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(71) Applicant
Total Temperature Control Limited

(Incorporated in the United Kingdom)

Levenmouth Business Centre, Riverside Road, Leven,
Fife, KY8 4LT, United Kingdom

(72) Inventor
David Chester Campbell

(74) Agent and/or Address for Service
Haseltine Lake & Co
Hazlitt House, 28 Southampton Buildings,
Chancery Lane, London, WC2A 1AT, United Kingdom

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(56) Documents cited
GB 2098362 A **US 4501125 A** **US 4283921 A**

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UK CL (Edition K) **G3R RBQ22 RBQ48**
INT CL^5 **F25B, F25D, G05D**
Online databases: WPI

(54) Control of refrigerators and freezers

(57) A refrigeration or freezer controller is formed as an ASIC or integrated circuit micro-controller to receive an actual temperature value from a temperature sensing thermistor (S1, S2). The circuit is supplied with or stores cut-in and cut-out temperature values for comparison (113) with the actual temperature value. In one embodiment a plurality of sets of cut-in and cut-out values is stored in non-volatile memory (100) and digital addressing means (101, 102) allow a user to select a set by means of an external actuator (104). Timing data may be stored in the controller to override temperature control when stored minimum and maximum refrigeration on and off times are attained, e.g. on failure of the temperature sensor or to prevent cycling of the controller. A temperature sensor simulator (Figure 6) may be used for calibration purposes.

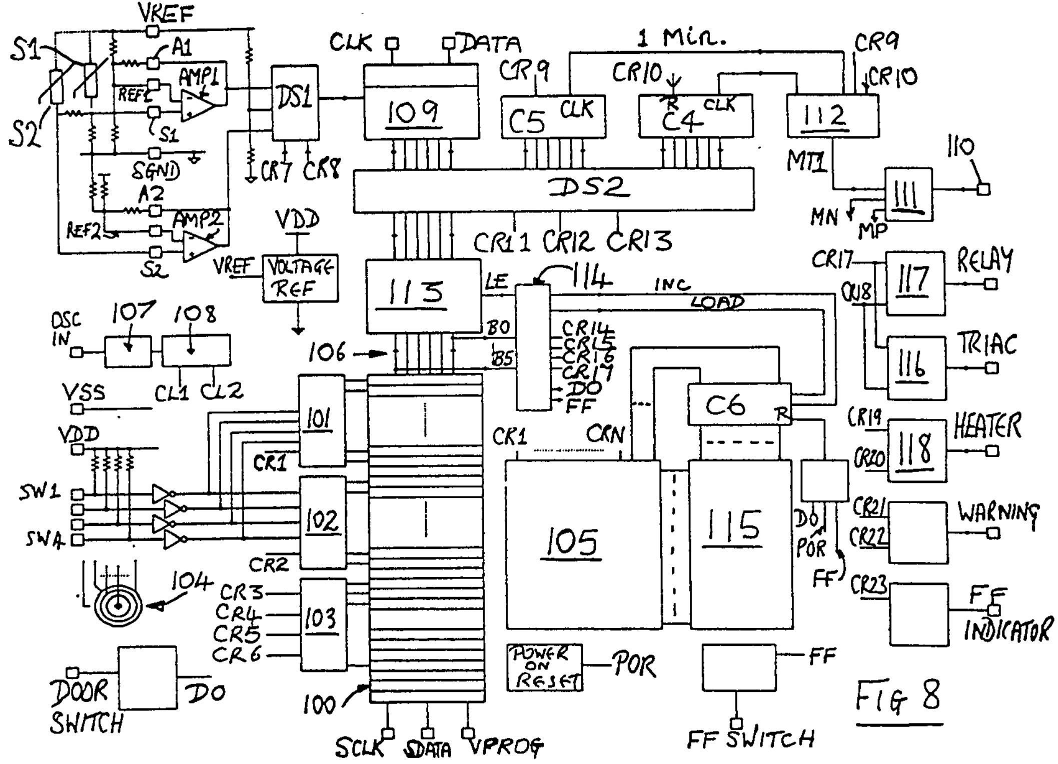

Fig 8

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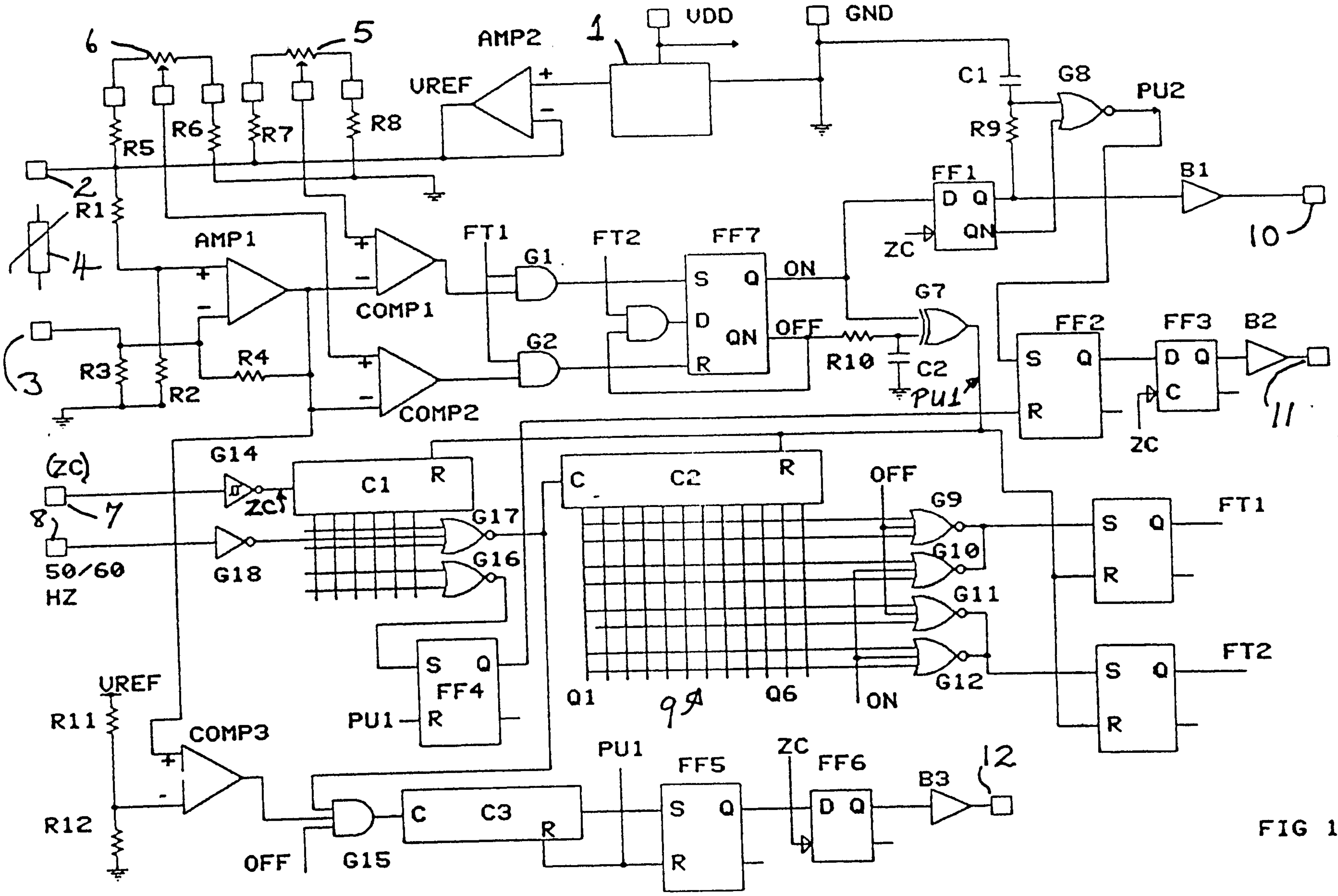
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.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GND
AMP2
UREF
1
6
5
R5
R6
R7
R8
2
R1
4
AMP1
3
R3
R2
R4
COMP1
COMP2
FT1
G1
G2
FT2
FF7
S
D
R
Q
QN
ON
OFF
R10
C2
PU1
G7
C1
R9
G8
PU2
FF1
D Q
ZC
QN
B1
10
FF2
S Q
R
FF3
D Q
C
ZC
B2
11
(ZC)
7
8
50/60
HZ
G14
ZC
G18
C1
R
G17
G16
FF4
S Q
PU1
R
C
C2
R
Q1
9A
Q6
OFF
ON
G9
G10
G11
G12
S Q
R
FT1
S Q
R
FT2
UREF
R11
R12
COMP3
OFF
G15
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C3
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PU1
FF5
S Q
R
ZC
FF6
D Q
B3
12

FIG 1

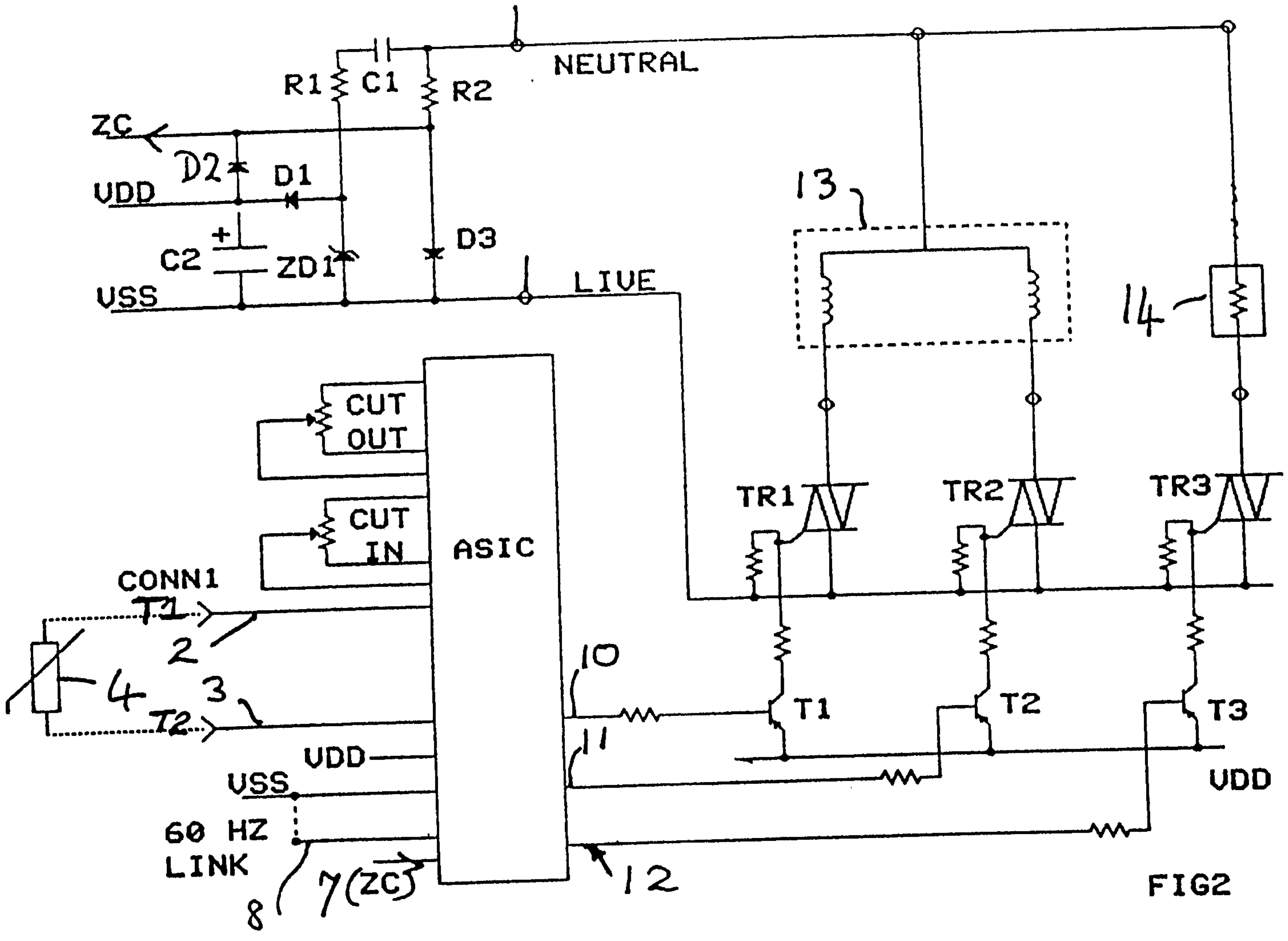
NEUTRAL
LIVE
R1
C1
R2
ZC
D2
D1
UDD
C2
+
ZD1
D3
USS
13
14
CUT OUT
CUT IN
ASIC
CONN1
T1
T2
2
3
4
UDD
USS
60 HZ LINK
8
7(ZC)
10
11
12
TR1
TR2
TR3
T1
T2
T3
UDD

FIG2

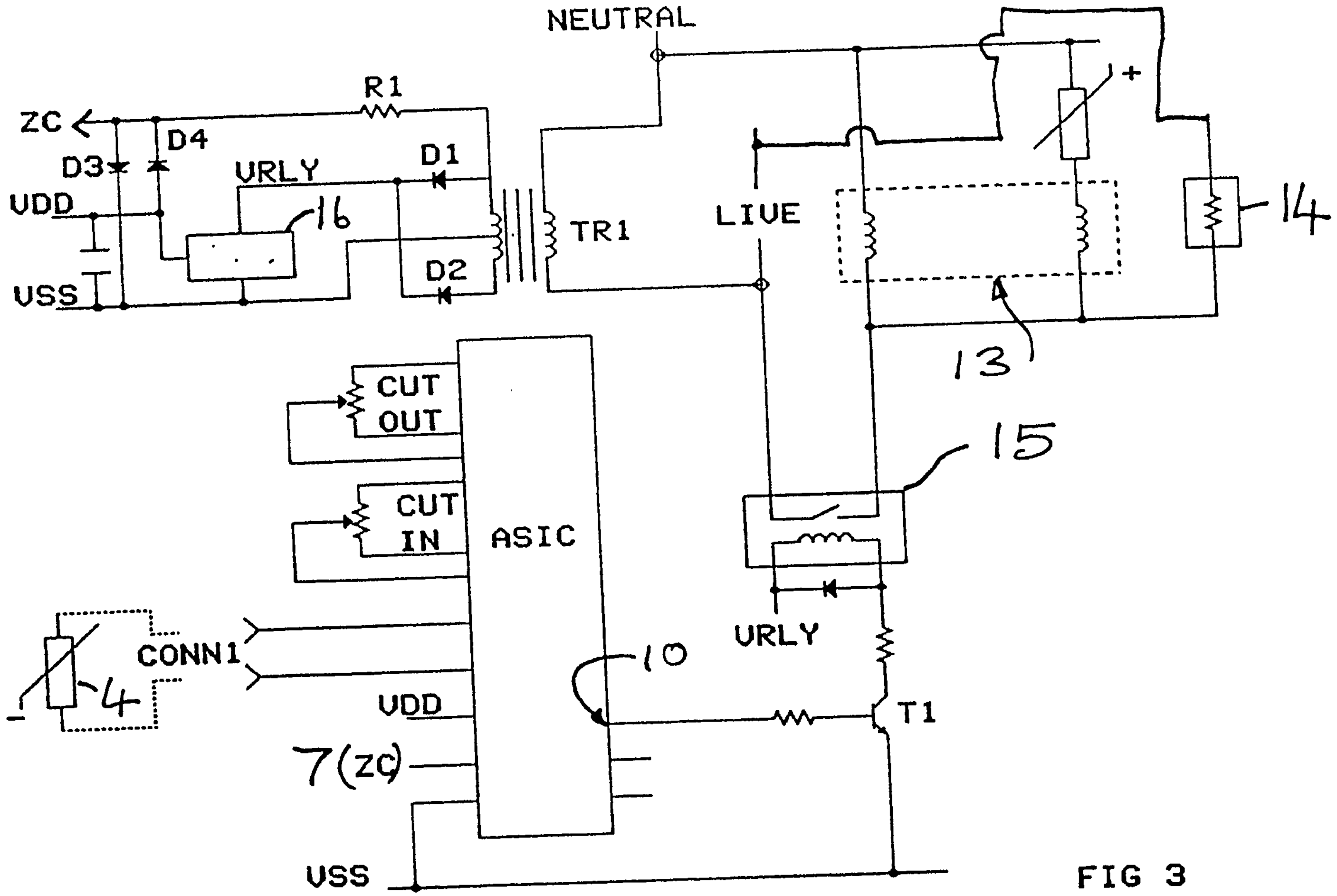
NEUTRAL
R1
ZC
D4
D3
D1
URLY
UDD
16
TR1
LIVE
+
14
D2
USS
13
CUT OUT
CUT IN
ASIC
15
URLY
CONN1
4
10
UDD
T1
7(ZC)
-
USS

