

12 EUROPEAN PATENT APPLICATION

21 Application number: 84630047.3

51 Int. Cl.<sup>3</sup>: G 07 C 3/00  
 G 06 F 15/20

22 Date of filing: 16.03.84

30 Priority: 14.04.83 US 484755  
 14.04.83 US 484756

43 Date of publication of application:  
 24.10.84 Bulletin 84/43

84 Designated Contracting States:  
 DE FR GB IT NL SE

71 Applicant: CARRIER CORPORATION  
 Carrier Tower 6304 Carrier Parkway P.O. Box 4800  
 Syracuse New York 13221(US)

72 Inventor: Wilson, Frederick Joseph  
 109 Archer Road  
 Syracuse New York 13207(US)

72 Inventor: Hargis, Larry Neal  
 338 Chestnut Street  
 North Syracuse New York 13212(US)

72 Inventor: Lamb, John Douglas  
 2088 Route 11  
 Lafayette New York 13084(US)

74 Representative: Waxweiler, Jean et al,  
 OFFICE DENNEMEYER S.à.r.l. 21-25 Allée Scheffer  
 P.O.Box 41  
 L-2010 Luxembourg(LU)

54 Temperature data recorder and method of storing data.

57 A number of temperatures and events indicative of the operation of a refrigeration system are recorded chronologically. The memory is filled and overwritten in such a way that the memory contains full data for the most recent events to

the extent of memory storage capacity. Depending upon whether the recorder is in continuous use, the memory will contain data for the last 62 days of use with storage in memory for at least a year.

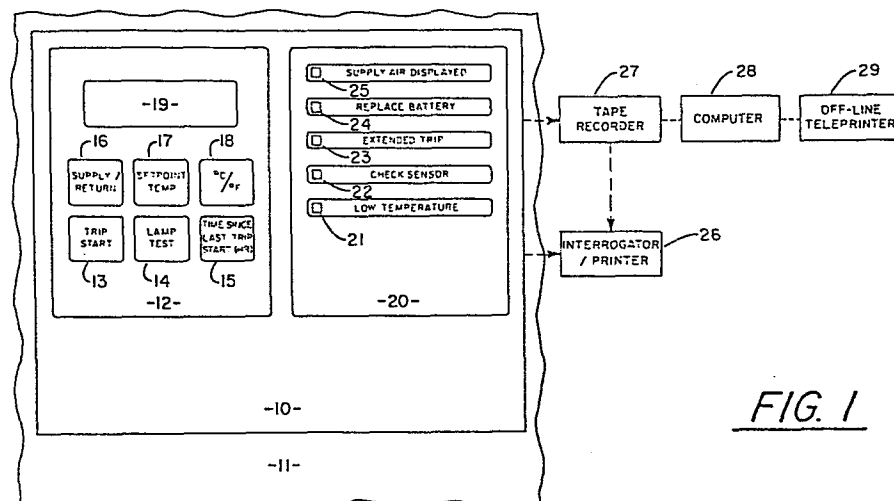


FIG. 1

-1-

TEMPERATURE DATA RECORDER  
AND METHOD OF STORING DATA

Background of the Invention

Perishable goods must be kept at a particular temperature range during shipment to avoid thawing, to prevent freezing or to delay/prevent ripening. To insure the quality of the goods, it is standard practice to monitor and record the temperature of the goods during shipment. Typically, a circular chart temperature recorder is used to record the temperature in the conditioned space during shipment. This arrangement provides a record of only the temperature in the conditioned space which is measured at the discharge of the evaporator and this record is removed from the container upon the removal of the paper chart. Additionally, data can be lost due to problems with the clock mechanisms, charts, stylus pens and inks. The data itself tends to be very compressed due to the physical limitation of space for logging the temperature readings over an extended period of time.

Summary of the Invention

The present invention is directed to a replacement for an indicating circular chart temperature recorder. More specifically, it is directed to an electronic replacement for a mechanical chart recorder and includes a data logger

for measuring temperature data which is stored for later recall by an interrogator/printer or through the display and keyboard.

- 5 The electronic data recorder is an indicating recorder for two temperatures in the range of  $-30.5^{\circ}\text{C}$  to  $+30.5^{\circ}\text{C}$ . It also records and displays the setpoint temperature from a temperature controller along with the controller defrost signal. The occurrence of a power interruption to the  
10 recorder is recorded as well as the number of recording intervals the power has remained interrupted. Stored data can be displayed using an auxiliary keyboard which is a part of the recorder keyboard. External connections permit the monitoring of the controller's active temperature probe  
15 signal via the setpoint display. An auxiliary control function is provided to monitor the supply air temperature and alarm when the supply air temperature remains 3 centigrade degrees below setpoint for 20 minutes for setpoints in the perishable temperature range. This low temperature alarm  
20 also energizes an interlock for use in controlling the monitored refrigeration equipment or activating remote alarms.

- The data retrieval and display device, referred to as the  
25 interrogator/printer, is intended to produce human readable documents to replace the chart from the commonly used chart recorder. The interrogator/printer also provides auxiliary functions for data inspection, exception - reporting and data analysis normally provided by an operator or clerk to  
30 ascertain performance of the refrigeration system.

It is an object of the invention to provide method and apparatus for measuring temperature data and storing the value for later recall.

It is another object of this invention to provide an independent verification of container return and/or supply air temperature.

It is a further object of this invention to provide a temperature data recorder having an extended operating temperature range and improved accuracy and clarity of data.

0 It is an additional object of this invention to provide a temperature data recorder which will record the actual setpoint value, monitor refrigeration unit performance, and record events pertinent to temperature control/unit operation including the occurrence and duration of power interruptions.

5 It is another object of this invention to provide a device which avoids the problems associated with clock mechanisms, charts, pens and ink which are necessary for mechanical recording.

0 It is a further object of this invention to obtain additional information from the temperature data.

5 It is another object of this invention to provide apparatus for providing temperature information to an interrogator/printer without loss of data from memory.

It is a further object of this invention to provide apparatus for retrieving and processing data and providing a hard copy of the processed data.

0 It is a still further object of this invention to provide a recorder which retains data in memory until it is replaced by new data. These objects, and others as will become apparent hereinafter, are accomplished by the present invention.  
5

Basically, the present invention is directed to an electronic temperature data recorder having an electronic memory and control circuitry for the acquisition, display, and storage of temperature and events. The acquired data is stored in a manner to allow recovery in chronological order for display and/or transfer to other storage media. This device records multiple temperatures and a setpoint plus a number of discrete events at time intervals to provide a history of temperature and related events. Typical temperatures and events stored are the supply air temperature; the return air temperature; defrost occurrences; power outage occurrences; and, controller setpoint temperature. The stored information is retrieved from the recorder by an interrogator/printer which processes the retrieved data and provides a hard copy.

15

#### Brief Description of the Drawings

For a fuller understanding of the present invention, reference should now be made to the following detailed description thereof taken in conjunction with the accompanying drawings wherein:

20

Figure 1 is a schematic representation of the recorder and data transfer structure;

25 Figure 2 is a functional block diagram of the recorder;

Figure 3 is a block diagram of the interrogator/printer; and

Figures 4A, B and C are a block diagram of the recorder;

30

Figure 5 is a schematic diagram of the recorder power supply;

Figure 6 is a schematic diagram of the reset circuit; and

Figure 7 is a view of a modified panel.

Description of the Preferred Embodiment

In Figure 1, the numeral 10 generally designates the electronic data recorder of the present invention which is installed on a refrigerated container 11 for monitoring and recording temperatures and events occurring therein. The electronic data recorder 10 is a microprocessor based data acquisition and recording apparatus. Coupled with the interrogator/  
0 printer 26 it performs the display, recording, retrieval and printing of temperatures and events normally associated with the performance of refrigeration equipment (not illustrated) for cooling container 11. Recorder 10 includes an operator's control panel 12 having a plurality of membrane keys 13-18  
5 and a display 19 as well as an indicator panel 20 having a plurality of indicator lights 21-25. To transfer the data from the recorder 10, interrogator/printer 26 may be directly connected to recorder 10 or indirectly connected through tape recorder 27. Data may also be recalled via control  
0 panel 12. Tape recorder 27 provides storage for data that has not been processed in reports. Alternatively, the output of tape recorder 27 can be connected to a computer 28 for storage and/or use and transferred to a desired location via off-line teleprinter 29.

5 Referring now to Figure 2, the signal interface 32 of recorder 10 receives analog signals in the form of analog voltages representing the setpoint temperature, defrost, supply temperature and return temperature. The signal interface  
0 also receives discrete signals in the form of switch closures representing the on or off condition of an input signal. These discrete signals include those from keys 13-18 and other on/off signals selecting the operating mode and functions. The analog voltages are selected by a multiplexer,  
5 digitized in an analog-digital (A/D) converter and supplied

-6-

to the control logic 34 along with the discrete signals. Control logic 34 is in two-way communication with memory 36 and interrogator/printer/tape recorder interface 38 and supplies an output signal to display interface 40. The  
5 output signal supplied to display interface 40 contains control and data information which appears on display 19 and as the activation of the corresponding indicator light 21-25 depending upon the data currently appearing on display 19 as well as the activation of any alarms. Interrogator/printer/  
10 tape recorder interface 38 permits an interrogator/printer or a tape recorder to be in communication with memory 36 and to receive the data stored in memory 36 in chronological order in response to a control signal supplied to control logic 34 from interface 38. Time information, which is part  
15 of the control logic 34, is supplied to the recorder 10 by time keeping device 30.

As best shown in Figure 3, the power supply 42 is normally run off of battery pack 43. Power supply 42 contains elec-  
20 trical regulation structure for stepping down the voltage supplied by battery pack 43, 12 volts, to the operating voltage, 5 volts, necessary to run the various electronic components of interrogator/printer 26. Also, power supply 42 detects insufficient voltage and gives a signal indicative  
25 thereof. The battery pack 43 can be connected to a power source such as a shipboard power supply power source through a charger 44 for recharging the battery pack 43. I/O connector 45 is a female multipin rack and panel type connector. I/O connector 45 provides the external connection to the  
30 memory 36 of recorder 10 and provides the connection between interrogator/printer 26 and/or tape recorder 27. The interrogator/printer 26 provides a single parallel bi-directional channel via I/O buffer 47 and control circuits 46 to provide communication with the recorder 10. A strobe  
35 signal controls the timing when the output channel is from

-7-

the recorder 10. Data for transmission to the recorder 10 is placed in an I/O buffer 47 to be read by the recorder 10 as it polls the interrogator/printer 26. A data acknowledge signal is generated by the recorder 10 to gate data from the  
5 interrogator/printer 26 onto the communication channel.

