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# (54) A comfort controls system

(57) A domestic heating system 20 serving a space-heating circuit 2 and a domestic hot waster circuit 4 has: a base unit 21 which is located next to boiler 7 and which monitors and controls operations of the system 20; a room unit 22 located in a room containing radiator 3 of the space-heating circuit 2; a mid-position valve 23; a cylinder sensor 24 and a frost kit 25.

Base unit 21 has a microprocessor-run communications and control function to process appropriate information from the elements of system 20 and to ensure suitable operation of those elements at all times.

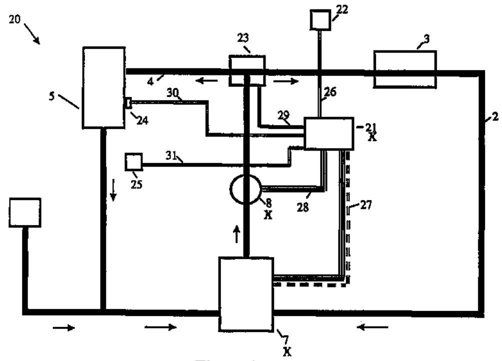


Figure 2

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## Description

**[0001]** The present invention relates to a comfort controls system and a method of operating a comfort controls system.

**[0002]** Typically, a conventional heating system with separate hot water and space-heating circuits has a boiler and a pump controlled by a room thermostat, a timer-unit, a mid-position valve and a cylinder thermostat.

**[0003]** However, this conventional apparatus has the disadvantage that it requires numerous electrical connections between the various components, many of them being at electrical mains supply voltage levels. Thus it is normally necessary to have an experienced electrician to wire up the electrical components. Also, some of the components may be located in inaccessible places, sometimes under flooring, thereby causing wiring-up of the system to be slower and more difficult.

**[0004]** One approach, which has been taken in the past, in an attempt to overcome various disadvantages, is to utilise radio-frequency links, for example between a room thermostat and a timer. However, this feature is of limited benefit because it cannot be used for power transfer and is only of use in reducing the length of wiring used and does not reduce the mains wiring complexity and number of terminations . In some installations there may be positioning constraints due to wall construction material and adjacent appliances and furniture.

**[0005]** According to the present invention, there is provided a comfort controls system comprising:

a boiler to provide water at a raised temperature,
a pump to circulate heated water around the system,
storage means for part of the water heated by the boiler,
radiator means to provide space heating,
a room unit for provision of heating and/or hot water demand,
a base unit to control operation of the boiler and pump, and linkage means and a communication protocol to provide a two-wire low voltage dc power and data transfer between the base unit and the room unit.

**[0006]** In this way, a system embodying the present invention may provide a reduced number of connections between components as compared to conventional systems, with consequential easier and faster installation of the system. Moreover, such a system may more readily be installed without requiring the assistance of an experienced electrician.

**[0007]** Furthermore, a system embodying the present invention allows the use of low voltage links, typically between 8V and 25volts, whether a.c. or d.c., thereby ensuring that the system can be installed more safely (whether by an experienced electrician or not) than can conventional systems. Additionally, the system provides safer operation, not only by virtue of the extensive use of low voltages reducing the likelihood of malfunctioning of components caused e.g. by over- heating, but also by virtue of there being reduced consequential damage to property and people from malfunctioning of the system or components, howsoever caused.

**[0008]** The system may include the features as defined in any one or more of Claims 2 to 9.

**[0009]** The present invention also provides a method of operating a comfort control system having a boiler to provide water at a raised temperature, a pump to circulate heated water around the system, storage means for at least part of the water heated by the boiler, radiator means to provide space-heating, a room unit for provision of heating and/or hot water demand, the method comprising a base unit controlling operation of the boiler and pump and providing a two-wire low voltage dc power and data link with a communication protocol between the base unit and the room unit.

**[0010]** The method may include any one or more of the preferred featues as defined in Claims 11 or 12.

**[0011]** The present invention also provides a computer program product directly loadable into the internal memory of a digital computer, comprising software code portions for performing the steps of the method of the present invention when said product is run on a computer.

**[0012]** The present invention also provides a computer program product stored on a computer usable medium, comprising:

computer readable program means for causing a computer to control a base unit for operation of a boiler to provide water at a heated temperature in a comfort control system including storage means for at least part of the water heated by the boiler, radiator means to provide space-heating, a room unit for provision of heating and/or hot water demand;
computer readable program means for causing the computer to control a linkage means and a communication protocol to provides a two-wire low voltage dc power and data transfer between the base unit and the room sensor.

**[0013]** The present invention also provides electronic distribution of a software program according to the present invention.

**[0014]** The system of the present invention may include any one or more of the following features:

- a first circuit for the passage of water at a raised temperature to provide space heating,
  a base unit to control operation of a boiler and pump to provide heated water for space heating to at least the first circuit, means to provide a hard-wire dedicated power link between the base unit and at least one ancillary unit to provide additional functionality for the system.

  - the base unit provides a regulated supply and an unregulated supply.
  - the power link provides a DC supply.
  - linkage means and a communication protocol to provide a power and data transfer between the base unit and the room unit.
  - the at least one ancillary unit communicates with the base unit and/or other components of the system using the linkage means and communication protocol.
  - the data transfer between at least one of the base unit, the room unit and the at least one ancillary unit includes a radio frequency transmission link.
  - the ancillary unit provides an additional zone for space heating.
    The method may include any one or more of the following:
  - providing a two-wire low voltage dc power and data link with the communication protocol between the base unit and a second room unit for a second zone for space-heating.
  - providing a two-wire low voltage dc power and data link using the communication protocol between the base unit and at least one further component of the system.
  - providing a data link only using the communication protocol between the base unit and at least one further component of the system.
  - the base unit power the pump.
  - the base unit power the boiler.
  - the power link provides an unregulated supply.
  - the base unit provides a regulated supply and an unregulated supply.
  - the at least one ancillary unit communicates with the base unit and/or other components of the system using the linkage means and communication protocol.
  - using a radio frequency transmission link for the data transfer between at least one of the base unit, the room unit and the at lest one ancillary unit.
  - The ancillary unit provides an additional zone for space heating.

**[0015]** The invention is particularly applicable to heating control systems, and especially but not solely to domestic heating systems; the invention may also be applicable to systems incorporating cooling and/or ventilating systems for small to medium size locations, for example in commercial or industrial premises.
**[0016]** In order that the present invention may more readily be understood, a description is now given, by way of example only, reference being made to the accompanying drawings, in which:-

Figure 1 is a schematic diagram of a conventional domestic heating system showing the water flow and the control signal paths;
Figure 2 is a schematic diagram of a domestic heating system embodying the present invention;
Figure 3 shows the configuration of the electric components in the system of Figure 2;
Figure 4 shows schematically movement of a valve of the system of Figures 2 and 3;
Figure 5 shows the configuration of the electric components of a second embodiment of the present invention;
Figure 6 shows the bus timing sequences for signals of the systems of Figures 2 and 5;
Figure 7 shows the power period timing of the systems of Figures 2 and 5;
Figure 8 shows a circuit of part of the systems of Figures 2 and 5; and
Figure 9 shows the internal functions of part of the systems of Figures 2 and 5.

**[0017]** Figure 1 shows one type of conventional heating system 1 incorporating a space-heating circuit 2 represented by a set of radiators 3 (only one being shown) and a domestic hot water circuit 4 represented by hot-water cylinder 5 with cylinder thermostat 6. The system 1 includes a boiler 7 to provide heated water, a pump 8 to pass the heated water around system 1, a mid-position valve 9 which passes water to either or both circuits 2 and 4 selectively as required by the system 1, a room thermostat 10 to provide temperature information on space-heating, and a timer 11 to control the time, optionally also the temperature, operation of the system 1.
**[0018]** Details of the operation of these various components and the system as a whole are given in British Patent Specification No. 2026794B. System 1 requires cylinder 5, boiler 7, pump 8, and mid-position valve 9 to be powered

from the electrical mains supply, and timer 11 is powered either by the electrical mains supply or by an internal dry-cell battery; also, cylinder thermostat 6 uses mains voltage. Each component of system 1 requiring mains power is shown with a symbol being a dot with an "x" through it, while timer 11 also has a "B" against it indicating that it can be powered by battery. If mid-position valve 9 is replaced by two zone valves, each has to be also powered from the electrical mains supply.

**[0019]** As can be seen from Figure 1, system 1 also requires numerous links between the various electrical components in order to ensure appropriate control of the operations of the system. Attempts to facilitate wiring-up and installation of a system as in Figure 1 by incorporating a wiring centre can actually increase significantly the number of electrical connections which must be made, for example there may well be of the order of 35 connections even for a straightforward implementation of a system as shown in Figure 1. The consequential complexity typically results in the installer of a heating system needing to employ an electrician to handle the wiring-up of the components, thereby adding significant overall cost and possibly slowing down the speed of installation of the system.

**[0020]** Figure 2 shows a domestic heating system embodying the present invention while serving a space-heating circuit 2 and a domestic hot water circuit 4 identical to that of Figure 1. In Figure 2, where a feature is identical to that in Figure 1, the same numeral is used. System 20 has: a base unit 21 which is located next to boiler 7 and which monitors and controls operations of the other elements of system 1; a room unit 22 located in a room containing radiator 3 of the space-heating circuit 2; a mid-position valve 23; a cylinder sensor 24 and a frost kit 25 (comprising a low voltage frost thermostat and pipe thermostat connected in series).

**[0021]** Base unit 21 has a microprocessor-run communications and control function to process appropriate information from the elements of system 20 and to ensure suitable operation of those elements at all times.

**[0022]** A two-wire D.C. bus 26 links base unit 21 and room unit 22 such that bus 26 provides the transfer therebetween of signals conforming to a communication protocol and containing multiplexed power and data, for example temperature sensing data coming from room unit 22 and operational data of base unit 21.

**[0023]** Base unit 21 has a three-wire (Switched Live, Neutral and Earth) link 27 with boiler 7 to send power signals at electrical mains voltage levels to operate and power boiler 7 when required. In the case of a pump-overrun boiler, an extra two wires may be present to carry the pump-overrun signal and a (permanently) Live supply.

**[0024]** Base unit 21 has a three-wire (Live, Neutral and Earth) link 28 with pump 8 to send a power signal at electrical mains voltage levels to operate and power pump 8 when operation of it is required.

