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(71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; 1 River Road, Schenectady, NY 12305 (US).

(72) Inventors: FARNSWORTH, Richard, George; 308 York Street, York, ME 03909 (US). ROBINSON, Paul, Bradford; 9 Fogg Drive, Durham, NH 03824 (US).

(74) Agents: EDERER, Norbert; General Electric Company, 570 Lexington Avenue, New York, NY 10022 (US) et al.

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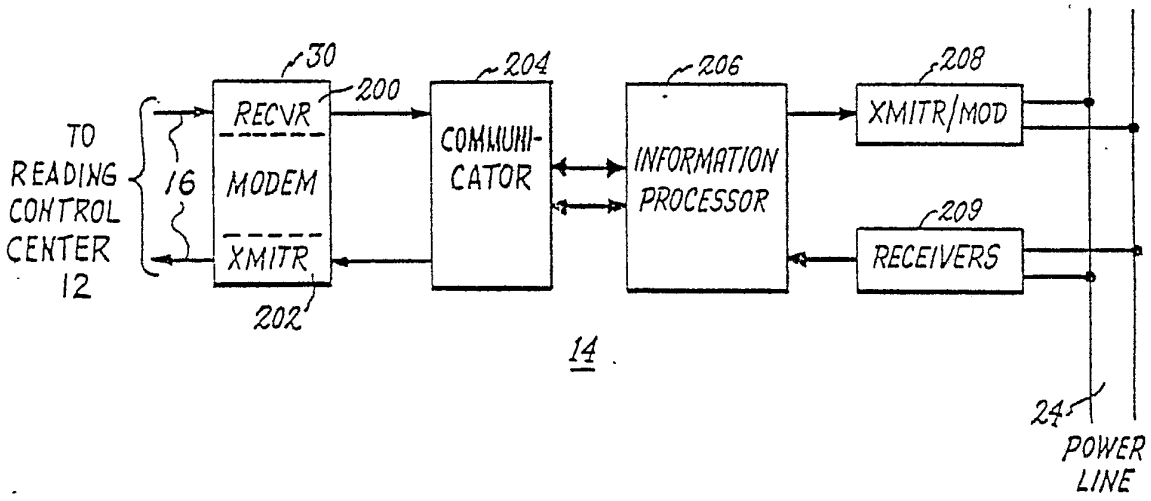

(57) Abstract

The control unit is operable to substantially simultaneously operate a first receiver (200) to receive (at 16) a currently received command within a group of commands from a reading control center (12) and to operate a first transmitter (208) to transmit (at 24) an earlier received command within the same group of commands to meter terminal units when an earlier command has been received, and to operate a second receiver (209) to receive messages (at 24) from the meter terminal units responding to a single earlier transmitted command within the same group of commands when an earlier command has been transmitted, and to operate a second transmitter (202) to transmit to the reading control center (12) the messages from the meter terminal units responding to the single earlier transmitted command.

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CONTROL UNIT FOR AUTOMATIC METER READING SYSTEM

Technical Field

The present invention relates to an improved control unit for an automatic meter reading system. The invention is especially useful in automatic remote meter reading systems for reading and transmitting utility meter readings from the users premises to a central location for recordation and billing. For instance, the invention is especially useful for reading and transmitting data from electric power meters, or gas meters, or water meters, which measure consumption of those commodities.

Background Art

The present invention represents an improvement upon a prior system disclosed in British patent specification 1,543,501, General Electric Company, published on 4 April 1979. In that prior system, a reading control center communicates over voice grade communication lines with a number

of section control units frequently referred to herein simply as "control units", and through the control units and through electric power lines to individual meter terminal units. The present invention relates particularly to improved control units for use in such a system. The control units of the prior system were capable of rapidly receiving commands from the reading control center and transmitting corresponding commands to the meter terminal units, and for receiving messages in response to the commands, and for transmitting corresponding messages back to the reading control center.

However, in a large system, there are a tremendous number of different terminal units to which commands must be sent, and from which messages must be processed. Accordingly, it has been determined that it is very desirable to provide for additional speed and efficiency in the operation of the control units in relaying commands from the reading control center to the appropriate terminal units, and in relaying corresponding data messages from the terminal units back to the reading control center.