The strobe signal (normally high, negative going pulse) accompanies the data during a transfer to the interrogator/printer 26. The busy signal channel to the recorder 10  
10 becomes logically high to indicate a busy condition of the output channel until the interrogator/printer 26 is once again ready to receive data. The Data Available line of the input channel is set low whenever valid input data exists on the input channel. As data is read by the recorder 10, an  
15 acknowledge signal is presented as a negative going pulse which resets the Data Available, DATA AVAIL, signal on the low to high transition. This allows coordination of the input of data to the recorder 10. In interrogator/printer 26, I/O connector 45 is in two-way communication with single  
20 chip central processing unit (CPU) 48 via control circuits 46 and I/O buffer 47. CPU 48 is accessed via 58 key keyboard 52 through keyboard controller 50 and scan decode 51. Keyboard controller 50 is an integrated circuit which performs the function of converting contact closures in the keyboard  
25 matrix to binary signals for CPU 48. Scan decode 51 receives three signals from the keyboard controller 50 and selects one of eight columns on the keyboard. CPU 48 supplies /READ and /WRITE signals to keyboard controller 50 and receives an interrupt, /INT, signal for controlling the printing of  
30 data. The /READ, /WRITE and /INT signals are negative true logic signals i.e. 0=on, 5 volts = off. CPU 48 is also in two-way communication with the printer mechanism 56 via printer drive electronics 55. CPU 48 is connected to program memory 60 and data memory 62 directly and through address  
35 latch 64. CPU 48 provides a /READ signal directly to audible



-8-

signal 66 and a KEY CONTROL signal indirectly through address decode 65.

5 In Figures 4A, B and C, the numeral 70 designates the evaporator of the refrigeration system or temperature controller 68 for refrigerated container 11. The discharge from the evaporator 70 is supplied to the refrigerated container via line 71 and returned via line 72. The analog or signal interface section 32 contains signal conditioning circuits and an analog to digital converter (A/D) to convert temperature and controller signals into binary numeric data for the CPU. The signal conditioning consists of amplifiers and attenuation networks to scale temperature controller setpoint or active temperature, defrost and reference voltage signals into the range of the A/D converter. There are passive excitation circuits and a reference divider circuit to interface the recorder thermistors to the A/D converter. A dual 4 channel analog multiplexer (2 pole, 4 position switch) controlled by the microprocessor selects one of the 4 analog inputs (setpoint, defrost, supply or return) and one of two references (controller/4 or internal precision X 0.8) as the input signal and reference voltage for the analog to digital converter. The input signals and references are coordinated to allow the A/D converter to make a ratiometric conversion eliminating errors due to variations in reference voltages. The temperature of the air supplied to the container 11 via line 71 is sensed by thermistor 74 which provides a signal indicative thereof to excitation circuit 76. Similarly, thermistor 75 senses the temperature of the air returning to the evaporator from the container 11 via line 72 and provides a signal indicative thereof to excitation circuit 76. Multiplexer (MUX) 78, which is physically a portion of the same element as MUX 79, is operatively connected to excitation circuit 76 to receive signals indicative of the supply and return air temperature, as well as being connected to clamping

-9-

circuit 80 and divider 82. Clamping circuit 80 receives a signal indicative of a refrigeration system defrost from temperature controller 68 via interface and power connector 69 and provides a 1.5 volt signal to the MUX 78 upon the occurrence of a defrost. Divider 82 receives a setpoint signal indicative of the setpoint temperature selected on temperature controller 68 and which is divided by four and provided as an input to MUX 78. MUX 78 selects one of the four analog signals supplied by excitation circuit 76, clamping circuit 80 and divider 82, respectively, for digitization in response to a channel selecting signal supplied by CPU 92 via channel select signal line 83. The selected signal is supplied by MUX 78 to A/D converter 84 where it is digitized. A nominal 2.0 volt reference signal is supplied to MUX 79 by circuit 86 and also provides excitation to excitation circuit 76. A 9 volt  $\pm 5\%$  reference signal is supplied from temperature controller 68 via interface and power connector 69 to divider 88 which divides the reference signal by four and supplies the resultant signal to MUX 79. Responsive to a channel selection signal supplied by CPU 92 via line 83, MUX 79 provides a reference signal to A/D converter 84. A/D converter 84 provides an output signal via buffer 90 and the data bus to CPU timer RAM 92, and is connected by the data bus to address latch 106, low RAM address 116, 6Kx8 CMOS RAM 124, clock 130, display control 134 and printer data buffer 146.

Power supply 94 which is identical to power supply 42 of Figure 3 except for the AC input, receives power from a wide range of suitable AC and DC sources including a battery 93 which serves as a standby energy source. For example, power supply 94 can be connected to a 12-15 volt DC source or a nominal 24 volt AC source with a frequency range of 47-63 Hz. The power supply 94 subsystem provides operating voltages for the electronics and is derived from the 24v AC input and

the 12v DC supplied from the temperature controller 68 via interface and power connector 69. A 24v/12v transformer provides line isolation. The 12v AC secondary voltage is rectified and filtered. An electronic regulator maintains the main DC supply voltage at 5.7v DC with a pair of diodes isolating and stepping down the working voltages to 5.0v DC. The internal operating voltages include 5v DC operating supply, a 5v DC memory and clock supply, and a precision 2.5 volt reference. A nominal 3.6 volt primary battery 93 and switching circuit are provided to support the memory and clock when the 5 volt supplies are absent. A low battery voltage detection circuit senses a battery voltage above 2.95v DC and generates a "battery ok" signal to the CPU 92. An input voltage monitoring circuit monitors the 12v AC and detects inadequate input voltage level and generates a "low voltage" signal to the CPU 92 and the signal is inverted in inverter 133 to a "not low voltage" signal which is supplied to the display controller 134. The reset circuit which detects the application of DC voltage to the logic is provided to properly initialize the CPU 92 in a known state when power is restored. The reset circuit provides an indication of power interruption and restoration. Power supply 94 provides a stable output to components 92, 106, 108, 110, 90, 84, 78, 79, 76, 86, 88, 116, 118, 124, 130, 134 and 146. Power supply 94 provides a stable output to components 118, 124 and 130 in the absence of input power sufficient to maintain operation.

More specifically, the power supply subsystem 94 (42) provides the recorder 10 with operating voltages and reference voltages and several power related control signals. The control signals are a "low voltage" signal which is asserted when the input supply voltage falls below a preselected level and a "reset" signal indicating the requirement to place the CPU 92 into a reset state.

Referring now to Figure 5, the power supply 94 is composed of an alternating current transformer T1, rectifier diodes D1-D5, D9 and D10, filter capacitors C and an electronic voltage regulator A1 to produce regulated 5.7 VDC power as the primary operating power source. The 5.7 VDC power is passed through a diode D7 to the main 5 VDC power, Vcc, distribution to the electronic components excluding RAM 124, the real time clock 130, and the RAM high address latch 118. The components not powered from the main 5 VDC receive 5 VDC power, Vcmos, through a separate diode D6 from the 5.7 VDC source and alternately from a 3.6 VDC battery B1 via another diode D8 in the absence of the 5.7 VDC source.

A precision monolithic voltage reference A5 provides a 2.5 volt signal to the input of the unity gain operational amplifier A4 which buffers this signal and produces a 2.5 volt signal at its output which is utilized as the system reference voltage, Vref.

An operational amplifier A3 configured as a comparator and having two inputs one of which is connected to the precision 2.5 VDC reference and the other connected to a resistive/capacitive, RL/CL, network sampling the voltage level at the input of the voltage regulator and providing a signal proportional to the input voltage level. The output of the operational amplifier A3 is driven to the ground voltage level when the input voltage level falls to a level too low to sustain reliable operation, in this instance 17 VAC or 11.5 VDC. Otherwise the comparator output is near the 5 VDC level. This "low voltage" signal is routed to the central processor interrupt input to warn the CPU 92 of an impending power interruption and provide it sufficient operating time before loss of the operating voltage Vcc to save any information necessary for performing its functions after power is restored. These parameters include saving the time of the

last recorded data in memory and completion of storing any current record in the process of being stored. Capacitor C provides stored energy to the 5 volt supplies allowing operation after loss of input power. The stored energy is  
5 blocked from the low voltage detection circuit by a diode D9 enabling it to function autonomously.

The low voltage signal is also supplied to the reset circuit as one of the inputs. Referring to Figure 6, the /RESET  
10 input of the CPU 92 is shown connected to the common point of transistor Q1, diode Dr, resistor Rr, and capacitor Cr. The reset circuit operates in two modes as a consequence of power application or power removal from the system. The reset circuit is provided with a timed pulse on power applica-  
15 tion through the RC network, Rr/Cr, holding the reset input active low for a period of time sufficient to guarantee proper initialization of the CPU 92 and inhibiting it from operating until the supply voltage Vcc is adequate. Diode Dr acts to rapidly discharge Cr to insure reset action on  
20 short power interruptions.

Transistor Q1 which is driven from the logic circuit composed of gates and inverters U1 through U4 operates to place or hold the CPU 92 in a reset state whenever input voltage is  
25 inadequate for proper operation. The active low "low voltage" signal input to OR gate U3 is ORed with the signal from U4 inverted by U2 to cause the output of U3 to be low whenever the low voltage signal is true (low) and the CPU's "RESET ENABLE" output is also true (low) or the output of U3 is  
30 already low. The output of U3 becomes latched low when the low voltage signal is present and the enable signal is present simultaneously. Since all the CPU outputs are made logically high by the reset state, the RESET ENABLE signal exists only from the time the CPU 92 sets the signal low  
35 until the CPU enters the reset state thereby removing one

of the inputs enabling reset. The removal of the reset enable condition allows the reset to be removed when the low voltage signal becomes false. This enables the CPU 92 to resume operation from the reset state. The use of this  
5 circuit allows the CPU 92 to delay reset on sensing power interruption for completion of necessary shutdown procedures while permitting control of reset from the low voltage input.