**[0025]** Further details of the electrical links between elements of system 20 are given in Table 1.

TABLE 1

| Electrical connections in system 20 from base unit 21. | | | | |
|---|---|---|---|---|
| Component | Physical Link with base unit 21 | Voltage Level | Information | Power |
| Room unit (22) | 2-wire bus 26 | Low DC | CH Demand, DHW Demand, Diagnostics, Status, etc. | Yes |
| Boiler (7) | 3 to 5 wire 27 | 230v AC | ON/OFF, Pump Overrun | Yes |
| Pump (8) | 3-wire 28 | 230v AC | ON/OFF | Yes |
| Mid-position valve (23) | 2-wire 29 | Low DC | Direction | Yes |
| Cylinder sensor (24) | 2-wire 30 | Low DC | Resistance | N/A |
| Frost kit (25) | 2-wire 31 | Low DC | Call for Heat | N/A |

**[0026]** Figure 9 shows the functional blocks that constitute the base unit 21. Power supply 70 produces safety-isolated low voltage supplies from the mains supply to power the other blocks within the base unit 21 and also to power other devices external to base unit 21 within the system 40 described later. The microcontroller circuit 71 comprises a microcontroller, containing a stored control program which controls and responds to the other blocks within 21 to implement the overall functions of base unit 21 and microcontroller support functions such as oscillator and reset circuitry. Relay and drive circuit 72 switches mains to boiler 7 and pump 8. Microcontroller 71 switches the relay drive 72 at a duty cycle in accordance with heat demands received via communication bus 26. Frost kit interface 73 converts the switch closure demand from the frost kit 25 into a logic level for microcontroller 71 which controls the relay and drive circuit 72 and valve drive 75 to satisfy this demand. Communications interface 74 switches 12V DC power to bus 26 in response to a regular control pulse from microcontroller 71 at the communications bit rate to power devices such as room unit 22. Communications interface 74 also converts a signal produced by microcontroller 71 to bus signal levels to synchronise bit-level communication on bus 26. This signal is also used to send data from the base unit 21 to other devices on the bus. Communications interface 74 also detects communications on the bus and converts bus signal levels into logic levels. Generation and processing of messages is accomplished by microcontroller 71. Messages are used to control other functions within base unit 21 and to send base unit 21 status information to other devices on bus 26 such as room unit 22. Valve drive 75 uses control signals from microcontroller 71 to switch power to valve 23 (or valves 44 and 45 in system 40 as described later) in accordance with heat demand messages received via the communications interface 74 or frost kit input signal. It also includes protection against a short circuit across the terminals and signals this information to microcontroller 71. It also sends feedback on the presence of actuator current to allow control of valve position. Cylinder sensor interface 76 converts the resistance of cylinder sensor 24 which is an NTC thermistor into a pulse whose width corresponds to the resistance of the sensor. The microcontroller 71 initiates the pulse and measures the time till the end of the pulse. It also initiates measurement of two reference resistances within interface 76 and uses these time measurements to calculate the cylinder temperature based on the thermistor characteristic specification.

**[0027]** Base unit effects valve synchronisation to ensure that the valve 23 is moving correctly in both directions, calculates the time required to reach the mid position and does not assume any initial start position. The valve synchronisation is done in three operations:-

1. The valve is driven fully to the B position. Arrival at the B position is detected via the CurrentSense signal. If the arrival at the B position does not occur within a nominal maximum time, then the unit assumes an actuator jam fault. There is no minimum time for the arrival at B.

2. The valve is driven to the A position, again terminated by the CurrentSense signal. The time taken to travel is measured, and halving the B to A travel time gives the mid position time. The newly calculated mid position time is compared with the previous mid position time. If a previous time is not available, a nominal mid position is used. If the CurrentSense signal is not detected within the nominal travel time plus a tolerance, then the unit will assume an actuator jam fault. If the new travel time is less than the nominal time minus a tolerance, then the unit assumes a valve jam fault.

3. The valve is driven to the AB position, terminated on the mid-position time. If the CurrentSense signal is detected during this operation, the unit will assume a valve jam fault has occurred.

**[0028]** The timing tolerance for the valve synchronisation is initially wide (+/- 1.8 seconds) to allow for a fairly large variance in travel times between valves, but subsequently a tighter tolerance is used (+/- 0.6 seconds).

**[0029]** Thus, base unit 21 determines the mid-position for valve 23 by measuring the time ($t_m$) taken for the actuator to move between the rest positions A and B, (normally of the order of 10 to 12 seconds), and then calculating the time $t_m$ which would be taken to reach mid-position from either stop, $t_m$ being calculated as half of $t_s$. This procedure is done each time the system is powered-up, and also at a specified time (midday) each day, thereby ensuring that the accurate positioning of valve 23 at the mid-position is maintained, and minimizing the possibility of the actuator becoming stuck against either stop, (e.g. by the build-up of detritus from the water). Once this procedure is completed, the actuator is returned to whatever state is contemporaneously required by the system. This valve positioning method allows accurate positioning of the actuator while being insensitive to water flow or water fluctuations, ensures that the valve is operating in both directions and calculates the time required to reach the mid-position.

**[0030]** The actuator run time $t_s$ is also used by base unit 21 as a position indicator to allow detection of fault conditions as described elsewhere herein. If system 20 has two zone valves instead of mid-position valve 23, then the above procedure is effected for each valve, preferably sequentially in order to limit the maximum instantaneous power requirement; time measurement is still done in order to establish the "full flow" position of each valve, being determined as midway between the two stops for a valve; also, time measurement is used in the detection of fault conditions as described elsewhere herein. Thus, for example, from whatever state each valve is in, the HW valve is operated to be in the fully-closed state and then the actuator is moved mid-way between the two stops so that the HW valve is now in the fully open state. Thereafter, the sequence is repeated for the CH valve with its actuator first being moved to one stop and then to mid-way between the two stops. Then each of the two valves is put into whatever mode is appropriate to the existing demand signals. This procedure is done each time the system is powered up, and also at the specified time (midday) each day; normally, the time taken to travel between stops is of the order of 10 to 12 seconds. The procedure ensures that synchronization of the two valves is maintained.

**[0031]** With regard to the form of valve used, the type of heating system incorporating a mid-position valve in the manner as illustrated in Figures 1 or 2 is known conventionally as a Y-plan system, the distinctive characteristic of which is that the valve controls the system to provide the following operational modes:-

(a) water flow only to domestic hot water circuit 4;

(b) water flow only to space-heating circuit 2;

(c) water flow to both circuits simultaneously.

**[0032]** Another conventional valve arrangement of a heating system (known generally as the S-plan system) has two zone valves instead of mid-position valve 23, each valve being located in one of the circuits 2 and 4, thereby providing the following operational modes:-

(a) water flow only to HW circuit 4;
(b) water flow only to CH circuit 2;
(c) water flow to both circuits simultaneously.

**[0033]** Another conventional valve arrangement of a heating system (known generally as the W-plan system) has a single three-port valve whereby this valve gives preference to any calls for heat from the HW circuit 4 over calls for heat from the CH circuit 2, thereby providing the following operational modes:-

(a) water flow only to HW circuit 4;
(b) water flow only to CH circuit 2;
(c) water flow only to HW circuit 4 in preference to a simultaneous call from CH circuit 2, and then water flow only to CH circuit 2 once HW circuit 4 ceases calling for heat.

**[0034]** Turning back to the details of the operation of the valve in the present invention, the Valve Status messages reported by base unit 21 indicates the position of the valve as shown in Table 2. The data is encoded, with "0" to represent closed, "50" to represent moving, and "100" to represent open. The valve status does not indicate that CH or HW is actually being serviced (as the boiler/pump may be turned off) just that the valve is "open", "closed" or "moving". In Table 2 for the Y-plan configuration, the 3-port mid-position valve function is separated into its two constituent functions, one for CH and one for HW, and the positions in Table 2 reflect these two functions. Note that in the Y-plan configuration at least one of the outlet ports is always open (position 100), since the three-port valve cannot close both outlet ports at the same time. For the S-Plan configuration the positions in Table 2 apply to both the CH and the HW valve independently.

TABLE 2

| Valve positions as reported by base unit | | | |
|---|---|---|---|
| | **Y-plan** | | **S-plan** |
| | **CH Valve Port** | **HW Valve Port** | |
| **At A** | 0 | 100 | 0 |
| **Moving A to AB** | 50 | 100 | 50 |
| **At AB** | 100 | 100 | 100 |
| **Moving AB to B** | 100 | 50 | 100 |
| **At B** | 100 | 0 | 100 |
| **Moving B to AB** | 100 | 50 | 100 |
| **At AB** | 100 | 100 | 100 |
| **Moving AB to A** | 50 | 100 | 50 |
| **Unknown (Init.)** | 0 | 0 | 0 |

**[0035]** In the above, the initial valve position is reported as "closed". At initialisation, the state is unknown and is reported as "closed". The Valve Status messages can also take on other values to represent error conditions.
**[0036]** There are four possible valve faults, three of which are shown in Figure 4.

1. Actuator Open Circuit - The valve is driven for longer than a fixed maximum time, without the "CurrentSense" signal indicating the end of travel.
2. Actuator Short Circuit - The "OverCurrent" input is detected whilst a valve is being driven.

3. Valve Jam - The valve is driven, the "CurrentSense" signal detects movement, but end of travel is detected before a fixed minimum time has elapsed.

4. Actuator Jam - The valve is driven and the "CurrentSense" signal does not detect movement, but it detects an end of travel before the minimum time has elapsed.

**[0037]** The expected mid position time is 3.48 seconds, and the tolerance is +/- 1.8 seconds. An "actuator jam" fault is not detected when moving a 3 port valve to its mid-position or a 2 port valve to the open position as this movement does not involve the actuator in interrupting the current. The jam would be detected when the 3 port valve was moved to either CH only or HW only, or the 2-port valve was closed.

**[0038]** If any of the valve faults are detected, the base unit will "retry" the valve, by performing a valve synchronisation. If two retries are unsuccessful, then the base unit will signal the failure to the room unit via the appropriate Valve Status message.

**[0039]** In a Y-plan system, if a fault occurs, the fault code is reported in both the CH valve status message and the HW valve status message. Further retries then occur at the end of each boiler cycle (typically there are 6 cycles an hour, so a cycle is every 10 minutes). If one of the retries is successful, then the fault is cleared. Once a valve fault is detected and reported, no other further valve faults are reported until the initial fault is cleared e.g. if a valve jam is detected and then the valve is disconnected, the room unit will not show an actuator open circuit.

**[0040]** The "OverCurrent" signal is used to detect valve over-current faults. During normal operation, the "OverCurrent" signal should remain inactive unless a current fault has occurred. The "CurrentSense" signal is used to detect the end of travel of a valve. When a valve is moving, there will be current flowing in the drive circuit and the "CurrentSense" input will go to the active state (see Table 3). It remains active until the valve reaches an end position and the current stops. The signals are sampled and debounced every 333 useconds. However, they are acted upon in the main control routine which executes every 60 mseconds only. Thus, the maximum delay before a change in the signals is detected and acted upon is just over 60 mseconds.

