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(54) Abstract Title: **electronic control units for central heating systems.**

(57) An automatic electronic control unit for controlling the operation of a central heating system where the time settings are determined automatically from a detection of the user's activity and lifestyle habits. An apparatus includes an electrical load sensor 22 for measuring the electrical load of one or more electrical appliances within the building and providing an output signal indicative of the electrical load of the one of more electrical appliances, and an electronic control unit that uses the output signal from the electrical load sensor to control an operation of the central heating system.

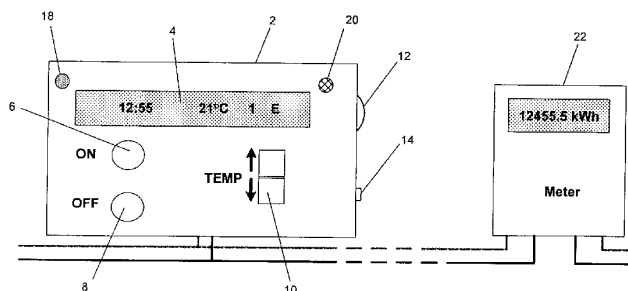


Figure 3

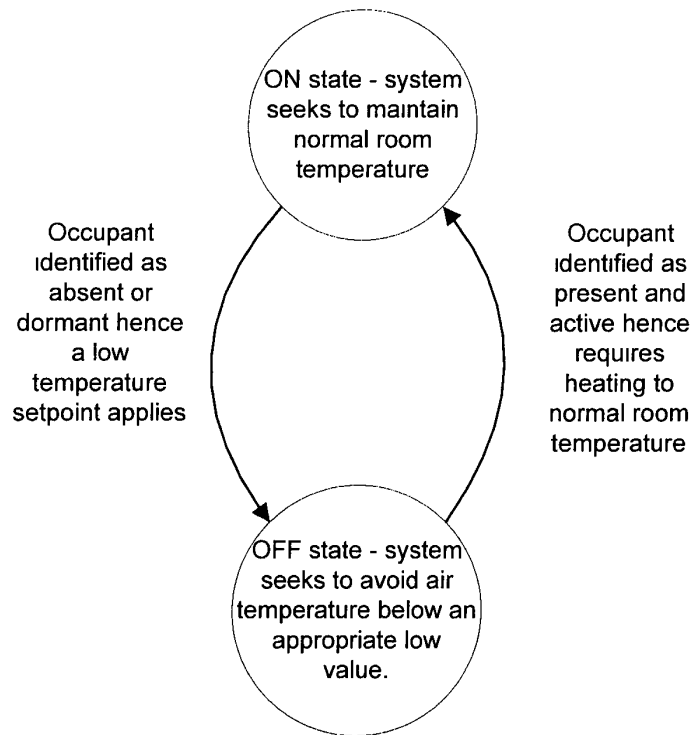


Figure 1

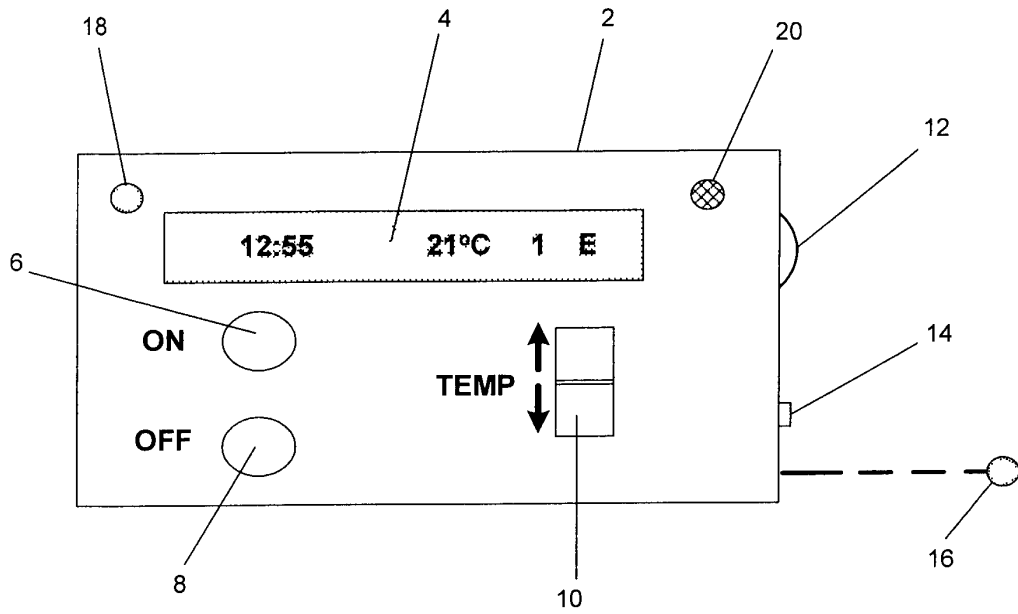


Figure 2

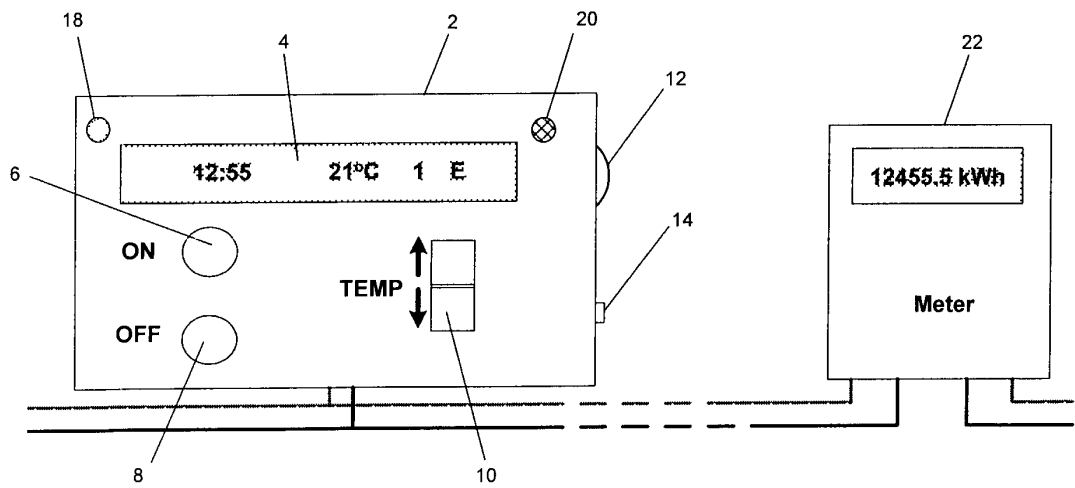


Figure 3

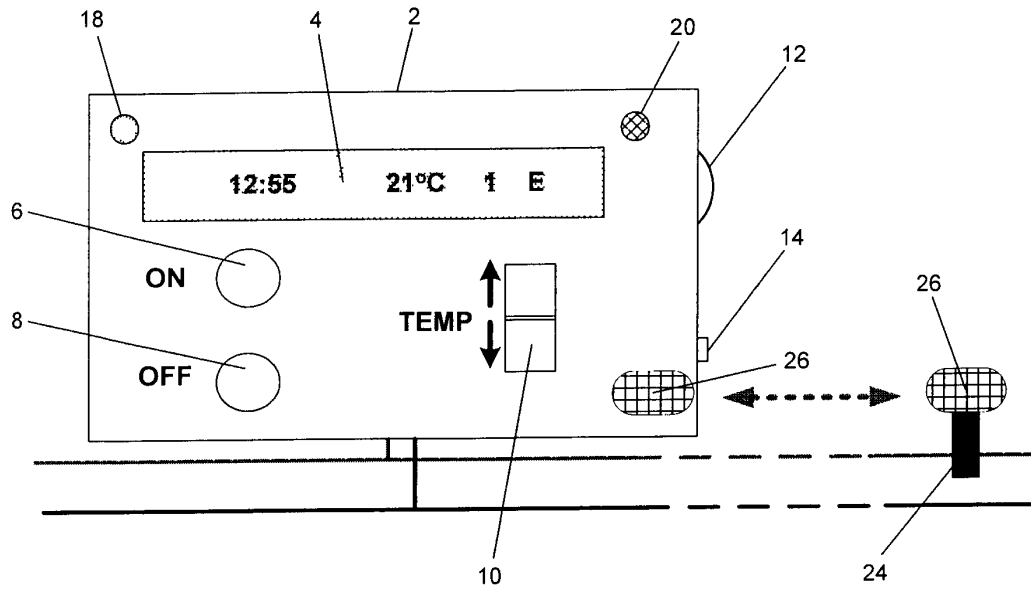


Figure 4

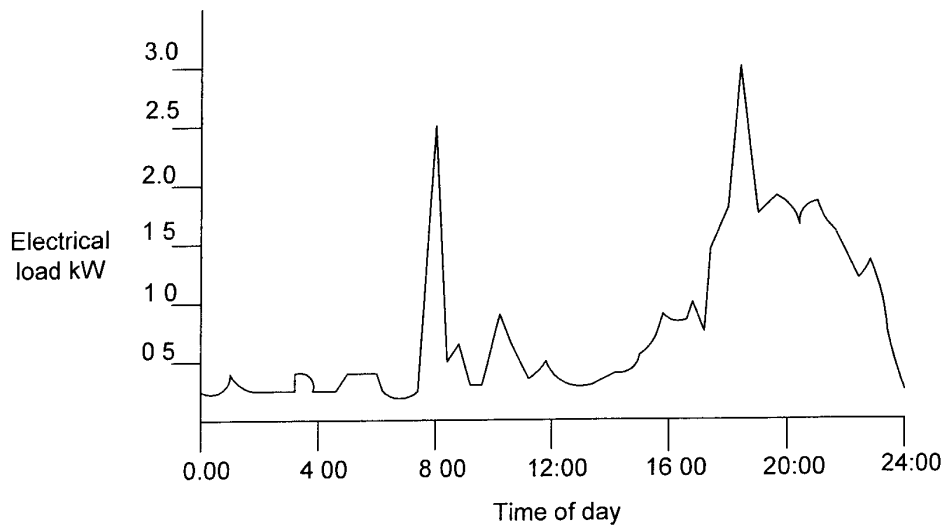


Figure 5

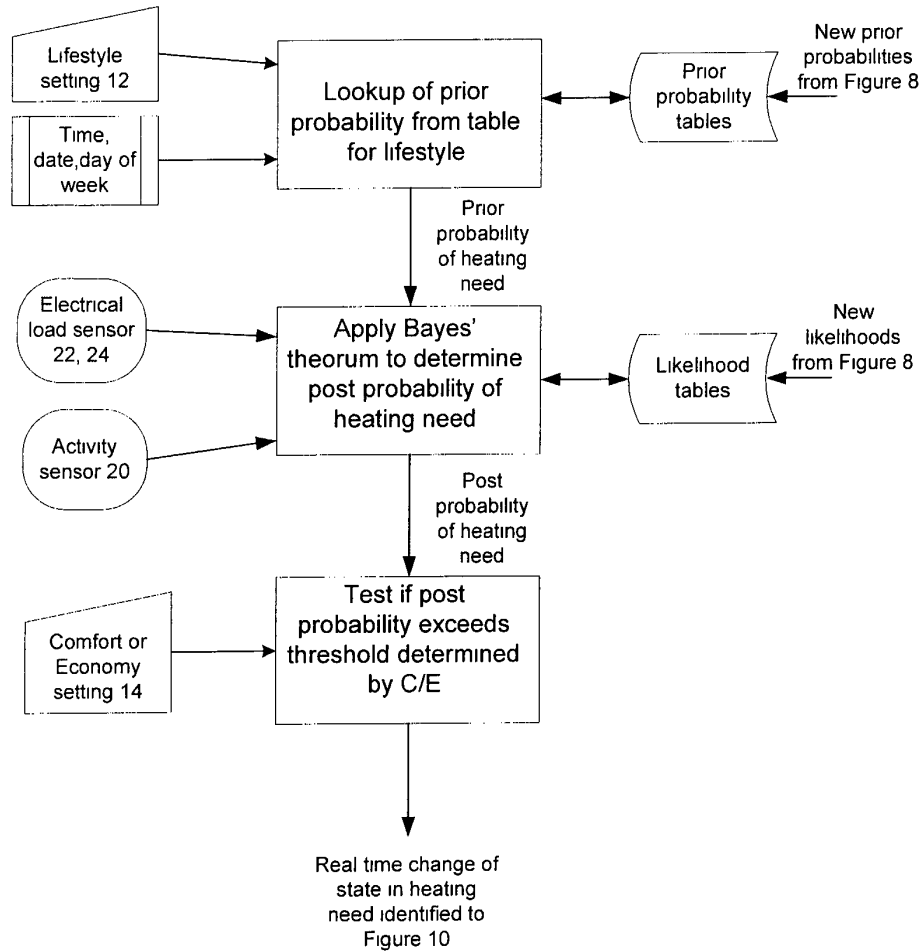


Figure 6

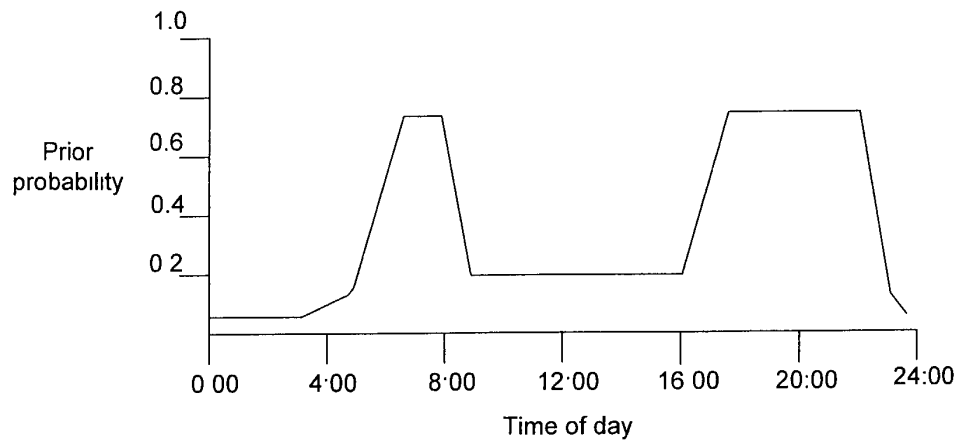


Figure 7

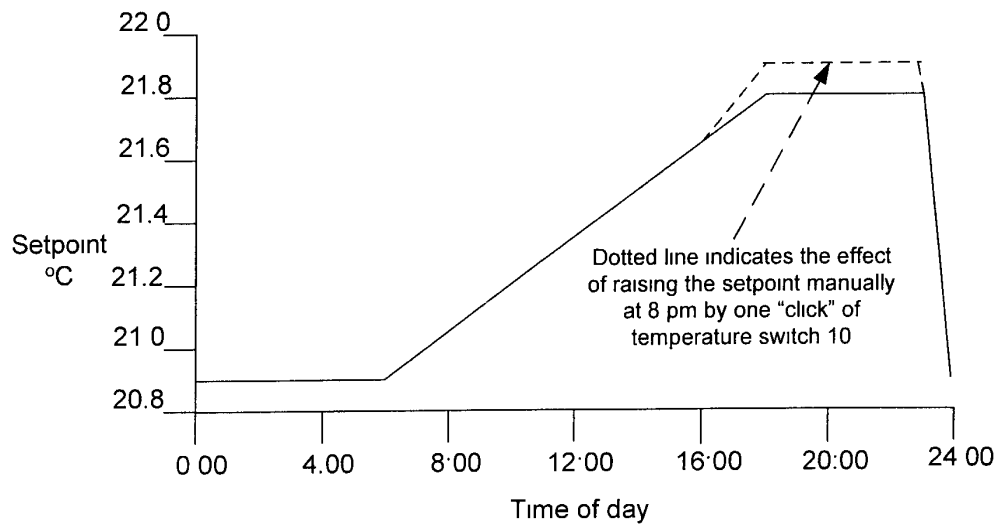


Figure 9

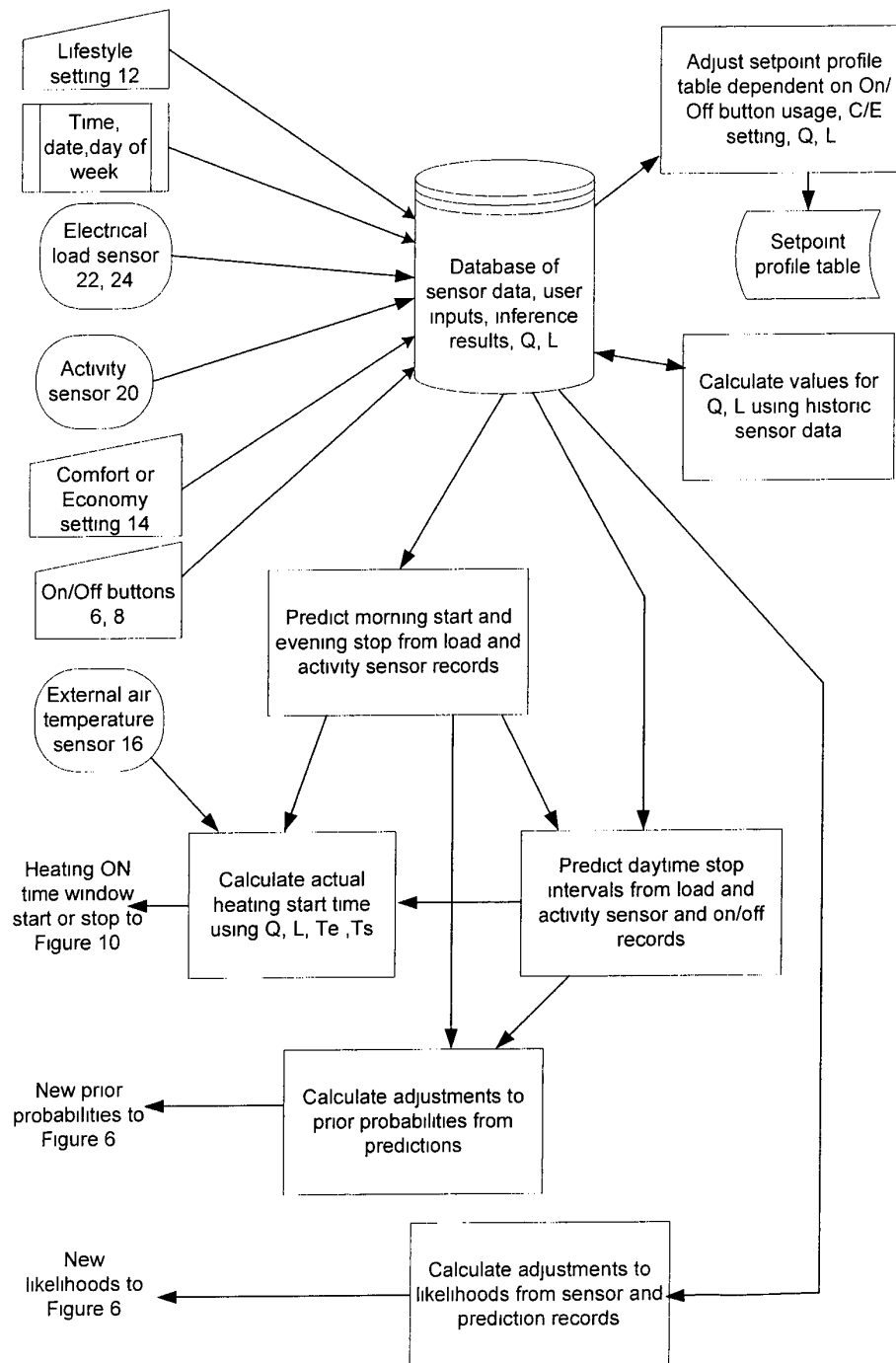


Figure 8

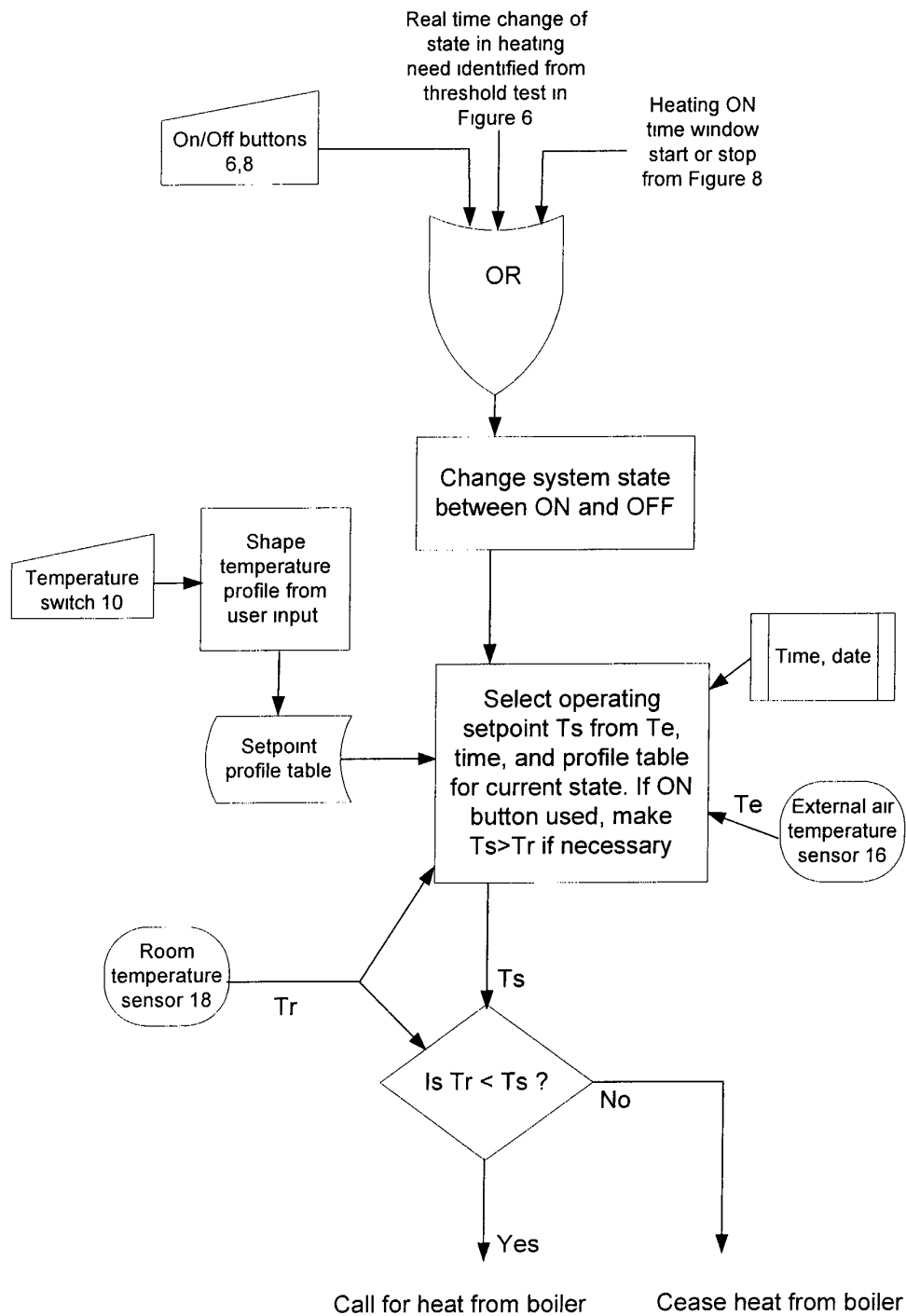


Figure 10

TITLE

Electronic control units for central heating systems

DESCRIPTION5 Technical Field

The present invention relates to electronic control units for central heating systems, and in particular to electronic control units that can use real-time and predictive inference processes to control the central heating systems.

10 Background Art

Electronic control units for central heating systems are known and typically require a user to set the times when they want the system to provide heating. To allow for periods when the user is not at home, and for changes in routine between weekdays and weekends, it is often necessary to enter a number of time settings on a physically
15 small control box with a poor man-machine interface. Many users find entering time settings quite difficult and an incorrect selection will often result in the inefficient operation of the central heating system with heat being provided when it is not needed and *vice versa*.

20 There is therefore a need for an automatic electronic control unit where the time settings are determined automatically from a detection of the user's activity and lifestyle habits. There is also a need for an electronic control that can make the central heating system operate in a most cost-effective manner.

25 Summary of the Invention

In a first aspect, the present invention provides an apparatus for controlling the operation of a central heating system for heating and/or cooling a building, the apparatus including an electrical load sensor for measuring the electrical load of one or more electrical appliances within the building and providing an output signal
30 indicative of the electrical load of the one of more electrical appliances, and an electronic control unit that uses the output signal from the electrical load sensor to control an operation of the central heating system.

For the purposes of the following description, the term "building" will be taken to include any domestic, commercial or industrial building including (but not limited to) a private house, flat, apartment or bungalow, a shop, warehouse, office building or
