIG     CLR A
00746  366  4B            ORL A, R3
00747  367  E7            RL A
00748  368  AB            MOV R3, A
00749  369  30            XCHD A, @R0
00750  36A  02            OUTL BUS, A
00751  36B  BD 20         MOV R5, #$20     LOAD WAIT TIMER
00752  36D  00     DELAY  NOP
00753  36E  ED 6D         DJNZ R5, DELAY  JMP ON R5 ≠ ZERO
00754  370  98 0F         ANL BUS, #$0F   DIG SEL LO
00755  372  20            XCHA, @R0
00756  373  47            SWAP A
00757  374  20            XCHA, @R0
00758  375  EA 65         DJNZ R2, DIG     JMP ON R2 ≠ ZERO
00759  377  EC 81         DJNZ R4, GROUP  JMP ON R4 ≠ ZERO
00760  379  76 7E         JF1 PSIGN        JMP ON SIGN FLG HI
00761  37B  8A 40         ORL P2, #$40     MINUS SIGN ON
00762  37D  93            RETR
00763  37E  9A BF  PSIGN  ANL P2, #$BF     MINUS SIGN OFF
00764  380  93            RETR
00765  381  18     GROUP  INC R0
00766  382  64 63         JMP CNT2
00767  384  B9 3E  OUTF   MOV R1, #$3E
00768  386  74 CF         CALL 1*8R1       COMPUTE F DEGS
00769  388  B8 37         MOV R0, #$37
00770  38A  B0 03         MOV @R0, #$03
00771  38C  C8            DEC R0
00772  38D  B0 20         MOV @R0, #$20
00773  38F  76 98         JF1 ADDF         JMP ON SIGN FLG HI
00774  391  14 A1         CALL SUB2B       SUBTR F OFFSET
00775  393  F6 9A         JC END           JMP ON RSLT PLUS
00776  395  B5            CPL F1           SET SIGN FLG PLUS
00777  396  64 9A         JMP END
00778  398  74 B3  ADDF   CALL ADD2B       ADD F OFFSET
00779  39A  18     END    INC R0
00780  39B  34 F4         CALL MOV01
00781  39D  64 5C         JMP OUTC
00782  39F  B8 3E  OUTK   MOV R0, #$3E
00783  3A1  B9 3D         MOV R1, #$3D
00784  3A3  B1 27         MOV @R1, #$27
00785  3A5  C9            DEC R1
00786  3A6  B1 32         MOV @R1, #$32
00787  3A8  76 AF         JF1 ADDK         JMP ON SIGN FLG HI
```

```
00788  3AA  14 A1               CALL SUB2B       SUBTR DEGS C
00789  3AC  B5                  CPL F1           SET SIGN FLG PLUS
00790  3AD  64 5C               JMP OUTC
00791  3AF  74 B3   ADDK        CALL ADD2B       ADD K OFFSET
00792  3B1  64 5C               JMP OUTC
00793               *
00794               *
00795               *****SUBROUTINES ADD2B, DIVL, 1*8R1*****
00796               *    DIV10, SHIFT BEGIN HERE
00797               *
00798               *
00799  3B3  F1      ADD2B       MOV A, @R1
00800  3B4  60                  ADD A, @R0       ADD LO BYTES
00801  3B5  57                  DA A
00802  3B6  20                  XCHA, @R0        STO RSLT
00803  3B7  18                  INC R0
00804  3B8  19                  INC R1
00805  3B9  F1                  MOV A, @R1
00806  3BA  70                  ADDC A, @R0      ADD HI BYTES
00807  3BB  57                  DA A
00808  3BC  20                  XCHA, @R0        STO RSLT
00809  3BD  C8                  DEC R0
00810  3BE  83                  RET
00811  3BF  B9 27   DIVL        MOV R1, #$27
00812  3C1  B1 00               MOV @R1, #$00
00813  3C3  31                  XCHD A, @R1
00814  3C4  47                  SWAP A
00815  3C5  21                  XCHA, @R1
00816  3C6  03 FB               ADD A, #$FB      REMDR FIVE OR MORE?
00817  3C8  21                  XCHA, @R1
00818  3C9  E6 CE               JNC DRTRS        JMP ON LESS THAN FIVE
00819  3CB  03 01               ADD A, #$01
00820  3CD  57                  DA A
00821  3CE  93      DRTRS       RETR
00822  3CF  F9      1*8R1       MOV A, R1
00823  3D0  A8                  MOV R0, A
00824  3D1  74 B3               CALL ADD2B       MULT BY TWO
00825  3D3  74 E3               CALL DIV10       DIVIDE BY TEN
00826  3D5  E6 D9               JNC CMPT2
00827  3D7  19                  INC R1
00828  3D8  11                  INC @R1
00829  3D9  C8      CMPT2       DEC R0
00830  3DA  F8                  MOV A, R0
```

```
3DB  A9                  MOV R1, A
3DC  B8 34               MOV R0, #$34
3DE  14 A1               CALL SUB2B       SUBTR TWO TENTHS
3E0  18                  INC R0
3E1  24 F4               JMP MOV 01
3E3  F0        DIV10     MOV A, @R0
3E4  74 BF               CALL DIVL        DIV LO BYTE BY TEN
3E6  B9 34               MOV R1, #$34
3E8  A1                  MOV @R1, A       STO RSLT
3E9  18                  INC R0
3EA  19                  INC R1
3EB  27                  CLR A            START DIV HI BYTE
3EC  A1                  MOV @R1, A
3ED  F0                  MOV A, @R0
3EE  47                  SWAP A
3EF  31                  XCHD A, @R1
3F0  C9                  DEC R1
3F1  61                  ADD A, @R1
3F2  57                  DA A
3F3  A1                  MOV @R1, A       STO RSLT
3F4  83                  RET
3F5  C5        SHIFT     SEL RB0          REGISTER BANK
3F6  FF                  MOV A, R7        GET CONTR REG
3F7  D3 20               XRL A, #$20      CPL RNGE FLG
3F9  43 40               ORL A, #$40      SET SHFT FLG
3FB  AF                  MOV R7, A        SET CONTR REG
3FC  D5                  SEL RB1          REGISTER BANK
3FD  83                  RET
3FE  00                  NOP
3FF  00                  NOP
               *
               *
               *****TRACY LINWOOD VARNUM*****
               *    10/25/78
               *    VERSION 2*0
               *    COPYRIGHT 1978
               *    CASPAR INTEGRATED SYSTEMS
               *
               *
```

SYMBOL TABLE

CKMOD	015	GOLTCH	02C	GODT/M	030	MINRCL	034
MAXRCL	038	INDIC	03B	TRVOK	041	START	043
PREX	04A	INFO	04D	FLGP	058	INP2	059
RPT	05E	VALX	062	CMBK	066	CPLR0	06B
STCPL	077	DRET	079	LKHI	07B	TRVLD	084
3EOC	090	EOCSK	094	EOC	096	DECR2	09A
DECR	09E	SUB2B	0A1	SRET	0AB	INCRT	0AC
UPDMM	0B0	LTCHMM	0B5	LTCHST	0BF	CPMIN	0C5
CPMAX	0CD	LTCHPL	0D1	CMPRV	0D2	OLD	0D8
MORE	0D9	NEW	0DC	STNEW	0E3	STMAX	0E7
STLTCH	0EB	SETUP	0EF	TCPLMT	0F7	MOV10	0FE
IDATA	105	WLOOP	106	ENTER	10A	INPT	119
SHFTU	11D	GOOVFL	125	OKRGE	129	PACK	138
CKDEC	13C	MIN30	143	PMOVF	14B	TSTRGE	151
SHFTD	159	LINR	163	ADD6	17F	TADDR	185
UNMSK	192	STO2	195	STODIF	19F	DOWN	1A2
ADR00	1A7	ADR51	1B1	ADR09	1BC	2DIFF	1C6
IRETR	1C9	INTRP	1CA	TIMES	1D7	READY	1DD
ADDDF	1E3	OFFBR	1E5	USE2	1EF	MOV01	1F4
ADDOF	1FB	STOH	20A	CARR1	20D	INCTH	211
LATCH	216	SIGCK	226	UPWRD	23F	SIG	241
SIGYS	24C	ROLL	24E	MMCK	260	DECRT	264
EXIT	267	RQOK	26B	OVFL	26C	HIGH	275
DBLST	277	CPOVF	27F	ORET	28D	LLOOP	28E
WTRET	298	DT/M	29C	REGO	2A6	COUNT	2B9
FLGOK	2CA	CKR7	2D4	RIGHT	2D7	DTOUT	2E7
ADJST	2F1	TABLE	301	OUT	33D	SCALE	356
OUTC	35C	CNT2	363	DIG	365	DELAY	36D
PSIGN	37E	GROUP	381	OUTF	384	ADDF	398
END	39A	OUTK	39F	ADDK	3AF	ADD2B	3B3
DIVL	3BF	DRTRS	3CE	1*8R1	3CF	CMPT2	3D9
DIV10	3E3	SHIFT	3F5				

HARDWARE COMPONENTS

Referring to FIGS. 2-4, the following tables give standard commercial designations or electrical nomenclature and values for the components shown in the respective Figures.

