Apparatus for controlling a number of electrical loads, for example lights, comprises a main telecommunications network (1). Connected to this are various modules, each comprising one or more switches (11, 12, 13) operating loads (21, 22, 23) in response to control means (10) and commands entered at input stations (2, 3). The communications network is adapted so that commands entered at one module and intended for a switch within that module are not entered on the main communication line. Commands entered at one module and intended for another module, are transmitted along the main communication network using asynchronous transmission.
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<td>Mali</td>
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<td></td>
</tr>
</tbody>
</table>
APPARATUS FOR CONTROLLING ELECTRICAL LOADS

The present invention relates to apparatus for controlling electrical loads, and relates particularly though not exclusively to apparatus for installation in buildings to allow lighting, heating and other circuits to be controlled.

The conventional system for providing lighting in a room of a building is by means of an electrical circuit which includes a source of power (mains electricity supply or generator), a light, a switch, and electrical power cables linking these circuit components. In a private dwelling the light switch will typically be located quite near the light. In larger buildings the light switch may be some distance from the light, an extreme example being buildings such as factories where all the widely separated lights can be controlled from a single switchboard.

Proposals have in the past been made for providing a system for controlling the lighting of a building. One approach, illustrated for example by US4,240,011, US 4,388,567 and US 4,716,344 has been to use a centralized control system such as a computer. Such arrangements, while providing control, do not offer much flexibility and are quite complex. US 5,059,871 illustrates an alternative approach in which control of the system is distributed to a series of input control units communicating via a network. In this arrangement, however, all control units are connected directly to a single communications network. When a large number of units are provided this can cause congestion on the network requiring sophisticated, and therefore expensive, communications hardware and software.

According to the present invention there is provided
apparatus for controlling a number of electrical loads comprising an electrical switch for each load, a telecommunication network including a connection to each electrical switch, command input stations connected to the telecommunication network, and control means whereby a command entered at an input station travels along the network and operates a switch thereby switching on or off a load, characterised in that said network comprises a plurality of network modules connected in series by a main telecommunication line, each module comprising an input station, and one or more switches, and wherein in the case of commands from an input station to a switch within the same module said control means is adapted to send these commands from the station to the switch without entering the command on the main communication line.

The apparatus according to the invention has many advantages over the conventional systems. Firstly, because a network is used, instructions entered at any one of the input stations can switch any or all loads connected to the network. Secondly, the switch for a particular load can be located in physically close proximity to the load thereby reducing the amount of electrical cable required and thus reducing the expense of installation. Thirdly, reducing the amount of electrical cable enhances the safety of the system. Fourthly, the use of a network allows extra input stations and switches to be easily added to the system. Fifthly, the use of a telecommunication network allows instructions to be entered by non-manual means, for example through telephones or by computers connected to the network. Sixthly, commands may be transmitted over large distances.

By using a modular form of telecommunication network comprising network modules connected in series by a main telecommunication line, a large proportion of commands may be
kept within the modules and off the main communication line. This enables the use of simpler and cheaper communications software and hardware. The modular system also allows the system to be expanded easily.

In a preferred construction of the apparatus the transmissions are asynchronous, thus greatly reducing the cost of the hardware.

The commands may be sent in the form of a first or second protocol. The first protocol may contain less information than the second, but may be transmitted faster and may therefore be used for transmitting emergency signals.

The apparatus preferably includes an electrical switch status indicator for indicating the status of the electrical switches. The indicator may take the form of a light emitting diode associated with each key of a keypad used to input commands.

Some embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a system in accordance with the invention installed in a private dwelling;

Figure 2 is a block diagram of an alternative system with the output side omitted;

Figure 3 is a block diagram of one module of a system;

Figure 4 is a circuit diagram for the keypad;

Figure 4A is a front view of the keypad;
Figure 4B is a circuit diagram of an alternative circuit for the keypad;

Figure 5 is a circuit diagram of a load switching circuit;

Figure 6 is a circuit diagram of a telephone circuit for connecting a telephone to the system;

Figure 7 is a user chart for entering commands by keypad;

Figure 8 is a user chart for entering commands by telephone;

Figure 9A and 9B together constitute a flowchart illustrating the operation of the keypad;

Figure 10A and 10B together constitute a flowchart illustrating the operation of the telephone circuit; and

Figure 11 is a flowchart illustrating the operation of a module.

Figure 12 shows the command protocol for commands entered on a keypad;

Figure 13 shows the command protocol for commands entered by telephone;

Figure 14 illustrates a first protocol format;

Figure 15 illustrates a second protocol format;

Figure 16 illustrates the transmission of data using the
first protocol in one example;

Figure 17 illustrates the transmission of data using the first protocol as a second example;

Figure 18 illustrates the use of the second protocol;

Figure 19 illustrates a possible system architecture; and

Figure 20 illustrates how a command input station may control the electrical switches.

Referring initially to Figure 1 the system comprises five modules designated (a), (b), (c), (d) and (e) and separated by vertical dashed lines. The modules are linked by main communications line 1.

Module (a) is located in the kitchen, living room and hallway and consists of keypads 2 and 3 out of reach of children, a monitor 5 located in the hallway, local telecommunication lines 6, 7 and 8, a switching circuit 10, switches 11, 12 and 13 power lines 16, 17 and 18, and electrical loads 21, 22 and 23 which may be lights, heaters and the like.

Module (b) is located in an adult bedroom, and consists of a keypad 30 a local telecommunication line 31, a switching circuit 32, three electrical power lines 33, 34, 35, three switches 36, 37, 38 and three loads 39, 40, 41, which may be a light, a heater and an electrical socket. Also shown is a remote controller 42 of the type used to operate a television set, which may have been used to operate the keypad 30 from a distance.
Module (c) is located in a child's room and consists of a keypad 50 with just three keys within reach of the child, a local telecommunication line 51, switching circuit 52, three electrical power lines 53, 54, 55, three switches 56, 57, 58 and three electrical loads 59, 60, 61 consisting of a light and two sockets.