5 factory. Similarly, the term "electrical appliance" is to be interpreted broadly to include any item or object that is electrically powered and which preferably operates on a non-continuous basis. Typical examples might include kitchen appliances such as electric cookers, microwaves, washing machines, tumble driers, dishwashers and kettles (but not necessarily refrigeration appliances like fridges and freezers which
10 operate continuously and therefore give no indication of whether the occupant of the building is active and has a need for heating), entertainment appliances such as televisions, videos and games machines, lighting appliances, hairdryers, irons and commercial and industrial appliances such as computers and computer peripherals, checkouts, electrical machinery and the like.

15 In the case of a domestic building, monitoring the electrical load of one or more appliances within the building provides a robust day-by-day indication of when the occupant or occupants of the building get up in the morning (electrical load increases) and go to bed at night (electrical load falls). By correlating these times with the days
20 of the week the routine behaviour of the occupant or occupants can be determined. The same is also true for commercial and industrial buildings where monitoring the electrical load provides an indication of when the building is occupied (electrical load increases) and when it is empty (electrical load falls).

25 The electrical load sensor can be configured to measure the aggregate electrical load of the building or the electrical load of one or more particular electrical appliances by identifying an appliance through pattern recognition of their load variations, for example. The appliances will usually be supplied with electricity from the mains supply but they may also be supplied from an auxiliary source such as a stand-alone
30 generator.

- The electronic control unit can be used with any suitable central heating system for heating and/or cooling a building. In its broadest aspect the central heating system can include a heating and/or cooling device for supplying heating and/or cooling fluid and a network for distributing the heating and/or cooling fluid to at least one output
- 5 device that uses the heating and/or cooling fluid to heat and/or cool the interior of the building. For example, the central heating system can be a conventional "water based" system with a gas or oil-fired central heating boiler that supplies hot water through a network of pipes to a series of radiators or under floor heating piping. Cold water can also be supplied from a heat-exchange unit through the same or a parallel
- 10 network of pipes to the series of radiators or under floor heating piping. The central heating system can also be a conventional "air based" system (generally favoured in commercial and industrial buildings) where hot or cold air is distributed via ducting to a series of air vents located in the rooms of the building.
- 15 The control of an operation of the central heating system by the electronic control unit can be as straightforward as simply turning the central heating system on when the electrical load exceeds a predetermined threshold and turning the central heating system off when the electrical load falls below a predetermined threshold.
- 20 However, it is generally preferred that the central heating system is capable of operating in a first state and a second state so that the electronic control unit can use the output signal from the electrical load sensor to switch the central heating system between the first and second states. It will be readily appreciated that the central heating system can operate in more than two states and can be switched between these
