US007083109B2

(12) **United States Patent**
Pouchak

(10) **Patent No.: US 7,083,109 B2**
(45) **Date of Patent: Aug. 1, 2006**

(54) **THERMOSTAT HAVING MODULATED AND NON-MODULATED PROVISIONS**

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(73) Assignee: **Honeywell International Inc.**, Morristown, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 133 days.

(21) Appl. No.: **10/643,376**

(22) Filed: **Aug. 18, 2003**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
F25B 29/00 (2006.01)

(52) **U.S. Cl.** ..... **236/1 E**; 236/1 EA; 62/126; 62/127; 62/175

(58) **Field of Classification Search** ..... 236/51, 236/44 R, 44 C, 46 R, 46 A, 46 E, 94, 1 EA, 236/1 EB, E1; 62/125, 126, 127, 129, 130, 62/175, 157, 231, 176.5
See application file for complete search history.

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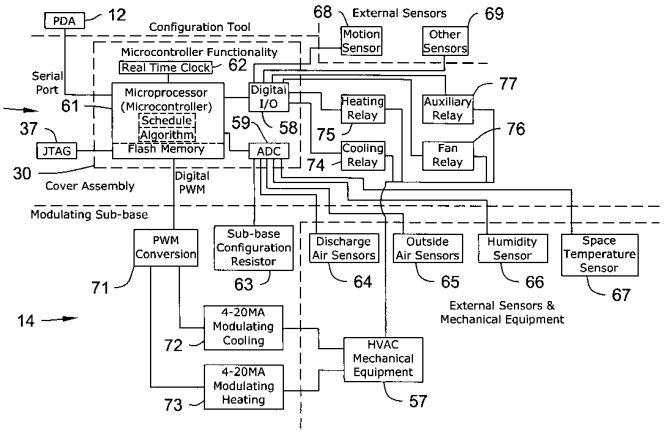
(74) *Attorney, Agent, or Firm*—Gregory M. Ansems

(57) **ABSTRACT**

A thermostat providing modulated or analog control of valves or dampers of an air management system. This permits operating a single cooling or heating stage with partially open valves or dampers as needed, since one full stage that is either fully on or off may not be easy to manage for effective air management of a particular type of building, zone or facility. The thermostat may also provide non-modulated control of multi-stage cooling and heating systems. The thermostat may even be used to control a modulated system having more than one stage of cooling or heating.

31 Claims, 32 Drawing Sheets



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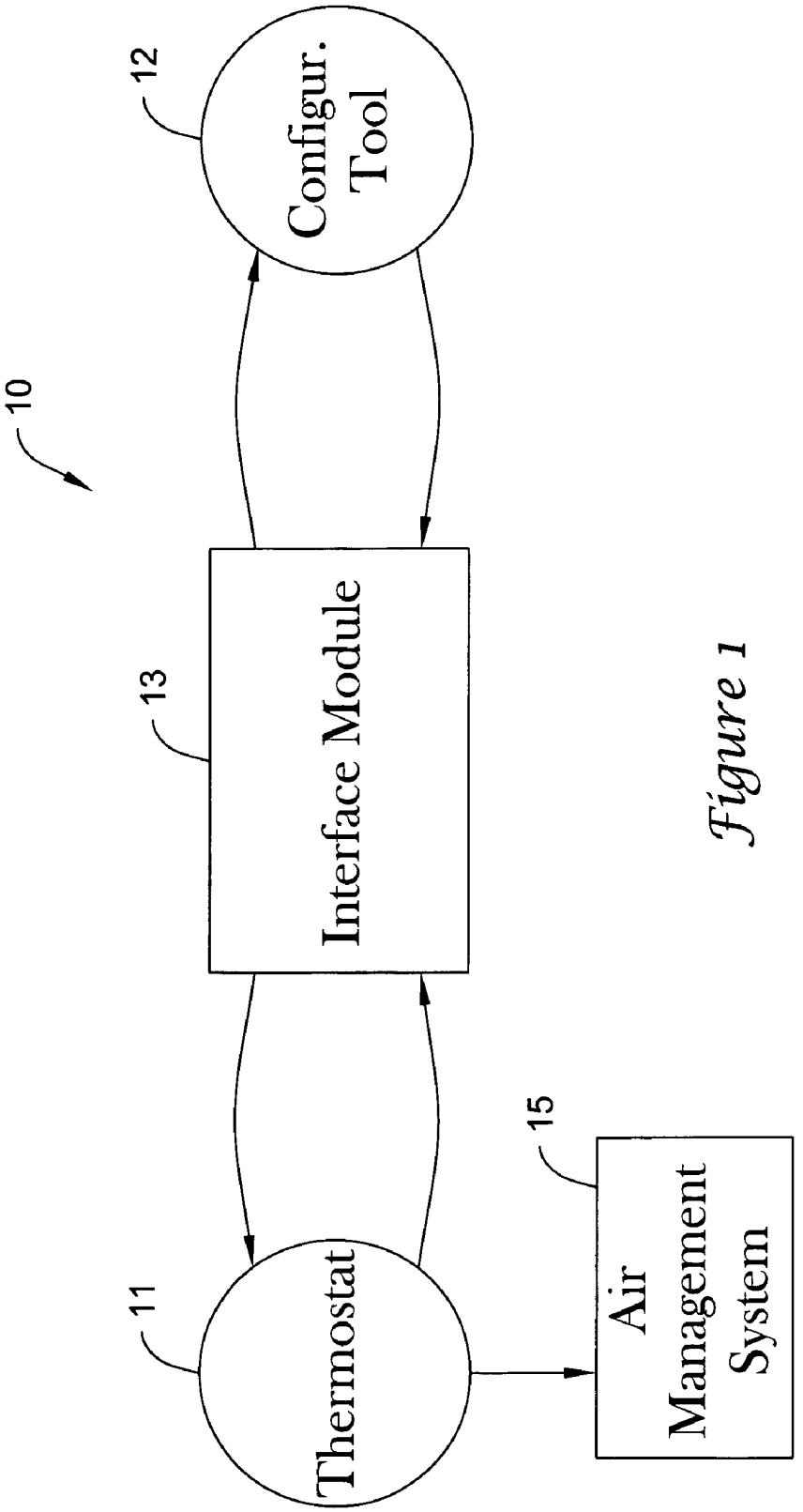

10
11
Thermostat
12
Configur. Tool
13
Interface Module
15
Air Management System

Figure 1

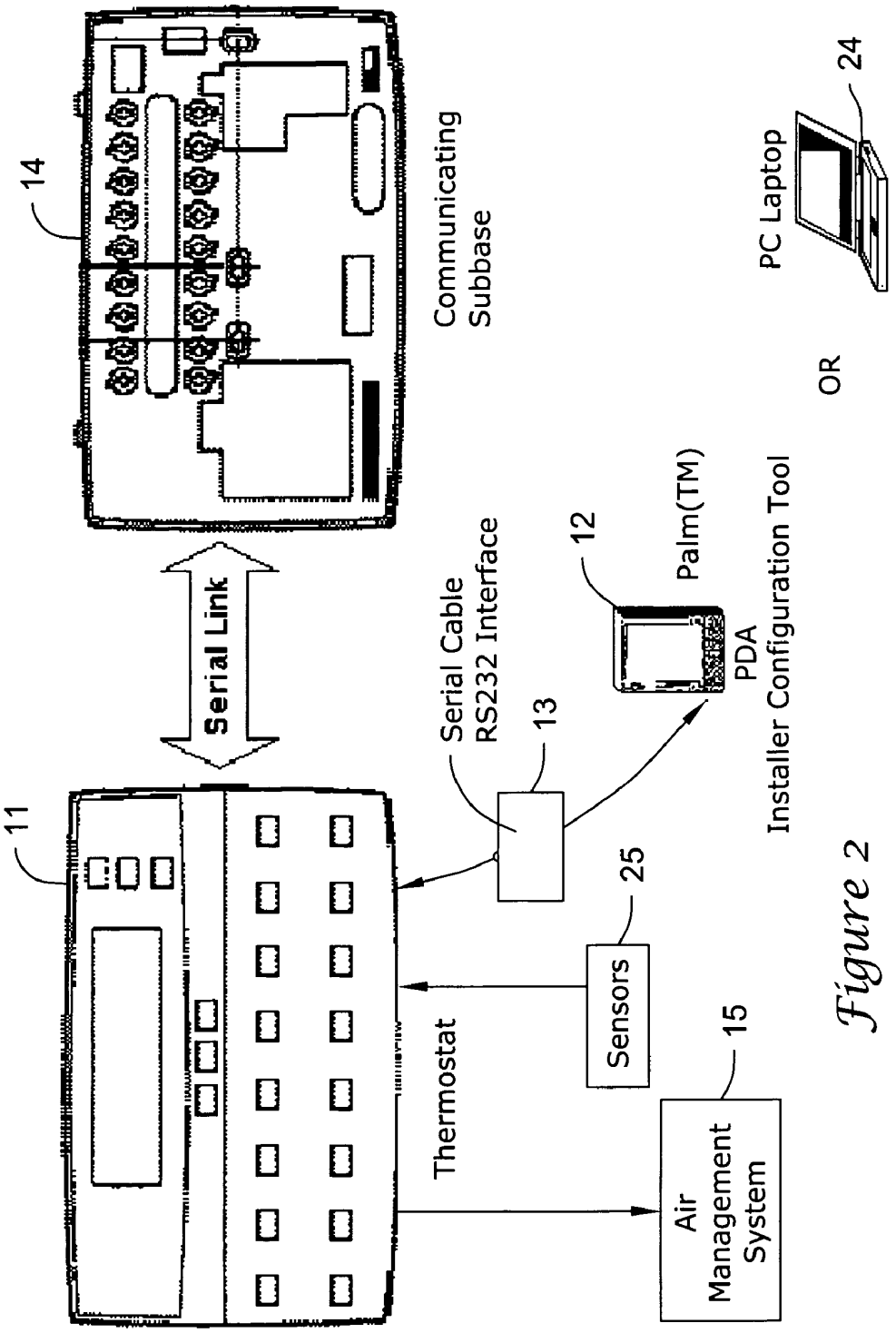
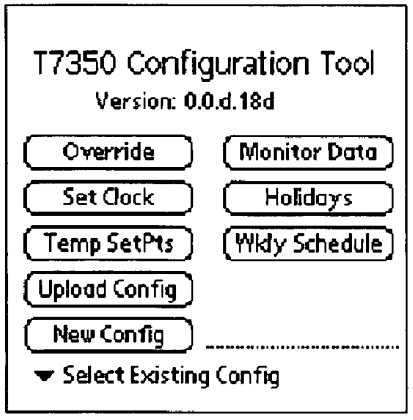

14
Communicating Subbase
Serial Link
11
Serial Cable RS232 Interface
13
12
Palm(TM) PDA
Installer Configuration Tool
OR
PC Laptop
24
Thermostat
Sensors
25
Air Management System
15

Figure 2



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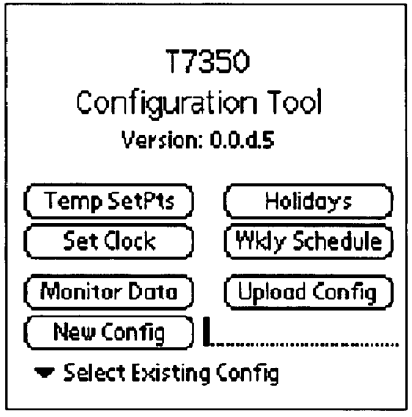

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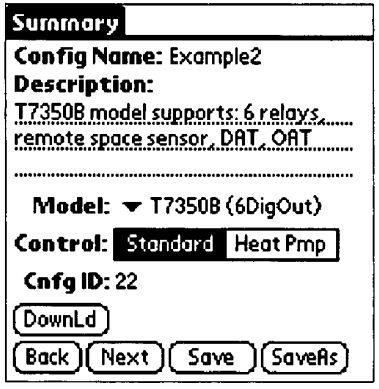

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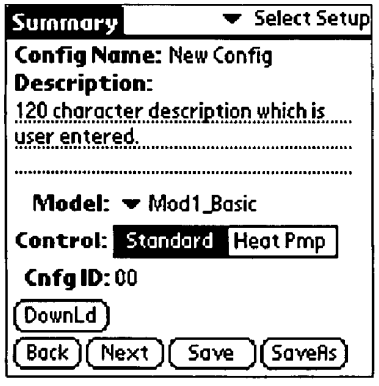

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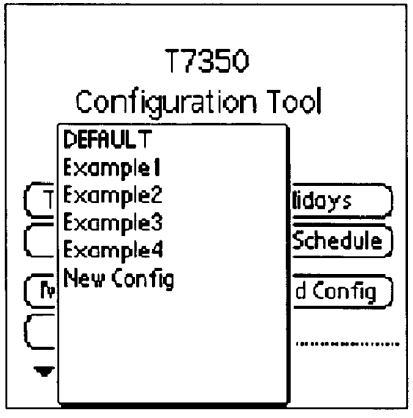

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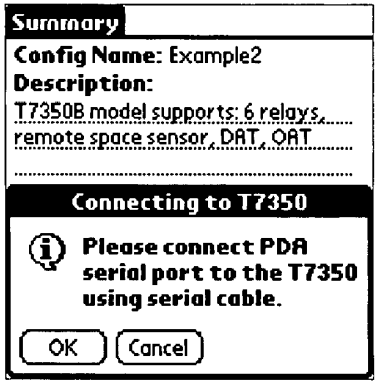

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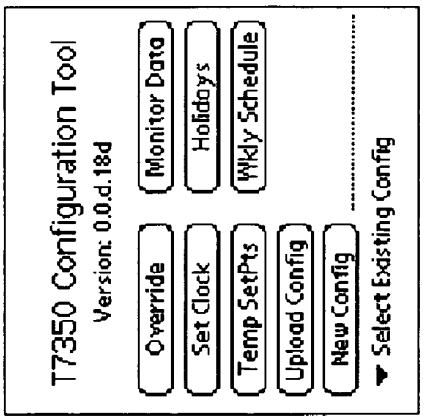

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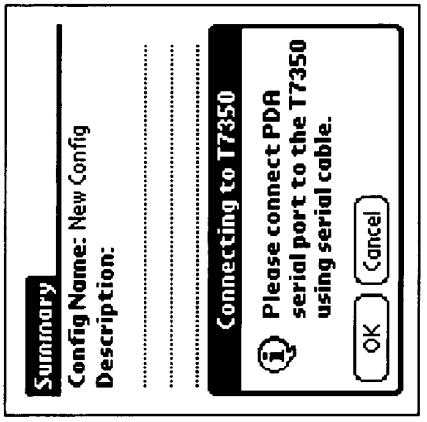

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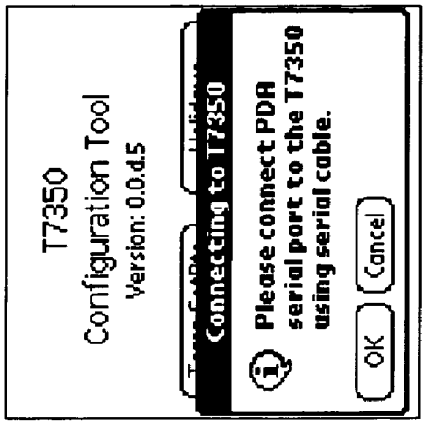

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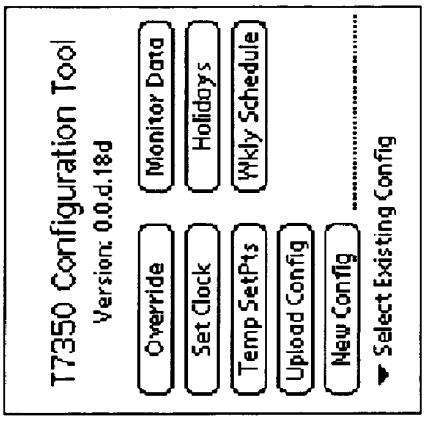

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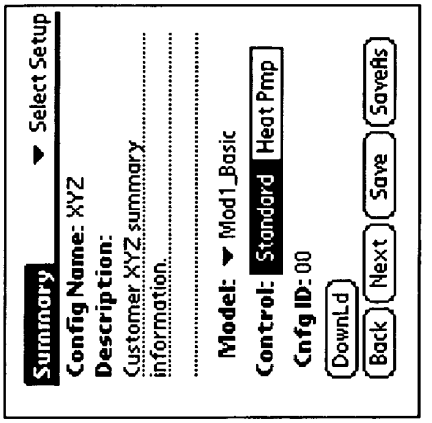

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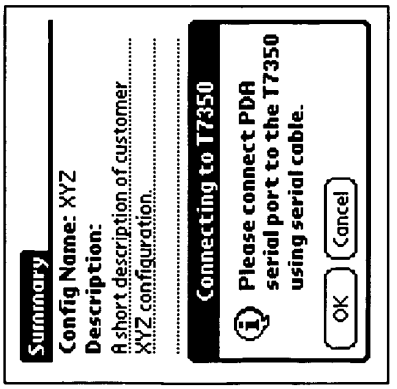

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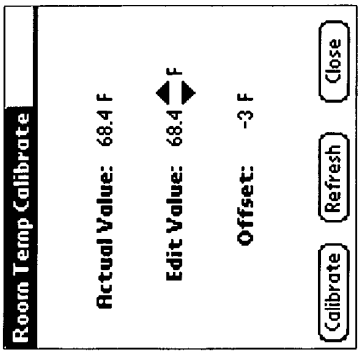

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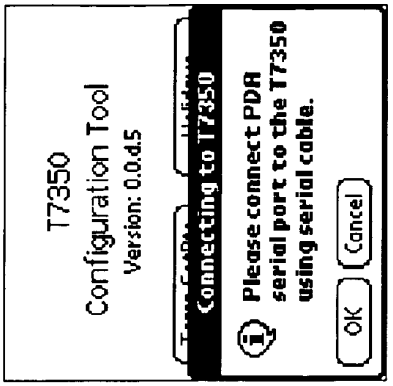

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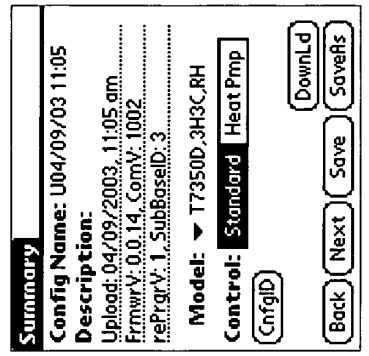

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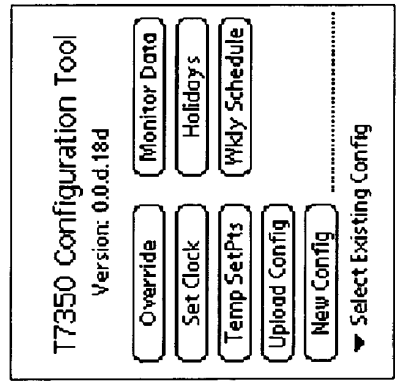

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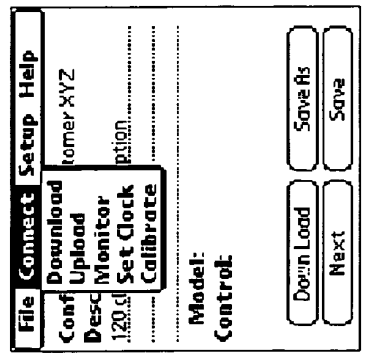

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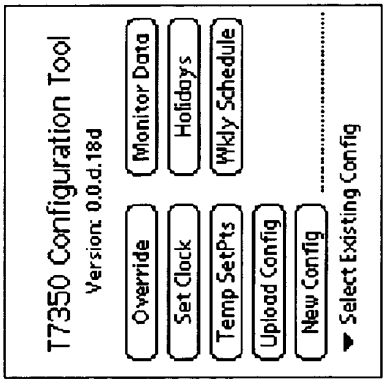

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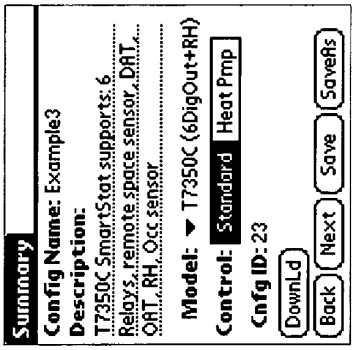

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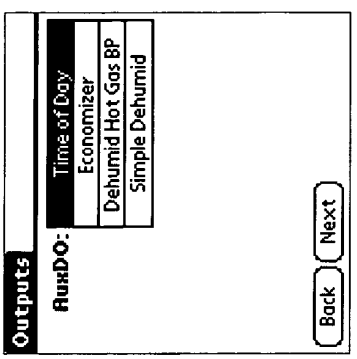

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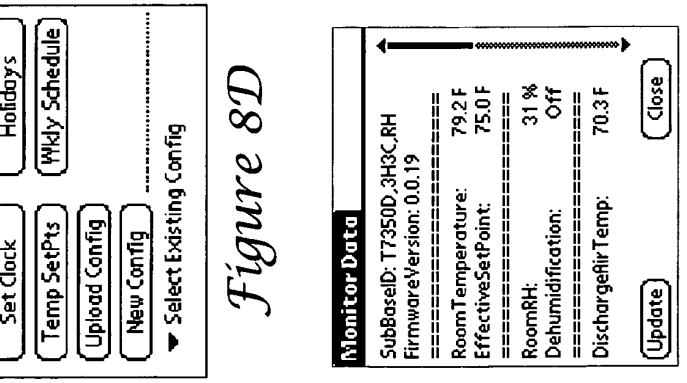

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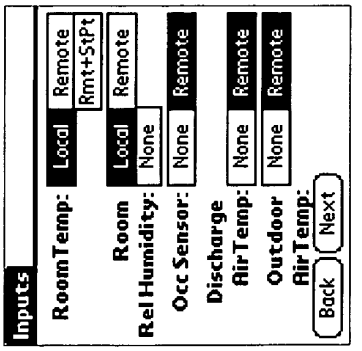

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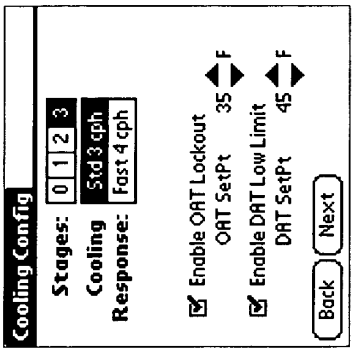

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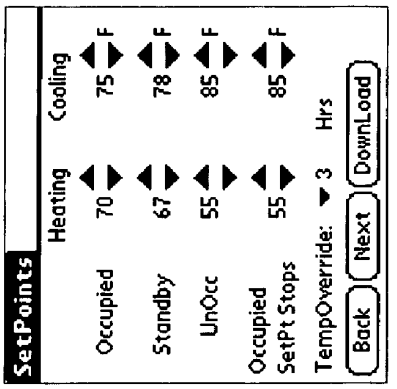

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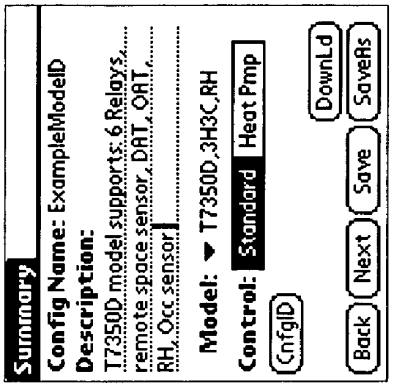

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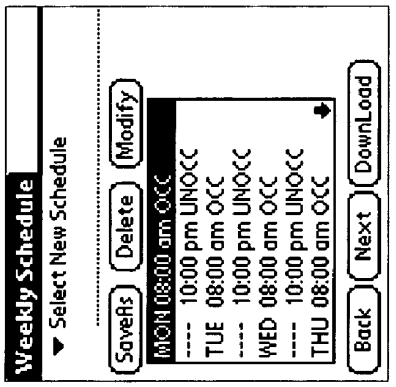

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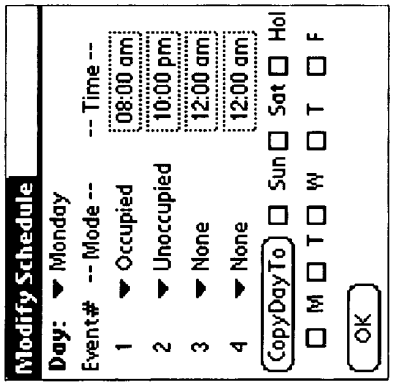

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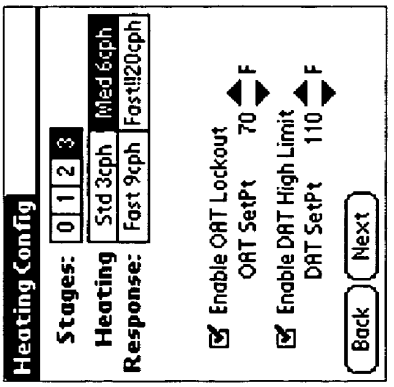

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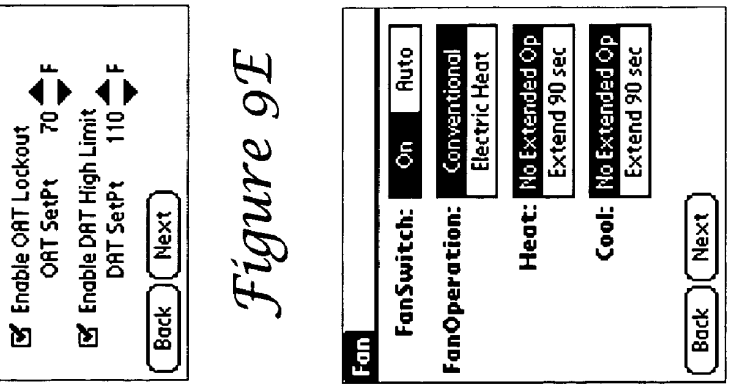

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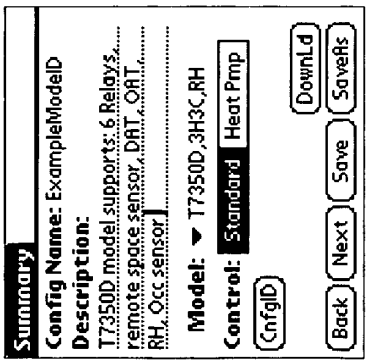

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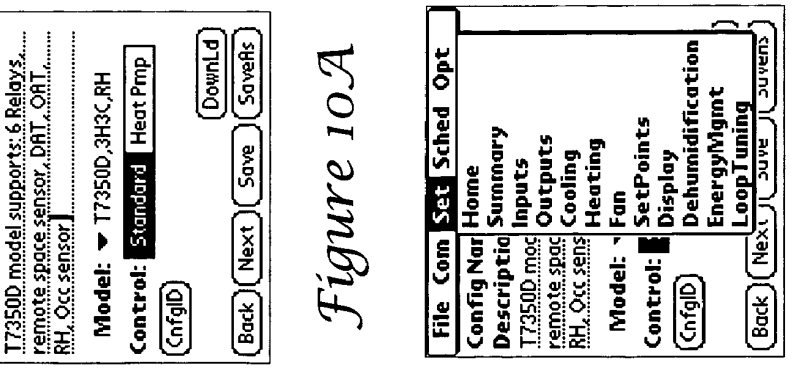

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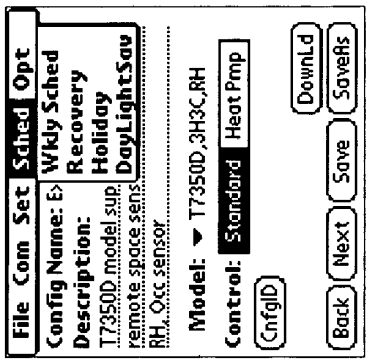

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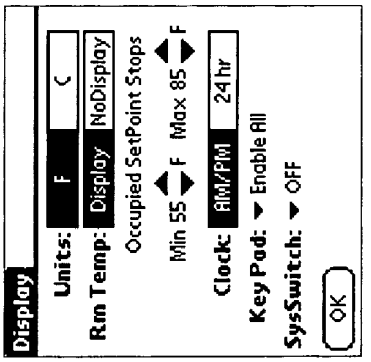

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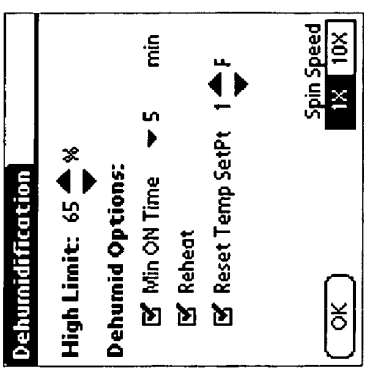

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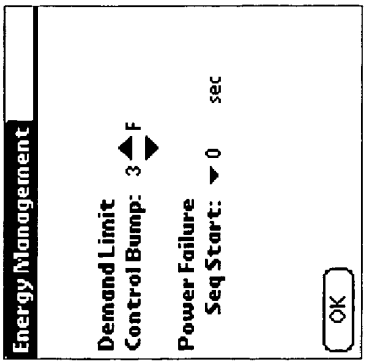

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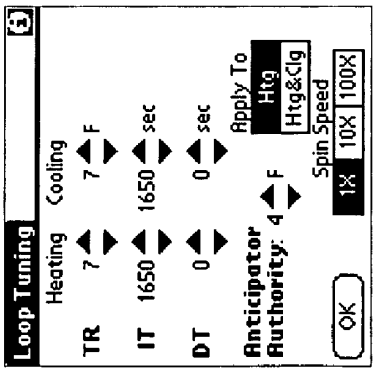

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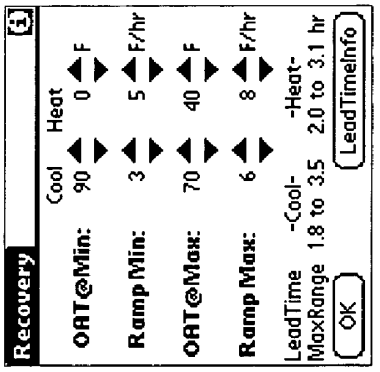

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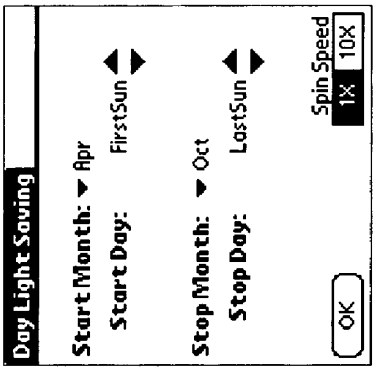

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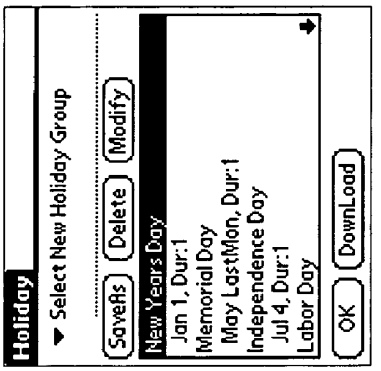