FIG 3

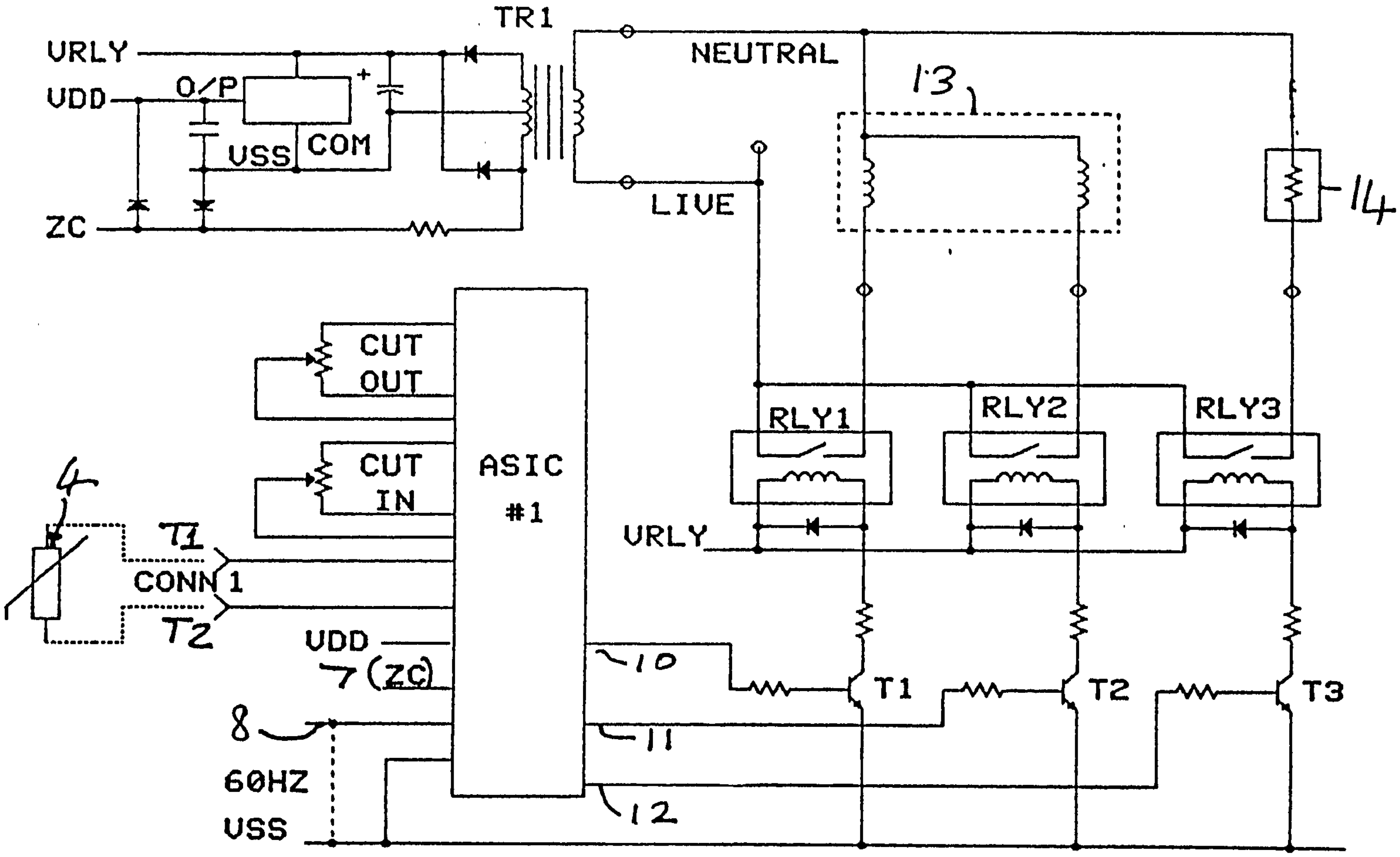
TR1
URLY
UDD
O/P
USS
COM
ZC
NEUTRAL
LIVE
13
14
RLY1
RLY2
RLY3
URLY
CUT OUT
CUT IN
ASIC #1
4
T1
CONN 1
T2
UDD
7 (ZC)
8
60HZ
USS
10
11
12
T1
T2
T3

FIG 4

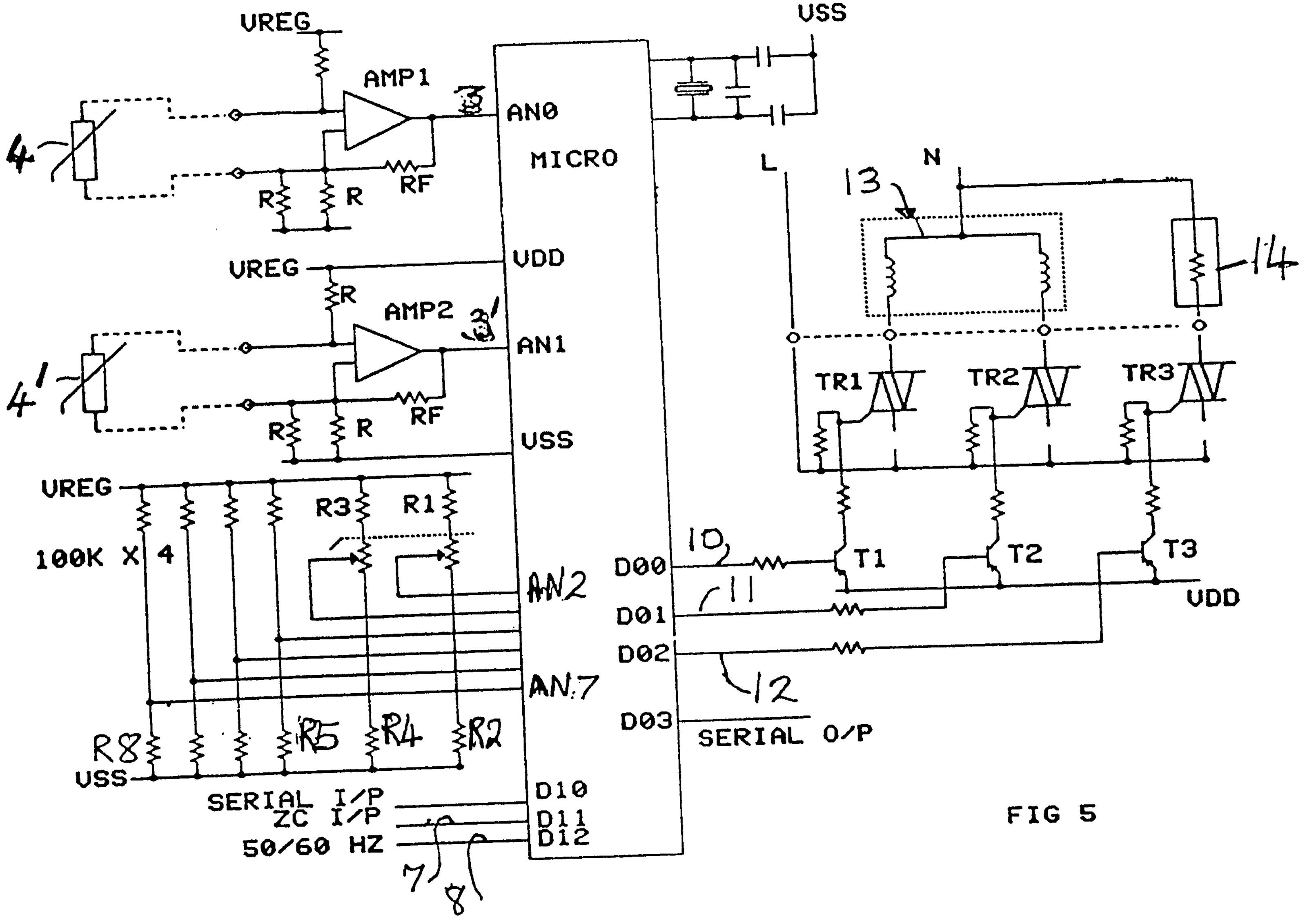
UREG
AMP1
3
AN0
MICRO
4
R
R
RF
UREG
VDD
R
AMP2
3'
AN1
4'
R
R
RF
VSS
UREG
R3
R1
100K X 4
AN2
AN7
R8
R5
R4
R2
VSS
SERIAL I/P
ZC I/P
50/60 HZ
7
8
D10
D11
D12
D00
D01
D02
D03
10
11
12
SERIAL O/P
VSS
L
N
13
14
TR1
TR2
TR3
T1
T2
T3
VDD

FIG 5

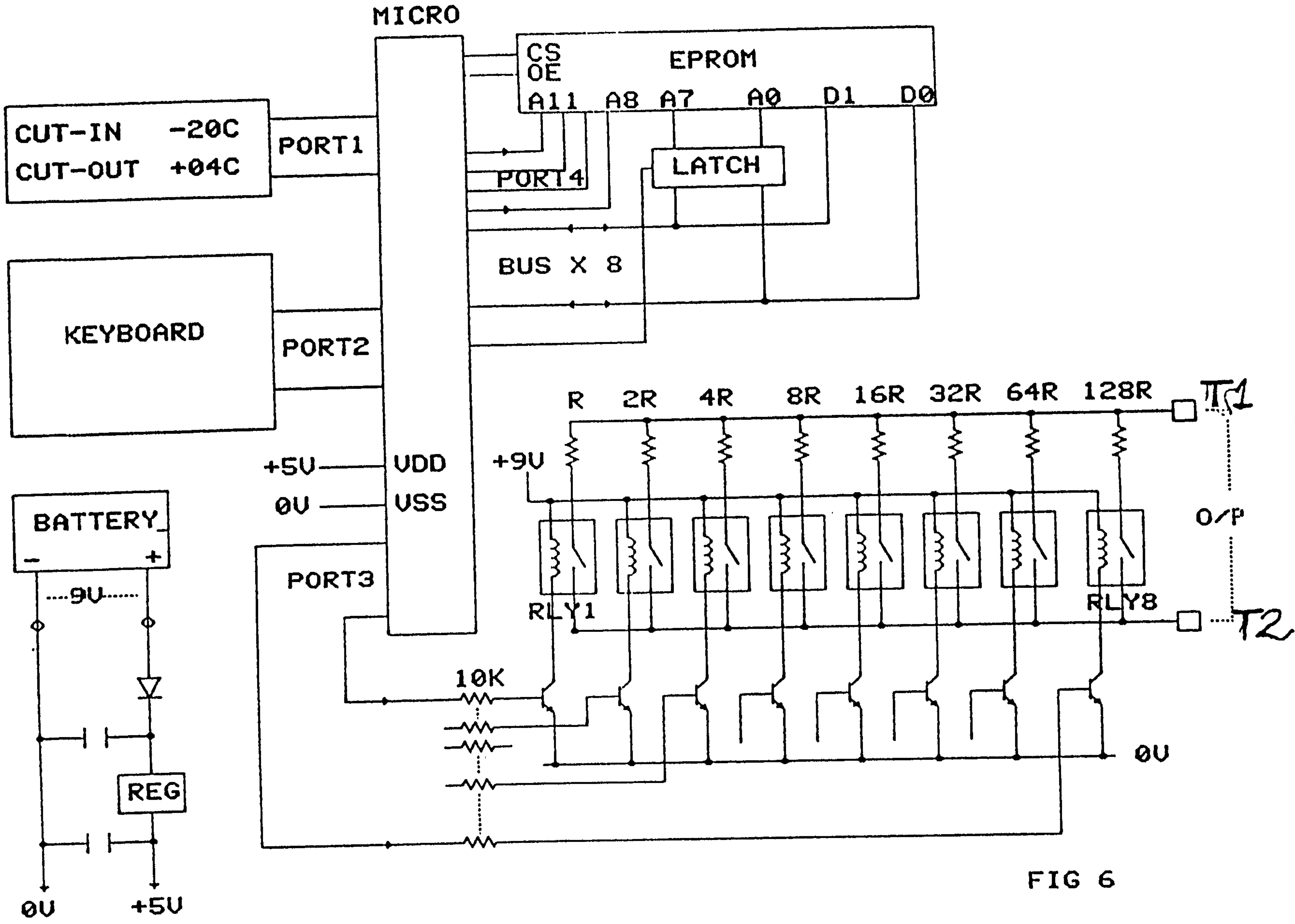
MICRO
EPROM
CS
OE
A11
A8
A7
A0
D1
D0
LATCH
PORT4
BUS X 8
CUT-IN -20C
CUT-OUT +04C
PORT1
KEYBOARD
PORT2
+5V
0V
VDD
VSS
PORT3
BATTERY
-
+
9V
REG
0V
+5V
R
2R
4R
8R
16R
32R
64R
128R
T1
O/P
T2
+9V
RLY1
RLY8
10K
0V