- 25 plural states under the automatic control and direction of the electronic control unit. The states will be a simplified representation of the condition of the occupant or occupants of the building. For example, the central heating system may operate in a first state where it can provide heating to keep the temperature in the building (or a room or part of the building) above a low temperature of about 5°C when the building
- 30 is empty (such as when the occupant or occupants are out at work or on holiday), a second state where it can provide heating to keep the temperature in the building (or a room or part of the building) above a slightly higher temperature of about 12°C when

the occupant or occupants are asleep, a third state where it can provide heating to keep the building (or a room or part of the building) at a predetermined room temperature of about 20°C when the occupant or occupants are present in the building and active.

- 5 The apparatus preferably further comprises an activity sensor for measuring activity within the building and providing an output signal indicative of activity within the building. The activity sensor can be positioned at any suitable location within the building and can use any known technology such as microwave, infra-red or acoustic.
- 10 The electronic control unit can use a first inference process to determine when to switch the central heating system between the first and second states. The first inference process preferably operates in real time and uses a range of inputs to determine when heating is and is not needed. Inputs to the first inference process can include the output signal from the electrical load sensor, the output signal from an
- 15 activity sensor and a time-varying prior probability. The prior probability can in turn be based on a lifestyle setting and a comfort mode and economy mode setting described in more detail below.

20 The apparatus preferably further comprises a first manual switching device that can be manually activated by an operator to switch the central heating system from the first state to the second state for a predetermined period of time. The first manual switching device can be manually activated by the operator a number of times and the predetermined period of time can then be determined by the number of times the first manual setting device is activated.

25 The apparatus preferably also further comprises a second manual switching device that can be manually activated by an operator to switch the central heating system from the second state to the first state for a predetermined period of time. The second manual switching device can be manually activated by the operator a number of times

30 and the predetermined period of time can then be determined by the number of times the second manual setting device is activated.

The electronic control unit may also use the output signal from the electrical load sensor to derive a first time for switching the central heating system from the first state to the second state and a second time for switching the central heating system from the second state to the first state. The electronic control unit preferably uses a
5 second inference process to derive a first time for switching the central heating system from the first state to the second state and the second time for switching the central heating system from the second state to the first state. In both cases, the electronic control unit can switch the central heating system between the first and second states when the actual time determined by some sort of timer is equal to the first and second
10 times.