Disclosure of Invention

It is a major object of the present invention to provide an improved control unit for an automatic meter reading system which provides for greatly improved speed and efficiency in the handling of commands and messages to be transmitted between the reading control center and the meter terminal units.

In carrying out the invention there is provided a control unit for an automatic meter reading system of the type which also includes a reading control center for sequentially transmitting commands and receiving messages representative of measurement data and a plurality of meter terminal units for recording data at the sites where the data is available and for transmitting that data over a power line in the form of data messages in response to commands, said control unit being operable for relaying the commands and messages between the reading control center and the meter terminal units, said control unit including a first receiving means for receiving commands over a voice grade communication line from the reading control center, a first transmitting means for

transmitting commands corresponding to received commands over a power line to the meter terminal units, a second receiving means for receiving data messages from the meter terminal units over the power line, a second transmitting means for transmitting to the reading control center data messages corresponding to the data messages from the meter terminal units, data processing and decoding means for decoding and processing and switching commands and messages between said first receiving means and said first transmitting means and between said second receiving means and said second transmitting means, said data processing and communicating means being operable to substantially simultaneously (a) operate said first receiving means to receive a currently received command within a group of commands from the reading control center and (b) operate said first transmitting means to transmit an earlier received command within the same group of commands to the meter terminal units when an earlier command has been received and (c) operate said second receiving means to receive messages from the terminal units responding to a single earlier transmitted command within the same group of com-

mands when an earlier command has been transmitted and (d) operate said second transmitting means to transmit to the reading control center the messages from the meter terminal units responding to the single earlier transmitted command.

Brief Description of Drawings

FIG. 1 is a schematic block diagram of an entire system of the type incorporating the present invention.

FIG. 2 is a schematic block diagram showing the major components and interconnections of the control unit of the present invention.

FIGS. 3 and 4, taken together, form a more detailed schematic diagram of the control unit of FIG. 2

Best Mode of Carrying Out the Invention

Referring particularly to FIG. 1 of the drawings, there is shown a schematic diagram of a system in which the present invention is particularly useful. The system is generally designated as 10 and includes a reading control center (RCC) 12 which communicates with a section control unit (SCU) 14 over a communication link 16. The section control unit 14 communicates with a plurality of

meter terminal units (MTU) over a communication link 24. The communication link 24 preferably consists of an electric power distribution grid. Each meter terminal unit 18 has the capability of reading a plurality of different utility meters by taking readings from meter reading encoders 54. Each terminal unit 18 also has the capability of controlling a number of different loads 58 or alert signal devices 56. Each terminal unit also has the capability for reporting the status of a plurality of devices such as relay contacts (not shown). In the preferred embodiment, each meter terminal unit 18 has the capability for reading three meter encoders 54, controlling three external loads 58, and two alert signalling devices 56; and for reporting the status of up to six external contacts.

The reading control center 12 controls the overall operation of the system. Control center 12 includes a digital computer 26 which communicates with the rest of the system through one or more communications interface units (CIU) 28.

The communications interface unit 28 issues commands and receives data over the communication link 16, which is preferably a voice grade telephone circuit, through a modulator-demodulator circuit (MOD) 30. A similar modulator-demodulator circuit 30 is provided as shown at the section control unit 14 end of the communication link 16.

Preferably, the section control unit 14 is installed at a sub-station of the utility, such as the electric power utility which may be using the system. The section control unit then communicates with all of the meter terminal units 18 for customers who are served by that sub-station.

Commands or messages are preferably transmitted from the section control units 14 over their associated power lines 24 by means of carrier signals which are binary phase-modulated at thirty bits per second.

Generally, the meter terminal units 18 can be commanded to perform any of the following functions: reading and storing meter data, performing a reading of demand data and calculation of demand, transmitting previously stored meter or demand data, turning loads off and on, turning customer alerts on and off, and providing the status of external contacts.