FIG 6

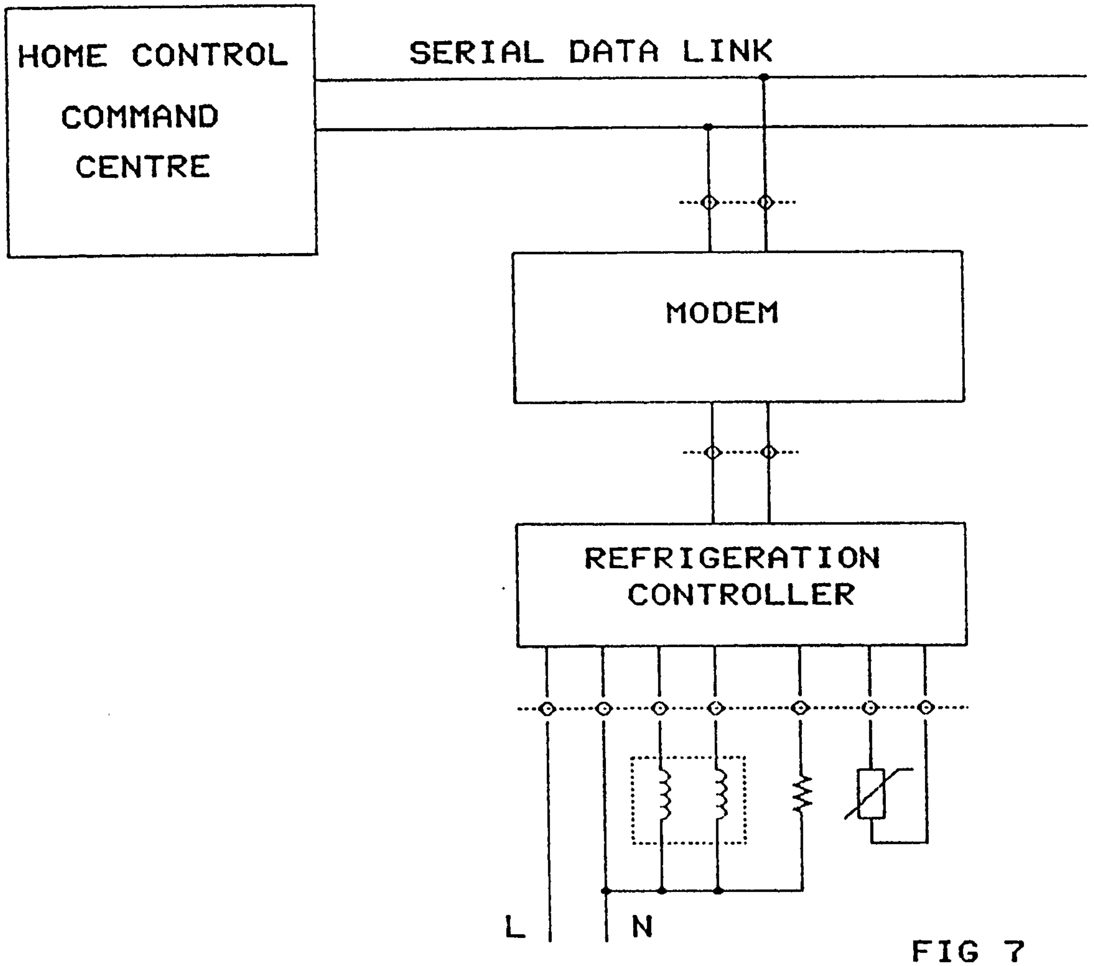
HOME CONTROL
COMMAND
CENTRE
SERIAL DATA LINK
MODEM
REFRIGERATION
CONTROLLER
L
N

FIG 7

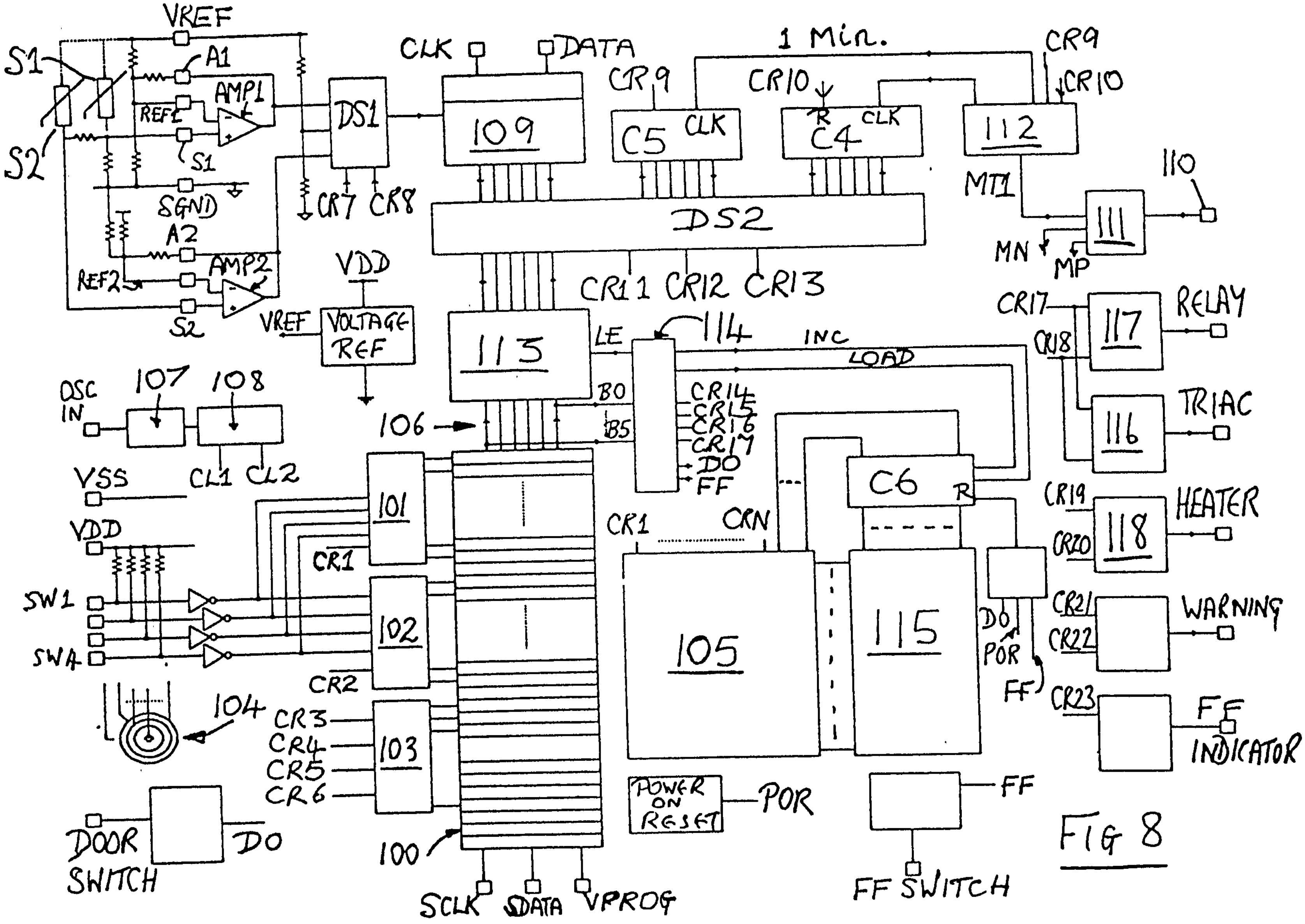
VREF
S1
S2
A1
AMP1
REF1
S1
SGND
A2
AMP2
REF2
S2
DS1
CR7
CR8
CLK
DATA
109
CR9
C5
CLK
CR10
R
C4
CLK
1 Min.
CR9
CR10
112
MT1
110
111
MN
MP
DS2
CR11
CR12
CR13
VDD
VOLTAGE REF
VREF
113
LE
B0
B5
114
INC
LOAD
CR14
CR15
CR16
CR17
DO
FF
CR17
CR18
117
RELAY
116
TRIAC
C6
R
CR19
CR20
118
HEATER
CR21
CR22
WARNING
DO
POR
FF
CR23
FF
INDICATOR
OSC IN
107
108
CL1
CL2
106
VSS
VDD
101
CR1
SW1
SW4
102
CR2
104
CR3
CR4
CR5
CR6
103
CR1
CRN
105
115
POWER ON RESET
POR
FF
FF SWITCH
DOOR SWITCH
DO
100
SCLK
SDATA
VPROG

FIG 8

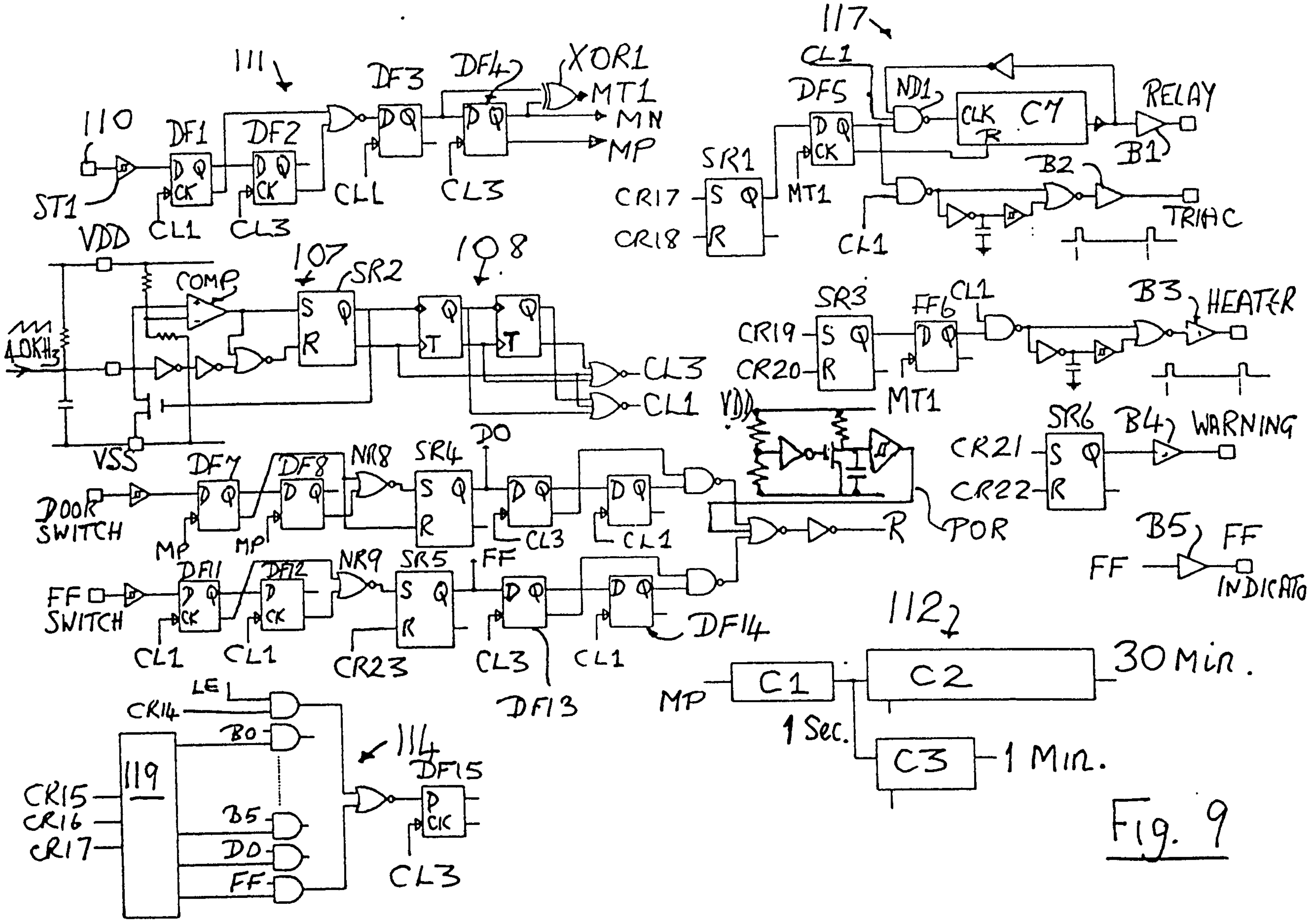
111
110
ST1
DF1
DF2
DF3
DF4
XOR1
MT1
MN
MP
CL1
CL3
CLL
CL3
117
CL1
DF5
ND1
CLK
C7
R
RELAY
B1
B2
TRIAC
SR1
CR17
CR18
MT1
CL1
VDD
COMP
107
SR2
108
CL3
CL1
40KHz
VSS
SR3
CR19
CR20
FF6
CL1
B3
HEATER
MT1
VDD
POR
SR6
CR21
CR22
B4
WARNING
DOOR SWITCH
DF7
DF8
MP
MP
NR8
SR4
DO
CL3
CL1
R
FF SWITCH
DF11
DF12
NR9
SR5
FF
CL1
CL1
CR23
CL3
DF13
CL1
DF14
B5
FF
FF
INDICATOR
112
C1
C2
C3
MP
1 Sec.
30 Min.
1 Min.
LE
CR14
BO
B5
DO
FF
119
CR15
CR16
CR17
114
DF15
CL3

Fig. 9

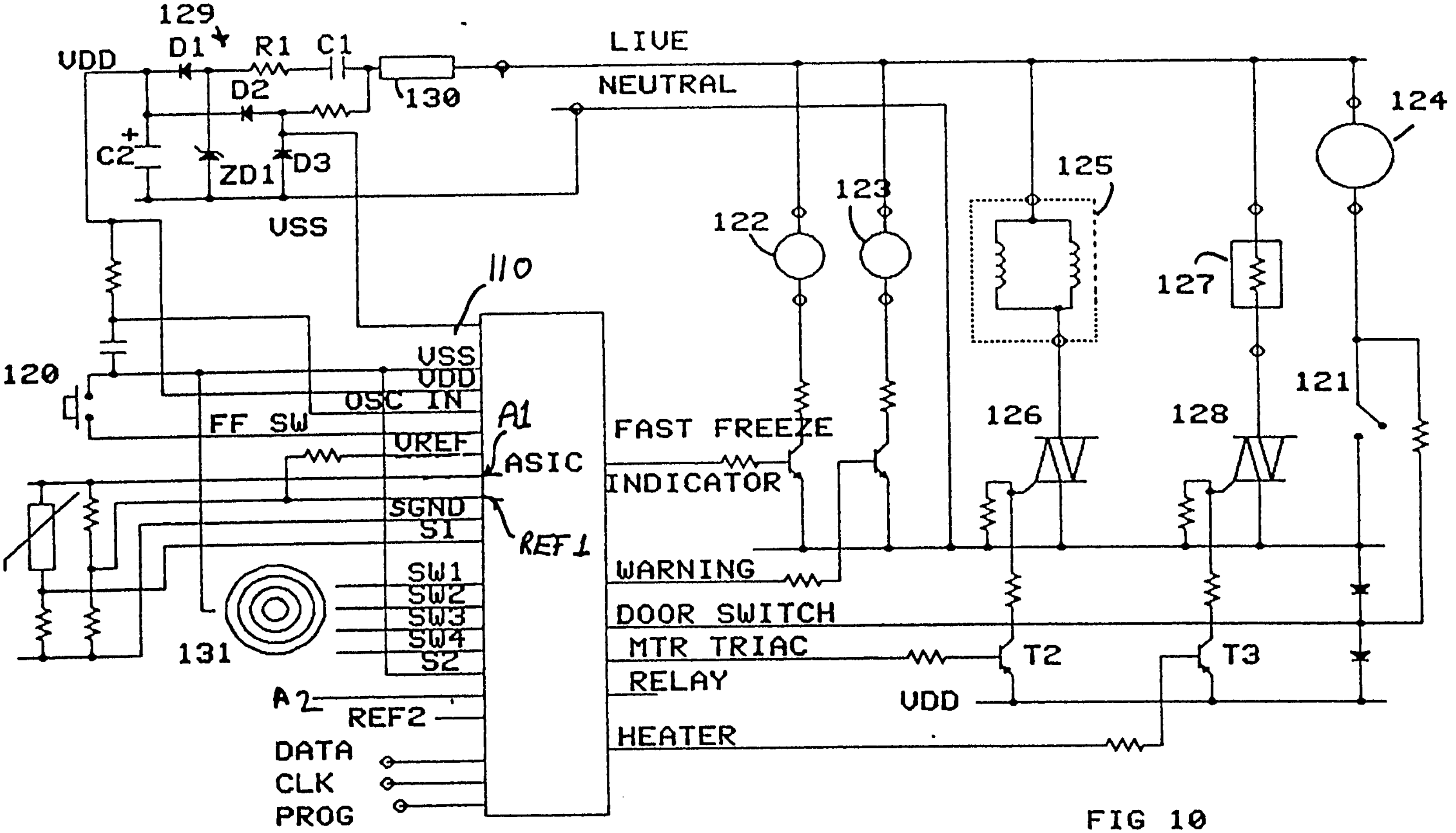
129
VDD
D1
R1
C1
D2
C2
ZD1
D3
USS
130
LIVE
NEUTRAL
122
123
125
124
127
110
120
USS
UDD
OSC IN
FF SW
UREF
A1
ASIC
SGND
S1
REF 1
SW1
SW2
SW3
SW4
S2
131
A2
REF2
DATA
CLK
PROG
FAST FREEZE
INDICATOR
WARNING
DOOR SWITCH
MTR TRIAC
RELAY
HEATER
126
128
121
T2
T3
UDD