10 The low voltage signal assures that the last recorded time is stored in RAM 124 prior to completion of activity terminated by a power interruption. Operational amplifier A6, also connected as a comparitor, senses the level of the 5 VDC  
15 Vref. The output of the "switch" A6 is connected to the output enable control input on the RAM high address latch 118 and places a low active signal when Vcc is above the 4 volt level enabling the latch to control the chip select inputs of the RAM 124 thereby enabling data transfers to or  
20 from the RAM 124 via the data bus. The "switch" A6 places a high signal on the output enable control of the latch when Vcc is below 4 volts thereby disabling control of the chip select signals to RAM 124 and allowing RAM 124 to be disabled from transferring data and preventing any changes in data  
25 stored in RAM 124 while the supply voltage is insufficient for operation of the CPU 92.

The RESET signal places the CPU 92 in the reset state where its data and control registers are initialized into a known  
30 state. Among these initializations is the setting of the program counter to zero. Upon leaving the reset state when the RESET signal is removed the CPU 92 begins executing instructions from program memory 108 at the current value of the program counter (e.g. zero). The processes performed  
35 include clearing all internal registers including one reserved

to indicate the status of recording power interruption.

This register is set to one after the power fail duration which is calculated by subtracting the last recorded time from the current value of time read from the CLOCK 130 after power is restored and data is to be recorded in RAM 124.

The first record stored in RAM 124 after a power interruption is information indicating the occurrence of the power interruption and information indicating the number of recording intervals elapsed since data was last recorded in RAM 124.

This method of measuring the duration of power interruptions permits the temperature record to be reconstructed chronologically without the need to record data during the periods when power is off and the refrigeration equipment is not operational. The temperature during power interruption is generally not meaningful as air circulation has stopped and supply and return air temperatures may not be indicative of the load condition. The temperatures at the restoration of power and the duration of power interruption are useful.

Furthermore, it is common for this equipment to remain unpowered for long durations (e.g. 15 days operating, 15 days non-operating) when operated for carrying perishable commodities in one direction and non-perishable commodities in the other direction between two points. Since only the standby CLOCK 130 and RAM 124 are operated during power interruptions the battery capacity requirements are minimized and the time span of retaining stored information is extended with a minimum number of RAM storage locations.

The modified recorder keyboard 12' when configured as shown in Figure 7 can provide access to the data stored in RAM 124. The "SHIFT" key 14' when held while depressing the °C/°F key 18' can enable or disable the recalling of data from RAM 124. When enabled, the secondary functions of the keys are active. The enabling of "RECALL" causes the first

-15-

record after "Trip Start" to be displayed. The records are displayed showing the record interval as the first item of a record. The "NEXT ITEM" key 17' will cause succeeding items of a record to be displayed. The items contained in a  
5 record include setpoint change information if the setpoint is changed in that interval, power interruption information if the interval follows an interval in which the power was interrupted, the supply air temperature, the return air temperature and the status of the defrost signal. Actuating  
10 the "NEXT RECORD" key 16' will cause the display of the same item in the next record or the record interval if that item is not present in the next record. The "RAPID ADVANCE" key 15' allows the next item or next record functions to be repeated by holding the selected function and rapid advance  
15 keys simultaneously.

The display recall feature permits review of the data stored in RAM 124 without the interrogator/printer 26. This is of interest in locations where an interrogator/printer is not  
20 available or functional and also provides feedback to the operator or maintenance personnel in evaluating previous operation of the refrigeration equipment.

The digital control logic electronics 34 and memory 36  
25 include a single chip microprocessor, 6144 low power random access memory (RAM) locations, 4096 program memory locations, a real time crystal controlled clock and miscellaneous gates and buffers to control the flow of data to and from the microprocessor. The 6144 (6K) bytes of RAM store recorded  
30 data and control parameters to be retained throughout power interruptions. The RAM and CLOCK are normally powered from the main 5 volt supply, but are supported by the battery 93 during power interruptions. This enables the system to maintain continuity of data and time. The switch 119  
35 detects loss of 5v supply and disables RAM input/output



circuitry to prevent erroneous alteration of the RAM contents during the removal, absence or application of control power.

The microprocessor 92 is a complete computer in itself,  
5 requiring only power source and clock signal for operation.  
Its program memory 108 is contained in a separate programmable  
read only memory (PROM) and has a capacity for up to 4096  
program instructions or data. Internal to the microprocessor  
10 are 128 bytes (locations) of RAM, an 8-bit timer and the  
central processing unit (CPU). There are 27 input/output  
(I/O) lines utilized to sense and control signals to and  
from the CPU. Additional control signals regulate the  
timing and direction of data flow to and from the microproces-  
sor, and select the destination or source of the data via  
15 external gates and buffers.

The RAM 124 is organized as three segments of 2048 bytes and  
an individual storage location is selected by loading the  
specific address into a memory address latch 116 and 118.  
20 Data can then be read or written to that location over the  
system data bus.

The CLOCK 130 which corresponds to time interface 30 of  
Figure 2 is a circuit containing frequency division circuitry  
25 and counters which accumulate values representing real time  
in seconds, minutes, hours, days, and months. The counters  
are individually addressable permitting the CPU to acquire  
the time information. The clock may also be set to a specific  
time or reset to 0 time by the CPU.

30

The A/D converter data is also addressable. The CPU can  
obtain status and data over the data bus making the analog  
values available to the processor.

A single bi-directional I/O buffer 146 routed to a connector 150 provides access to the CPU and permits the CPU to transfer data from itself or other devices on the data bus to an external device. This signal path is intended for use with the interrogator/printer when retrieval and printing of recorded data is required. It may alternatively be used with the aid of external circuitry to transmit or remotely display operating data.

CPU timer RAM 92 is accessed by keyboard switch matrix 100 which may have an auxiliary keyboard for displaying stored data. CPU 92 provides a channel selection signal to MUX 78 and 79, "read" and "write" signals to address decode 110, an address latch enable (ALE) signal to address latch 106 and a program strobe enable signal to 4Kx8 program memory 108 to distinguish program memory from other devices. Additionally, CPU 92 is in one-way communication with address latch 106, low RAM address 116, and display control 134 and is in two-way communication with 6Kx8 CMOS RAM 124, clock 130, and printer data buffer 146 via the data bus. Address latch 106 provides an address signal via the address bus to program memory 108, display control 134 and address decode 110. The output of program memory 108 is supplied via the data bus to CPU 92, to supply a stream of instructions coordinating the activities of CPU 92 and the peripheral parts to perform its functions.

Address decode 110 provides a plurality of mutually exclusive, unique signals which are provided to the various external devices one at a time. Specifically, address decode 110 provides an A/D address signal to select one of four digits for transfer to the CPU 92 via the data bus and buffer 90 and A/D read signal to cause the data transfer of the A/D digit selected, a RAM address decode signal to low RAM address 116 and high RAM address 118, a RAM read decode

-18-

signal and a RAM write decode signal to CMOS RAM 124, a clock I/O decode signal to clock 130, a "printer read" signal to printer data buffer 146 to control the direction of the buffer 146 and the printer I/O connector 150 to read  
5 data from a device, such as interrogator/printer 26, connected to the I/O connector 150, a "printer write" signal to control the timing of data transfer to the external device and a display write signal to display control 134.

10 Low RAM address 116 and high RAM address 118 each supply address information to CMOS RAM 124 which supplies data to CPU 92 via the data bus. Clock 130 supplies timing information to CPU 92 via the data bus. Clock 130 also receives  
15 data via the data bus from CPU 92 to initialize the state of the clock 130. The display control 134 controls the 5 digit LED display 140 through current control 136 and digit driver 138. Printer data buffer 146 supplies data to or reads data from the printer I/O connector 150 for printing by the  
20 external device, and receiving control signals from the external device.

The display includes five 7-segment hexadecimal indicators and five discrete light emitting diodes. All display indicators are driven by a single display controller which holds  
25 the desired display information in its memory and operates the indicators in a multiplexed configuration. The four rightmost 7-segment displays may indicate any of 16 hexadecimal codes while only three horizontal segments are displayable in the fifth digit. The rightmost digit is  
30 inverted to permit its decimal point to be displayed as a degree indicator. The display controller together with a segment current limiting resistors and digit drivers compose the balance of the display subsystem. A negative true low voltage signal disables the display drivers when active to  
35 blank the display signaling non-operating condition of the recorder.

Operation

Applying power to the recorder 10 will enable it to operate. The supply voltage must be between 17 and 30 volts AC with a frequency greater than 47 hertz and less than 63 hertz.

5 Adequate supply voltage level will be indicated by the red data display and other indicators illuminating. All indicators should light and the display read "AAAA" while the initial diagnostics and warmup routines are being exercised. Successful completion of warmup is confirmed by the current value  
10 of the default display (supply or return air temperature - see configuration) to appear in the data display. The status indicators will extinguish if the condition lighting the indicator is absent. Detection of a failure in a diagnostic will result in a "bbbb" being displayed on the  
15 data display and operation of the recorder being inhibited.

The default temperature is indicated on the data display when the warmup routine is complete. The default selection will be one of three modes depending upon recorder configuration:  
20 tion:

	<u>Mode</u>	<u>Description</u>
25	Return default	Return air temperature is displayed on power up. Supply is displayed by actuating the supply/return key. Supply Air Temperature indicator lights when supply temperature is displayed.
30	Supply default	Supply air temperature is displayed on power up. Return is displayed when supply/return key is depressed. Supply indicator is normally illuminated.

-20-

Supply/Return  
Alternate

5 The display of supply air temperature is alternated with return air each time the supply/return key is depressed. The last selected display will be shown on power up. The supply air indicator is lit when supply air temperature is displayed.

10 Selection of other displays is controlled by the three other display control keys. Each key causes the selected parameter to be displayed while the key is depressed. Releasing all keys returns the display to the default display. The other display control keys are:

15	<u>Display Key</u>	<u>Description</u>
	Lamp Test	Turns on all displays and indicators.
	Setpoint	Displays controller setpoint temperature (Displays controller active
20		probe temperature when external probe test switch is actuated).
	Elapsed Time	Displays time from trip start in hours.

25 The units of temperature are indicated according to the default units selection as configured when power is first applied. The temperature units may be changed by depressing the °C/°F key. Each time the °C/°F key is depressed the

30 units will alternate and the selected units will be displayed in the rightmost position of the data display.

The beginning of a trip record is indicated by recording the event in the recorders memory. Only one trip beginning can

35 be recorded and is done so by the following sequence of steps:

-21-

1. Depress the Elapsed Time key and observe the elapsed time.
2. Depress the Trip Start key while holding the Elapsed Time key.
3. Observe that the elapsed time is reset to zero.
4. Release both keys.