TABLE 3

| Valve signals | | |
|---|---|---|
| | **Inactive** | **Active** |
| **OverCurrent** | OverCurrent fault not detected | Overcurrent fault detected |
| **Current-Sense** | No valve connected. Valve not being driven. Valve at end of travel. | Valve actuator is being driven and is drawing current. |

**[0041]** The boiler is cycled at a rate set by the room. Control (where demand is between 0% and 100%) is achieved by cycling the valve or boiler. The cycle period is the duration of one complete "boiler on-off" cycle, timed to a resolution of 15 seconds. For a rate of 6 cycles per hour, the cycle period is 10 minutes i.e. 40 increments. At the end of each cycle period, the demands are convened from percentages to "on" durations. To prevent the boiler being turned on for a very short time, if the larger of the two demands is less than 10%, then they are both rounded down to 0%. Similarly to prevent the boiler being turned off for a short time, if the larger of the two demands is greater than 90%, it is rounded up to 100%. These limits result in a "boiler minimum on-time" and "boiler minimum off-time" of 1 minute for a 6 cycles per hour system.

**[0042]** The "on" duration is compared with the current cycle time. If the current cycle time is less than the "on-time" then a CH demand signal is generated. If the time is greater than the "on time" then the demand signal is cleared. These demand signals are used to make decisions on valve movements as described earlier. If the demand changes by more than 40%, or if either of the demand change to or from 0%, then the cycle is effectively aborted and a new cycle started. This is to ensure quick reaction to large changes in demand.

**[0043]** For a Y-plan system, if there is no fault reported on the valve, then the boiler is turned on when the demand requests it. For an S-plan system, if there is no fault reported on the valve and at least one of the valves is in the open position then the boiler is turned on when demand requests it. If a zone unit requests heating, the boiler is turned on.

**[0044]** Installation of system 20 is done as follows. Base unit 21 is fixed on to a wall in a location allowing ready access for the installer and for anyone servicing the system and preferably adjacent to the valve 23 and cylinder 5 to facilitate plugging valve 23 and sensor 25 in to base unit 21 using the cables supplied with the system. Also, preferably, the chosen location of base unit 21 is convenient for connection to pump 8 and/or boiler 7.

**[0045]** Cabling 36 (this time cable suitable for supplying electrical mains supply and normally flexible) is likewise laid and terminated between base unit 21 and boiler 7, also cabling 27 between base unit 21 and pump 8. If a pump-overrun arrangement is not used i.e. boiler 7 is a basic boiler, cable 36 has three wires (2+earth). If boiler 7 is a "pump overrun" boiler, then cable 36 uses five-wire cabling (4+earth). Cabling 27 is three-wire (normally flexible) cable (2 + earth).

**[0046]** Room unit 22 is then fixed on to a wall in a location suitable for the occupant of the building to view it and to make any required programming or adjustments of the operation of system 20; two-wire cabling 35, suitable for supplying low voltage bus 26, is laid between base unit 21 and room unit 22, and the ends of the cabling 35 are secured onto electrical terminations at base unit 21 and room unit 22.

**[0047]** Optionally, if frost protection of exposed pipework is required, two-wire cabling 39 suitable for low voltage, is laid between base unit 21 and the frost kit comprising a low voltage frost thermostat 24 and a low voltage pipestat 25 connected in series; the ends of the cabling 35 are secured onto electrical terminations at base unit 21 and either frost thermostat 24 or pipestat 25, depending on the series wiring arrangement of the kit.

**[0048]** Then a cable 38, which has a plug at each end, is fitted into appropriately marked sockets in base unit 21 and mid-position valve 23. The socket in the valve is to facilitate installation and servicing if the valve 23 is installed remote from the base unit 21. Likewise, a cylinder sensor 24, attached to 39 with a plug on the other end, is then connected to base unit 21 by inserting the plug into an appropriately marked socket in base unit 21. Once these connections have been made, system 20 is ready for system commissioning to begin, by powering up of base unit 21.

**[0049]** In system 20, complex mains connections associated with the cylinder sensor, valve, timer and optional frost kit in conventional systems have been removed and replaced with simple point-to point low voltage connections. The remaining mains connections to supply spur, boiler and pump have been simplified to point-to-point wiring topologies and are within the capability of an installer with basic electrical training or even a D-I-Y enthusiast.

**[0050]** Base unit 21 has the facility to interrogate the system to check/determine the type of system installed and accordingly ensure that the system operates in an appropriate manner. The interrogation occurs as part of the commissioning or power-on routine of the system; also the interrogation can be initiated at any time after commissioning while system 20 is powered, for example by holding down two override buttons, for hot water and heating, on room unit 22 for five seconds.

**[0051]** In the interrogation routine, base unit 21 applies a driving signal to its two valve sockets and monitors any resultant current as described above to determine if a valve is connected to the sockets. This facility can be used in two ways - one where information on the intended system is not provided and one where it is provided.

**[0052]** In the first case, once base unit 21 recognises the system from the valve configuration, the installer compares this value with what he intended and, if different, he corrects the valve connections. In the second case, the installer sets the intended configuration and, after base unit 21 checks the valve configuration, it is able to highlight the specific discrepancies.

**[0053]** In the first case:-

a) If a valve is detected at the CH socket but none at the HW socket, base unit 21 assumes that the system is a Y-plan (or a W-plan system) and that the valve is a mid-position valve. If this was in fact intended to be an S-plan system but the CH valve was not plugged in properly, the installer would recognise the discrepancy from the displayed system and correct the problem.

**[0054]** If a valve is detected at both sockets, the base unit 21 assumes that the system is an S-plan system and that the two valves are zone valves.

**[0055]** If a valve is detected in the HW socket but none in the CH socket, base unit 21 assumes that the system is an S-Plan with the CH valve not correctly connected and flags an open circuit CH valve. This may have been intended as a Y-plan but with the valve plugged in the wrong socket, but the installer would recognise the discrepancy in the system code and correct the error.

**[0056]** If no valves are detected, then an invalid system is indicated and open circuit faults for CH and HW valves would be flagged.

**[0057]** Once a correct system is identified, the value is stored in non-volatile memory so that the system does not incorrectly re-configure on loss of power. An installer action is required to re-initiate system configuration. This is particularly necessary in the case of loss of power after a valve open-circuit fault condition.

**[0058]** In the second case, a selector switch in base unit 21 selects the intended system configuration - a Y-plan system or an S-plan system. This selector switch can either be a physical switch or a selection made by the installer via room unit 22, stored in non-volatile memory.

**[0059]** If the selector switch is in the Y-plan position and :-

- a valve is detected at the CH socket but none at the HW socket, base unit 21 recognizes the system as a valid Y-plan (or a W-plan system) and assumes that the valve is a mid-position valve;
- a valve is detected at both sockets, base unit 21 treats the valve in the HW socket as an error and flags a fault;
- no valves are detected at either socket, then base unit 21 flags a CH valve open circuit fault.

If the switch is in the S-plan position and:-

- a valve is detected at both sockets, base unit 21 recognizes the system as a valid S-plan system and assumes the two valves are zone valves;
- a valve is detected at the HW socket but none at the CH socket, base unit 21 flags an open-circuit fault at the CH socket;
- no valves are detected at either socket, then base unit 21 sees it as open-circuit faults on both valve sockets. One fault would be flagged on the room unit till it was rectified then the other would be displayed.

**[0060]** With regard to the valve actuator drive operation, base unit 21 drives a DC actuator at 8V, the actuator having a DC motor with a 470uF capacitor in parallel and steering diodes with a switch contact in series to shut off the current when the end position is reached. After shutoff, the other steering diode provides a path to drive the actuator in the opposite direction.

**[0061]** The actuator drive circuit drives both the CH and the HW valve actuators. As the valves operate one at a time, they share a common drive circuit which is one half of the H-bridge arrangement associated with each valve.

**[0062]** The actuator control circuit monitors the current through the drive circuit (actuator current) to determine when the actuator is consuming current within the normal running limits, and when the actuator has switched the current off at the ends of travel. It is also used to determine if the actuator drive output is open circuit or short circuit. Software measures the time for end-to-end travel is measured by the control program in microcontroller 71 to check for stuck valve or actuator and to provide the duration to power the actuator to the mid-position. The current is measured using a resistor in series with the actuator drive and is amplified using an op-amp. The amplified signal is fed to a comparator circuit which is set to a level equivalent to a current of around 5mA in the actuator. This threshold is set to detect the presence of current and is low compared to the normal running current of the actuator (10-30mA). A filtering function is performed to provide immunity to current dropouts which occur due to the commutator of the motor. The bias is in favour of current presence, i.e. takes longer to recognise the current presence than its absence. The resulting signal is fed to the processor.

**[0063]** The amplified current signal is also fed to a threshold detector set to switch at a voltage equivalent to a current of 200mA nominal. This is then fed back to the actuator supply regulator and reduces the supply voltage to limit the current to 200mA. A low pass filter is provided to prevent instability of the supply. This current limiter is necessary due to the charging current of the 470uF capacitor across the actuator motor.

**[0064]** The current limiter is also an essential part of the protection against an actuator short circuit condition. When a short circuit is present, the current goes to the 200mA limit. The current signal is delayed using an RC filter and when the delayed signal exceeds a threshold corresponding to 140mA, the actuator drive is switched off. When the current switches off, the capacitor in the RC filter discharges until a lower current threshold is reached when the current is switched on again and the cycle is repeated. This oscillation continues until the processor reacts to the overcurrent signal and switches the drive off to the actuator. Resistors are chosen to give a low duty cycle (around 15%) which protects a transistor having a heatsink sufficient to cope with a short circuit indefinitely.The drive transistors themselves are held in saturation to avoid dissipating heat there.

**[0065]** The circuit provides an initial delay period of around 60mseconds before invoking the protection to cater for the actuator which for a period of around 20msec keeps the current limit active while its capacitor charges. If the protection circuit activated during this time, the capacitor would not charge and the actuator would not move.

**[0066]** All sockets on the base unit are of the same basic type, i.e. they are mechanically the same but have different numbers of terminal positions populated. In one implementation, the sockets are of the FCC68 Modular Jack type with 6 contact positions, but with different positions populated.

**[0067]** Valve 23 connects to base unit 21 using a 4 pin modular jack (6way FCC68 Modular plug with middle 4 pins populated). The common drive signal connects to the middle two pins (3 and 4) and the CH (or HW) drive signal connects to the adjacent pins (2 and 5). As valve 23 is connected to pins 2 and 3 of its modular plug, this provides insensitivity to the use of a cable which is flipped about the centre which might occur when the installer makes an extension cable. If an external module is plugged into the socket, damage does not occur as pins 2 and 4 are open circuit, so there is no path for the current. The valve sees this as an open circuit. If a sensor is plugged into the valve socket, no damage occurs, as this results in connection between pins 3 and 4 which are connected together - this will also be seen as open circuit.

**[0068]** Once base unit 21 has done appropriate analysis of the current states, room unit 22 can be interrogated to display a code indicating the type of system detected by base unit 21; the codes are as follows:-

| Code | System detected |
|---|---|
| 0 | invalid system |
| 1 | Y-plan |
| 2 | S-plan |
| 3 | W-plan |

**[0069]** The interrogation routine can be initiated at any time, e.g. by holding down the two override buttons on room unit 22, which will then display the code appropriate to the system it has detected.