Module (d) is located in an office and consists of a telephone receiver 70 and computer 71, local telecommunication lines 72, 73, an adaptor 74 for converting signals arriving on the telecommunication lines 72, 73 into signals compatible with the system of the invention a switching circuit 75, and loads 76, 77, 78.

Module (e) is located outside the house at the front door and consists of a keypad 80 with just one key, a local telecommunication line 81 and a switching circuit 82 and loads 83, 84 and 85.

Figure 2 is a block diagram similar to Figure 1, but showing a slightly modified system comprising four modules, designated #1, #2, #3, and the fourth module being designated #N to indicate that any number of modules may be included.

Figure 2 illustrates only the input side of the system comprising keypads 90 and telephone 91.

Some examples of use will now be given. An adult leaving a house can go to the hallway, and using the keypad in the hallway can switch off all the electrical loads in the house, and can check on the monitor that all loads have been switched off.

An adult arriving home can use the keypad in the hallway to switch on selected electrical loads, for example lights
and heaters.

A person attacked at the doorway of the house while entering or leaving can switch on all lights by pressing the keypad located at the doorway.

An adult who is in bed reading can switch off the bedroom light and other loads throughout the house without leaving the bed, by using the remote control device to operate the keypad in the bedroom.

A person away from home can switch on and off loads by telephone, calling in on a fixed cable or from a mobile phone.

A child can switch on and off loads in the child's bedroom using the simplified three-key keypad.

Load switching can be controlled by a computer programme. Different programmes may be written for different types of building e.g. bank, restaurant, private dwelling. The computer programme is stored in conventional manner on disc, tape or the like; is loaded into a computer, which may be a personal computer, lap top computer or the like; and the computer is then connected to the system so as to programme the system. Once the system has been programmed the computer may be disconnected and used for other purposes. In the case of a private dwelling the owner may have separate programmes for different seasons of the year, or for when the dwelling is occupied or unoccupied. In the case of larger buildings such as factories, hotels and the like the computer may be left permanently connected.

In addition the use of loads can be monitored by computer. Thus in the case of a hotel, condominium or the
like a detailed billing system can be implemented based on actual use of various electrical loads, without the necessity of installing a separate meter for each load, which would be very expensive.

Each keypad comprises an array of keys each of which is made of translucent material and includes a light emitting diode (LED) immediately behind the key. In operation, whenever any of the loads in the same module (for example loads "1", "3" and "6" of the module) are switched on, then the appropriate LED is also switched on, that is to say the LED's behind keys designated "1", "3" and "6". The LED's thus serve as a continuous reminder to the user which loads are switched on. The keypad may also be used in an enquiry mode, by entering enquiries in accordance with a user protocol to enquire the status of loads in other modules, and again the LED's will light up to indicate the status of loads in the other module.

The monitor can be used to read the status of the system in more detail including reading system fault diagnosis produced by the system and reading the history of load switching and other such detailed information.

In addition to allowing remote control, the system also uses less power cable and is therefore less expensive and safer than conventional systems. Thus in the case of the child's bedroom the keypad may be located just inside the door where the light switch is traditionally located but the switching circuit and switches may be located at ceiling level very near the three loads, and there is no requirement to lead a power cable from these loads to the door.

The system may also be more aesthetically pleasing than traditional systems in that only one keypad is required at
each switching location, whereas traditional systems often include an unsightly row of switches, one for each different load.

For aesthetic reasons, the householder may wish to replace one keypad by another, in just the same way as householders traditionally replace one switch by another. Replacing one keypad by another involves removing the wiring from the keypad and then attaching the wiring to the new keypad and this is relatively simple, and in particular is much safer than replacing an electrical switch because the householder is handling a low voltage telecommunication circuit instead of a higher voltage power supply circuit.

Adding an extra keypad to the system is much simpler than adding a new electrical switch to a traditional system. Adding a new electrical switch involves installation of a power line which for safety reasons extends within the interior of the wall or is enclosed in a conduit or thick sheathing, and involves damage to the wall when securing the electrical switch to the wall by screws and possibly making a hole in the wall for the power line. In contrast the keypad according to the invention may be secured to the wall by adhesive and the telecommunication line may take the form of a very fine ribbon cable which may be fixed externally to the wall and which is neither dangerous nor unsightly.

Each keypad has its own memory. The keypads may be programmed so that for certain very commonly used loads it is necessary to press just one key. This programming can be easily carried out by the home owner and can be readily changed. For example pressing the "ON" key only may result in several lights and heaters being switched on.

The system illustrated by way of example in Figure 1 is
intended for a small private dwelling and illustrates many of the advantages of the invention. However when a system according to the invention is used in other applications further advantages may arise as explained in some more detail in the following paragraphs.

The system may be used to operate an outdoor water sprinkler. A telecommunication line is laid from the dwelling to the water sprinkler, and instructions may be given from the dwelling, either manually or generated by computer. It is not necessary to lay an electrical power line from the house to the sprinkler. Instead a power line may be laid directly from the mains electricity supply or from an outdoor generator. Commands may be given over a considerable distance.

A system according to the invention may also be used in hotels, and the telecommunication network may be used to monitor and switch on and off electric loads such as heaters and lights in guest bedrooms, and may also control the bedroom door combination lock by changing the electronically stored combination, and may also be used to monitor smoke detectors in unoccupied rooms. All of these switching and monitoring operations may be carried out from a central location.

A system in accordance with the invention may be installed in a high security premises, for example an industrial premises and any person visiting such a premises on a temporary basis may be required to carry a signal emitting device, and the signal can then be detected by detectors located in each room and connected to the network, so that the movement of the person through the building can be monitored.
Figure 3 is a block diagram of the control elements of a module comprising a power supply, memory storing the identification of the module, an interface to the local network, an interface to the intercommunications network, a communications cable, a microprocessor, a memory for storing data, an input/output interface, a driver, and electrical switches.