10

At the beginning of a shipment, the operator will indicate a new trip by actuating "trip start" keypad 13 while holding "time since last trip start (hr)" keypad 15. This denotes the beginning of a new record in RAM 124 by causing the NEXT pointer to be copied into the START pointer while the count of record intervals is reset to zero. Additionally, the elapsed time held in clock 130 is also reset to zero. This causes the new record to follow the old record in memory, preserving the old data as long as possible.

20

The data logger or recorder 10 will record the specified parameters once each thirty minutes whenever power is applied to the refrigeration equipment. Timing is internally generated by clock 130 for use in reporting the chronology of temperature measurements and event occurrences. Recorded data is retained and timing is continued in the event of a loss of power to the refrigeration unit. Data is not taken or recorded during power outages, however, the time of last data recording, LTIME, is stored in RAM for use in recovering the duration of power interruptions. The acquired data is stored in such a manner as to allow recovery in chronological order. The temperatures and events to be stored are:

30

1) the supply air temperature which is the temperature of the air being discharged from the refrigeration unit after passing through the coil of evaporator 70 and is sensed by thermistor 74 in line 71.

5

2) the return air temperature which is the temperature of the air being returned from the conditioned airspace to the refrigeration unit prior to entering the coil of evaporator 70 and is sensed by thermistor 75 in line 72.

10

3) a defrost occurrence which is the state of the defrost signal from the refrigeration unit temperature controller 68.

15

4) a power outage occurrence which is an event evidenced by the removal and re-application of AC or DC input control power and the duration of outage computed from the current clock value, CTIME, at power restoration and the last recorded time, LTIME, counted in 30 minute intervals.

20

5) the controller setpoint temperature which is the selected operating temperature obtained from the temperature selection potentiometer of the refrigeration unit.

25 The supply and return air sensors, thermistors 74 and 75, are independent of the sensors used for box temperature control. Each of the thermistors 74 and 75 is sampled at least once every five seconds, averaged over time period, e.g. a half hour, and recorded in RAM 124 at the end of the  
30 interval. The setpoint temperature is recorded in the first data record after initiating a "trip start" and then, only when changed by more than 0.5°C for the remainder of the trip. The data is stored in 6K RAM 124 which provides a worst case storage for data for sixty-two days without  
35 overwriting data, allowing storage of up to sixty setpoint

changes and up to sixty power interruptions of a duration greater than one record period.

RAM 124 is operated as a circular buffer using two pointers. One pointer locates the first record (START), and the other locates the last record (NEXT) recorded in memory. The circular buffer can be pictured as an endless memory loop. Data is stored in RAM 124 from the lowest RAM address selected by 116 and 118, ascending to the highest RAM address selected by 116 and 118, followed by a return to the lowest memory location. A segment of the data memory is reserved to store the pointers and other control parameters. Simultaneous erasure of the entire memory is not permitted. Each time data is written to memory and the address pointer (NEXT) is advanced, it is compared to the first (START) pointer to determine if every memory location has been used once. As NEXT is incremented and used as a pointer to the next available memory location, it will be equal to START if and only if all memory locations have been filled. Sixty days after trip start, the extended trip indicator 23 will start flashing on and off. When the pointers are equal, the extended trip indicator 23 is continuously energized and the extended trip flag is set. The extended trip flag is set to assist in correctly identifying the data for printout and is reset only upon the actuation of a trip start.

Battery 93 is connected to power supply 94 and is suitable for the retention of data in RAM 124 for one year over the operating temperature range. Power supply 94 includes circuitry for sensing a low battery capability or missing battery condition, when the recorder 10 is powered externally, and responsive thereto energizes replace battery indicator 24.



The temperature values obtained from the supply and return air thermistors 74 and 75 are compared to limits, e.g.  $-38^{\circ}\text{C}$  to  $+38^{\circ}\text{C}$ , to determine if an abnormal sensor condition exists such as open or shorted. If a temperature outside of the limits is detected, check sensor indicator 22 is energized and remains energized as long as there is external power to the recorder 10 or until a valid temperature is detected.

For setpoints of  $-10^{\circ}\text{C}$  and above, the recorder 10 will act to shut down the refrigeration unit if the supply air temperature drops  $3^{\circ}\text{C}$  below setpoint for twenty minutes. When the supply air temperature, under these conditions, is continually  $3^{\circ}\text{C}$  below setpoint for twenty minutes, a relay driver 160 is energized causing relay 162 to open its normally closed contacts interrupting power to the refrigeration control unit and signaling the condition remotely at indicator light 21. When shutdown occurs, low temperature indicator 21 is energized as a warning to the operator and, once initiated, the low temperature shutdown is latched and can be reset only by removal of external power to the recorder. The relay contacts can alternatively be used for remote signalling.

Display 19 normally displays return air temperature on power up and at all times thereafter unless one of the momentary functions is selected. Actuating the supply/return key 16 causes display 19 to indicate the supply air temperature and energizes supply air displayed indicator 25 as long as the key 16 is pressed. Releasing key 16 extinguishes indicator 25 and allows display 19 to revert to return air temperature indication. Optionally, the supply and return air temperature display indicator can be interchanged. This permits the supply air temperature indicator 25 to be the default temperature display. Also, supply/return key 16 may be operated in a toggle mode, switching between holding the supply or return air temperature on each actuation of key 16. The

default display will remain set to the last selected mode even through power interruption and restoration. The supply air displayed indicator 25 is energized whenever the supply air temperature is indicated on display 19.

5

The °C/°F key 18 permits selection of the units in which temperatures are displayed on display 19, key 18 works in a toggle fashion on each actuation of the key, i.e. the selected mode remains set until the next actuation of key 18. The

10 depressing of time since last trip start (hr) key 15 causes the current value of the recording interval counter, divided by two, to be displayed on display 19 as long as key 15 is held. A displayed value of zero represents the reset state.

15 Depressing lamp test key 14 energizes all of the lamps 21-25 for as long as it is held. This allows visual verification of proper operation of the lamps. Display 19 should indicate "-88.8°8" and indicator lights 21-25 should be illuminated. Releasing key 14 allows display 19 and indicator lights 21-  
20 25 to return to their normal mode.

The temperature controller's active temperature sensor value may be displayed by actuating an external momentary toggle switch (which will switch the setpoint temperature signal  
25 from the controller to the active probe temperature signal from the controller and input this to the recorder as well as indicating a test condition to the recorder by opening a set of normally closed contacts so the active probe temperature will not be recorded as a new setpoint) and depressing  
30 setpoint temperature key 17 to display this value. Both controller sensors may now be checked by adjusting the setpoint potentiometer above and below -10°C since the setpoint signal to the recorder 10 is ignored during this test mode. Releasing key 17 returns the display 19 to its  
35 default mode.

The recorder 10 provides a single parallel eight bit bi-directional channel to communicate with the interrogator/printer 26 or tape recorder 27. A strobe signal is generated by /WRITE when the output channel is addressed and data is  
5 supplied to printer I/O connector 150 to control timing for the data transfer into the external device, i.e. interrogator/printer 26 or tape recorder 27. An acknowledge signal is generated to the external device when the input channel is read and is furnished to CPU 92.

10

Data transfer is initiated by interrogator/printer 26 or tape recorder 27 which places a unique 5 bit code on the input lines of I/O connector 150 and asserts the data ready  
15 signal so as to be interpreted by the recorder 10 as a request to transfer data.

Upon recognition of a successful data transfer request, the recorder's display indicates data transfer activity. Data is then transferred from the recorder to the interrogator/  
20 printer 26 in fixed record lengths followed by a check sum. If the interrogator/printer 26 transmits a negative acknowledge, the previous record will be retransmitted. A positive acknowledge causes the next block to be transferred and so on until record transfer is complete. The number of allowable  
25 retransmission attempts shall be limited by the interrogator/printer 26.

An acknowledge or negative acknowledge character is sent to the recorder 10 as a result of the check sum computation and  
30 comparison performed on the received data by the interrogator/printer 26. A positive acknowledge will enable the recorder to transmit the next successive block of data or terminate output if data transfer is complete. A negative acknowledge will result in a retransmission of the previous block. The  
35 interrogator/printer thereby retains control of the number of attempts to transfer a block of data.

Failure to get an acknowledge, complete a one byte data transfer or loss of the /PRINTER PRESENT signal for more than 250 msec will terminate interrogator service, requiring the re-initiation of recorder/interrogator communications.

5

The interrogator/printer 26 receives data at its maximum data transfer rate and stores the data in an internal buffer memory where it is available for analysis and printing.

10 The data received from the recorder 10 is decoded into temperatures and status information, isolated into individual records for each recording interval.

Data is formatted as it is output to the printing device to  
15 minimize working memory requirements.

The interrogator/printer 26 carries on a dialog with the operator via the keyboard 52 (input) and printer 56 (output). The dialog provides communications with the operator necessary  
20 to configure the interrogator, retrieve data from the recorder or print reports.

To transfer data to a tape recorder 27, the recorder 10 is instructed through keyboard 100 or from the tape recorder to  
25 transfer data to the tape recorder 27. Since the data transfer of information from recorder 10 is a reading of the information stored in RAM 124 the information remains in RAM 124 until overwritten.

30 In summary, the recorder 10 monitors and records the temperature of the air supplied to and returned from the refrigerated container, the setpoint for the temperature in the refrigerated container as well as recording the occurrence and duration of defrost and power interruption. The recorder serves to  
35 only record data except for the occurrence of too low of a

temperature in the refrigerated container for a predetermined time whereupon the recorder exerts a control function which serves to shut down the temperature controller or refrigeration system 69. The data is recorded such that the records  
5 for the last sixty-two days of operation is stored in memory whereby the data, or at least most of it, is available for a number of days after the completion of a trip. Also, the reading of data out of the recorder does not remove the record of the data as is the situation with a paper record.  
10 The data can be read out by an interrogator/printer which processes the data and provides a hardcopy report or can be recorded, as stored in memory, by a recorder for later transfer to a microprocessor, or the like, for processing.