The output signal from the electrical load and activity sensors, and information relating to when the central heating system is switched between the first and second states (including switches determined by the first inference process and by the manual
15 activation of the first and second manual switching devices) can be stored in a memory of the electronic control unit. At least a part of this stored information can then be used by the second inference process to derive the first and second times.

The electronic control unit preferably controls the central heating system to heat
20 and/or cool the building during the period of time between the first time and the second time.

The apparatus preferably further comprises an internal temperature sensor for measuring the temperature inside the building and providing an output signal
25 indicative of the temperature inside the building. The sensor can be of any suitable type. The electronic control unit can use the output signal from the internal temperature sensor to control the central heating system to heat and/or cool the building when the temperature inside the building measured by the internal temperature sensor deviates from a temperature setpoint.

30

The temperature setpoint can be determined with reference to a first temperature profile when the central heating system is operating in the first state and with

reference to a second temperature profile when the central heating system is operating in the second state. For example, when the central heating system is operating in the first state where it might be trying to provide heating to keep the temperature in the building above a predetermined low temperature (say between 5 and 12°C) then this
5 predetermined low temperature can be determined with reference to a first temperature profile. Similarly, when the central heating system is operating in the second state where it might be trying to provide heating to keep the temperature of the building at a predetermined room temperature (say around 20°C) then this predetermined room temperature can be determined with reference to a second
10 temperature profile. It is generally preferred that at least one of the first and second temperature profiles varies with time.

The apparatus preferably further includes an external temperature sensor for measuring the air temperature outside the building and providing an output signal
15 indicative of the air temperature outside the building. The sensor can be of any suitable type. The electronic control unit can use the output signal from the external temperature sensor to modify at least one of the first and second temperature profiles. It is also preferred that the apparatus includes a manual temperature setting device that can be manually activated by an operator to modify at least one of the first and
20 second temperature profiles. The temperature profile that is modified will depend on whether the central heating system is operating in the first state or the second state at the time when the manual temperature setting device is activated. For example, if the manual temperature setting device is activated when the central heating system is operating in the first state then the first temperature profile will be modified but if the
25 manual temperature setting device is activated when the central heating system is operating in the second state then the second temperature profile will be modified. It will be recalled that the central heating system can be manually switched between the first and second states using the first and second manual switching devices.

30 The present invention further provides a method of controlling the operation of a central heating system for heating or cooling a building, the method including the steps of measuring the electrical load of one or more electrical appliances within the

building, and using the measurement of the electrical load to control an operation of the central heating system.

5 The remaining method steps correspond generally to the features of the apparatus described above and are set out in the claims.

10 In a second aspect, the present invention provides an apparatus for controlling the operation of a central heating system for heating and/or cooling a building, the apparatus including an internal temperature sensor for measuring the temperature inside the building and providing an output signal indicative of the temperature inside the building, and an electronic control unit that uses the output signal from the internal temperature sensor to control the central heating system to heat and/or cool the building when the temperature inside the building measured by the internal temperature sensor deviates from a temperature setpoint determined with reference to a time-varying temperature profile.

20 The present invention further provides a method of controlling the operation of a central heating system for heating or cooling a building, the method including the steps of measuring the temperature inside the building, and using the measurement of the temperature inside the building to automatically control the central heating system to heat and/or cool the building when the measured temperature inside the building deviates from a temperature setpoint determined with reference to a time-varying temperature profile.

25 The remaining features of the second aspect of the present invention correspond generally to the features of the first aspect described above.

Drawings

30 Figure 1 is a diagram showing the two states (ON state and OFF state) for the operation of a central heating system controlled by an electronic control unit according to the present invention;

Figure 2 is a schematic diagram of an electronic control unit according to the present invention;

Figure 3 is a schematic diagram showing how the electronic control unit of Figure 2 can receive input signals indicative of electrical load from an electricity meter;

5 Figure 4 is a schematic diagram showing how the electronic control unit of Figure 2 can receive input signals indicative of electrical load from an induction sensor;

Figure 5 is a graph showing typical variation in domestic electrical load during a 24 hour period;

10 Figure 6 is a schematic flow diagram showing the operation of a real-time inference process used by the electronic control unit of Figure 2;

Figure 7 is a graph showing a typical prior probability during a 24 hour period;

Figure 8 is a schematic flow diagram showing the operation of a predictive inference process used by the electronic control unit of Figure 2;

15 Figure 9 is a graph showing a typical time-varying temperature profile during a 24 hour period; and

Figure 10 is a schematic flow diagram showing the operation of a temperature control process used by the electronic control unit of Figure 2.

20 A central heating system (not shown, but for the purposes of this description consisting of a central heating boiler for supplying hot water to one or more radiators through a network of pipes) for a domestic house is controlled by an electronic control unit. For simplicity, the following description assumes that the house only has a single occupant but it will be readily appreciated that the house can have two or more occupants. Any reference to "the occupant" of the house should therefore be
25 interpreted as being a reference to "any occupant" or "all occupants" as applicable. Similarly, it will be readily appreciated that the electronic control unit can be used to control a central heating system in any other domestic, commercial or industrial building.

30 With reference to Figure 1, the central heating system operates in two different states, namely an ON state and an OFF state. For the purposes of the following description, the central heating system is said to be turned on or operating in an ON state when it

operates to maintain the temperature inside the house at a desired room temperature. The desired room temperature is sometimes referred to below as the room temperature setpoint and is typically somewhere in the region of about 20°C. The central heating system is most likely to be operating in the ON state during the daytime when the occupant is present in the house. The central heating system is said to be turned off or operating in the OFF state when it operates to keep the temperature inside the house above a desired anti-frost or overnight temperature (which for reasons that will become clear is also sometimes referred to below as the low temperature setpoint and is typically between 5°C and 12°C). The central heating system is switched between these two states (in other words experiences ON/OFF control) under the direction of the electronic control unit. It will be readily appreciated that the term "desired overnight temperature" has been chosen for convenience to denote the lower temperature above which the house should be kept when the occupant is asleep. However, the electronic control unit can be used in situations where the occupant is active during the night and asleep during the day.

With reference to Figures 2 to 4, the electronic control unit includes a control box 2 that might be installed in a hallway of the house, for example. The control box 2 incorporates a central processor unit (not shown) and has a display panel 4 that displays the current time, the temperature setpoint in °C and an indication of the current lifestyle and comfort mode or economy mode settings. The central processor unit includes a timer so that it can record the precise time and date when external signals are received by the electronic control unit, when any operating processes or mathematical routines are carried out by the central processor unit, and when any ON/OFF control of the central heating system is carried out. The time and date information supplied by the timer can be used to point to various look-up tables and can also be used as an input to the operating processes and mathematical routines themselves.

The electronic control unit normally operates in an automatic mode where it uses real-time and predictive inference processes (described in more detail below) to control the ON/OFF operation of the central heating system. However, the control box 2

includes an ON button 6 and an OFF button 8 that can be manually activated by the occupant of the house to override the automatic mode and turn the central heating system on or off for a set period of time such as 1 hour. If the ON button 6 and OFF button 8 are pressed more than once then the central heating system will be turned on or off for multiples of the set period of time. For example, if the ON button 6 is pressed three times then the central heating system will be turned on for 3 hours. The current time in the display panel 4 can be replaced with the time when the central heating system will revert to its automatic mode and a marker can appear in the space between the time and the temperature setpoint to inform the occupant that the electronic control unit is operating in a manual mode. If the ON button 6 has been pressed and the electronic control unit is still operating in a manual mode then the electronic control unit can be made to revert back to its automatic mode early by pressing the OFF button 8.

A temperature switch 10 can be manually activated by the occupant of the house to raise and lower the temperature setpoint by a small predetermined amount such as 0.1°C for each depression of the switch. When the central heating system is in the ON state, the activation of the temperature switch 10 adjusts the room temperature setpoint. However, when the central heating system is in the OFF state, the activation of the temperature switch 10 adjusts the low temperature setpoint.

The occupant of the house can also use a switch 12 on the control box 2 to select one of a predetermined number of different lifestyle settings that best fits the occupant's typical pattern of behaviour. A list of possible settings might include:

25

- The occupant is in the house most of the time.
- The occupant is out at work from Monday to Friday and in the house on Saturday and Sunday.
- The occupant is out of the house at different times depending on his or her shift pattern at work.
- The occupant is in and out of the house on an irregular basis.

30

The control box 2 also includes a switch 14 that allows the occupant of the house to select if the electronic control unit should operate in a comfort mode or an economy mode. This is a binary setting and makes sure that the electronic control unit can be used safely by houses with an elderly, infirm or infant occupant. If the occupant
5 selects the comfort mode then the electronic control unit will bias its decision making processes in favour of providing or maintaining the supply of heat. However, if the occupant selects the economy mode then the electronic control unit will bias its decision making processes in favour of delaying or ending the supply of heat so that the central heating system is operated in a more cost-effective and environmentally-
10 friendly manner.

The control box 2 is connected to an external temperature sensor 16 mounted outside the house for measuring the air temperature outside the house. An internal temperature sensor 18 for measuring the air temperature inside the house is provided
15 directly on the control box 2 but it could also be independently mounted as a stand-alone unit. For example, the internal temperature sensor might be mounted in the living room or main living space of the house and connected to the control box 2 in the hallway by an electrical cable or any suitable wireless means.

20 The control box 2 also includes an activity sensor 20 for monitoring movement inside the house. It can also be independently mounted as a stand-alone unit and positioned such that it can detect movement of the occupant in a particular room, or through the front or back door of the house, for example. The activity sensor 20 can use any known technology such as microwave, infra-red or acoustic and if mounted as a
25 stand-alone unit can be connected to the control box by an electrical cable or any suitable wireless means.