Figure 10J

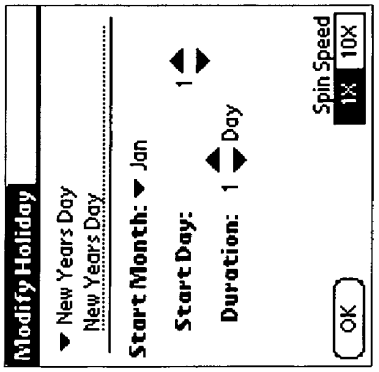

Figure 10K

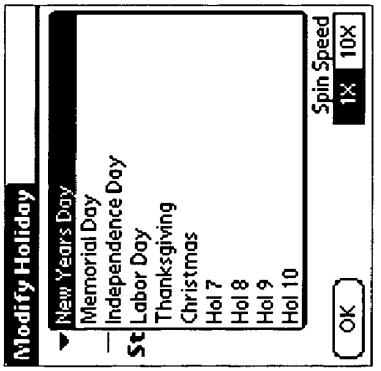

Figure 10L

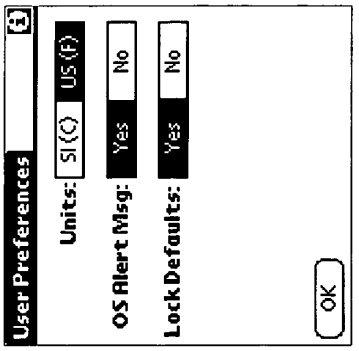

Figure 11A

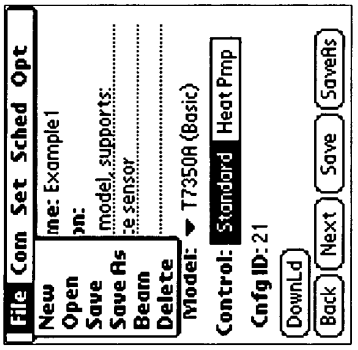

Figure 12A

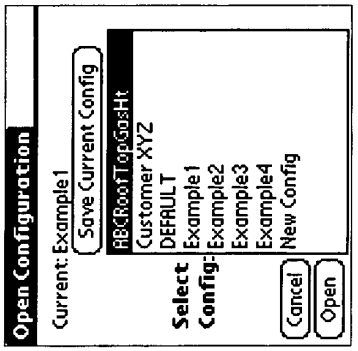

Figure 12C

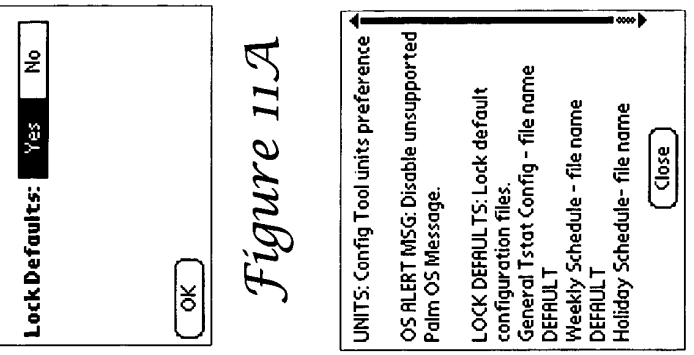

Figure 11B

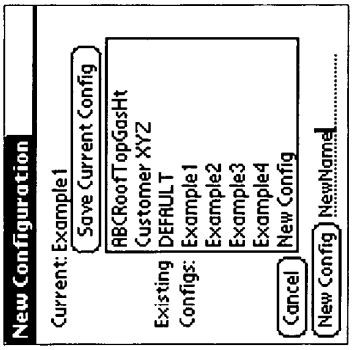

Figure 12B

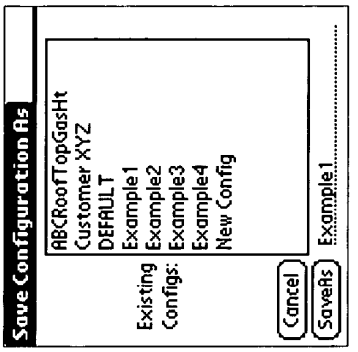

Figure 12D

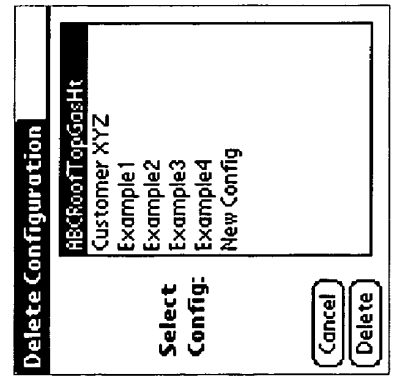

Figure 12E

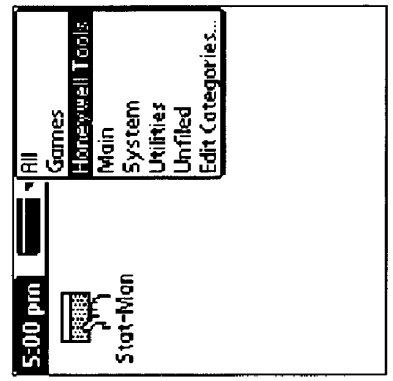

Figure 14A

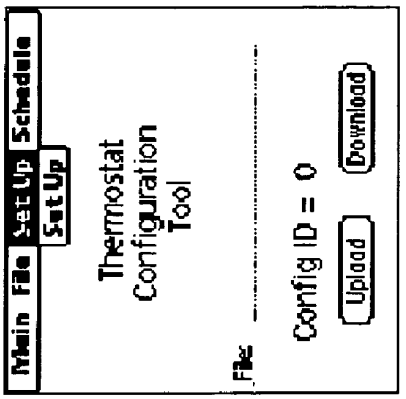

Figure 14C

Figure 13

Figure 14B

Figure 14D

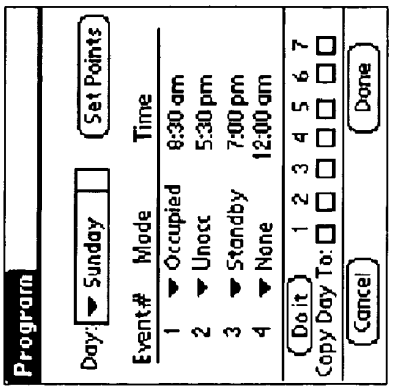

Figure 14E

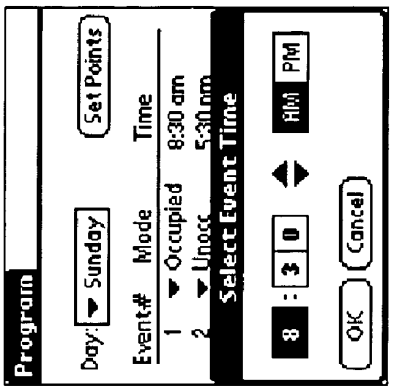

Figure 14G

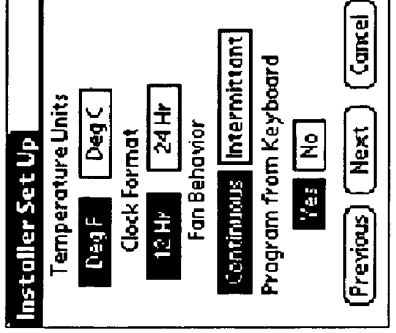

Figure 14I

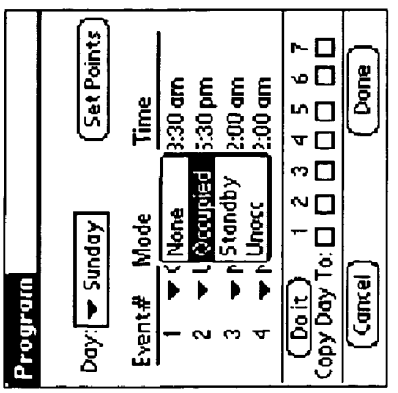

Figure 14F

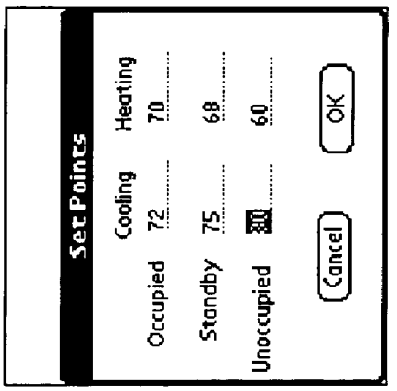

Figure 14H

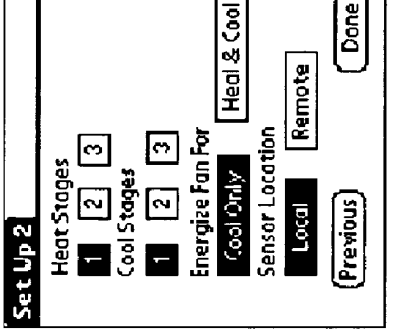

Figure 14J

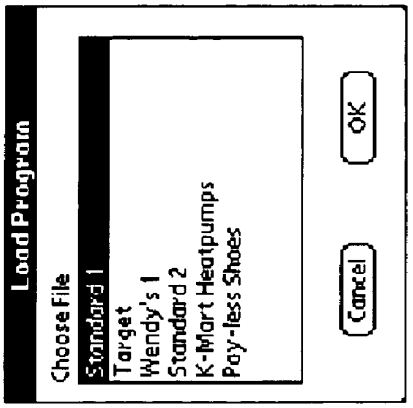

Figure 14K

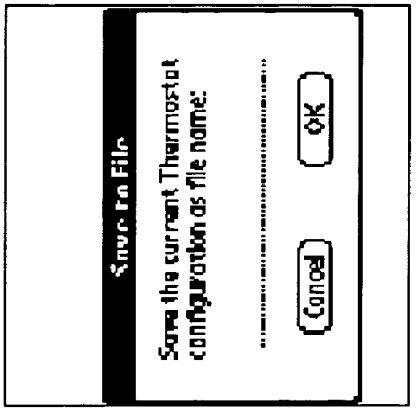

Figure 14M

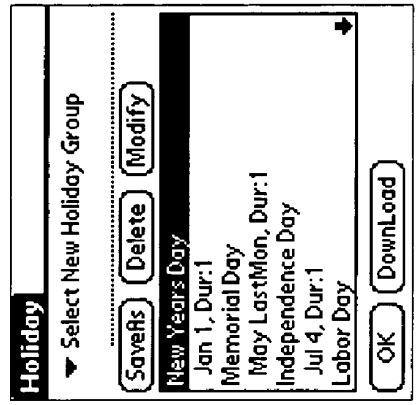

Figure 14O

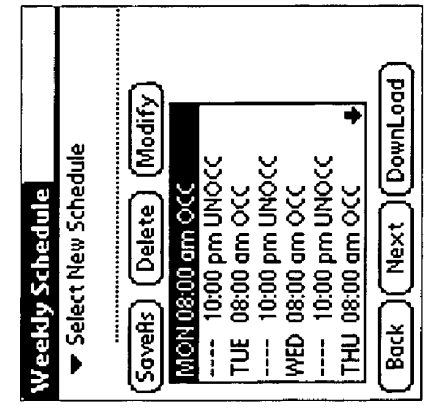

Figure 14L

Figure 14N

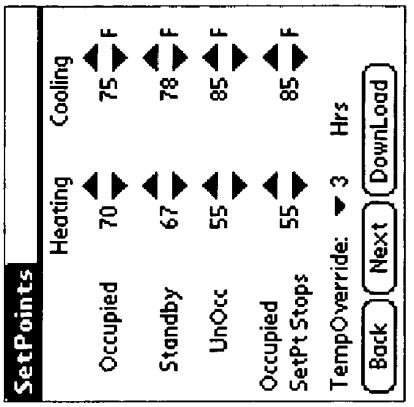

Figure 14P

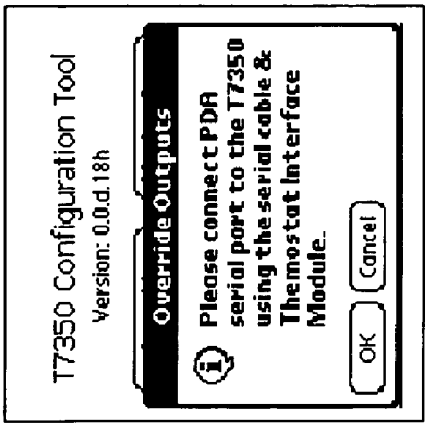

Figure 14U

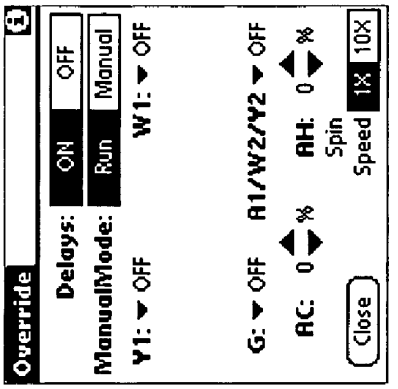

Figure 14V

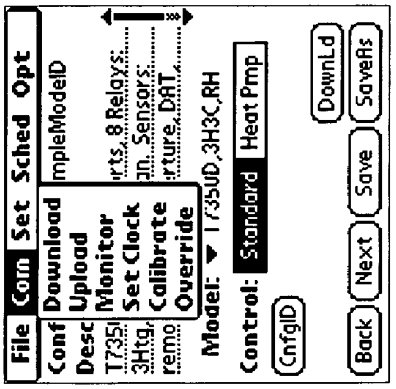

Figure 14S

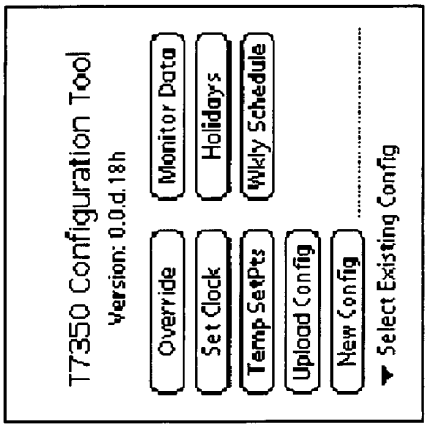

Figure 14T

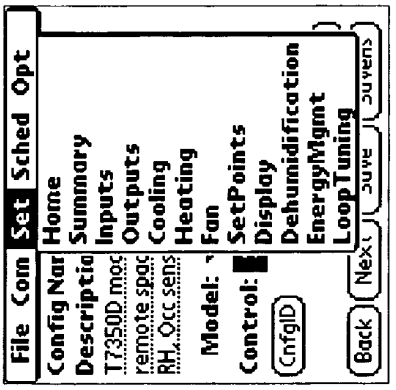

Figure 14Q

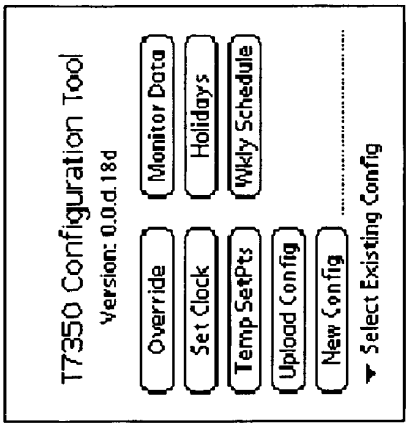

Figure 14R

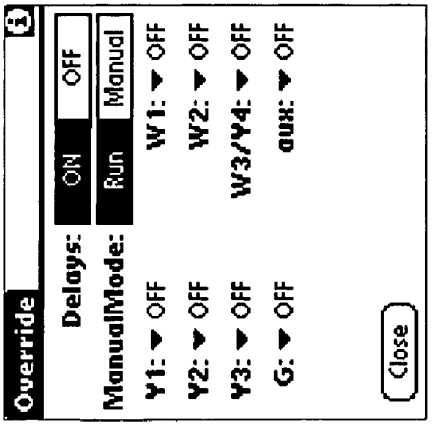

Figure 14W

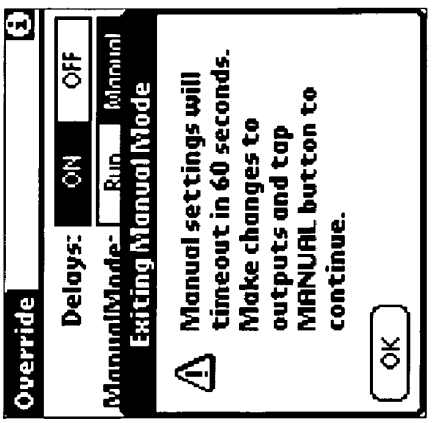

Figure 14Y

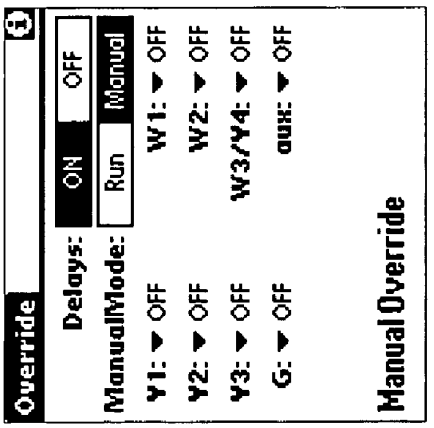

Figure 14Z

Figure 14X

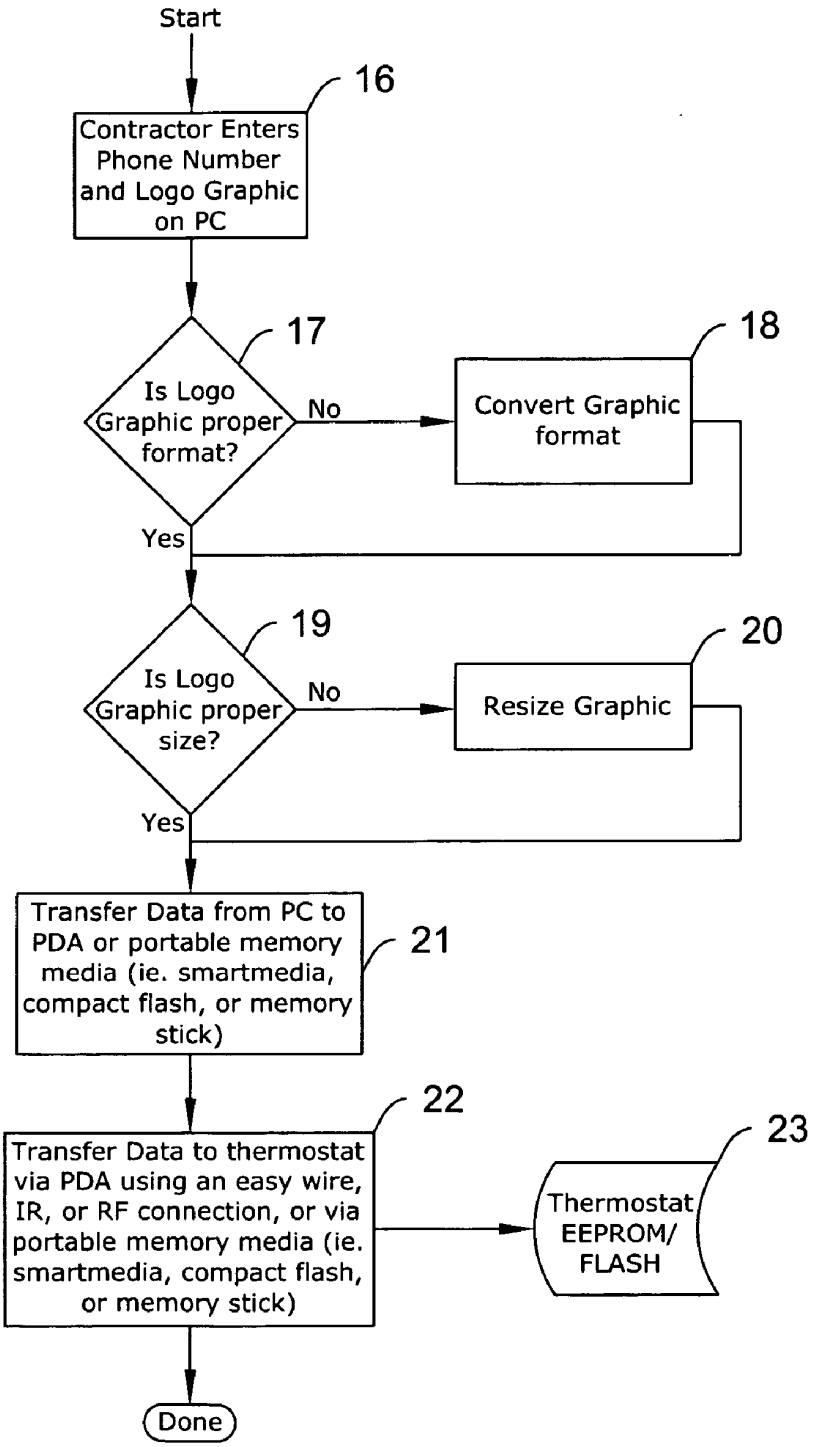
Start
16
Contractor Enters Phone Number and Logo Graphic on PC
17
Is Logo Graphic proper format?
No
18
Convert Graphic format
Yes
19
Is Logo Graphic proper size?
No
20
Resize Graphic
Yes
Transfer Data from PC to PDA or portable memory media (ie. smartmedia, compact flash, or memory stick)
21
22
Transfer Data to thermostat via PDA using an easy wire, IR, or RF connection, or via portable memory media (ie. smartmedia, compact flash, or memory stick)
23
Thermostat EEPROM/ FLASH
Done

Figure 15

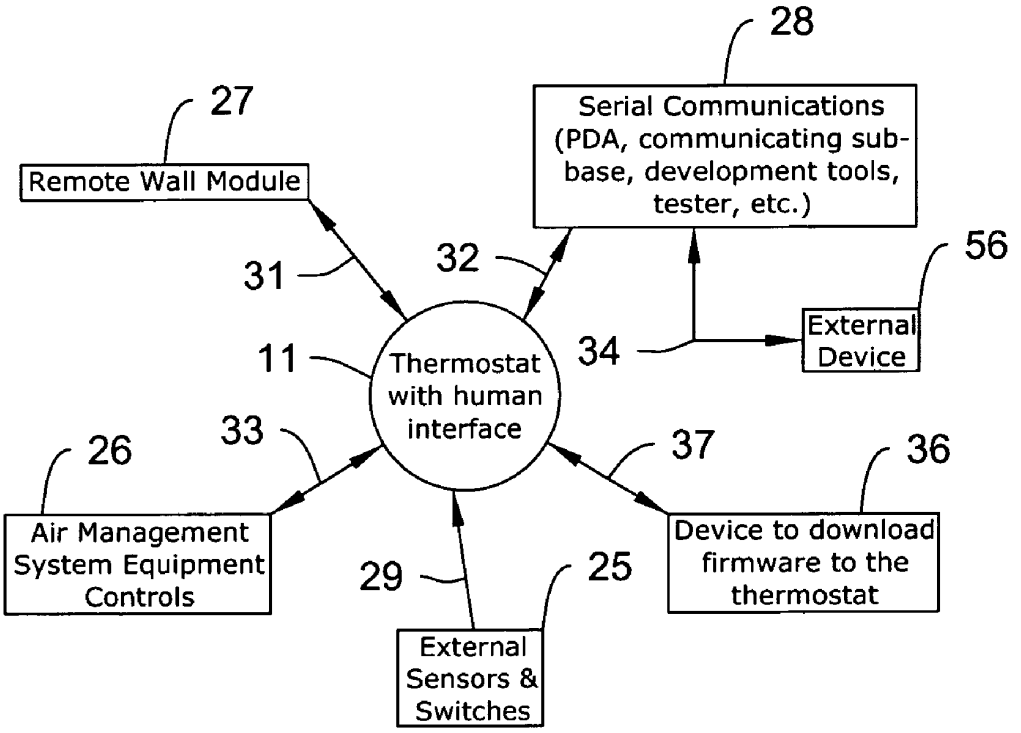
28
Serial Communications (PDA, communicating sub-base, development tools, tester, etc.)
27
Remote Wall Module
31
32
56
External Device
34
11
Thermostat with human interface
33
26
37
36
Air Management System Equipment Controls
Device to download firmware to the thermostat
29
25
External Sensors & Switches

Figure 16

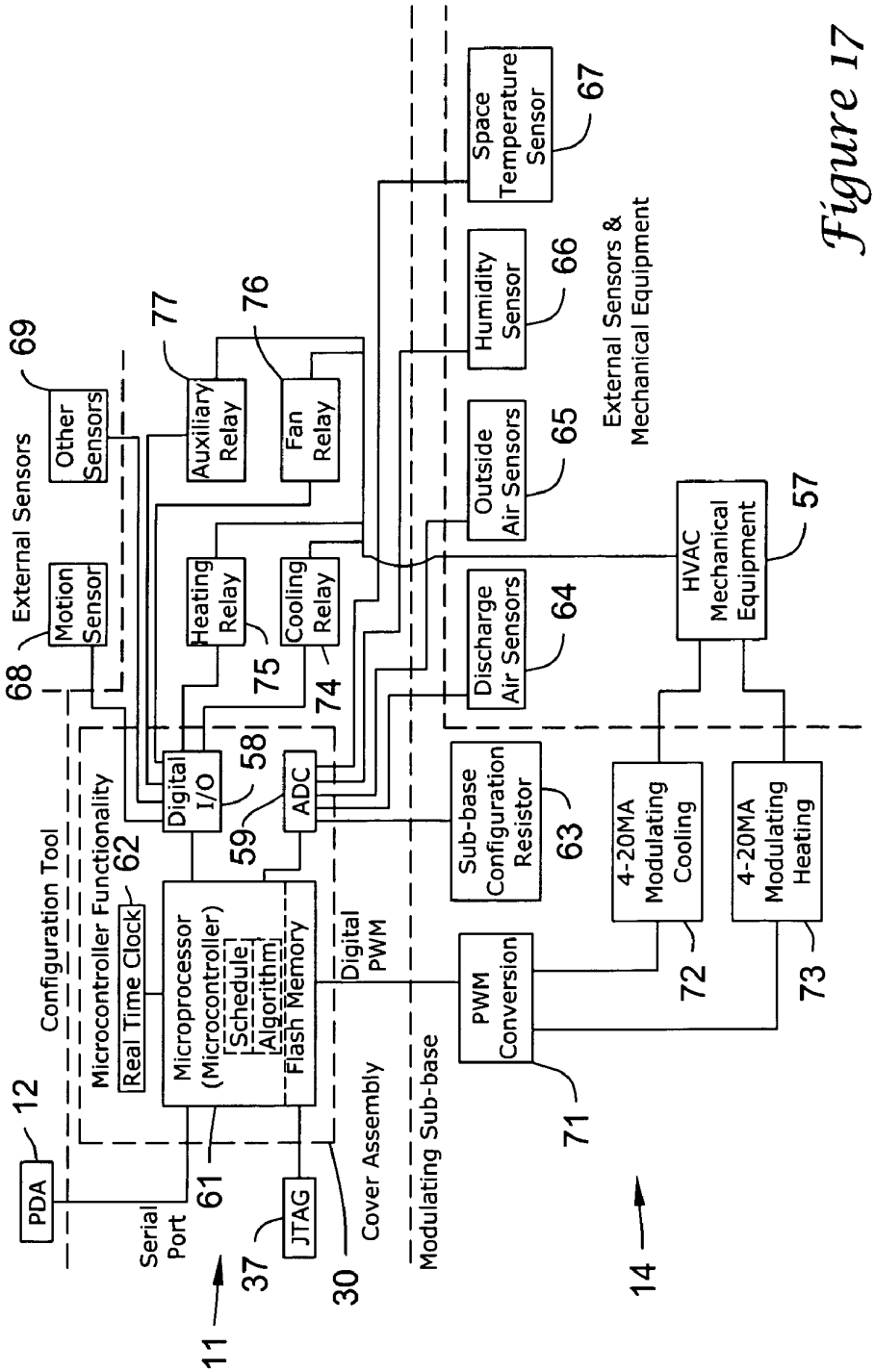
Configuration Tool
PDA
12
Serial Port
11
Microcontroller Functionality
Real Time Clock
62
Microprocessor (Microcontroller)
Schedule
Algorithm
Flash Memory
61
JTAG
37
Digital I/O
58
ADC
59
Digital PWM
Cover Assembly
30
External Sensors
Motion Sensor
68
Other Sensors
69
Heating Relay
75
Cooling Relay
74
Auxiliary Relay
77
Fan Relay
76
Modulating Sub-base
PWM Conversion
71
Sub-base Configuration Resistor
63
4-20MA Modulating Cooling
72
4-20MA Modulating Heating
73
14
Discharge Air Sensors
64
Outside Air Sensors
65
Humidity Sensor
66
Space Temperature Sensor
67
External Sensors & Mechanical Equipment
HVAC Mechanical Equipment
57

Figure 17

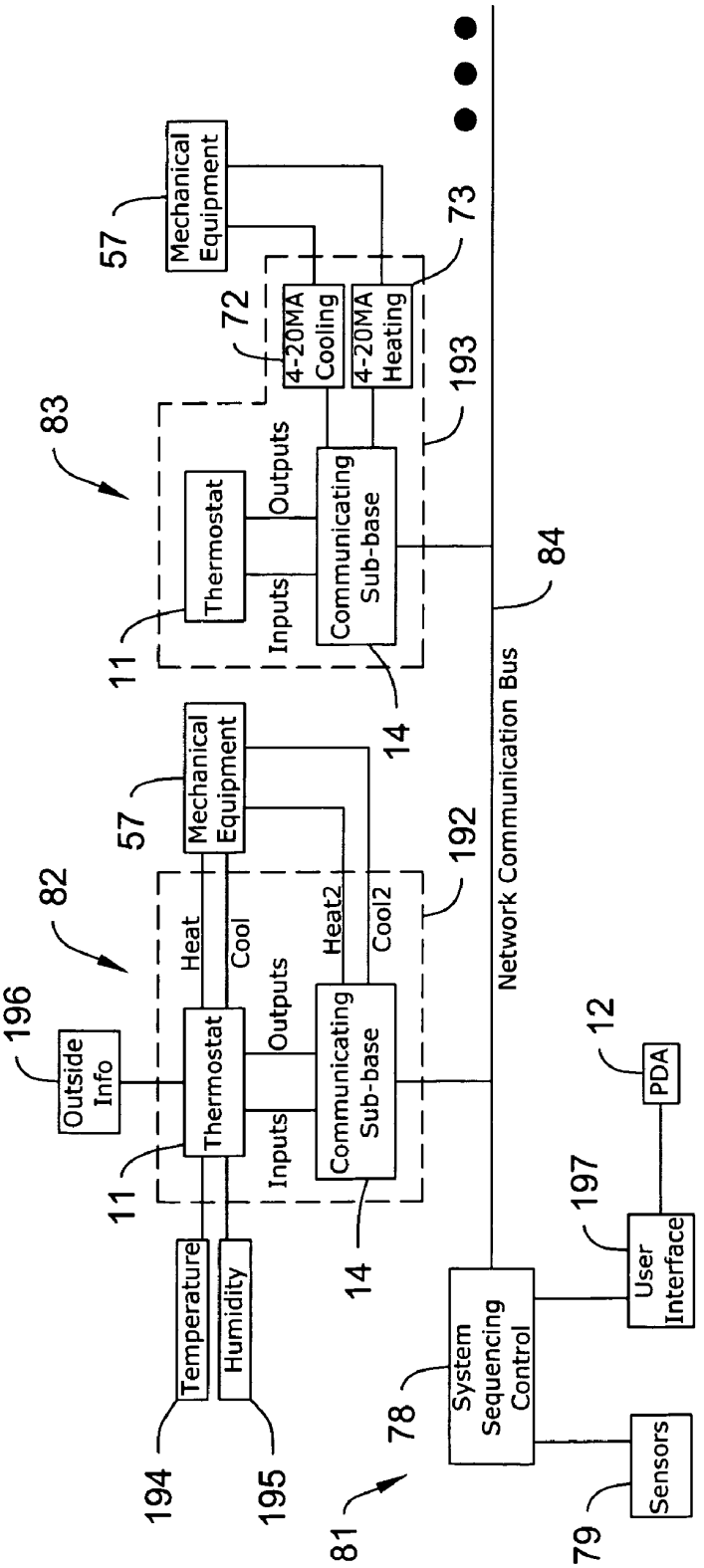
Mechanical Equipment
57
73
72
4-20MA Cooling
4-20MA Heating
193
83
Thermostat
Outputs
Inputs
Communicating Sub-base
11
14
84
Network Communication Bus
Mechanical Equipment
57
192
82
Heat
Cool
Heat2
Cool2
196
Outside Info
Thermostat
Outputs
Inputs
Communicating Sub-base
11
14
12
PDA
197
User Interface
Temperature
Humidity
194
195
System Sequencing Control
78
81
Sensors
79