TABLE I
(FIG. 2)

Designation in Figure	Description
R1	Resistor, 2.49k ohm
R2,8	Resistors, 10k ohm
R3	Resistor, 3.4k ohm
R4	Resistor, 1.47k ohm
R5, 7, 12	Resistors, 8.45k ohm
R6	Resistor, 100k ohm
R9, 11 Trimpots	Resistors, 1k ohm
R10	Resistor, 11k ohm
R13	Resistor, 2.7k ohm
A1-4	LM324
A5	CA3160
Q1	Transistor, 2N3905
C1	Capacitor, .47microF
Sensor, platinum	Din Std. .00385 ohm/ohm/°C 100 ohm ±.1 ohm at 0.0°C

TABLE II
(FIG. 3)

Designation in Figure	Description
IC1	Integ. Cir. MC1403U
IC4	ADC3711CCN
IC5	Intel 8048
X1	Crystal, 2.903 MHz
C2	Capacitor, .01 microF
C3, 4	Capacitor, .47 microF
C5	Capacitor, 10 microF
C6,7	Capacitor, 20pF
C8	Capacitor, 2.2 microF
R14	Resistor, 2.49k ohms

R15	Trimpot, 1k ohm
R16	Resistor, 11.8k ohm
R17	Resistor, 100k ohm
R18	Resistor, 1.5k ohm
R19	Resistor, 10k ohm

TABLE III
(FIG. 4)

Designation in Figure	Description
IC6	Integ. Cir. DF411CJ
IC7	MC14070B
IC8	CA3290
IC9	LM340H-5.0
LXD Display	LXD 45D5RO3
D1	Diode, 1N4001
C9,10	Capacitors, 10 microF
C11	Capacitor, 390 pF
R20	Resistor, 10.4k ohm
R21,22	Resistors, 10k ohm

OPERATION

In use, the instrument is powered by either internal storage cells or an external plug-in AC/DC adaptor. When operating on dry cell power, a low battery indication will automatically appear, comprising the displaying of decimal points between each digit of the display, should the batteries become depleted.

Application of power to the instrument, selection of operating modes, and selection of recall or conversion functions is achieved by user manipulation of the front-panel switches shown in FIG. 8.

FIG. 8 shows a front panel view of one embodiment of the invention. Shown in this view are the display, the rocker switches used to communicate scale, mode, and recall requests to the microcomputer, a slide switch used to turn power to the instrument on and off, and a connector for a sensor, shown in the lower left-hand corner of the panel.

Calibration of the instrument is achieved in the following manner: (while operating in the Continuous mode)

--the sensor is subjected to a known temperature of 0.0°C. and the ZERO trimpot R9 of FIG. 2 is adjusted so that the display shows 0.0°C.,

--next, the sensor is subjected to a known temperature of 100.0°C. and the GAIN trimpot R15 of FIG. 3 is adjusted to obtain that reading in the display. Two or three iterations of these first two steps will be necessary in order to achieve best calibration as these two adjustments are not entirely independent,

--finally, the sensor is subjected to a known temperature above 170° C. by means of a constant-temperature oil bath or similar device and the OFFSET trimpot R11 of FIG. 2 is adjusted so that the proper reading is displayed.

In the foregoing a preferred embodiment of the invention has been described; however, it will be understood that there is no intent to limit the invention by such disclosure, and that it is intended to cover any and all other embodiments falling within the scope of the following claims:

CLAIMS:

1. An electronic thermometer comprising a resistance temperature detector, a source of constant current, means for connecting said source of constant current in electrical communication with said detector, amplifier means, means for connecting said amplifier means in electrical communication with said detector, analog to digital converter means, means for connecting said amplifier means in electrical communication with said analog to digital converter means, microcomputer means, means for connecting said microcomputer means in electrical communication with said analog to digital converter means, display means, means for connecting said display means in electrical communication with said microcomputer means, selection means for inputting signals to determine the type of data output to said display means, means for connecting said selection means in electrical communication with said microcomputer means, means whereby said microcomputer means monitors said input signals, means whereby said microcomputer means calculates data which represents a corrected temperature equivalent of the resistance of said detector, wherein the improvement comprises means whereby said microcomputer means calculates data which represents rate of temperature change, and means whereby said microcomputer means detects a temperature change - regardless of the direction of said change - and derives by calculation data which represents a temperature equivalent representing the extreme of said change since the time of detection of said change by said microcomputer means.

2. An electronic thermometer as in claim 1 wherein there is provided means for selection of any one of several temperature scales and means for expressing any output data in any selected scale.

3. An electronic thermometer as in claim 1 including means for recalling data stored in memory means of said microcomputer means.

4. An electronic thermometer as in claim 1 wherein said microcomputer means comprises a single-chip microcomputer.

5. An electronic thermometer comprising a resistance temperature detector, a source of constant current, means for connecting said source of constant current in electrical communication with said detector, amplifier means, means for connecting said amplifier means in electrical communication with said detector, analog to digital converter means, means for connecting said amplifier means in electrical communication with said analog to digital converter means, microcomputer means, means for connecting said microcomputer means in electrical communication with said analog to digital converter means, display means, means for connecting said display means in electrical communication with said microcomputer means; wherein the improvement comprises voltage offset means for applying a predetermined voltage to said amplifier means, means for connecting said voltage offset means in electrical communication with said microcomputer means, means for control of said voltage offset means by said microcomputer means, means for representation of application of said voltage to said amplifier as a temperature differential by said microcomputer means for purposes of increasing the number of bits of information resolved by said analog to digital converter means.

6. An electronic thermometer comprising:

A. means to sense temperature and to produce an electrical signal which is an analog function of said temperature;

B. analog-to-digital converter means connected to said signal-producing means to provide digital data representations of said temperature;

C. circuit means connected to receive said digital data representations and to operate in a mode to provide a signal, representative of an extreme value of temperature attained since initiation of operation in said mode; and

D. means connected to receive said signal representative of an extreme value of temperature.

7. The electronic thermometer of claim 6 wherein said electrical signal is a voltage whose magnitude is an analog function of temperature.

8. The electronic thermometer of claim 7 wherein said voltage is proportional to temperature.

9. The electronic thermometer of claim 6 wherein said sensing and signal-producing means of A. comprises a resistive temperature detector having a resistance proportional to temperature, and a constant-current source in series with said temperature detector, whereby a voltage proportional to temperature is produced across said detector.

10. The electronic thermometer of claim 9 wherein said signal-producing means of A. comprises an amplifier to increase the amplitude of said temperature-proportional voltage.

11. The electronic thermometer of claim 6 wherein said analog-to-digital converter provides binary-number representations of said temperature.

12. The electronic thermometer of claim 6 wherein said circuit means includes means to sense the direction of the first deviation of temperature since said initiation, which deviation exceeds a preselected magnitude, and to select the extreme value of temperature which lies in the same direction as said deviation.