In the embodiment of Figures 1 to 3 the control means and the switches may be physically integrated to form one unit. As shown in Figure 20, however, they may be separated and this makes it easier to add new loads to an existing system. In Figure 20 the control means 100 receives signals either from the main communication line 101, or from command inputs such as a keypad 102, computer 103, sensor 104, or telephone 105 within its own module, and transmits output signals to microswitches 106 that either control loads directly or in turn operate relays 107.

DESCRIPTION OF CIRCUIT DIAGRAMS

Figure 4 shows the keypad circuit which consists of the keys, light emitting diodes (LED's) 401, central processing unit 402, memory 403, and an interface 404 for transmitting signals onto the local communications line.

Figure 4a illustrates a possible keypad configuration. Figure 4B shows a possible PC adaptor circuit for connecting a personal computer to the network, and includes voltage converter 407, and interface 406.

Figure 5 shows a load switching circuit in which the loads are switched by TRIACs. A switching circuit of this type is useful for switching small loads, for example lights. The switching circuit comprises a communication circuit 501.
for communicating with the local telecommunication lines, shown as lines LOC-TXH and LOC-TXL connected to pins 6 and 7 of the circuit 501, a communication circuit 502 for communicating with the main communications line shown as lines IN-TXH and IN-TXL connected to pins 6 and 7 of the circuit 502, a central processing unit 503, an address-memory 504 storing the addresses of switches in the module, a memory for storing data arriving on the communications lines, output circuits 506, and TRIAC circuits 507 connected to the output circuits 506 to switch the respective loads.

Instead of TRIAC's, solenoids may be used to switch the loads. A switching circuit of this type is useful for switching larger loads. A solenoid circuit is essentially the same as that illustrated in Figure 5, except that the TRIACs are replaced by solenoids.

Figure 6 shows the telephone circuit for connecting a telephone receiver to the local communications line. The telephone circuit comprises a telephone line 601 from the telephone receiver (not shown in Figure 6) a ringing circuit 602, a pickup-hangup circuit 603, a tone decoder circuit 604, a central processing unit 605, a memory 606, and an interface circuit 607 for communicating with a local communications line.

The circuits illustrated in the drawings allow a maximum of eight loads in each module. However, it should be appreciated that in appropriate circumstances many more loads may be included within a single module.

**GENERAL DESCRIPTION OF SOFTWARE**

A command entered at a particular input (keypad) is analyzed by the corresponding switching circuit. As a result
of this analysis the command is either routed to the appropriate switch within the module, or alternatively is entered on the main communications line. In designing a system those inputs and outputs which are commonly used together, for example an input in a particular room and the output in the same room, should be grouped together within the same module, thereby minimizing the numbers of commands entered on the main communications line.

Where a command is entered on the main communications line, the switching circuit of each module analyzes the command to determine whether the command is intended for a load within that module and, if so, routes the command to the appropriate output. Because each switching circuit analyzes the command, there is no transmission delay.

Within each module, where two or more commands are entered from different inputs at almost the same time, the software determines a priority sequence for handling the commands so that they do not interfere with one another, and causes the later command to be stored temporarily and dealt with later.

To prevent two or more commands being entered on the main communications line at the same time, each switching circuit first checks the status of the main communications line before entering any command, and if the switching circuit determines that a command is already on the main communications line, then the software causes the later command to be temporarily stored and dealt with later. Commands are repeated with a waiting time of the order of 5 or 6 ms, more urgent commands having shorter waiting times whereby they will be entered onto the network first when the network becomes free.
When a command is entered on the main communications line, the software detects whether the command is in fact received at any of the modules. If the command is not received by any of the modules the software initially assumes that the command has been incorrectly transmitted due to noise or interference, and the command is re-transmitted. In the event of a second failure, the software then assumes that a fault exists, either in the command given or in the circuit. In response to this assumption the software causes the non-reception of the command to be recorded either at the location where the command was given so that the person giving the command appreciates that the command has not been obeyed, or at a central monitoring location to assist in diagnosing any fault in the circuit.

A command entered at a particular input (keypad) relating to loads within that module results in a corresponding signal to the appropriate LED within the keypad, and all other keypads in the same module.

An enquiry entered at a particular keypad concerning the status of loads in another module results in sending an enquiry signal on the main communication line to the other module, receiving the response, and signalling the response to the keypad at which the enquiry is entered.

DESCRIPTION OF USER CHARTS AND FLOWCHARTS

Figure 7 is a chart giving the user commands or enquiries on the keypad. The keypad itself is illustrated in Figure 4A and includes a total of 16 keys in a 4 x 4 array. In the user chart the four left hand columns represent the command or enquiry which is made by pressing between one and four keys. The fifth column is a brief description of the command.
Figure 8 is a chart giving the user commands or enquiries by telephone keypad. A conventional telephone has only twelve keys instead of the sixteen in the keypad shown in Figure 4A, and accordingly a different protocol must be used. According to a further feature of the invention a telephone is provided which has a keypad having the same keys and LED's as the keypad of the invention. A home owner may install such a telephone in his workplace and control loads in his home from his workplace.

Figures 9A and 9B together form a flowchart illustrating the operation of the keypad microprocessor. The keypad microprocessor responds to two types of signal, firstly "outgoing" signals consisting of commands or enquiries entered on the keypad which must then be distributed to other parts of the system, and secondly "incoming" signals consisting of commands from other parts of the system to switch on LED's at the keypad. For a better understanding of the outgoing signals the flowchart of Figures 9A and 9B should be read in conjunction with the keypad user chart illustrated in Figure 7 and the protocol chart Figure 12. The decision making process includes questions (diamond shaped boxes) resulting in either a positive answer indicated by "Y" (for "yes") or a negative answer indicated by "N" (or "no").