Figure 18

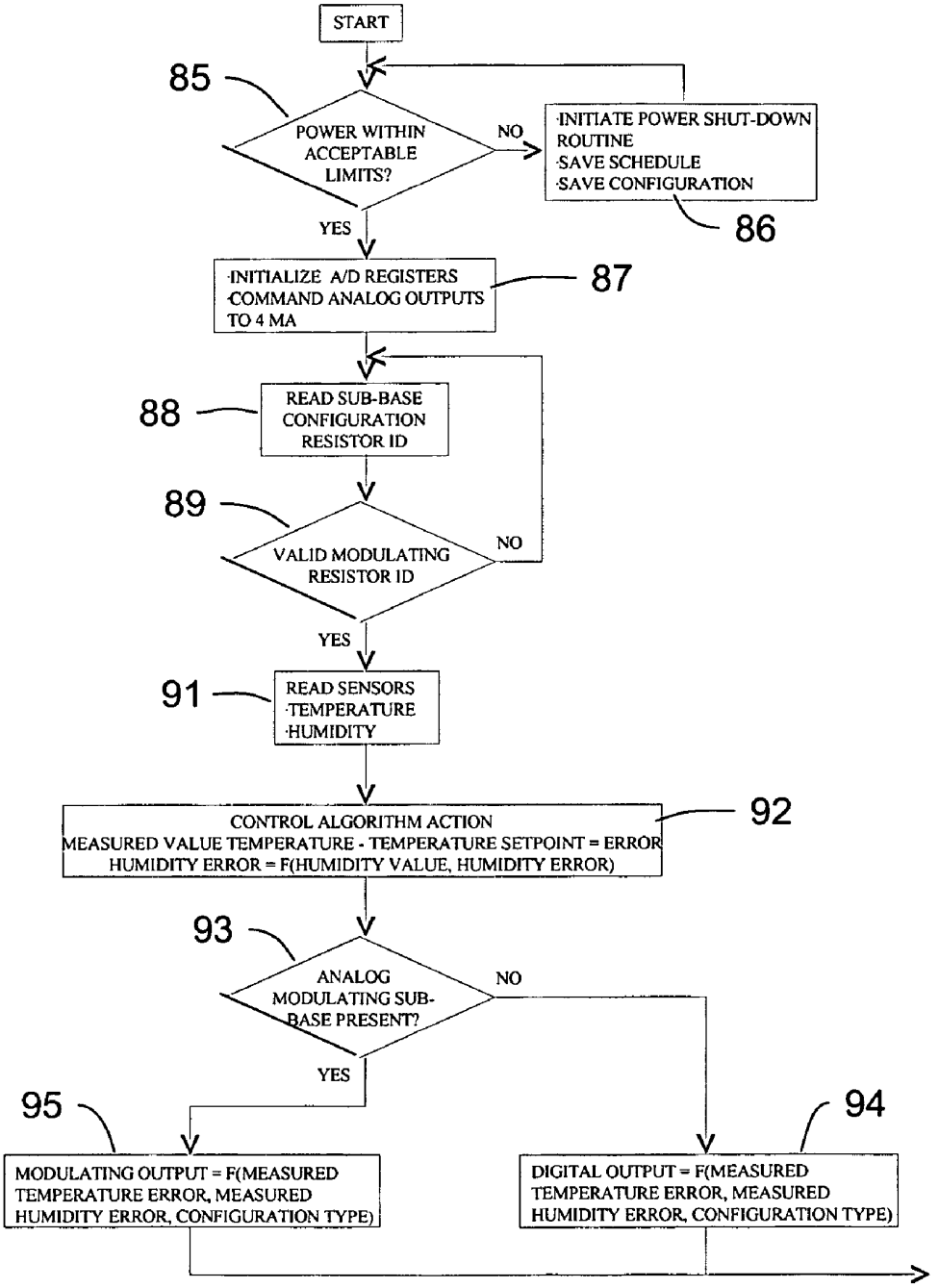
START
85
POWER WITHIN ACCEPTABLE LIMITS?
NO
·INITIATE POWER SHUT-DOWN ROUTINE
·SAVE SCHEDULE
·SAVE CONFIGURATION
86
YES
·INITIALIZE A/D REGISTERS
·COMMAND ANALOG OUTPUTS TO 4 MA
87
88
READ SUB-BASE CONFIGURATION RESISTOR ID
89
VALID MODULATING RESISTOR ID
NO
YES
91
READ SENSORS
·TEMPERATURE
·HUMIDITY
CONTROL ALGORITHM ACTION
MEASURED VALUE TEMPERATURE - TEMPERATURE SETPOINT = ERROR
HUMIDITY ERROR = F(HUMIDITY VALUE, HUMIDITY ERROR)
92
93
ANALOG MODULATING SUB-BASE PRESENT?
NO
YES
95
94
MODULATING OUTPUT = F(MEASURED TEMPERATURE ERROR, MEASURED HUMIDITY ERROR, CONFIGURATION TYPE)
DIGITAL OUTPUT = F(MEASURED TEMPERATURE ERROR, MEASURED HUMIDITY ERROR, CONFIGURATION TYPE)

Figure 19

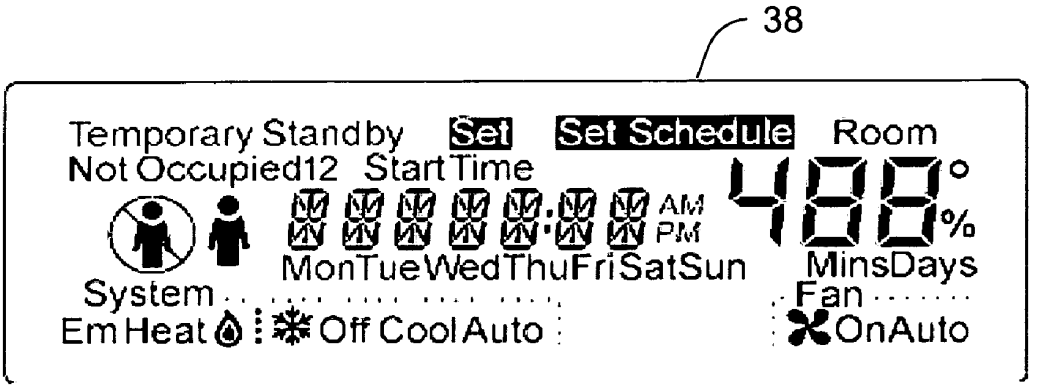

Figure 20A

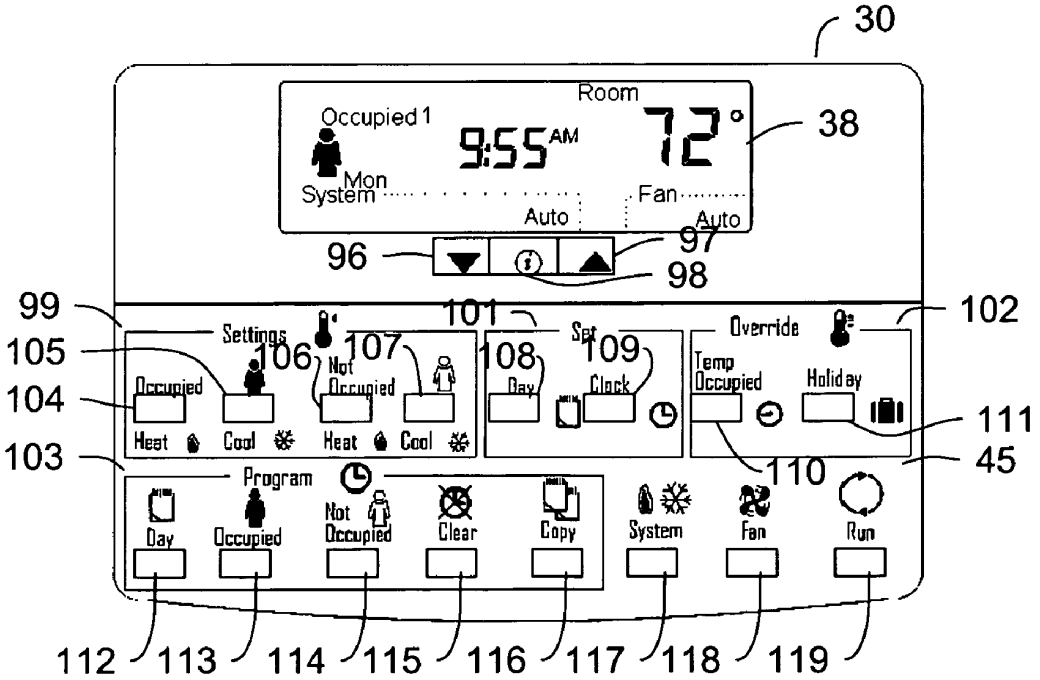

Figure 20B

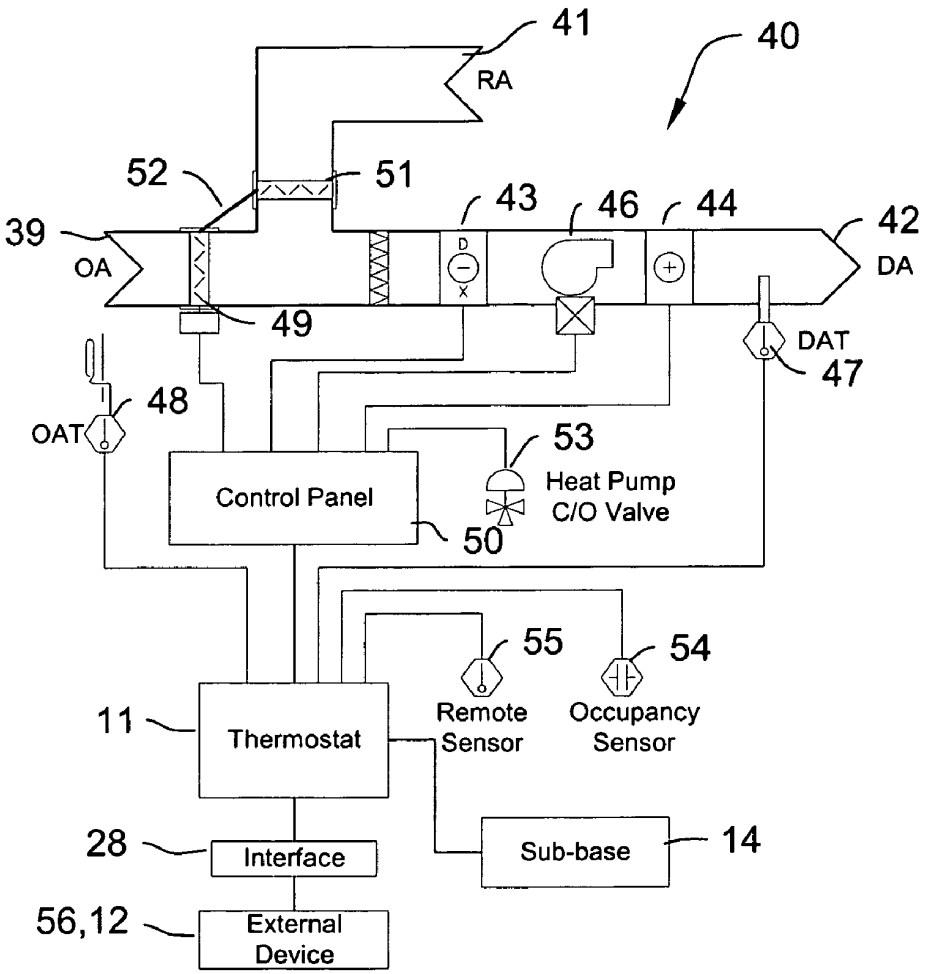
41
40
RA
52
51
43
46
44
42
39
OA
DA
49
DAT
47
48
OAT
53
Heat Pump
C/O Valve
Control Panel
50
55
54
11
Thermostat
Remote
Sensor
Occupancy
Sensor
28
Interface
Sub-base
14
56,12
External
Device

Figure 21

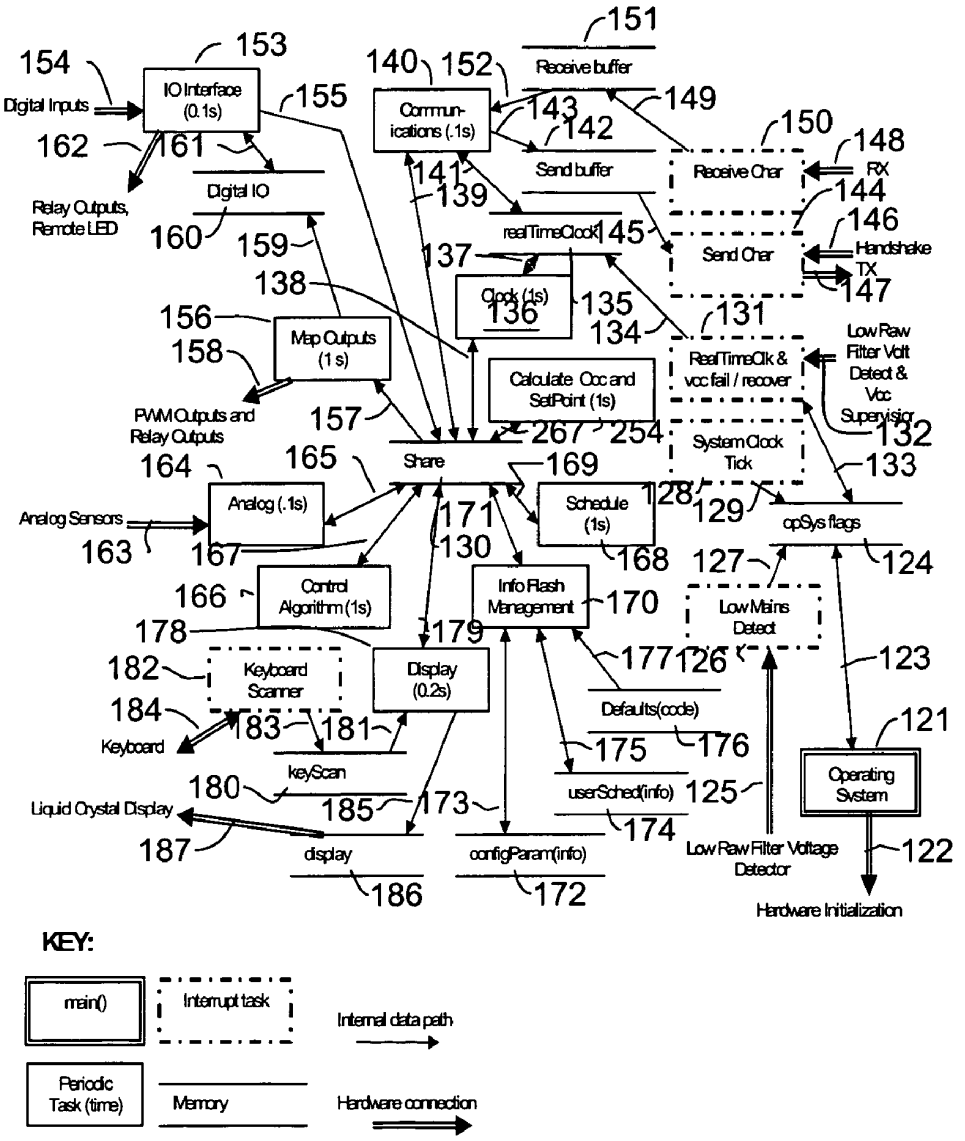
IO Interface (0.1s)
Digital Inputs
Relay Outputs, Remote LED
Digital IO
Communications (.1s)
Receive buffer
Send buffer
Receive Char
Send Char
RX
Handshake
TX
realTimeClock
Clock (1s)
Map Outputs (1 s)
PWM Outputs and Relay Outputs
Calculate Occ and SetPoint (1s)
RealTimeClk & vcc fail / recover
Low Raw Filter Volt Detect & Vcc Supervisor
System Clock Tick
Share
Analog (.1s)
Analog Sensors
Schedule (1s)
opSys flags
Control Algorithm (1s)
Info Flash Management
Low Mains Detect
Keyboard Scanner
Display (0.2s)
Defaults(code)
Keyboard
keyScan
Liquid Crystal Display
display
configParam(info)
userSched(info)
Operating System
Low Raw Filter Voltage Detector
Hardware Initialization
KEY:
main()
Interrupt task
Internal data path
Periodic Task (time)
Memory
Hardware connection

Figure 22

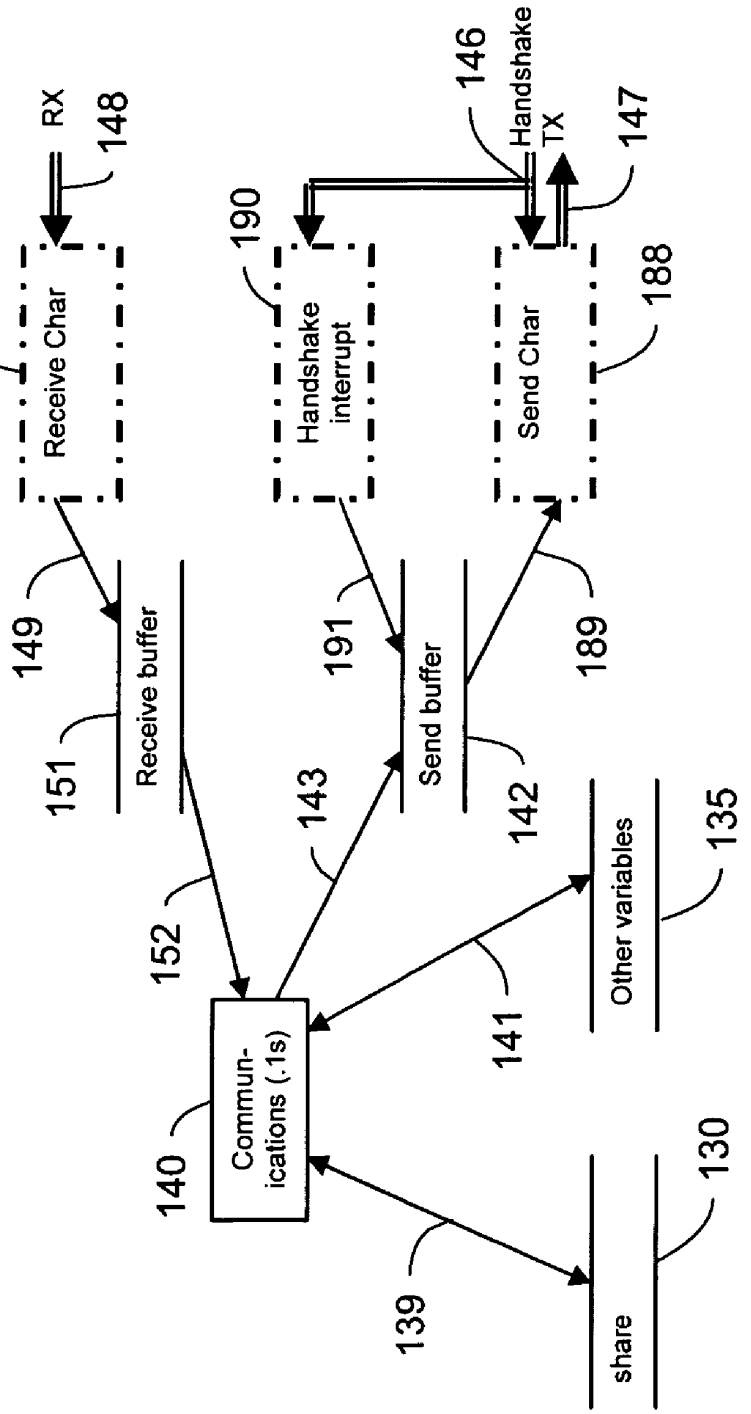
RX
148
150
Receive Char
149
151
Receive buffer
152
140
Commun-
ications (.1s)
139
share
130
190
Handshake
interrupt
191
143
Send buffer
142
141
146
Handshake
TX
147
Send Char
188
189
Other variables
135

Figure 23

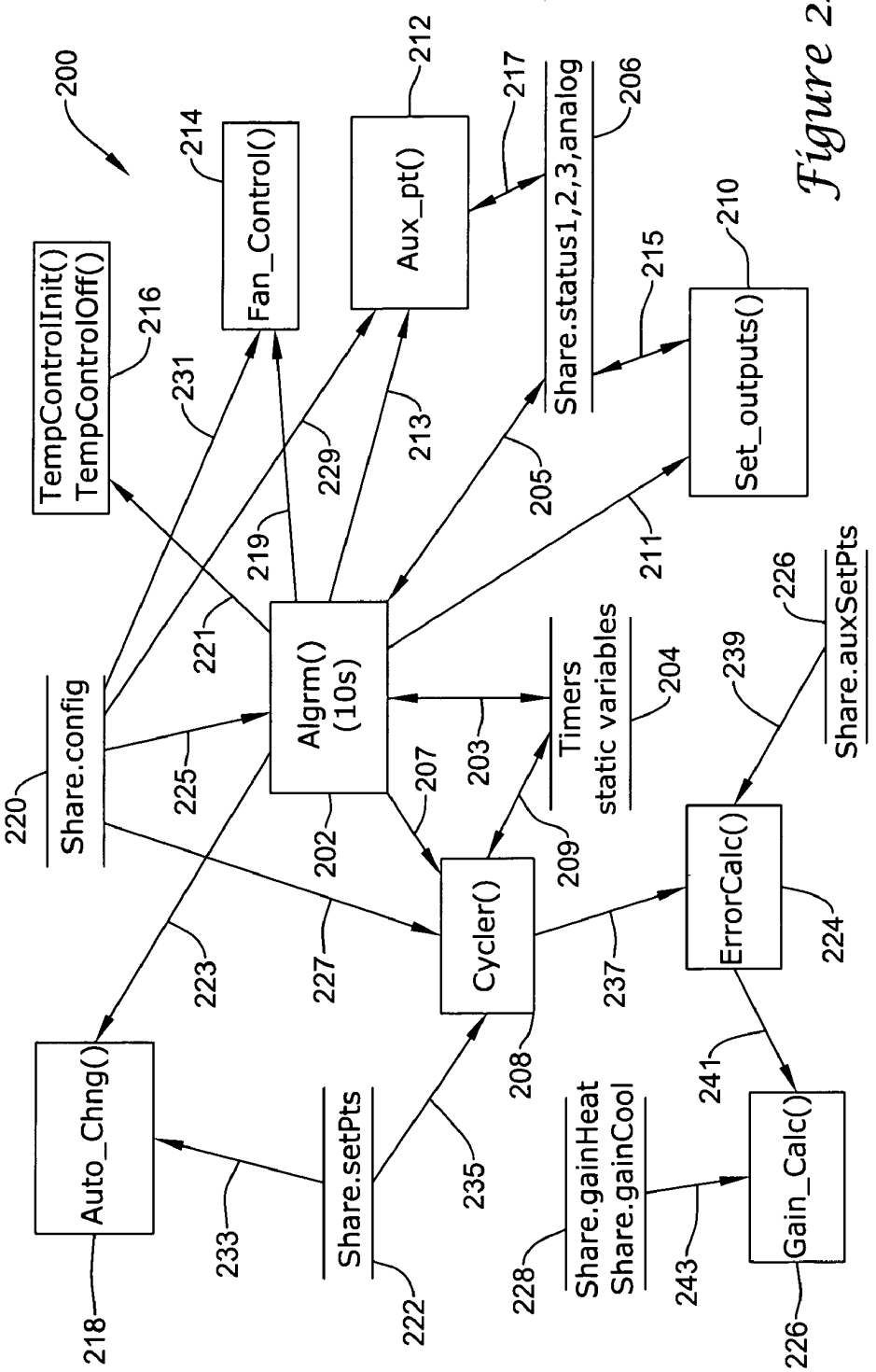
200
TempControlInit()
TempControlOff()
216
Fan_Control()
214
Aux_pt()
212
217
Share.status1,2,3,analog
206
215
Set_outputs()
210
231
229
213
205
219
211
221
Algrm()
(10s)
202
Timers
static variables
204
203
207
209
Share.config
220
225
Cycler()
208
223
227
237
ErrorCalc()
224
239
Share.auxSetPts
226
Auto_Chng()
218
233
Share.setPts
222
235
Share.gainHeat
Share.gainCool
228
243
Gain_Calc()
226
241

Figure 24

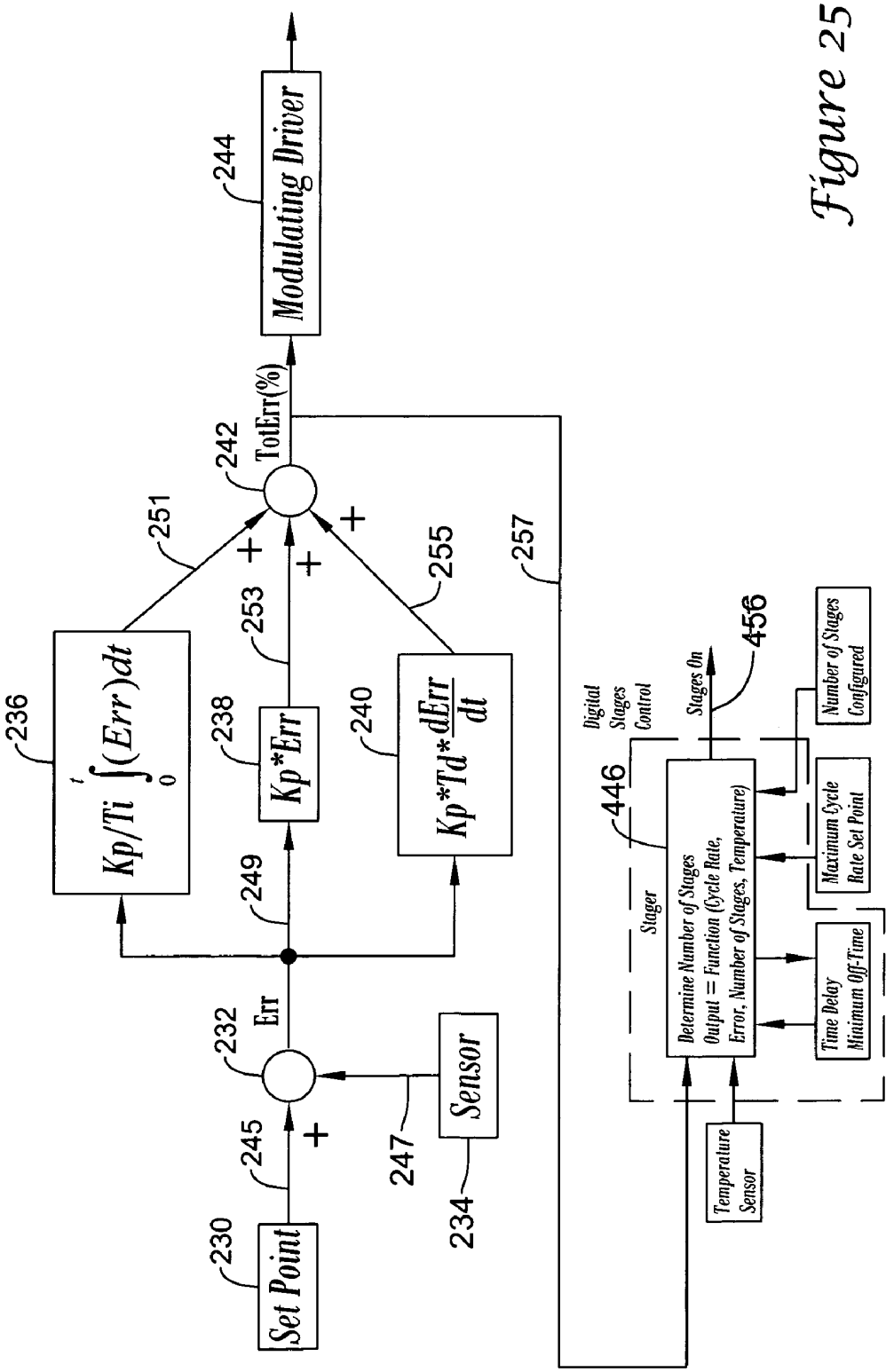
Modulating Driver
244
TotErr(%)
242
251
253
255
257
236
Kp/Ti ∫(Err)dt
238
Kp*Err
240
Kp*Td*dErr/dt
249
232
Err
245
247
234
230
Set Point
Sensor
Digital Stages Control
Stages On
456
446
Stager
Determine Number of Stages Output = Function (Cycle Rate, Error, Number of Stages, Temperature)
Number of Stages Configured
Maximum Cycle Rate Set Point
Time Delay Minimum Off-Time
Temperature Sensor