13. The electronic thermometer of claim 6 wherein said means connected to receive said signals representative of an extreme value of temperature comprises an alphanumeric display to display said value in visual form.

14. An electronic thermometer comprising:

A. means to sense temperature and to produce an electrical signal which is an analog function of temperature;

B. analog-to-digital converter means connected to said signal-producing means to provide digital data representations of said temperature;

C. circuit means connected to receive said digital data representations and operable to derive from said digital data representations a signal representative of a rate of temperature change averaged over a preselected interval; and

D. means connected to receive said signal representative of a rate of temperature change.

15. The electronic thermometer of claim 14 wherein said electrical signal is a voltage whose magnitude is an analog function of temperature.

16. The electronic thermometer of claim 15 wherein said voltage is proportional to temperature.

17. The electronic thermometer of claim 14 wherein said sensing and signal-producing means of A. comprises a resistive temperature detector having a resistance proportional to temperature, and a constant-current source in series with said temperature detector, whereby a voltage proportional to temperature, is produced across said detector.

18. The electronic thermometer of claim 17 wherein said signal-producing means of A. further comprises an amplifier to increase the amplitude of said temperature-proportional voltage.

19. The electronic thermometer of claim 14 wherein said analog-to-digital converter provides binary-number representations of said temperature.

20. The electronic thermometer of claim 14 wherein said means connected to receive said signal representative of a rate of temperature comprises an alphanumeric display to display said rate in a visual form.

21. The electronic thermometer of claim 14, wherein said circuit means derives a rate of temperature change over an interval of substantially six seconds.

22. The electronic thermometer of claim 14, wherein said circuit means of C. is further operable in a mode to select from said digital data representations an extreme value of temperature attained since initiation of operation in said mode.

23. The electronic thermometer of claim 22 further including means to permit the selectable control of said circuit means to either select said extreme value of temperature or derive said rate of temperature change.

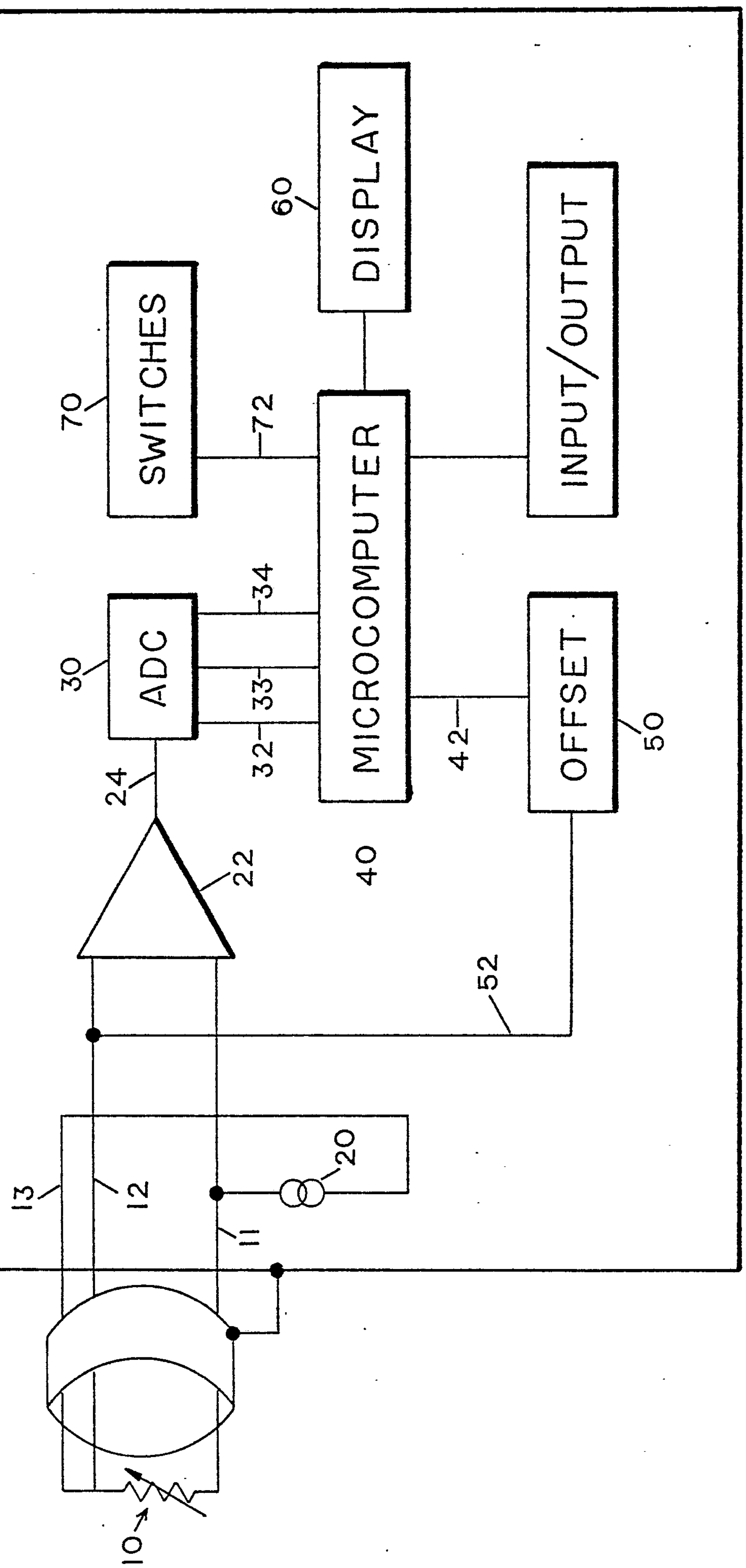
DISPLAY
60
SWITCHES
70
72
MICROCOMPUTER
INPUT/OUTPUT
ADC
30
34
33
32
42
OFFSET
50
24
22
40
52
20
13
12
11
10

FIG. 1

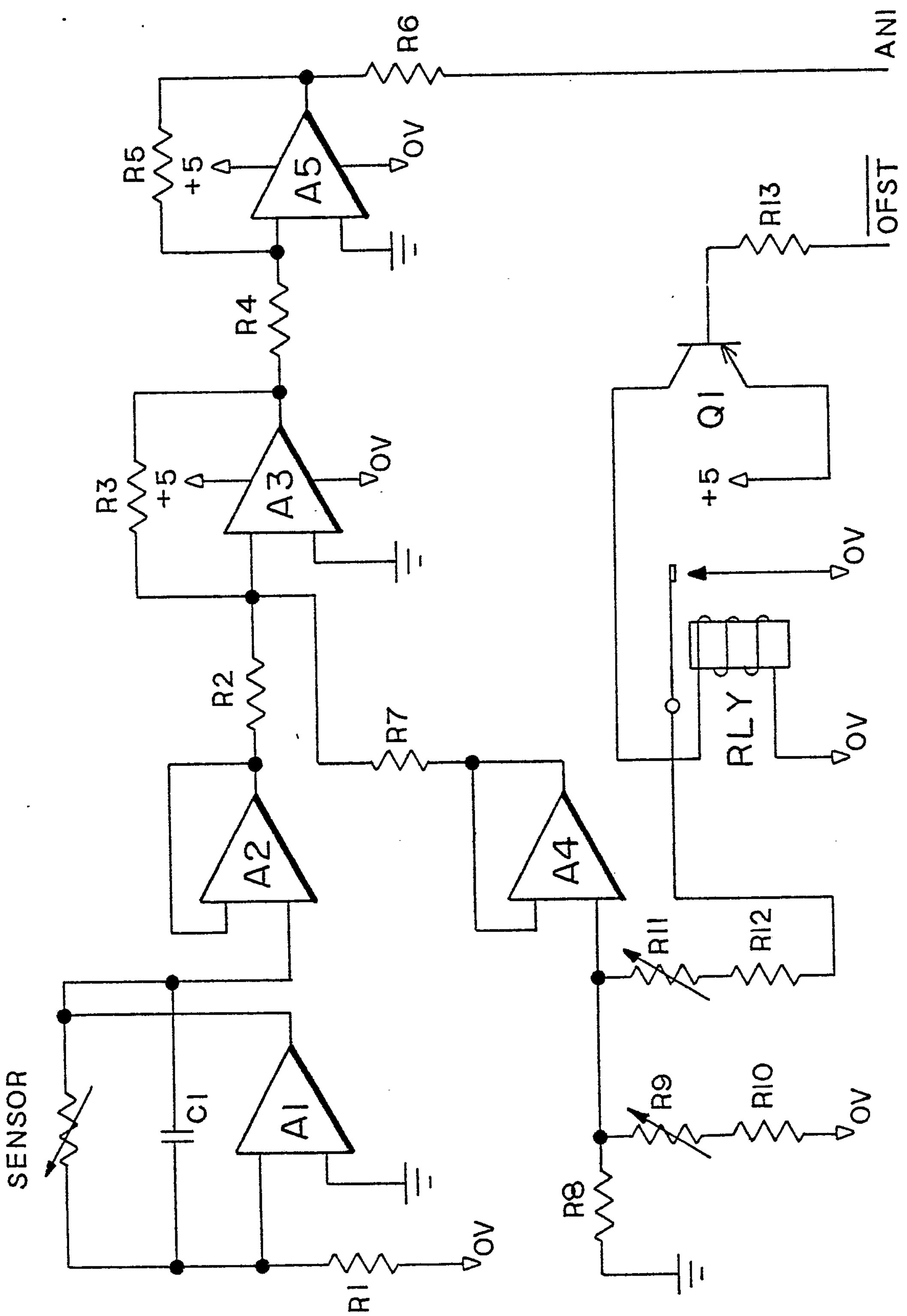
R6
AN1
R5
+5
A5
OV
R13
OFST
R4
R3
+5
A3
OV
Q1
+5
OV
R2
RLY
OV
R7
A2
A4
R11
R12
SENSOR
C1
A1
R9
R10
OV
R8
R1
OV

FIG. 2

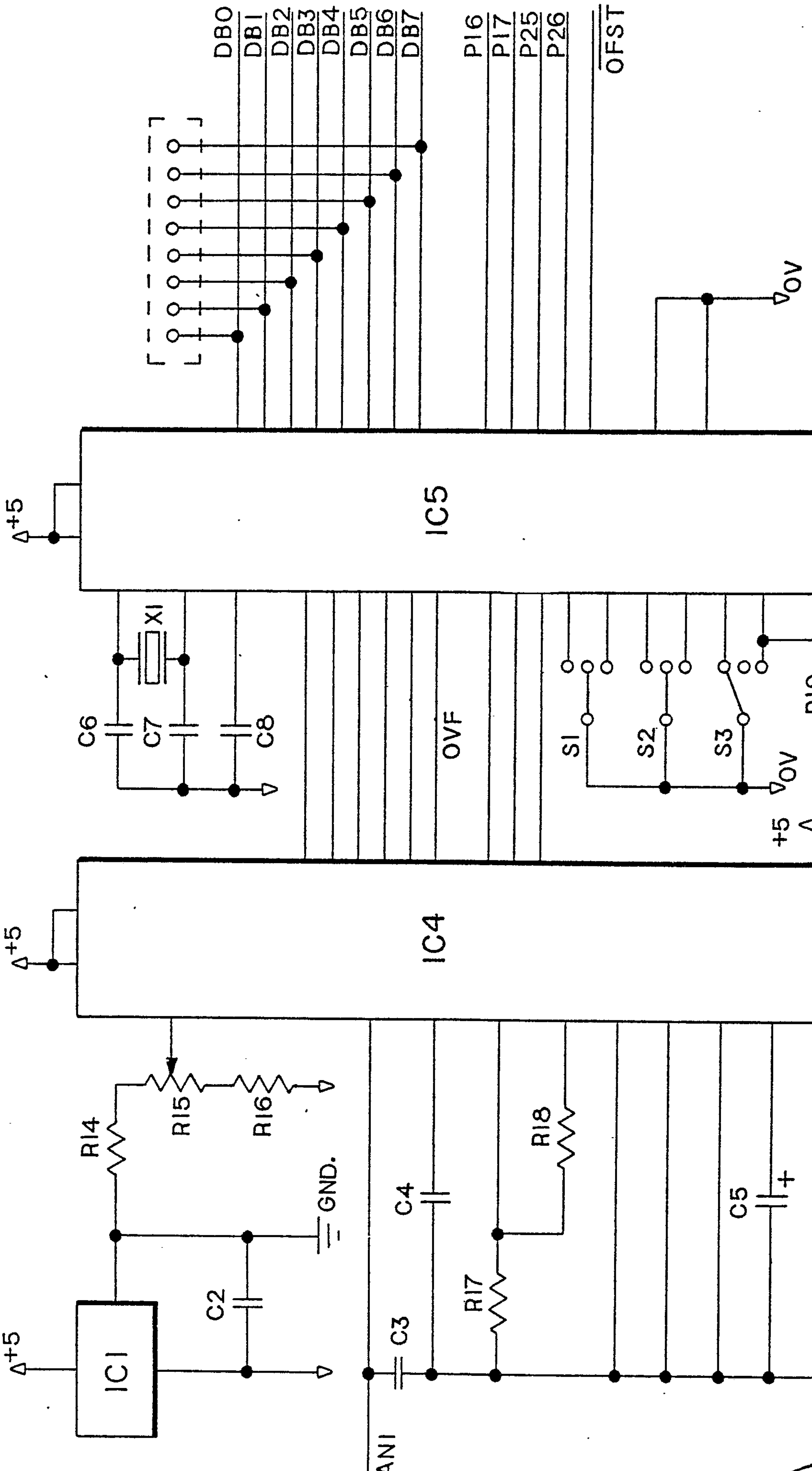
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
P16
P17
P25
P26
OFST
IC5
IC4
IC1
+5
0V
X1
C6
C7
C8
OVF
S1
S2
S3
R19
R14
R15
R16
R17
R18
GND.