**[0070]** Base unit 21 uses the information derived from the interrogation routine in the normal operation of system 20. Thus, for example, once base unit 21 has determined that system 20 is a Y-plan system whereby valve 23 is a mid-position valve, then base unit 21 controls valve 23 in the "mid-position valve" manner according to the appropriate CH and HW demands, as shown in Table 4.

TABLE 4

| Actuator position according to circuit demands for Y-plan | | |
|---|---|---|
| CH Demand | HW Demand | Actuator position |
| Yes | Yes | Mid-position |
| Yes | No | HW port closed |
| No | Yes | CH port closed |
| No | No | Last Demand position |

**[0071]** If system 20 were a S-plan system, then once base unit 21 has made the identification, base unit 21 controls the two zone valves in the "two-zone valves manner" as shown in Table 5, in which mid-position corresponds to the "passage of water through the respective valve" state and Closed corresponds to the "no passage of water" state.

TABLE 5

| Actuator position according to circuit demands for S-plan system | | | |
|---|---|---|---|
| CH Demand | HW Demand | Actuator position of CH Zone Valve | Actuator position of HW Zone Valve |
| Yes | Yes | Mid-position | Mid-position |
| Yes | No | Mid-position | Closed |
| No | Yes | Closed | Mid-position |
| No | No | Closed | Closed |

**[0072]** If, at any stage during operation of system 20, power is removed from valve 23 (or indeed either valve in a S-plan system), then any movement of the actuator 30 stops immediately and it remains in that position.

**[0073]** Throughout normal operation of system 20, base unit 21 receives (continuously or intermittently e.g. once every ten minutes) two sets of signals from room unit 22 (being any CH demand signal and any HW demand signal) and, together with the boiler switching rate (typically being 6 cycles per hour), produces a schedule for boiler 7 to satisfy this demand, together with any instructions for other components of system 20 in order to ensure implementation of this boiler schedule. The base unit 21 measures the cylinder temperature using cylinder sensor 24 at regular intervals and signals its value to the room unit. The room unit 22 compares this value with the HW setpoint programmed by the user in the room unit to generate the HW demand signal.

**[0074]** Room unit 22 has the following functionality:-

- it operates the CH time with three "on" periods each day, in a seven day sequence;
- it operates the DHW program with three "on" periods each day, in a seven day sequence;
- it programs "on" temperature for Central Heating;
- it programs "on" temperature for Domestic Hot Water;
- it sends signals concerning "CH demand" and "HW demand" to base unit 21;
- it indicates when CH and HW profiles are active;
- it indicates the status of the boiler relay in the base unit;
- it displays system faults (e.g. valve stuck, plug in wrong socket). Base unit 21 has the following functionality:-
- it controls DHW to the set point from room unit 22;
- it cycles boiler 7 (and pump 8 as appropriate) according to CH and DHW demands;
- it operates the valve(s) in accordance with the valve configuration detected/selected;
- it drives the valve actuator(s) between end-stops at power-up and regularly during operation;
- it positions the valve(s) appropriately, including ensuring accurate placing in the mid-position or full flow (for two port) valves;
- it detects valve-jam faults;
- it provides remedial action for valve-jams;
- it reports to room unit 22 the system status.

**[0075]** Cylinder sensor 24 is an NTC thermistor with a cable and modular plug in which the middle two pins (3 and 4) are connected to the sensor. This plugs into a 4 pin modular socket (for example a standard 6way plug with the middle 4 pins populated) on the base unit. Pins 4 and 5 are connected to a processor input of the base unit such that when a valve is plugged into the socket, a fault is flagged up. A "short circuit" mode and "open circuit" mode are detected by the measurement being out of range.

**[0076]** Frost kit 25 provides protection to exposed pipework in the system and comprises a low limit (normally open) frost thermostat connected in series with a high limit (normally closed) pipe stat, these being wired onto terminals at base unit 21 indicated as "Frost Protection". This signal is processed by frost kit interface 73 and passed to microcontroller 71. In the conventional system 1, this function is provided using mains switching versions of the above thermostats wired into the mains valve circuit, thus further complicating the mains wiring. The frost thermostat is a low voltage, high limit thermostat whereby, when the temperature in its location falls below the set value, base unit 21 ignores requests from room unit 22 and controls the boiler pump and valves(s) to 100% CH operation only, until the signal disappears. When the terminals are open (no call for heat), a voltage divider puts about 10V across the contacts and the voltage divider provides a high (active) signal to the processor. The low voltage then is passed to the processor to switch the boiler on and to open the valve(s). The line open-circuits again when the pipe stat exceeds its setpoint. The frost protection kit is wired using low voltage cable to dedicated terminals in the base unit. Low voltage pipe thermostat 25 is included when the frost thermostat is located in an unheated location (e.g. a garage) to prevent the house from overheating.

**[0077]** Figure 5 illustrates a second embodiment of heating system according to the present invention, wherein domestic heating system 40 has a number of additional components and extra functionality as compared to system 20. As before, where a feature is identical to that in Figures 1 to 4, the same numeral is used.

**[0078]** System 40 has:

- boiler 7;
- pump 8;
- cylinder sensor 24;
- base unit 41 which has the capability to provide power for, and communicate with, external modules via an accessory port 43;
- room unit 42 which has the ability to control, and respond to, other modules on the bus or connected via the accessory port socket;
- a two-port zone valve 44 for the domestic hot water circuit 4;
- a two-port zone valve 45 for a first CH zone 46 in which room sensor 42 senses temperature;
- a zone unit 47 which is connected by a two-wire cable 48 plugged into accessory port socket 43 of base unit 41;
- a two-port zone valve 49 for a second CH zone 50;
- a room sensor/override 51 for second CH zone 50.

**[0079]** Further details of the electrical links between elements of system 40 are given in Table 6.

TABLE 6

| Electrical connections in system 40 from base unit 41 | | | | |
|---|---|---|---|---|
| Component | Physical link with base unit 41 | Voltage level | Information | Power |
| Enhanced room unit (42) | 2-wire bus 52 | Low DC | CH Demand, DHW Demand, Diagnostics, Status, etc | Yes |
| Boiler (7) | 3/5-wire 36 | 230v AC | ON/OFF, Pump Overrun | Yes |
| Pump (8) | 3-wire 37 | 230v AC | ON/OFF | Yes |
| DHW valve (44) | 2-wire 38 | Low DC | Direction | Yes |
| CH1 valve (45) | 2-wire 38 | Low DC | Direction | Yes |
| CH2 valve (49) | 2-wire 38 | Low DC | Direction | Via accessory port socket 43 |
| Room sensor/ Override (51) | 2-wire bus | Low DC | Room Temperature, Setpoint Override | Yes |
| Zone unit (47) | 2-wire bus + power 48 | Low DC | CH Demand, Diagnostics, Status, etc | Via accessory port socket 43 |
| Cylinder sensor (24) | 2-wire 39 | Low DC | Resistance | N/A |
| Frost kit (25) | 2-wire | Low DC | Call for Heat | N/A |

**[0080]** Of course, system 40 may have one or more additional zones, each additional zone requiring that a further two-port valve similar to valve 49 is connected to zone unit 47 and that a further room sensor/override similar to room sensor/override 51 is likewise linked to base unit 41.

**[0081]** Base unit 41 has, on its exterior, accessory port socket 43 to plug in cable 48 to enable expansion of system 40 functionality by connection of external modules (e.g. zone unit 47) to system 40 to operate with base unit 41 and other components connected via the bus. Port 43 and cable 48 carry the bus connections and an unregulated DC supply of 12 Volts, at rated load, from power supply 70 for powering additional module(s); the supply has sufficient current capacity to power at least four add-on modules requiring less than 10 mA each. In system 40, base unit 41 may drive a valve at the same time as zone unit 47, so the supply additionally supports this. Bus supply current may also be traded to supply more accessory current if there are fewer than the maximum bus devices Each additional module will have two accessory port sockets (IN and OUT) to allow the ports to be "daisy-chained" with one or more modules as required.

**[0082]** Accessory port socket 43 of base unit 41 (or any other accessory port eg in an add-on module) can be used also as an access point for local/remote diagnostic purposes, whether interconnecting with a portable personal computer, and/or a telephone interface, or a portable dedicated diagnostic tool; in this way, a service engineer can readily monitor data being transmitted in system 41 and can request information from components of the system, can override the system and can download CH/HW program information. Likewise, these functions can be done in system 20 through an accessory port for base unit 21.

**[0083]** Base unit 41 notes when a valve is plugged into an incorrect socket, for example into a sensor socket or into an accessory port or a valve socket, and also when a sensor is plugged into an incorrect socket, for example into an accessory port 43 or a valve socket, and displays on room unit 42 a code indicating a fault.

**[0084]** An accessory port can be included in base unit 21 of system 20 to provide equivalent functionality to that of accessory port 43 as described hereinbefore.

**[0085]** Bus 52 links base unit 41 to room unit 42, room sensor/override 51 and accessory port 43.

- Other additional modules which may be incorporated into system 40 include:
- one or more domestic hot water override units;
- an enhanced domestic hot water control module;
- an unvented hot water system control module;

- an immersion heater driver module;
- a radio teleswitch receiver module;
- man/machine interface for a p.c.;
- an outside sensor measurement module;
- a heating system water sensor measurement module;
- an OTC control unit;
- a radio timecode receiver;
- telephone line interface modules (for cabled or RF phone systems) to allow remote control and programming of the system and to send status and diagnostic information to a remote service centre;
- an Internet interface module to allow remote control and programming of the system and diagnostic access by a remote service centre;
- an interface (or interfaces) to other systems in and around the home/building for ventilation/heat recovery, lighting/appliance control, security, access, entertainment, indoor air quality etc to allow co-ordination of house modes and also sharing of resources including external access means. Use of the television as a user interface for the heating system would also be an example;
- modules to monitor the performance of other devices in the heating system such as the boiler (eg flue gas quality) and the pump and to provide diagnostic information via the communication bus to a local user interface and/or a remote service centre;
- modules to detect events in the home/building such as a gas (natural and/or CO) or water leak or other malfunction of another appliance such as a freezer and to provide status/alarm information via the communication bus to the local user interface and/or a remote monitoring centre. Inactivity of elderly occupants or latchkey access could also be monitored remotely;
- a man/machine interface for a telephone, with over-ride to operate system remotely;
- radiator valve(s) and/or controllers;
- radio-frequency transmitter/receiver units to provide a radio-frequency transmission between base unit 41 and/or zone unit 47 and/or any of the appropriate components of system 40 and/or any of the additional modules mentioned;
- a user interface unit to enable a user of system 40, or an occupant of the premises, to enter programming and operation information such that the unit can display system status and diagnostic information.