An electrical load sensor forms part of the electronic control unit and is used to measure the aggregate electrical load of the house. If the electricity meter 22 installed
30 in the house is sufficiently sophisticated then this can be used as the electrical load sensor as shown in Figure 2. The control box 2 is powered directly from the mains supply and the signals from the electricity meter 22 can be transmitted to the control

box using one of the established techniques for mains supply signalling such as LONWORKS. Alternatively, an independent induction sensor 24 is clamped around the mains supply as shown in Figure 3. The induction sensor 24 can receive power directly from the mains supply to operate the measurement electronics. The signals
5 from the induction sensor 24 can be transmitted to the control box 2 using an electrical cable or a wireless module 26 like a low-power radio frequency ZIGBEE module. The signals from the electricity meter 22 or the induction sensor 24 provide a robust indication of when the occupant of the house gets up in the morning (electrical load increases) and goes to bed at night (electrical load falls). By
10 correlating the signals with the day of the week and the time when they are received then the routine behaviour of the occupant can be determined. The measurement of electrical load is equally effective when the house has a number of occupants because it reflects the total or combined behaviour of all the occupants. An example of a signal indicative of electrical load that might be output from the induction sensor 24 is
15 shown in Figure 5. It can be seen that during the early hours of the morning, the electrical load is low and reflects the continuous operation of refrigeration appliances, for example. The electrical load then rises sharply at about 8.00 am, typically due to the occupant getting up and using electrical appliances such as an electric kettle, electric shower, hairdryer or entertainment appliances. The amount of electrical load
20 falls back during the day when the occupant is out at work but rises again once the occupant returns home in the evening and starts to use cooking and entertainment appliances. It eventually drops sharply as the electrical appliances are turned off when the occupant retires for the night.

25 The electronic control unit uses three different operating processes to independently control the ON/OFF operation of the central heating system.

The first process is a real-time inference process where control decisions are made based on current sensor measurements, the selected lifestyle mode and the selected
30 comfort or economy mode. The real-time inference process uses a mathematical routine to determine when the house needs to be heated to the desired room temperature and also to determine when that level of heating is no longer required.

The second process is a predictive inference process where control decisions are made based on previous sensor measurements, previous transitions between the ON and OFF states and manual inputs that are stored in a memory of the electronic control unit. The predictive inference process uses a mathematical routine to predict a series of times when the central heating system should be switched to operate in the ON state to heat the house to the desired room temperature (start times) and a series of times when the central heating system should be switched to operate in the OFF state to keep the temperature inside the house above the desired overnight temperature or the predetermined anti-frost temperature (stop times).

The third process is a manual input process where the occupant of the house switches the central heating system to operate in the ON state for a predetermined period of time by activating the ON button 6. The occupant of the house can also switch the central heating system to operate in the OFF state for a predetermined period of time by activating the OFF button 8.

When the central heating system is operating in an ON state, the electronic control unit uses a temperature control process to determine when the central heating boiler actually needs to supply hot water to the radiators in order to heat the house and maintain the temperature at the desired room temperature. The same temperature control process is used when the central heating system is operating in an OFF state but in this case the temperature control process will determine when the central heating boiler actually needs to supply hot water to the radiators in order to keep the temperature of the house above the desired overnight temperature or the predetermined anti-frost temperature.

Real-time inference process

The real-time inference process is shown in Figure 6 and makes use of Bayes' theorem, which may be expressed as:

$$P(A_1|S) = \frac{P(S|A_1) \times P(A_1)}{P(S|A_1) \times P(A_1) + P(S|A_0) \times P(A_0)}$$

where:

$P(A_1|S)$ is the probability that the occupant of the house is present and active (A_1)
5 and therefore has a need for the house to be at the desired room temperature, given that a sensor has given a positive indication (S). This is referred to below as the posterior probability,

$P(S|A_1)$ is the probability that the sensor will give a positive indication if the occupant of the house is active. This is referred to below as the likelihood of the
10 sensor. The likelihood of the sensor quantifies the reliability of the associated sensor and can be determined by experiment and experience,

$P(A_1)$ is the probability in the absence of any other information that the occupant of the house is present and active. This is referred to below as the prior probability. Its inverse is the probability $P(A_0)$ that the occupant of the house is absent or not active
15 so that there is no need for the house to be at the desired room temperature, and

$P(S|A_0)$ is the probability that the sensor will give a positive indication even when the occupant is absent or not active (in other words, a false indication).

The real-time inference process starts by selecting the relevant prior probability for
20 the current day from a look-up table. An example of a prior probability is shown in Figure 7 and is essentially an assumed probability varying over 24 hours that the occupant of the house is at home and requires the central heating system to be operating in the ON state.

25 When it is used for the very first time, the electronic control unit selects a predefined prior probability based on the lifestyle setting selected by the occupant of the house. For example, if a lifestyle setting has been selected that suggests that the occupant will be out at work from Monday to Friday and at home on Saturday and Sunday then the prior probability for Monday to Friday might vary over the 24 hour period in such

- a way that the probability that heating is needed will be relatively high between 6.00 am and 8.00 am, relatively low between 9.00 am and 4.00 pm, relatively high between 5.30 pm and 10.30 pm, and relatively low between 11.00 pm and 5.00 am with intermediate values interpolated between the intervals of high or low probability.
- 5 Similarly, the prior probability for the Saturday and Sunday might vary over the 24 hour period in such a way that the probability that heating is needed will be relatively high between 8.00 am and 11.30 pm and relatively low between 12.30 pm and 7.00 am.
- 10 The real-time inference process operates continuously but for the purposes of this description it is assumed that the time is the early morning and the central heating system is operating in an OFF state. The process will therefore determine the probability that occupant needs the house to be heated to the desired room temperature (in other words that the central heating system should be switched from
- 15 the OFF state to the ON state) by firstly computing the posterior probability (as defined above) using each of the sensors.

The posterior probabilities derived from each sensor are then fused (or combined) using a simple weighted addition:

20

$$P_c = W_e \times P(A_i|S_e) + W_a \times P(A_i|S_a)$$

- where P_c is the fused probability, $P(A_i|S_e)$ and $P(A_i|S_a)$ are the posterior probabilities for the electrical load sensor and the activity sensor 20, respectively, and
- 25 W_e and W_a are the weights given to each of the posterior probabilities. For example, the electronic control unit can be biased in favour of the signals from the electrical load sensor over the activity sensor, or *vice versa*. However, it is generally preferred that the weights W_e and W_a are chosen by experience to produce the most effective combination of the posterior probabilities.

30

The fused probability P_c is compared to a threshold level which is determined with reference to the occupant's decision to bias the electronic control unit to comfort mode or economy mode. If the threshold level is exceeded then the process determines that heating is needed and the positive decision is passed to a temperature control process that puts the central heating system into the ON state so that if necessary, hot water can be supplied from the central heating boiler to the radiators in the house so that the house is gradually heated to the desired room temperature. The temperature control process will be described in more detail below with reference to Figure 10. If the threshold level is not exceeded then the process is repeated at regular time intervals until it determines that heating is needed or until the whole of the 24 hour period covered by the prior probability has ended. The process then continues by selecting the relevant prior probability for the next day from the look-up table.

It is important to note that the electronic control unit does not rely solely on the prior probability to determine when the central heating system should be turned on or off. Instead, the electronic control unit takes a signal from the electrical load sensor and the activity sensor 20 and independently combines the likelihood of each sensor with the prior probability to derive two separate posterior probabilities that the occupant of the house is present and active for the particular instant in time when the inference step is carried out. Therefore, even if the prior probability suggests that the occupant should be present in the house and active at a certain time, the electronic control unit will not turn the central heating system on unless this is supported by a positive indication from at least one of the electrical load sensor and the activity sensor 20.

Once the central heating system has been turned on, the real-time inference process will calculate the probability that heating to the desired room temperature is no longer needed. The process is the same as that described above but the sensor likelihoods and weights are different. In the case of the activity sensor 20, for example, the condition where heating is no longer required is determined by the absence of any activity for a predetermined period of time and this is reflected in the likelihood for the sensor. A fused probability is derived from the posterior probabilities of the electrical load sensor and the activity sensor 20 (which in turn are derived using the

prior probability, the sensor outputs and the sensor likelihoods at the particular instant in time when the inference step is carried out) and this is compared to a threshold level which is determined with reference to the occupant's decision to bias the electronic control unit to comfort mode or economy mode. If the threshold level is exceeded then the process determines that heating to the desired room temperature is no longer needed and the positive decision is passed to the temperature control process that switches the central heating system from the ON state to the OFF state. If the threshold level is not exceeded then the process is repeated at regular time intervals until it determines that heating is no longer needed or until the whole of the 24 hour period covered by the prior probability has ended. The process then continues by selecting the relevant prior probability for the next day from the look-up table.

Predictive inference process

The predictive inference process is shown in Figure 8 and relies on previous sensor measurements, ON/OFF information (that is the times when the central heating system was switched between the ON state and the OFF state by the electronic control unit in accordance with the real-time inference process) and manual inputs that are stored in a memory of the electronic control unit. The amount of stored information may vary depending on the circumstances but in this example the electronic control unit holds the sensor measurements, records of transitions between ON and OFF states and manual inputs made every day for the previous five weeks. The electronic control unit can also store information for particular dates such as Christmas Day, Boxing Day and Bank Holidays when the occupant's pattern of behaviour might be expected to be different. By analysing the stored information, the electronic control unit is able to detect the occupant's normal patterns of behaviour over a relatively long period of time. However, until sufficient information is stored to allow the predictive inference process to make an effective contribution, the electronic control unit will rely entirely on the real-time inference process. At the very least, this may require two or three days' worth of the sensor measurements, ON/OFF information and manual inputs to be stored.

The first step in the predictive inference process is to analyse the stored information to determine from the ON/OFF information those periods of time during which the central heating system was in the OFF state that overlap with preselected night and crepuscular periods. These are identified as dormant periods when the occupant is most likely to be asleep or resting. The measurements from the electrical load sensor and the activity sensor 20 are then analysed forwards and backwards in time from the centre of these overlapping periods of time using the same Bayesian process described above with respect to the real-time inference process, but using parameters that require more robust evidence for the determination of a positive decision when the central heating system should be switched between the ON state and the OFF state. Any manual inputs made by the occupant to override the automatic operation of the electronic control unit using the ON and OFF buttons for a certain period of time are also taken into account.