15 The components configured to make the recorder 10 and the interrogator/printer 26 are off-the-shelf components with the following components being suitable for use in the disclosed device:

20

<u>Ref. #</u>	<u>Name</u>	<u>Model or Part No.</u>
42,94	regulator (Mfg. - National Semiconductor)	7805
25	diodes (Mfg. - Fairchild)	IN4005
30	transformer (Mfg. - Essex)	24 to 12 volt
	operational amplifier (Mfg. - RCA)	CA3140

		operational amplifier	LM224
		(Mfg. - National Semiconductor)	
5		control circuits	74HC10, 74HC04
		(National Semiconductor)	74HC32,
	43	battery	V2008
		(Mfg. - Union Carbide)	
10	46	control circuits	74HC10, 74HC04,
		(National Semiconductor)	74HC32,
	47	I/O buffer	74HC245
		(Mfg. - National Semiconductor)	
15			
	48	CPU	8031
		(Mfg. - Intel)	
	50	keyboard controller	8259A
20		(Mfg. - Intel)	
	51	scan decoder	74HC138
		(Mfg. - National Semiconductor)	
25	52	keyboard	
		(Mfg. - Advanced Input Devices)	
	55	printer drive electronics	
		(Mfg. - Star Micronics)	
30			
	56	printer mechanism	
		(Mfg. - Star Micronics)	
	60	program memory	2732A
35		(Mfg. - Intel)	

-30-

62	data memory	μ PD446
	(Mfg. - NEC)	
5	64	address latch 74HC374
		(Mfg. - National Semiconductor)
	65	address decode 74HC138
		(Mfg. - National Semiconductor)
10	68,70	temperature controller/ refrigeration system
		(Mfg. - Carrier Transicold Co.)
15	69	interface and power connector
		(Mfg. - Molex)
	74,75	thermistor probe 12-00216
		(Mfg. - Carrier Transicold Co.)
20	76	resistors
	78,79	analog multiplexer, CD4052
		dual 4 channel
		(Mfg. - RCA)
25	80	diodes IN4005
		(Mfg. - Fairchild)
		resistors
30	82,88	operational amplifier LM224
		(Mfg. - National Semiconductor)
35	84	A/D converter, 12 bit ADC3711
		integrating
		(Mfg. - National Semiconductor)

-31-

86	voltage reference	LM236
	(Mfg. - National Semiconductor)	
90	buffer - tri state	HCMOS 74SC244
5	(Mfg. - Semi Processes)	
92	microprocessor - single	8039
	chip with RAM and timer	
	(Mfg. - Intel)	
10		
93	battery - memory back	V2008
	up type	
	(Mfg. Eveready)	
15	100	keyboard/escutcheon - Custom
		membrane type
		(Mfg. - EECO)
	106	latch octal D type 74HC374
20		(Mfg. - National Semiconductor)
	108	memory - read only, LD2732A
		programmable
		(Mfg. - Intel)
25		
	116,118	latch octal D type 74HC373
		(Mfg. - National Semiconductor)
	124	memory CMOS RAM 2Kx8 UPD446
30		bits, 3 required
		(Mfg. - NEC)
	130	real time clock MM58167
		(Mfg. - National Semiconductor)



-32-

134	display controller	74C917
	(Mfg. - National Semiconductor)	
136	resistors	
5		
138	transistor array	ULQ2003
	(Mfg. - Sprague)	
140	5 digit LED display	MAN6740
10	(Mfg. - General Instrument)	
146	buffer octal bi-directional	74SC245
	(Mfg. - Semi Processes)	
15		
160	relay driver	ULQ2003
	(Mfg. - Sprague)	
162	relay	LZ-12
20	(Mfg. - ITT)	

Although a preferred embodiment of the present invention has been illustrated and described, other changes will occur to those skilled in the art. For example, the interrogator/printer could be located at a remote location and connected to the recorder through suitable lines and a modem. Also, the interrogator/printer could be combined with the recorder to provide storage and recall in one unit. It is therefore intended that the scope of the invention is to be limited only by the scope of the appended claims.

CLAIMS

What is claimed is:

1. Recorder apparatus for recording for later recall a plurality of conditions in a refrigeration system comprising:

I. means for receiving a plurality of inputs representing refrigeration system conditions and including;

a. means for receiving information indicative of supply air temperature and providing a first analog signal indicative thereof;

b. means for receiving information indicative of return air temperature and providing a second analog signal indicative thereof;

c. means for receiving information indicative of a defrost condition and providing a third analog signal indicative thereof;

d. means for receiving information indicative of temperature setpoint and providing a fourth analog signal indicative thereof;

e. multiplexing means for individually selecting each one of said four analog signals and providing said selected signals as first output signals;

f. analog to digital converter means for digitizing said first output signals and producing said digitized first output signals as second output signals;

II. logic and memory means for processing and periodically chronologically storing said second output signals including;

a. random access memory means for storing and recalling stored data;

-34-

- b. random access memory address means for supplying address information to said random access memory means to cause said random access memory means to operate as a circular buffer;
- c. address decode means having a plurality of output signals for providing instructions to said random access memory means and said random access memory address means;
- d. central processing unit and program memory means operatively connected to:
  - i. said multiplexing means to cause said individually selecting of each one of said four analog signals;
  - ii. said analog to digital converter means for receiving said second output signals;
  - iii. said address decode means to cause said address decode means to provide said output signals; and
  - iv. said random access memory means to furnish data for storage;

III. means for receiving information queries and for transferring said data stored in said random access memory means responsive to said information queries including;

- a. input/output connector means operatively connected to said logic and memory means for transmitting information queries thereto and for transferring said data stored in said random access memory means responsive to said information queries and under the control of said central processing unit and program memory means.

2. The recorder apparatus of claim 1 further including:

-35-

## IV. display means including;

- a. display means for digitally displaying one of said four analog signals;
- b. selector means for selecting which one of said four analog signals is displayed digitally.

5

3. The recorder apparatus of claim 1 further including:

## IV. display means including;

- a. display means for digitally displaying one of said four analog signals or said stored data corresponding thereto;
- b. selector means for selecting which one of said four analog signals or said stored data corresponding thereto is displayed digitally.

10

15

4. The recorder apparatus of claim 1 further including disabling means operatively connected to and controlled by said central processing unit and program memory means for providing a shutdown signal to a refrigeration system responsive to overcooling over a predetermined period.

20

5. The recorder apparatus of claim 1 wherein said means for receiving a plurality of inputs representing system conditions further includes:

25

- g. second multiplexing means for providing signals to said analog to digital converter means;
- h. means for sensing a power interruption to a refrigeration system and for providing a signal representative thereof to said central processing unit and program memory means;
- i. means for sensing a power restoration and for providing a signal representative thereof to said central processing unit and program memory means.

30

35

-36-

6. The recorder apparatus of claim 1 wherein said logic and memory means further include:

- 5 e. means for sensing the absence of power and for protecting said data stored in said random access memory responsive thereto.

7. The recorder apparatus of claim 6 wherein said logic and memory means further include:

- 10 f. time keeping means for accurately measuring the passage of time and for providing a signal indicative thereof to said central processing unit and program memory means thereby controlling the frequency and chronology of said second output signals and measuring  
15 the duration of a power interruption.

8. The recorder apparatus of claim 1 further including:

- 20 IV. interrogator/printer means adapted to be connected to said means for receiving information queries to provide information queries and to receive data transferred responsive to said information queries and including:

- 25 a. input/output connector means for connecting said interrogator/printer means to said recorder apparatus;  
b. printing means;  
c. keyboard means;  
30 d. second logic and memory means operatively connected to said input/output connector means, said printing means and said keyboard means for providing information queries entered by said keyboard means to said recorder apparatus via said input/output connector  
35 means and for processing, storing and printing

said processed data transferred by said recorder apparatus in response to said information query.

9. Recorder apparatus for recording for later recall a plurality of conditions in a refrigeration system comprising:

means for receiving a plurality of inputs representing refrigeration system conditions;

memory means for periodically, chronologically storing said plurality of inputs representing refrigeration system conditions; and

means for receiving instructions and for transferring said stored plurality of inputs responsive to said instructions.

10. The recorder apparatus of claim 9 further including display means for selectively displaying one of said stored plurality of inputs.

11. The recorder apparatus of claim 9 further including an interrogator/printer means adapted to be selectively connected to said means for receiving instructions, said interrogator/printer means including means for providing instructions to said means for receiving instructions and means for receiving said stored plurality of inputs responsive to said instructions.

12. The recorder apparatus of claim 9 further including means for shutting down a refrigeration system responsive to overcooling.

-38-

13. A method for storing information for later recall comprising the steps of:

receiving a plurality of inputs representing operating conditions in a system;

periodically, chronologically storing in memory the inputs representing the operating conditions in the system; and

responsive to receiving instructions, transferring from memory the stored inputs.

14. The method of claim 13 wherein the step of periodically, chronologically storing in memory includes the steps of:

periodically checking each of the plurality of inputs representative of air temperature over a period of time;

averaging the values of each of the plurality of inputs representative of air temperature over a fixed period of time; and

storing the averaged values in memory.

15. The method of claim 14 further including the step of shutting down the system when one of the inputs representative of an air temperature is below a setpoint by a predetermined amount for a predetermined time.

16. The method of claim 14 wherein the step of storing the averaged values in memory includes the steps of:

determining whether memory is full; and

if the memory is full, storing the averaged values by overwriting the oldest data in memory.