Figure 25

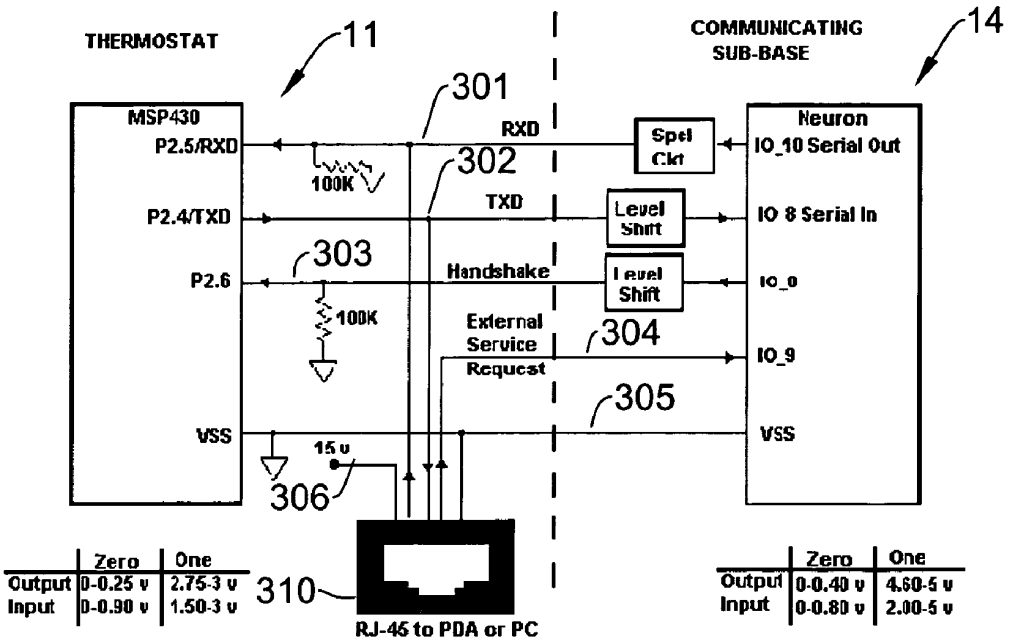

Figure 26

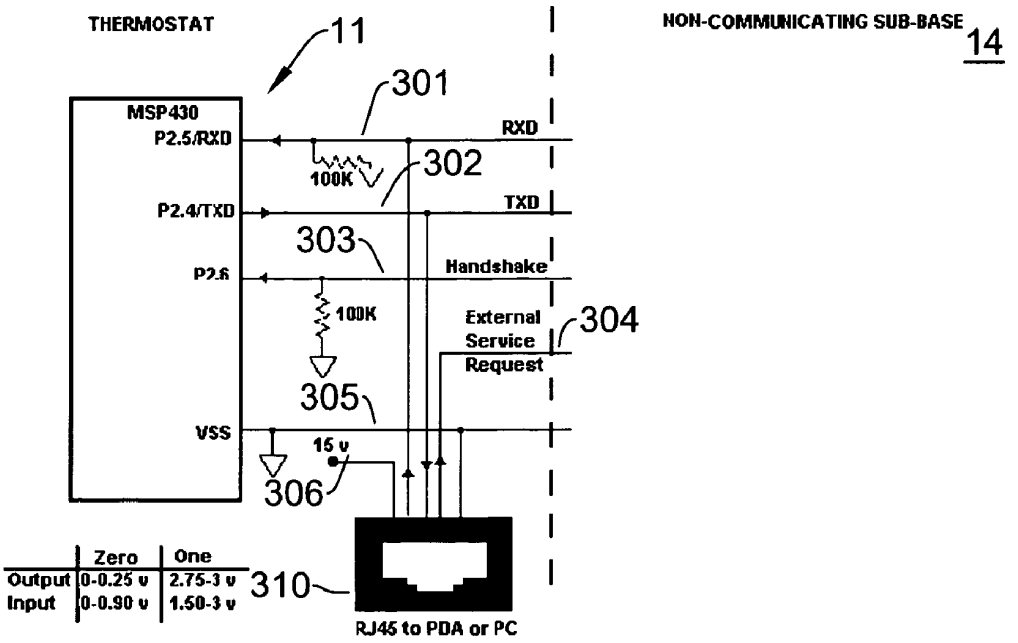

Figure 27

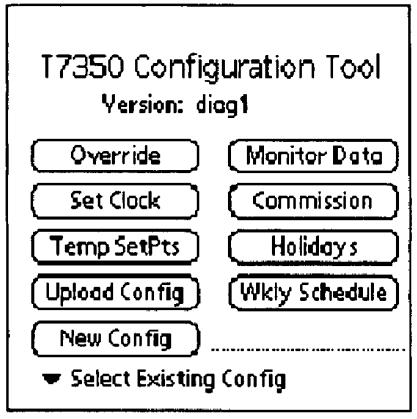

Figure 28A

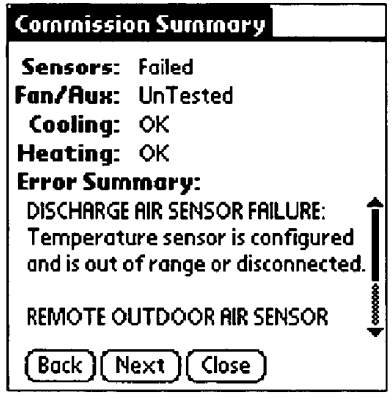

Figure 28C

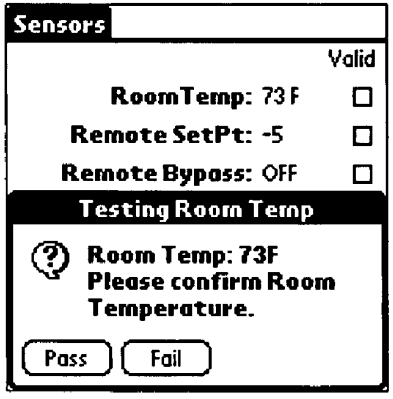

Figure 29B

Figure 28B

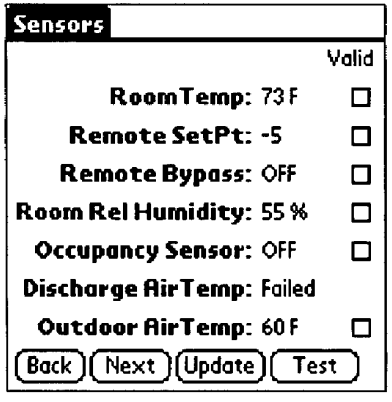

Figure 29A

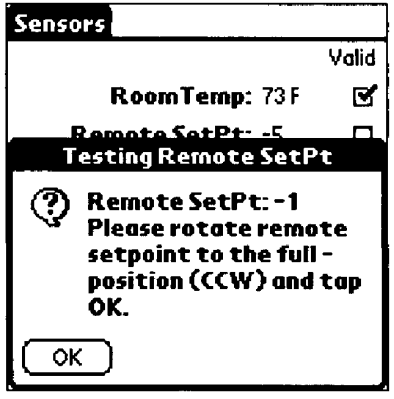

Figure 29C

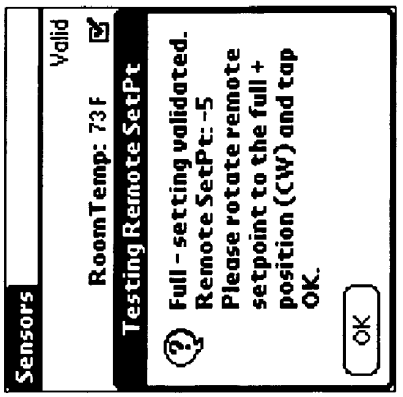

Figure 29D

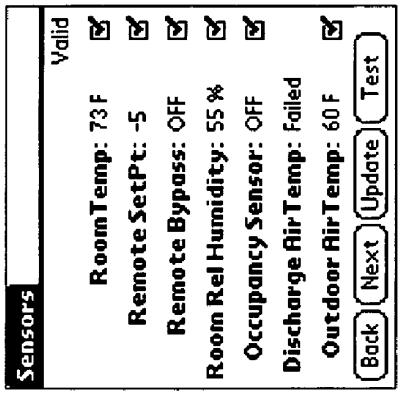

Figure 29F

Figure 31A

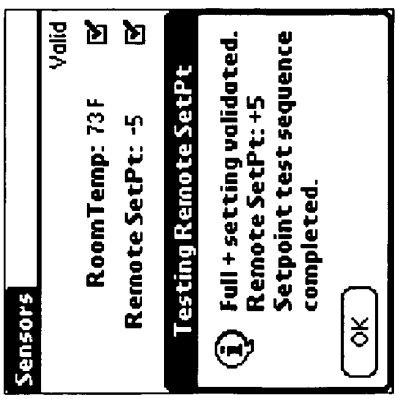

Figure 29E

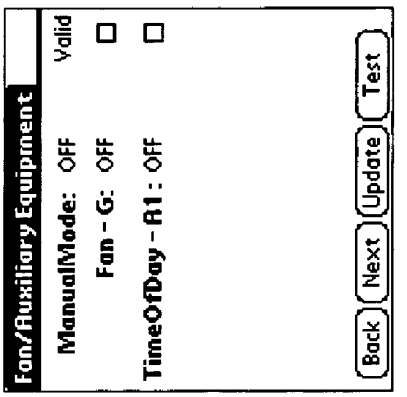

Figure 30

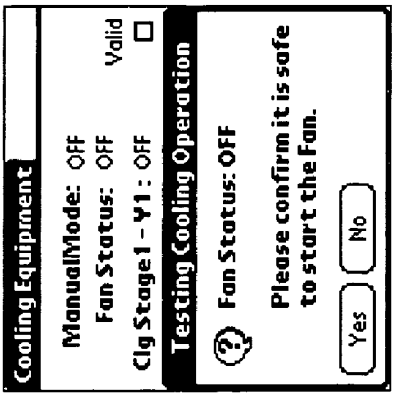

Figure 31B

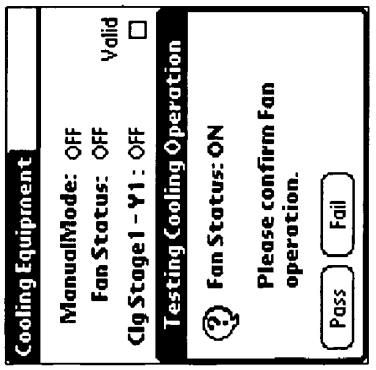

Figure 31C

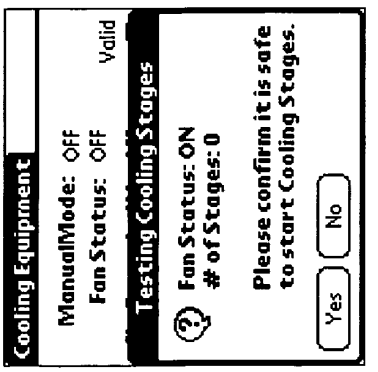

Figure 31D

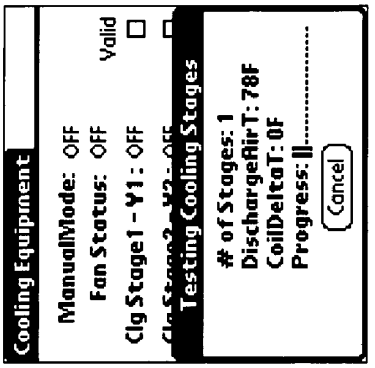

Figure 31E

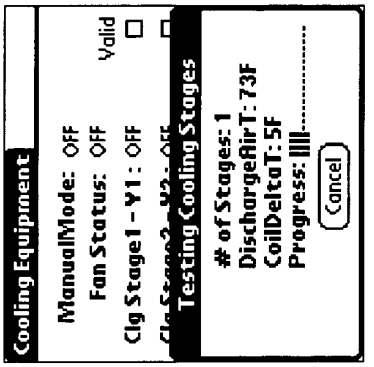

Figure 31F

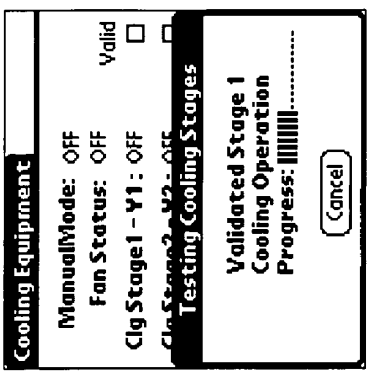

Figure 31G

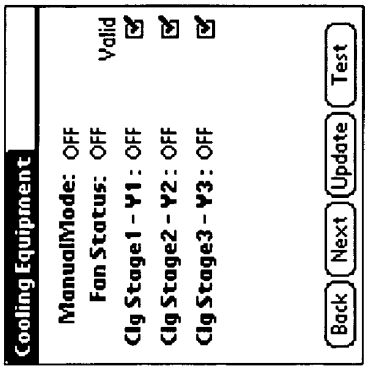

Figure 31H

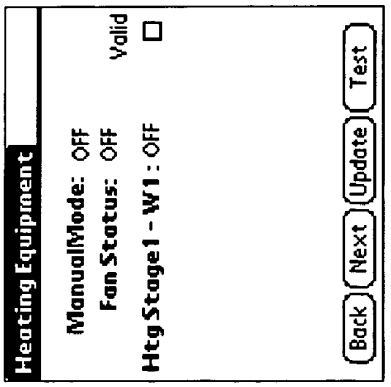

Figure 32A

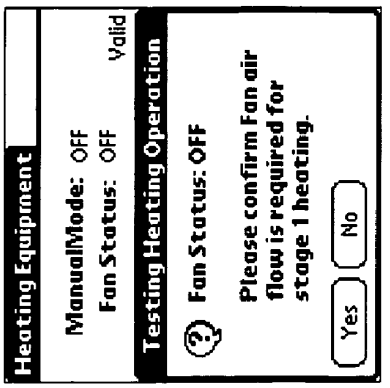

Figure 32B

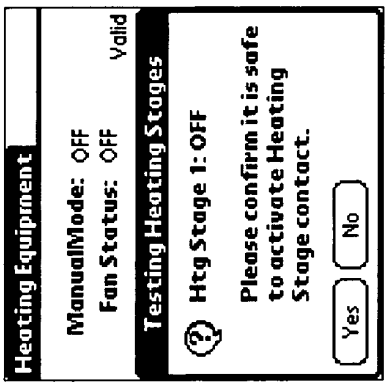

Figure 32C

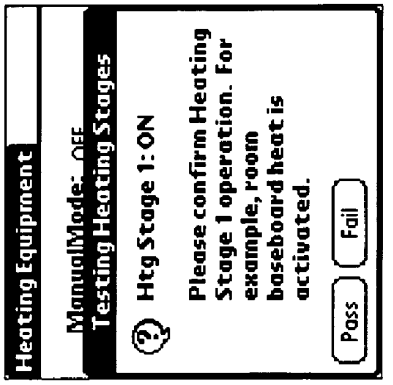

Figure 32D

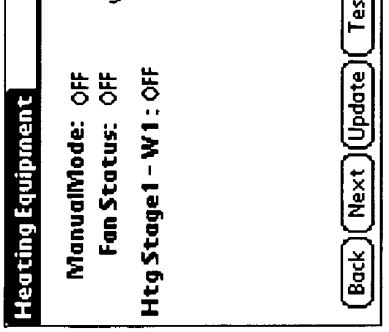

Figure 32E

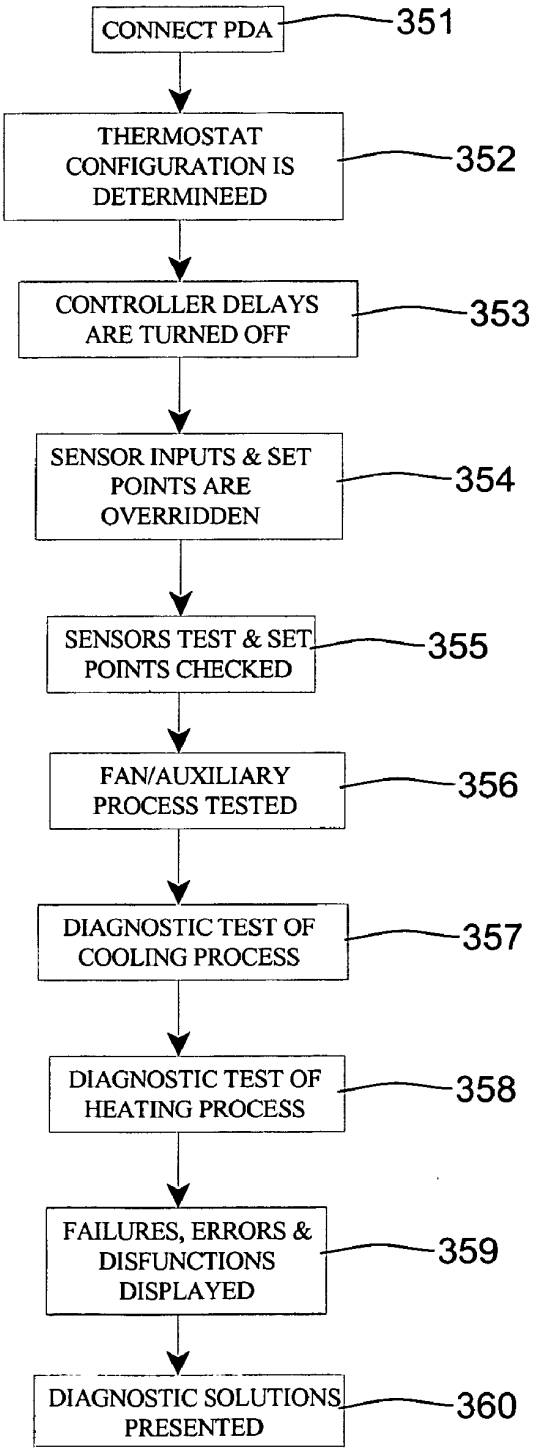
CONNECT PDA
351
THERMOSTAT CONFIGURATION IS DETERMINEED
352
CONTROLLER DELAYS ARE TURNED OFF
353
SENSOR INPUTS & SET POINTS ARE OVERRIDDEN
354
SENSORS TEST & SET POINTS CHECKED
355
FAN/AUXILIARY PROCESS TESTED
356
DIAGNOSTIC TEST OF COOLING PROCESS
357
DIAGNOSTIC TEST OF HEATING PROCESS
358
FAILURES, ERRORS & DISFUNCTIONS DISPLAYED
359
DIAGNOSTIC SOLUTIONS PRESENTED
360

Figure 33

THERMOSTAT HAVING MODULATED AND NON-MODULATED PROVISIONS

BACKGROUND

The present invention pertains to thermostats and particularly to the control of air management systems. More particularly, it may pertain to programmable thermostats providing modulated and non-modulated control of air management systems.

Air management systems that have several stages of cooling and heating do not function particularly efficiently, inexpensively, or provide comfort with ease. It may be that one stage provides too much cooling or heating. If the stage could be operated at partial capacity, there would be flexibility of control that could benefit smaller buildings and the possibly smaller businesses that may reside in them. The present thermostat has a way of minimizing these issues and may do so with a modulated or analog control of the system. Also, the same thermostat may utilize staged cooling and heating as needed.

The setting and adjusting of air management system thermostats, especially programming thermostats, to control air conditioning, heating, humidity, volume of moved air, and the like, may have settings and conditions that determine which equipment is modulated, turned on or off, and for when and what duration. Many commercial and residential places may have complex and confusing controls for air management systems which have features such as programmable thermostats. Some proprietors may obtain a programmable control system for controlling heating and cooling in their buildings. However, they may have frustrations with the adjusting and operating those kinds of systems and often stop trying to take advantage of certain control features of the systems. An installer may initially set a system up and get it operating satisfactorily; however, the adjusting and setting the system may not be easy for the new recipient or owner of the system because of the apparent complexity, user unfriendliness, and the lack of convenient and sufficient time to learn, set and adjust various parameters of the system for controlling, for instance, heating, ventilation and air conditioning (HVAC).

SUMMARY

Programmable commercial thermostat systems have been gaining in popularity due to the energy savings associated with programmable schedules and set points. Most small commercial buildings with one or two zones typically may have rooftop equipment controlled through relay contacts such as heat stage **1**, heat stage **2**, cooling stage **1**, cooling stage **2**, and fan. These controls may be interfaced through remote wiring from the zone thermostat to the associated rooftop unit. As commercial thermostat requirements and thermostats become more sophisticated, there may be a need to control heating and cooling coils at control ranges in between specific stage loads. This could be particularly important as chilled water systems and partial load or oversized systems are used. Further, there appears to be a need to control modulating zones and a need for a commercial modulating thermostat that is able to support both traditional staged and modulating outputs.

This invention may solve the problems associated with control issues by implementing a true analog heating and cooling signal to be implemented by the roof top control system. Several enhancements and options exist in the algorithm and thermostat configuration to assist and lead to control of water valves and oversized heating coils and loads. Under staging conditions, traditional control algorithm techniques may be used to control the on/off control to the heating coils, cooling coils and fan. When used in a modulating configuration, special analog driver circuits may allow the output from the thermostat to provide 4 to 20 milliamps and 2 to 10 volts for direct interfacing for the control of modulated components. These control parameters are popular ranges for many modulated dampers and valves used in air management systems, such as HVACs.

The thermostat may contain a software component that allows automatic configuration of the output actuation type (modulation and discrete) identified by the sub-base with preset configuration resistors. The hardware component of the output actuation may be implemented through an analog interface set from the thermostat. Analog control and interface to the modulation may be controlled through software algorithm PID and staging information. If additional heating is desired after a stage is added at low load, additional supply is available through increasing of the analog heating signal. Applications of this modulating thermostat may be used for boiler firing rate controls and other energy supply or cooling type equipment. Through the use of programmable memory, additional algorithms can be developed to apply to a wide range and variety of control applications besides air management system control.

The present thermostat may provide modulated/analog control of an air management system and discrete/digital control of the same or another air management system. This thermostat may provide modulating control of a single stage of heating and/or cooling. On the other hand, this thermostat may provide modulating control of multiple stages of heating and cooling. The modulating output to one cooling or heating stage may result in an efficient level of output of the controlled stage. If more output is needed from that stage, the thermostat may with the modulating output call on another stage and control it for more heating or cooling, so as to maintain the better efficiency of the first stage. Also, modulated control may result in the next stage's approaching an efficient level of output. This approach may continue for more output or less output as needed form the respective stages. The thermostat may provide analog or digital signals for controlling single or multiple cooling or heating stages. Humidity control may also be implemented by the thermostat and associated air management equipment. A group of thermostats may be connected to a common communications bus. Such bus may have a sequencer connected to the bus. Instructions, software changes, commands, parameters and other information may be communicated among the thermostats and the sequencer. Operations of the thermostats may be sequenced.

The thermostat system may minimize the issues of complexities, user unfriendliness, and the amount of time and convenience involved in setting up, adjusting and controlling an air management system, such as an air handling and conditioning system. The system makes it possible for one at a convenient time at any place to set and adjust a thermostat, controller or computer having numerous parameters and options that may be selected for a desired operation of the air management system. One does not need to be at the thermostat, controller or computer of the air management system to configure, set or adjust the parameters of it. The parameters may include, but not be limited to, temperatures, humidity, sensor selection, volume of air movement, fan or air mover behavior such as continuous or intermittent and speed, the percentage of added fresh air, stages of cooling and heating at various zones, control of heat pumps, heaters

and air conditioners, modes of occupied, unoccupied or standby of respective spaces in a building, for day and night, between specific times, at certain days, for certain buildings at specific locations. The system may easily enable one to easily and conveniently achieve these tasks with an interfacing of a PDA (viz., a personal digital assistant) to the control system. These tasks may be accomplished on a PDA in an armchair remote from the facility with the air management system.

A program with configuration information may be uploaded to the PDA from a controller of an air handling and conditioning system, such as the HVAC. Such controller may be similar to a programmable thermostat having adjustment and settings for controlling the parameters of the system. All of the items that need to be done for configuring, setting, adjusting and controlling a system via the thermostat, controller or computer may be done on a PDA at any time at a location as desired, possibly remote from the building having the system. Whether at the office, home or other place, one may configure, set and adjust, among other things, with the PDA, parameters and actions of a controller relative to various air management systems at different facilities. Programmed configurations, settings, adjustments and the like may be done with the PDA. Then one may take the PDA and go to the various thermostats, controllers, computers or other air management system control devices and upload the programs specific to the respective systems. These may be placed in memory. One interface connection for the uploading and downloading between the PDA and the thermostat, controller or computer of the air management system may be an infrared (IR) connection. One may obtain a PDA that is readily available in stores, such as a Palm™, or the like, and take it to a thermostat, controller, computer or control module of the air management system and upload a program, including the configuration and the settings the system. Then one may deal with various configurations, settings, adjustments and related activities as desired relative to the parameters of the air management system and then download any changes to the respective thermostat, controller, computer or control module of the system.

The interfacing between the PDA or similar commercially available device and the controller or thermostat may also be done via radio frequency communications (such as Bluetooth or Wi-Fi), electrical lines such as the telephone, or optical fiber systems. The internet, Ethernet, or intranet in its various aspects may be used for interfacing between the PDA and the controller or thermostat. Other forms of interfacing between the PDA and the system may be implemented.

A technical person, installer, representative or technician, trained for configuring, setting and adjusting control mechanisms of air management system thermostats, may go to various buildings such as stores, factories or offices and do control changes for the air management systems of those places. The control mechanism of the air management system of each place may have its own specific configuration and settings which may be different from the others. The technician may go from place to place and download specific configurations and settings with the PDA very quickly and efficiently to the air management system thermostats at these places.

Even though there are many ways that programmable thermostats, controllers, control mechanisms, computers, control modules or their equivalents (hereinafter each of these may be referred to as a "thermostat") of air management systems may be communicated with, relative to the setting and configuration inputs, the PDA using the infrared interface is inexpensive and easily adaptable. Many individuals have a PDA of one kind or another which may have an infrared or direct connection port. No modification is of these devices needed to use them with the system. One merely may go to the respective thermostat of the system and upload a program that has the appropriate protocol, configuration and setting information of the system. Then one may enter the desired settings, adjustments and schedule information relative to the control of the air management system. The information is presented on the PDA in a clear and step by step instructive manner. And as indicated above, the PDA may contain numerous and differing configurations and settings applicable to specific systems at different places. Anyone with a PDA or the like may participate in this program. However, there may be security measures requiring codes or other permission granting procedures so that the integrity of the control of air management systems may be maintained.

An installer's configuring of high end programmable commercial thermostats has become very complex due to all of the features that can be implemented by low cost microprocessors. There is a trade-off between the ease of use and the complexity of the user interface. Configuring might be done only once by the installer and then usually is not required again for the life of the thermostat, whereas for settings and adjustments, the operator interface may be used periodically and should be as user friendly as possible. In the past, the installer configuration process was very obscure and error prone since it had been a secondary function of the operator user interface that partially reused some of the operator interface features in an obscure secondary manner so as to attempt reducing costs associated with the device. This approach was time consuming and error prone, had to be repeated for each installation, and was still costly.

By removing the thermostat configuration installer interface from the thermostat operator interface to a PDA, as in the present system, the following benefits are noted. There is an easy to use configuration process with context checking on previous selections so only valid options are presented and errors cannot be made, and also easy to use navigation of thermostat configuration screens. Novice users may be directed to the next appropriate parameter entry screen based on the context of previous configuration selections. Configurations can be done ahead of time and downloaded quickly at installation time. Similar configurations do not have to be repeated on every device but simply recalled from storage and downloaded. The PDA based thermostat configuration application may generate a code that represents the raw configuration. This code can be recorded (for example on paper) and entered by hand quickly into the thermostat keyboard if a PDA is not available at the job site. There is context dependent control loop tuning. The thermostat PID (viz., proportional, integral and derivative gains) control loop tuning parameters may be automatically adjusted as a function of equipment type, number of output stages, output type (modulating or discrete), the HVAC process, and other factors as desired.

A PDA and its interfacing with the thermostat of an air management system may also be used for automatic testing, checkout, analysis and diagnosis of the system. Testing and trouble-shooting a complex fully featured commercial thermostat may be time consuming and confusing since the configuration must first be understood and then the operation must be run through valid modes with inputs and set points temporarily manipulated, plus waiting for the delays built into the controller, to verify operation.

Commissioning a complex fully featured commercial thermostat also may be time consuming and confusing. The thermostat configuration should first be understood and then the commissioning process may be run through valid operational modes with inputs and set points temporarily manipulated while waiting for the delays built into the controller to verify operation.

The PDA based online diagnostics may automatically discover the thermostat configuration, turn off normal controller delays, temporarily override sensor inputs and set points, verify proper output action including monitoring the discharge air temperature for the resulting temperature behavior based on the equipment stages activated. Problems discovered may be reported, automatically recorded and the original operating parameters may be restored. This means that less expertise may be required by the technicians sent to install and trouble shoot thermostat installations.

A thermostat may be designed to interface to a PDA or other handy low cost device with an easy wire, IR or RF connection that will allow it do fast, accurate automatic thermostat testing, diagnosing and trouble-shooting. The PDA may automatically obtain the thermostat configuration, turn off normal controller delays, temporarily override sensor inputs and set points, and verify proper output action including monitoring the entry and discharge air temperatures for the resulting temperature behavior based on the equipment stages activated. Problems discovered can be reported, automatically recorded and the original operating parameters can be restored. This means that less expertise is required by the technicians sent to install and trouble shoot thermostats. Smart status reporting simplifies the thermostat installers' field-commissioning task of selecting and monitoring the appropriate real time data. The smart status report content and layout may be based on a theme of management by exclusion. The report generator may respond to real time parameter and data changes in the thermostat environment. There may be a possible web-based system in which the installer or technician need not to go out to the site of the air management system. The installer or technician may be able to diagnose and can fix the system over the internet, Ethernet or the like. However, using the PDA and its infrared interface may be as or more reasonable than the configuring or diagnosing a thermostat, its sub-base and corresponding air management system. PDA configuring and diagnostics may be utilized in residential homes as well as commercial facilities.

Information about an example sequencer may be disclosed in U.S. Pat. No. 6,536,678 B2, entitled "Boiler Control System and Method", issued Mar. 25, 2003, and by inventor Michael A. Pouchak, which is hereby incorporated herein by reference. Information about an example humidity controller may be disclosed in U.S. patent application Ser. No. 10/314,604, entitled "Humidity Controller", filed on Dec. 4th, 2002, and by inventor Paul C. Wacker, which is hereby incorporated herein by reference. Information about an example HVAC may be disclosed in U.S. Pat. No. 5,172,565, entitled "Air Handling System Utilizing Direct Expansion Cooling", issued Dec. 22, 1992, and by inventors Richard A. Wruck et al., which is hereby incorporated herein by reference.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows a configuration tool for a thermostat of an air management system.

FIG. **2** shows the configuration tool of FIG. **1** in conjunction with a sub-base.

FIGS. **3***a* and **3***b* show screens of a personal digital assistant (PDA) for entering a new thermostat configuration.

FIGS. **4***a*–**4***d* show PDA screens for selecting an existing configuration and connecting the PDA to the thermostat for uploading the configuration.

FIGS. **5***a*–**5***c* reveal screen for downloading a new configuration to the thermostat.

FIGS. **6***a*–**6***d* are screens that relate to uploading and modifying an existing configuration, and downloading it.

FIGS. **7***a* and **7***b* are screens showing a download and upload connection selection to a thermostat and a room temperature calibrate, respectively.

FIGS. **8***a*–**8***e* are screens showing a process for connecting to a thermostat, reading information and saving it, and monitoring data.

FIGS. **9***a*–**9***j* illustrate steps of reviewing the configuration of a thermostat, making possible changes and saving them.

FIGS. **10***a*–**10***l* show the screens and steps for an advanced configuration review, possible modification, and saving of any modification.

FIGS. **11***a* and **11***b* show screens for selecting units and locking default configuration files.

FIG. **12***a* shows a file command screen.

FIGS. **12***b*–**12***e* are screens that show various actions that may be taken relative to a configuration.

FIG. **13** relates to setting the time and date of the thermostat being configured.

FIGS. **14***a*–**14***m* are screens showing steps for scheduling various temperature set points on different days, selecting fan operation, selecting heating and cooling stages, selecting sensor location, loading the program for a particular facility and saving the current thermostat configuration.