FIG 10

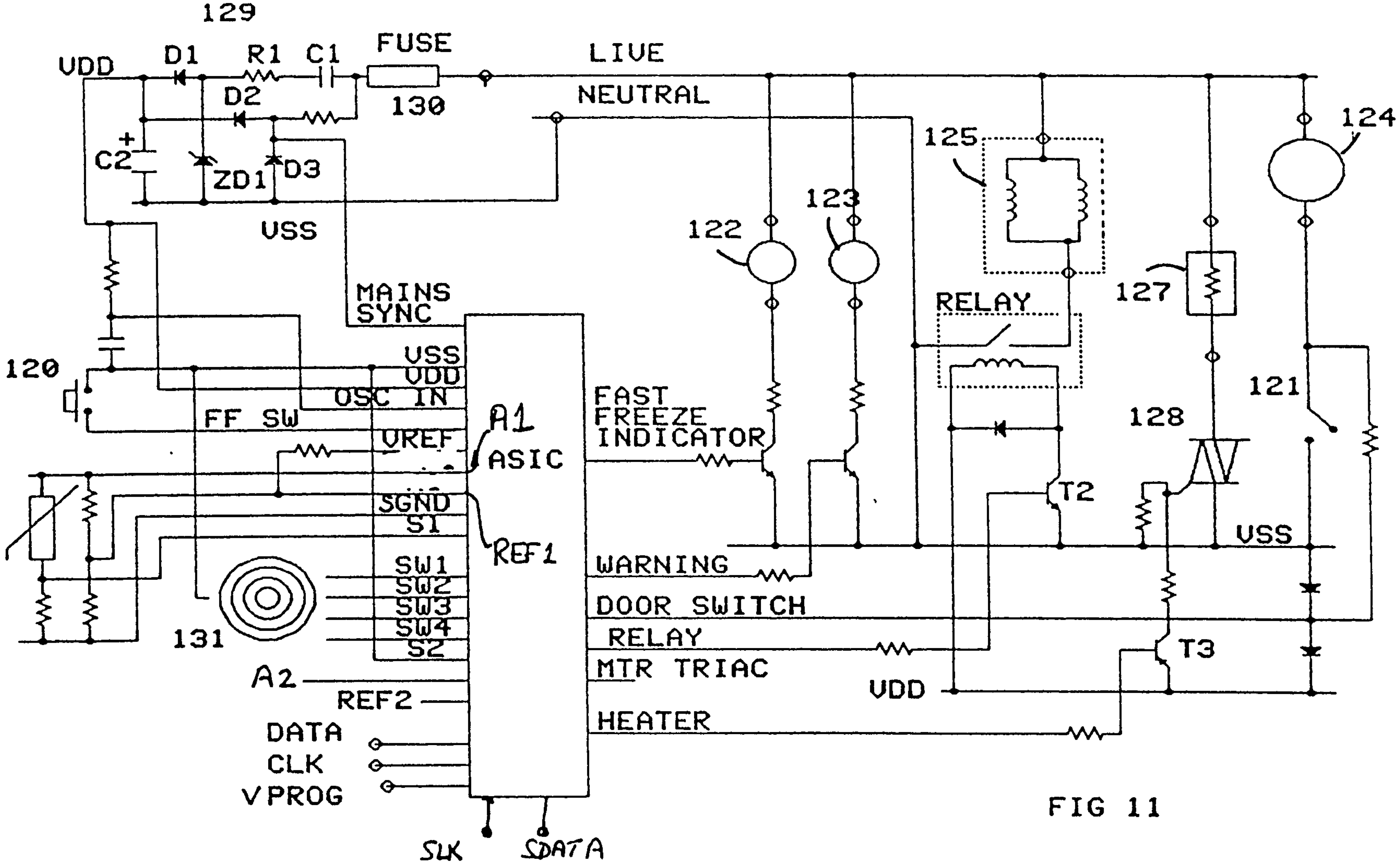
129
VDD
D1
R1
C1
FUSE
130
LIVE
NEUTRAL
D2
C2
ZD1
D3
VSS
124
125
123
122
127
RELAY
MAINS SYNC
VSS
VDD
OSC IN
FF SW
VREF
A1
ASIC
SGND
S1
REF1
SW1
SW2
SW3
SW4
S2
120
131
A2
REF2
DATA
CLK
VPROG
SLK
SDATA
FAST FREEZE INDICATOR
WARNING
DOOR SWITCH
RELAY
MTR TRIAC
HEATER
VDD
T2
T3
128
121
VSS

FIG 11

CONTROL OF REFRIGERATORS AND FREEZERS

This invention relates to the control of refrigerators and freezers and is particularly concerned with domestic equipment.

Almost all domestic refrigerators, freezers or combination fridge/freezers still use a Vapour Pressure Thermostat to control the temperature. The Thermostat responds to a sensor.

An implementation of the sensor consists of a length of capillary tube containing a "vapour fill". The capillary tube connects to the thermostat housing which contains the switch mechanism. Changes in temperature at the sensor result in changes of pressure which are converted into a travel by a bellows. The travel operates a lever which closes and opens an electrical switch contact. "Differential" (Hysteresis) is introduced mechanically. The temperature at which the thermostat switch closes is known as the cut in temperature. The lower trip point at which the thermostat switch opens is called the cut out temperature. The difference between the cut in and cut out temperatures is known as the Differential. The Range of a Thermostat is the temperature range covered between cut in and cut out. (This is not the same as the differential).

Cut in, cut out, Range and Differential are usually adjustable by mechanical means. The correct operation of a refrigeration appliance depends critically on the location, trip points, range, and differential of the Thermostat.

In domestic refrigerators and freezers with vapour pressure thermostats, it is common practice to attach the vapour filled capillary sensor to the evaporator. The sensor works best when located at the coldest point in the refrigerator. With this location, the cabinet temperature control is indirect and correct operation of the appliance requires the thermostat to have a large "Differential". For example in a domestic refrigerator the cut-in could be +4 degC and the cut-out - 20 degC.

The following brief description applies to a refrigerator which operates by the evaporation and compression of the refrigerant. This is the most common type of refrigerator for domestic use. Many of the observations made here relating to the performance of the thermostat, will be just as valid for the absorption type of refrigerator which is also relatively common (Electrolux type). The cooling element is an evaporator filled with a suitable refrigerant. The compressor is driven by an electric motor, controlled by the thermostat.

The compressor runs until the cut-out temperature of the thermostat is reached, at which point the motor is switched off. The cabinet then heats up due to heat gain from the ambient until the cut-in temperature of the thermostat is reached, whereupon the motor re-starts and the cycle begins again. A degree of user adjustment is normally provided by a rotary knob on the thermostat which usually acts to move the cut-in to a higher or lower temperature by increasing or decreasing the pressure on the bellows. Typical cut-in and cut-out temperatures for a domestic refrigerator could for example be +4 Deg C and -20 Deg C, so the cabinet is being cooled by an element whose temperature varies over that range.

There are many variations on the simple refrigerator described above. Many refrigerators switch on a defrost heater during the Off time of the motor. While preventing frost build up on the evaporator, the heater is also warming the air in the cabinet, and wasting energy, for the heat supplied will have to be removed during the next On period of the evaporator.

Accuracy of Temperature Control

In the method where the thermostat sensor is fixed to the evaporator, the temperature of the air in the cabinet is controlled only indirectly, thus making fine temperature control difficult. A more accurate control of the air temperature can be obtained if the sensor is located so as to measure the air temperature in the cabinet. The differential of the thermostat in a refrigerator for example could then be set as 4 Deg C, and the range from 2 degC to 6 degC, so that the mean temperature would be around 4 degC. In theory, the temperature control could be made as fine as required by reducing the differential of the thermostat. In practice there is a limit to the reduction in differential which is possible. The differential is used, in conjunction with the thermal time constants of the cabinet, to regulate the frequency of the On/Off cycles of the compressor motor. Setting a very small differential would result in frequent starting and stopping of the motor, which would reduce its life, and could cause malfunction of the compressor. Frequent starting and stopping could also be a source of annoyance to the user. The sensor at the end of the capillary system of a vapour pressure thermostat should be at the coldest point in the system. This can make it difficult to find a suitable location for use in the air sensing mode.

Compressor Motor Control

The compressor of refrigerators and freezers is commonly driven by a mains electric motor. The size and power of the motor will vary with the size of the compressor. A common arrangement is for the motor to have two windings. When starting, power is applied to both windings to supply maximum torque. An arrangement is usually made to switch off the current to the "start winding" after sufficient time has elapsed to allow the motor to accelerate to the required speed. This arrangement can consist of a PTC thermistor in series with the start winding. As the PTC heats up, the current in the winding is reduced.

Another method uses a "drop out" relay to supply the current to the start winding. The relay coil is self heating, and this reduces the current in the coil causing the relay to drop out. Depending on the design of the motor, connections to the start winding can be made via a "starting capacitor."

Defrost

Various defrost methods are used at present to overcome the build up of frost in refrigerators. Some models can only be defrosted by switching off the thermostat for long enough to allow the frost to melt.

Another method makes use of a thermostat in which the cut-in temperature is set sufficiently high that under normal operating conditions, the evaporator temperature will remain above freezing for long enough in each cycle to melt any build up of frost.

Another method makes use of a thermostat with a spring loaded latch activated by a pin. When the pin is pushed, the normal cut-in temperature is overridden for one heating cycle, allowing the appliance to warm to a higher cut-in temperature. When this temperature is reached, the compressor cuts in, and the latch is released returning the thermostat to the normal cut-in value.

Another method is to switch on a Defrost Heater for a time during the warming part of each cycle. The defrost heater consists of a resistive heating element, usually placed behind the evaporator panel. When using this method, care must be taken to prevent the temperature of the sensor becoming higher than that of the bellows in the thermostat. Special versions of the Thermostat are used with a resistor to provide "Bellows Heating" during the defrost operation.

Disadvantages of Vapour Pressure Thermostat

1. The design and manufacture is complicated. During manufacture, the cut-in and cut-out temperatures are set up using a "standard sensor" with the capillary immersed in baths at the required cut-in and cut-out temperatures. An alternative set up procedure uses a machine to supply pressure to the bellows equivalent to that which would be applied by the sensor at cut-in and cut-out. The settings in the factory are made at an atmospheric pressure equivalent to 260m above sea level.
2. Temperature settings are affected by atmospheric pressure.
3. Factory set values for cut-in, cut-out, and differential can drift due mechanical ageing, vibration, and changes in ambient temperature at the thermostat housing.
4. The capillary tube is fragile and liable to damage due vibration or bending.
5. In coming quality control (IQC) testing of sensors and thermostats is difficult. The measurements have to take into account atmospheric pressure. Measurements require that the capillary end of the sensor is held in the correct attitude and dipped to the correct depth into testing baths at the required temperatures. Results can depend on the skill and interpretation of the operator.
6. Factory settings of the thermostat can in theory be changed "in the field", for example to allow a refrigerator manufacturer to use the same thermostat for different designs of appliance in the same factory or to allow for adjustments by the retailer or service engineer for local climactic conditions. In practice adjustment can cause problems owing to the difficulty in testing the thermostat with the new settings. There is no feedback to indicate how much any adjustment has changed a setting, and the adjustments are usually non-linear. The manufacturers recommend that any adjustments are checked by immersing the sensor capillary in test baths at the

required temperature.

Operational Problems and Limitations

1. The practice of attaching the sensor to the evaporator has arisen mainly from the fact that the vapour pressure sensor needs to be at a colder point than the bellows. This indirect method of controlling the air temperature in the cabinet leads in practice to wider than necessary spacial variations of temperature within the refrigerated space at a given time, and wider than necessary temperature fluctuations with time, in a given position.

2. A freezer operating in a cold ambient environment will have a problem if the ambient temperature is lower than the cut-in temperature of the thermostat, due to the fact that the freezing cycle will not start. This could cause some of the food to be stored for long periods, or for many hours each day at higher temperatures than is recommended. This could happen for example to a freezer kept in a garage in a cold climate. The problem is particularly annoying and hard for the consumer to accept. The best place to keep a freezer should be in an unheated area to minimise energy use and running cost.

3. A refrigerator operating in a very warm ambient temperature can have a problem if the evaporator temperature cannot reach the cut-out temperature of the thermostat. The motor will then run continuously wasting energy, and the consumer will not be aware of the problem.

4. Unless a separate cut out or alarm circuit has been fitted, a refrigerator or freezer in which the door has been left open will still attempt to work, wasting energy, and giving the consumer no indication that the food is thawing out.

5. The setting of On/ Off times for the compressor motor can not be separated from the temperature control cycle. In practice, the motor running time will always be

affected by the cooling and warming time constants of the cabinet, and these are affected by outside influences such as ambient temperature, load in the cabinet, and door opening. It would however be an advantage to manufacturers if they were able to impose restraints on the maximum and minimum On and Off times, independent of the temperature control system.

6. In a refrigerator with a traditional vapour pressure thermostat, temperature adjustment is usually provided by a rotary knob attached to the thermostat housing. Turning the knob adjusts the average temperature of the cabinet by moving the cut-in and/or the cut-out settings of the thermostat. In general there is no precise relationship between the position of the knob and the amount of adjustment, and there is hysteresis between adjustments made when turning the knob clockwise, and turning it to the same position anti-clockwise. Another problem is that the Differential tends to vary as the temperature Range is adjusted. Adjustment of the Range inadvertently adjusts the Differential, and by an amount which is hard to specify. The adjustment range of a refrigeration thermostat is usually defined as the range of temperatures between the cut-in at the warmest position of the temperature adjuster, and the cut-in at the coldest position of the temperature adjuster. For thermostats with "constant cut-in ", the adjustment range is defined as the range between the warmest cut-out, and the coldest cut-out points. A vapour pressure thermostat can normally be adjusted only over a limited part of its operating range. It is usual that different thermostats are sold by the manufacturer, which are set up at the factory so that they may be adjusted over a specific part of the operating range.