C2
C3
C4
C5
AN1

FIG.3

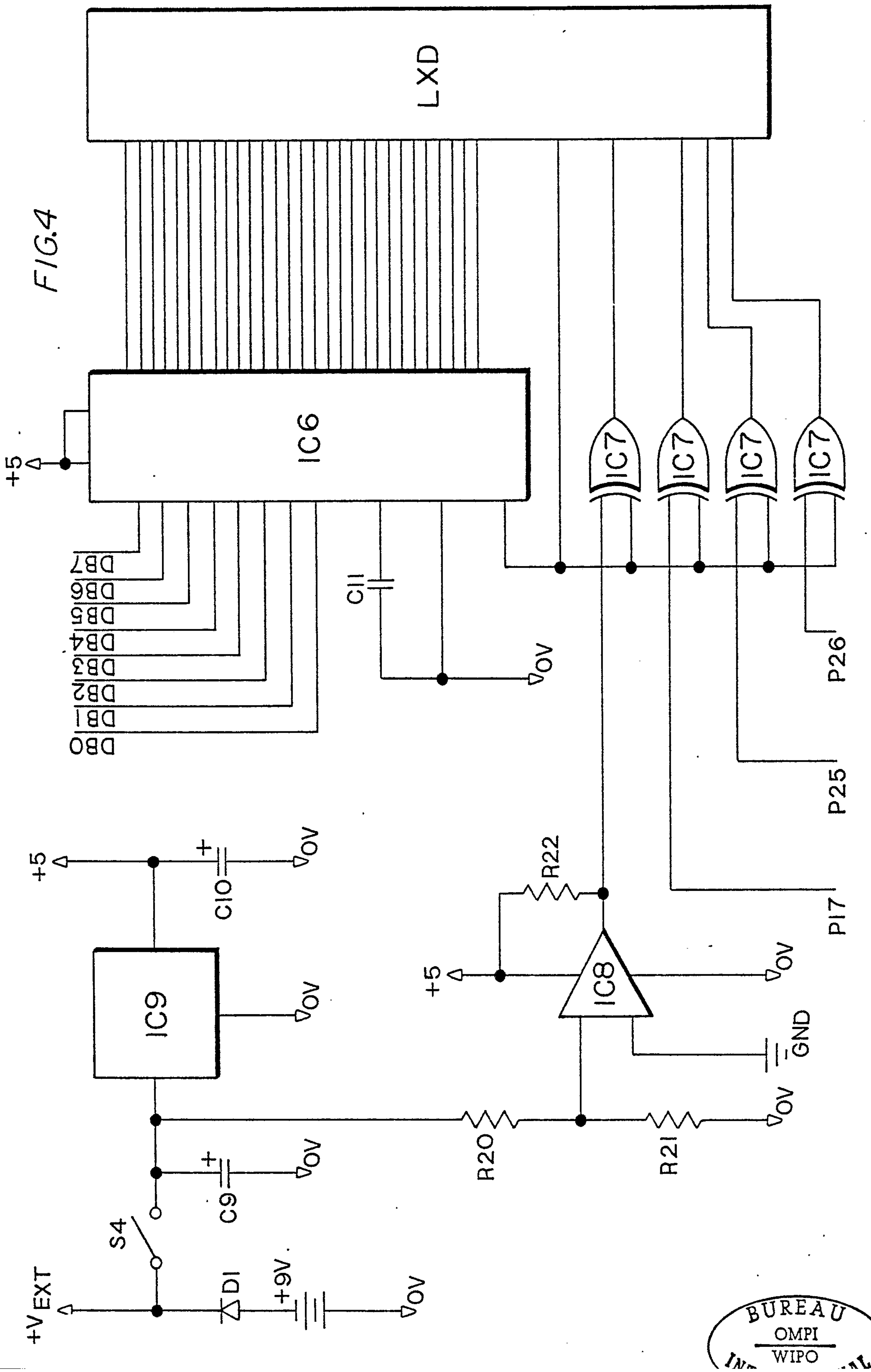
LXD
IC6
+5
DB7
DB6
DB5
DB4
DB3
DB2
DB1
DB0
C11
0V
IC7
IC7
IC7
IC7
P26
P25
P17
R22
IC8
+5
0V
GND
IC9
+5
C10
0V
R20
R21
C9
S4
+VEXT
D1
+9V

FIG.4

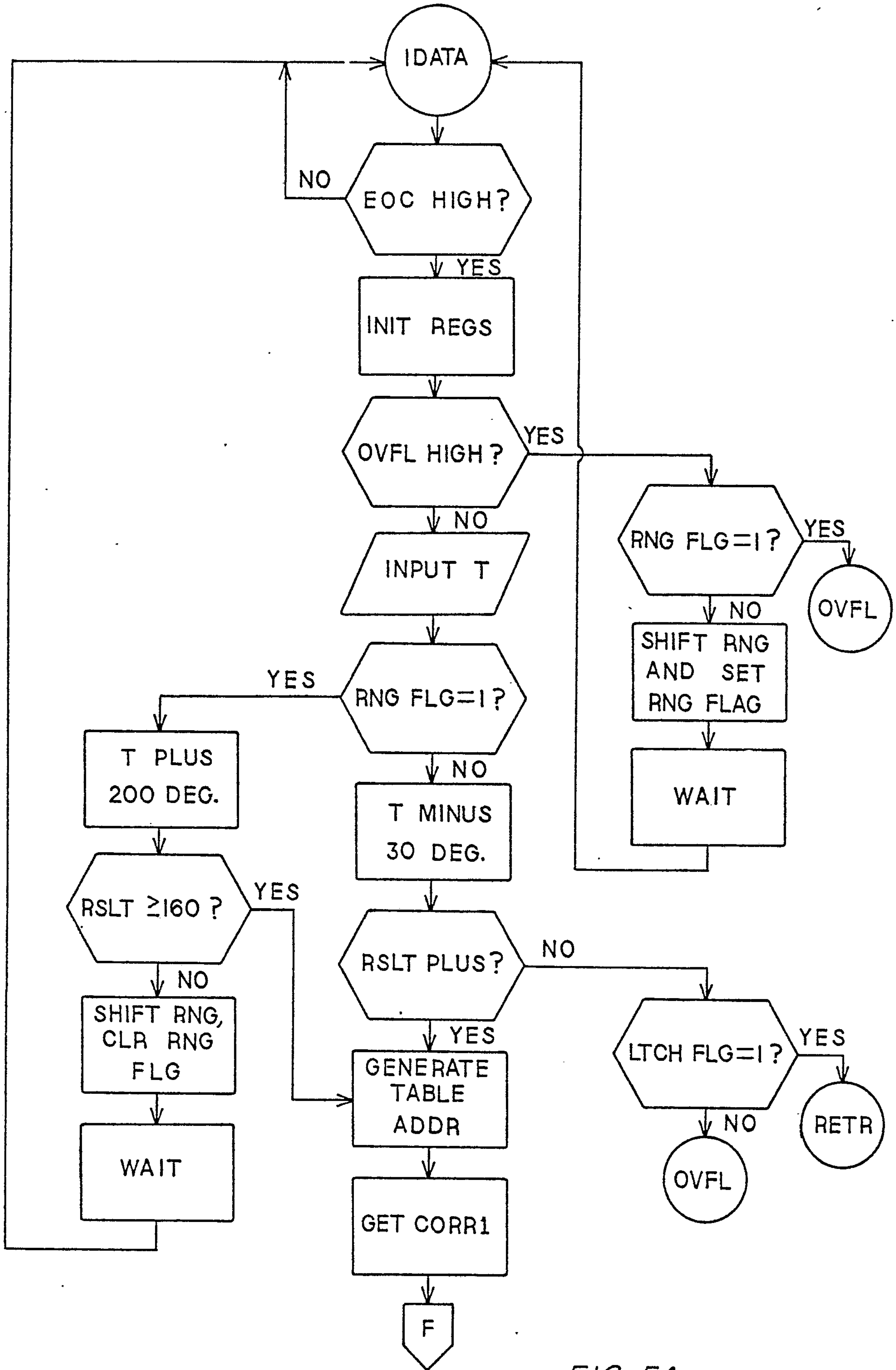
IDATA
EOC HIGH?
NO
YES
INIT REGS
OVFL HIGH?
YES
NO
RNG FLG=1?
YES
OVFL
NO
SHIFT RNG AND SET RNG FLAG
WAIT
INPUT T
RNG FLG=1?
YES
NO
T PLUS 200 DEG.
T MINUS 30 DEG.
RSLT ≥160 ?
YES
NO
SHIFT RNG, CLR RNG FLG
WAIT
RSLT PLUS?
NO
YES
LTCH FLG=1?