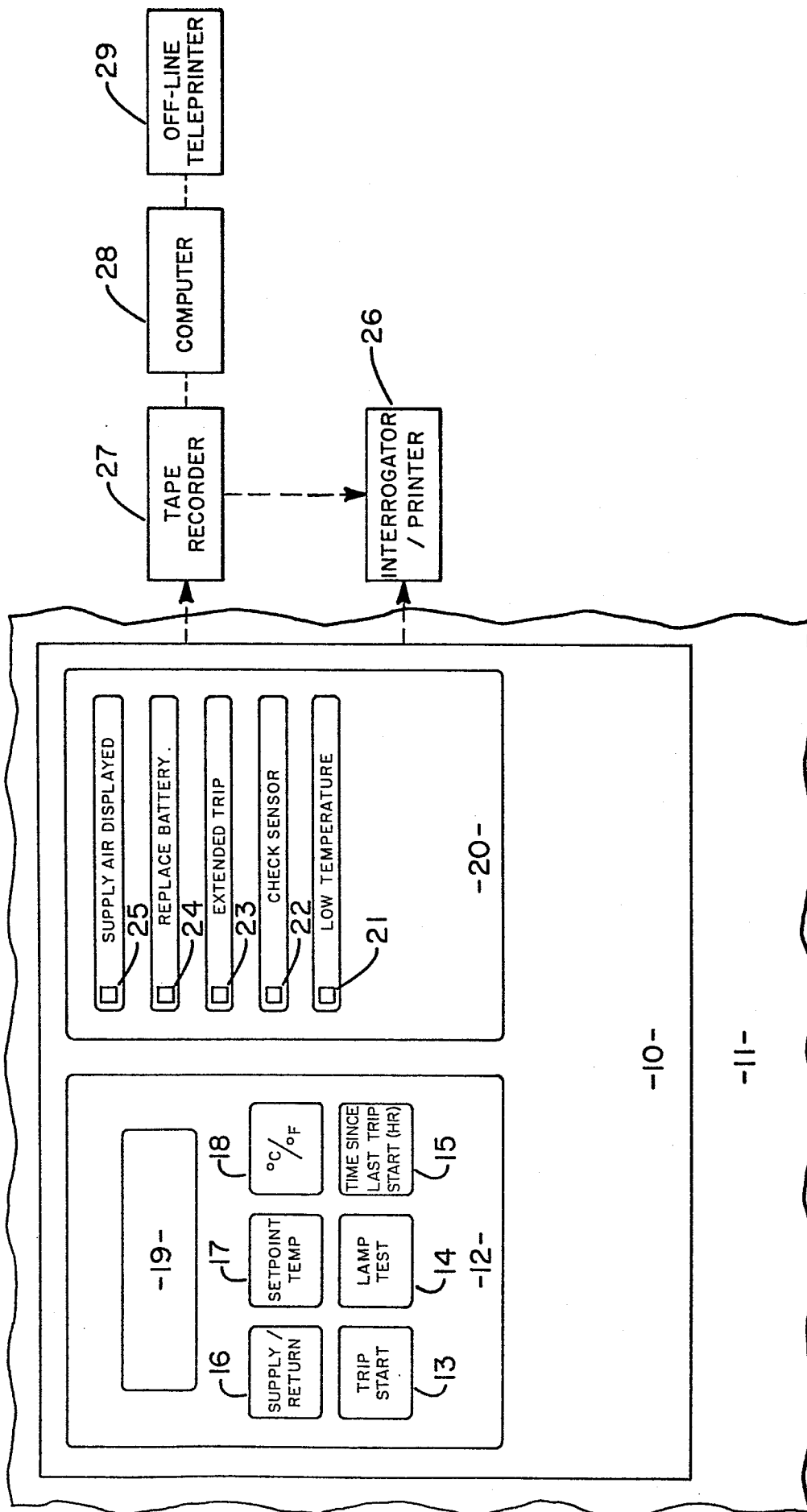
17. The method of claim 13 wherein the step of chronologically storing in memory the inputs representing the operating conditions in the system includes the steps of:

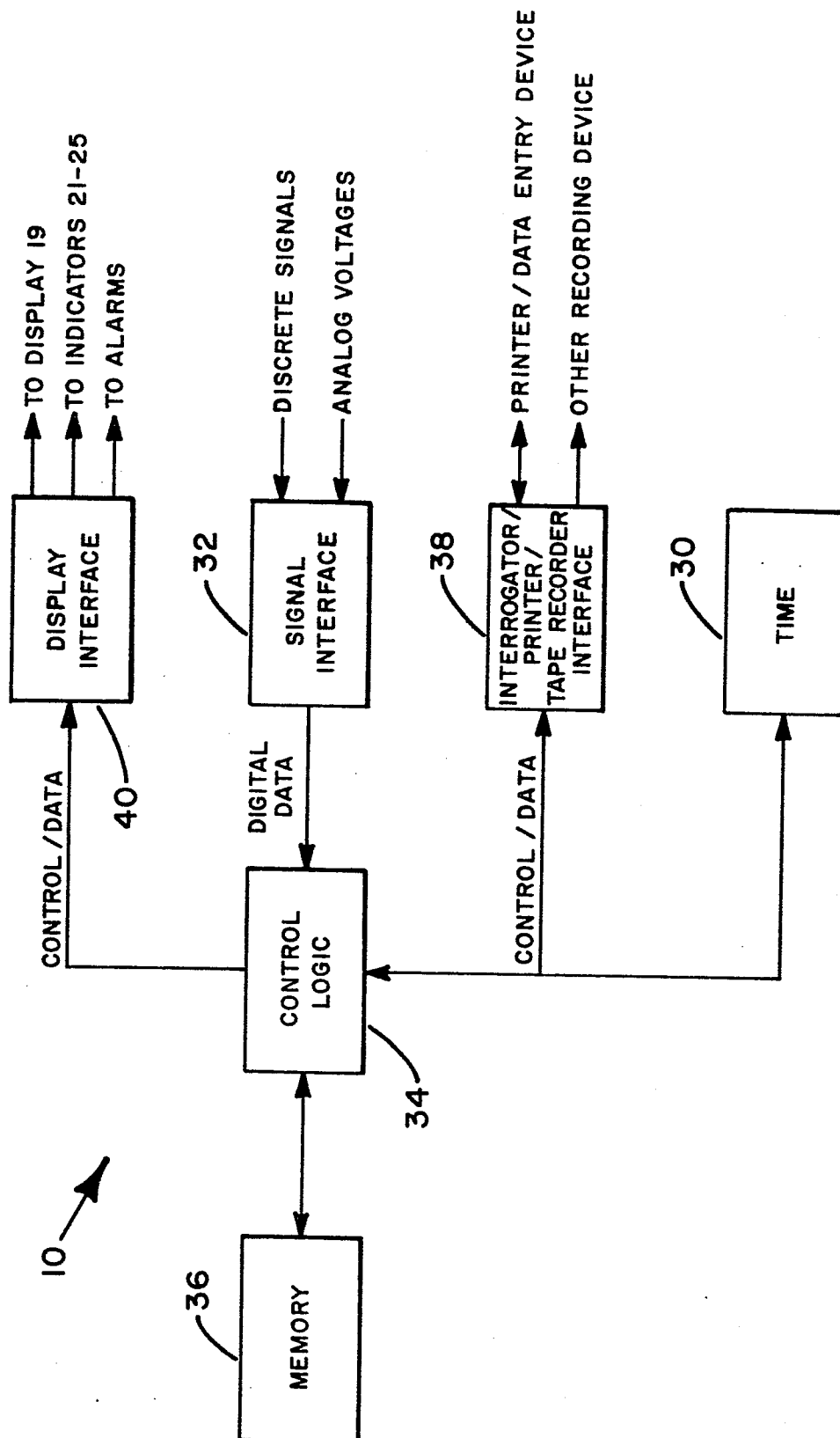
- storing the time of the start of a power outage;
- storing the time of the end of a power outage;
- computing the duration of a power outage;
- storing the duration of a power outage whereby power outages are tracked with the use of little memory while providing a complete reconstruction of the chronological record of system operations.

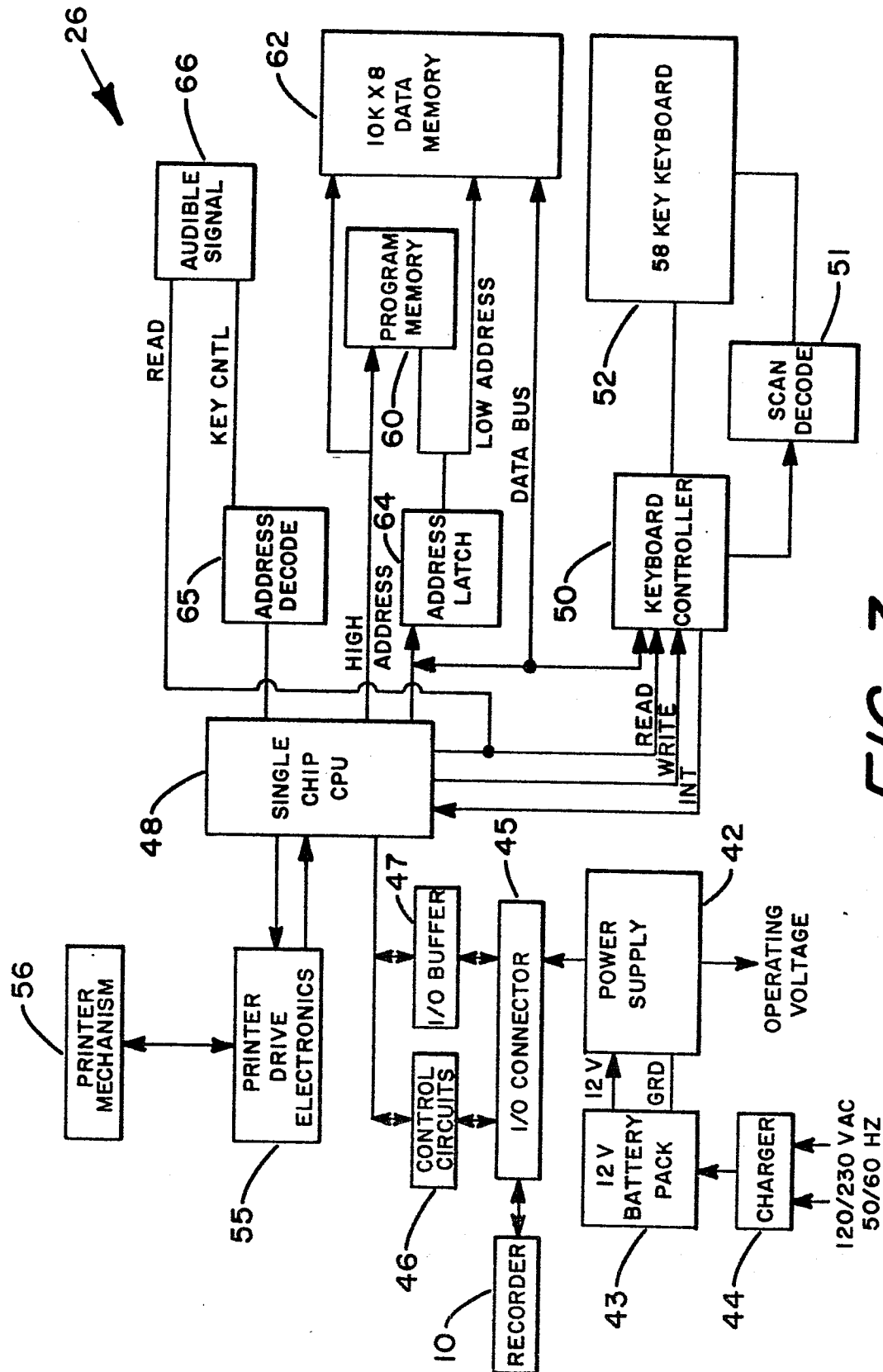
18. A method for recording the interruption of power comprising the steps of:

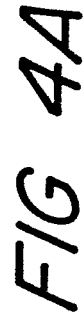
- detecting the removal of power;
- storing the time of power removal;
- detecting the reapplication of power;
- storing the time of power reapplication;
- computing the duration of power removal;
- storing the duration of power removal whereby power outages are tracked.