Base Unit 41 may also be enhanced to include functionality to support unvented hot water systems.

**[0086]** Power for certain of the components in systems 20 and 30 is provided by base units 21 and 41 with an isolated, regulated DC supply (part of power supply 70) which is switched onto the 2-wire bus for a portion of each bit on the bus. This method of powering is reserved for those system components which are remote from the base unit (e.g. enhanced room unit 42, room sensor/override 51). Local modules connected to accessory port 43 only use the bus for signalling and are powered by the unregulated supply connection on accessory port 43. The base unit also provides the synchronising signal for all devices on the bus, pulsing the bus low at a frequency of 200Hz. All devices communicating on the bus are connected to the 2-wire line and all information is transmitted and received over this 2-wire line. The power pulse is used to power the remote nodes which use a blocking diode and storage capacitor to power the nodes when the bus is in the high impedance state. A diode bridge is provided at each remote node to render the two-wire connection polarity insensitive. The high impedance state is used by the nodes to signal by pulling the line low. Synchronisation of the nodes is achieved using the rising edge of the bus voltage.

**[0087]** The system defines two complementary logical values that the bus can take on, "dominant" and "recessive". During simultaneous transmission of dominant and recessive bits, the resulting value on the bus is dominant. The system uses Variable Pulse Width Modulation (VPWM) such that a dominant value is represented by an encoded pulse with the first third of the bit period logic HIGH and the remaining two thirds logic LOW; the recessive value has the first two thirds logic HIGH and the remaining third logic LOW. The base unit always signals either the dominant or recessive bit pattern to maintain synchronisation so that, when it has no message to send, it will signal recessive bits. The low impedance state is only asserted by the base unit for one fifth of the bit period, starting one fifteenth of a bit after the rising edge of the bus voltage, thus providing a safety margin to allow for timing variations in the bus nodes (early or late). A bit encoding scheme with a fixed period of each bit when the signalling level is at or close to the supply voltage, maintains power to remote nodes independent of the bit pattern which is especially important in a protocol where the bit stream is continuous. VPWM coding is an example of such encoding. Without some such encoding there could be periods when the bus is continuously low for during strings of "low" bits and there would be no opportunity to power the remote nodes. Details of the bit timing are given in Table 7 and in Figure 6, details of the power period timing are given in Table 8 and Figure 7, and details of the input/output specifications are given in Table 9.

TABLE 7

| Bit timing details | | |
|---|---|---|
| Timing Designator | Description | Time (msec) |
| t1 | bit time | 5 |
| t2 | dominant (high) | 1.67 |
| t3 | dominant (low) | 3.33 |
| t4 | recessive (high) | 3.33 |
| t5 | recessive (low) | 1.67 |

TABLE 8

| Power period timing | | |
|---|---|---|
| Timing Designator | Description | Time (msec) |
| t6 | guard period A | 0.33 |
| t7 | power period | 1 |
| t8 | guard period B | 0.33 |

TABLE 9

| Input/output specifications | | | | |
|---|---|---|---|---|
| **Parameter** | **Conditions** | **Min** | **Max** | **Units** |
| SYSTEM SPECS | | | | |
| Supply Voltage | | 11.5 | 12.5 | VDC |
| TRANSMITTER SPECS | | | | |
| Bus Voltage | Output dominant, sink current = 10mA | 0.6 | 2.2 | VDC |
| RECEIVER SPECS | | | | |
| Threshold | bus voltage | 5.5 | 6 | VDC |
| Input Current | | 0.1 | 0.2 | mA |

**[0088]** Figure 8 shows the circuit for base unit 41 (which is part of communications interface 74) and one remote node, e.g. room unit 22. Base unit 41 provides the power for all remote nodes and also the voltage for signalling for all nodes. When not providing power, a resistance of 1k ohms (BR1) connects the bus to the base unit DC power supply (Vsupply). When power is being supplied, a transistor (BT4) shorts out the resistance, presenting a low impedance to the bus, and charges up RC1 in the remote node.

**[0089]** The transceiver circuit consists of:-

1) a voltage detector to provide a logical LOW to the device microprocessor during transmission of a high or 'recessive' portion of bit. This consists of BT2,BD1, BR3 to BR5 in the base unit schematic (similar in room unit).
2) a transistor switch BT2 (BR2 in room unit) which can be activated by a transmitter to pull the data line LOW during the low or 'dominant' portion of a bit transmission. Series resistors RR1 and RR2 help protect the switch in a fault condition, in conjunction with the voltage detector and software in the microcontroller.

**[0090]** A transmitter (other than the base unit) wishing to transmit a recessive bit lets the data line be driven by the base unit transmitter. If no other device is attempting to transmit a dominant bit, the data input to the microprocessor follows the recessive bit pattern generated by the base unit transmitter.

**[0091]** A transmitter (other than the base unit) wishing to transmit a dominant bit drives the data line low by turning on RT1 at a time 1/3 of a bit period (1.66 milliseconds) after the rising edge generated by the base unit. The transmitter lets the line go after a 1/3 bit period (1.66 milliseconds) leaving the base unit to hold the line low for the final 1/3 bit period. This prevents timing delays in any of the other transmitters causing jitter in the rising edge. Jitter on the falling edge may appear as noise on the decoded signal and thus reduce the overall noise margin of the system so jitter is minimised as much as possible.

**[0092]** The power supply 70 within the base unit may provide four supplies for the systems 20, 40, namely:

(i) An unregulated supply for accessory port 43 (Vsupply);
(ii) A regulated 12V supply for the communications interface, the relay drive circuit and the frost protection circuit;
(iii) A regulated 8.2 V supply for the valve actuator drive circuit; and
(iv) A regulated 5V supply for the processor, actuator drive, temperature measurement and communications circuits.

**[0093]** The unregulated supply comprises an isolating 6VA transformer T1 with full-wave bridge rectification and a 1000uF 25V smoothing capacitor and additional capacitors for transient protection. The DC supply voltage varies from 24.6V max under low load conditions (50mA) and high line voltage (254VAC) to 13V min at 400mA. Much of the load may be of a transient nature so the transformer is not continuously driven at full load, but the voltage regulation is such that the higher rating is needed in order to maintain the 12V regulated supply for communication etc when the valve starts up and closes off.

**[0094]** The regulated 12V supply uses the unregulated supply and comprises a series regulating transistor (Q13) whose base voltage is set by a Zener diode and resistor to provide a little under 12V at the emitter, a capacitor providing some decoupling. R1 is chosen to provide sufficient base current at minimum Vsupply (maximum load). Due to the large variation in load and the Vsupply variation with this, Q13 has to cope with a large power dissipation under certain conditions and requires a large heatsink. If an actuator stalls while the maximum continuous load is on the system, a power peak of 1.3W may be generated but only for the time taken to recognise the fault and switch off the actuator.

**[0095]** The 8V2 supply uses the 12V supply and drops it down using the same circuit form as the 12V but with an 8V7 zener VR4 and R53 with C23 as a decoupler. This supply is current limited to 200mA by the actuator drive circuit which pulls more current through a resistor, dropping the base voltage to balance the actuator load. This is active during the actuator startup and in the actuator short circuit condition.

**[0096]** The unregulated supply is provided to accessory port 43 which accommodates a 6-pin modular plug. The accessory port socket 43 is used to power accessory modules such as a zone control box, an OTC box or an RF interface. The smoothing capacitor is intended to support only the load of the base unit, actuators connected to the base unit and the communications bus (with any connected units). Any accessory module (e.g. zone unit 47) is required to provide smoothing for its own load. For instance, the zone unit ( with more actuators connected) requires another capacitor of the order of 1000uF such that the total reservoir capacitance is 2000uF. The accessory port 43 also carries the communications bus as provided to the room unit although the accessory modules will not draw power from the bus. The pins of the accessory port are arranged to protect a sensor or actuator incorrectly plugged into it, a signal line flagging such a condition as a specific fault. The accessory plug connections are arranged such that, if an accessory cable is plugged into the HW sensor socket, it appears as a valve in sensor socket fault (via the two common connections). Similarly, if an accessory cable is plugged into the valve socket, it appears as a valve short circuit via the two common connections. An alternative option is to remove one of the OV connections on the accessory port. In this case, the accessory is not flagged as a fault but is not, of course, recognised by the system.

**[0097]** In the relay/drive arrangement 72, the relay K1 is a 2-pole changeover type, one pole being used in the NO configuration to drive the boiler, the other being used in the changeover configuration to drive the pump which is supplied from the moving contact with the mains supply on the NO contact. The pump overrun signal (from a pump overrun boiler) is routed to the NC contact and on to the pump when there is no call for heat, thereby avoiding the need for links to configure the base unit for a simple boiler or a pump overrun boiler.

**[0098]** The communication interface 74 supplies power for remote devices connected to it such as room 22 unit in system 20 and the remote sensor/override units 51 in zoned system 40; the interface enables the passage of information between any components connected to it in a peer-to-peer manner, i.e. there is no central bus controller.

TABLE 10: Pin configurations for modular connectors

| | PINS | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| **Cylinder sensor :plug** | Pin not present | No connection | Sensor | sensor | No connection | Pin Not present |
| : socket | No connection | Valve detect | Sensor | sensor | Valve detect | No connection |
| **HW Valve :plug** | Pin not present | HW 1 *or* *No connection (cable reversed)* | HW2 *or* *No connection (cable reversed)* | No Connection *or HW2 (cable reversed)* | *No connection or HW1 (cable reversed)* | Pin not present |
| : socket | No connection | HW Drive | Common Drive | Common Drive | HW Drive | No connection |
| **CH Valve :plug** | Pin not present | CH 1 *or* *No connection (cable reversed)* | CH2 *or* *No connection (cable reversed)* | No Connection *or CH2 (cable reversed)* | *No connection or CH1 (cable reversed)* | Pin not present |
| : socket* | No connection | CH Drive | Common Drive | Common Drive | CH Drive | No connection |
| **Accessory Port : plug** | Comms Bus | No connection | Module 0V | No connection | Module 0V | Module supply |
| : socket | Comms Bus | Valve/sensor detect | Base Unit 0V | Valve/sensor detect | Base Unit 0V | 12V unreg supply pin |

* This socket is used for the mid position valve in a Y-plan system.