YES
NO
RETR
OVFL
GENERATE TABLE ADDR
GET CORR1
F

FIG. 5A

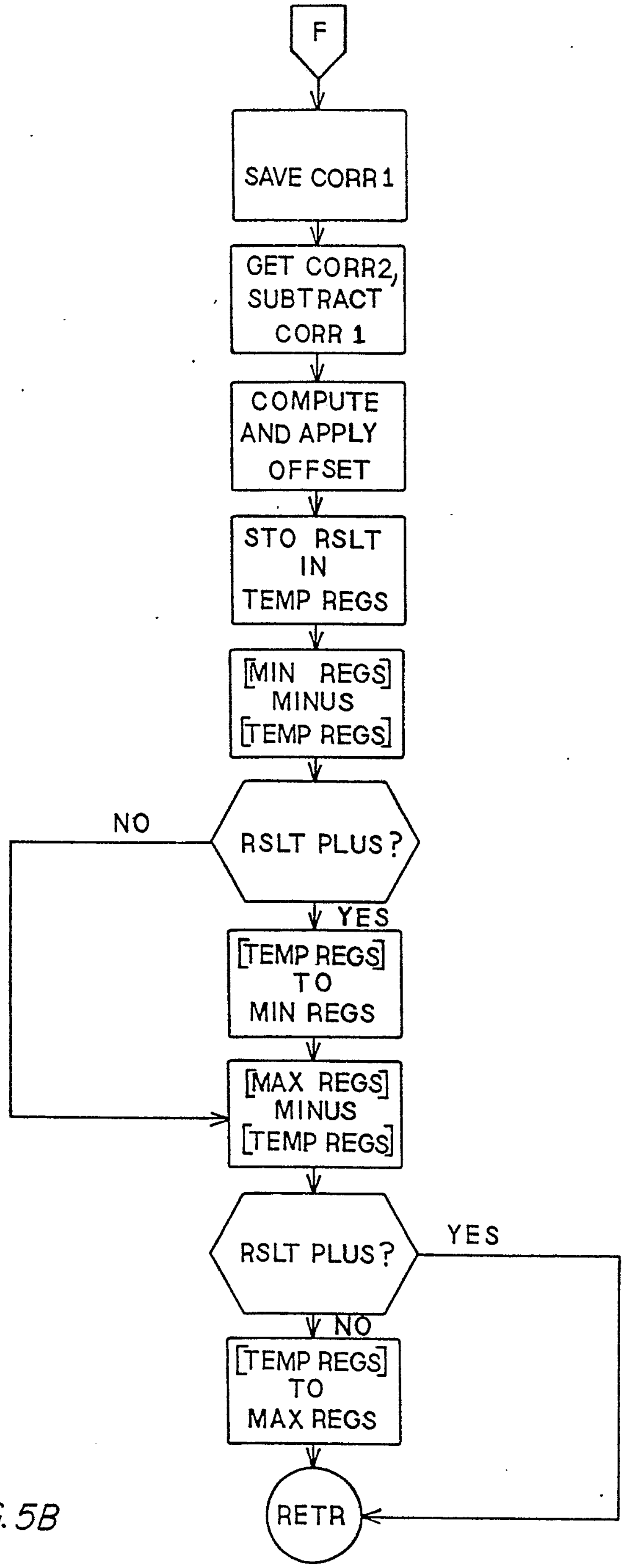
F
SAVE CORR 1
GET CORR2, SUBTRACT CORR 1
COMPUTE AND APPLY OFFSET
STO RSLT IN TEMP REGS
[MIN REGS] MINUS [TEMP REGS]
RSLT PLUS?
NO
YES
[TEMP REGS] TO MIN REGS
[MAX REGS] MINUS [TEMP REGS]
RSLT PLUS?
YES
NO
[TEMP REGS] TO MAX REGS
RETR

FIG. 5B

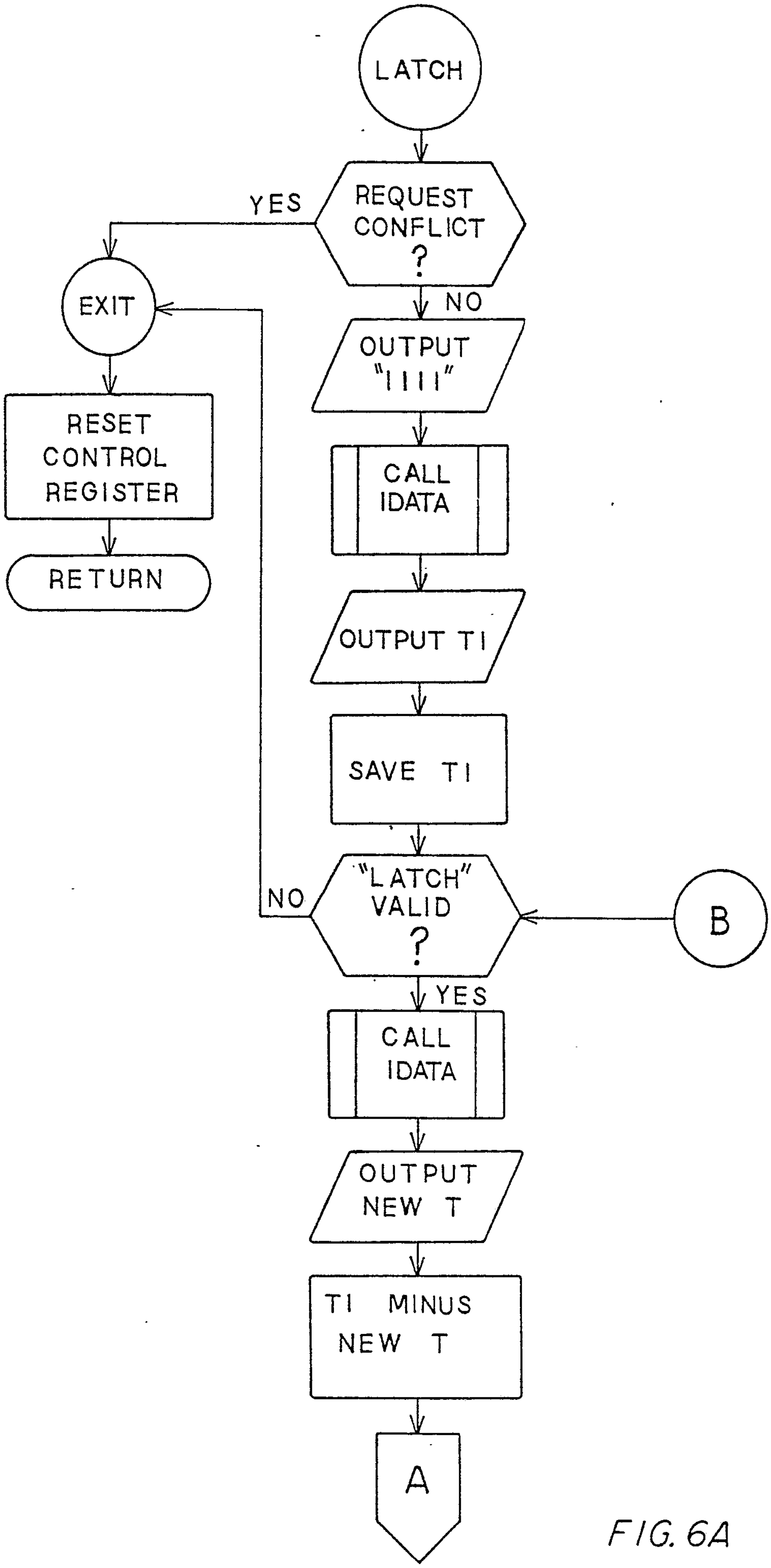
LATCH
REQUEST CONFLICT ?
YES
NO
EXIT
RESET CONTROL REGISTER
RETURN
OUTPUT "1111"
CALL IDATA
OUTPUT TI
SAVE TI
"LATCH" VALID ?