The questions are listed below in tabular form:

<table>
<thead>
<tr>
<th>Question Box No.</th>
<th>Question</th>
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<tbody>
<tr>
<td>101</td>
<td>Has a key of the keypad been pressed?</td>
</tr>
<tr>
<td>102</td>
<td>Has a communication been received from the system?</td>
</tr>
<tr>
<td>103</td>
<td>Is the &quot;recall&quot; flag on?</td>
</tr>
</tbody>
</table>
104 Is the signal a status report command to display LED's?
105 Is the "recall" flag on?
106 Is the command a single key command?
107 Is the single key command the "ON" key?
108 Is the single key command the "OFF" key?
109 Is the single key command the "STORE" key?
110 Has a key been pressed subsequent to the "STORE" key?
111 Is the subsequent key any one of keys "1" to "8"?
112 Is the subsequent key the "STORE" key?
113 Is the subsequent key the "*" key?
114 Is the subsequent key the "CLEAR" key?
115 Has the flag been marked to send to store into module memory?
116 Is the key one of keys "1" to "8"?
117 Is the key the "CLEAR" key?
117a Is the key the "CLEAR" key?
117b Is the key the "#" key?
118 Is the key the "ON" key?
119 Is the key the "OFF" key?
120 Is the key the "RECALL" key?
121 Is the key the "CLEAR" key?
122 Has there been an error in the identification number?
123  Is the first key the "#" key?
124  Is the first key the "*" key?
125  Is the second key the "ON" key?
126  Is the second key the "OFF" key?
127  Is the second key the "ON" key?
128  Is the second key the "OFF" key?
129  Is the second key the "#" key?
130  Is the third key the "ON" key?
131  Is the third key the "OFF" key?

The answer to each question leads either to another question or back to a previous question or to the start or leads to a command being issued by the keypad microprocessor, these commands including the following:

<table>
<thead>
<tr>
<th>Command Box No.</th>
<th>Description of Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>Displays status of all loads in module on LED's</td>
</tr>
<tr>
<td>151</td>
<td>Store the key pressed and increment the keypad buffer pointer</td>
</tr>
<tr>
<td>152</td>
<td>Clear LED's of the keypad</td>
</tr>
<tr>
<td>153</td>
<td>Mark the &quot;#&quot; flag to indicate that it has been pressed</td>
</tr>
<tr>
<td>154</td>
<td>Clear all flags and all buffers</td>
</tr>
<tr>
<td>155</td>
<td>Send a command to request status of the loads of that module</td>
</tr>
<tr>
<td>156</td>
<td>Mark flag to store in memory of that module</td>
</tr>
<tr>
<td>157</td>
<td>Store status in the keypad memory</td>
</tr>
<tr>
<td>158</td>
<td>Send command to store status in memory of that module and report</td>
</tr>
</tbody>
</table>
status of loads in module back

159  Invert status of LED's
160  Save status of LED's in buffer
161  Send command from keypad to module to switch off loads as stored in keypad memory
162  Send command from keypad to module to switch on loads as stored in module memory
163  Send command to invert the loads of this module
164  Send command to invert the loads of recalled module
165  Send commands from keypad to module to switch off loads as stored in module memory
166  Send commands from keypad to module to switch on loads as stored in module memory
167  Send command from keypad to module to switch off all loads of the module
168  Send command from keypad to module to switch on all loads of the module
169  Send command from keypad to all modules to switch off all loads
170  Send command from keypad to all modules to switch on all loads

Figures 10A and 10B together form a flowchart illustrating the operation of the telephone microprocessor. The telephone microprocessor distributes "outgoing" signals in the same way as for the keypad, but differs from the keypad in a number of respects. Firstly because the telephone does not have LED's and therefore does not receive incoming signals, secondly because the telephone may also be
used in a normal telephone mode for purposes other than to control the system, and thirdly because the telephone has a lesser number of keys than the keypad. For a better understanding of the outgoing signals from the telephone to the system according to the invention the flowchart of Figures 10A and 10B should be read in conjunction with the telephone user chart illustrated in Figure 8 and protocol chart Figure 13. The decision making process includes questions (diamond shaped boxes) resulting in either a positive answer indicated by "Y" (for "yes") or a negative answer indicated by "N" (or "no"). The questions are listed below in tabular form:

<table>
<thead>
<tr>
<th>Question Box No.</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>201</td>
<td>Is the telephone ringing?</td>
</tr>
<tr>
<td>202</td>
<td>Has the telephone been picked up?</td>
</tr>
<tr>
<td>203</td>
<td>Has a key of the telephone keypad been pressed?</td>
</tr>
<tr>
<td>204</td>
<td>Has the telephone been hung up?</td>
</tr>
<tr>
<td>205</td>
<td>Is the first key the &quot;*&quot; key?</td>
</tr>
<tr>
<td>206</td>
<td>Has the telephone been hung up?</td>
</tr>
<tr>
<td>207</td>
<td>Has another key been pressed?</td>
</tr>
<tr>
<td>208</td>
<td>Has the telephone been hung up?</td>
</tr>
<tr>
<td>209</td>
<td>Is the subsequent key the &quot;*&quot; key?</td>
</tr>
<tr>
<td>210</td>
<td>Is the subsequent key the &quot;#&quot; key?</td>
</tr>
<tr>
<td>211</td>
<td>Is the first key the &quot;*&quot; key?</td>
</tr>
<tr>
<td>212</td>
<td>Is the first key the &quot;#&quot; key?</td>
</tr>
<tr>
<td>213</td>
<td>Is the first key any one of keys &quot;1&quot; to &quot;9&quot;?</td>
</tr>
<tr>
<td>214</td>
<td>Is the first key the &quot;ZERO&quot;-key?</td>
</tr>
</tbody>
</table>
Is the third key the "*" key?
Is the third key the "#" key?
Has the "*" key been pressed?
Has the "#" key been pressed?
Is the second key the "*" key?
Is the second key the "#" key?
Is the third, fourth, or subsequent key the "*" key?
Is the third, fourth, or subsequent key the "#" key?
Has the phone been picked up before ringing nine times?
Has a key been pressed?
Has fifteen seconds elapsed?
Is the key the "*" key?
Is the key the "#" key?
Is the first key the "*" key?
Is the first key the "#" key?
Is the first key any one of keys "1" to "9"?
Is the first key the "ZERO" key?
Is the third key the "*" key?
Is the third key the "#" key?
Is the fourth key the "*" key?
Is the fourth key the "#" key?
Is the second key the "*" key?
Is the second key the "#" key?
Is the third key the "*" key?
Is the third key the "#" key?