**[0099]** The connecting of various components of systems 20 or 40 into base units 21, 41 uses a standard six-pin modular plug (cf North American telephone plug) on the component leads, whereby only certain of the pins are used for a given component. By appropriate selection of pins for the respective components and by base units 21, 41 effecting appropriate monitoring of those lines, which correspond to certain pins, for each socket, incorrect connections are readily determined. One possible arrangement of pin connections is shown in Table 10. In this way, base units 21, 41 are able to detect when the plug for a given function is plugged into the socket for a different function; for example, if a plug for a valve is plugged into the cylinder sensor socket, the low impedance of the valve actuator is either across pins 2 and 3 or across pins 4 and 5; if across 2 and 3 this connects the valve plug detect signal to the sensor measurement node within cylinder sensor interface 76. During the measurement process, this node voltage goes from a high level to a low level due to the charging of the measurement capacitor. The measurement threshold is well below the detect input threshold, so the input goes low indicating the connection fault. If the connection is across pins 4 and 5, the sensor measurement select signal is corrected to the valve detect signal. Whenever a sensor measurement begins, the select signal goes low, pulling the valve plug detect signal low and indicating a connection fault. As a second example, if the cylinder sensor 24 is plugged into the accessory port socket by mistake, the impedance of the sensor typically (20K at 25C) is connected between pins 3 and 4 of accessory port 43. Pin 3 is 0V and pin 4 is the valve/sensor plug detect line. The pullup on the detect line is 470K which is much greater than the sensor impedance even at the lowest temperature, so the voltage division resulting from this causes the input to detect a low logic level and flag a fault. A valve cable wrongly plugged into the accessory port places a very low impedance across pins 2 and 3 (or pins 4 and 5 if the cable connections are inverted). The result in either case is the detect line being virtually shorted to 0V resulting in an error being flagged. A sensor plugged into a valve socket is not detected explicitly but, assuming it is the only sensor in the system, it is detected as a missing (or open circuit) sensor and flagged as such, or may show as an open circuit valve depending on which system is selected and which valve socket was involved.

**[0100]** The term "incorrect engagement" is used to mainly to refer to the various situations described above where a system component cable is plugged into the wrong socket in the base unit. The main means of detection is by registering short circuits (or low inpedances) across terminal pairs which are not used by the correct device for the socket. In some cases, incorrect engagement is inferred by detection of an open circuit at a socket which has a device plugged into it. "Incorrect engagement" also includes the situation where a cable is plugged into the correct socket but not fully engaged, registering as an open circuit across the sensor input or valve drive terminal pairs.

**[0101]** Operation of the system is not affected by erroneously inserting a plug into a socket such that the connections are oriented inversely from normal (e.g. in a connector with 6 pin positions (1-6) in a row, CH valve plug pin 3 is connected to CH valve socket pin 4 and CH valve plug pin 2 is connected to CH valve socket pin 5. Inherent insensitivity of the sensor element plus positioning of the pins centrally on the connector (pins 3 and 4) achieves this for the cylinder sensor. Positioning the valve pins to one side of centre on the plug and commoning up the mirrored alternative drive pins on the socket in the base unit achieve this for the valve drive.i.e. pin 3 and 4 are connected to one side of the drive circuit and 2 and 5 to the other. This is shown in Table 10 which shows the alternative cable orientations. The condition could arise if a non-polarised plug socket arrangement was used but with the modular plug used, the most likely scenario is incorrect assembly of the plug to the cable in a custom extension cable. In the arrangement described in Table 10 only the cylinder sensor socket and the two valve sockets have this feature as these are the most likely to require extension cables. The accessory port is intended for local operation.

**[0102]** The system also ensures detection of disengaged valve/sensor connectors, being another aspect of the detection of missing/ misconnected components at installation. The system also detects connectors which are plugged back into the wrong socket after being disengaged. Power distribution in the system involves incorporation of the power provision to the bus devices in a specific portion of the bit period of the communications. An advantage is that regular power is provided to the bus independent of the communications activity and indeed allows continuous communications. Most importantly, it is provided to one node (the base unit) while allowing any node to send messages at any time.

**[0103]** In a variant to the systems described hereinbefore, the base unit 21 or 41 controls and operates another heating zone in place of the hot water circuit 4, with appropriate modification of the components of systems 20 and 40 where required.

## Claims

**1.** A comfort controls system comprising:

a boiler to provide water at a raised temperature,
a pump to circulate heated water around the system,
storage means for part of the water heated by the boiler,
radiator means to provide space heating,
a room unit for provision of heating and/or hot water demand,
a base unit to control operation of the boiler and pump, and
linkage means and a communication protocol to provide a two-wire low voltage dc power and data transfer between the base unit and the room unit.

**2.** A system according to Claim 1 wherein the linkage means connects a second room sensor for a second zone for space-heating to the base unit to provide a two-wire low voltage dc power and data transfer therebetween.

**3.** A system according to Claim 1 or 2 where the linkage means connects with one or more additional components of the system to provide a two-wire low voltage dc power and data transfer therebetween.

**4.** A system according to any preceding Claim, wherein the linkage means connects with one or more additional components of the system to provide only data transfer therebetween.

**5.** A system according to any preceding claim wherein the dc power is supplied to the linkage means via a low impedance during a specific portion of the data bit period that is always at or about the supply voltage level, and is supplied via a higher impedance for the remainder of the bit period to allow signalling.

**6.** A system according to any preceding claim, wherein the base unit has means to power the pump.

**7.** A system according to any preceding Claim wherein the base unit has means to power the boiler.

**8.** A system according to any preceding claim comprising

a first circuit for the passage of water at a raised temperature to provide space heating,
a second circuit for the passage of water at a raised temperature to provide domestic hot water,
a base unit to control operation of a boiler and pump to provide heated water to the two circuits,
means to provide a hard-wire dedicated power link between the base unit and at least one ancillary unit to provide additional functionality for the system.

**9.** A system according to Claim 8 wherein the power link provides an unregulated supply.

**10.** A method of operating a comfort control system having a boiler to provide water at a raised temperature, a pump to circulate heated water around the system, storage means for at least part of the water heated by the boiler, radiator means to provide space-heating, a room unit for provision of heating and/or hot water demand, the method comprising a base unit controlling operation of the boiler and pump and providing a two-wire low voltage dc power and data link with a communication protocol between the base unit and the room unit.

**11.** A method according to Claim 10 comprising supplying the dc power to the linkage means via a low impedance during a specific portion of the data bit period that is always at or about the supply voltage level, and via a higher impedance for the remainder of the bit period to allow signalling.

**12.** A method according to Claims 10 or 11 the method comprising providing a hard-wire dedicated power link with the base unit and at least one ancillary unit to the system to provide additional functionality for the system.