The predictive inference process therefore determines a morning start time and an evening stop time (it will be readily appreciated that the terms "morning start time" and "evening stop time" have been chosen for convenience but the electronic control unit can be used in situations where the occupant is active during the night and asleep during the day) for each of the Mondays in the five weeks of stored data, each of the Tuesdays and so on. The control unit executes this process for the coming day during the preceding dormant period. So if execution of the process was being performed during a dormant period extending from Sunday night to Monday morning, the morning start times and evening stop times for each of the Mondays that are within the time window would be averaged together and the average result is taken as the predicted morning start time and predicted evening stop time for the coming Monday. Similarly, if the process is executed on a Monday night for the following Tuesday, then the morning start times and evening stop times for each of the Tuesdays that are within the time window would be averaged together and the average result is taken as the predicted morning start time and predicted evening stop time for the coming Tuesday. The time window can be varied according to the lifestyle setting but a typical example might be an hour. If the results of the analysis are consistent (for example, the morning start times and evening stop times for least four out of the five

Mondays fall within the time window) then the prior probability for Mondays used in the real-time inferencing process can be adjusted to synchronise with the predicted morning start time and predicted evening stop time.

- 5 Once the predicted morning start time and the predicted evening stop time have been determined, the predictive inference process may analyse the stored information to try and find periods of time when the occupant appears to be absent from the house. This additional analysis will be carried out depending on the lifestyle setting. For example, the additional analysis will be carried out if the lifestyle setting suggests that the
- 10 occupant will be absent from the house at work during some period between the morning start time and the evening stop time on weekdays. Once again, a Bayesian process is used to determine the intervening stop and start times periods when heating is or is not needed for each day of the week and if the results appear reliable then the prior probabilities for the current day (or the next day if the analysis is carried out the
- 15 night before) used in the real-time inferencing process can be adjusted to synchronise with the intervening stop and start times as described above.

By constantly adjusting the prior probability for the individual days of the week based on the stored information, the electronic control unit can fine-tune the real-time

20 inference processes to match the occupant's normal pattern of behaviour. The electronic control unit can also adapt the inference processes to significant changes in the occupant's normal pattern of behaviour as and when they occur.

The interpretation of the data from the electrical load sensor and the activity sensor 20

25 can also be optimised and updated by working out the actual likelihoods from the stored information (for example, by comparing the times when the activity sensor 20 indicated that the occupant was active with the decisions from the overall real-time inference process that heating was needed). This adjustment is shown by the two inputs to the boxes on the left-hand side of Figure 6 representing the prior probability and likelihood tables and the corresponding outputs from the lower two boxes of

30 Figure 8 representing the calculation adjustments to the prior probabilities and sensor likelihoods.

The specific thermal capacity of the house Q (Joules/°C) and the specific heating load L (Watts/°C of temperature difference between the inside and outside of the house) are calculated by the electronic control unit from the gradient of the fall in temperature overnight, and the rise in temperature when the central heating boiler is supplying heat by solving the following equations:

$$Q \times \delta T_r = L \times (T_r - T_e) \times t$$

when the house is cooling, and

$$Q \times \delta T_r = (H \times t) - (L \times (T_r - T_e) \times t)$$

when the house is being heated, where:

15

T_r is the measured room temperature,

T_e is the measured external temperature,

t is the observation interval in which a small change in room temperature δT_r takes place, and

20 H is the boiler heat output in Watts.

The electronic control unit can then use the specific thermal capacity of the house Q and the current heat load ($L \times (T_r - T_e)$) to calculate back from the morning start time, evening stop time and any intervening stop and start times the points in time that the central heating boiler must start or stop providing hot water to the radiators. For example, on a very cold morning if the predicted morning start time is 6.30 am then the central heating boiler can be turned on by the electronic control unit earlier (at say 5.45 am) so that the house has been heated up to the relevant temperature setpoint by the time the predicted morning start time is reached.

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Temperature profile

As described in more detail below, the actual supply of hot water from the central heating boiler is controlled by the temperature control process with reference to a temperature setpoint that represents the desired room temperature or the desired minimum low temperature depending on the whether the central heating system is operating in the ON state or the OFF state, respectively. The room temperature setpoint does not remain constant but has a temperature profile varying over 24 hours as shown in Figure 9. The low temperature setpoint also has a temperature profile which is a default over 24 hours at about 12°C, but which may be varied by the occupant. The relevant default room temperature profile for the current day is selected from a look-up table and is usually based on the lifestyle and comfort mode or economy mode settings. The temperature setpoint at any particular instant in time can then be derived directly from the applicable time-varying temperature profile and used by the various inference and control processes.

Each temperature profile can be manually altered by the occupant using the temperature switch 10. The alteration will apply to the room temperature profile if the central heating system is in the ON state and to the low temperature profile if the central heating system is in the OFF state. The occupant may force the central heating system to switch to the correct state for the purpose of altering the room temperature profile or the low temperature profile using the ON and OFF buttons 6 and 8. Any adjustment will not raise or lower the temperature profile for the whole day. Instead, the temperature profile is raised or lowered smoothly over a predetermined period of time in such a way that the temperature profile will eventually return to its pre-existing profile later in the day. This is shown by the dashed line in Figure 9, which indicates the effect of raising the temperature profile by 0.1°C (in other words a single activation of the temperature switch 10) at 8.00 pm. The room temperature setpoint is immediately raised by 0.1°C and continues to follow the dashed path for the rest of that evening. Over succeeding 24 hour intervals, the room temperature setpoint will follow the dashed profile between 4.00 pm and 11.30 pm. Adjusting the temperature profile in this way encourages the occupant to employ the ON button 6 to meet short

term needs for additional heat and avoids the situation where the occupant forgets to lower the temperature setpoint back to a normal level.

5 If either the ON and OFF buttons 6 and 8 are operated regularly at the same time of the day (as recognised by the predictive inference process) then the room temperature profile will be automatically adjusted so that it is raised or lowered smoothly over a predetermined period of time approximately centred on the time of day when the manual operation of the ON or OFF buttons takes place. However, the adjustment will be made to decay over a long period (perhaps in the order of weeks) so that the
10 temperature profile eventually returns to the default. It is important to note that the adjustments made using the temperature switch 10 are durable whereas those made using the ON or OFF buttons 6 and 8 are not.

The entire temperature profile can also be automatically shifted up or down depending
15 on the air temperature outside the house. For example, if the air temperature measured by the external temperature sensor 16 is relatively high (say within about 5°C of the room temperature setpoint at any particular instant in time) then the whole room temperature profile can be lowered. This reflects the fact that comfort is associated with temperature variation within the house and a lower average
20 temperature is acceptable if the variation is less. Similarly, during cold weather when the air temperature measured by the external temperature sensor 16 is very low then the whole room temperature profile can be raised. The amount of adjustment will depend on the occupant's comfort mode or economy mode preference, the time of year and the thermal parameters of the house.

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Temperature control process

The temperature control process will now be explained with reference to Figure 10.

The temperature control process operates in real time and controls when the hot water
30 is supplied from the central heating boiler to the radiators. The temperature control process uses the appropriate temperature setpoint T_s as determined by the state of the central heating system (which selects between the room and low temperature profiles)

and the time of day (which identifies the relevant temperature setpoint value from the selected profile). The steps around the transition of the central heating system from the OFF state to the ON state for each of these processes are described below.

- 5 It is important to again emphasise the fact that the real-time inference process and the predictive inference process are independent of each other. For example, if the predictive inference process has determined a morning start time of 6.30 am but the occupant has to get up earlier than normal and the signals from the activity sensor 20 and the electrical load sensor indicate that the occupant is active and has a need for heat at 3.30 am then the central heating system will be turned on at this earlier time and the temperature control process will operate to turn the central heating boiler on and off as described below. Similarly, if the predictive inference process has determined an intervening stop time of 9.00 am after the occupant has left for work but the occupant does not leave the house and is detected by the electrical load sensor and/or the activity sensor 20 then the real-time inference process will effectively
10
15 override the intervening stop time and make sure that the desired room temperature is maintained.

- In a first mode of operation, the central heating system is manually switched from the OFF state to the ON state for a predetermined period of time by the occupant of the house using the ON button 6. In this case, the temperature control process selects the room temperature setpoint T_s for the current time according to the room temperature profile. If the central heating system is switched to the ON state and the measured temperature in the room T_r is not less than the selected room temperature setpoint T_s then the electronic control unit will adjust or modify the selected room temperature setpoint T_s by the amount necessary so that heat is called for and the central heating boiler will start to supply hot water to the radiators. In other words, the selected room temperature setpoint T_s may be set to a value that is higher than the measured room temperature T_r by a predetermined small margin sufficient to ensure that the central heating boiler is activated. This value of room temperature setpoint T_s only persists for the duration of the predetermined period initiated by the ON button 6 but gives the
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occupant confidence that pressing the ON button will always result in heat from the central heating system.

5 In a second mode of operation, the central heating system is automatically switched from the OFF state to the ON state when the real-time inference process decides that heating is needed. Once again, the temperature control process selects the room temperature setpoint T_s for the current time according to the room temperature profile.

10 In a third mode of operation, the central heating system is automatically switched from the OFF state to the ON state at the morning start time or another start time determined by the predictive inference process. The actual time may be earlier than the start time if the electronic control unit has taken the specific thermal capacity of the house Q and the current heat load ($L \times (T_r - T_e)$) into account. The temperature
15 control process selects the room temperature setpoint T_s for the current time according to the room temperature profile.

Similar steps using any of the above three modes apply to the transition of the central heating system from the ON state to the OFF state. When the central heating system
20 is switched from the ON state to the OFF state the temperature control process selects the low temperature setpoint T_s for the current time according to the low temperature profile.

The temperature control process uses a simple control loop by sending a command to
25 the central heating boiler to provide hot water to the radiators only when the room temperature T_r is less than the relevant temperature setpoint T_s . In practice, there will be some hysteresis (that is slightly different values of temperature setpoint for starting and stopping the heating command) dependant on the specific thermal capacity of the house Q and the minimum running time specified by the central heating boiler
30 manufacturer so that the central heating boiler always runs for an efficient time interval.