FIGS. **14***n*–**14***r* are screens relating to the enabling of partial downloads after the opening screen.

FIGS. **14***s*–**14***z* are screens pertaining to various override options.

FIG. **15** is a flow chart of formation and downloading contractor information to a thermostat.

FIG. **16** is a diagram showing the major components and communication channels of the thermostat.

FIG. **17** is a block diagram of a modulating thermostat system.

FIG. **18** is a block diagram of a networked modulating and non-modulating thermostat system.

FIG. **19** is a flow diagram of a modulating sub-base sequence.

FIGS. **20***a* and **20***b* show a display and a thermostat assembly with the display and a keyboard.

FIG. **21** shows a roof top air management system.

FIG. **22** is a context diagram revealing a process structure in a thermostat.

FIG. **23** is a diagram of a transmit and handshake portion of a communications process of the thermostat.

FIG. **24** shows an overview of an algorithm mode relative to the thermostat.

FIG. **25** shows details of a function in the algorithm shown in FIG. **24**.

FIGS. **26** and **27** reveal the various connections between the thermostat, sub-base and an external device such as a PDA.

FIGS. **28***a*–**28***c* show PDA screen steps to attain a commission summary screen of a test and diagnosis of a thermostat system.

FIGS. **29***a*–**29***f* show screens for a diagnosis of temperature and other sensors, and set points.

FIG. **30** is a screen for a fan check.

FIGS. **31***a*–**31***h* are screens showing steps for cooling equipment testing and diagnosis.

FIGS. **32***a*–**32***e* show PDA screens for testing heating equipment of the thermostat system.

FIG. **33** is a flow diagram of an illustrative diagnostic test sequence for a thermostat system.

DESCRIPTION

The system may include an installation and/or configuration tool **10** for a programmable thermostat **11**, or the like, of an air management system **15**, as shown in FIGS. **1** and **2**. Thermostat configuration tool and system **10** may consist of application code and two hardware devices. A PDA application code may be used to configure the thermostat. The first hardware device may be a tool platform **12**, that is, a PDA hand held device. The second device may be an RS232 interface module **13** including a connection cable. Sensors **25** may be connected to thermostat **11**. Configuration tool and system **10** may provide the following value added features: an armchair thermostat **11** setup; a saving of tested thermostat configurations for reuse; a reduction of configuration errors; a reduction in warranty returns and customer callbacks; an updating of control setpoints (for example room temperature occupied, unoccupied and standby setpoints); weekly and holiday schedules; and user defined default configuration values. A PDA hardware platform is preferred over a laptop personal computer (PC) **24** for several reasons including, but not limited to, lower initial cost and smaller size.

An illustrative example of thermostat **11** may be a prototype programmable thermostat, model T7350, built by Honeywell International Inc. in Minneapolis, Minn. The configuration tool **12** application software and a 10 pin serial interface module may be compatible with the following PDA hardware platforms: Palm™ m105; Palm™ m100; Palm™ Vx Series; Palm™ VII Series; Palm™ III Series; Palm™ i705; Palm™ Zire71; Palm™ TungstenT; and TRG-Pro™. The application code may be compatible with PALM OS™ software version 3.5.x. "OS" is an operating system of a Palm™ platform. The OS version compatibility may be for all versions greater than or equal to 3.5x, such as OS 5.2.1. The system may also be hosted on a Microsoft WindowsT™ CE OS PDA platform. Configuration tool serial interface **13** module may be compatible with the various models and versions of thermostat **11**. The thermostat serial interface module may support IR, WiFi, Bluetooth and other wireless communications media. Thermostat **11** may have serial communications to allow communications with installer configuration tool **12** and a sub-base **14**. Thermostat **11** may be configured using an installer setup through the thermostat keys **15** for basic setup functions. Advanced features may be available through installer configuration tool **12**.

Thermostat configuration tool **12** may be used in the context of the following scenarios. In configuring offline, the user may arrange and save various named thermostat configurations with tool **12** disconnected from the thermostat **11**. The user may have the option to note a configuration identification code and manually set the code using tool or user interface **12**. Then interface **12** may connected to a thermostat **11** and air management system **15** may be configured with an existing named arrangement of parameters. Configuration tool **12** may read and verify the existing arrangement of parameters. Virtually all of the parameters may be changed resulting in a modified or new configuration. Also, the temperature display of thermostat **11** may be calibrated. The user may have an option to save the modified or new configuration file under another name.

Tool **12** may be utilized for performing online diagnostics. For example, tool **12** may be connected to thermostat **11** and diagnostic information such as the thermostat firmware version, the thermostat hardware version, the sub-base hardware version, and run time error messages may be read.

The thermostat configuration tool **12** may have a configuration which may include third party PDA hardware platform supporting application software and serial connection cable with the RS232 interface of module **13**. The Palm™ PDA, as an illustrative example, may be used in conjunction with the serial interface having connections as noted in the following table 1 showing the terminals for a Palm™ PDA serial connection.

TABLE 1

Pin #	Signal Name & Direction	Function
1	DO (out)	DTR
2	VCC (out)	+3.30 V Palm ™ III through a 330 ohm resistor. +4.07 V Palm ™ V
3	RXD (in)	Receive Data.
4	RTS (out)	Request to send.
5	TXD (out)	Transmit Data.
6	CTS (in)	Clear to send.
7	HS IRQ (in)	Interrupt line for waking the device, Palm OS ™ default is to initiate the HotSync process.
8	ID (in)	Peripheral ID line.
9	unused	Not connected
10	SG	Signal Ground

One may note that pin **10** is located at left as viewed from the back of the Palm™ PDA. The HotSync cradle button shorts pins **2** & **7**. Palm™ devices i705, m125, m130 m500, m505, m515 require a 16 pin connector. One may refer to http://www.palmos.com/dev/tech/hardware/palmhardware/electrical_interface(16-pin)signals.pdf for details regarding the Palm™ 16 pin connector.

Thermostat **11** configuration may be changed or varied according to certain aspects which are provided as an illustrative example in the following tables. There are setup parameters and default values which may be noted. Table 2 may reveal some display/user interface options.

TABLE 2

Config Option	Default	Min	Max	Res	Units	Description
Degree temperature display	0	0	1	1		Temperature display 0: ° F. 1: ° C.
Maximum Occupied Cooling Setpoint stop	85	45	99	1	F.	Highest the occupied cooling setpoint can be adjusted. MaxCoolStPt >= OccCl >= OccHt + 2

TABLE 2-continued

Config Option	Default	Min	Max	Res	Units	Description
						Display Resolution: 1 (F./C.)
Minimum Occupied Heating Setpoint stop	55	40	90	1	F.	Lowest the occupied heating setpoint can be adjusted. MinHeatStPt <= OccHt <= OccCl − 2 Display Resolution: 1 (F./C.)
Unoccupied Heat Setpoint	55	40	90	1	F.	
Standby Heat Setpoint	67	40	90	1	F.	
Standby Heat Setpoint	67	40	90	1	F.	
Occupied Heat Setpoint	70	40	90	1	F.	
Occupied Cool Setpoint	75	45	99	1	F.	
Standby Cool Setpoint	78	45	99	1	F.	
Unoccupied Cool Setpoint	85	45	99	1	F.	
Clock format	0	0	1	1		0: 12-hour clock format 1: 24-hour clock format
Keypad lockout level	0	0	2	1		Keypad lockout enable/disable through special keypad sequence. 0: No lockout. 1: Lockout all keys except Temporary Occupied, increase, decrease and information **. 2: Lockout all keys except information **. ** Do not allow adjustments on dehumidification high limit setpoint.
System Switch	0	0	3,7	1		0: Auto 1: Cool 2: Heat 3: Emergency Heat 7: Off

Table 3 shows an input/output configuration.

TABLE 3

Config Option	Default	Min	Max	Res	Units	Description
Remote space temperature sensor	0	0	2	1		0: Local sensor only. 1: Remote sensor only. 2: Network Rm Sensor (Sub-base)
Space humidity sensor	0	0	3	1		0: No space humidity sensor. 1: Local space humidity sensor enabled. 2: Remote space humidity sensor enabled. 3: Network room RH sensor (Sub-base)
Discharge air sensor	0	0	1	1		0: No discharge air sensor. 1: Discharge air sensor enabled.
Outside air sensor	0	0	2	1		0: No outside air sensor. 1: Outside air sensor enabled 2: Network OAT sensor (Sub-base)
Auxiliary contact operation	0	0	3	1		0: Time of day contact. 1: Economizer contact. 2: Dehumidification hot gas bypass contact 3: Simple Dehumidification contacts. Notes: Aux contact not available if heat pump selected and Sub-base #1.
Occupancy Sensor	0	0	2	1		0: No Occupancy sensor. 1: Use Remote Occupancy sensor. 2: Use Network Occupancy sensor (future).

Table 4 reveals the fan operation options.

TABLE 4

Config Option	Default	Min	Max	Res	Units	Description
Fan Switch	0	0	1	1		0: On 1: Auto
Fan Operation	0	0	1	1		0: Conventional applications where equipment controls fan operation in heat mode. That is, the plenum switch controls the fan when in heat mode and the Thermostat controls the fan when in cool mode. 1: Electric heat applications where thermostat controls fan operation in heat mode.
Extended fan operation in heating	1	0	1	1		0: No extended fan operation after call for heat ends. 1: Fan operation extended 90 seconds after call for heat ends.
Extended fan operation in cooling	0	0	1	1		0: No extended fan operation after call for cooling ends. 1: Fan operation extended 45 seconds after call for cool ends.

Table 5 shows the control tuning options.

TABLE 5

Config Option	Default	Min	Max	Res	Units	Description
Cycler Authority	4	2	15	1	R	Thermostat Cycler Authority (Theta).

Table 6 reveals the cooling operation options.

TABLE 6

Config Option	Default	Min	Max	Res	Units	Description
Cooling Output stages	2	0	4	1		Stages of cooling. 0: No cooling. 1: One cooling stage. 2: Two cooling stages. 3: Three cooling stages. 4: Four cooling stages.
Cooling system response	0	0	1	1	Cph	0: Standard response 3 cph. 1: Fast response 4 cph
Cooling TR	4	1	30	1	R	Cooling proportional gain (deg F.)
Cooling IT	2500	0, 10	5000	1	Sec	Cooling integral time (seconds). 0 = disable.
Cooling DT	0	0	3000	1	Sec	Cooling derivative time (seconds). 0 = disable.
Cooling Action	0	0	1	1		Cooling action. Applies only to proportional outputs. 0 = direct acting. 1 = reverse acting
Cooling Lockout	0	0	1	1		0: No OAT lockout 1: cooling locked out if Outdoor air valid and OAT < ClgLockoutSP
Cooling Lockout SP.	35	−40	120	1	F.	
DAT Low Limit	45	35	60	1	F.	Discharge Air Temperature Low Limit.
Minimum cool recovery ramp rate	3	0	20	1	F./Hr	Minimum cooling recovery ramp rate, 0–36° F./hr.
Min cool OAT	90	−20	100	1	F.	Minimum cooling outdoor air temperature
Max cool recovery ramp rate	6	0	20	1	F./hr	Maximum cooling recovery ramp rate
Max cool OAT	70	−20	100	1	F.	Maximum cooling outdoor air temperature

Table 7 shows the heating operation options.

TABLE 7

Config Option	Default	Min	Max	Res	Units	Description
Heating output stages	2	0	3	1		Stages of heating. 0: No heating. 1: One heating stage. 2: Two heating stages. 3: Three heating stages. (Not available if configured for 4 stages of cooling)
Auxiliary heating stages	0	0	2	1		0: No auxiliary heating 1: one stage of auxiliary heat 2: two stages of auxiliary heat
Heating system response	1	0	3	1		0: Standard response 3 cph. 1: Medium response 6 cph. 2: Fast 9 cph 3: Super fast response 20 cph
Heating TR	4	1	30	1	R	Heating proportional gain (deg F.)
Heating IT	2500	0, 10	5000	1	Sec	Heating integral time (seconds). 0 = disable.
Heating DT	0	0	3000	1	Sec	Heating derivative time (seconds). 0 = disable.
Heating Action	1	0	1	1		Heating action. Applies only to proportional outputs. 0 = direct acting. 1 = reverse acting
Heating Lockout	0	0	1	1		0: no lockout 1: heat locked out if OAT valid and (OAT > HtgLockoutSP)
Heating Lockout SP.	70	−40	120	1	F.	
DAT High Limit	110	65	140	1	F.	Discharge Air Temperature High Limit
Minimum heat recovery ramp rate	5	0	20	1	F./hr	Minimum heating recovery ramp rate
Min heat OAT	0	−20	100	1	F.	Minimum heating outdoor air temperature
Maximum heat recovery ramp rate	8	0	20	1	F./hr	Maximum heating recovery ramp rate
Max heat OAT	40	−20	100	1	F.	Maximum hearing ramp rate outdoor air temperature

Table 8 shows the heat pump options.

TABLE 8

Config Option	Default	Min	Max	Res	Units	Description
Heat Pump Control	0	0	1	1		0: Conventional Control 1: Heat Pump Control
Heat Pump Reversing Valve	1	0	1	1		0: energize O/B on call for Heat 1: energize O/B on call for Cooling

Table 9 reveals the relative humidity control options.

TABLE 9

Config Option	Default	Min	Max	Res	Units	Description
RH high limit	65	10	90	1	%	Relative Humidity high limit setpoint.
Dehumidify using minimum ON time	0	0	1	1		0: None 1: Dehumidification using minimum on time
Dehumidify Min On Time	5	5	15	1	min	This is the minimum on time used for if the user chose "Dehumidify Minimum On".
Dehumidify using reset	0	0	1	1		0: None 1: Dehumidification using Room Temperature SetPoint reset
Dehumidify using reheat	0	0	1	1		0: None 1: Dehumidification using reheat
HumTempReset	2	1	5	1	R	Humidity temperature reset The dehumidify reset must be smaller than

TABLE 9-continued

Config Option	Default	Min	Max	Res	Units	Description
						the occupied zero energy band (ZEB) or standby ZEB.

Table 10 is a list of energy management options.

TABLE 10

Config Option	Default	Min	Max	Res	Units	Description
Demand limit control bump	3	0	10	1	R	Demand limit control set point bump
Sequential start	0	0	15	1		Delay in 10 second increments. 0 is no delay. Delays start of equipment after power restored to thermostat. For example, setting of 3 is a 30 second delay. 0–0 seconds 1–10 seconds 2–20 seconds . . . 15–150 seconds

Table 11 indicates the calibration options.

TABLE 11

Config Option	Default	Min	Max	Res	Units	Description
Temperature display adjustment	0	0	7	1		Room Temperature display adjustment 0: No difference in displayed temperature and actual room temperature. 1: Display adjusts to 1° F. (0.6° C.) higher than actual room temperature. 2: Display adjusts to 2° F. (1.1° C.) higher than actual room temperature. 3: Display adjusts to 3° F. (1.7° C.) higher than actual room temperature. 4: Display adjusts to −4° F. (0.6° C.) lower than actual room temperature. 5: Display adjusts to −3° F. (1.1° C.) lower than actual room temperature. 6: Display adjusts to −2° F. (1.7° C.) lower than actual room temperature. 7: Display adjusts to −1 F. lower than actual room temperature.

Table 12 shows the override and bypass options.

TABLE 12

Config Option	Default	Min	Max	Res	Units	Description
Temporary override duration	2	0	7	1	Hr	Override duration in hours. 0: 1 hour 1: 2 hours . . . 7: 8 hours

Table 13 shows a time schedule with default time schedule settings. The time resolution may be one minute. The limit may be no more than two occupied or two unoccupied or two standby events per day.

TABLE 13

Day	Event	Mode	Time
Sun	1		
0	2		
	3		
	4		
Mon	1	Occupied	8:00 AM
1	2	Unoccupied	10:00 PM
	3		
	4		
Tue	1	Occupied	8:00 AM
2	2	Unoccupied	10:00 PM
	3		
	4		

TABLE 13-continued

Day	Event	Mode	Time
Wed	1	Occupied	8:00 AM
3	2	Unoccupied	10:00 PM
	3		
	4		
Thr	1	Occupied	8:00 AM
4	2	Unoccupied	10:00 PM
	3		
	4		
Fri	1	Occupied	8:00 AM
5	2	Unoccupied	10:00 PM
	3		
	4		
Sat	1		
6	2		
	3		
	4		
Hol	1		
7	2		
	3		
	4		

Table 14 shows the daylight savings schedule settings. The default range may be from the first Sunday in April to the last Sunday in October.

TABLE 14

Config Option	Default	Min	Max	Res	Units	Description
DlsStartDay	33	0	74	1		0: None 1, 2, 3, . . . 31, 32: LastDayOfMonth 33: FIRST_SUN 34: FIRST_MON . . . 67: FIFTH_SAT . . . 74: LAST_SAT
DlsStopDay	68	0	74	1		0: None 1, 2, 3, . . . 31, 32: LastDayOfMonth 33: FIRST_SUN 34: FIRST_MON . . . 67: FIFTH_SAT . . . 74: LAST_SAT
DlsStartMonth	4	0	12	1		0: None 1: Jan, . . . 12: Dec Default Value: April
DlsStopMonth	10	0	12	1		0: None 1: Jan, . . . 12: Dec Default Value: October

Table 15 relates to holiday schedule settings. This table shows one typical schedule of ten schedules.

TABLE 15

Config Option	Default	Min	Max	Res	Units	Description
Holiday Schedule	0	0	12	1		0: Unprogrammed 1: January

TABLE 15-continued

Config Option	Default	Min	Max	Res	Units	Description
Month						12: December
Holiday Schedule Day	0	0	74	1		0: Unprogrammed 1, 2, 3, . . . 31, 32: LastDayOfMonth 33: FIRST_SUN 34: FIRST_MON . . . 67: FIFTH_SAT . . . 74: LAST_SAT
Holiday duration	0	0	99	1	days	0: No holiday 1: 1 day holiday 99: 99 day holiday

Table 16 is a default holiday schedule. Configuration tool **12** may provide the following default holidays.

TABLE 16

Holiday	Month	Day	Duration
New Year's Day	1	1	1
Memorial Day	5	Last Monday	1
Independence Day	7	4	1
Labor Day	9	First Monday	1

TABLE 16-continued

Holiday	Month	Day	Duration
Thanksgiving	11	Fourth Thursday	1
Christmas	12	25	1

Table 17 relates to a real time configuration with real time clock settings.

TABLE 17

Config Option	Default	Min	Max	Res	Units	Description
Clock Year	255	0	175, 255	1		Valid range is Jan. 1, 2000 to Dec. 31, 2175 0: 2000 1: 2001 2: 2002 . . . 175: 2175 255: Invalid/Not Used
Clock Month	0	0	12	1		0: UnProgrammed 1: January . . . 12: December
Clock Day	0	0	31	1		0: Unprogrammed 1: 1 2: 2 31: 31
Clock Minutes	720	0	1439	1		0: Midnight = first minute of the day 720: noon. 1439: 11:59 p.m
Clock Seconds	0	0	59	1		0: 0 = first second of the minute 1: 1 . . . 59: 59 = last second of the minute

Configuration tool **12** may calculate a configuration identification as a function of a selected group of thermostat **11** configuration parameters, using an algorithm. Configuration tool **12** may display the computed thermostat **11** configuration identification. There are configuration parameter dependencies. Here are summarized configuration rules governing limits on parameter data entry and display in the context of thermostat **11** functional sub-base configured inputs, configured outputs and occupancy mode. There may be a temperature setpoint and mode dependency. Configuration tool default time values may be initialized based on the context of the user selected occupancy mode. Table 18 shows default schedule time values. Events **1** and **3** may be either occupied or standby. Events **2** and **4** may be either standby or unoccupied. It may be that there should be no more than two occupied or two unoccupied events per day.

TABLE 18

Mode Selected	Default Time
Occupied	8:00 AM
Standby	11:30 AM
Unoccupied	10:00 PM

Table 19 reveals the set point range and resolution. Setpoint constraints may include MinHeatStPt<=OccHt<=OccCl−2, MaxCoolStPt>=OccCl>=OccHt+2, UnoccHt<=OccHt<=OccCl−2, UnoccHt<=StdByHt<=StdByCl−2, UnoccCl>=OccCl>=OccHt+2, UnoccCl>=StdByCl>=StdByHt+2.

TABLE 19

Config Option	Min	Max	Res	Units
Cooling Setpoint	45	99	1	F
	7	37	1	C
Heating Setpoint	40	90	1	F
	5	32	1	C

A heat pump configuration screen context rule may be to enable a heat pump configuration if the sub-base type is **1**, **2** or **3**. A standard control configuration screen context rule may be to enable a standard control configuration if the sub-base type **1**, **2**, **3** or **4**. A dehumidification configuration screen context rule may be to enable if the sub-base type is **3** or **4** and the relative humidity sensor is configured. A variable recovery rate configuration screen context rule may be to enable if the sub-base type is **2**, **3** or **4** and the outside air temperature (OAT) sensor is enabled. The relative humidity sensor configuration screen context rule may be to enable if the sub-base type is **3** or **4**. The discharge air temperature (DAT) and OAT sensor configuration screen context rule may be to enable if the sub-base type **2**, **3** or **4**.

Sub-base **1** may be a base wall plate configuration. A total of four relays may be available with the thermostat and sub-base. An auxiliary relay may be configured for an economizer, the time of the day, dehumidification, or an additional stage of heating or cooling. The selections that may be disabled are the relative humidity Sensor, the DAT sensor, the OAT sensor, the occupancy sensor and the remote room sensor. Table 20 shows an installer configuration option for sub-base **1**.

TABLE 20

Installer Configuration Option	Sub-base 1
Heating output stages	1
Cooling Output stages	1
Room humidity sensor	0

Sub-base **2** may be a two heat stage/two cool stage basic configuration. A total of six relays may be available with the thermostat and sub-base. The auxiliary relay may be configured for an economizer, time of the day (TOD), dehumidification, or an additional stage of heating or cooling. The selections that may be disabled are the network input options, the relative humidity sensor and the occupancy sensor. Table 21 shows an installer configuration option for sub-base **2**.

TABLE 21

Installer Configuration Option	Sub-base 2
Heating output stages	2
Cooling Output stages	2
Room humidity sensor	0

Sub-base **3** may be a three heat stage/three cool stage configuration. This sub-base may allow for conventional or heat pump operation. A total of 8 relays may be available with the thermostat and sub-base. The auxiliary relay may be configured for an economizer, the time of the day, or dehumidification. This sub-base may be configured for a two heat stage/four cool stage configuration by using the third stage of heat for an additional stage of cooling. The selections that may be disabled are the network input options. Table 22 shows an installer configuration option for sub-base **3**.

TABLE 22

Installer Configuration Option	Sub-base 3
Heating output stages	3
Cooling Output stages	3
Room humidity sensor	1

Sub-base **4** may be a modulating configuration. Relative to the modulating sub-base configuration screen context rules, a total of 4 relays may be available with the thermostat and sub-base. The auxiliary relay may be configured for an economizer, time of the day, dehumidification or an additional stage of heating or cooling. The cooling and heating action (direct and reverse) may be shown. Table 23 shows an example installer configuration option for the various sub-bases.

TABLE 23

Installer Configuration Option	Sub-base 1	Sub-base 2	Sub-base 3	Sub-base 4
Heating output stages	1	2	3	0
Cooling Output stages	1	2	3	0

PDA configuration tool **12** may arrange and store user preferences. A preference selection for units may include SI (C) and US conventional (F). There may be a preference for alert messages such as an enable/disable alert warning regarding unsupported PDA OS™ versions. User preferences may be stored in a dedicated file. There may be one user preference set per PDA platform.

Preferences for regional design parameters may be stored in a default thermostat configuration. New configuration files may be instantiated with the default thermostat configuration. The user may modify the default thermostat configuration. One may lock configuration default files. The user preferences may support functions for locking and unlocking the default configuration files including the general thermostat configuration, the weekly schedule and the holiday schedule.

The configuration tool database manager may support 250 named configuration files in a space of 500 K bytes of PDA memory. The tool application software may use up to 500 K bytes of PDA memory.

The following figures effectively show what may be displayed on a PDA when configuring or doing settings. FIG. **3***a* may be the opening screen of configuration tool **12** of programmable thermostat **11**. One may configure offline by selecting a new configuration. Then, in the next screen, illustrated in FIG. **3***b*, one may enter a description of the new configuration under "Description".

One may connect and configure with an existing arrangement on the PDA. Various versions of firmware and software in thermostat **11** may support the processes in the following figures. FIG. **4***a* is an opening screen where one may click "Select Existing Config". The next screen in FIG. **4***b* shows existing configurations on which one may click "Example2", which may result in the next screen as illustrated in FIG. **4***c*. Here, one may click "Downld", which may bring a screen as shown in FIG. **4***d*. Then one may click "OK" to connect the PDA serial port to the T7350 thermostat. On the other hand, one may configure a new arrangement and then connect in FIGS. **5***a*, **5***b* and **5***c*. One may click a "New Config" on the opening screen of FIG. **5***a* and enter the new configuration name and its description on the next screen in FIG. **5***b*. The thermostat may be configured clicking the "Next" button to navigate it for entering the new configuration selections, features and settings. Clicking the "DownLd" button may result in the screen of FIG. **5***c* for the opportunity of serially connecting the PDA **12** port to thermostat **11**.

FIGS. **6***a* through **6***c* relate to connecting and modifying the existing configuration. On the opening screen of FIG. **6***a*, one may click "Upload Config" and get the connecting screen in FIG. **6***b* where one may connect the PDA to the thermostat by clicking "OK". In FIG. **6***c*, customer XYZ configuration may be loaded. Using the "Next" button, one may navigate and modify the loaded configuration. After modification of the configuration, one may click the "DownLd" button of screen in FIG. **6***c* to get the box for connecting PDA **12** to the thermostat **11** for downloading the modified configuration. FIG. **6***d* shows a dialog box for connecting PDA **12** to the thermostat **11**.

FIGS. **7***a* and **7***b* show screens that may be used for connecting and calibrating the thermostat. FIGS. **8***a*, **8***b* and **8***c* illustrate the sequence for connecting, reading and saving, that is one may click "Upload Config" on the opening screen and connect in the box that comes up and when ready to save, click the "Save" button in the screen of FIG. **8***c*. FIGS. **8***d* and **8***e* relate to monitoring data.

FIGS. **9***a* through **9***j* illustrate novice configuration and navigation. One, i.e., the user, may click on the "Next" button of the screen of the selected existing configuration, viz., Example3, in FIG. **9***a* to navigate it. FIG. **9***b* shows a selection of sources of inputs for room temperature, room relative humidity, discharge air temperature and outdoor temperature. After clicking the selections, the user may click "Next" and go to another screen for an output selection of "AuxDO" of the time of the day, economizer or the dehumid hot gas BP shown in FIG. **9***c*. A next screen may be the cooling configuration in FIG. **9***d* for a selection of the number of stages, cooling response, lockout, and set point degrees F. FIG. **9***e* shows a similar screen for heating configuration with a selection for stages, auxiliary stages, heating response, lock out and OAT. FIG. **9***f* is a screen that relates to features of the fan such as the switch of "On" or "Auto", operation of conventional or electric heat, extended operation or not for heat and cool. An events schedule screen in FIG. **9***g* provides for the modification of the schedule relative to unoccupied and occupied times of each day of the week. To insert changes, the user may click on "Modify", which may bring up the screen shown in FIG. **9***h*, where the user may enter the times of occupancy for the various days

of the week. FIG. **9***i* shows the screen where one may enter the temperature set points for heating and cooling for the events of a space that is occupied, unoccupied and the standby mode. Also, a temperature override interval in terms of hours may be entered. The "Summary" screen of FIG. **9***j* may be returned to upon which the user may save the changes to the configuration.

FIGS. **10***a* through **10***m* reveal a sequence for an advanced user configuration. FIG. **10***a* is a summary screen of the selected configuration. The user may click the "Summary" tab or menu and one gets the menu across the top of the screen as shown in FIG. **10***b*. "Set" may be clicked for a menu of items that may be set. "Sched" may be clicked as in FIG. **10***c* for a menu of scheduling items. One may click "Display" under "Set" in FIG. **10***b* and get the screen of FIG. **10***d* where certain display options can be selected. Clicking on dehumidification in FIG. **10***b*, one may get the screen of FIG. **10***e* where one may select dehumidification options. Clicking on "EnergyMgmt" under "Set" may result in several choices in FIG. **10***f*, such as the demand limit control bump and the power failure sequence start. Loop tuning under set may bring forth a screen in FIG. **10***g* where one may select appropriate set points. "Recovery" may be selected under "Sched" on the screen of FIG. **10***c* where one may select temperatures for starting cooling and heating based on outside air temperatures and ramping up and down rates, as in FIG. **10***h*. The daylight saving time selected under schedule may result in the screen as shown in FIG. **10***i* where the start and stop of daylight saving is to start and stop for the year. The "Holiday" selection under schedule may result in the list of holidays in FIG. **10***j* or **10***l* of which one may want to click on "Modify" to get the screen in FIG. **10***k* and thereby select the start time and duration of the selected holiday. The user may click on "Opt" in FIG. **10***c* and then click on "User Pref". Then one may select units, the OS alert message and the lock of defaults as shown in FIGS. **11***a* and **11***b*.

FIGS. **12***a* through **12***c* show file commands. One may click on "Summary" to get the menu which includes "File". A click may be applied to "New", "Open", "Save", "Save As", "Beam" or "Delete" relative to a configuration. FIGS. **12***b*, **12***c*, **12***d* and **12***e* show the resulting screens, respectively, to start a new configuration, open a current configuration, save a configuration as and delete a configuration.

The time clock may be set with configuration tool **12**. However, the configuration tool should be connected to thermostat **11** so that the thermostat real time clock may be set. The calendar year, month and day may also be set. These settings may be effected by using the PDA **12** time or it may be entered manually. FIG. **13** shows the screen for the set clock mode.

FIG. **14***a* shows a start-up screen for a tool on a Palm™ PDA **12**. The main screen appears in FIG. **14***b* and one may upload a program from thermostat **11**. Then "set up" may be selected in FIG. **14***c* and get to a program in FIG. **14***d*. One may select a day such as Sunday to schedule. FIG. **14***e* shows a schedule of Sunday and the occupied time may be selected, as in FIG. **14***f*. One may select the even time or time period for that occupied time in the screen of FIG. **14***g* and do the set points in the screen of FIG. **14***h*. One may also do the installer set up, for example, relative to the display in FIG. **14***i*. Setup **2** may include selecting the heat and cool stages, for energization selection and sensor location, as shown in FIG. **14***j*. Then one may load the program for a particular file, to be for the HVAC system for a particular location, such as a merchant, like "Standard **1**", as indicated in FIG. **14***k*. The configuration for Standard **1** may be downloaded to the respective thermostat **11**, as in FIG. **141**. This configuration may also be saved under a file name in FIG. **14***m*.

FIGS. **14***n*, **14***o* and **14***p* show screens about the enabling of partial downloads after the opening screen. Partial downloads may include weekly schedule, holiday and set points. FIG. **14***q* has "Home" added to the Set menu for returning to the opening screen in FIG. **14***r*. The user may be asked to save the current configuration before moving on.