The answers to these questions lead either back to the beginning, or lead to another question, or lead to the microprocessor issuing a command, as listed in the following table:

<table>
<thead>
<tr>
<th>Command Box No.</th>
<th>Description of Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>Store the pressed keys in the key buffer</td>
</tr>
<tr>
<td>251</td>
<td>Obtain the module number from the first and second key</td>
</tr>
<tr>
<td>252</td>
<td>Obtain the load number to be switched ON or OFF from the fourth key until the end</td>
</tr>
<tr>
<td>253</td>
<td>Send command to turn off loads in the same module</td>
</tr>
<tr>
<td>254</td>
<td>Send command to turn on loads in the same module</td>
</tr>
<tr>
<td>255</td>
<td>Send command to turn off all loads in the same module</td>
</tr>
<tr>
<td>256</td>
<td>Send command to turn on all loads in the module</td>
</tr>
<tr>
<td>257</td>
<td>Send command from telephone pad to module to switch on loads as stored in module memory</td>
</tr>
<tr>
<td>258</td>
<td>Send command from telephone pad to module to switch off loads as stored in module memory</td>
</tr>
<tr>
<td>259</td>
<td>Send command to turn on all loads in that module</td>
</tr>
<tr>
<td>260</td>
<td>Send command to turn off all loads in that module</td>
</tr>
<tr>
<td>261</td>
<td>Send command to turn off all loads in that module</td>
</tr>
<tr>
<td>262</td>
<td>Send command to turn on all loads in</td>
</tr>
</tbody>
</table>
that module

Send command to automatically pick up telephone

Store the key in the key buffer

Obtain the module number from the first and second key

Obtain the load number from the fourth key until the end

Send a command to turn off all loads in that module

Send a command to turn on all loads in that module

Send a command to turn off all loads in that module

Send a command to turn on all loads in that module

Send command from telephone pad to module to switch on loads as stored in module memory

Send command from telephone pad to module to switch off loads as stored in module memory

Obtain load number from third key until end

Send a command to turn off all loads in that module

Send a command to turn on all loads in that module

Send a command to turn off all loads in that module

Send a command to turn on all loads in that module

Figure 11 is a flowchart of the operation of the microprocessor in each module. This microprocessor receives
signals from outside the module and from within the module, and issues commands to other modules and within the module. The decision making process includes questions (diamond shaped boxes) resulting in either a positive answer indicated by "Y" (for "yes") or negative answer indicated by "N" or "no". The questions are listed below in tabular form:

<table>
<thead>
<tr>
<th>Question Box No.</th>
<th>Brief Description of Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>301</td>
<td>Is there any command on the main communications line?</td>
</tr>
<tr>
<td>302</td>
<td>Is there any command on the local communications line?</td>
</tr>
<tr>
<td>303</td>
<td>Is the command for the attention of all modules?</td>
</tr>
<tr>
<td>304</td>
<td>Is the command for the attention of just one module?</td>
</tr>
<tr>
<td>305</td>
<td>Is the command the &quot;RECALL&quot; command?</td>
</tr>
<tr>
<td>306</td>
<td>Does the &quot;RECALL&quot; command request status only?</td>
</tr>
<tr>
<td>307</td>
<td>Does the &quot;RECALL&quot; command require that the status be complemented?</td>
</tr>
<tr>
<td>308</td>
<td>Does the &quot;RECALL&quot; command match the identification of this module?</td>
</tr>
<tr>
<td>309</td>
<td>Does the &quot;RECALL&quot; command match the identification of this module?</td>
</tr>
<tr>
<td>310</td>
<td>Does the command match the identification of this module?</td>
</tr>
<tr>
<td>311</td>
<td>Is the command for the attention of all modules?</td>
</tr>
<tr>
<td>312</td>
<td>Is the command the &quot;ON&quot; command?</td>
</tr>
<tr>
<td>313</td>
<td>Is the command the &quot;OFF&quot; command?</td>
</tr>
<tr>
<td>314</td>
<td>Is the command to invert the status of the loads?</td>
</tr>
<tr>
<td>315</td>
<td>Is the command to store in module</td>
</tr>
</tbody>
</table>
memory?

316 Is the command to recall from module memory and switch on?

317 Is the command to recall from module memory and switch off?

318 Is the command a request for the status of loads within the module?

319 Is the command for the attention of all modules?

320 Does the command match the identification of this module?

321 Is the command the "RECALL" command?

322 Does the command match the identification of this module?

323 Is the command a command to recall the status?

324 Is the command to invert the status and then report?

325 Is the command a status request?

326 Does the command include the identification of this module?

The answers to the questions may lead to the microprocessor going back to the start of its analysis, or may lead to a further question, or may lead to a different part of the flowchart, or may lead to the microprocessor issuing a command. The possible commands are listed in tabular form below.