The meter terminal units are individually addressable, group addressable, or block addressable. In each of the latter two cases, a number of meter terminal units are simultaneously addressed, and simultaneously respond to the commands.

Referring more particularly to FIG. 2, there is shown a schematic block diagram of the section control unit 14 of FIG. 1. The control unit 14 includes a modulator-demodulator 30, which is commonly referred to as simply a "modem", and which includes a receiver 200 and a transmitter 202. The transmitter 202 of modem 30 transmits digital data signals on the telephone line 16 to the reading control center 12 on a carrier frequency. Typically, the transmitter 202 shifts back and forth between two carrier frequencies to indicate the presence of each digital "one" in a serial train of digital pulse signals. The receiver 200 of the modem 30 likewise receives signals on the telephone line 16 from the reading control center 12 which are also transmitted in the form of carrier signal pulses signified by shifting back and forth between two carrier signal frequencies. Alternatively, a single carrier may be

switched on and off, or otherwise modulated, to carry the digital pulse signals received or transmitted. The carrier signal frequencies for the receiver are different from the carrier signal frequencies for the transmitter so that both sets of signals can exist on the telephone line at the same time, without interference. Since concurrent, or substantially simultaneous operation is available, the telephone line 16 is schematically indicated as comprising two lines in FIG. 2. As previously mentioned in connection with FIG. 1, a corresponding modem, including both a transmitter and a receiver, is provided at the reading control center 12.

The signals from the receiver 200 and to the transmitter 202 are handled within the control unit by means of a communicator circuit 204. The function of circuit 204 may be carried out by a synchronous receiver-transmitter circuit which is available as an integrated circuit component manufactured by Intel Corporation of Santa Clara, California, U.S.A., under product model No. 8251A. This component is sometimes referred to as a programmable communication interface. The communi-

cator 204 receives commands from the reading control center 12 through receiver 200 which are in serial form, and converts those commands to a parallel format for transmission to an information processor 206, which is included within the control unit 14. The communicator 204 also receives message information from the information processor 206 in parallel form and converts that information to serial form for subsequent transmission through the transmitter 202 to the reading control center 12. The communicator 204 is preferably program controlled by the information processor 206.

The information processor 206 is operable in response to commands received from the reading control center 12 through receiver 200 and communicator 204 to transmit corresponding information or commands through a transmitter modulator 208 to the power line 24, and thus to the meter terminal units 18 of FIG. 1. The information processor 206 also responds to commands from the reading control center 12 to condition itself and to stand ready to receive information transmitted back from the meter terminal units 18 through the power line 24 and through receivers 209, whenever the original command orders the meter terminal units to transmit information.

The receiver 200 of FIG. 2 is sometimes referred to below as a first receiving means, and the receivers 209 are sometimes collectively referred to below as a second receiving means. The transmitter modulator 208 is sometimes referred to below as a first transmitting means and the transmitter 202 is referred to as a second transmitting means. Furthermore, the communicator 204 and the information processor 206 are sometimes collectively referred to below as a data processing and communicating means.

It is a very important feature of the present invention that the data communicator 204 and the information processor 206 are operable in combination to substantially simultaneously operate the receiver 200 to receive a currently received command within a group of commands from the reading control center 12, and to operate the transmitter 208 to transmit a command corresponding to an earlier received command within the same group of commands to the meter terminal units 18 (when an earlier command has been received), and to operate the receivers 209 to receive messages from the terminal units 18 responding to a single earlier

transmitted command within the same group of commands (when an earlier command has been transmitted), and to operate the transmitter 202 to transmit to the reading control center 12 messages from the meter terminal units 18 responding to the single earlier transmitted command.

In the above described substantially simultaneous transmissions and receptions of commands and messages, the control unit preferably operates such that when there is an earlier received command which is transmitted through the transmitter 208 to the terminal units, that earlier command is the earlier command received by the control unit immediately prior to the reception of the command which is currently received from the reading control center 12, and the messages received from the terminal units 18 are in response to the immediately preceding command transmitted to those terminal units.