PDA tool **12** may support thermostat field commissioning tasks including a temporary checkout mode (such as eliminating time delays) as well as a manual output mode. FIGS. **14***s*–**14***z* are screens supporting an override option scenario. The screen of FIG. **14***s* or **14***t* may provide the menu or home screen, respectively, for selecting an override option. FIG. **14***u* shows the connection message. FIGS. **14***v* and **14***w* reveal override screens for "Mod SubBase" and "3H3C SubBase", respectively. In the override screen of FIG. **14***x*, the user may tap the manual button. Tapping the screen of FIG. **14***y* may let the user exit the manual mode. The screen of FIG. **14***z* may warn the user if there is an exit with delays off or disabled.

Configuration tool **12** may be connected to thermostat **11** to read an online status report. The status report may include data, but not limited to, such as the thermostat firmware version, thermostat hardware version, sub-base hardware version, run time error messages, space temperature, remote temperature set point input, discharge air temperature, outside air temperature, number of heating stages active, heating capacity output in percent, number of cooling stages active, cooling capacity in terms of percent, remote space relative humidity in percent, occupancy status (on or off), effective fan setting (on, off or auto), fan status (on or off), mode (heating or cooling), economizer logic state (on or off), occupancy override status, and run time data. The configuration arrangement and/or the online status report may be transferred (HotSync) to, for instance, a Palm™ or desktop PC application or to another PDA **12**, via light beam technology or other ways. Thermostat configuration summaries may be saved to a Palm TM memo, which may also be similarly transferred. There may be a password or other security approach to prevent other PDA users from changing the default files established by the local control manager.

PDA **12** may be connected to thermostat **11** to make limited changes, such as one or several configuration parameters, holiday schedules, weekly schedules, operating mode, temperature settings, and so forth. The PDA **12** tool may support thermostat field commissioning tasks including a check-out mode (eliminating time delays during check-out). The check-out mode may be automatic or manual. Table 24 shows a configuration option with related information.

TABLE 24

Config Option	Default	Min	Max	Res	Units	Description
DisableDelays	0	0	1	1		0: Not in system Checkout Mode 1: In System Checkout Mode (disable delays on relays, sequential start, . . . etc)

TABLE 24-continued

Config Option	Default	Min	Max	Res	Units	Description
ManualMode	0	0	2	1		There may be a couple of bits for mode: 0 = Run, 1 = manual, 2 = Factorytest.
ManualMode	0	0	2	1		Each relay/AO labeled on the Palm like it is on the Stat. So the Palm would determine if it is a Heat pump or conventional and then display the labels.
ManualMode	0	0	2	1		Will provide a Manual Mode to turn on/off each output. The user enters and exits manual mode using the PalmTM OS Configuration Tool. The T7350 automatically terminates manual mode if periodic updates are not received or the user disconnects the serial cable from the PalmTM OS Configuration Tool.
ManualMode	0	0	2	1		Manual Mode is not a flashed "permanent" state. Manual mode or test-speedup mode is not remembered through a power down or restart.
Relay1	0	0	1	1		There will be 8 bits (1 byte) for the 8 relays. 0 = off 1 = On
Relay2	0	0	1	1		
Relay3	0	0	1	1		
Relay4	0	0	1	1		
Relay5	0	0	1	1		
Relay6	0	0	1	1		
Relay7	0	0	1	1		
ModOut1	0	0	100	1	%	There will be 2 bytes for the modulating outputs: 0–100% each. When thermostat sees mode change to manual, it may set the outputs to the values specified.
ModOut2	0	0	100	1	%	

One may monitor thermostat operating data to determine the health of the thermostat. Tables 25 and 26 indicate the various configuration items and parameters that may be monitored. Table 25 shows the input data that may be monitored.

TABLE 25

Min	Max	Res	Units	Description
				Space Temperature
				Remote temperature setpoint input
				DAT
				OAT
				Space RH %
				Occupancy sensor status (on/off)
				Fan status (on/off)
				Occupancy override status

Table 26 shows the output data that may be monitored. Operating modes may likewise be monitored.

TABLE 26

Min	Max	Res	Units	Description
				# of heating stages active
				Heating capacity output %
				# of cooling stages active

TABLE 26-continued

Min	Max	Res	Units	Description
				Cooling capacity output %
				Economizer logic state (on/off)

Table 27 lists some models and their data that may be monitored.

TABLE 27

Min	Max	Res	Units	Description
				Dehumidification: Reheat
				Dehumidification: SetPoint Reset
				Dehumidification: Min On Time
				Extended
				Recovery Mode
				Operational Mode: Heating/Cooling
				Effective SetPoint
				DLC
				Real Time
				Operating Date
				Heating Lockout Mode
				Cooling Lockout Mode

Thermostat operating data may be monitored. A table 28 may provide data values with display dependency rules.

TABLE 28

Thermostat Data	Display	Display Dependency	Report Text Description	Comments
version.major	A		FirmwareVersion: 0.0.19	
version.minor				
version.bug				
version.commVer	V		ComVersion: 1	
version.rePgmrVer	V		ReProgrammerVersion:	
status3.subBaseType	A		SubBaseID: T7350D, 3H3C	
subBase.connected	V		CommunicatingSubBase: Yes	
statusAnalog.spaceTemp	A		RoomTemperature: 75 F.	
statusAnalog.dischTemp	D	configured	DischargeAirTemp: 105 F.	config.dischAirSensor
statusAnalog.spaceHumidity	D	configured	Room RH: 33%	config.humiditySensor
statusAnalog.oDTemp	D	configured	OutdoorAir: 25 F.	config.oDAirSensor
statusAnalog.remoteStPtOffset	D	configured	RemoteSetPtOffset: 2 F.	config.remoteSetPoint
statusAnalog.temporarySetPt	D	value < > 0	TemporarySetPt: 76 F.	Display actual temporary setpoint if Delta value < > 0
status1.totalError	N			Total error reported by the control loop.
status1.bypassTime	D	value > 0	BypassTime: 180 min	
status1.tuncos	N			Time until next scheduled change of occupancy state:
status1.DaysLeftKeypadHoliday	D	value > 0	HolidayDaysRemaining: 7	
status1.currentState	A		TimeSchedule: OCC	Current scheduled occupancy state 0: OCC 1: UNOCC 2: BYPASS 3: STANDBY 7: OCCNUL
status1.nextState	N			
status1.occSensor	D	configured	OccSensor: 0	config.occSensor = 1
status1.holiday	N			
status2.heatStgsOn	A	configured	HeatingStagesActive: 2	
	D	configured	AuxHeatingStagesActive: 2	Control = HeatPump
status2.coolStgsOn	A	configured	CoolingStagesActive: 1	
status2.percentCmdHeat	D	configured	HeatingOutput: 57%	SubBaseID = M
status2.percentCmdCool	D	configured	CoolingOutput: 33%	SubBaseID = M
status2.outFan	N			
status2.outCool1	N			
status2.outCool2	N			
status2.outCool3	N			
status2.outAux	A			
status2.outHeat1	D	configured	O/BChangeoverOver: ON	Control = heatpump config.heatPump
status2.outHeat2	N			
status2.outHeat3	N			
status2.effMode	A		EffectiveMode: Cool	Effective operating mode: 0: OFF_MODE 1: COOL_MODE 2: HEAT_MODE 3: EMERG_HEAT_MODE 4: REHEAT 5: MANUAL 6: FACTORY_TEST
status2.fan	A		FanStatus: ON	
status2.auxRelay	D	configured	Economizer: ON	NotHeatPmp AND Subbase > 1 config.auxOpMode = 1
	D	configured	HotGasDehumidification: ON	config.auxOpMode = 2
	D	configured	SimpleDehumidification: ON	config.auxOpMode = 3
	D	configured	TimeOfDayContact: ON	config.auxOpMode = 0
status2.unused1	N			
status2.stagesActive	N	configured		
status2.noAuxHeat1	N			
status2.noAuxHeat2	N			
status2.dehumidActive	N	configured	Dehumidification: ON	RH sensor configured
status2.DALimit	D	configured	DishargeAirLimiting: ON	config.enableDALoLimit = 1 OR config.enableDAHiLimit = 1
status2.unused2	N			
status3.effOccTuncos	N			
status3.effSetPt_s6	A		EffectiveSetPoint: 72 F.	
status3.effOccCurrentState	A		EffectiveOccupancy: OCC	
status3.unused1	N			
status3.effOccNextState	N			
status3.unused2	N			
status4.terminalLoad	V			

TABLE 28-continued

Thermostat Data	Display	Display Dependency	Report Text Description	Comments

Display Key: A - Always display
D - Display based on context Dependency
N - Never displayed
V - Verbose mode only

One may backup thermostat configuration files from PDA **12** to a PC. These PDA configuration files may be restored in the event of battery failure or PDA demise or loss. If the latter occurs, one may go to a store and purchase another PDA and upload the files from the PC, and continue about the business with the new PDA.

A PC archive of thermostat configuration information may have several benefits. The PC archive database may support multiple PDA users. Individual thermostat configuration files may be organized in groups by customer building or project name. PDA users may from such database select individual configurations and incrementally install them on a specific PDA using the PC hot sync function. The function may be hardwired or be of an IR or other wireless method. Other connective functions may be implemented. There may be last session information. In other words, the PDA or PC user may be returned to the last edited configuration file and last used configuration screen. Also, a list of the last five or so configuration files opened by the user may be presented upon going into the configuration program. There may also be various warnings about the adequacy of the PDA hardware and software.

The PDA user may be able to field calibrate analog outputs. For high accuracy on the analog outputs or inputs, the user may modify gain and offset constraints. For instance, the user may field calibrate the humidity sensor. The user may be able to add an offset to the sensor reading. Various abbreviated titles, terms and acronyms may be connected by PDA **12** with a button toggle to obtain the full title or meaning. For instance, one may toggle on "LeadTimeInfo" to get "Lead Time Table of Information."

PDA **12** may not only upload a configuration from thermostat **11**, but it may be able to upload a contractor's name, logo and telephone number. This information may be presented on the screen of PDA **12**. Also, it may likewise be displayable on thermostat **11**. Such information may be useful in case there is a thermostat problem, regular preventive maintenance or routine check scheduled, filter change needed, a seasonal configuration change, or other items in which contacting a contractor could be helpful.

FIG. **15** is a flow diagram of an entry of a contractor's phone number and logo graphic (and possibly additional information) on a PC at block **16**. The format of the logo graphic may be checked at junction **17**. If the format is not proper, then it may be converted at block **18**. If or when the format is proper, then it may be checked for size at junction **19**. If the logo is not the correct size, then it is not resized at block **20**. If and when the logo is of acceptable size, then the contractor information may be stored in the PC. At block **21**, the contractor information may be transferred as data from the PC to a PDA or portable memory media (e.g., smart media, compact flash or a memory stick). At block or step **22**, the contractor information data may be transferred to thermostat **11** EEPROM/FLASH **23** via PDA **12** using an easy wire, IR or RF connection, or via a portable memory.

The electronic thermostat assembly may consist of two pieces, the cover assembly **30** and sub-base **14**. The cover assembly may include, but is not limited to, the MMI and a display **38** for 7-day programming. Assembly **30** and display **38** are shown in FIGS. **17***b* and **17***a*, respectively. The sub-base(s) include the equipment control connections. The sub-base is mounted on the wall and the thermostat cover assembly is mounted on the sub-base. Different sub-bases will be used for different applications including; up to 3 heating stages/3 cooling stages or 2 heating stages/4 cooling stages, modulating outputs, and dehumidification high limit control. Each sub-base is compatible with the common cover assembly.

There may be a disable delay/sequential start option. This may allow faster testing in the field by disabling the minimum on/off time delays for relay outputs and the sequential start delay. The rate at which the control algorithm runs (once every 10 seconds) determines the rate at which stages cycle on and off. Other test options may include the following.

The installer may enter the disable delay option by pressing a special combination of keys and selecting "in-test" and then pressing the "run" key. The installer may exit the disable delay option by pressing a special combination of keys and selecting "no-test" and then pressing the run key.

There may be a capability to field flash thermostat **11** from the serial port. This may allow the user to upgrade the firmware in the field. Initially, a lap-top PC **24**, running a special program may be used to connect to the thermostat serial port. Later, a program may be developed to do this through the Palm™ OS configuration tool. Schedule programming, installer configuration options, set points, system switch, fan switch, and keypad lockout may all be field adjustable through the thermostat keypad/LCD or a Palm™ OS configuration tool. Some parameters may be configured and monitored only through the Palm™ OS configuration tool. Others can be configured and monitored from both the keypad/LCD and Palm™ OS configuration tool **12**.

FIG. **16** is a thermostat system level diagram with major components and a system communications overview. Thermostat **11** may interface with remote air management system or HVAC equipment controls **26**, external sensors and switches **25**, and a remote wall module **27**. Signals, including commands to equipment, between thermostat **11** and air management or HVAC controls **26** may be via connection **33**. External sensors and switches **25** may include discharge air temperature, outdoor air temperature, humidity and occupancy sensor. Information from sensors and switches **25** may be conveyed along connection **29** to thermostat **11**. Remote wall module **27** may include a temperature sensor, an override switch with an LED and a warmer/cooler (set point offset) knob, with related information being conveyed between module **27** and thermostat **11** along connection **31**.

Thermostat **11** may have a serial communications set-up or interface module **28** to allow inboard and outboard information to go between thermostat **11** and set-up **28** along a connection **32**. Communications between set-up or module **28** and an external device **56**, such as an installer configuration tool **12** and a communicating sub-base **14**, may be via

a connection **34**. Firmware to thermostat **11** may be downloaded form an appropriate device **36** via a JTAG interface connection **37**.

Thermostat **11** may be configured using an "Installer Setup" through the thermostat keys on cover assembly **30** for basic setup functions. More advanced features may be available through installer configuration tool **12**. Installer configuration tool **12** may be compatible with a Palm™ OS handheld computer.

There may be a thermostat **11** output modulation control. This approach may solve problems associated with control issues by sending analog heating and cooling signals to be implemented by controls of an air management system or roof top unit **40** of FIG. **21**. System or unit **40** may have a duct **39** for taking in outside air (OA), a duct **41** for taking in return air (RA) of a space, and a duct **42** for discharging air (DA). Unit **40** includes a cooling unit **43** and a heating unit **44**. Several enhancements and options may exist in the algorithm and thermostat configuration to assist and lead to control of water valves and oversized heating coils and loads. There may be various approaches for implementing analog output and modulation in a thermostat. One may use configuration codes in the sub-base combined with a configuration tool and interchangeable sub-bases.

The present electronic thermostat system may consist of two components, thermostat **11** and the sub-base **14**. The thermostat may include a human interface and display for user programming, the microprocessor, four relays, a space sensor and a power supply. The sub-base may include equipment control connections, additional relays, optional analog output, and some power supply components. The sub-base may be mounted on the wall and the thermostat may be mounted on the sub-base. Different sub-base types may be used for different applications including up to three heat/three cool or two heat/four cool, modulating outputs, dehumidification high limit control, and communications with a building automation system. All sub-base types may be compatible with the thermostat.

A Palm™ PDA may be connected to the thermostat and be used to configure or program the thermostat. The communications port may be used by the factory to test the hardware features of the device. An optional remote wall module may be attached to the device to sense space temperature, control the set point, initiate a schedule override timer, and display the status of the override timer.

Thermostat **11** of FIG. **1** may contain a software component in the thermostat that allows automatic configuration of the output actuation type (modulation and discrete) identified by the sub-base with preset configuration resistors. Additional configuration information may be provided in the Palm™ configuration tool that allows setting of the parameters related to the modulating outputs. The following table reveals the various options for the sub-bases.

TABLE 29

Installer Configuration Option	Sub-base 1	Sub-base 2	Sub-base 3	Sub-base 4
Heating output stages	1	2	3	0
Cooling Output stages	1	2	3	0
Heating Throttling Range ®	3	4	7	5
Cooling Throttling Range ®	3	4	7	5

The next table relates to modulating system valve control.

TABLE 30

Cooling Valve	Applies to the modulating Cooling valve 0 = direct acting. 1 = reverse acting.
Heating Valve	Applies to the modulating Heating valve 0 = direct acting. 1 = reverse acting.

The hardware component of the output actuation may be implemented though an analog output set. The microprocessor may output the signal as a duty cycle signal that is driven into a digital to analog conversion circuit.

This invention may solve the problems associated with control issues by implementing a true analog heating and cooling signal to be implemented by the roof top **40** control system. Several enhancements and options exist in the algorithm and thermostat configuration to assist and lead to control of water valve control and oversized heating coils and loads. Under staging conditions, traditional control algorithm techniques may be used to control the on/off control to the heating coils, cooling coils and fan. When used in a modulating configuration, special analog driver circuits may allow the output from the thermostat to provide 4 to 20 milliamps and 2 to 10 volts for direct interfacing for the control of modulated components. These control parameters are popular ranges for many modulated dampers and valves used in air management systems, such as HVACs.

The thermostat may contain a software component that allows automatic configuration of the output actuation type (modulation and discrete) identified by the sub-base with preset configuration resistors. The hardware component of the output actuation may be implemented through an analog interface set from the thermostat. Analog control and interface to the modulation may be controlled through software algorithm PID and staging information. If additional heating is desired after a stage is added at low load, additional supply is available through increasing of the analog heating signal. Applications of this modulating thermostat may be used for boiler firing rate controls and other energy supply or cooling type equipment. Through the use of programmable memory, additional algorithms can be developed to apply to a wide range and variety of control applications besides air management system control.

The present thermostat may provide modulated/analog control of an air management system and discrete/digital control of the same or another air management system. This thermostat may provide modulating control of a single stage of heating and/or cooling. On the other hand, this thermostat may provide modulating control of multiple stages of heating and cooling. Using a modulating signal to control each cooling or heating stage may result in maintaining the outputs of the controlled stages at efficient levels. If more output is needed from that stage, the thermostat may, with a modulating output, call on another stage and control it for more heating or cooling, so as to maintain the better efficiency of the first stage by not increasing the modulating output to the first stage to increase its output. Also, modulated control may result in the next stage's approaching an efficient level of output. This approach may continue for more or less output as needed from the respective stages. The thermostat may provide analog or digital signals for controlling single or multiple cooling or heating stages. The thermostat may have any combination or all of these features.

FIG. **17** is a block diagram of a modulating commercial thermostat system. The system is composed of several major components including a Honeywell™ T7350 thermostat **11**, a configuration tool (PDA) **12**, and external mechanical equipment **57**. Thermostat **11** may be composed of several major sections including a cover assembly **30**, modulating sub-base **14** and external sensors. External sensors may include discharge air sensors **64**, outside air sensors **65**, a humidity sensor **66**, and a space temperature sensor **67**. These sensors may be connected to an analog-to-digital converter (ADC) **59**. Within a cover assembly **30**, a microprocessor **61** may contain the software instructions that control the interface between the control algorithm and the ADC and digital input/output (I/O) blocks **59** and **58**, respectively. Microprocessor **61** may be a microcontroller having a schedule and an algorithm, and a flash memory. A JTAG connection **37** to microprocessor **61** may allow upgradeable field programming and real time emulation of operation. A real-time clock **62** may be connected to processor **61**. Sub-base **14** configuration resistor **63** may be read on power-up and provide an indication of a unique resistor value that indicates the presence of a modulating sub-base.

ADC block **59** may convert the incoming analog resistance values into digital values that can be read by microprocessor **61**. The analog resistors values to ADC **59** may come from discharge air sensors **64**, outside air sensors **65**, humidity sensor **66**, space temperature sensor **67**, motion sensor **68**, and other sensors **69**. Another analog input to ADC **59** may be from sub-base configuration resistor **63**. A modulation signal may be derived from a pulse width modulated (PWM) signal conversion circuit which converts the time-multiplexed duty cycled signal from the algorithm of processor **61** into a 4–20 milliampere (mA) modulating signal. The 4–20 mA signals may be fed, via the modulating cooling interface **72** and modulating heating interface **73**, to HVAC mechanical equipment **57** and may be used to control space temperature with analog control dampers among other HVAC mechanical equipment **57**, as needed. A digital I/O **58** may be connected to microprocessor **61**. A motion sensor **68** and other external sensors **69** may provide signals to processor **61** via digital I/O **58**. Processor **61** may provide signals to cooling relay **74**, heating relay **75**, fan relay **76** and auxiliary relay **77**. The outputs of these relays may be connected to HVAC mechanical equipment **57**.

Since modulating control of both heating and cooling valves may be under microprocessor **61** control via modulating cooling and heating interfaces **72** and **73**, respectively, and since thermostat **11** may be capable of humidity control, the thermostat can in general control or limit humidity effectively through the use of modulating the cooling as necessary to reduce the humidity of the outside air that typically accounts for most of the humidity load in a commercial building. Different strategies may be used to do dehumidification control including the use of both heating and cooling relays and heating and cooling modulating valves in different ratios. Modulation of dampers to control the volume of air per unit of time through the cooling mechanism may also be used for dehumidification control.

FIG. **18** is a block diagram of the networked modulating thermostat. Components associated with thermostat **11** may include the system sequencing control **78**, which may be a Lonworks™ communicating node that allows network information to be shared on a network communications bus **84** in the form of "network variables". Standard network variables may exist for standard representations of temperature, humidity, and digital on/off and analog values. Sequencer **78** may have a local sensors **79** connection. The availability of modulating controls may allow for a master sequencing control **78** node to make staging and modulating decisions for the whole system based on local sensors. Also, local sensor information may be shared on a one-to-one, or one-to-many basis using a Lonworks™ process called "binding". It may allow, for instance, the outside air temperature and outside humidity signals to be shared across multiple controllers, including information for temperature and humidity control for individual nodes **82** and **83**. Controller **192** may be associated with node **82**. Controller **192** may have a thermostat **11** and a sub-base **14** which are set up for two stage cooling and two stage heating. Mechanical equipment **57** may be driven with digital-like, discrete, non-modulated signals from controller **192**. Sources **194**, **195** and **196** connected to thermostat **11** may provide temperature, humidity and outside parameter information, respectively, to controller **192**. Other controllers on bus **84** may likewise have such sources connected to them. Also, a controller **193** may be associated with node **83**. Controller **193** may have a thermostat **11** and a sub-base **14** which are set up for modulated one stage cooling and heating. Mechanical equipment **57** may be driven with analog, modulated signals from controller **193**. Thermostat **11** of controllers **192** and **193** may be the same thermostat or different thermostats. If these controllers have the same thermostat, that thermostat may have the capability of controlling both non-modulated air management systems and modulated air management systems.

In FIG. **18**, there may be numerous other nodes having additional controllers (though not explicitly shown) associated with them, respectively. The controllers may output non-modulated or modulated control signals to their respective mechanical equipment which may consist of HVACs, respectively, having valves and/or dampers controlled by signal outputs from their corresponding controllers. Often, the air management systems, such as HVACs, that are recipients of the non-modulated control signals, are multiple stage cooling and heating systems. And often, the air management systems, such as HVACs, that are recipients of the modulated control signals, are single unit cooling and heating systems. However, in lieu of the latter single unit systems, there may be modulated multiple stage cooling and heating systems. Both modulated and non-modulated systems may also have humidity control.

Sequencing information may be collected from sensors **79** on node **81** or network binding sensors to allow for sequential staging and algorithm enhancements. Local and non-local sensors may be those for measuring temperature and humidity, and other parameters. The sensors may be situated in various locations such as outside, the controlled space and in or proximate to the air management equipment. Since the individual nodes may command analog and digital values from both the local node and the system node, the system node can command individual node analog and digital values as required in temperature (and sometimes humidity and other parameter) control systems, such as HVACs.

System sequence control **78** may be a controller configured as a sequencer with controllers **192**, **193** and others added and connected to the network communications bus **84**. Controllers **192**, **193** and the like may act as individual controllers which periodically send status messages to sequencer **78**. Also, sequencer **78** may periodically send information, instructions and commands to controllers **192**, **193** and other like controllers, if any. Such information, instructions or commands may affect the respective control-

ler's control of mechanical equipment **57** of an HVAC or other air management equipment.

Sequencer **78** may also control a multi-stage heating and cooling system via thermostat(s). That is, there may be modulated control of each stage of heating and cooling. The percentage a stage's maximum output may be somewhat less than 100 percent. That percentage may be determined, for example, by an effective operating efficiency singlely or in combination with one or more other stages. Other bases may be used for determined the percentage of maximum operation of a stage. The percentages may be different among the stages and dependent upon parameters such as temperatures, humidity and so forth. Sequence control may also be of non-modulated stages or of a mix of modulated and non-modulated stages. The sequence may be utilized for air management systems having humidity control. A user interface **197**, similar to interface **30**, having a keyboard and a display, may be connected to sequencer **78** for programming, configuring and testing the sequencer and associated controllers on communications bus **84**. A personal digital assistant (e.g., PDA **12**) may be connected to user interface **197** or directly to sequencer **78** for programming, configuring and testing the sequencer and associated controllers on communications bus **84**. The connection of the PDA to interface **197** or sequencer **78** may be via a wire or wireless medium (e.g., RF, infrared or optical fiber). Each thermostat **11** associated with bus **84** may likewise have a user interface **30** and PDA **12** as disclosed herein.

FIG. **19** is a flow diagram of the modulating sub-base sequence. An input may enter the sequence at decision **85** which asks whether the power is within acceptable limits. If not, a power shut-down may be initiated along with the saving of the schedule and configuration, as indicated in block **86**. If the power is within acceptable limits, then the analog/digital (A/D) registers may be initialized and the analog outputs commanded to 4 mA, according to block **87**. The output of block **87** may go to block **88** and cause the sub-base configuration resistor ID to be read. The next question of symbol **89** may be whether the modulating resistor identification (ID) is valid or not. If not, a signal may be sent back to the beginning of block **88** and the process may repeat itself with the same question of validation of the modulating resistor ID. If the resistor ID is valid, then a signal may be sent from decision diamond **89** to block **91** for the temperature and humidity sensors to be read. After these readings, control algorithm action of block **92** may occur. The measured value temperature minus a temperature set point may equal the error, and the humidity error may be a function of humidity value and the humidity high limit. After the action of block **92**, an output may go to symbol **93** to ask whether an analog modulating sub-base is present. If not, then a digital output may be a function of measured temperature error, measured humidity error, and configuration type, as in block **94**. If so, then a modulating output may be a function of measured temperature error, measured humidity error and configuration type, as in block **95**.

FIGS. **20***a* and **20***b* show an illustrative example of a display **38** and a keypad **45** user interface **30**. Keypad **45** may control HVAC equipment often described as a conventional roof top unit (RTU) **40** with gas or electric heat and direct expansion (DX) cooling. There may be 0–3 stages of heat, and up to 6 stages of heating and cooling combined. There may be 0–4 stages of compressor, and up to 6 stages of heating and cooling combined. There may be a single speed fan. An auxiliary relay may be used to enable economizer dampers, TOD or dehumidification. A heat pump roof top unit **40** may have gas or electric auxiliary heat. There may be 0–2 stages of auxiliary heat, 0–3 stages of compressor, a heating or cooling changeover valve, and be configurable for ON for heat or ON for cool. It may have a single speed fan. Also, an auxiliary relay may be used to enable economizer dampers, TOD (time of day) or dehumidification.

A modulating roof top unit may have a hot water valve or modulating gas heat and/or chilled water valve. FIG. **21** shows a typical roof top unit **40**. Roof top unit may have cooling equipment **43** and heating equipment **44**. It may also have a fan **46**, a DAT **47** and an OAT **48**. There may be dampers **49** and **51** to regulate the flow of the outside air and return air to RTU **40**. Dampers **49** and **51** may have a common mechanical connection **52** which coordinates their movements relative to each other. A control panel **50** for RTU **40** may be connected to cooling equipment **43**, heating equipment **44**, fan **46**, dampers **49** and **51**, and a heat pump cutout valve **53**. Control panel may receive control signals from and send signals to thermostat **11**. A DAT sensor **47**, an OAT sensor **48**, an occupancy sensor **54** and a remote sensor **55** may be connected to thermostat **11**.

RTU **40** may have a heat enable, cool enable, or 0–2 stages of heat or compressor. The modulating outputs may be always active. They may be always being driven 0–100 percent. When the number of stages is zero, the relay outputs may be used to enable heating or cooling outputs. This means the relay may turn on when the modulating output is nonzero and turn off when the output is zero. Staged action may be used in addition to the modulating outputs. The number of stages may be set to 1 or 2, or more if desired. In this particular case, the relay output(s) may be used for up to 2 stages of heating or cooling. Note that the user might not have both two stages of cooling and two stages of heating. In another example, the user may have modulated heat, a heat pump enable relay and one stage of cooling. Or the user may have modulated heat, a heat pump enable relay, and two stages of cooling. The cooling analog output may be direct or reverse acting. The heating analog output may be direct or reverse acting. The may be a single speed fan. Although a multiple speed fan may be used. There may an auxiliary relay used to enable economizer dampers, TOD or dehumidification.

The hardware of thermostat **11** may have the following configuration, which includes an internal room temperature sensor, an LCD display **38** with back-lighting, a keypad **45**, a system and fan switching capability through the keypad, as indicated in FIGS. **20***a* and **20***b*. Also, there may be a serial communications link from thermostat **11** to configuration tool **12** (Palm™ OS) and a network communicating sub-base. There may be four onboard relays with one for heat, one for cooling, one for a fan, and one auxiliary relay.

Recognition of the sub-base I/O (input/output) may be through the hardware. The thermostat cover assembly may indicate the sub-base I/O configuration by a resistor located on the sub-base. Each I/O configuration may have a unique resistor value. One sub-base configuration may have modulating outputs. A total of four relays may be available with a thermostat cover assembly and the sub-base. The auxiliary relay may be configured for an economizer, TOD, dehumidification or an additional stage of heating or cooling. There may be a modulating heating output and a modulating cooling output. Also included may be a humidity sensor mounted in the sub-base, a remote room sensor, a remote room humidity sensor, a remote discharge air temperature sensor, a remote outdoor air temperature sensor, and remote occupancy input (digital input). There may be access to the

serial communications port on the thermostat. The modulating sub-base may or may not support heat pumps.

An open, short, or out-of-range on the internal or remote room sensor input(s) to the thermostat may cause the outputs to be turned off. The fault detection might be just done on the sensor being used. That is, if the internal sensor is being used, faults on the remote sensor are ignored. The system may provide proportional plus integral plus derivative temperature control.

There may be testability capabilities. The thermostat may cooperate with factory testers such as in-circuit and functional tests to verify its functionality. The industry standard JTAG port will be available for the factory tester to program the flash memory and test the device. Boundary Scan, formally known as IEEE/ANSI 1149.1_1190 is a standard which facilitates testing, device programming and debugging at the semiconductor, board and system levels. The standard came about as a result of the efforts of a Joint Test Action Group (JTAG) formed by several North American and European companies. IEEE Std 1149.1 was originally developed as an on-chip test infrastructure capable of extending the lifetime of available automatic test equipment (ATE). This methodology of incorporating design-for-test allows complete control and access to the boundary pins of a device without the need for a bed-of-nails or other test equipment. The OS label applied to the control represents the features of the control. This product may be designed such that 100 percent of the inputs and outputs can be tested in the factory.