Various aspects of the invention are exemplified by the following numbered paragraphs:

1. According to one aspect of the invention, there is provided a refrigeration controller comprising an

electronic circuit having an input for receiving, as an electrical parameter, a value representative of temperature, means enabling a lower (cut-out) and an upper (cut-in) temperature value to be registered by the circuit, control means for comparing the value representative of temperature with the lower and upper values and for producing an output, refrigeration control, signal in dependence upon the electrical parameter attaining values corresponding to the lower and upper values respectively to tend to maintain the temperature of a refrigeration space in a given range, means for enabling timing data to be registered by the circuit, and means for overriding the dependence of the state change upon the electrical parameter, such override being a function of said timing data in such a manner that there are durations between the changes in state of said output signal which do not go below and above respective durations defined by the timing data, despite said parameter attaining values which would otherwise determine those durations.

2. The invention in another aspect relates generally to a refrigeration controller for domestic use and which is a single, monolithic, integrated circuit comprising an input to receive, as an electrical parameter (such as impedance, voltage or current) a value representative of temperature and means to produce a signal to control refrigeration in dependence upon preset lower and upper temperature values.

3. A refrigeration controller according to paragraph 1 or 2 and comprising means whereby setting and adjustment of the lower and upper temperature values is provided for by analogue circuit means, e.g. potentiometers coupled to the integrated circuit.

4. A refrigeration controller according to paragraph 1, 2 or 3 and comprising digital means in the integrated circuit for storing the lower and upper temperature values, e.g. a digital non-volatile memory, with

provision for writing data into the digital means for set up and adjustment of the values.

5. A refrigeration controller according to paragraph 4 and comprising digital means in the integrated circuit for storing discrete digital values representing a plurality of sets of cut-in and cut-out values.

6. A refrigeration controller comprising a first input to receive, as an electrical parameter, a value representative of temperature and control means to produce an output signal to control refrigeration in dependence upon stored lower and upper temperature values, there being digital memory means in the controller for storing discrete digital values representing a plurality of sets of lower (cut-in) and upper (cut-out) values, a second input to receive data defining a required set and memory addressing means coupled to the second input to use that data to provide a digital address to address the set to be used by the control means.

7. A refrigeration controller according to paragraph 5 or 6 in combination with a temperature adjustment means having a discrete position rotary or linear action and which is operable to provide digital selection of any one set from a plurality of the sets of the discrete values of cut-in and cut-out representations. Each position of the adjustment means corresponds to the selection of a cut-in value and a cut-out value to be used by the controller. The selection of different values of cut-in and cut-out in this manner allows the adjustment means to vary the mean temperature of a refrigerated area.

8. A refrigeration controller as described in paragraph 5, 6 or 7, and in which the discrete digital values representing cut-in and cut-out temperatures can be programmed and reprogrammed to adjust the performance of refrigeration controller for use with different types of refrigeration appliance. The programming or reprogramming can be carried out after assembly of the

complete controller.

9. A refrigeration controller as described in the previous paragraph and in which the digital values representing cut-in and cut-out can also be programmed or reprogrammed to allow the controller to be used with different types of temperature sensor.

10. A refrigeration controller as described in any one of paragraphs 5 to 9 and in which the difference between the cut-in and cut-out programmed values, i.e the differential, can be programmed to be a constant value for different temperature selections, or can be made to vary in a pre-defined manner for different selections.

11. A refrigeration controller as described in any one of paragraphs 1 to 10, and with memory space for storing "option bits" which can be tested by a sequence control logic of the controller to select different modes of operation. By programming or re-programming the option bits, different functions can be included or excluded during the control sequence.

12. A temperature sensor simulator for use in adjusting lower and/or upper temperature values of a refrigeration controller of a form comprising an input to receive, as an electrical parameter (such as impedance, voltage or current) a value representative of temperature and means to produce a signal to control refrigeration in dependence upon stored lower and upper temperature values, the simulator comprising means storing a plurality of temperature vs electrical parameter values to provide a range of values of said electrical parameters, each value being selectable by the user, as a corresponding temperature value, for connection across said input.

According to another aspect of the invention, there is provided a simulator as set forth above and adapted for use to simulate a thermistor during set up or adjustment of a thermistor-responsive temperature controller of any type, not limited to refrigerators.

13. A simulator according to paragraph 12 and comprising means for selecting two electrical parameter values, e.g. resistance, corresponding to two temperatures, respectively for the lower and upper value, and means for switching between the selected electrical parameter values during use in setting or adjusting the controller.

14. A refrigeration controller according to paragraph 1, wherein the timing means is operable to control the minimum refrigeration ON time after cut-in, the timing means overriding temperature control to prevent cut-out before a minimum time has elapsed.

15. A refrigeration controller according to paragraph 1 or 14, wherein the timing means is operable to control the minimum refrigeration OFF time after cut-out, the timing means overriding temperature control to prevent cut-in before a minimum time has elapsed since cut-out.

16. A refrigeration controller according to paragraph 1, 14 or 15, wherein there are timing means to override temperature control to force cut-in of refrigeration if more than a stored maximum time has elapsed since cut-out.

17. A refrigeration controller according to paragraph 1, 14, 15 or 16, wherein there are timing means to override temperature control to force cut-out of refrigeration if more than a stored maximum time has elapsed since cut-in.

18. A refrigeration controller according to any one of paragraphs 14 to 16, and which also contains means to provide a warning or alarm indication if the cut-in and/or cut-out overrides occur with a given frequency, e.g. on more than a given number of successive refrigeration cycles. The warning can be by an audible device such as a piezo buzzer, or a visible indicator such as an LED or a neon.

19. A refrigeration controller according to any one of paragraphs 1 to 11 and 14 to 18, and which comprises a micro-controller to interface between a temperature sensor and refrigeration means, and which contains values

for cut-in and cut-out temperature stored in digital form, e.g. in either program memory or data memory.

20. A refrigeration controller according to any one of paragraphs 1 to 11 and 14 to 19 and comprising means by which the temperature of a refrigerated compartment can be monitored during cooling and warming periods of a refrigeration cycle, and means to store these temperature readings in digital form within a memory.

21. A refrigeration controller as described in paragraph 20 and comprising means for storing digital data corresponding to elapsed time after the refrigeration means is switched ON or OFF, thus storing a temperature profile of a refrigerated area during the ON and OFF periods of the refrigeration cycle.

22. A refrigeration controller as described in any one of paragraphs 19 to 21 and comprising means to calculate from stored digital temperature and time data mean values for the temperature of refrigerated areas during the ON and OFF parts of a refrigeration cycle.

23. A refrigeration controller as described in paragraph 22, and comprising means to compare the mean temperature values with pre-programmed digital data corresponding to a desired mean temperature and to use the comparison along with a command program to adjust the stored values for cut-in and/or cut-out so as to maintain the mean temperature of the refrigerated area within a given range of the pre-programmed values.

24. A method to improve the temperature stability of a refrigerated area over a period of time by using a controller according to paragraph 23 and comprising subtracting the mean temperature and the pre-programmed value for the mean temperature over a number of refrigeration cycles, the stored cut-in and/or the cut-out values being changed only if the absolute magnitude of the resulting difference is greater than a pre-programmed threshold value. The number of cycles over which the measurement is made before adjusting the

parameters will determine the response time of the controller. The use of a threshold value prevents any changes to the stored parameters until the mean temperature has moved out of range for longer than the response time.

25. A refrigeration controller according to any one of paragraphs 1 to 11 and 14 to 24 with means to sense the waveform of the mains, and means for ensuring that the switching on or off of the refrigeration means occurs near to or coincident with the zero crossing of the mains live with respect to the mains neutral. Suitable switching means could be a relay, a thyristor, a high voltage power MOS transistor, or a combination of one or more of the above.

26. A refrigeration controller according to any one of paragraphs 1 to 11 and 14 to 25 and containing a microprocessor or micro-controller with means which allow a modem or module of a home control system, (or other remote signalling system), by means of serial data commands, to interrogate the controller for information regarding the temperature of a refrigerated area or areas.

27. A refrigeration controller according to any one of paragraphs 1 to 11 and 14 to 26 containing a microprocessor or micro-controller with means which allow a modem or module of a home control system, (or other remote signalling system), by means of serial data commands, to program parameters of the controller in such a manner that the performance of the refrigeration appliance is modified. In particular the cut-in and cut-out points of the controller might be modified in this manner to adjust the temperatures(s) of the refrigerated area(s).

A controller according to at least paragraphs 5 to 7 will preferably use non-volatile memory to store sets of cut-in and cut-out parameters.

In this application, by non-volatile memory we mean a memory structure, contained in an integrated circuit, which will allow the user to program data into this memory by some means. After data has been programmed, it will be retained even if power, other than a back-up supply, is removed from the circuit which incorporates the memory. As for preferred embodiments, we additionally mean that data is retained even if all power is removed.

The definition would include all sorts of different memory structures, MASK ROM, EPROM, EEPROM, PLA, and GLA. The most flexible arrangement for a parameters memory would be to use an EEPROM structure (electrically erasable, programmable read only, memory) or NVRAM (non-volatile random access memory). Other types of memory can only be programmed once (OTP or one time programmable). An EPROM device can be re-programmed, but it has the disadvantage that the original data must first be erased by exposure to UV light. One time programmable devices can be EPROMS (without the quartz window which would allow erasure) or can be devices such as PLAs or GLAs, which use fusible links as the programmable element.

EPROM and EEPROM devices would normally contain special transistors with "floating gate tunnelling structures" which are used to achieve programmable threshold voltages. Programming these transistors would move the threshold from enhancement into depletion or vice versa depending on the polarity of the applied pulse. The transistors will retain their new threshold voltages, after removal of the programming pulse, and this is the non-volatile structure. The modified threshold is retained with and without power to the chip in which these transistors are incorporated.

EPROMS can only be programmed electrically and are usually erased by exposure to UV light. The packages of such devices usually have a quartz window to allow the chip to be exposed to the light. Versions of EPROM known as OTP (one time programmable) are also common. The package does not contain a quartz window, and so although the device can be programmed, it cannot be erased for re-programming. The use of an EPROM in a refrigeration controller would require the integrated circuit to be removed from the printed circuit board and placed in a special box with a UV light source to erase the old program. This could take several minutes. A special programmer could then be used to write or "burn" the data into the memory.

EEPROMS are similar to EPROMS, except that they have the additional powerful feature of being electrically erasable.

Advantages to be gained by using a non-volatile memory as a "parameters memory" in a refrigeration controller are as follows:

1. No potentiometers or other manual adjusters are required to set up the cut-in, cut-out and range of the controller. These parameters are stored as digital values in the parameters memory.

2. Digital adjustment of the mean temperature of a refrigeration cabinet becomes possible, by using a digital switch to address the programmed range of cut-in and cut-out values. This adjustment method allows a precise selection of the cut-in and cut-out temperature values. With a digital means of range selection, the differential is precisely the difference between the values programmed for cut-in and cut-out and can be programmed to remain constant, or vary in an exact manner with the adjustment.

3. Provided the parameters memory is re-programmable, a "Universal Refrigeration Controller" can be manufactured which would be suitable for use with a number of different types of appliance. The controllers could be supplied pre-programmed for a particular appliance. However, should the manufacturer require it, he could re-program the operational parameters for a different type

of appliance. For example, a controller which had been delivered to be used in a refrigerator could be re-programmed to be used in a freezer, or a bottle cooler, or a refrigerated display cabinet. This re-programming could even be included as part of the production procedure for the appliance. This would allow improved stock control to a manufacturer who would normally use more than one type of refrigeration thermostat controller.

4. The cut-in and cut-out temperatures stored in digital form in the parameters memory could be programmed to match the characteristics of the temperature sensor. By re-programming this data, the same controller could be used for different temperature sensors.

5. The parameters memory could also be programmed with digital values representing temperatures other than cut-in and cut-out. For example, two locations could be programmed with lower values of cut-in and cut-out, which the controller would use during a "fast freeze" operation. Another location could be programmed with values representing an "alarm temperature". If the temperature of the refrigerated space is above this level, a warning indicator would be activated. Another location could be programmed with a value representing the temperature of the evaporator to terminate a defrost operation.

6. The parameters memory could be programmed with digital values corresponding to time intervals during the operation of the refrigeration cycle. Examples of time intervals which could be stored in this fashion are: The minimum running time for the refrigeration means during the ON part of the refrigeration cycle; the maximum running time for the refrigeration means and during the OFF part of the refrigeration cycle; the time

interval between operation of the defrost means and the length of time for which the defrost means will operate; and the running time for a "Fast Freeze" operation.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a circuit diagram of a refrigerator/freezer controller chip;

Figures 2 to 4 show three applications of the chip of Figure 1;

Figure 5 is a diagram of a microprocessor controller;

Figure 6 is a diagram of a thermistor simulator;

Figure 7 is a diagram of a home control interface;

Figure 8 is a block diagram of a further controller chip;

Figure 9 is a diagram of details of Figure 8; and

Figures 10 and 11 show two applications of the chip of Figure 8.

Two different technical approaches are outlined in the following description. The first solution uses an Application Specific Integrated Circuit or ASIC. The ASIC contains mixed analogue and digital circuitry outlined in the schematic diagram of FIG 1 or FIG 8. The second solution uses a Microcontroller with an 8 channel A/D converter input. A complete controller using this device is shown in FIG 5.

Fig 1 is the schematic diagram of an ASIC which could be used to interface between a single temperature sensor as the input, and the compressor pump and defrost heater as the outputs. The ASIC allows for simple selection and adjustment of cut-in, cut-out and range.

It provides timing to control the minimum and maximum ON and OFF times of the compressor, and additional timing and temperature sensing circuitry to implement a Frost Sensor. It also includes circuitry to ensure that switching of the output devices occurs at or near to the mains zero crossing points.

The ASIC would be manufactured using a CMOS technology. The supply connections are VDD(+) and GND. A Bandgap Reference 1 is used to provide an accurate voltage source from which comparator reference voltages can be derived, and to provide a stable reference for a bridge circuit at the sensor input 2, 3. A sensor 4 is coupled across terminals 2 and 3.

The sensor 4 is an NTC thermistor, which could be selected from the Philips "Accuracy" range, e.g part number 2322 640 90012. AMP1 is an Op-Amp used to amplify the voltage from the bridge comprising the sensor 4 and resistors R3, R1, R2 and R4.

In practice R1, R2 and R3 would have the same value, R, and the output voltage of the AMP1 is given by the following formula :

$$\mathrm{Vout} = \left(\frac{\mathrm{VREF}}{2}\right)\left(\frac{R4}{R}\right)\left(\frac{a}{1+a}\right)$$

where a is the temperature coefficient of the thermistor.