FIGS. 3 and 4, taken together, show the section control unit, generally referred to as the control unit 14, in a more detailed schematic block diagram. FIG. 4 should be placed to the right of FIG. 3 to

best show how they relate to one another. FIG. 3 again shows the modem 30 with the receiver 200 and the transmitter 202 from FIG. 2, and the communicator 204 is again shown in FIG. 3. The transmitter modulator 208 of FIG. 2 is shown in FIG. 4, and the receivers 209 are shown to include preferably eight receivers 209 schematically indicated in FIG. 4.

Most of the details added to the schematic diagram of FIGS. 3 and 4, in addition to showing additional connections, consist in the elaboration of the contents of the information processor 206. For information processor 206 preferably includes a microcomputer 210, which includes an internal random access memory "RAM" 211, an address latch circuit 214, an electrically programmable read only memory "EPROM" 212, an address buffer 216, and address switches 230, all of which are shown on FIG. 3. The information processor 206 also includes a clock generator 224 illustrated on FIG. 4.

Various components of the information processor may preferably be embodied by components available from Intel Corporation of Santa Clara, California, U.S.A., and carrying product model numbers as follows:

the microcomputer 210 may be model 8035. The electrically programmable read only memory (EPROM) may be model 2716. The address latch circuit 214 and the address buffer 216 may each be model 8212. The microcomputer 210 is often referred to hereinafter as simply a computer.

The receiver 200 within the modem 30, in the preferred mode of operation, continuously receives a carrier signal having a frequency f_1 which is preferably a frequency of 660 Hz. The carrier signal frequency f_1 is continuously modulated in a predetermined pattern to provide a continuous stream of ASCII characters at a rate of 30 characters per second. ASCII is a standard pulse code representation for numbers and letters, the full identification of which is American National Standard Code for Information Interchange. Whenever the carrier is on, receiver 200 responds to the reception of the carrier to generate a "carrier detect in" signal which is carried on a connection 201 to a DSR input terminal of the communicator 204. Also, the modulated carrier is applied on a "data in" line 203 by the receiver to an RXD input terminal of the communicator 204. As each character is received, the communicator 204 generates a ready

signal at an output terminal labeled RXRDY which is carried to an inverter circuit 242, and after inversion is carried to an INT input terminal of the computer 210. This signal as received by the computer, is interpreted as an interrupt signal which causes the initiation of the execution of a program by the microcomputer 210. The ready signal is also carried from the RXRDY output terminal on a connection 226 to the clock generator circuit 224 of FIG. 4, where it serves to synchronize the clock generator with the incoming signal received on the telephone line 16 from the reading control center 12. Since the clock generator 224 controls all of the clocking functions within the control unit, all of the operations of the control unit are thus synchronized with the signals from the reading control center 12. Thus, all of the clocking signals RC2, RC3, BC, and TC, are synchronized with the pulses from the reading control center. In order to assure continuous synchronization of the control unit with the reading control center 12, the carrier frequency f_1 is sent continuously by the reading control center and continuously modulated to provide a continuous train of binary 1's which are recognized

by the system as "idle" characters which merely serve to synchronize the control unit with the reading control center.

When a command message is transmitted by the reading control center 12 and received by the control unit, ten characters will be stored by the communicator 204, and then transferred to the computer 210. As each of the ten characters is received, the ready signal received at the INT terminal of the computer 210 will cause an interrupt to the computer which commences the interrupt sub-routine program of the computer.

The random access memory (RAM) 211 within the computer 210 performs substantially all of the storage functions within the computer. RAM 211 is thus a working storage. RAM 211 includes a number of different addressable storage locations which are dedicated to the storage of different information. In particular, at least two of the data word positions within RAM 211 are devoted to the purpose of storing the first and second commands of a set of commands received from the reading control center 12. Additional addressable positions within the RAM 211 are devoted to a storage of counts, and are characterized as counters which are associated with

the storage for the first and second commands, and which are responsive to the signals from clock 224 for counting the characters of the commands received by the control unit.