NO
YES
B
CALL IDATA
OUTPUT NEW T
TI MINUS NEW T
A

FIG. 6A

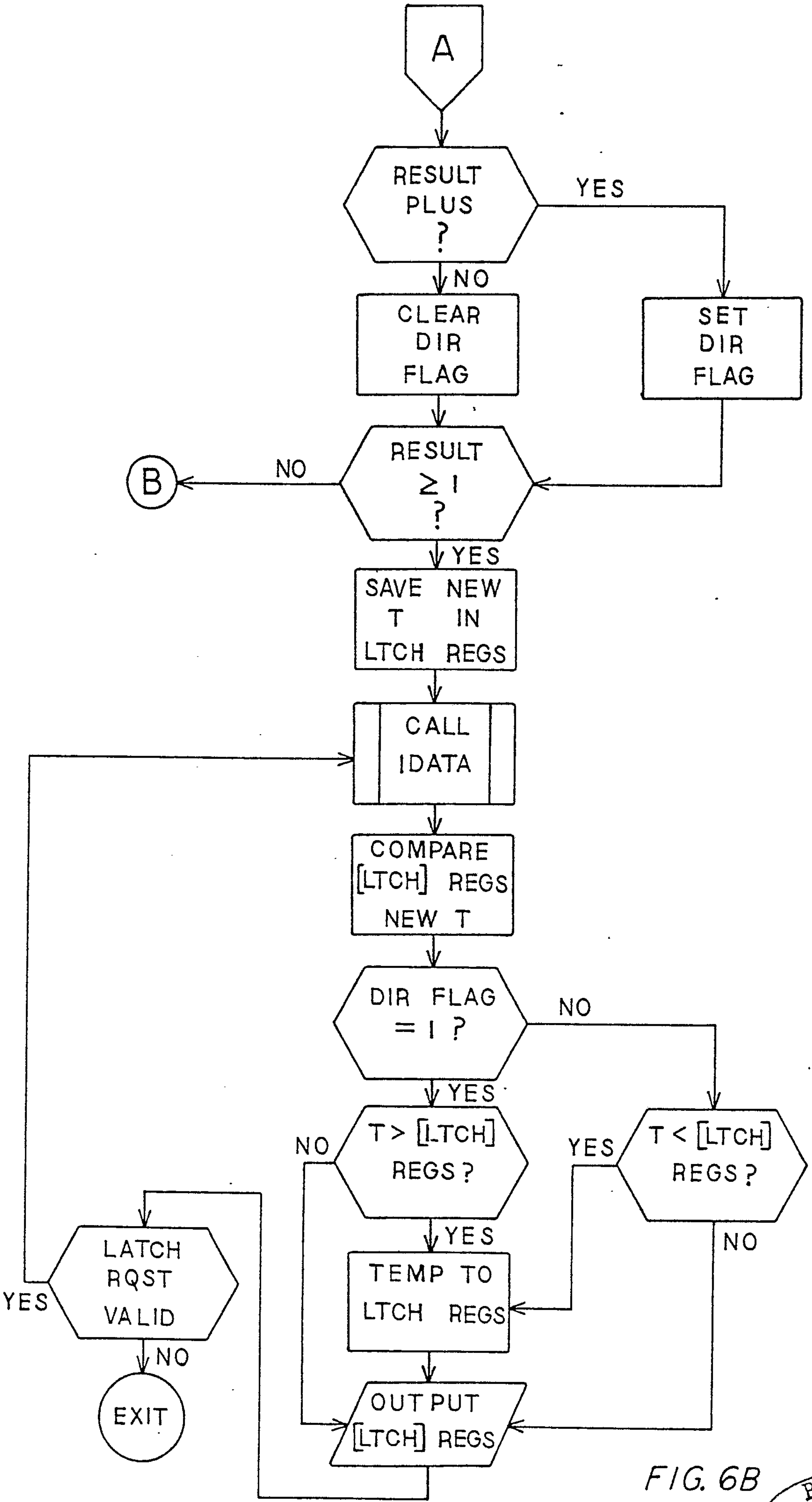
A
RESULT PLUS ?
YES
NO
CLEAR DIR FLAG
SET DIR FLAG
RESULT ≥ 1 ?
NO
B
YES
SAVE NEW T IN LTCH REGS
CALL IDATA
COMPARE [LTCH] REGS NEW T
DIR FLAG = 1 ?
NO
YES
T > [LTCH] REGS ?
NO
T < [LTCH] REGS ?
YES
NO
YES
TEMP TO LTCH REGS
LATCH RQST VALID
YES
NO
EXIT
OUTPUT [LTCH] REGS

FIG. 6B

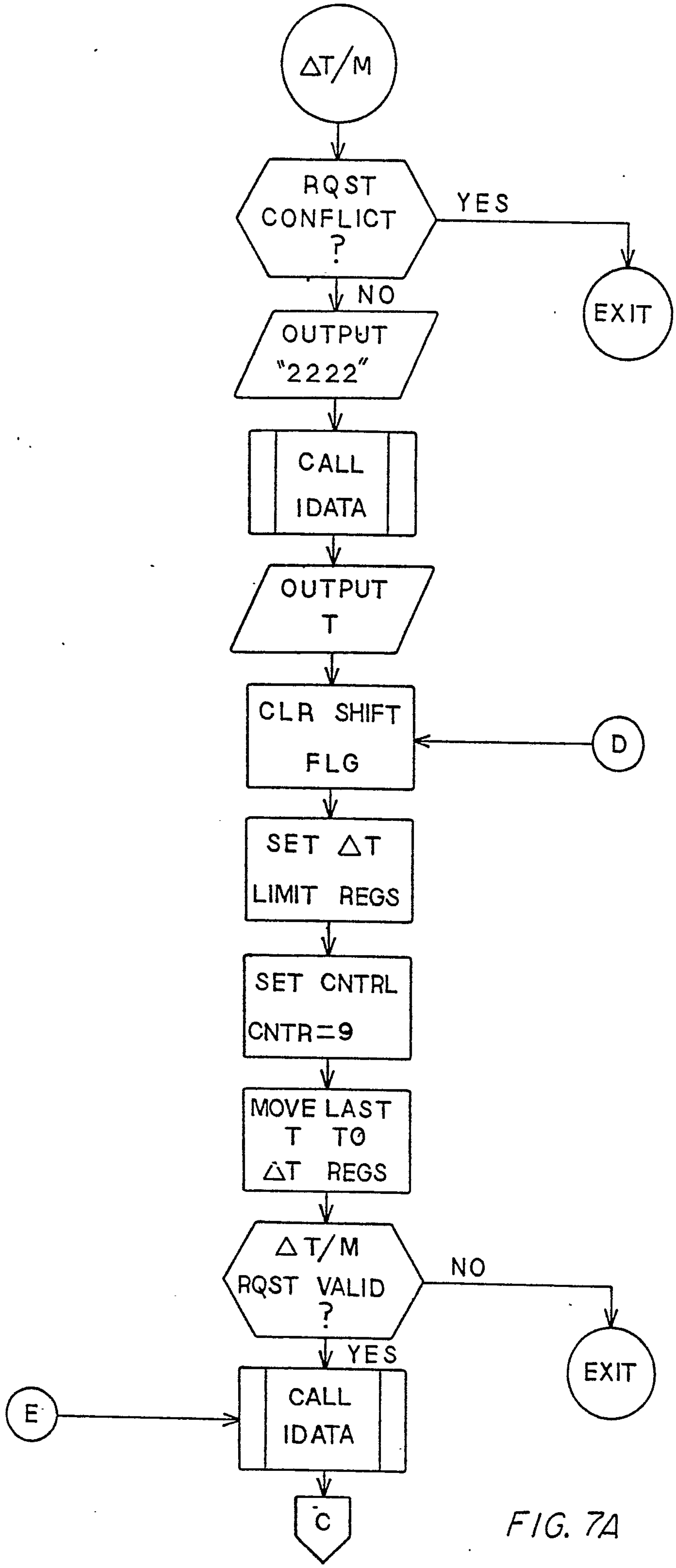
ΔT/M
RQST CONFLICT ?
YES
EXIT
NO
OUTPUT "2222"
CALL IDATA
OUTPUT T
CLR SHIFT FLG
D
SET ΔT LIMIT REGS
SET CNTRL CNTR=9
MOVE LAST T TO ΔT REGS
ΔT/M RQST VALID ?