<table>
<thead>
<tr>
<th>Command Box No.</th>
<th>Brief Description of Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>351</td>
<td>Update the status of the loads within the module to module memory</td>
</tr>
<tr>
<td>352</td>
<td>Send a command to the main communications line</td>
</tr>
</tbody>
</table>
ASYNCHRONOUS COMMUNICATION

In use, systems according to the invention typically receive commands and enquiries in much lower volume than the volume at which commands and enquiries are received by many computer systems. In addition many commands and enquiries are kept within a particular module. As a result it is possible to use a low speed networking technique in which data is transmitted asynchronously at a speed ranging from 50 baud to 56 kilobaud using communications lines meeting international standard RS 422. Asynchronous communication is much less expensive than synchronous communication.

Figure 12 is a chart similar to Figure 7 but also showing the communications protocol for data entered through the keypad. Figure 13 is a chart similar to Figure 8 but also showing the communications protocol for data entered through the network lines.
A first protocol format is illustrated in Figure 14 and consists of eleven bytes of data, the first byte being a start byte, the second and third bytes identifying the source of the command or enquiry, the fourth and fifth bytes identifying the destination of the command or enquiry, the sixth and seventh bytes being the command or enquiry instruction, the eighth and ninth bytes containing data information, the tenth byte being a cyclic redundancy check (CRC) byte, and the eleventh byte being the end byte.

Figure 15 illustrates a second data protocol. This is similar to the first, but longer including 21 bytes of information alone.

Before transmitting data a request for attention is made so that all parties connected to the network are alerted concerning the transmission of data. A simple logic low with a given time constitutes the request. A stable logic high for a minimum of 10 milliseconds indicates that the network is not occupied, and then a stable logic low for the given time indicates that data is about to be transmitted.

The first protocol, being shorter, can be transmitted quickly and is used for transmitting urgent data; for example a warning signal from a smoke detector or the like, or security information. The second protocol is used in normal circumstances when more information is required and speed is not so important. As an example, Figure 16 illustrates how the first protocol may be used to transmit data from a sensor S1 in one module, to an alarm in a different module via the main communications network.

Signals can be transmitted on a point-to-point basis, or may be transmitted more widely. Figure 17 illustrates a sensor S1 transmitting data to two alarms and a PC. Such information is simple and can be transmitted using the first
protocol. More complex information can be sent using the second protocol. An example is illustrated in Figure 18 in which information from a card-reader, for example controlling an electronic lock, is transmitted to a controlling PC in a different module.

It should be understood that while the description has primarily centered on the control and operation of simple devices such as lights, the invention is not limited thereto. It will be appreciated that the apparatus could be used to control many other types of devices including, but of course not limited to, sensors such as smoke detectors or motion detectors, electronic security locks, video cameras, heating systems or air conditioning units. In effect all aspects of a building, or even group of buildings, can be controlled using the present apparatus.

The examples illustrated previously show a single level of modules connected to the main transmission line. It should be understood, however, that each module can include sub-modules, and a branched tree-like architecture can be employed. The configuration in any practical situation will depend on the requirements of a particular application. As a general rule, however, control units which are more frequently called upon to converse with one another are grouped together. Figure 19 illustrates just one possible example. The four main modules 1001, 1002, 1003 and 1004, may represent four different buildings; the next level of modules 2001, 2002 ... may correspond to the individual floors within each buildings and these modules in turn may comprise further sub-modules 3001, 3002 ... for individual rooms.
1. Apparatus for controlling a number of electrical loads comprising an electrical switch for each load, a telecommunication network including a connection to each electrical switch, command input stations connected to the telecommunication network, and control means whereby a command entered at an input station travels along the network and operates a switch thereby switching on or off a load, characterised in that said network comprises a plurality of network modules connected in series by a main telecommunication line, each module comprising an input station, and one or more switches, and wherein in the case of commands from an input station to a switch within the same module said control means is adapted to send these commands from the station to the switch without entering the command on the main communication line.

2. Apparatus according to claim 1 wherein at least some of said modules comprise one or more sub-modules, each said sub-module comprising an input station, one or more switches and control means, whereby said network is formed with a branched structure.

3. Apparatus according to claim 1 or 2 in which communications are transmitted asynchronously.

4. Apparatus according to claim 3 wherein messages are transmitted on said network in either a first protocol or a second protocol, said first protocol being shorter than said second and being used for messages of greater urgency.

5. Apparatus according to claim 4 in which the asynchronous transmission takes place at speeds in the range of 50 baud to 56 kilobaud in the form of a logic inversion to command attention followed by an eleven byte first protocol
transmission comprising a starting byte, two source identification bytes, two destination identification bytes, two command or enquiry bytes, two data information bytes, a cyclic redundancy check byte, and an end byte.

6. Apparatus according to claim 4 in which the asynchronous transmission takes place at speeds in the range of 50 baud to 56 kilobaud in the form of a logic inversion to command attention followed by a thirty-four byte second protocol transmission comprising twenty-one command information bytes.

7. Apparatus according to any preceding claim including an electrical switch status indicator means for indicating the status of the electrical switches connected to the network.

8. Apparatus according to any preceding claim comprising means for connection to an external communication line so as to enable the apparatus to receive commands from the outside communication line and enter these commands on to the network.

9. Apparatus according to claim 8 wherein said external communications line comprises a directly wired-in telephone line, a remote telephone, or a computer link.

10. Apparatus according to any preceding claim wherein each input station comprises a keypad consisting of keys for entering commands on the network and a light associated with each key of the keypad for indicating the status of the electrical switches within the same module as said input station.

11. Apparatus according to any preceding claim in which each command input station is independently programmable to store complex commands which may be recalled upon receipt of a relatively simple command either directly at said command
input station or by means of a command received from the network.

12. A telephone for use in connection with apparatus according to claim 9 comprising a keypad consisting of keys for entering commands on the network and a light associated with each key of the keypad for indicating the status of electrical switches of the apparatus.
Fig. 2.