The interrupt program sub-routine is commenced by providing a specific bit configuration on the computer bus lines DBO-DB7. This bit configuration is applied to the address latch circuit 214. To latch the address into the address latch circuit 214, an enable signal is also supplied from the computer 210 output terminal ALE to the DS2 input terminal of the address latch circuit 214. The receipt of the address by the address latch circuit 214 results in the emission of signals on output lines DO5 and DO6 from the address latch circuit 214 to the C/D (control/data) and S (select) input terminals of the communicator 204. The communicator 204 is now conditioned to supply the character information to the computer 210 upon the emission of a read signal from the RD terminal of the computer 210 to the RD terminal of the communicator 204. The read signal is a pulse which will cause the character to be transferred from communicator 204 through communicator terminals DO-D7 into the computer bus port lines DBO through DB7 (in parallel form). Thus, the

characters are each received in the form of a serial train of pulses from the reading control center 12, are stored in communicator 204, and then the components are read out in parallel form from communicator 204 to computer 210. For each character received by the communicator 204, the above process will be repeated to transfer that character into the computer 210.

The communicator 204 is controlled from the computer 210 to transfer data from the computer to the reading control center 12 through the transmitter 202. This is accomplished by the computer 210 by executing a command which conditions the communicator 204 with a binary signal of sense opposite to the sense of the previous signal applied to the control data (C/D) input terminal of the communicator 204 through address latch 214. The computer can then transfer through the bus connections DBO through DB7, a control word into the communicator 204 at terminals DO through D7 upon the application of a write pulse from the WR terminal of the computer 210 to the WR terminal of communicator 204. The control word thus transferred to communicator 204 will condition the communicator to receive subsequent data words from computer 210 with the generation of each write pulse.

When communicator 204 is commanded to transfer information to the reading control center 12, the communicator will enable the modem transmitter 202 by applying a binary 1 output signal from the communicator RTS terminal to the modem transmitter 202. The information is then shifted out from the communicator TXD output terminal, the timing of this operation being controlled by a 300 Hz timing signal received from the clock frequency generator 224 on connection 228 to terminals RXC and TXC of communicator 204.

The output carrier frequency from the modem transmitter 202 can be any one of three different frequencies F_2, F_3, or F_4. These frequencies represent separate sub-channel frequencies to allow more than one control unit to simultaneously communicate with a single communication channel of the reading control center 12. Usable frequencies for this purpose may be, for instance, F_2 equal to 1260 Hz, F_3 equal to 1860 Hz, and F_4 equal to 2460 Hz. As previously described, the binary pulse coded information may be transmitted by the modem transmitter 202 by shifting between two frequencies of the carrier, in which case, a complimentary fre-

quency is employed with each of the frequencies F_2, F_3, and F_4. However, if desired, the data can also be transmitted in binary pulse coded form by simply switching the carriers on and off, using only one frequency for each carrier.

The entire program for the computer is contained in the EPROM 212. The EPROM is addressed from the address latch 214 via its output lines DOO-DO7 applied to the EPROM input terminals AO-A7. To select a particular address location in the EPROM during program execution, an address is placed on the computer BUS DBO-DB7 and latched into the address latch 214 via the ALE output terminal applying the enable signal on terminal DS2 of the address latch. To now read the program component from the addressed location of the EPROM, the computer executes an instruction which causes its $\overline{PSEN}$ output terminal to provide a binary 0 select signal to a $\overline{CS}$ input terminal of the EPROM. This causes the addressed word in the EPROM 212 to be read out and transferred via the BUS DBO through DB7 into the computer for execution of the retrieved instruction.

An output port 2 of computer 210 is connected through lines PO through P2 to address input lines A8 through A10 of the EPROM 212 for page addressing of that memory as required by the system. The

port 2 P7 output line from 210 is connected to a reset RS input terminal of the communicator 204. By the execution of an instruction by the microcomputer 210 the communicator 204 can be reset at a system start up in preparation to receiving and transmitting information between the control unit and the reading control center.

Whenever a command is received by the control unit from the reading control center 12, that command must be examined to see if it contains the address of the control unit which has received the command. The control unit accomplishes this testing by comparing its own address, which is predetermined by a plurality of address switches schematically indicated at 230. The settings of these switches provide input signals through associated lines 232 to the address buffer circuit 216.