One may interface to a Palm™ OS tool to do installer configurations, set parameters, set schedules and tests, including factory-like testing, and diagnostics. The Palm™ OS configuration tool has several basic functions installer configuration (defines the equipment attached to the thermostat); parameter modification (gains, set points, and the like), schedule changes, and testing and diagnostics.

Keypad **45** and LCD display **38** user interface **30** may be in the flash memory file (accessed through document management software). Thermostat **11** may have the LCD segments depicted in FIGS. **20***a* and **20***b*. FIG. **20***a* shows the available LCD elements in display **38**. There are elements for displaying time, temperature, days of the week, humidity, occupied status, far status, heat and cool status, setting for schedules and times, and so forth. Further, display **38** may be a dot-matrix system with shading of the respective pixels. Display **38** may be a black and white display with a gray scale system, or a color display which is capable of displaying graphics, pictures and symbols, including company or contractor logos. Display **38** may be capable of displaying video-like or television-type pictures. Interface **30** may have a speaker for providing sound associated with video information on display **38**. Also, a microphone may be attached to interface **30** for voice instructions or other audio purposes.

FIG. **20***b* shows user interface **30** with display **38** and keyboard **45**. Button or keys **96** and **97** may be used for entering up and down settings, respectively. Key **98** may be used to obtain information. Keypad or keyboard **45** may have a settings group **99**, set group **101**, override group **102** and a program group **103** of keys. Buttons or keys **104** and **105** may be for the heat and cool temperature set points for occupied periods. Keys **106** and **107** may be for heat and cool temperature set points for unoccupied periods. The day and time of the clock may be set with keys **108** and **109**, respectively. Keys **110** and **111** of override group **102** may be used for temporary occupied and holiday schedule selection, respectively. Alternatively, key **111** may be for "Temporary Not Occupied" override, as indicated in Table 31. One may program schedules of occupied and unoccupied times for various days in key group **103**. Key **112** may be used to select the day to be scheduled, key **113** may be used for selecting the occupied times and key **114** for selecting the not occupied times for the selected day. Key **115** may be used to clear the set schedule of that day. Key **116** may be used to copy a schedule of one day into another. Other keys of interface **30**, include a system key **117** for selecting a cooling or heating system, and a key **118** for putting the fan "on" or on "auto". Key **119** may be used to run the system. Table 31 provides some description of the various keys on keyboard **45**.

TABLE 31

Reference Number	Grouping	Button	Definition
96	Information	Down Arrow	Used for lowering setpoints, days, and times. When setting times or temperatures, holding this key down results in continuously decreasing the time.
98	Information	❶	Used to obtain information (and setting humidity "high-limit" value)
97	Information	Up Arrow	Used for raising setpoints, days, and times. When setting times or temperatures, holding this key down results in continuously increasing the time.
104	Temperature	Occupied Heat	Set Occupied Heat setpoint
105	Temperature	Occupied Cool	Set Occupied Cool setpoint
106	Temperature	Not Occupied Heat	Set Not Occupied Heat setpoint
107	Temperature	Not Occupied Cool	Set Not Occupied Cool setpoint
108	Set	Day	Set day of week. Tapping this key when the 'Set Value' segment is on will also increase the current day (same effect as up arrow key)
109	Set	Time	Set time. Tapping this key when the "Set Value" segment is on will also increase the time in one hour increments
110	Override	Temporary Occupied	Temporary occupied setting for length of time defined by installer.
111	Override	Temporary Not Occupied	Set Not Occupied length. User can select length of days ("0"–"99"), or "---" for continuous override

TABLE 31-continued

Reference Number	Grouping	Button	Definition
112	Schedule	Day	Selects day schedule to modify
113	Schedule	Occupied	Selects occupied event start times for specified day. Repeatedly pressing this key toggles between two occupied events.
114	Schedule	Not Occupied	Selects not occupied event start times for specified day. Repeatedly pressing this key toggles between two not occupied events.
115	Schedule	Clear Start Time	Clears start time for specified period and day
116	Schedule	Copy	Copies schedule from one day to another.
117		System	Selects System Mode. Toggles between Em Heat, Heat, Off, Cool, and Auto modes.
118		Fan	Selects mode of fan operation. Toggles between On and Auto.
119		Run Schedule	Resumes running schedule (cancels any Temporary Occupied action, Temporary Not Occupied, or Temporary setpoint change.)

In system checkout there may be disable delay, test and monitoring from Palm™ configuration tool **11**. One may be able to access a manual mode from the Palm™ OS configuration tool. This may allow the user to manually turn on and off or modulate each output to verify wiring.

The electronic thermostat system may consist of two pieces, thermostat **11** and sub-base **14**. Thermostat **11** may include a human interface **30** and display **38** for user programming, a microprocessor **61**, four relays **74**, **75**, **76**, **77**, a space sensor **67**, and a power supply. Sub-base **14** may include the equipment control connections, additional relays, optional analog output, and some power supply components. Sub-base **14** is mounted on the wall and thermostat **11** may be mounted on sub-base **14**. Different sub-base **14** types may be used for different applications including up to three heat/three cool or two heat/four cool, modulating outputs, dehumidification high limit control, and communications with a building automation system. All sub-base **14** types may be compatible with thermostat **11**.

A Palm™ PDA **12** may be connected to thermostat **11** and used to configure or program thermostat **11**. Future sub-base **14** types may have the capability of communications to a building automation system via a net connection. The communications port may be used by the factory or a PDA to test the hardware features of the device.

An optional remote wall module may be attached to the device to sense space temperature, control the set point, initiate a schedule override timer, and display the status of the override timer. Optional remote discharge, outdoor air, humidity, and occupancy sensors may be attached to thermostat **11** via sub-base **14**.

In the factory, thermostat **11** may be connected to a programming device that programs the flash memory via the industry standard JTAG port. This port may also by used to down load revised software in the field.

There may be control algorithms in thermostat **11**. Thermostat **11** may be used to control the temperature and humidity in the controlled space using heating and cooling equipment. The equipment may be conventional with up to three stages of heating and four stages of cooling, or it may be heat pump with up to two compressor stages and two stages of auxiliary heat. In addition economizer options and analog control options are available with some sub-bases. The control algorithm may be customized for various applications using keyboard and display or an external personal digital assistant (e.g., PDA **12**).

In the factory test phase, the device may cooperate with the factory tester to test the hardware inputs, outputs, keyboard **45**, display **38**, and associated equipment. The hardware of thermostat **11** may include certain significant components. Thermostat **11** may use a Texas Instruments Inc. MSP **430** family microprocessor. Processor **61** may contain on chip flash program memory, flash information memory, RAM, microprocessor oscillator, real time clock oscillator (external crystal), timers for real time clock, timers for operating system and pulse width modulation (analog output), digital IO **58** ports for relays/inputs/keyboard scanning, 12 bit analog-to-digital converter (ADC) **59** with an input multiplexer, and an LCD display **38** driver.

The microprocessor **61** port pins may be connected to: keyboard **45** rows (inputs) and columns (outputs); an LCD display **38**; eight analog input circuits (one on thermostat **11** and up to seven connected via sub-base **14**); one digital input for remote wall module bypass button—connected via sub-base **14**; one digital input for occupancy sensor—connected via sub-base **14**; transistorized relay drivers (four on thermostat **11** and up to four on sub-base **14**); a low pass filter to convert pulse width modulation into analog output voltage (up to two on sub-base **14**); one digital output for bypass LED on remote wall module—connected via sub-base **14**; one digital output to put the power supply into relay power saving mode; a serial input, output, and handshake input used to connected to the personal digital assistant **12**, sub-base **14** communications system, factory tester, or tcomm (a specialty development tool); a 32,768 KHz crystal; three volt power derived from a higher voltage power supply (the three volt supply may use a super-capacitor to keep the circuit alive for 48 hours or more after mains power failure); an on chip low voltage detect circuit which may be connected to the mains side of the higher voltage power supply (a detection of low voltage may cause microprocessor **61** to enter a low power mode.

The context diagram of FIG. **22** illustrates the various processes in thermostat **11**. There may be two kinds of tasks: 1) interrupt driven; and 2) operating system driven. The interrupt driven tasks may run when a hardware interrupt calls them. Interrupts do not interrupt interrupts. The operating system tasks may run periodically when an operating system **121** calls them. When no tasks are being performed, operating system **121** may run in an endless loop. The tasks may communicate with one another through shared RAM variables. The memory in this illustration may be regarded

as RAM, unless otherwise specified. The code may be written in the C language except that some critical routines or utilities may be written in assembler.

Operating system **121** may have an outgoing hardware connection **122** to hardware initialization. One may note a key of symbols for FIG. **22**. A double line block may represent a main( ) system such as operating system **121**. A single solid line block may represent a periodic task (time), a dot-and-dash line block may represent an interrupt task, two horizontal parallel line symbol may represent a memory, a single line with an arrow or arrows at at least one end may represent an internal data path and a double line with an arrow at at least one end may represent a hardware connection. There may be a two-way internal data path connection **123** from system **121** to opSys flags memory **124**. From a low raw filter voltage detector may be an inward hardware connection **125** and a low mains detect interrupt task **126**. Task **126** may have an internal path connection **127** to opSys flags memory **124**. A system clock tick interrupt task **128** may have an output to opSys flags memory **124** via internal data path **129**. A RealTimeClk and Vcc fail/recover interrupt task **131** may have an incoming hardware connection **132** from a low raw filter voltage detector and Vcc supervisor. Interrupt task **131** may have a two-way internal data path connection **133** with opSys flags **124**. From interrupt task **131** may be an internal data path connection **134** to RealTimeClock memory **135**, which may be connected to a clock (periodic task) **136** via a two-way data path **137**. Clock **136** may be connected to a central share memory **130** via a two-way data path **138**. Calculate Occ and SetPoint periodic task **254** may be connected to share memory **130** via two-way path **267**. Share memory **130** may be connected to communications periodic task block **140** via a two-way path **139**.

Communications task **140** may be connected to realTimeClock **135** via a two-way data path **141**. Output from communications task **140** may go to a second buffer memory **142** via a one-way data path **143**. The output from send buffer **142** may go to send character interrupt task **144** via a two-way data path **145**. Task **144** may have an incoming handshake hardware connection **146** so as to indicate when character data may be transmitted out via a TX hardware connection **147**. Character information may be received via RX hardware connection **148** to receive character interrupt task **150**. This information may go to a receive buffer memory **151** via a one-way data path **149**. The information may then go to communications periodic task block **140** via a one-way data path **152**. From communications task **140**, the received information may go to share memory **130** via data path **139**.

ID interface periodic task **153** may receive digital inputs via a hardware connection **154**. An output from IO interface **153** may go to share memory **130** via a one-way data path **155**. An output from share **130** may go to map outputs periodic task block **156** via a data path **157**. Map outputs task **156** may output on a hardware connection **158** PWM outputs and relay outputs. Also, an output from map outputs task **156** may go to a digital IO memory **160** via a data path **159**. Such output may go to IO interface task **153** via a two-way data path **161**. IO interface **153** may provide relay outputs and remote LED signals on an outgoing hardware connection **162**.

Input from analog sensors may go to an analog periodic task block **164** via a hardware connection **163**. Analog task **164** may be connected to share memory **130** via a two-way connection **165**. A control algorithm periodic task block **166** is connected to share memory **130** via a two-way data path **167**. A schedule period task **168** is connected to share memory **130** via a two-way data path connection **169**. Information flash management periodic task **170** may be connected by a two-way data path **171** to share memory **130**. A configParam(info) memory **172** may be connected via a two-way data path **173** to information flash management periodic task **170**. A userSched(info) memory **174** may be connected via a two-way data path **175** to information flash management task **170**. Defaults(code) memory **176** may be connected to information flash management task **170** via a one-way data path **177**.

A display periodic task block **178** may be connected to share memory **130** via a data path **179**. A keyScan memory **180** may be connected to display task **178** via a one-way data path **181** towards display task **178**. A keyboard scanner interrupt task **182** may be connected to keyScan memory **180** via data path **183** in a direction towards keyScan memory **180**. Keyboard scanner **182** may be connected to keyboard **45** via a two-way hardware connection **184**. Display periodic task **178** may be connected to a display memory **186** via a one-way data path towards display memory **186**. The latter may be connected to liquid crystal display **38** via hardware connection **187**.

FIG. **23** shows further detail of the "transmit-out" portion of the system in FIG. **22**. Send buffer memory **142** may be connected to send character interrupt task block **188** via a one-way data path **189** towards send character task **188**. Task **188** may send out character information via hardware connection **147**. Handshake related information may be received by send character task **188** via hardware connection **146**. Connection **146** also may go to handshake interrupt task **190**. Handshake interrupt task **190** is connected to send buffer memory **142** via a one-way data path **191** towards send buffer **142**. Data paths **189** and **191** may be represented by data path **145**, and the send character task **188** and handshake interrupt task **190** may be represented by send character interrupt task **144** in FIG. **22**. Further, realTimeClock task **135** may have a broader label of "other variables" as the clock may be one of the variables.

The tables below summarize the usage of the relays for each sub-base type and the type of equipment controlled (conventional or heat pump). The modulating output sub-base has two analog outputs in addition to relays. The sub-base type is detected by measuring the voltage set by resistor values on the sub-base. The following table shows the features for conventional equipment of an air management system.

TABLE 32

Output (internal designation)	Sub-base1 Use As	Sub-base2 Use As	Sub-base3 Use As	Sub-baseMod Use As
Fan	Fan	Fan	Fan	Fan
Heat1	Heat 1	Heat 1	Heat 1	Heat 1
Cool1	Cool 1	Cool 1	Cool 1	Cool 1

TABLE 32-continued

Output (internal designation)	Sub-base1 Use As	Sub-base2 Use As	Sub-base3 Use As	Sub-baseMod Use As
Aux	Aux or Heat 2 or Cool2 (note 1 and 2)	Aux or Heat3 or Cool3 (note 1 and 2)	Aux or Heat3 or Cool3 (note 1 and 2)	Aux or Heat 2 or Cool2 (note 1 and 2)
Heat2	n/a	Heat2	Heat2	n/a
Cool2	n/a	Cool2	Cool2	n/a
Heat3	n/a	n/a	Heat3/Cool4	n/a
Cool3	n/a	n/a	Cool3	n/a
ModHeat	n/a	n/a	n/a	Modulating Heat
ModCool	n/a	n/a	n/a	Modulating Cool

The designation "n/a" means that the item may not be available for that sub-base configuration. The aux (auxiliary) relay normal function may be one of the following: time of day occupancy signal, economizer enable, dehumidifier hot gas, and simple dehumidification. An additional stage of heating or cooling may be configured using the aux relay.

There may be two analog outputs available when SubbaseMod is used with the thermostat. Microcontroller internal timers may be used to generate a pulse width modulation output. A low pass filter on the sub-base may convert the pulse width modulated outputs to analog current. By connecting an appropriate value resistor, the output may be converted to voltage output. The cycle time may be set at 8 MHz/200 counts (i.e., the frequency is 40 KHz and each counter pulse is 25 microseconds). The duty cycle may be set between 0 and 100 percent. There may be 200 steps in the 0 to 100 percent control range.

Thermostat **11** may communicate with an external device such as a Personal Digital Assistant (PDA), factory tester, PC based development tool, or an optional communicating sub-base. The sub-base in turn communicates with other devices via a digital data network. There may be a software interface between the thermostat and the external device, and the sub-base, including the protocol, and the data structures. There may be an external device and the communicating sub-base connected at the same time. It is not necessary to communicate directly between the sub-base and the external device. There may be a need to coordinate the communications flow from sub-base to thermostat and from external device to the thermostat. The object of the interface may be to share information between the thermostat and the external device (e.g., PDA) or between the thermostat and a communicating sub-base using a simple low cost protocol.

Communications between the sub-base or external device, and the thermostat may be via an asynchronous five wire connection. The connections between the external device and the thermostat may include an input to receive data (i.e., data flowing from the sub-base or external device to the thermostat), an output to transmit data (i.e., data flowing to the external device or sub-base from the thermostat), an input for handshake (i.e., used to tell the thermostat that it is acceptable to send data to the external device), a pass-through connection (i.e., an external service request which may be used by the PDA to request access to the receive data. The latter connection may be between the external device and the communicating sub-base and only passes through the thermostat. There may also be a circuit ground connection.

Information may be passed between the thermostat and the external device using asynchronous characters having one start bit, eight data bits, no parity bit and one stop bit. The start bit is a logic 0 input (i.e., 0 volts) at the common hardware interface. The stop bit is a "logic 1" input (i.e., 3 volts).

The baud rate is 4800 baud. The maximum number of characters per message may be 11 characters. The limitation may be based on the fact that an entity that is exchanging information with the thermostat may not be able to process messages any larger than that at that rate.

The message format is shown below in table 33. The message may be 11 bytes long. The least significant bit of each byte is sent first. The "variable number" byte is the first byte sent and the "CheckSum" is the last byte sent. The same message format may be sent by the thermostat and the external device. The message length is fixed so that the external device will be most efficient on using processor time resources. The processor may become inefficient if the message length is not the same as the length of the message it is expecting.

TABLE 33

Variable nr	1 to 8 data bytes	0 to 7 fill bytes	CheckSum

FIG. **23** shows the elements involved in providing communications with an external device. "Share" is a structure that may contain most of the thermostat global variables. Included in "share" may be configuration parameters, current status, and copies of inputs from the external device. "Share" may be broken into "variables" for transfer to/from an external device. In addition "other variables" may be included in the list of variables shared with the external device.

The receive buffer may contain room for four received messages, the number of buffers currently in use, a pointer to the buffer being used to receive characters, a pointer to the next location to store a received character, and the value of the partially calculated check sum.

The receive character interrupt routine may store characters into the receive buffer as they are received via the hardware UART one character at a time. A universal asynchronous receiver/transmitter (UART) controller may be the key component of the serial communications subsystem of the processor. The UART may take bytes of data and transmit the individual bits in a sequential fashion. At the destination, a second UART may re-assemble the bits into complete bytes. The receive character also may detect the start of the message using the gaps between messages, calculate the checksum, update buffer pointer and count when a valid message is received. If the buffer is full, the receive character interrupt routine may ignore received messages.

The send buffer may contain room for four received messages, the number of buffers currently in use, a pointer to the buffer being used to send characters, a pointer to the next character to be sent, and the value of the partially calculated check sum.

The send character interrupt routine may send characters from the send buffer to the hardware UART one character at a time. It also may calculate the check sum to send, put in four character gaps between messages, and update buffer pointers as messages are completely sent. When the send buffer is empty, or the handshake line is not asserted at the end of a message, the send character interrupt routine may turn it self off.

The handshake interrupt routine may run when the handshake line becomes asserted. If the send UART is turned off and there is data in a buffer, asserting the handshake line causes the first character of a ready send buffer to be sent via the UART.

The communications task may run every 100 milliseconds and perform the following communication tasks. First, if there are any messages in the receive buffer, it may reset the communications timer. If there are any messages in the receive buffer, it may copy them to their destination in local RAM providing their class permits them to be copied. In 100 ms, it is possible to receive 3.2 messages. If there is any space in the send buffer, it may select the next variables to send to the external device and copy them to the send buffer until the send buffer is full. In 100 ms, it is possible to send 3.2 messages. Receiving selected variables may cause a failure detect timer to be restarted. If a failure detect timer times out, the variables may be reset to a default value. Failure detect timers may be intended to provide fail safe operation of selected functions. If an in Use signal is received with the re-programmer code, the communications task may turn off controlled equipment, save configuration parameters and user schedule in INFO flash memory, and call ProgramCodeFlash( ).

The alarmError signal may contain bits indicating that certain errors have been detected in the thermostat and may be viewed via the communication port. Table 34 shows the various alarm fields that may be used in testing and diagnostics.

TABLE 34

alarmError field	Meaning	What happens in the device on error	Method of displaying error on the device
almUsrScdCkSum	User Schedule Check Sum Error. Calculated when the user tries to retrieve the user schedule 0: User schedule was retrieved successfully 1: User schedule was not retrieved successfully	Current schedule continues to be used.	Display will not allow the user to select "yes" to retrieve the saved user schedule. It will display "no" when the user tries to change the selection to "yes"
almCnfPrmCkSum	Configuration Parameter Check Sum Error. Calculated when mains power is restored or upon a reset 0: Configuration Parameters were retrieved successfully from non-volatile memory. 1: Configuration Parameters were not retrieved successfully from non-volatile memory. The factory default configuration parameters are being used instead.	Factory default configuration is being used. almCnfPrmCkSum is set to zero when config1.installConfig is set to one by the installer.	No display action
almSub-baseType	Sub-base type error. Read from the sub-base resistive voltage divider in the sub-base 0: The sub-base is a valid sub-base type 1: The sub-base is not a valid sub-base type	Thermostat relays and analog outputs are turned off.	No display action
almIOConfig	Output configuration error. Considers sub-base type, heat pump/conventional application. maxCoolStgs, maxHeatStgs. 0: The outputs configuration is consistent with the sub-base type selected 1: The number of outputs configured exceeds the capability of the sub-base to support them.	In conventional mode, fan and only one stage of heating and cooling is enabled. If modulating sub-base is connected, modulation is activated. In heat pump mode, fan and only one compressor (heating or cooling) is available. Auxiliary heat is not available. Note: Modulating sub-base is not supported (All outputs turned off)	No display action
errDischSensr	Discharge sensor out of range or disconnected. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	Discharge air temperature limiting will not be done.	Display shows "- - -" for the value.
errRemtSetPt	Remote wall module set point is out of range or disconnected. 0: Value is OK. 1: Remote wall module set point is configured to function and is out of range or disconnected.	Remote setpoint offset of zero (0) is used.	No display action.

TABLE 34-continued

alarmError field	Meaning	What happens in the device on error	Method of displaying error on the device
errNetOdSensr	Network Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	There is no heat/cool lockout. The minimum heat/cool recovery ramps are used. See Note 1.	Display shows "- - -" for the value if the sensor is invalid. See Note 1.
errOdSensr	Remote Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no heat/cool lockout. The minimum heat/cool recovery ramps are used. See Note 1.	Display shows "- - -" for the value if the sensor is invalid. See Note 1.
errNetHumSensr	Network Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	There is no humidity control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
errRemtHumSensr	Remote Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no humidity control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errLoclHumSensr	Local Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no humidity control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errNetSpaceSensr	Network space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	There is no temperature control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errRemtSpaceSensr	Remote space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no temperature control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errLoclSpaceSensr	Local space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no temperature control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.

If a network sensor is configured for use, but invalid, then the thermostat processor may look for a valid sensor on the remote terminals. If it is valid it may use the remote as the value. If the remote is also invalid, it may look at the local sensor. If it is valid it may use the local sensor as the value. If all of them are invalid, then "invalid" may be reported as the sensor value and the display will show "- - - ". This allows the user to configure the network (or remote) as the primary sensor and have a backup in case the primary fails. If the network sensor is configured and is invalid, it may report an alarm error. If the remote sensor is configured and is invalid, it may report an alarm error. If the local sensor is configured and is invalid, it may report an alarm error. In other words if the configured sensor is invalid, then it may report an alarm error.

A factory test mode may be used to test the thermostat and a connected sub-base. Components tested in the factory test mode may include keys in the keypad (19 Keys), display segments, four relays on the thermostat board, up to four relays on the sub-base, one wall module LED driver, two Digital inputs (i.e., occupancy sensor and one wall module bypass push button switch), two analog outputs (plus up to two analog outputs on the sub-base where the modulating sub-base is required), eight analog inputs (i.e., the local space temperature on thermostat, the remote space temperature, the remote wall module set point control, the local humidity sensor on sub-base, the remote humidity sensor, the outdoor temperature sensor, the discharge air sensor, and the sub-base identifier), and the communications port (for data in, data out, and the handshake line).

The configuration parameters may be saved in INFO FLASH memory when mains power has failed. There may be verification that when mains power has been restored, the configuration is also restored as saved. This may test the circuitry that senses power failure and the power supply capacitors ability to supply power for a few milliseconds while INFO FLASH memory is being written.

The following may not necessarily be tested by the software. One item is the super capacitor ability to supply power to the device for the rated number of hours after mains power has failed. Clock frequency may be another. A general recommended approach to final factory test may be as follows. Lock thermostat with sub-base into test fixture. Apply power (24 volts AC—set voltage at low end of 24 VAC tolerance). The display should initially turn on all segments after mains power up. The test fixture may communicate with thermostat via communications port and puts it into the factory test mode. The test fixture may press the keys one at a time. Each key may cause certain actions (e.g., provide a LDC display pattern, turn on one relay, set the

analog output to certain values, and so on). A vision system may watch the display and reject units having an invalid display. The test fixture may sense digital and analog outputs for proper operation. Simultaneously, the test fixture may connect various analog sensors to the analog inputs and monitors the sensed analog values via the communications port. Simultaneously the test fixture may turn on and off the various analog inputs and monitors the sensed digital states via the communications port.

One may turn off the power. After 5 seconds one may cycle the power back on. Then one may verify that, via the communications port, the configuration was read correctly from INFO FLASH memory into RAM upon power up. There is no need to enter factory test mode. The display should initially turn on all segments after mains power up. Turn off power and report success or failure. Remove thermostat from test fixture. There may be a separate test sequence or just one test sequence for each sub-base type. Also, one may test the outputs and inputs on the thermostat even if they are not present in the particular sub-base type being tested.

To read and view the state of the inputs, one may read the following variables via the communications port. The variables may be read in the normal operating mode or in the factory test mode. In the factory test mode, a filter is turned off so that the analog value changes more rapidly in the factory test mode. Table 35 shows the various variables and what the typical test values may be.

successful writing of INFO FLASH memory generally depends on the charge remaining in the filter capacitors and the super cap.

During the write process at power fail, the following items may occur. First, the check sum of the configuration parameters is calculated. Second: the FLASH is erased. Third, configuration parameters are copied into INFO FLASH memory, and finally, the check sum of the configuration parameters (including schedules) are written to INFO FLASH. Upon return of mains power, if the stored check sum and the calculated check sum agree, the configuration parameters are copied from INFO FLASH into operating RAM. If the calculated and stored check sums do not agree, then the factory default settings are copied into the operating RAM. Also, if they do not agree, alarmError.almCnfPrmCkSum is set to TRUE.

In the factory, when the device is first powered up, INFO FLASH will not have any useful information stored in it, so the calculated check sum will not agree with stored check sum, and alarmError.almCnfPrmCkSum will be set to TRUE. However, when the unit is powered down the first time, INFO FLASH may be written correctly (assuming the power supply is working correctly) and upon power up alarmError.almCnfPrmCkSum will be set to FALSE indicating a successful writing of INFO FLASH. The factory tester should check alarmError.almCnfPrmCkSum after powering the unit up the second time.

TABLE 35

Variable	Reads	Typical Values
rawAnalogA.remoteHum	Remote Humidity	14880 when input is 10.00 volts
rawAnalogA.localHum	Local Humidity	5460 when input is 1.00 volts
rawAnalogA.odTemp	Outdoor Temperature	13124 when input is connected to 3000 ohm resistor
rawAnalogA.discTemp	Discharge Air Temperature	3796 when input is connected to 10,000 ohm resistor
rawAnalogB.remoteStPt	Remote Set point	11228 when input is connected to 5500 ohm resistor
rawAnalogB.sub-baseSel	Sub-base Selection	8600 when input is connected to 10200 ohm resistor
rawAnalogB.remoteSpaceTemp	Remote Space Temperature	3796 when input is connected to 10,000 ohm resistor
rawAnalogB.localSpaceTemp	Local Space Temperature	3796 when input is connected to 10,000 ohm resistor
status1.occSensor	State of Occupancy Sensor	TRUE when occupancy sensor input is shorted FALSE when occupancy sensor input is open
status1.bypassTime	State of Remote Bypass	Set to 180 minutes when the remote bypass input is shorted to ground. Decrements every minute when the remote bypass input is open

To enter the factory test mode, one may set manMode. manualMode to FactoryTest. In the factory test mode the following may occur. The algorithmic control of the analog and digital outputs is turned off. Instead, the outputs are controlled by the internal factory test software. Every 15 seconds, manMode should be sent to the thermostat or the thermostat will return to Run mode. The LCD and display no longer function in the normal manner. Pressing a key pad button may cause the following action. The output and pattern do not change until another key is pressed.

One may verify that FLASH was written correctly upon mains power fail. When mains power fails, the configuration parameters and schedules are written to INFO FLASH memory as soon as the power failure is detected. The

One may verify the microprocessor reset button. When the reset button is pressed, the microprocessor will restart itself and the display will temporarily turn on all its segments. Other side effects may include such things as time is lost, alarm bits reset, and all RAM status variables are reset to their default values until the processor updates them to their correct values. If the configuration or schedule has been changed, the changes will be lost.

The manual mode is intended for field use. When the thermostat is in manual mode, the equipment is controlled manually via the communications port. Algorithmic control of the equipment is turned off. The state of the eight relays is controlled individually. The modulated heat and cool outputs are controlled independently. Returning from factory test or manual mode to run mode causes a reset.

The error count variable, errCnt, applies to the diagnostics of the system. The errCnt.rxCkSumErrCnt may relate to receiving messages from the PDA, tcomm, or the sub-base. The message may include a check sum. Thermostat **11** may calculate the check sum and compare it with the check sum in the received message. The errCnt.rxCkSumErrCnt may be incremented every time the calculated check sum does not match the received checksum. Check sums may not match if the receiver receives a bit incorrectly or if the start of message at the receiver was received incorrectly. This count might be incremented once in a while but the rate should be low, such as one or two counts in a day.

The errCnt.rxBufferFullCnt relates to receiving messages from the PDA, tcomm, or the sub-base. There may be a receive buffer that has space for four received messages. Received messages may be received using interrupts and placed into the buffer. Once every 100 ms, the Comm. task may run, read the messages and clear the buffer. If a message is received and there is not enough space in the buffer for more messages, then the message may be lost and errCnt.rxBufferFullCnt may be incremented by one. The latter should always be zero. It takes about 25 ms to send one message.

The errCnt.wdtCnt may be incremented if the program starts over and the reason for the reset was a watchdog timer time out (i.e., the program was lost and the watchdog timer caused a reset). The errCnt.wdtCnt should always be zero. Failures may occur due to hardware problems (e.g., reading memory incorrectly) caused by electrical noise which is not very likely because memory is on the same chip as the processor. Failures may also occur due to a code that goes into an endless loop or a corrupted stack after a return from a subroutine call or the like. The watch dog timer may be "hit" once every 100 ms at the end of the tasks for each 100 ms time slot.

The errCnt.flashViolations may be incremented whenever there is a flash violation interrupt. Flash violation may occur if code is running from flash memory and tries to write the same flash memory module at the same time. The errCnt.flashViolations should always be zero. Flash writes may occur during re-programming, power down, and update of user schedule.

Each display state is listed in the following table 36. A description for each state and a table listing actions for each key press follows. In general, a change of display state occurs if a key is pressed or because no key has been pressed for a defined period of time and the information for the previous state is saved. Exceptions may be listed in the description for each state.