NO
EXIT
YES
E
CALL IDATA
C

FIG. 7A

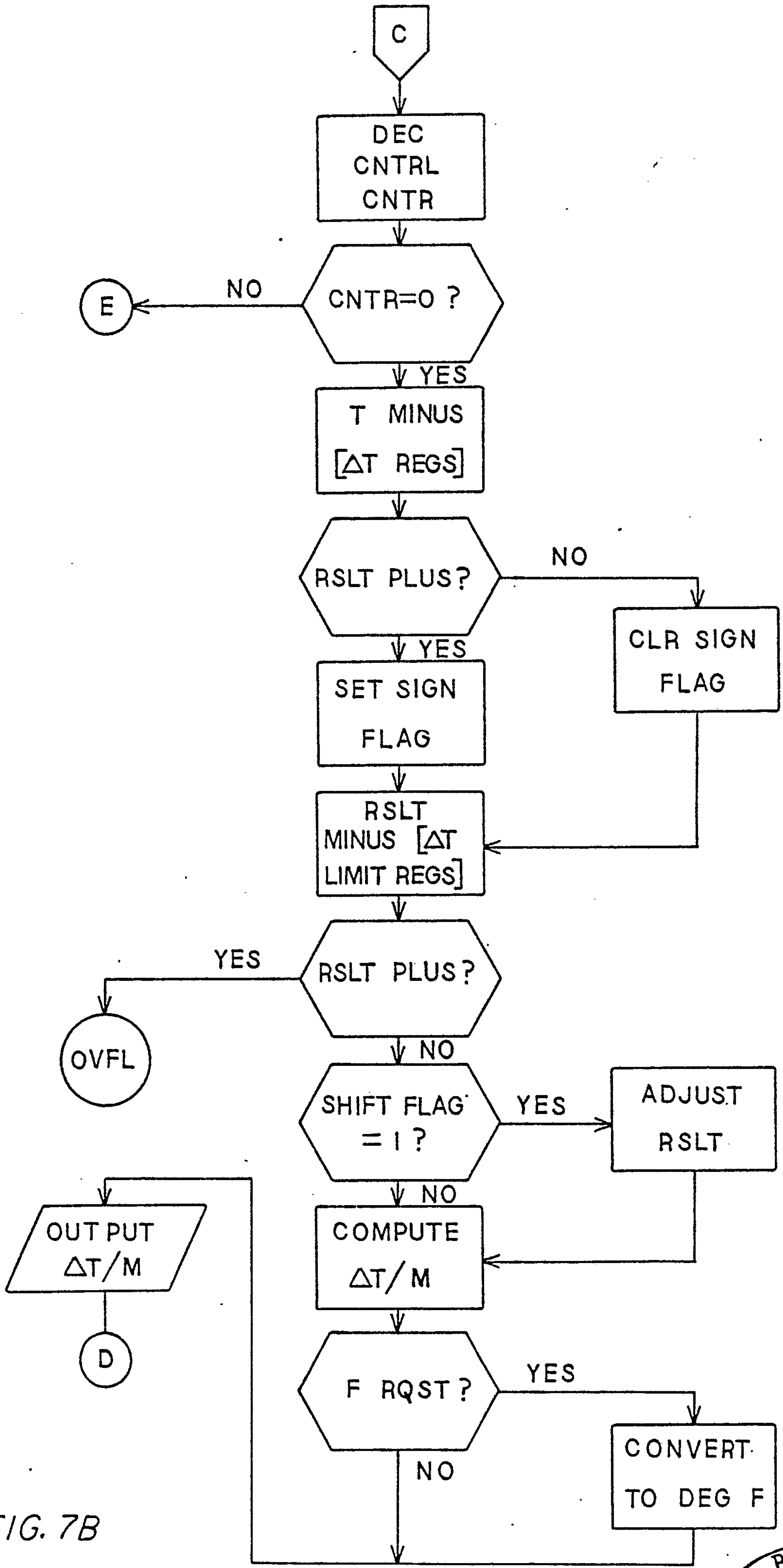
C
DEC CNTRL CNTR
CNTR=0 ?
NO
E
YES
T MINUS [ΔT REGS]
RSLT PLUS?
NO
CLR SIGN FLAG
YES
SET SIGN FLAG
RSLT MINUS [ΔT LIMIT REGS]
RSLT PLUS?
YES
OVFL
NO
SHIFT FLAG = 1 ?
YES
ADJUST RSLT
NO
COMPUTE ΔT/M
OUT PUT ΔT/M
D
F RQST ?
YES
CONVERT TO DEG F
NO

FIG. 7B

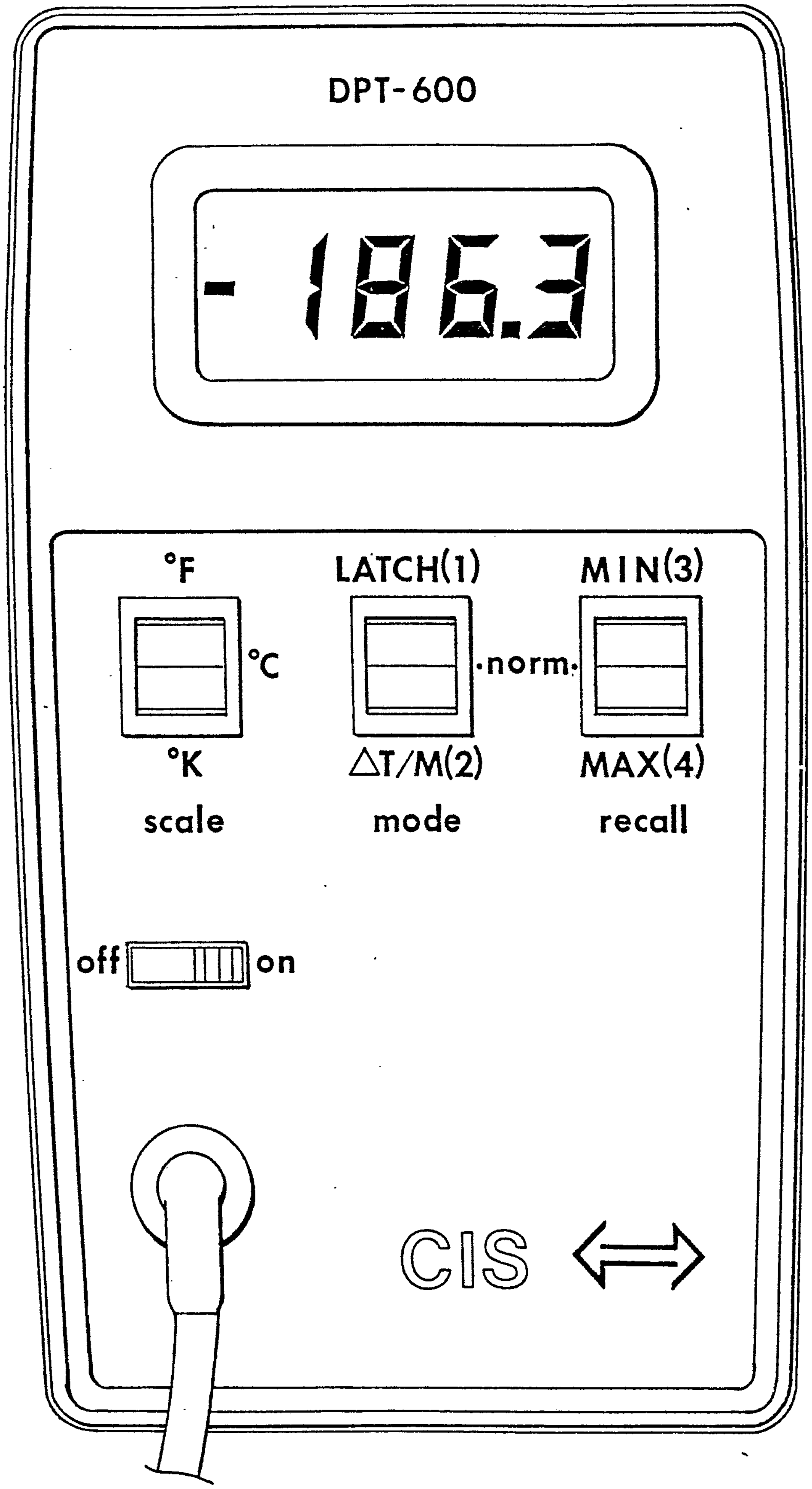
DPT-600
-186.3
°F
°C
°K
scale
LATCH(1)
·norm·
ΔT/M(2)
mode
MIN(3)
MAX(4)
recall
off
on
CIS

FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No PCT/US79/01135

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.3 G01K 7/14
U.S. CL. 364/557; 73/362AR

WO 80/01317

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	364/557 73/339R,342,362AR, 362SC

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X,P	U S , A, 4,161,880, Published 24 July 1979	1-23
X	U S , A, 4,122,719, Published 31 October 1978	1,3
X	U S , A, 4,068,526, Published 17 January 1978	4
A	U S , A, 4,068,138, Published 10 January 1978	6,14
A	U S , A, 3,982,110, Published 21 September 1976	6,14

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
01 April 1980	11 APR 1980
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Edward J. Wise

Form PCT/ISA/210 (second sheet) (October 1977)