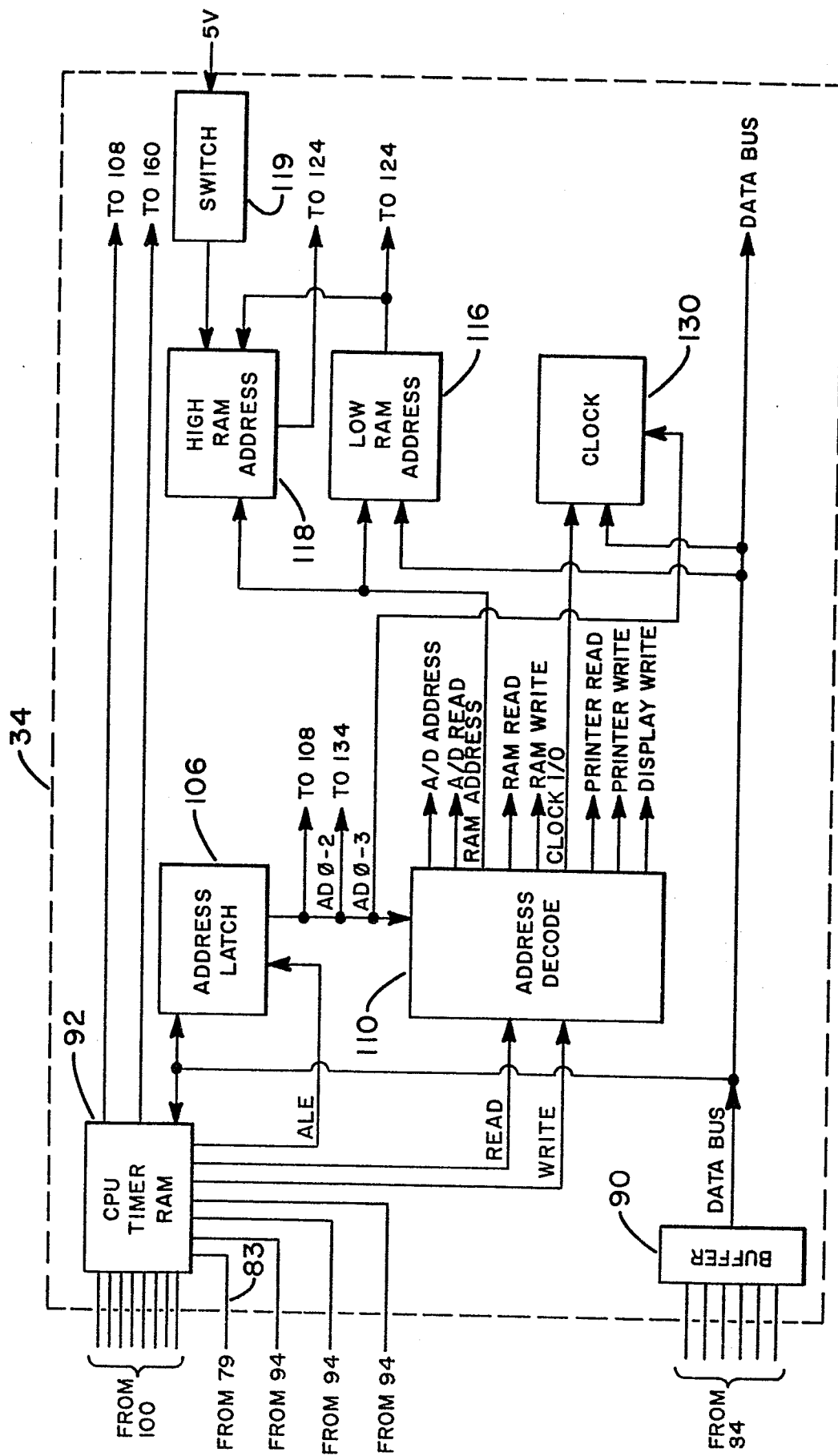


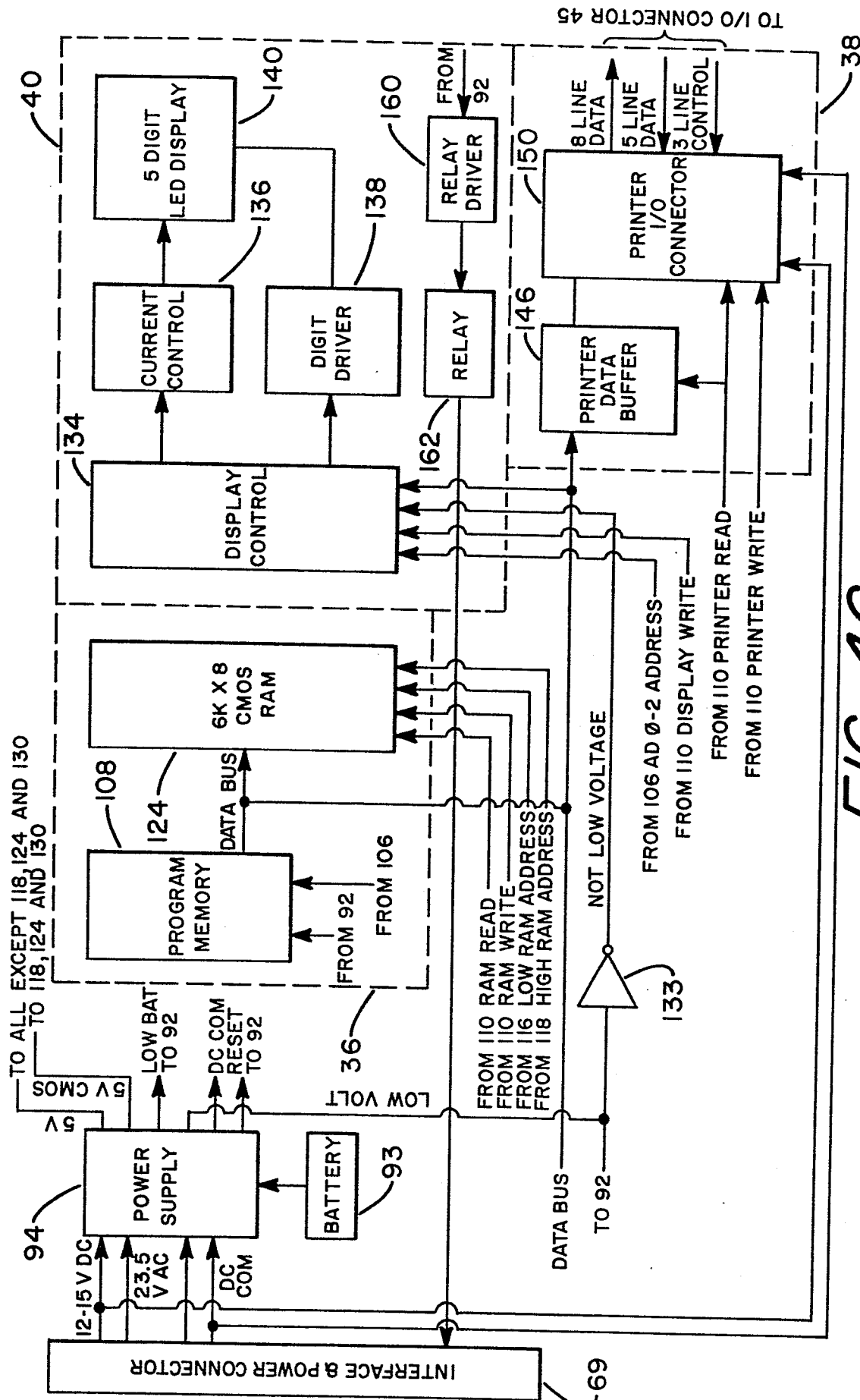
FIG. 1

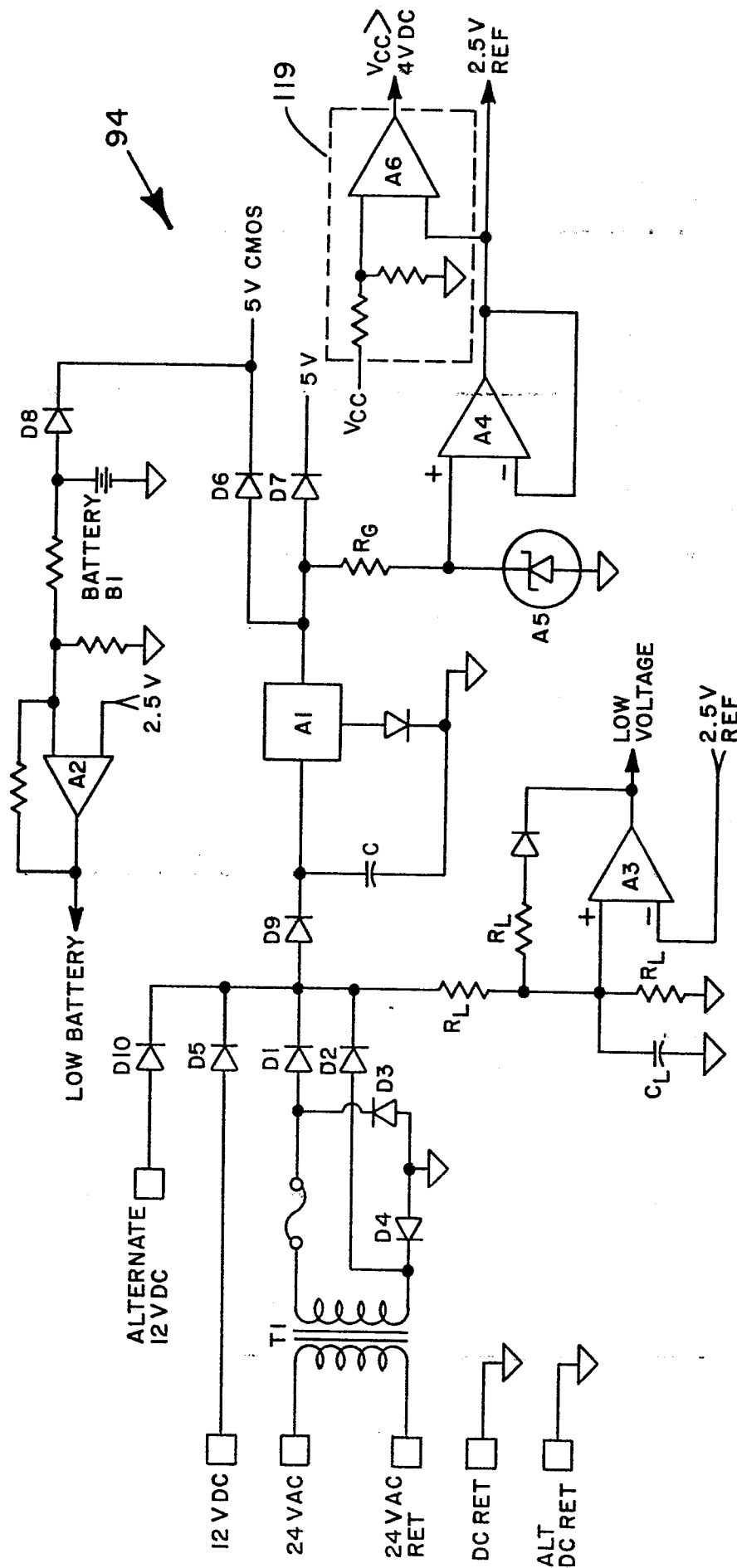
FIG. 2

FIG. 3



FIG. 4B