TABLE 36

State	Keypress	Description
dsRunNormal	keyRun	Display
dsHeatOcc	keyHeatOcc	Set Occupied Heat Setpoint
dsCoolOcc	keyCoolOcc	Set Occupied Cool Setpoint
dsHeatNotOcc	keyHeatNotOcc	Set Not Occupied Heat Setpoint
dsCoolNotOcc	keyCoolNotOcc	Set Not Occupied Cool Setpoint
dsSetDay	keySetDay	Set Day of Week
dsSetTime	keySetTime	Set Time of Day
dsTempOcc	keyTempOcc	Set Temporary Occupied Override
dsTempNotOcc	keyTempNotOcc	Set Temporary Not Occupied number of days
dsSetSched	keySchedDay, keySchedOcc, or keySchedNotOcc	Set Schedules
dsSchedCopy	keySchedCopy	Copy schedule from one day to another
dsTempStpt	keyInfo, keyUp, or keyDown	Set Temporary Setpoint
dsInfo	keyInfo	Display Information screens
dsInstaller	keyRun and keySchedCopy	Set Installer configuration options
dsTestMode	keyRun, keySystem, and keyFan	Enter Test Mode (no delays of heating and cooling stages)
dsGetFactorySched	keyRun and keySchedClear	Restore factory schedules from flash memory to current schedules
dsGetUserSched	keyInfo and keySystem	Restore user defined schedules from flash memory to current schedules
dsSaveUserSched	keyInfo and keySchedCopy	Save current schedules to user define schedules in flash memory
dsFactoryConfig	keyRun and keySchedClear	Restore factory configuration
dsShowAll	Power up	Show all LCD segments for 2 seconds
dsShowLocked	—	Display 'LOCKED' or 'MANMODE' for 1 second

The test mode may be the dsTestMode. Pressing the combination key press ('scheduled day', 'schedule occ' and 'scheduled unocc) for 'Test Mode' may allow the user to disable time delays between stages to minimize time to test the wiring and operation. The following information may be displayed: 'Set' segment—'NO TEST'.

Pressing the Up and Down keys may toggle the selection between 'IN TEST' and 'NO TEST' and save to the variable share.sysMode.disabledelays. The 'IN TEST' will disable delays. 'NO TEST' is normal operation. After 10 minutes with no key pressed, the thermostat will change back to normal operation or 'NO TEST'. The following is the test mode table for the dsTestMode.

TABLE 37

Keypress	Actions:
keyNone	Increment NoKeyPressTimer. Change state to dsRunNormal after 5 minutes. Set share.sysMode.disableDelays to 'NO TEST' after 10 minutes.
keyDown	Toggle share.sysMode.disableDelays ('IN TEST' or 'NO TEST')
keyDown & keyHold	N/A
keyInfo	Change state to dsInfo
keyUp	Toggle share.sysMode.disableDelays ('IN TEST' or 'NO TEST')
keyUp & keyHold	N/A
keyHeatOcc	Change state to dsHeatOcc

TABLE 37-continued

Keypress	Actions:
keyCoolOcc	Change state to dsCoolOcc
keyHeatNotOcc	Change state to dsHeatNotOcc
keyCoolNotOcc	Change state to dsCoolNotOcc
keySetDay	Change state to dsSetDay
keySetTime	Change state to dsSetTime
keyTempOcc	Change state to dsTempOcc
keyTempNotOcc	Change state to dsTempNotOcc
keySchedDay	Change state to dsSetSched Initialize sbDisplayDay to current day of week Initialize sbDisplayEvent to event Occupied 1
keySchedOcc	Change state to dsSetSched Initialize sbDisplayDay to current day of week Initialize sbDisplayEvent to event Occupied 1
keySchedNotOcc	Change state to dsSetSched Initialize sbDisplayDay to current day of week Initialize sbDisplayEvent to event Not Occupied 1
keySchedClear	N/A
keySchedCopy	N/A
keyRun	Change state to dsRunNormal.*
keyInstaller	Change state to dsInstaller.*
keySaveUserSched	Change state to dsSaveUserSched
keyGetUserSched	Change state to dsGetUserSched
keyGetFactorySched	Change state to dsGetFactorySched

*One may set the share.status1.bypassTime and share.status1.daysLeftKeypadHoliday to 0.

Thermostat **11** control algorithm may provide for control of various kinds of commercial HVAC equipment. More specifically it may be designed to control constant volume packaged roof top units used for single zone space temperature conditioning. A provision may also be provided to reduce humidity in the zone if it exceeds a high limit. Configuration parameters may allow for the control to be for single stage, multistage or modulating heating and cooling in conventional or heat pump units. The control is capable of automatically switching between heating and cooling as required if AUTO is selected as the run mode. The fan and an auxiliary output may also be controlled depending on configuration choices.

FIG. **24** shows an algorithm module **200** overview. Algrm( ) function **202** may be connected to timers and static variables memory **204** via a two-way data path **203**, and connected to a share.status 1,2,3,analog memory **206** via a two-way data path **205**. Algrm( ) function **202** may be connected to a Cyclero function **208** via a one-way data path **207** towards Cyclero function **208**. Cyclero function **208** may be connected to timers and static variables via a two-way data path **209**. Algrm( ) function **202** may be connected to a Set_outputs( ) function **210** via a one-way data path **211** towards Set_outputs( ) function **210**. Algrm( ) function **202** may be connected to an Aux_pt( ) function **212** via a one-way data path **213** towards Aux_pt( ) function **212**. Share.status **1**,**2**,**3**,analog memory **206** may be connected to Set_outputs( ) function **210** via a two-way data path **215**, and connected to Aux_pt( ) function **212** via a two-way data path **217**.

Algrm( ) function **202** may be connected to TempControlInito and TempControlOff( ) functions **216** via a one-way data path **221** towards functions **216**. Algrm( ) function **202** may be connected to an Auto_chng( ) function **218** via a one-way data path **223** towards function **218**. Share.config memory **220** may be connected to Algrm( ) function **202** via a one-way data path **225** towards function **202**. Share.config memory **220** may be connected to Cycler( ) function **208** with a one-way path **227** towards function **208**. Share.config memory **220** may be connected to Aux_pt( ) function **212** via a one-way data path **229** towards function **212**. Share.config memory **220** may be connected to Fan_Control( ) function **214** via a one-way data path **231** towards function **214**.

Share.setPts memory **222** may be connected to Auto_chng( ) function **218** via a one-way data path **233** towards function **218**. Share.setPts memory **222** may be connected to Cycler( ) function **208** via a data path **235** towards function **208**.

Cycler( ) function **208** may be connected to an Error Calc( ) function **224** via a one-way data path **237** towards function **224**. A Share.auxSetPts memory **226** may be connected to Error Calc( ) function **224** via a one-way data path **239** towards function **224**. ErrorCalc( ) function **224** may be connected to a Gain_Calc( ) function **226** via a one-way data path **239** towards function **226**. A Share.gainHeat and Share.gainCool memory **228** may be connected to Gain_Calc( ) function **226** via a one-data data path **243** towards function **226**.

Algrm( ) function **202** may be called every 10 seconds from the operating system task scheduler. It may read the commanded system mode and space temperature sensor input to arbitrate the effective run mode of thermostat **11**. Also, the configuration may be read to determine which control features to perform and the resultant "logical" control commands which are generated and written to the status RAM (random access memory) variables. The commands may be logical in that they generically list the run mode (heat or cool) and the number of stages of heat and cool that should be active. A separate function called from the task manager may be responsible for reading the logical control output commands from status RAM and driving the physical outputs appropriately based on sub-base type and output configuration.

Looking further at the Algrm( ) **202** function overview, one may note that if the manual mode command is factory test or manual, or the manual mode command is run and the system mode command is system switch=off, or the space sensor is invalid, then the logical control outputs may be set to initialization values and no other action is taken. If the manual mode command is run and the system mode command is system switch=heat or cool, then Cycler( ) function **208** may be called with the effective mode set accordingly so that the proper set points may be used to calculate the space temperature error and its sign. If the manual mode command is run and the system mode command is system switch=auto, then Auto_chng( ) function **218** may be called to calculate the proper effective mode (heat or cool) and thus the proper set points before Cycler( ) function **208** is called. After Cycler( ) **208** runs, then Set_outputs( ) function **210** may be called to take the Cycler( ) function **208** output and, based on the configuration, set the control status variables appropriately. Likewise, based on the configuration and the Cycler( ) function **208** output status, the Fan_Control( ) function **214** and the Aux_pt( ) function **212** may be called to set their logical output values per the control scheme selected. All the timers associated with the control algorithm may be kept in this function. These may be the four stage timers (one per possible stage), the interstage timer, the start-up fan delay timer and the dehumidify flag timer. When the disable delay ("test mode") is selected, all of the control algorithm timers that delay action may be kept cleared.

Cycler( ) function **208** may be implemented in the control block diagram of FIG. **25**. An output **245** from a set point

230 may go to a junction 232. An output 247 from a sensor 234 may go to junction 232. Output 247 may be subtracted from output 245 at junction 232 to result in an error signal output (Err) 249 which may go to the inputs of a

$$\text{“}Kp/Ti\int_0^t (Err)dt\text{”}$$

function block 236, a “Kp*Err” function block 238 and a “Kp*Td*(dErr/dt)” function block 240. Outputs 251, 253 and 255 from function blocks 236, 238 and 240, respectively, may be added at junction 242 to result in a total error (TotErr(%)) output 257 in terms of percentage. Output 257 may go to a modulating driver 244.

In the preferred embodiment, output 257 may also go to an input of a stager block 446. Stager block 446 may convert and proportionally adjust the cycling rate for the digital stages, and control the number of stages requested based on the configuration of cycle rate, the number of stages configured, sensed temperature, time delay minimum time and total error. Output 456 of block 446 may provide a “stages on” signal for the individual heating and cooling stages.

Along with minimum on time, minimum off time and interstage delay times may also be enforced before a stage is added or subtracted from the stages active command that is the output of this function. This function also may set the status of the dehumidify flag (dehumidActive). It may use both a minimum on timer and a 5 percent hysteresis for turning off the flag once it is set. If the sensed humidity is above the programmed high limit the flag may be set. Only after the humidity is 5 percent below the high limit set point for the min on time will the flag be reset. The minimum on time may also be variable based on the occupancy mode when the high humidity set point reset strategy is configured. If the high humidity set point reset strategy is configured, and the current occupancy mode is unoccupied, the dehumidactive flag min on time may be 20 minutes; at all other times it may be set to 5 minutes.

The ErrorCalc( ) function 224 may call the Gain_calc( ) 226 to convert the gain configuration parameters into the proper units and fixed point offset to be directly used in the PID error calculation. It then may calculate the base PID error as TotErr 257 in percent. This may be used to drive the modulating output if it is configured. The secondary function performed may be the discharge air limit function. If the discharge air limit function is active then if the discharge air is within 5 degrees F. of the limit the TotErr is reduced proportionally down to 0 as it approaches the limit. If the discharge temperature is over the limit, TotErr is set to 0, integration is stopped and a flag is set to enable Cycler( ) 208 to turn off a stage and prevent other stages from coming on.

Thermostat 11 may communicate with an external device 56 and an optional communicating sub-base 14. External device 56 could be a personal digital assistant (PDA) 12, factory tester, or a PC-based development tool. Only one external device might be connected at a time. Sub-base 14 in turn may communicate with other devices via a digital data network. It may be possible to have an external device 56 and communicating sub-base 14 connected at the same time. There may be no need to communicate directly between sub-base 14 and external device 56. There may be coordination of the communications flow from sub-base 14 to thermostat 11 and from external device 56 to thermostat 11.

One object of the interface is to share information between thermostat 11 and the external device (PDA) or between thermostat 11 and a communicating sub-base 14 using a simple low cost protocol. Communications between sub-base 14 or external device 56, and thermostat 11 may be typically via an asynchronous five wire connection. FIGS. 26 and 27 reveal similar connections. The connections between external device 56 and thermostat 11 may include an input to receive data (i.e., data flowing from the sub-base or external device to the thermostat) on line 301, an output to transmit data (i.e., data flowing to the external device or sub-base from the thermostat) on line 302, an input to handshake (i.e., used to tell the thermostat that it is acceptable to send data to the external device) on line 303, and a pass through connection for an external service request (i.e., used by the PDA to request access to the receive data) on line 304. The latter connection may be between external device 56 and communicating sub-base 14, and only pass through thermostat 11. Another connection may be a circuit ground on line 305. A 15 volt supply line 306 may be present. Lines 301, 302, 304 and 305 may be connected to external device 56 via a connector 310.

Information may be passed between thermostat 14 and external device 56 using asynchronous characters having one start bit, eight data bits, no parity bit and one stop bit. The start bit is a logic 0 input (0 volts) at the common hardware interface. The stop bit is a “logic 1” input (3 volts). The baud rate may be 4800 baud.

Data may be sent in both directions at the same time (a full-duplex operation). Thermostat 11 may receive data at any time. There may be thermostat transmitter flow control via handshake circuit. Generally, data may be sent from thermostat 11 only when the handshake input is asserted. Communicating sub-base 14 may control the flow of data to it. External device 56 may send and receive at the same time. When external device 56 requests service by asserting an external service request, communicating sub-base 14 may assert a handshake line 303 so that the data may be sent continuously by thermostat 11. If sub-base 14 is non-communicating, handshake line 303 may be asserted continuously, so that an external device 56 may send and receive data at the same time. FIGS. 26 and 27 show a communicating sub-base 14 and a non-communicating sub-base which is blanked out to indication non-functionality.

Thermostat 11 may receive flow control via an external service request circuit line 304. Either communicating sub-base 14 or external device 56 may send data to thermostat 11 at any time. However, both typically do not send data at the same time. The external service request circuit via line 304 may be used to select the active sender on the thermostat 11 receive circuit.

When the external service request is not asserted, communicating sub-base 14 may be allowed to communicate with thermostat 11 in both directions, using the handshake circuit via line 303 to control data flow from thermostat 11 to sub-base 14. When external device 56 asserts external service request (using the RTS circuit on the external device’s port) via line 304, communicating sub-base 14 may be allowed to complete the message it is currently transmitting, before it asserts handshake line 303 and ceases communications with thermostat 11. External device 56 then may communicate with thermostat 11 in both directions until external device 56 unasserts the external service request. Note that sub-base 14 typically does not listen to transmit data while external service request is asserted since handshake is also asserted. When sub-base 14 is a non-communicating sub-base, then external device 56 may still assert an

external service request, and wait for at least one message time before sending on the thermostat **11** receive circuit via line **301**.

The handshake input to thermostat **11** microprocessor **61** may control whether or not thermostat **11** sends information to external device **56**. When sub-base **14** is a non-communicating sub-base, the handshake input may be pulled to "active" by a resistor on thermostat **11**. Thermostat **11** may send information continuously on TXD of line **302**, one message after another with the required gap between messages. When sub-base **14** is a communicating sub-base, the handshake input may be set to active by sub-base **14** whenever it is able to receive a message. Thermostat **11** may send information on TXD line **302** whenever the handshake input is active.

When a communicating sub-base **14** is connected, then sub-base **14** may periodically send the sub-base variable to thermostat **11**, with sub-base.connected=1. An external device **56** may never send sub-base **14** to thermostat **11**. This flag may let an external device **56** know that a communicating sub-base **14** is present.

The inUse (i.e., in use) variable may be used to indicate that an "inUse session" with an external device, a remote network tool or network work station is in progress. The the sub-base (and its associated network tool) may not be allowed to start an "in Use session".

The external device located next to the thermostat should have priority over a network tool that may be located in another room or even hundreds of miles away. Some related "inUse Session" scenarios may or may not involve some of the following examples. For instance, it may not be necessary for the external device to start an "in Use session" to just read any variables. It may not be necessary for the sub-base to start an "inUse session" just to read any variables or write sub-base, comSchedOcc, comTimeIn, sysMode, or comIn. All of these variables may be either overhead variables (sub-base) or connected to some other network variables that may be bound to other devices.

It may be necessary for the external device to start an "in Use session" to read the varCONFIG variables, allow a user to modify them, write them to the thermostat, and then monitor their effects. That any time the PDA is connected to the thermostat, and the PDA is actively performing the Honeywell Palm software, it should start an "in Use session" and set manMode to 0. The external device may start an "in Use session" by writing inUse.by=2. Table 38 may provide more "inUse session details.

TABLE 38

inUse.by	Meaning	Communicating sub-bas	External Device
0	Not in an "inUse session"	May send any variables to the thermostat.	Variables may not be sent to the thermostat except for inUse.
1	The remote network is in an "inUse session" with the thermostat via the communicating sub-base	May send any variables to the thermostat. Note: When nvilnUse (a network variable) is updated to non-zero by a network tool, and inUse is 0, then the sub-base writes, inUse.by = 1.	Variables may not be sent to the thermostat except for inUse.
2	The external device (such as a PDA) is in an "inUse session" with thermostat	May send only varWRITE class variables to the thermostat (except manMode and inUse). Note: The sub-base sets nvilnUse (an e-bus mechanism variable) to 64129 when it sees that inUse.by is 2 to prevent a network tool from attempting to put the thermostat into manual mode or commission the device.	May send any variables to the thermostat.
3	The flash programmer is requesting to re-program the thermostat firmware	When the external device is the re-programmer, the sub-base may not send or receive any thing. The sub-base may re-program the thermostat using the re-programmer protocol.	External device uses the re-programmer protocol to down load the memory image. When the sub-base is reprogramming the thermostat, the external device should be disconnected or disabled.

inUse.by may also be used to initiate programming flash memory. An "in Use session" may involve any of the following: an external device (Palm Personal Digital Assistant)–inuse.by=2; a read/write thermostat configuration using a PDA; a read/write schedule using a PDA; a status report via a PDA (optional at the discretion of the PDA designer); and manual control via a PDA.

An "inUse session" may be started by either the external device or the communicating sub-base when the other device (i.e., a sub-base or external device) could interfere with a process begun by the first device. The external device may have priority over the sub-base. If a sub-base has initiated an "inUse session", the external device may cancel the sub-base session and initiate its own session. If an external device has already established an "inUse session",

Table 39 provides variable information relating to the alarm error system.

TABLE 39

Variable Description and Notes	VarNamefields.txt
User Schedule Check Sum Error. Calculated when the user tries to retrieve the user schedule 0: User schedule was retrieved successfully 1: User schedule was not retrieved successfully	alarmError.almUsrScdCkSum

TABLE 39-continued

Variable Description and Notes	VarNamefields.txt
Configuration Parameter Check Sum Error. Calculated when mains power is restored or upon a reset 0: Configuration Parameters were retrieved successfully from non-volatile memory. 1: Configuration Parameters were not retrieved successfully from non-volatile memory. The factory default configuration parameters are being used instead.	alarmError.almCnfPrmCkSum
Sub-base type error. Read from the sub-base resistive voltage divider in the sub-base 0: The sub-base is a valid sub-base type 1: The sub-base is not a valid sub-base type	alarmError.almSub-baseType
Output configuration error. Considers sub-base type, heat pump/conventional application. maxCoolStgs, maxHeatStgs. 0: The outputs configuration is consistent with the sub-base type selected 1: The number of outputs configured exceeds the capability of the sub-base to support them.	alarmError.almIOConfig
Discharge sensor out of range or disconnected. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errDischSensr
Remote wall module set point is out of range or disconnected. 0: Value is OK. 1: Remote wall module set point is configured to function and is out of range or disconnected.	alarmError.errRemtSetPt
Network Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	alarmError.errNetOdSensr
Remote Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errOdSensr
Network Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	alarmError.errNetHumSensr
Remote Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errRemtHumSensr
Local Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errLoclHumSensr
Network space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	alarmError.errNetSpaceSensr
Remote space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errRemtSpaceSensr
Local space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errLoclSpaceSensr

The thermostat configuration may be identified and then the commissioning process may be run through valid operational modes with inputs and set points temporarily manipulated while waiting for the delays built into the controller to verify operation. The PDA based Online Diagnostics may automatically discover the thermostat configuration, turn off normal controller delays, temporarily override sensor inputs and set points, verify proper output action including monitoring the discharge air temperature for the resulting temperature behavior based on the equipment stages activated.

Problems discovered may be reported, automatically recorded and the original operating parameters may be restored. This means that less expertise may be required by the technicians sent to install and trouble shoot thermostat installations

To begin the commissioning startup, the user may tap on the commission button on a PDA screen as shown in FIG. **28***a*. The next screen may prompt the user to connect the PDA **12** serial port to thermostat **11**, as in FIG. **28***b*. Then the configuration tool (i.e., PDA **12**) may upload the thermostat model and current configuration from the thermostat. A commission summary screen appears as revealed in FIG. **28***c*. This screen may appear after an analysis of the thermostat configuration. Navigation through the commissioning process by the user may be accomplished with the "Back" and "Next" buttons. The diagnostics may be executed in a logical order of sensors, fan/auxiliary process, cooling process and heating process. The status of each step of the diagnostics process may be reported as "OK", "UnTested" or "Failed". An error summary may report known problems (via thermostat diagnostic messages) and summarize all session related messages.

The "Next" button may navigate the user to the sensors screens shown in FIGS. **29***a*–**29***f*. In FIG. **29***a*, the sensors screen may summarize the status of sensor/input diagnostics. Sensor data may be displayed in a context sensitive format using the actual thermostat model and configuration data to mask irrelevant sensor tests. Of the buttons on the screen, the "Update" button may update sensor data values, "Back" button may navigate to the previous screen, "Next" button may navigate to the "Fan" screen, and the "Test" button may initiates the automatic sensor diagnostics test sequence.

As a result of tapping the Test button on the sensors screen, one may get a reading testing the room temperature data value which may be confirmed or not by tapping the "Pass" or "Fail" button on the screen of FIG. **29***b*, respectively. As a result of tapping the "Testing Room Temp" Pass button, the diagnostics may move to the remote SetPoint test sequence, which begins with the screen in FIG. **29***c*. The user may tap the "OK" button after positioning the remote

SetPoint knob to the full CCW position. As a result of tapping the Testing Remote SetPt OK button, the diagnostics tool may validate the Remote SetPt value at full CCW, as indicated in the screen of FIG. **29***d*. Then one may be instructed to position the remote SetPoint knob to the full CW position. As result of tapping the Testing Remote SetPt OK button, the diagnostics tool may validate the Remote SetPt value at full CW. Then the user may tap the OK button in the screen of FIG. **29***e* to proceed with remaining sensor diagnostics. In a similar fashion, all of the sensor inputs may be validated. At the end of the sensor diagnostics sequence, configuration tool **12** may indicate the status of all relevant (hardware model and user configuration) sensors, as in the screen of FIG. **29***f*. All Error messages may be recorded on the diagnostics summary screen.

The user may tap the Next button to navigate to the Fan/Auxiliary screen of FIG. **30**. The Fan/Auxiliary Equipment screen may summarize the status of the Fan/Aux output diagnostics. Output data may be displayed in a context sensitive format using the actual thermostat model and configuration data to mask irrelevant output tests. Tapping the Update button may update the data values. The Back button may navigate the user to the previous screen. The Test button may initiate the automatic Fan/Aux diagnostics test sequence. The Next button may navigate the user to the first cooling screen in FIG. **31***a*.

The Cooling Equipment screen may summarize the status of the cooling output diagnostics. Output data may be displayed in a context sensitive format using the actual thermostat model and configuration data to mask irrelevant output tests. In this screen the Update button may update data values, the Back button may navigate to the previous screen, the test button may initiate the automatic Cooling diagnostics test sequence. The Next button may navigate the user to the Heating screen. In FIG. **31***b*, the screen asks whether it is safe to start the fan. And if so, then the Yes button may be tapped and a screen of FIG. **31***c* may appear. The user may tap the Test button on this screen and confirm that the fan is running by tapping the Pass button. The next screen to appear may be that of FIG. **31***d*, asking if it is safe to start the cooling stages. The user may tap "Yes" to confirm that it is safe to start the cooling stages. The screens of FIGS. **31***e* and **31***f* may appear, respectively. Here, configuration tool **12** may collect and analyze data. The data collected may include the time interval on the progress line, the entry and discharge air temperatures over the time interval and the cooling coil delta temperature which may be the difference between the coil entering and discharge air temperatures. After this process, tool **12** may validate the cooling stage under test as in the screen of FIG. **31***g*. All of the remaining stages may be likewise checked out. FIG. **31***h* shows a completion of the cooling equipment validation.

Tapping the Next button, one may get the Heating Equipment screen of FIG. **32***a*, which may begin with the checkout of the heating stage **1**. The Heating Equipment screen may summarize the status of heating output diagnostics. Output data may be displayed in a context sensitive format using the actual thermostat model and configuration data to mask irrelevant output tests. On this screen, the Update button may update data values, the Back button may navigate the user to the previous screen, and the Next button may navigate to the summary screen. The Test button may initiate the automatic heating diagnostics test sequence, which may start with the screen in FIG. **32***b*. The user may tap "No" to indicate that fan airflow is not required for stage **1** heating. Such airflow may be typical for baseboard heat installations. The next screen may be that in FIG. **32***c* asking whether it is safe to activate the heating stage contact. The user may tap "Yes" to confirm that activation. That heating stage may be turned on, which is indicated by the screen of FIG. **32***d*. After checking to see in the heating stage is actually on, the user may then tap "Pass" to validate the stage **1** heating. A screen of FIG. **32***e* may next appear indicating that the heating tests have been completed. Wiring and connections between the controls and fan, heating, cooling, air flow process, interfaces and other items may be tested and validated.

FIG. **33** is a flow diagram of an illustrative diagnostic test sequence for a thermostat system. In block **351**, one may connect PDA **12** to thermostat **11** and upload the configuration identification as in block **352**. The normal controller delays may be turned off as in block **353**. Block **354** shows the sensor inputs and set points being overridden. Then the sensors may be tested and the set points checked in block **355**. The fan/auxiliary process may be tested in block **356**. The cooling process may be tested in block **357** and the heating process may be tested in block **358**. Then the noted failures, errors and dysfunctions of thermostat **11** may be displayed on PDA **12** as in block **359**. In block **360**, diagnostic solutions may be presented.

Although the invention has been described with respect to at least one illustrative embodiment, many variations and modifications will become apparent to those skilled in the art upon reading the present specification. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.

The invention claimed is:

1. A thermostat system comprising:
- a processor having a user interface; and
- a program, in the processor, having an at least one configuration for an air management system, the at least one configuration comprising:
  - an air management system identification;
  - a listing of zones for the air management system;
  - parameter settings for each zone;
  - schedules of the parameter settings;
  - a modulated control for a plurality of heating stages for at least one zone;
  - a modulated control for a plurality of cooling stages for at least one zone; and
  - a modulated control for a simultaneous operation of a heating device and a cooling device.

2. The system of claim **1**, further comprising:
- a plurality of programmable thermostats; and
- wherein the processor may download the program having at least one configuration to each thermostat of the plurality of thermostats.

3. The system of claim **1**, wherein the simultaneous heating device and the cooling device is for affecting humidity.

4. The system of claim **3**, wherein the at least one configuration comprises a modulated control for an air mover.

5. The system of claim **4**, wherein the modulated controls comprise PIT) (proportional, integral and derivative) control loop tuning.

6. The system of claim **5**, wherein the parameters are selected (tom a group consisting of temperatures, humidity, sensor selection, volume of air movement, the percentage of added fresh air, modes of occupied, unoccupied or standby of certain spaces for at least one zone.

7. The system of claim 5, wherein the at least one configuration further comprises a selectable non-modulated control for the pluralities of the heating and cooling stages and for the air mover.

8. The system of claim 7, wherein the processor is a portable configuring device.

9. The system of claim 8, wherein the processor has a capability comprising:

uploading a configuration from a thermostat of the plurality of thermostats;

modifying the configuration; and

downloading the configuration to the thermostat.

10. The system of claim 9, wherein the processor may download the configuration to several thermostats of the plurality of thermostats.

11. The system of claim 8, wherein:

the processor may upload a configuration from a thermostat of the plurality of thermostats;

the configuration may be diagnosed for possible problems;

the configuration may be modified to remove the possible problems; and

the configuration may be downloaded to the thermostat of the plurality of thermostats.

12. The system of claim 8, wherein the processor is a personal digital assistant.

13. The system of claim 12, wherein the personal digital assistant is selected from group of devices consisting of a Palm™ and the like.

14. A thermostat system comprising:

a plurality of thermostats; and

wherein each thermostat of the plurality of thermostats comprises at least one configuration for an air management system, the at least one configuration comprising:

an air management system identification;

a listing of zones for the air management system;

parameter settings for each zone;

schedules of the parameter settings;

modulated controls for a plurality of heating stages for at least one zone; and

modulated controls for a plurality of cooling stages for at least one zone.

15. The system of claim 14, wherein the plurality of thermostats is connected to a communications bus.

16. The system of claim 15, further comprising a sequencing system controller connected to the communications bus, for controlling and staging the plurality of thermostats.

17. The system of claim 16, wherein the at least one configuration further comprises a modulated control for a simultaneous operation of a heating device and a cooling device.

18. The system of claim 17, wherein the simultaneous heating device and the cooling device is for affecting humidity.

19. The system of claim 18, wherein the at least one configuration comprises a modulated control for an air mover.

20. The system of claim 19, wherein the modulated controls comprise PID (proportional, integral and derivative) control loop tuning.

21. The system of claim 19, wherein the parameters are selected from a group consisting of temperatures, humidity, sensor selection, volume of air movement, the percentage of added fresh air, modes of occupied, unoccupied or standby of certain spaces for at least one zone.

22. The system of claim 19, wherein the at least one configuration further comprises a selectable non-modulated control for the pluralities of the heating and cooling stages and for the air mover.

23. The system of claim 22, further comprising:

a configuring device; and

wherein;

the configuring device may communicate with system sequencing controller; and

the configuring device may upload, store, modify and download one or more configurations of the system sequencing controller and at least one configuration of the plurality of thermostats.

24. The system of claim 22, wherein the configuring device is a personal digital assistant.

25. A thermostat system for controlling at least part of an HVAC system, wherein the HVAC system includes three or more heating and/or cooling stages, the thermostat comprising:

a first modulated output coupled to a first stage of the three or more stages and providing a first modulated variable output for controlling the first stage;

a second modulated output coupled to a second stage of the three or more stages and providing a second modulated variable output for controlling the second stage at the same dine as the first modulated output provides the first modulated variable output for controlling the first stage; and

a discrete on/off output coupled to a third stage of the three or more stages for providing a discrete on/off output for controlling the third stage.

26. The thermostat of claim 25 wherein the first stage is a heating stage.

27. The thermostat of claim 26 wherein the second stage is a heating stage.

28. The thermostat of claim 27 wherein the third stage is a cooling stage.

29. The thermostat of claim 25 wherein the first stage includes a first boiler stage.

30. The thermostat of claim 29 wherein the second stage includes a second boiler stage.

31. A thermostat system for controlling at least part of an HVAC system, wherein the HVAC system includes two or more heating stages and one or more cooling stages, the thermostat comprising;

a first modulated output coupled to a first heating stage and providing a first modulated variable output for controlling the heat output of the first heating stage;

a second modulated output coupled to a second heating stage and providing a second modulated variable output for controlling the heat output of the second heating stage at the same time as the first modulated output provides the first modulated variable output for controlling the heat output of the first heating stage; and

a discrete on/off output coupled to a cooling stage fir providing a discrete on/off output for controlling the cooling stage.

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