The manufacturer's data sheet for the thermistor supplies values for "a" over a wide temperature range, thus allowing the output voltage to be derived as a function of the temperature at the sensor. A comparator COMP1 is used to set the cut-in temperature reference. On-chip resistors R7 and R8 limit the range of the adjustment. An external potentiometer 5 is connected between R7 and R8 and is used to adjust the cut-in temperature. When the voltage at the output of AMP1 is greater than the level set at the -ve input of COMP1, the output of COMP1 switches to a high level, thereby setting a logic 1 at the input of a gate G1.

A comparator COMP2 is used to set the cut-out temperature reference. On-chip resistors R5 and R6 limit the range of adjustment and an external potentiometer 6 is used to set the switching point. When the output of AMP1 is below the level at the +ve input of COMP2, a logic 1 is set at the input of a gate G2. R5, R6 and R7, R8 are manufactured on the ASIC using either diffused or polysilicon resistive elements. The ratio between each pair can be very accurately controlled and is to a large extent independent of any variations due to the ASIC manufacturing process. Also any temperature drift will be the same for each pair of resistors in the potential divider.

Potentiometers 5 and 6 may be releasably ganged. When ganged, their adjustment alters the range.

Timing

A Mains Sync input 7 receives a voltage synchronous with the mains waveform (50 HZ or 60 Hz). The voltage is limited externally to prevent damage at the input. Device G14 is a Schmidt trigger used to provide hysteresis and speed up the transition edges of the waveform on the mains sync input. The output (ZC) from G14 is used to clock counter C1 and flip flops FF1, FF3 and FF6. C1 acts a pre-scaler, dividing the mains frequency to provide a pulse at its output at one minute intervals. This pulse appears at the output of a gate G17. For 50 Hz mains, the decode at the inputs of G17 corresponds to a count of 3000. For 60Hz mains, the decode corresponds to a count of 3600. An Option Input 8 is used to select the G17 decode via a gate G18. C1 is a

12 stage ripple counter made up of "T-Type" flip flops, with the real and inverse outputs from each stage as the possible inputs for gates G16 and G17. C1 is reset by a signal PU1 generated by a gate G7, so that the counter C1 begins to count after each change from ON to OFF or OFF to ON.

A counter C2 counts the output pulses from C1 and is a 6 stage ripple counter of "T Type" flip flops. The real and inverse outputs from each stage are used as inputs to a decoder 9. The decoded outputs correspond to the min and max ON and OFF times for the compressor motor. G9, G10, G11 and G12 are the decoder gates, with inputs selected from the parallel outputs of C2. The decoder is laid out in matrix form on the ASIC so that the inputs to gates G9 to G12 can be selected by the gate mask pattern in the matrix. With this implementation, the decoded states are fixed at the time of fabrication of the ASIC; however a different implementation could use external pins of the ASIC to optionally select the terms of the decoder. G9 and G11 are disabled by an OFF signal from flip-flop FF7. G10 and G12 are disabled by an ON signal. G9 selects the minimum ON time of the compressor motor. G10 selects the minimum OFF time. G11 selects the maximum ON time, G12 selects the maximum OFF time. With a 6 stage counter the maximum ON and OFF times would be 64 minutes.

FT1 is set by the "Wired OR" of G9 or G10. G9 is enabled when the Controller is ON, and G10 is enabled when the controller is OFF. Similarly, FT2 is set by the "Wired OR" of G11 or G12. FT1 is used to inhibit cut-in or cut-out until after the minimum OFF or ON times have elapsed. The output from FT1 is applied to gates G1 and G2, thus allowing the ON/OFF flip-flop (FF7) to be set or reset in response the levels on COMP1 and COMP2. FF7 is a "D-Type" flip-flop with synchronous set and reset inputs. Signal FT2 toggles the ON/OFF flip-flop when the maximum ON or OFF time has elapsed.

G7 is an Exclusive OR gate which, together with R10 and C2, is used to provide a One Shot pulse (PU1) in response to a change in state of the ON/OFF bistable. PU1 resets C1, C2, C3, FF4, FF5, FT1 and FT2 thus starting the timing from when the controller cuts in or cuts-out. FF1 is a "D-Type" Flip Flop, clocked by ZC, and is used to clock the output from the ON/OFF bistable to the output buffer B1. Clocking by signal ZC ensures that the main O/P 10 will switch on or off at the mains zero crossing points.

G16 provides a second decoded output from counter C1 and is used to generate a "Drop Out Delay" for the start winding of the pump motor. A gate G8 provides a One Shot pulse PU2 whenever the ON/OFF bistable FF7 switches to the ON state. This pulse in turn sets FF2. The output from FF2 is clocked into a D-flip flop FF3 by ZC and switches on the Start O/P 11 at the same time as the Main O/P 10. FF4 is set by G16 going to logic 1. The output from FF4, resets FF2, thereby ensuring that the Start O/P 11 will switch off at the next zero crossing of the mains. The length of the Drop Out Delay depends on the decode selected at the input of G16. Again this could be made gate mask selectable by arranging the outputs from C1 and the inputs to G16 and G17 in matrix form during the design of the ASIC layout.

A comparator COMP3 and a counter C3 together provide a "Frost Detect" feature. The output from COMP3 is at a Logic 1 when the temperature at the sensor is below 0 degC. R11 and R12 set the comparator -ve input to the level which corresponds to the 0 degC point. G15 allows C3 to be clocked at 1 minute intervals by the output from

C1, provided the On/Off bistable is in the OFF state. The output from the most significant stage of C3 sets FF5, and the output of FF5 is clocked through to an output buffer B3 at the next zero crossing. FF5 and C3 are reset by PU1. Thus a defrost O/P 12 will switch ON while the compressor is OFF, provided the temperature at the sensor remains below zero for the time taken to clock C3 to its max count. The defrost O/P 12 will remain ON until the start of the next compressor cycle. An ASIC such as described above could be used to implement refrigerator controllers with the temperature sensing, ON/OFF timing means, and the combined temperature and Frost Sensor as described in the aspects of the invention above.

In the above embodiment, the cut-in and cut-out values are stored outside the ASIC by analogue circuit means, in this case potentiometers.

As an alternative, they may be stored by digital means integrated into the ASIC. For example, a digital non-volatile memory for the values can be integrated into the chip.

The circuit will be similar to that of Fig. 1, except that the cut-in and cut-out values are stored in digital form, in a non-volatile memory, rather than on the potentiometers as in Fig. 1. The output from AMP1 of Fig. 1 would be converted to a digital signal, using a D/A converter, and the comparison with the stored values would be made using an 8 bit magnitude comparator logic circuit. Other differences from Fig. 1 are the addition of an oscillator and clock generator, to produce the timing signals to control the reading and writing of the memory, and a serial data input to communicate with the programmer described below. When used in a domestic refrigerator, an external potentiometer could be used to adjust the "Range". The spindle of the potentiometer would be connected to the knob which is normally found in a refrigerator for this purpose. Programming this ASIC would be achieved using a "programmer" with a connector which plugs into the controller. The programmer would be similar to the simulator (described below) in construction, however it would not have the resistance network, and would be used instead to write data into the non-volatile memory of the ASIC, that data corresponding to the entered data for cut-out and cut-in temperatures. The output would be a serial data stream containing commands and data to control the write logic of the ASIC non-volatile memory.

Figure 2 is a schematic diagram of a complete temperature controller.

A Motor 13 and a Defrost Heater 14 are not part of the Controller. They are shown in the diagram to illustrate one set of possible connections from the Controller.

C1, R1, D1, ZD1, C2 form a "Capacitor Dropper" Power Supply.

Suitable values would be :

C1	0.22 uF class X
C2	100uF, 40V, Electrolytic,
R1	220R, 1/2W carbon composition
ZD1	zener diode, 10V, 1W, BZX type
OD1	1N4004

R2,D2 and D3 are used to provide the Mains Sync input to the ASIC. Typical values would be

R2	220K, 1/2W, carbon composition.
D2,D3	1N4148

Triac types would depend on the motor current rating.

The cut-in and cut-out temperatures are set up or adjusted using trimpots 5 and 6. Connector Conn 1 is provided to facilitate setting of the cut-in and cut-out temperatures. During setup, a special simulator, to be described, would be plugged into Conn 1 which would allow the cut-in and cut-out temperatures to be displayed in degrees during the adjustment process.

In this circuit, the compressor motor 13 and the defrost heater 14 are switched by triacs TR1, TR2 and TR3. The Triac gates are driven by transistors T1, T2, T3, which are controlled by the outputs from the ASIC. The ASIC outputs function as previously described. The outputs switch towards VSS, (current sink) to switch on the transistors and hence the triacs.

In this version of the controller the circuitry is not isolated from the mains. To ensure that the triacs are breaking the live connections to the motor and heater, the power supply is referenced to Live. This means that the thermostat connections would require to be double insulated.

A method for easy set-up and adjustment of cut-in and cut-out will now be described.

As stated previously, one of the biggest disadvantages of the vapour pressure thermostat is the difficulty in setting up or adjusting the cut-in or cut-out temperatures. One procedure involves connecting the thermostat mechanism to a suitable sensor, normally a vapour filled capillary tube, and then dipping the sensor in baths at the different temperatures for cut-in and cut-out. The adjustment is affected by atmospheric pressure, by the attitude of the sensor, and by the ambient temperature at the bellows of the thermostat switch mechanism.

The electronic thermostat shown in Fig 1 allows for a much easier and more accurate means to be used to set up and adjust the cut-in and cut-out temperatures, and thereby also adjusting the Range and Differential. A special sensor simulator is provided for this purpose (Figure 6). The simulator has two output terminals, to be connected to the sensor input terminals, 2 and 3, of the electronic thermostat (Inputs T1 & T2 of CONN1, Fig 2.)

Across these output terminals, the simulator contains a binary coded resistance network, the value of which is adjusted electronically by an 8 bit microprocessor (e.g. 80C51). The simulator contains programming means in the form of a command program in a U.V. erasable EPROM. The EPROM communicates with the microprocessor using the 8 bit BUS for the data I/O and also for the 8 least significant address lines. The EPROM also contains look-up tables corresponding to the resistance versus temperature characteristics of the various thermistors which could be used in the refrigeration controller. A digital display is used to display the cut-in and cut-out temperatures which are to be set up on the potentiometers of the refrigeration controller together with prompt information to guide the user through the programming sequence. The binary coded resistance network is controlled from Port 3 of the microprocessor. RLY 1 to RLY 8 are small reed relays, used to provide an isolated interface between the resistors and the power supply of the simulator. The simulator also has a keyboard for data entry. A sequence to adjust the thermostat settings could be as follows:-

1. Plug the simulator into the connector of the controller (CONN1 of Figure 2).
2. Enter the part number for the required sensor thermistor into the simulator using the keyboard.
3. The display will then prompt for the cut-in temperature to be entered at the keyboard. Enter the

required cut-in temperature.

4. The display will then prompt for the required cut-out temperature. Enter the cut-out temperature.

5. The resistance network will assume the value corresponding to the resistance of the chosen sensor at the selected cut-in temperature. This then allows the cut-in potentiometer on the controller to be adjusted until the controller output is just switching to the ON state.

6. Pressing a button on the keyboard then causes the resistance network to assume the value corresponding to the sensor resistance at the cut-out temperature. The cut-out potentiometer is then adjusted until the controller output is just switching to the OFF state. If a circuit such as the ASIC of Figure 1 is used, an extra input would be provided on the ASIC to inhibit the minimum cut-in and cut-out times and so permit the thermostat outputs to switch under temperature control only during the adjustment. This inhibit input could be arranged automatically to be set to its inhibit state on plugging in the simulator.

Fig 3 shows an alternative controller. This version uses a transformer isolated power supply. A regulator 16 provides a stable operating voltage for the ASIC. The connections to the sensor 4 and the Connector CONN1 are isolated from the mains by the transformer TR1. The output circuit is a simplified version using only a single relay 15 to switch the pump motor 13 and the defrost heater 14. One side of the relay is connected to the unregulated DC supply. The Drop out delay is provided by a PTC thermistor in series with the motor start winding. The defrost heater is switched ON when the relay is open. This configuration where the motor windings and defrost heater are controlled by a single switching mechanism is presently used in some refrigerators with electro-mechanical vapour pressure thermostats. It has the disadvantage that the heater is switched on every refrigeration cycle, irrespective of the presence of frost, thus wasting energy. The switching times of the relay would have to be taken into account if it is desired that the contacts should open or close near to the zero crossing point of the mains.

Typical values:

TR1: 2VA mains Transformer, Class 2.
16V, Centre tapped secondary
D1,D2 : 1N4004
D3,D4 : 1N4148
R1: 100K, 1/4W, carbon film
C1: 100uF, 40V, electrolytic
C2 : 0.1uF, ceramic capacitor
T1 : 2N3904
Regulator : LM 78L05ACZ

Figure 4 shows a further embodiment of controller. The power supply and sensor circuits are the same as described for Fig 3. This time three relays are provided at the output, to take advantage of the "Drop Out Delay", and "Defrost as Required" features provided by the ASIC of Figure 1. Although relay RLY2 is an addition if added to the Controller, it replaces the drop out relay, or PTC thermistor which would normally be required anyway in a separate motor controller circuit. This Controller also provides isolation from the mains for the sensor connections.

Referring now to Figure 5, this controller uses a Micro-Controller to provide the interface between sensor inputs 3 and 3^1, and the Motor and Defrost Heater Outputs 10, 11 & 12.

A micro-controller or microprocessor is a well known device within the electronics industry. It is a programmable device which normally would contain a Program Memory, a Data Memory, an Arithmetic Unit or ALU, Input Ports, Output Ports, Timers and Counters.
Use of the micro-controller allows an "Auto Adjust" feature to be added to the features described for ASIC of Figure 1.

The Power Supply is not shown. However it could be of similar type to that shown in Fig 2 or Fig 3. If isolation is required for the sensors, the power supply would be similar to that of Fig 3, and the triacs could be replaced by relays, or the gates of the triacs could be driven via opto-isolators. The internal circuitry and functions of a Micro-Controller are well known and are not described here. The micro-controller is of the type which incorporates an 8 channel multiplexed A/D converter as one of its Input Ports.

Each of two sensing inputs 3, 3^1 is connected to a bridge circuit made from an OP-Amp and external resistors. The outputs from the Op-Amps are applied to respective analogue input ports 3, 3^1 of the micro. Each analogue voltage is a function of the temperature at its sensor. The analogue voltages from the sensors can be read into the micro via the multiplexed A/D converter and stored there as digital information. The sensor 4 can be used to control the temperature in the refrigerated zone as described for the preceding embodiment, whilst sensor 4^1 can be placed on the evaporator and be used in defrost detection (e.g. using the scheme of Figure 8 to 11 to be described later). The micro-controller can provide timing means either by counting the mains frequency transitions at the ZC input, or by using internal hardware or programmed timers which divide down from its own clock.

Cut-In and Cut-Out

Pre-Programmed cut-in and cut-out temperatures can be stored within the micro as digital information. This information can be stored either as fixed information in a mask programmed ROM, or as alterable information if the micro-controller uses E-Prom or EEROM as part or all of its program memory or data storage memory. The digital data in the micro from the temperature sensors can be compared to these preset digital data to decide, in conjunction with the timing means and the control program, when the compressor motor should be switched ON or OFF. Fig 5 shows an external adjustment means which can optionally be used to set up or adjust the preset information for cut-in and cut-out. The potentiometers and resistors R1, R2, R3, R4 are used to set analogue voltages at inputs AN2 and AN3 of the micro. These voltages can be read into the micro via the multiplexed A/D converter and used to modify or replace the preset values for cut-in and cut-out.