SYSTEM CONTROL

INTER-NETWORK COMMUNICATION

#1
INTER-NET
STATION CONTROL
LOCAL-NET

#2
INTER-NET
STATION CONTROL
LOCAL-NET

#3
INTER-NET
STATION CONTROL
LOCAL-NET

#N
INTER-NET
STATION CONTROL
LOCAL-NET

LOCAL NETWORK

90

LOCAL NETWORK

90

LOCAL NETWORK

90

LOCAL NETWORK

90
Fig. 4.

Fig. 4A.

Table:

<table>
<thead>
<tr>
<th>C0</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ON</td>
</tr>
<tr>
<td>R0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>R1</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>R2</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>R3</td>
<td>*</td>
<td>0</td>
<td>#</td>
</tr>
</tbody>
</table>

Legend:
- VCC
- GND
- TXH
- RXH
- TXL
- RXL
- TXEN
- RXDATA
- OSC1
- OSC2
- RTCC
- MCLR
- C7
- C6
- C5
- C4
- C3
- C2
- C1
- C0
- 1K
- 1N4148
- 1JF
- +5V

Key:
- +8V
- GND
- TXLOW
- TXHIGH
## Fig. 7

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLR</td>
<td>CLR</td>
</tr>
<tr>
<td>CLR</td>
<td>CLR</td>
</tr>
<tr>
<td>1-8</td>
<td></td>
</tr>
<tr>
<td>ON</td>
<td></td>
</tr>
<tr>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>ON/OFF</td>
</tr>
<tr>
<td>#</td>
<td>#</td>
</tr>
<tr>
<td>*</td>
<td>ON</td>
</tr>
<tr>
<td>*</td>
<td>OFF</td>
</tr>
<tr>
<td>STORE</td>
<td></td>
</tr>
<tr>
<td>STORE</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>STORE</td>
</tr>
<tr>
<td>#</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(AFTER RECALL OTHER BOX IS ON THEN)</td>
</tr>
<tr>
<td>1-8</td>
<td></td>
</tr>
<tr>
<td>CLR</td>
<td></td>
</tr>
</tbody>
</table>
## Fig. 8.

<table>
<thead>
<tr>
<th>PHONE PAD</th>
<th>(HIT * FIRST TO GO TO LOCAL MODE)</th>
<th>(19 BOXES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2,3,4</td>
<td>*</td>
<td>TURN ON BOX 1, LIGHT 2,3,4</td>
</tr>
<tr>
<td>1 2,3,4</td>
<td>#</td>
<td>TURN OFF BOX 1, LIGHT 2,3,4</td>
</tr>
<tr>
<td>0 0 2,3,4</td>
<td>*</td>
<td>TURN ON BOX 10, LIGHT 2,3,4</td>
</tr>
<tr>
<td>0 0 2,3,4</td>
<td>#</td>
<td>TURN OFF BOX 10, LIGHT 2,3,4</td>
</tr>
<tr>
<td>0 1</td>
<td>*</td>
<td>TURN ON BOX 11 ALL LIGHT</td>
</tr>
<tr>
<td>1</td>
<td>*</td>
<td>TURN ON BOX 1 ALL LIGHT</td>
</tr>
<tr>
<td>1</td>
<td>#</td>
<td>TURN OFF BOX 1 ALL LIGHT</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td>RECALL INTER MEMORY (ON)</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td>RECALL INTER MEMORY (OFF)</td>
</tr>
</tbody>
</table>
Fig. 9A.

START

KEY PRESS
N 105
Y 101

RECALL FLAG
N 116
Y 114

1-8 KEY
N 108
Y 103

N-KEY
N 117
Y 116

SEND CMD TO COMPLEMENT LIGHT AND REPORT STATUS BACK
START

CLEAR FLAG & BUFFER
START

SEND CMD REQUEST STATUS
START

SEND RECALL LOCAL MEMORY CMD
START

SEND RECALL LOCAL OFF CMD
START

DISPLAY STATUS LED
N 150
Y 104

OFF KEY
N 108
Y 107

STATUS REPORT CMD
N 104
Y 103

DISPLAY STATUS LED
START

ANY COMMUNICATION IN
N 102
Y 150

TO 109

START

(MORE THAN ONE KEY)
N 106
Y 105

SINGLE KEY
N 106
Y 105

START
Fig. 9A. (Cont.)

START

INCUREMENT KEY BUFF POINTER

CLEAR LED

MARK # FLAG ON

START

CLEAR KEY

STORE KEY

Y

N

CLEAR LED

KEY

START

CLEAR FLAG & BUFFER

SEND CMD REQUEST STATUS

1-8 KEY

KEY PRESS

B

N

Y

109 FROM 108

151

152

153

154

155

156

157

158

159

160

INTER STORE

N

Y

COMPLEMENT LED LG

SAVE STATUS IN BUFFER

SEND CMD TO STORE INTER MEM & REPORT STATUS BACK

START

START

STORE KEY

Y

N

START

CLEAR FLAG IN BUFFER

SEND CMD REQUEST STATUS

B

B

SEND CMD RQST. STATUS

(START)
Fig. 9B. (Cont.)

FROM 123

N

127

2nd. KEY = ON

Y

SEND CMD TO TURN ON ALL LOCAL LIGHTS

168

N

128

2nd. KEY = OFF

Y

SEND CMD TO TURN OFF ALL LOCAL LIGHTS

167

167

START

129

N

2nd. KEY = 

Y

START

3rd. KEY = ON

130

TILL END

Y

SEND CMD TO TURN ON ALL BOXES ALL LIGHTS

170

N

3rd. KEY = OFF

Y

TILL END

SEND CMD TO TURN OFF ALL BOXES ALL LIGHTS

169

START

START

START

START

SUBSTITUTE SHEET
Fig. 10A.