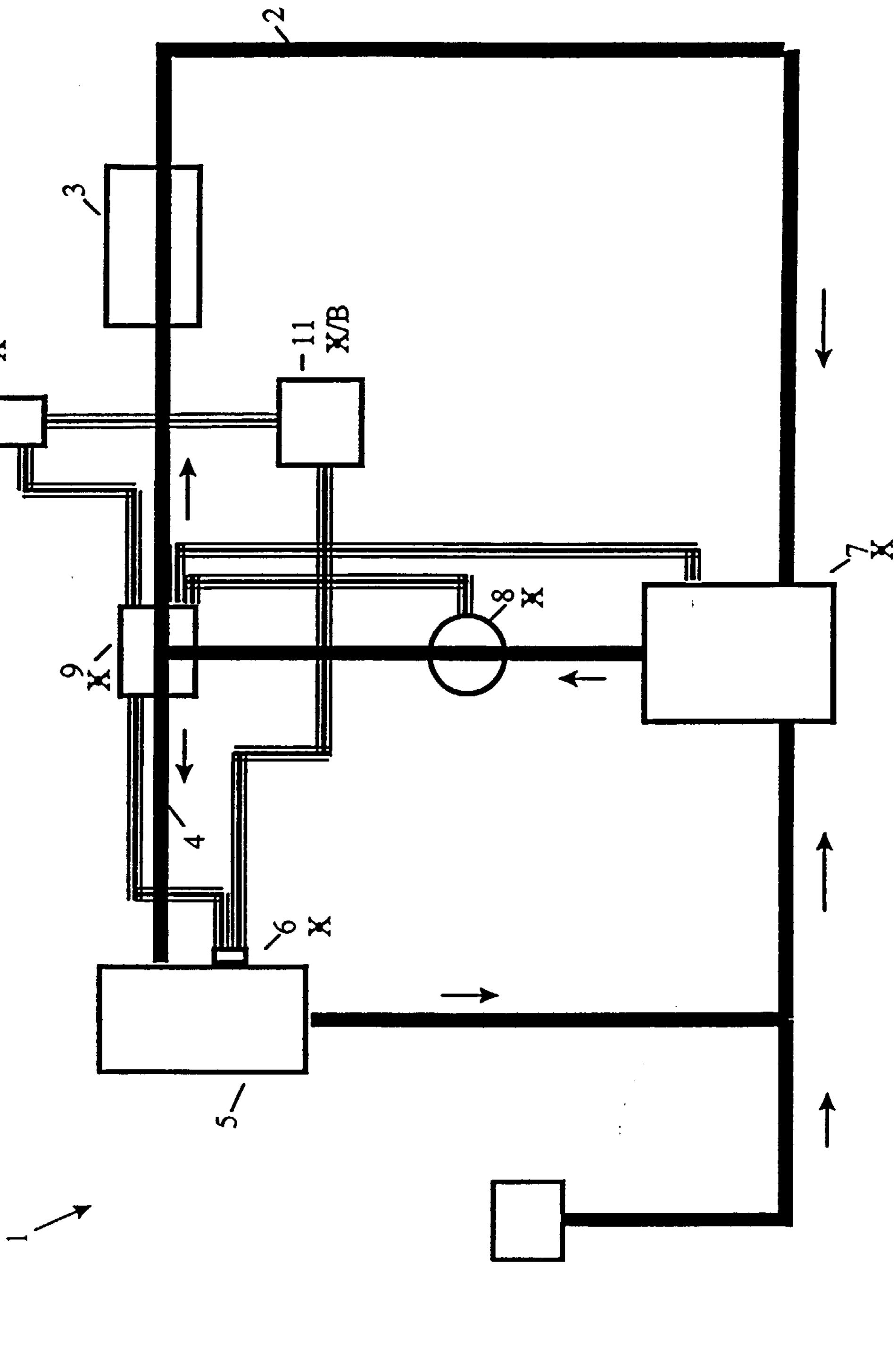



Figure 1

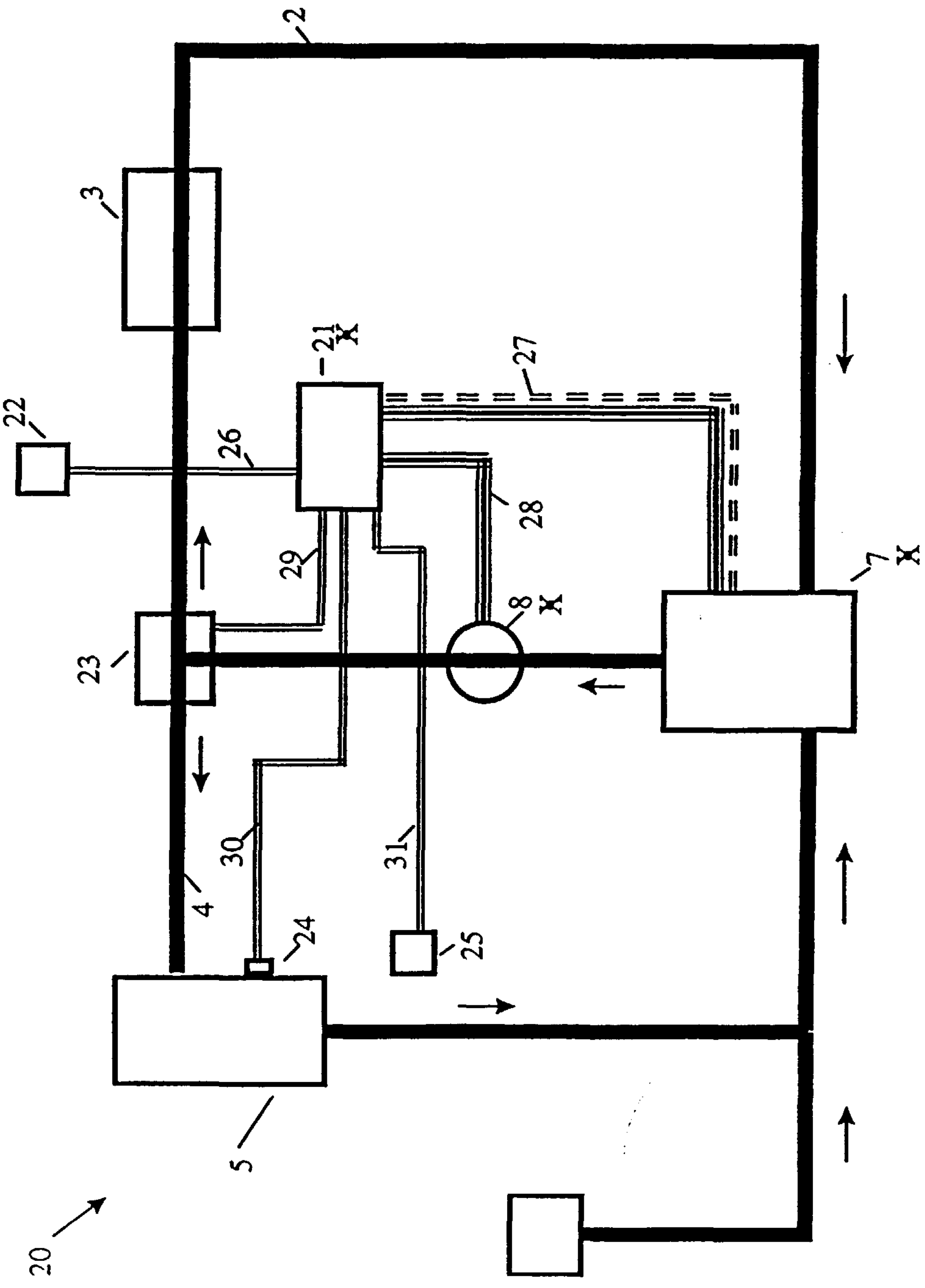



Figure 2

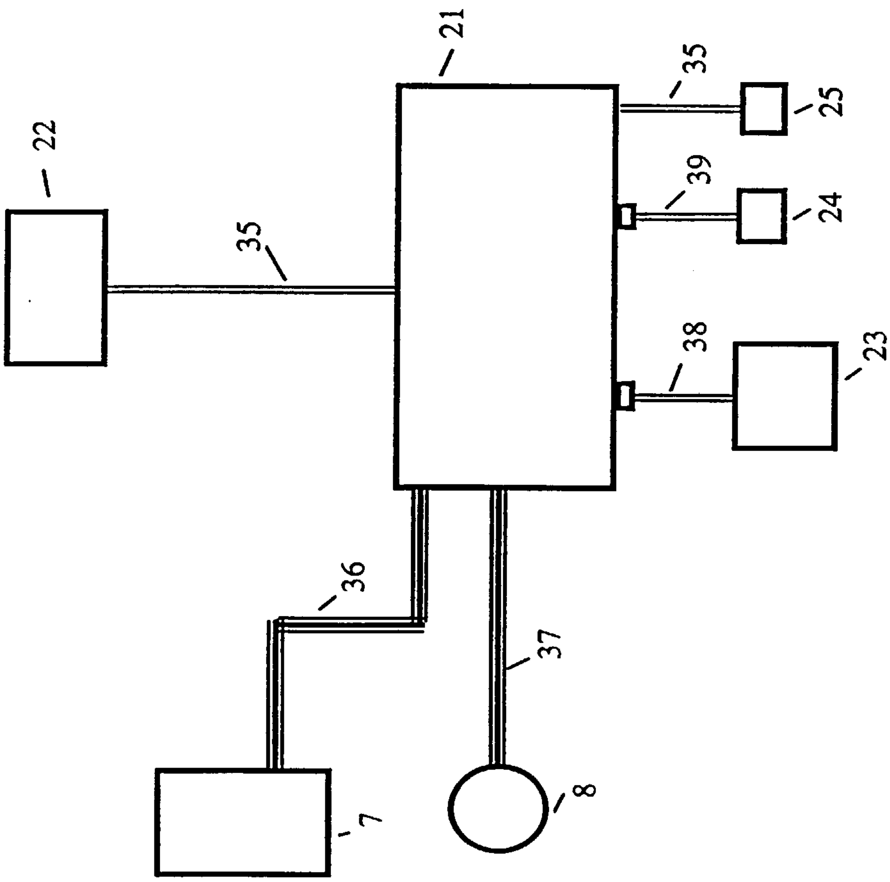
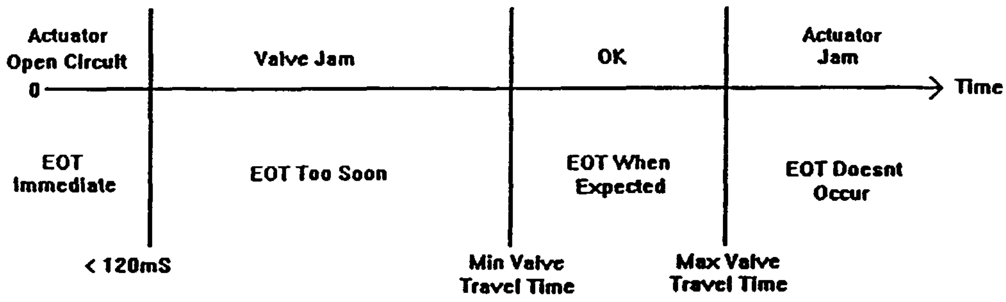



Figure 3




EOT = End Of Travel i.e. No current flowing in valve drive circuit
Min Valve Travel Time = Measured Mid Position Time - Margin Of Error
Max Valve Travel Time = Measured Mid Position Time + Margin Of Error