Timing

The maximum and minimum ON and OFF times of the compressor motor can be pre-programmed as digital information in the micro-controller or can be set up externally. Fig 5 shows potential dividers connected to inputs AN4, AN5, AN6 and AN7 of the micro. The voltages at these analogue inputs could be used as an analogue representation of the ON and OFF times. For example the voltage at AN4 could represent the min ON time of the motor, AN5 the max ON time, AN6 the min OFF time, and AN7 the max OFF time.

This Controller has the significant advantage over the controllers using the ASIC of Figure 1 in that it can "read" the temperature at the sensors periodically and is not fixed to respond only when the temperature exceeds certain preset levels. This ability allows implementation of an "Auto-Adjust Feature". The Controller can monitor the temperature of the refrigerated area during the cooling part of the refrigeration cycle while the compressor is running, and also during the warming part of the cycle when the compressor is OFF. For example, data from the sensors could be sampled periodically and stored in the data memory of the micro. This data could then be used to calculate a mean or average temperature for the refrigerated area. This mean or average could be compared with preset data stored in the program memory and, depending on the result, the micro-controller could adjust the pre-programmed data which represents the cut-in and cut-out temperatures. For example if the mean temperature was found to be less than the pre-programmed mean value, over a certain number of refrigeration cycles, then the pre-programmed values for cut-in and cut-out could be incremented over a number of refrigeration cycles thus raising the mean temperature. Similarly the pre-programmed cut-in and cut-out pre-programmed values could be decreased if the mean temperature over a number of cycles was found to be above the pre-programmed mean.

The ability to "Auto Adjust" could also be used to correct timing problems during operation of the appliance. For example, if the micro-controller detected that the time intervals between ON and OFF, or OFF and ON, of the compressor was consistently at the minimum level, the "Differential" could be increased by adjusting the cut-in to a higher value, and/or the cut-out to a lower value.

The simulator described above can also be used to set up and adjust this version of the controller. The micro-controller of Figure 5 may include a set up program putting the controller into a set-up mode in which it reads the simulated resistance values automatically from the simulator and determines, from these two simulated thermistor values, the appropriate cut-in and cut-out values to store in its memory.

The Serial Input and Serial Output of the microcontroller can be used to send and receive data or commands from a separate control system. For example international protocols have been developed for Home Control Systems, whereby a central Command Centre in a home can be used to supervise and control domestic appliances. Communication between the Command Centre and the appliances can use mains signalling, or transmit coded signals along low voltage wires such as telephone cable or "twisted pair" cable.

A Draft European Standard entitled "Signalling on Low Voltage Electrical Installations" has been drawn up and submitted to CENELEC members for approval. This standard refers to the signal amplitude and frequencies which will be permitted for Mains Signalling protocols. A Protocol, PROT/THORN/076.4, has been drawn up by the IHS Eureka protocols group to specify the Draft Architecture and Command Language which will be used in any Home Control System using a Serial Data Bus.

A modem or module would normally be used at each point of control to interface between the serial data bus and the appliance. Extensions of Home Control Systems provide the ability to request information from the Command Centre from remote locations, by using the telephone network and a special telephone modem. With a suitable application program in the Micro of the Refrigeration Controller of Fig 5, it would be possible for the Command Centre to interrogate the Refrigeration Controller to determine the mean temperature within the refrigerator. This information could then be displayed, stored or recorded at the Command Centre, or transmitted via the modem and the telephone line to remote locations. The serial data input could be used to adjust the pre-programmed digital values which represent cut-in, cut-out, minimum and maximum On/Off times, by sending commands and data from the Home Control Command Centre. In this manner, the parameters of the refrigeration appliance, and hence the mean temperature of the air in the refrigerated areas, could be altered in response to influences which are not local to the site of the appliance. For example, the parameters could easily be re-programmed in response to government regulations enforcing a change to the temperatures at which refrigerated food is allowed to be stored.

Systems commonly known as "Home Control Systems" can also be used in certain commercial premises. A system such as described above, could be used to monitor and modify the performance of refrigerators and freezers in premises such as shops, supermarkets, frozen food retail centres.

Figure 7 is a diagram of a refrigeration controller, as described above, when included in a home control system, e.g. such as that having a command centre and modem as marketed as Credanet by Creda Limited. The serial data link can use twisted pair or mains signalling or telephone wires or fibre optic cable. The modem provides the interface between the commands and data on the serial data link and the microprocessor inside the refrigeration controller.

The refrigeration controller controls the refrigeration appliance and also provides means by which the central controller can read temperature information from the refrigeration appliance.

Fig. 8 shows a block diagram of an ASIC circuit incorporating a digital non-volatile parameters memory 100. An EEPROM memory is used as the parameters memory 100 in this ASIC; however, other forms of non-volatile memory could be used. This ASIC illustrates only one implementation of a refrigeration controller using a non-volatile memory. Different circuits could be devised by anyone competent in the art of logic and analogue circuit design.

The memory 100 is addressed by three decoders 101, 102 and 103, decoders 101 and 102 being supplied with 4 bits from the coded outputs from a temperature adjusting switch 104, e.g. a rotary Gray code device.

The device can be rotary or linear but one implementation is a rotary switch which will produce digital codes as the switch is rotated and having means, such as a pointer or marks, to define the rotation, the codes produced corresponding to the position. The coding could be binary, but other codes could also be used. The switch coding arrangement could be formed by tracks on a PCB which also contains the ASIC. A wiper arrangement could be used to short the coded tracks to a common track. It would also be possible to use a separate switch with its own internal coding means and wires or contacts to connect the switch to the PCB. For example, it could be that the best location for the temperature adjustment switch would be at the front of the appliance, where it is easily reached, and the best location for the controller could be at the rear of the appliance close to the pump motor. In either arrangement, the switch outputs have connections to the pins of the ASIC, and the switch COMMON is also connected to a pin of the ASIC, and or to one of the power supply rails of the controller. The ground or Vss supply would be the usual choice. Internal pull up transistors or resistors on the ASIC would ensure that the pins connected with the switch pattern remain at "logic 1" except when they are shorted to the COMMON by the wiper. Mechanical "detents" could be used to define individual positions as the switch knob rotates. A position of the switch and a corresponding code could be reserved to switch OFF the appliance.

Each decoder provides 16 address output bits from the 4 bits of switch input data. The outputs from decoder 101 are used to address locations in the parameters memory 100 where digital values which represent sixteen cut-in temperatures are stored. Similarly the outputs from decoder 102 address the sixteen of the parameters memory where digital values representing sixteen cut-out temperatures are stored. Decoder 101 is enabled by an input CR1 from an instruction decoder 105 and decoder 102 is enabled by an input CR2 from the instruction decoder 105. Thus, sixteen alternative pairs of cut-in and cut-out values are available for selection.

Decoder 103 is used to address the remaining locations of the parameters memory in dependence upon four further bits, CR3 to CR6, from the instruction decoder. Only one row of the parameters memory is addressed at any one time and the data at the addressed location appears at the outputs 106 of the memory. A 6 bit wide memory has been used in this ASIC.

In this example, the remaining locations or rows of the parameter memory store:

fast freeze cut-in temperature;
fast freeze cut-out temperature;
defrost temperature;
alarm temperature;
minimum on time;
maximum on time;
minimum off time;
maximum off time;
defrost interval;
defrost minimum time;
defrost maximum time;
options word.

Provision may be made for storing further parameters, but an example will be given hereinafter of one use of the above set.

An RC oscillator circuit 107 provides a timing frequency, via a clock generator 108, for the ASIC, specifically clocks CL1 and CL3. The timing is not critical, except for control of triac outputs, which are to be switched at specific points with reference to the mains period, and the control timing of an A/D converter 109. For this application, 40KHz would be a suitable oscillator frequency. As shown in Figure 9, the RC oscillator circuit 107 comprises a comparator COMP, two inverters, a NOR gate, set-reset flip flop SR2 and an output transistor. An external resistor and capacitor are used to set the frequency. The oscillator frequency is divided in the clock generator 108 by T flip flops.

Two NOR gates provide the internal clock signals CL1 and CL3, which are two separated phases of a 4 phase clock system. For an oscillator frequency of 40 KHz, the frequency of the internal clock would be 10 KHz, and the width of CL1 and CL3 would be 25 μ secs.

A Mains Sync input terminal 110 will have a clamped waveform which follows the mains applied to it during operation of the ASIC. Its function is to provide a timing reference for the zero crossing points of the mains voltage. Connected to the Mains Sync terminal 110 is a circuit 111 comprising (Fig. 9) a Schmitt trigger ST1, two D-type flip flops DF1 and DF2, and a NOR gate which operates to prevent multiple pulses as the slow mains waveform crosses zero. The output of the NOR gate feeds two further D-type flip flops DF3 and DF4 and an exclusive OR gate XOR1, the output of which lasts from the leading edge of CL1 to the leading edge of CL3, and occurs shortly after the zero crossing point on each half cycle of the mains. This signal is labelled MT1. The outputs from flip flop DF4 are signals denoted MP and MN and which can be used by the ASIC to determine whether the mains waveform is positive or negative. MP1 is used to clock a pre-scaler 112 (Fig. 8). One implementation of the pre-scaler is shown in Fig 9. A counter C1 divides the mains frequency by 50 (or 60 for USA) to produce an output frequency of 1 second period. This is further divided by a counter C3 to provide an output pulse every minute. This output is used to clock an event timer C5 (Fig. 8). Another counter C2 provides an output pulse once every 30 minutes and this pulse is used to clock a defrost/fast freeze timer C4 (Fig. 8). Both timers C4 and C5 may be 6 stage ripple dividers in which case the maximum event time would be 64 mins and the maximum defrost/fast freeze interval would be 32 hours.

The event timer and the defrost timer can be reset by signals CR9 and CR10 of the instruction decoder and the outputs of the timers can be compared with timing data stored in the parameters memory 100.

Two temperature sensors S1 and S2 are NTC thermistors. The controller can respond to two sensors, although it is not necessary to use both. The resistance changes in the thermistors due to temperature are converted to voltage changes by the op-amp circuits AMP1 and AMP2. Data select circuit DS1 passes the analogue voltage from either sensor S1 or sensor S2 to A/D converter 109. Signals CR7 and CR8 from the instruction decoder 105 select which sensor is used at a particular time. For example, sensor S1 could be attached to the evaporator and used for cut-out, and sensor S2 could be attached inside the refrigerated space and used for cut-in. Alternatively, sensor S1 or S2 could be used for both cut-in and cut-out.

The A/D converter 109 converts the analogue voltages from the temperature sensors to digital data. A digital magnitude comparator 113 can compare data from the A/D converter or the timers C4 and C5 with data from the parameters memory 100. An output LE from the magnitude comparator 113 is a logic 1 only if the data from the timers or A/D converter is less than or equal to the data stored in the parameters memory. A data selector DS2, controlled by CR11, CR12 and CR13 from the instruction decoder, selects whether the upper input to the magnitude comparator comes from the A/D converter, the event timer or the defrost/fast freeze timer.

The flow of instructions CR1, CR2, etc. from the instruction decoder 105 is controlled via an address decoder 115 by a sequence counter C6, which is incremented every CL1, or can jump to a different count in response to the results of outputs from a test logic circuit 114. The test logic circuit 114 can test the output of the magnitude comparator 113, individual bits at the output of the parameters memory 100, and also logic signals from a door switch input DOOR SWITCH and a fast freeze input FF SWITCH.

The sequence counter C6 can be reset by a pulse POR generated when power is applied to the ASIC, or by a signal generated when the door of the appliance is open, or by the initiation of a fast freeze operation.

This ASIC example assumes that the parameters memory is an EEPROM. Data can be written to the memory by applying a sequence of addresses and data a serial data input SDATA, and clocking these data into the parameters memory using a serial clock input SCLK. For each address and data byte, a programming voltage is applied for a specific time at a VPROG pin. A typical programming voltage would be 15V and programming time per memory address would be 5 m.secs.

The logic to control and store the serial addresses and data during programming of the EEPROM is not shown in the figures.

The ASIC has internal logic which will permit the data from the A/D converter 109 to be clocked out in serial fashion on a DATA output pin, controlled by a CLK pin. This data could be used by a second ASIC or microprocessor to display the temperature reading of the refrigerated area.

Relay output logic 117 (Fig. 8) contains (Fig. 9) a flip flop SR1 which is set by CR17 and reset by CR18 from the instruction decoder. A D-type flip flop DF5 is used to sychronise the switching of the output to the zero crossing of the mains. A counter C7 is used to delay the switching of the relay coil, so that the relay contacts will close and open near to the mains zero crossing. This will reduce interference from pump motor switching and increase the contact life of the relay. Counter C7 is reset when the output of flip flop DF5 is off and is clocked by CL1 when enabled by the output of flip flop DF5. When counter C7 reaches the maximum count, further clocks are inhibited by NAND gate ND1. Counter C7 is held reset when the relay output is off. The relay output pin RELAY of the ASIC is driven by a buffer B1 which could be of open drain or push-pull configuration.

A triac output TRIAC provides the option of driving the pump motor from a triac instead of a relay. The circuit 116 comprising a NAND gate, an inverter, a Schmitt trigger and a NOR gate generates short pulses of approximately 5 μ secs duration, which are applied to the gate terminal of the triac, at a frequency of 10 Khz, while the triac output is on. This pulsing of the triac gate serves a dual purpose. To ensure that the triac will switch on in either quadrant may require a gate trigger current of 50 mA. A short pulse of around 5 μ secs is sufficient to switch the triac on, provided the current which flows between its main terminals is greater than the minimum specified holding current. The gate current would normally be supplied from the same DC supply which supplies the ASIC. Pulsing the gate of the triac reduces the average current drawn from this supply. For example, if the pulsing interval is 100 μ secs, the pulse width is 5 μ secs, and the gate pulse current is 50 mA, then the average gate current is 2.5mA. Repeated pulsing of the triac gate during each half cycle of the mains voltage also prevents the problem of the triac not switching on due to lack of holding current, and also ensures that it will be switched on again within a short period of time after it switches off in each half cycle owing to the current falling below the holding current. The motor current and voltage across the triac are not in phase due to the inductive nature of the motor load. The initial switching on close to the mains zero crossing points, and the repeated switching on shortly after the triac has switched off in each half cycle owing to lack of holding current, ensure that the motor will start and run correctly, and also minimise the radio frequency interference from the repeated switching of the motor current.

The heater output HEATER is produced by a heat drive circuit 118 switched on by CR19 (Fig. 9) from the instruction decoder and switched off by CR20, both acting on a set-reset flip flop SR3. A timing circuit comprising a D-type flip flop DF6, an inverter, a Schmitt trigger, a NAND gate, and a NOR gate ensures that the output will switch on and off close to the zero crossing of the mains, and also applies repetitive pulses to the output via a buffer B3. The heater would normally be a resistive load to the triac and so the current and voltage would be in phase. However, switching close to the mains zero crossing is still worthwhile to eliminate radio frequency interference. Repetitive firing of the triac gate is used again to minimise the current drawn from the supply and to ensure switch on at low holding currents.