CLAIMS

1. An apparatus for controlling the operation of a central heating system for heating and/or cooling a building, the apparatus including:
 - an electrical load sensor for measuring the electrical load of one or more
 - 5 electrical appliances within the building and providing an output signal indicative of the electrical load of the one of more electrical appliances, and
 - an electronic control unit that uses the output signal from the electrical load sensor to control an operation of the central heating system.
- 10 2. An apparatus according to claim 1, wherein the central heating system is capable of operating in a first state and a second state and the electronic control unit uses the output signal from the electrical load sensor to switch the central heating system between the first and second states.
- 15 3. An apparatus according to claim 2, wherein the electronic control unit uses a first inference process to determine when to switch the central heating system between the first and second states.
4. An apparatus according claim 3, wherein the electronic control unit uses the
- 20 output signal from the electrical load sensor as an input to the first inference process.
5. An apparatus according to claim 3 or claim 4, further comprising an activity sensor for measuring activity within the building and providing an output signal indicative of activity within the building.
- 25 6. An apparatus according to claim 5, wherein the electronic control unit uses the output signal from the activity sensor as an input to the first inference process.
7. An apparatus according to any of claims 3 to 6, wherein the electronic control
- 30 unit uses a time-varying prior probability as an input to the first inference process.

8. An apparatus according to any of claim 3 to 7, wherein the electronic control unit uses a user-defined setting as an input to the first inference process.
9. An apparatus according to any of claims 2 to 8, further comprising a first manual switching device that can be manually activated by an operator to switch the central heating system from the first state to the second state for a predetermined period of time.
10. An apparatus according to claim 9, wherein the first manual switching device can be manually activated by the operator a number of times and the predetermined period of time is determined by the number of times the first manual setting device is activated.
11. An apparatus according to any of claims 2 to 10, wherein the electronic control unit further comprises a second manual switching device that can be manually activated by an operator to switch the central heating system from the second state to the first state for a predetermined period of time.
12. An apparatus according to claim 11, wherein the second manual switching device can be manually activated by the operator a number of times and the predetermined period of time is determined by the number of times the second manual setting device is activated.
13. An apparatus according to any of claims 2 to 12, wherein the electronic control unit uses the output signal from the electrical load sensor to derive a first time for switching the central heating system from the first state to the second state and a second time for switching the central heating system from the second state to the first state.
14. An apparatus according to any of claims 2 to 13, wherein the electronic control unit uses a second inference process to derive a first time for switching the

central heating system from the first state to the second state and the second time for switching the central heating system from the second state to the first state.

15. An apparatus according to claim 14, wherein the output signal from the
5 electrical load sensor is stored in a memory and the electronic control unit uses at least a part of the stored output signal as an input to the second inference process.

16. An apparatus according to claim 14 or claim 15, wherein information relating
to when the central heating system is switched between the first and second states is
10 stored in a memory and the electronic control unit uses at least a part of the stored information as an input to the second inference process.

17. An apparatus according to claim 14 when dependent on claim 5, wherein the
output signal from the activity sensor is stored in a memory and the electronic control
15 unit uses at least a part of the stored output signal as an input to the second inference process.

18. An apparatus according to any of claims 13 to 17, wherein the electronic
control unit controls the central heating system to heat and/or cool the building during
20 the period of time between the first time and the second time.

19. An apparatus according to any of claims 2 to 18, further comprising an
internal temperature sensor for measuring the temperature inside the building and
providing an output signal indicative of the temperature inside the building, and
25 wherein the electronic control unit uses the output signal from the internal temperature sensor to control the central heating system to heat and/or cool the building when the temperature inside the building measured by the internal temperature sensor deviates from a temperature setpoint.

30 20. An apparatus according to claim 19, wherein the temperature setpoint is determined with reference to a first temperature profile when the central heating

system is operating in the first state and with reference to a second temperature profile when the central heating system is operating in the second state.

21. An apparatus according to claim 20, wherein at least one of the first and
5 second temperature profiles varies with time.

22. An apparatus according to claim 20 or claim 21, further including an external
temperature sensor for measuring the air temperature outside the building and
providing an output signal indicative of the air temperature outside the building, and
10 wherein the electronic control unit uses the output signal from the external
temperature sensor to modify at least one of the first and second temperature profiles.

23. An apparatus according to any of claims 20 to 22, further comprising a manual
temperature setting device that can be manually activated by an operator to modify at
15 least one of the first and second temperature profiles.

24. An apparatus according to claim 23, wherein the manual activation of the
manual temperature setting device modifies the first temperature profile if the central
heating system is operating in the first state and the second temperature profile if the
20 central heating system is operating in the second state.

25. An apparatus according to any of claims 20 to 24, wherein the first
temperature profile is used to determine a low temperature setpoint that is used by the
electronic control unit when the central heating system is operating in the first state
25 and the second temperature profile is used to determine a room temperature setpoint
that is used by the electronic control unit when the central heating system is operating
in the second state.

26. A method of controlling the operation of a central heating system for heating
30 or cooling a building, the method including the steps of:
measuring the electrical load of one or more electrical appliances within the
building, and

using the measurement of the electrical load to control an operation of the central heating system.

27. A method according to claim 26, wherein the central heating system is capable
5 of operating in a first state and a second state and method further comprises the step
of using the measurement of the electrical load to switch the central heating system
between the first and second states.

28. A method according to claim 27, further comprising the step of using a first
10 inference process to determine when to switch the central heating system between the
first and second states.

29. A method according claim 28, further comprising the step of using the
measurement of the electrical load as an input to the first inference process.

15 30. A method according to claim 28 or claim 29, further comprising the step of
measuring activity within the building.

31. A method according to claim 30, further comprising the step of using the
20 measurement of activity within the building as an input to the first inference process.

32. A method according to any of claims 28 to 31, further comprising the step of
using a time-varying prior probability as an input to the first inference process.

25 33. A method according to any of claim 28 to 32, further comprising the step of
using a user-defined setting as an input to the first inference process.

34. A method according to claim 33, wherein the user-defined setting is indicative
of the lifestyle of the user and is selected by a user from a pre-selected list.

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35. A method according to claim 33, wherein the user-defined setting is a binary setting that biases the electronic control unit in favour of a comfort mode or an economy mode.

5 36. A method according to any of claims 28 to 35, wherein the first inference process is a real-time inference process.

37. A method according to any of claims 27 to 36, further comprising the step of manually switching the central heating system from the first state to the second state
10 for a predetermined period of time.

38. A method according to any of claims 27 to 37, further comprising the step of manually switching the central heating system from the second state to the first state for a predetermined period of time.

15 39. A method according to any of claims 27 to 38, further comprising the step of using the measurement of the electrical load to derive a first time for switching the central heating system from the first state to the second state and a second time for switching the central heating system from the second state to the first state.

20 40. A method according to any of claims 27 to 39, further comprising the step of using a second inference process to derive a first time for switching the central heating system from the first state to the second state and the second time for switching the central heating system from the second state to the first state.

25 41. A method according to claim 40, further comprising the steps of:
storing the measurement of the electrical load in a memory, and
using at least a part of the stored measurement as an input to the second inference process.

30 42. A method according to claim 40, further comprising the steps of:

storing information relating to when the central heating system is switched between the first and second states in a memory, and
using at least a part of the stored information as an input to the second inference process.

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43. A method according to claim 40 when dependent on claim 30, further comprising the steps of:

storing the measurement of the activity within the building in a memory, and

using at least a part of the stored output signal as an input to the second

10 inference process.

44. A method according to any of claims 39 to 43, further comprising the step of controlling the central heating system to heat and/or cool the building during the period of time between the first time and the second time.

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45. A method according to any of claims 26 to 44, further comprising the steps of:
measuring the temperature inside the building, and

using the measurement of the temperature inside the building to control the central heating system to heat and/or cool the building when the temperature inside
20 the building deviates from a temperature setpoint.

46. A method according to claim 45, further comprising the step of determining the temperature setpoint with reference to a first temperature profile when the central heating system is operating in the first state and with reference to a second
25 temperature profile when the central heating system is operating in the second state.

47. A method according to claim 46, wherein at least one of the first and second temperature profiles varies with time.

30 48. A method according to claim 46 or claim 47, further comprising the steps of:
measuring the air temperature outside the building, and

using the measurement of the air temperature outside the building to modify at least one of the first and second temperature profiles.

49. A method according to any of claims 46 to 48, further comprising the step of
5 modifying at least one of the first and second temperature profiles in accordance with the manual activation of a manual temperature setting device.

50. A method according to claim 49, wherein the manual activation of the manual
temperature setting device modifies the first temperature profile if the central heating
10 system is operating in the first state and the second temperature profile if the central heating system is operating in the second state.

51. A method according to any of claims 46 to 50, wherein the first temperature
profile is used to determine a low temperature setpoint that is used when the central
15 heating system is operating in the first state and the second temperature profile is used to determine a room temperature setpoint that is used when the central heating system is operating in the second state.

52. An apparatus for controlling the operation of a central heating system for
20 heating and/or cooling a building, the apparatus including:

an internal temperature sensor for measuring the temperature inside the building and providing an output signal indicative of the temperature inside the building, and

an electronic control unit that uses the output signal from the internal
25 temperature sensor to control the central heating system to heat and/or cool the building when the temperature inside the building measured by the internal temperature sensor deviates from a temperature setpoint determined with reference to a time-varying temperature profile.

53. A method of controlling the operation of a central heating system for heating
30 or cooling a building, the method including the steps of:

measuring the temperature inside the building, and

using the measurement of the temperature inside the building to automatically control the central heating system to heat and/or cool the building when the measured temperature inside the building deviates from a temperature setpoint determined with reference to a time-varying temperature profile.