FIGURE 4

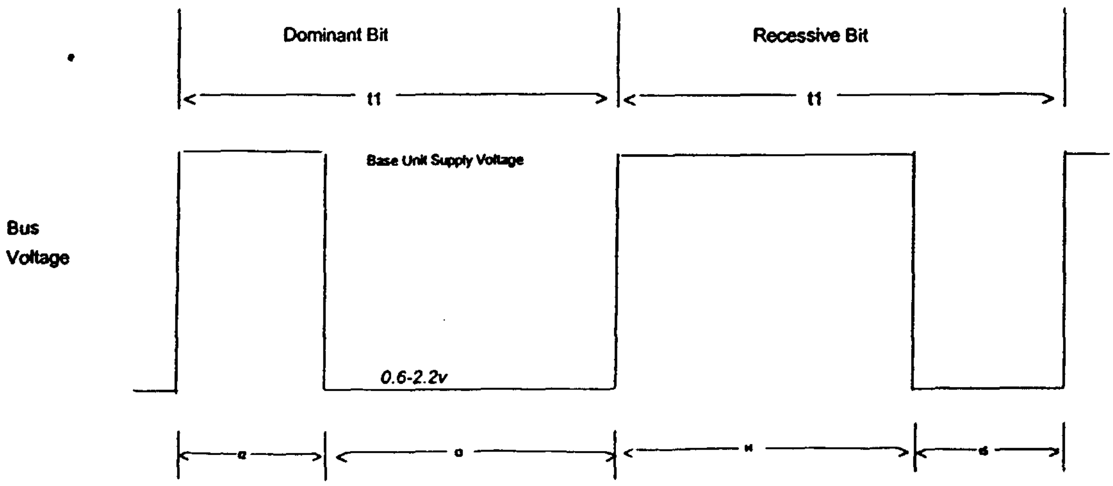



FIGURE 6

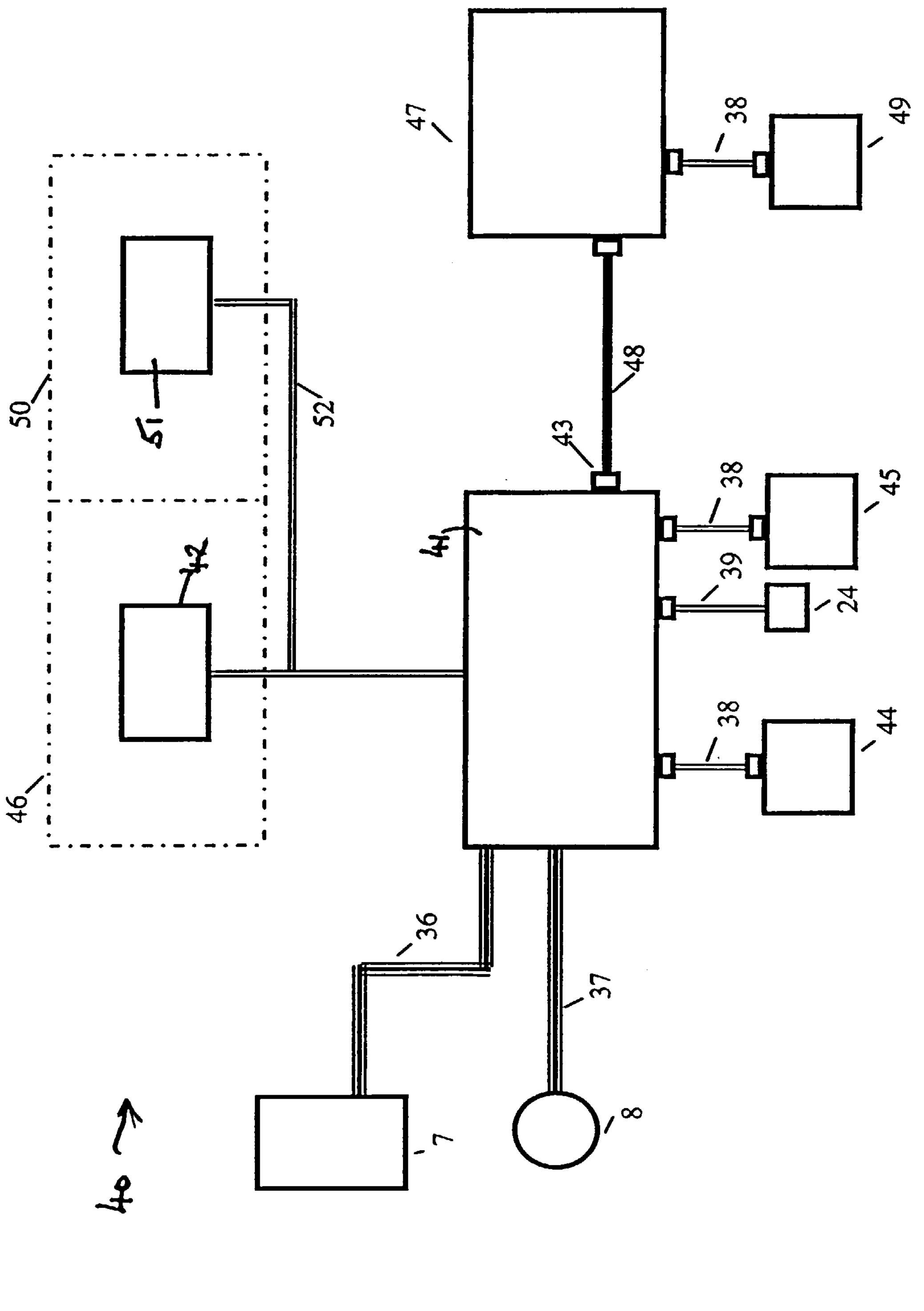



Figure 5

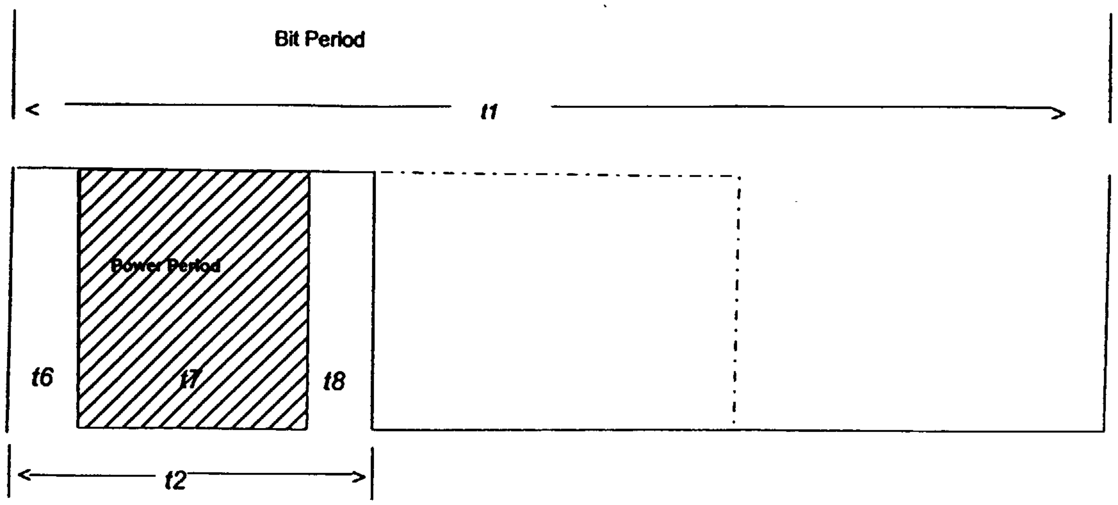



FIGURE 7

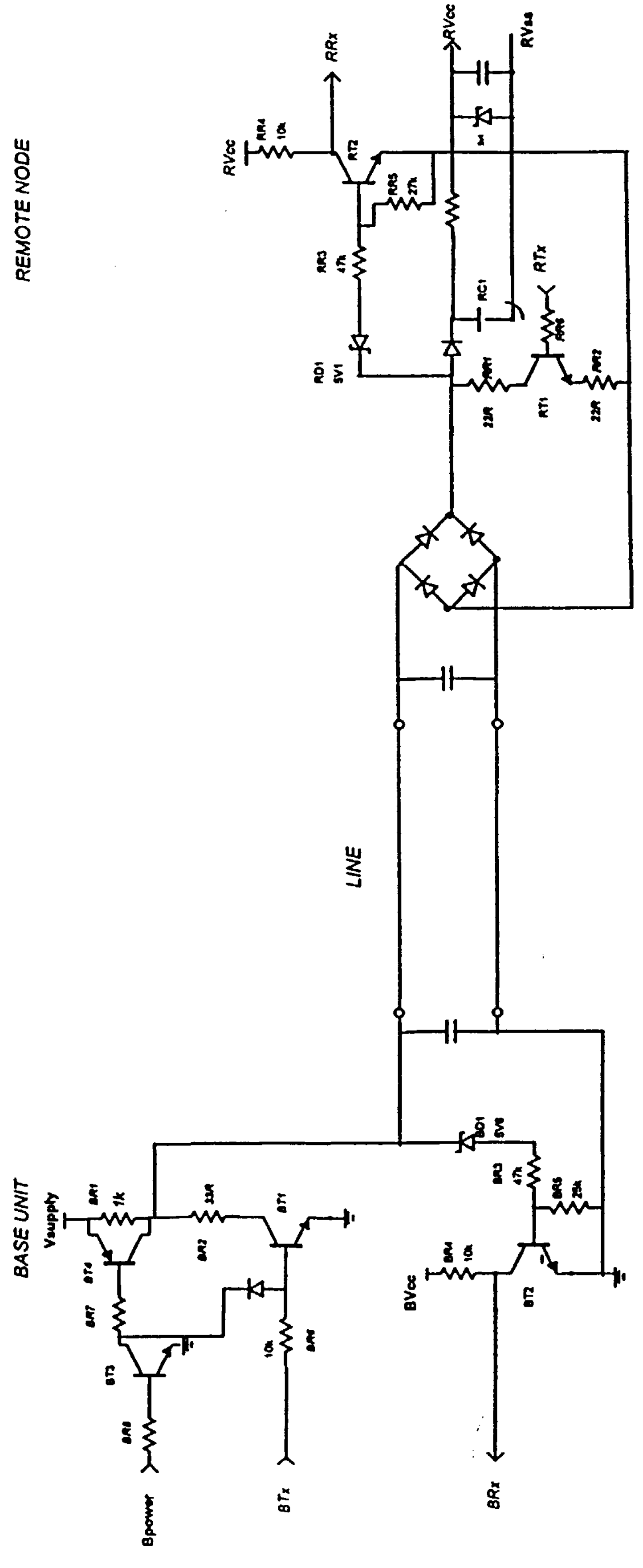

REMOTE NODE
RVcc
RRx
RVss
RTx
LINE
BASE UNIT
Vsupply
Bpower
BTx
BVcc
BRx

FIGURE 8

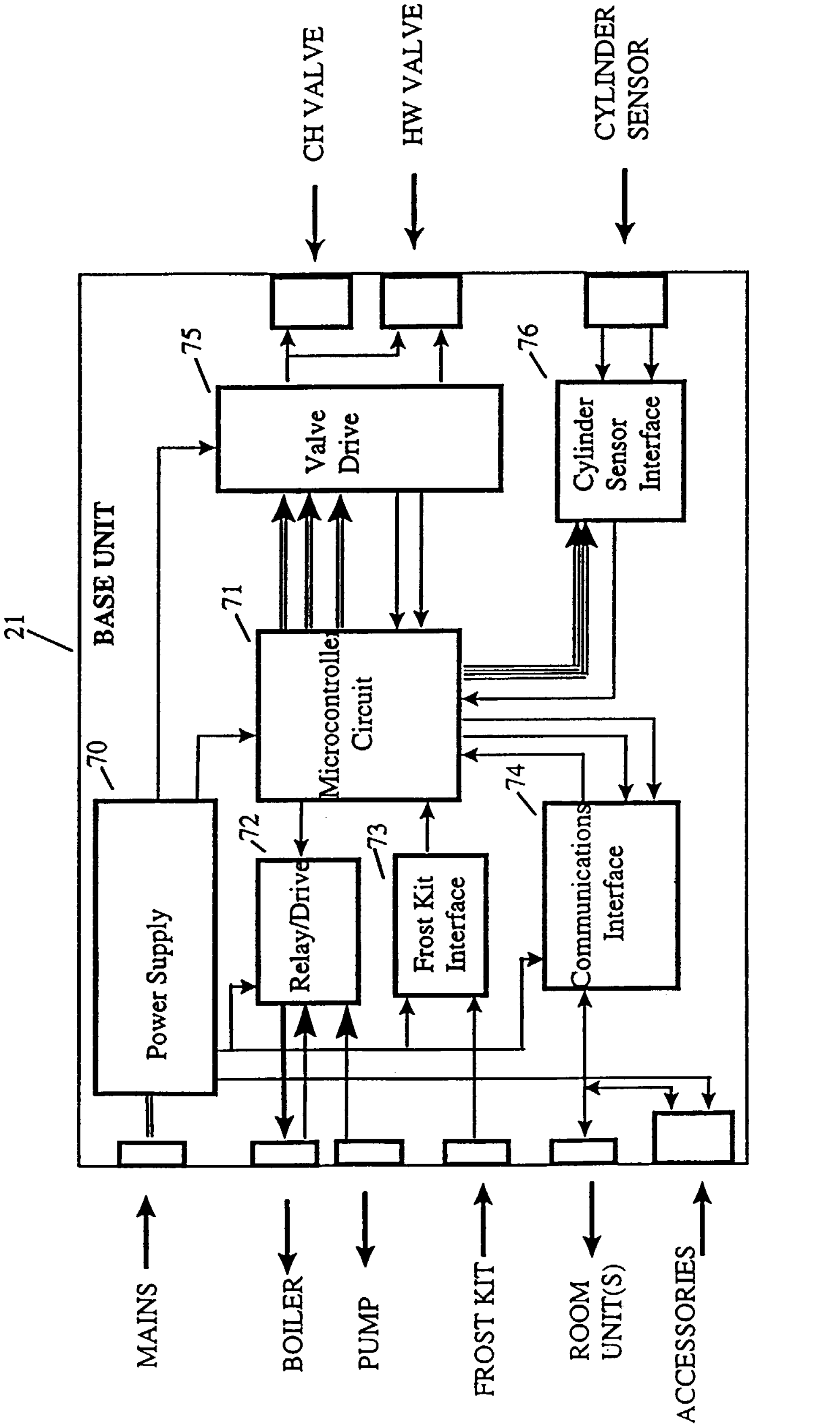

CH VALVE
HW VALVE
CYLINDER SENSOR
21
BASE UNIT
75
Valve Drive
76
Cylinder Sensor Interface
71
Microcontroller Circuit
70
Power Supply
72
Relay/Driver
73
Frost Kit Interface
74
Communications Interface
MAINS
BOILER
PUMP
FROST KIT
ROOM UNIT(S)
ACCESSORIES

Figure 9