FIG. 4C



**FIG. 5**

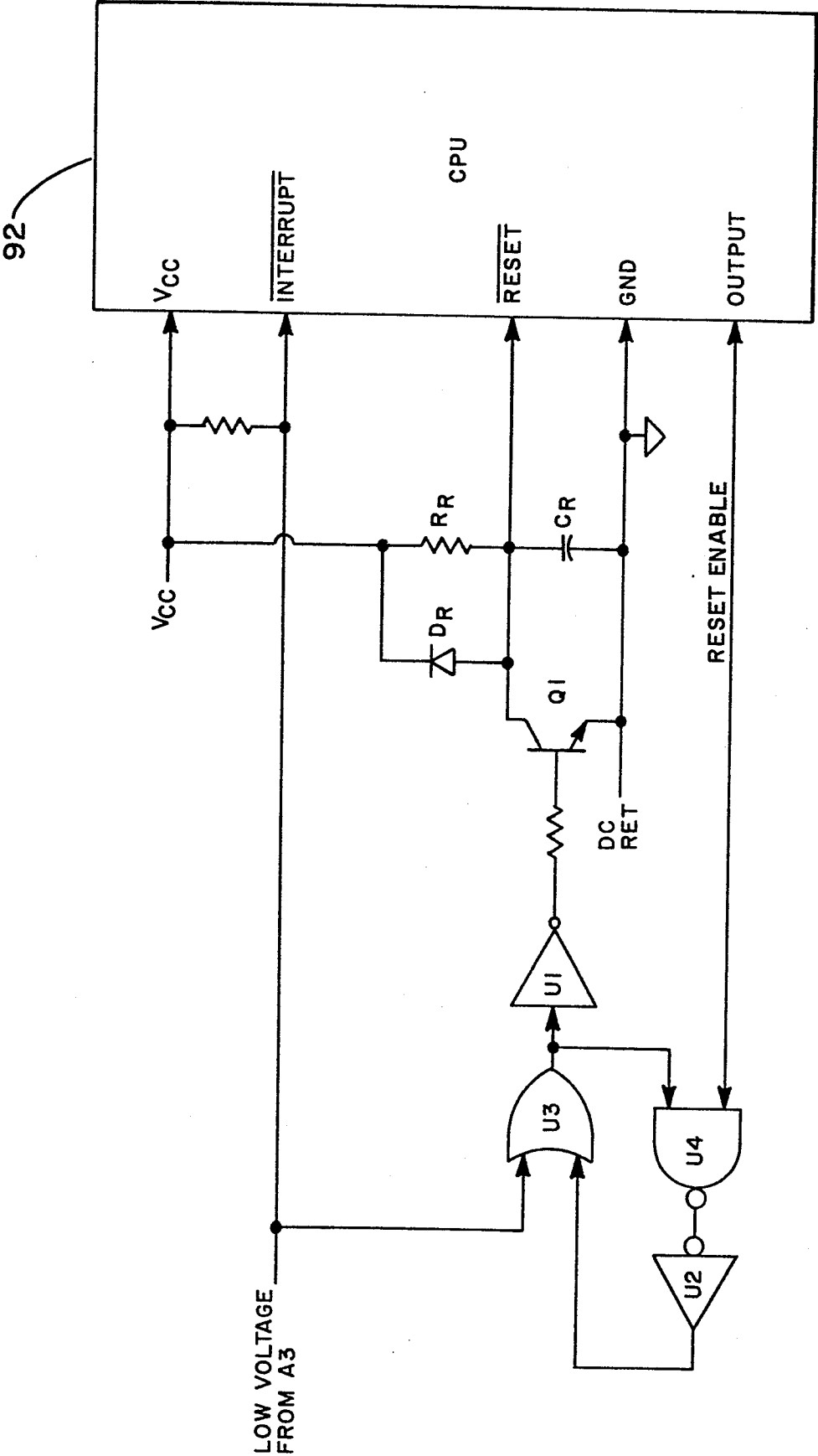


FIG. 6



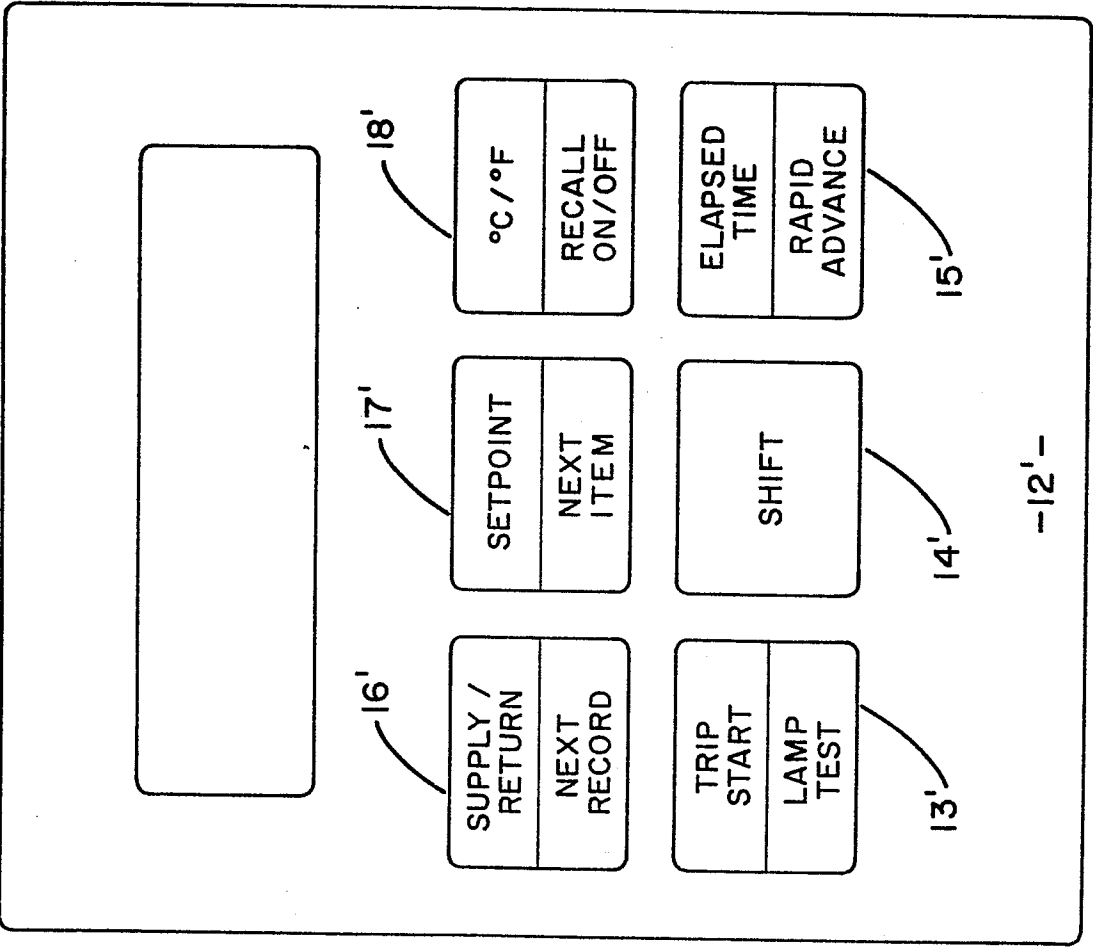
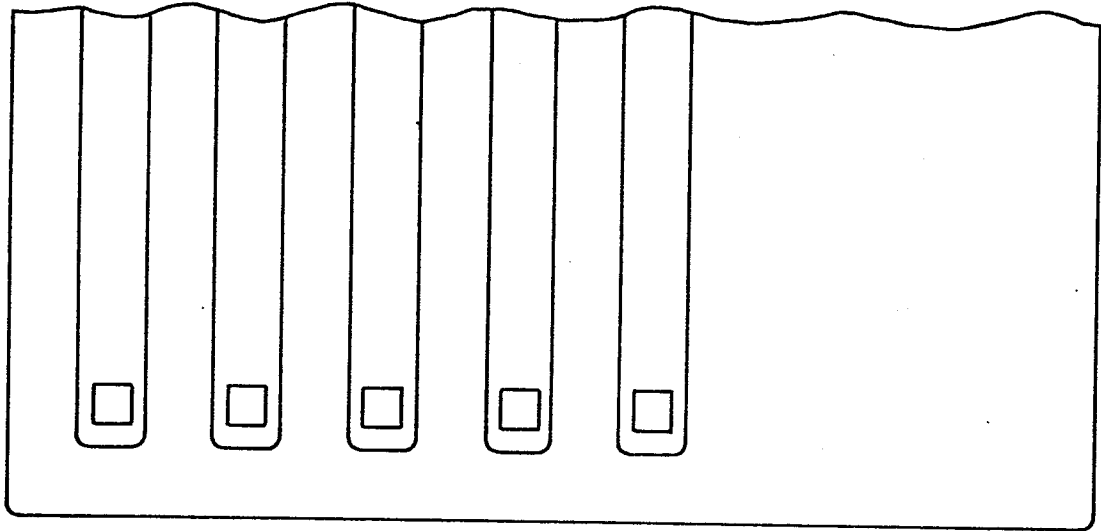


FIG. 7