In the course of accomplishing the test, the computer 210 executes an instruction to read the address buffer 216 into its internal memory 211. The computer does this by first selecting line DO3 to enable terminal DS2 of the address buffer 216 through the address latch circuit 214. The computer 210 then generates a pulse on the RD output terminal to enable the DS1 input terminal of the address buffer 216 to cause the control unit

address to be supplied at the connection 217 to the data bus connections DBO-DB7 of computer 210. This address is then compared by the computer with the received address contained in the command from the reading control center 12. If the compared addresses match, the computer will continue to carry out the operations specified by a function code portion of the command. Otherwise, the command is not carried out since it is not intended for this particular control unit.

Normally, when the command is to be carried out, it results in the transmission of a corresponding command through the transmitter 208 to the power line 24. To accomplish this, the computer 210 provides, through port 2, on one of the connections P4-P6 which is further identified as connection 234, a transmit gate signal (TG) to enable the transmitter/modulator 208. The computer 210 then proceeds to transmit the command in serial fashion through port 2 on the transmit data (TD) line 236 to transmitter 208. The TD signal on connection 236 modulates the transmitter carrier signal TXCAR which is applied to the transmitter/modulator from a phase locked loop and frequency generator circuit 222. The modulated output signal from the transmitter modulator 208 is coupled through a line coupler circuit 218 to

the power line 24 at 219. The frequency of the carrier is preferably 5010 Hz. The data bit rate of transmission is controlled by a transmit clock signal TC at 30 Hz which is applied to the transmitter modulator 208 from the clock generator 224. When the entire command has been transmitted to the meter terminal units, the computer 210 turns off the transmit gate signal TG, thus disabling the transmitter modulator 208.

If the function code portion of the command received from the reading control center 12, as decoded by computer 210, indicates that there is an expectation of a response from one or more of the addressed terminal units, the computer will generate an "IBRG on" signal on line 238 from port 2. That signal is carried to all of the receivers 209, as well as to an automatic gain control circuit 220 in FIG. 4, to enable those components to receive messages returning from the meter terminal units. The meter terminal unit messages may come from as many as eight separate addressed meter terminal units simultaneously, at different carrier frequencies FI1 through FI8, and are simultaneously received through the line coupler 218 and the automatic gain control circuit 220 by all eight of the receivers 209. The individual receivers 209 are tuned to

respond to the different individual carrier frequency signals by means of local oscillator signals from the phase locked loop and frequency generator circuit 222 over connections 223.

The clock circuit 222 also receives a 60 Hz signal from the power line 24 and provides a 60 Hz output signal at connection 225 which is applied to the automatic gain control circuit 220 for gain control purposes. The 60 Hz signal is also divided by 2 by means of a frequency divider 227 to provide a 30 Hz gating signal for gating the received binary digits from the receivers 209 which are applied through the data signal lines IBRD1-IBRD8 on conductors 240 back to port 1 of the computer 210. Additional 30 Hz timing signals RC2, RC3, and BC are provided from the system clock 224 to the receivers 209 for timing purposes.

As previously mentioned above, the system clock 224 is synchronized in its operation with the timing of the digital pulse signal train received from the reading control center 12 through the receiver 200, which is preferably at a uniform pulse rate of about 30 Hz. The transmitter modulator 208 of FIG. 4 is then caused to operate to transmit data to the meter terminal units at a synchronized

30 Hz pulse rate, which is in synchronism with the clock 224. The receivers 209 then operate also to receive serial pulse trains of binary signals at the same basic 30 Hz pulse rate, and when messages are relayed back to the reading control center 12 through the transmitter 202, those messages are also in the serial binary pulse format at the same 30 Hz pulse rate, and in synchronism with the timing signals from the clock 224. Thus, the same pulse rate is used in all of the transmitters and receivers of the control unit, and all are in synchronism.