The warning output WARNING is switched on by CR21 and off by CR22. A set-reset flip flop SR6 is set when the control circuit detects that the temperature of the refrigerated area is above a certain pre-programmed value. The ASIC output WARNING could be used to switch a neon, an LED, or an audible alarm such as a piezo buzzer.

A door switch input DOOR SWITCH of the appliance may be connected to a door switch to switch a light on inside a refrigerator. When the switch is open, the mains waveform will appear at the DOOR SWITCH input. D-type flip flops DF7 and DF8 and a NOR gate NR8 are used to de-bounce the switch. Set-reset flip flop SR4 is set when the switch is open and reset when closed. The output DO of flip flop SR4 can be tested by the test logic during operation of the controller.

The fast freeze output FF INDICATOR is switched on by a signal initiated by closing a fast freeze switch connected to the input FF SWITCH and which is de-bounced by D-type flip flops DF11 and DF12 and a NOR gate NR9. A set reset flip-flop SR5 is set when the switch is closed and reset by CR23 at the completion of the fast freeze operation. Fast freeze output buffer B5 is driven by signal FF from flip flop from SR5. The FF INDICATOR output could be used to switch a neon, an LED or other form of visible indicator to show the user that a fast freeze operation is in progress. During a fast freeze operation, the refrigeration means is either run continuously for a time decided by the fast freeze timer C4, or special (lower) values of cut-in and cut-out can be addressed in the parameters memory for a time decided by the fast freeze timer.

The logic circuit upstream of signals DO and FF comprises four D-type flip flops, two NAND gates, a NOR gate, and an inverter and is used to produce a reset pulse R to the address counter C6 if either the door switch or the fast freeze switch is closed. The pulse lasts from CL1 to CL3.

Figure 9 also shows details of the test logic 114 used to control the address counter C6. The output LE from the magnitude comparator 113 can be tested under the control of CR14. A 3-in to 8-out decoder 119 allows one of the other inputs to the test logic to be tested at the same time as LE. Testing the output bits B0 to B5 of the parameters memory would normally be done to test the "option bits" which decide the configuration of the controller. The status (DO & FF) of the door switch and the fast freeze flip flop can also be tested. A positive result to a test will result in a logic zero being clocked into a D-type flip flop DF15. This will cause the counter to be loaded with a new address. A negative result from a test will increment the address counter C6.

The "option bits" of the parameters memory could be programmed with data which would be tested by the logic of the controller to decide on modes of operation (branches in the flow chart of the sequential operating sequence).

Example 1. Sensor operation.

The controller has the ability to respond to two sensors, and two bits in the memory are tested to select one of the following modes of operation.

Bit1	Bit2	Mode
0	0	cut-in from sensor 1, cut-out from sensor 2
0	1	cut-in from sensor 1, cut-out from sensor 1
1	0	cut-in from sensor 2, cut-out from sensor 2

Sensor 2 could be attached to the evaporator, and sensor 1 used for the air temperature of the refrigerated area.

Example 2. Defrost option selection.

Bit3	Bit4	Mode
0	0	defrost disabled;
0	1	defrost initiated by time and completed by

		time;
1	0	defrost initiated by time and completed by sensor; and
1	1	defrost initiated by time, and completed by time or sensor.

The method of RANGE selection used in the above embodiment allows digitally defined values for the cut-in and cut-out temperatures to be used internally in the control ASIC simply by reading the contents of non-volatile memory. The "DIFFERENTIAL", which is the difference between the cut-in and cut-out temperatures for a particular range selection, is precisely and digitally defined, and can either be a constant value, or a value which varies with the RANGE selection, depending on the values programmed into the parameters memory. The digital data can be programmed so that the values correspond to the voltage vs temperature characteristics of the sensor. This feature means that a simple re-programming of the "non-volatile parameters memory " is all that is required to convert a controller for use with one sensor to use with another.

Figures 10 and 11 show examples of how the ASIC circuit of Figures 8 and 9 might be used in practice to build complete refrigeration controllers.

In Figure 10, only one sensor, S1, is used. Also shown are a fast freeze switch 120, a door switch 121, fast freeze and defrost neons 122 and 123, an internal light 124, a compressor motor 125 with start winding and triac 126, a defrost heater 127 with triac 128, power supply 129 with fuse 130 and temperature adjust switch 131.

Figure 11 shows a similar arrangement but with relay control of the compressor motor.

A flow chart of the operation of the ASIC circuit of Figures 8 and 9 as built into the instruction decoder might be as follows:

(a) produce reset pulse R and reset event timer C5 (CR9);

(b) reset defrost timer C4/(CR10);

(c) test for sensor temperature > selected cut-in (or fast freeze cut-in if in fast freeze mode) - if Y increment to step (d) else jump to step (k);

(d) turn motor on (CR17);

(e) reset event timer C5 (CR9);

(f) test for event timer count > minimum on time - if Y increment to step (g) else jump to step (f);

(g) reset event timer C5 (CR9);

(h) test for sensor temperature < selected cut-out (or fast freeze cut-out if in fast freeze mode) - if N increment to step (i) else jump to step (k);

(i) test for event timer count > maximum on time - if N increment to step (j) else jump to step (k);

(j) test for defrost time count > defrost interval - if Y jump to step (r) else jump to step (h);

(k) turn motor off (CR18);

(l) reset event timer (CR9);

(m) test for event timer count > minimum off time - if Y increment to step (n) else jump to step (m);

(n) reset event timer (CR9);

(o) test for sensor temperature > cut-in (or fast freeze cut-in) - if N increment to step (p)

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    else jump to step (d);
(p) test for defrost time count > defrost interval - if N increment to step (q) else jump to step (r);
(q) test for event timer count > maximum off time - if N jump to step (o) else jump to step (d);
(r) turn motor off (CR18);
(s) reset defrost timer (CR10);
(t) reset event timer (CR9);
(u) defrost heater on (CR19);
(v) test for event timer count > defrost minimum time - if Y increment to step (w) else jump to step (v);
(w) test for evaporator temperature > defrost cut-out - if N increment to step (x) else jump to step (y);
(x) test for event timer count > defrost maximum time - if Y increment to step (y) else jump to step (x);
(y) turn defrost heater off (CR20) and go to (a).
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It is possible to use "adaptive cycling" methods of controlling the refrigerated area, where the ON and/or OFF times are adjusted in response to the time taken to reach a preset temperature or by the mean temperature of the refrigerated area. The ASIC described herein does not use this technique. It switches ON and OFF normally only in response to the temperature sensors on the evaporator or in the refrigerated space. The electronic timing is not used to control the temperature, and does not vary with the temperature, it is rather used to ensure minimum ON and OFF times and to prevent excessive ON or OFF times. These "supervisory timing" functions could be viewed as useful by a manufacturer in that for example they would prevent too frequent starting and stopping of the refrigeration means which could cause a nuisance to the user and result in wear or damage to the appliance.

For example a faulty sensor could result in very frequent starting and stopping of the motor which could damage the motor or the compressor. A different problem with the sensor could result in continuous running of the refrigerator or freezer which could cause liquids in a refrigerator to freeze and damage to other food such as salads. The "supervisory timing" should be viewed as a background control which under normal conditions would only be used if there were a fault with the temperature sensors. This applies to all embodiments described herein.

The "Fast Freeze" operation is accomplished by addressing fast freeze cut-in and cut-out temperatures in the parameters memory, and the defrost operation by switching on a heater for a preset time at preset intervals, and sensing the temperature at the evaporator.

CLAIMS

1. A refrigeration controller comprising an electronic circuit having an input for receiving, as an electrical parameter, a value representative of temperature, means enabling a lower (cut-out) and an upper (cut-in) temperature value to be registered by the circuit, control means for comparing the value representative of temperature with the lower and upper values and for producing an output, refrigeration control, signal in dependence upon the electrical parameter attaining values corresponding to the lower and upper values respectively to tend to maintain the temperature of a refrigeration space in a given range, means for enabling timing data to be registered by the circuit, and means for overriding the dependence of the state change upon the electrical parameter, such override being a function of said timing data in such a manner that there are durations between the changes in state of said output signal which do not go below and above respective durations defined by the timing data, despite said parameter attaining values which would otherwise determine those durations.

2. A refrigeration controller according to claim 1, wherein the timing means is operable to control the minimum refrigeration ON time after cut-in, the timing means having an operating mode in which temperature control is overridden to prevent cut-out before a minimum time has elapsed.

3. A refrigeration controller according to claim 1 or 2, wherein the timing means is operable to control the minimum refrigeration OFF time after cut-out, the timing means having an operating mode in which temperature control is overridden to prevent cut-in before a minimum time has elapsed since cut-out.

4. A refrigeration controller according to claim 1, 2

or 3, wherein the timing means has an operating mode in which temperature control is overridden to force cut-in of refrigeration if more than a registered maximum time has elapsed since cut-out.

5. A refrigeration controller according to claim 4, and comprising means for testing for a defrost requirement before the forcing of cut-in.

6. A refrigeration controller according to any one of claims 1 to 5, wherein the timing means has an operating mode in which temperature control is overridden to force cut-out of refrigeration if more than a registered maximum time has elapsed since cut-in.

7. A refrigeration controller according to any one of claims 2 to 6, and which also contains means to provide a warning or alarm indiction if the cut-in and/or cut-out overrides occur with a given frequency, e.g. on more than a given number of successive refrigeration cycles.

8. A refrigeration controller according to any one of the preceding claims, wherein the electronic circuit is a single, monolithic, integrated circuit.

9. A refrigeration controller according to any one of the preceding claims and comprising means whereby setting and adjustment of the lower and upper temperature values is provided for by analogue circuit means, e.g. potentiometers coupled to the circuit.

10. A refrigeration controller according to any one of the preceding claims and comprising digital means in the integrated circuit for storing the lower and upper temperature values.

11. A refrigeration controller according to claim 10 and comprising digital memory means in the integrated circuit for storing discrete digital values, representing a plurality of sets of cut-in and cut-out values, a second input to receive data defining a required set and memory

addressing means coupled to the second input to use that data to provide a digital address to address the set to be used by the control means.

12. A refrigeration controller comprising a first input to receive, as an electrical parameter, a value representative of temperature and control means to produce an output signal to control refrigeration in dependence upon stored lower and upper temperature values, there being digital memory means in the controller for storing discrete digital values representing a plurality of sets of lower (cut-in) and upper (cut-out) values, a second input to receive data defining a required set and memory addressing means coupled to the second input to use that data to provide a digital address to address the set to be used by the control means.

13. A refrigeration controller according to claims 11 or 12 in combination with a temperature adjustment means coupled to the second input of the controller and having a discrete position rotary or linear action and which is operable to provide digital data at said second input for selection of any one set from a plurality of the sets of the discrete values of cut-in and cut-out representations.

14. A refrigeration controller according to claims 11, 12 or 13, and in which the discrete digital values representing cut-in and cut-out temperatures can be programmed and reprogrammed to adjust the performance of refrigeration controller for use with different types of refrigeration appliance or different temperature sensors.

15. A refrigeration controller according to any one of claims 11 to 14 and in which the difference between the cut-in and cut-out programmed values, i.e. the differential, can be programmed to be a constant value

for different temperature selections, or can be made to vary in a pre-defined manner for different selections.

16. A refrigeration controller according to any one of claims 10 to 15, wherein the digital means is a non-volatile memory.

17. A refrigeration controller according to any one of the preceding claims and comprising logic sequence testing means and memory space for storing "option bits" which can be tested by the logic sequence testing means to select different modes of operation.

18. A refrigeration controller according to any one of the preceding claims and which comprises a micro-controller to interface between a temperature sensor and refrigeration means, and which micro-controller contains values for cut-in and cut-out temperature stored in digital form, e.g. in either program memory or data memory.

19. A refrigeration controller according to any one of the preceding claims and comprising means by which the temperature of a refrigerated compartment can be monitored during cooling and warming periods of a refrigeration cycle, and means to store these temperature readings in digital form within a memory.

20. A refrigeration controller according to claim 19, and comprising means for storing digital data corresponding to elapsed time after the refrigeration means is switched ON or OFF, thus storing a temperature profile of a refrigerated area during the ON and OFF periods of the refrigeration cycle.

21. A refrigeration controller according to claim 19 or 20 and comprising means to calculate from stored digital temperature and time data mean values for the temperature of refrigerated areas during the ON and OFF parts of a refrigeration cycle.

22. A refrigeration controller according to claim 21, and comprising means to compare the mean temperature values with pre-programmed digital data corresponding to a desired mean temperature and to use the comparison along with a command program to adjust the stored values for cut-in and/or cut-out so as to maintain the mean temperature of the refrigerated area within a given range of the pre-programmed values.

23. A method to improve the temperature stability of a refrigerated area over a period of time by using a controller according to claim 22 and comprising subtracting the mean temperature and the pre-programmed value for the mean temperature over a number of refrigeration cycles, the stored cut-in and/or the cut-out values being changed only if the absolute magnitude of the resulting difference is greater than a pre-programmed threshold value.

24. A refrigeration controller according to any one of claims 1 to 22 with means to sense the waveform of the mains, and means for ensuring that the switching on or off of the refrigeration means occurs near to or coincident with the zero crossing of the mains live with respect to the mains neutral.

25. A refrigeration controller according to any one of claims 1 to 22 and 24, and containing a micro-processor or micro-controller with means which allow a modem or module of a home control system (or other remote signalling system), by means of serial data commands, to interrogate the controller for information regarding the temperature of a refrigerated area of areas.

26. A refrigeration controller according to any one of claims 1 to 22 and 24 and 25, and containing a micro-processor or micro-controller with means which allow a modem or module of a home control system (or other remote

signalling system), by means of serial data commands, to program parameters of the controller in such a manner that the performance of the refrigeration appliance is modified.

27. A temperature sensor simulator for use in adjusting lower and/or upper temperature values of a refrigeration controller of a form comprising an input to receive, as an electrical parameter (such as impedance, voltage or current), a value representative of temperature and means to produce a signal to control refrigeration in dependence upon stored lower and upper temperature values, the simulator comprising means storing a plurality of temperature vs electrical parameter values to provide a range of values of said electrical parameters, each value being selectable by the user, as a corresponding temperature value, for connection across said input.

28. A simulator according to claim 27 and comprising means for selecting two electrical parameters values, e.g. resistance, corresponding to two temperatures, respectively for the lower and upper value, and means for switching between the selected electrical parameter values during use in setting or adjusting the controller.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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(i) UK Cl (Edition K) G3R RBQ22 RBQ48

(ii) Int CL (Edition 5) F25B F25D G05D

Search Examiner

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Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

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Documents considered relevant following a search in respect of claims 1-11, 13-26 (PART)

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X Y	GB A 2098362	(SEA CONTAINERS) see page 2 lines 60-64 and 97-102	1, 2 (X); 8, 10, 16, 18, 25, 26 (Y)
Y	US 4501125	(TRANE) see column 9 line 42 to column 10 line 39	8, 10, 18, 25, 26
Y	US 4283921	(ELECTROMEDICS) see column 3 line 51 to column 4 line 55	10, 16, 18

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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