5

54. A central heating system for heating and/or cooling a building comprising:
a heating and/or cooling device for supplying heating and/or cooling fluid,
a network for distributing the heating and/or cooling fluid to at least one
output device that uses the heating and/or cooling fluid to heat and/or cool the interior
10 of the building, and

an apparatus according to any of claims 1 to 25 or claim 52 for controlling an
operation of the heating and/or cooling device.

10

55. An apparatus substantially as herein described and with reference to Figures 2
15 to 4.

15

Amendments to the claims have been filed as follows

CLAIMS

1. An apparatus for controlling the operation of a central heating system for heating and/or cooling a building and which is capable of operating in a first state and a second state, the apparatus including:

5 an electrical load sensor for measuring the electrical load of one or more electrical appliances within the building and providing an output signal indicative of the electrical load of the one of more electrical appliances, and

an electronic control unit that uses a first inference process to determine when to switch the central heating system between the first and second states,

10 wherein the electronic control unit uses the output signal from the electrical load sensor, user-defined settings and a time-varying prior probability as inputs to the first inference process.

2. An apparatus according to claim 1, further comprising an activity sensor for measuring activity within the building and providing an output signal indicative of activity within the building and wherein the electronic control unit uses the output signal from the activity sensor as an input to the first inference process.

3. An apparatus according to claim 1 or claim 2, further comprising a first manual switching device that can be manually activated by an operator to switch the central heating system from the first state to the second state for a predetermined period of time.

4. An apparatus according to claim 3, wherein the first manual switching device can be manually activated by the operator a number of times and the predetermined period of time is determined by the number of times the first manual setting device is activated.

5. An apparatus according to any preceding claim, wherein the electronic control unit further comprises a second manual switching device that can be manually activated by an operator to switch the central heating system from the second state to the first state for a predetermined period of time.

-35-

6. An apparatus according to claim 5, wherein the second manual switching device can be manually activated by the operator a number of times and the predetermined period of time is determined by the number of times the second manual setting device is activated.

7. An apparatus according to any preceding claim, wherein the electronic control unit uses the output signal from the electrical load sensor to derive a first time for switching the central heating system from the first state to the second state and a second time for switching the central heating system from the second state to the first state.

8. An apparatus according to any preceding claim, wherein the electronic control unit uses a second inference process to derive a first time for switching the central heating system from the first state to the second state and the second time for switching the central heating system from the second state to the first state.

9. An apparatus according to claim 8, wherein the output signal from the electrical load sensor is stored in a memory and the electronic control unit uses at least a part of the stored output signal as an input to the second inference process.

10. An apparatus according to claim 9 or claim 10, wherein information relating to when the central heating system is switched between the first and second states is stored in a memory and the electronic control unit uses at least a part of the stored information as an input to the second inference process.

11. An apparatus according to claim 8 when dependent on claim 2, wherein the output signal from the activity sensor is stored in a memory and the electronic control unit uses at least a part of the stored output signal as an input to the second inference process.

12. An apparatus according to any of claims 7 to 11, wherein the electronic control unit controls the central heating system to heat and/or cool the building during the period of time between the first time and the second time.

5 13. An apparatus according to any preceding claim, further comprising an internal temperature sensor for measuring the temperature inside the building and providing an output signal indicative of the temperature inside the building, and wherein the electronic control unit uses the output signal from the internal temperature sensor to control the central heating system to heat and/or cool the building when the
10 temperature inside the building measured by the internal temperature sensor deviates from a temperature setpoint.

14. An apparatus according to claim 13, wherein the temperature setpoint is determined with reference to a first temperature profile when the central heating system is operating in the first state and with reference to a second temperature profile when the central heating system is operating in the second state.
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15. An apparatus according to claim 14, wherein at least one of the first and second temperature profiles varies with time.

20 16. An apparatus according to claim 14 or claim 15, further including an external temperature sensor for measuring the air temperature outside the building and providing an output signal indicative of the air temperature outside the building, and wherein the electronic control unit uses the output signal from the external
25 temperature sensor to modify at least one of the first and second temperature profiles.

17. An apparatus according to any of claims 14 to 16, further comprising a manual temperature setting device that can be manually activated by an operator to modify at least one of the first and second temperature profiles.

30 18. An apparatus according to claim 17, wherein the manual activation of the manual temperature setting device modifies the first temperature profile if the central

heating system is operating in the first state and the second temperature profile if the central heating system is operating in the second state.

5 19. An apparatus according to any of claims 14 to 18, wherein the first temperature profile is used to determine a first temperature setpoint that is used by the electronic control unit when the central heating system is operating in the first state and the second temperature profile is used to determine a second temperature setpoint that is used by the electronic control unit when the central heating system is operating in the second state.

10

20. A method of controlling the operation of a central heating system for heating or cooling a building and which is capable of operating in a first state and a second state, the method including the steps of:

15 measuring the electrical load of one or more electrical appliances within the building, and

using a first inference process to determine when to switch the central heating system between the first and second states,

wherein the measurement of the electrical load, a user-defined setting and a time-varying prior probability are used as inputs to the first inference process.

20

21. A method according to claim 20, further comprising the step of measuring activity within the building and using the measurement of activity within the building as an input to the first inference process.

25 22. A method according to claim 20 or claim 22, wherein the user-defined setting is indicative of the lifestyle of the user and is selected by a user from a pre-selected list.

30 23. A method according to claim 22, wherein the time-varying prior probability is a predefined time-varying prior probability based on the user-defined setting that is indicative of the lifestyle of the user.

24. A method according to claim 20 or claim 21, wherein the user-defined setting is a binary setting that biases the electronic control unit in favour of a comfort mode or an economy mode.

5 25. A method according to any of claims 20 to 24, wherein the first inference process is a real-time inference process.

26. A method according to any of claims 20 to 25, further comprising the step of manually switching the central heating system from the first state to the second state
10 for a predetermined period of time.

27. A method according to any of claims 20 to 26, further comprising the step of manually switching the central heating system from the second state to the first state for a predetermined period of time.

15

20

28. A method according to any of claims 20 to 27, further comprising the step of using the measurement of the electrical load to derive a first time for switching the central heating system from the first state to the second state and a second time for switching the central heating system from the second state to the first state.

20

29. A method according to any of claims 20 to 28, further comprising the step of using a second inference process to derive a first time for switching the central heating system from the first state to the second state and the second time for switching the central heating system from the second state to the first state.

25

30. A method according to claim 29, further comprising the steps of:
storing the measurement of the electrical load in a memory, and
using at least a part of the stored measurement as an input to the second inference process.

30

31. A method according to claim 29, further comprising the steps of:

storing information relating to when the central heating system is switched between the first and second states in a memory, and
using at least a part of the stored information as an input to the second inference process.

5

32. A method according to claim 29 when dependent on claim 21, further comprising the steps of:

storing the measurement of the activity within the building in a memory, and

using at least a part of the stored output signal as an input to the second

10 inference process.

33. A method according to any of claims 28 to 32, further comprising the step of controlling the central heating system to heat and/or cool the building during the period of time between the first time and the second time.

15

34. A method according to any of claims 20 to 33, further comprising the steps of:

measuring the temperature inside the building, and

using the measurement of the temperature inside the building to control the central heating system to heat and/or cool the building when the temperature inside the building deviates from a temperature setpoint.

20

35. A method according to claim 34, further comprising the step of determining the temperature setpoint with reference to a first temperature profile when the central heating system is operating in the first state and with reference to a second temperature profile when the central heating system is operating in the second state.

25

36. A method according to claim 35, wherein at least one of the first and second temperature profiles varies with time.

30 37. A method according to claim 35 or claim 36, further comprising the steps of:
measuring the air temperature outside the building, and

using the measurement of the air temperature outside the building to modify at least one of the first and second temperature profiles.

38. A method according to any of claims 35 to 37, further comprising the step of
5 modifying at least one of the first and second temperature profiles in accordance with the manual activation of a manual temperature setting device.

39. A method according to claim 38, wherein the manual activation of the manual
10 temperature setting device modifies the first temperature profile if the central heating system is operating in the first state and the second temperature profile if the central heating system is operating in the second state.

40. A method according to any of claims 35 to 39, wherein the first temperature
15 profile is used to determine a first temperature setpoint that is used when the central heating system is operating in the first state and the second temperature profile is used to determine a second temperature setpoint that is used when the central heating system is operating in the second state.

41. A central heating system for heating and/or cooling a building comprising:
20 a heating and/or cooling device for supplying heating and/or cooling fluid,
a network for distributing the heating and/or cooling fluid to at least one output device that uses the heating and/or cooling fluid to heat and/or cool the interior of the building, and

an apparatus according to any of claims 1 to 19 for controlling an operation of
25 the heating and/or cooling device.

42. An apparatus substantially as herein described and with reference to Figures 2 to 4.



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Application No: GB0522544.6

Examiner: Mr Tyrone Moore

Claims searched: 1-55

Date of search: 17 February 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 26, 54 at least.	GB 2408592 A (OSWALD JAMES IAN et al.) See whole document.
X	1, 26, 54 at least	JP 2005283028 A (OSAKA GAS CO LTD.) See WPI, PAJ abstract and figures. AN-2005-718239 [74]
A	-	GB 2218540 A (MICROLEC FRANCHISING LIMITED) See whole document.
A	-	US 4217646 A (SINGER CO.) whole document. See

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X:

G3N

Worldwide search of patent documents classified in the following areas of the IPC

G05B; G05D

The following online and other databases have been used in the preparation of this search report

WPI; EPODOC.



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Application No: GB0522544.6

Examiner: Mr Tyrone Moore

Claims searched: 52, 53 and 54

Date of search: 7 April 2006

Patents Act 1977 Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	52, 53, 54	EP 0736826 A2 (WILO GMBH) WPI abstract and figures. See
X	52, 53, 54	EP 0444308 A1 (BUDERUS HEIZTECHNIK GMBH) See WPI abstract and figures.
X	52, 53, 54	US 2003/050737 A (OSANN R) whole document, particularly paragraphs [0127]-[0130]. See
X	52, 53	US 5790437 A (WATLOW ELECTRIC MFG) See whole document.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

G3N

Worldwide search of patent documents classified in the following areas of the IPC

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