BEGIN

RING

N

Y

A

PHONE PICK

202

Y

N

B

KEY PRESS

N

Y

203

204

HANG

205

KEY

206

N

Y

HANG

207

TO

Y

N

AUTO PICK BEEP

Ringing 9 Times)

PHONE

223

264

Y

N

INPUT UNTIL

FOUND TERMINATOR

IF LOCAL PICK PHONE THEN
WAIT FOR KEY (*) BEFORE BRANCH DOWN TO CONTROL ROUTINE.

SUBSTITUTE SHEET
Fig. 10A. (Cont.)

TO 205

KEY PRESS

TERMINATOR

HANG

208

INI

207

TO 209

N

KEY

TERMINATOR

Y

209

KEY

210

TO

211

STORE IN KEY BUFFER

TO 213

1st. KEY = φ

214

B

GET BOX NO. FROM 1st. & 2nd KEY

BOX > 9

215

3rd. KEY = *

216

N

Y

SEND CMD TURN ON ALL LIGHTS THAT BOX

3rd. KEY = #

SEND CMD TURN OFF ALL LIGHTS THAT BOX

GET LIGHT NO. FROM 4th. KEY UNTIL END

252

255

256

217

218

253

SEND CMD TURN OFF LIGHTS THAT BOX

SEND CMD TURN ON LIGHTS THAT BOX

B

B

B
Fig. 10B.

KEY INPUT UNTIL FOUND TERMINATOR THEN EXECUTE ELSE IF 15 SEC TIME OUT THEN GO INITIALIZATION

N 15 SEC Y
225
N

STORE IN KEY BUFFER
265

N KEY PRESS Y
224

N

226

1st. KEY = φ Y
231

N

GET BOX NO. FROM 1st. & 2nd KEY
266

N 3rd. KEY = * Y
232

3rd. KEY = # N
233

SEND CMD TURN ON ALL LIGHTS THAT BOX
269

SEND CMD TURN OFF ALL LIGHTS THAT BOX
270

SEND CMD TURN ON LIGHTS THAT BOX
271

GET LIGHT NO. FROM 4th. KEY UNTIL END
267

SEND CMD TURN OFF LIGHTS THAT BOX
272

268

269

270

271

272
**Fig. 12.**

**KEYPAD FUNCTION**

<table>
<thead>
<tr>
<th>1st</th>
<th>2nd</th>
<th>---</th>
<th>---</th>
<th>---</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLR</td>
<td>CLR</td>
<td>CLR</td>
<td>CLR</td>
<td>CLEAR</td>
</tr>
<tr>
<td>1-8</td>
<td>ON/OFF LIGHT (1-8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON</td>
<td>RECALL LOCAL MEMORY [ON]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFF</td>
<td>&quot; &quot; &quot; &quot; [OFF]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># ON</td>
<td>TURN ON THAT BOX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># OFF</td>
<td>&quot; OFF &quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* ON</td>
<td>RECALL INTER MEMORY [ON]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* OFF</td>
<td>&quot; &quot; &quot; &quot; [OFF]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># # ON</td>
<td>TURN ON ALL BOX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># # OFF</td>
<td>&quot; OFF &quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STORE BRANCH TO STORE MEMORY ROUTINE

STORE LOCAL MEMORY [WR TO EE]

STORE INTER MEMORY

# 1,2 RECALL BOX 12 STATUS

# 1,2,3,4 RECALL BOX 1234 STATUS (AFTER RECALL OTHER BOX ON)

1-8 ON/OFF RECALLED BOX LIGHT

CLR RETURN TO LOCAL BOX STATUS

SUBSTITUTE SHEET
**Fig. 12. (Cont.)**

<table>
<thead>
<tr>
<th>COMMUNICATION FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sync</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>EA</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
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**Fig. 13 (Cont.)**

**COMMUNICATION FORMAT**

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Fig. 16.

POINT TO POINT

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POINT TO POINT (INTER)
Fig. 17.

BROADCAST TO ALL DEVICES

FIRST PROTOCOL

START | SCR.1 | SCR.2 | DEST.1 | DEST.2 | DEVICE | CMD | DEV.ID | INFO.2 | CRC | END
EA    | 00    | 01    | XX     | XX     | 24     | 01   | 01=ON | 'CRC' E8 | 02=OFF

BROADCAST ENABLE
10XX XXXX
Fig. 19.

SUBSTITUTE SHEET
**INTERNATIONAL SEARCH REPORT**

**International Application No.** PCT/GB 93/00830

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**I. CLASSIFICATION OF SUBJECT MATTER**

(if several classification symbols apply, indicate all)\(^6\)

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H05B37/02; H02J13/00

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**II. FIELDS SEARCHED**

Minimum Documentation Searched\(^7\)

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Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched\(^8\)

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**III. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<th>Category</th>
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\(^6\) Special categories of cited documents:\(^10\)

\(^A^*\) document defining the general state of the art which is not considered to be of particular relevance

\(^E^*\) earlier document but published on or after the international filing date

\(^I^*\) document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

\(^O^*\) document referring to an oral disclosure, use, exhibition or other means

\(^P^*\) document published prior to the international filing date but later than the priority date claimed

\(^T^*\) later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\(^X^*\) document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

\(^Y^*\) document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

\(^&^*\) document member of the same patent family

---

**IV. CERTIFICATION**

Date of the Actual Completion of the International Search 30 JUNE 1993

Date of Mailing of this International Search Report 0 9, 07, 93

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

SPEISER P.
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| A        | US, A, 5 086 385 (LAUNEY)  
4 February 1992  
see column 1, line 29 - column 3, line 55;  
figure 1 | 1 |
| A        | WO, A, 8 905 562 (LEHUSVUO)  
15 June 1989 | --- |
ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. GB 9300830
SA 72712

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 30/06/93

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For more details about this annex: see Official Journal of the European Patent Office, No. 12/82