The commands received from the reading control center 12 include separate address and function code field portions, and the data processor 206, as shown in detail in FIG. 3, embodies decode means responsive to the address and function field code portions of the commands to effect the transfer of the received commands to terminal units 18 corresponding to the address and function code fields recognized by the decode means whenever the contents of those fields identify at least one terminal unit. The command also enables the control unit to transfer messages back to the reading control center 12 from those terminal units 18 which recognize the

function code and an address in the action field of commands received by the terminal units 18. The decode means is embodied in the computer 210 and the address buffer 216 and the address switches 230.

The counters, previously referred to above, which are associated with storage positions within RAM 211, are each responsive to clock signals for counting the characters of the commands received by the control unit, and the computer 210 includes a control means which is responsive to the counts in the counters to effect a generation of control signals at prescribed counts of the respective counters to selectively identify the respective storage positions for the first and second commands and to control the time of storage of the first and second commands in the selectively identified storage positions for those commands and to control the time of transmission of the first and second commands from those storage positions to the terminal units 18.

As previously mentioned above, the EPROM 212 of FIG. 3 stores a number of sub-routine programs for execution by the computer 210. One of these sub-routine programs is an interrupt sub-routine which is entered upon receipt of a command from the

reading control center 12, when a resulting interrupt signal is caused to be applied to the computer 210 at the interrupt (INT) input terminal. The interrupt sub-routine directs entry to others of the sub-routine programs which cause the computer to carry out the various operations previously described, including the substantially simultaneous operation of the receivers 200 and 209 and of the transmitters 202 and 208.

The communicator 204 is very important to the operation of the control unit. Thus, the communicator 204 is operable to couple the computer 210 through the receivers 209 and the transmitter 202 for causing the reception of messages from the terminal units 18 and the storage of those messages in the RAM 211 of the computer 210, and for causing the transmission of those messages from the RAM 211 to the reading control center 12 through the transmitter 202. The communicator 204 and the computer 210 are also operable together to sequentially transfer commands received from the reading control center 12 through the receiver 200 into the RAM 211, and to provide the aforementioned interrupt signal to the computer at prescribed intervals as commands are received from the control center to

thereby affect entry by the computer 210 into the interrupt sub-routine with each interrupt signal to thereby selectively direct entry into the other sub-routines for execution to carry out the substantially concurrent reception and transmission of commands and messages being transferred between the control center 12 and the terminal units 18.

It is one of the features of the control unit of the present invention that the computer 210 may be operable to append control unit status information to all of the messages from the meter terminal units 18 at the time those messages are transmitted from the control unit to the reading control center 12. Thus, the messages include status information of the control unit as well as information from the meter terminal units.

It is another feature of the invention that the computer 210 is operable in response to a special command from the reading control center 12 to respond with a message to the reading control center containing only control unit status information, and not including any meter terminal unit information, but having the same format as other messages transmitted to the reading control center 12.

It is another feature of the present invention that a plurality of the control units described in detail above may be incorporated in a single system in communication with a single reading control center 12. The system further typically includes a large number of meter terminal units 18, as shown in FIG. 1, which are in communication with various control units 14 through the power line 24. The terminal units 18 are addressable, and are substantially instantaneously responsive to commands which contain a recognizable address to transmit messages representative of measurement data onto the power line 24. The commands transmitted from the reading control center 12 include at least transmit and receive address fields which identify one of the control units, and further have an action field identifying at least one terminal unit. Each of the control units 14 is connected to a common channel of the reading control center 12, as well as to the power line 24 for selectively transferring commands and messages between the reading control center 12 and the meter terminal units 18.

Each of the control units, as explained above, includes address means such as the address switches 230 and the address buffer 216 for providing transmit

and receive address signals representative of transmit and receive addresses unique to the control unit. Also, each control unit includes, within the computer 210, means for selectively comparing the contents of the transmit and receive address fields in the commands received through the communicator 204 with the transmit and receive address signals provided by the address buffer 216. The computer operates in response to this comparison to generate a transmit enable signal when there is a matching of the transmit address field contents and the transmit address signals, and to generate a receive enable signal when there is a match between the receive address field contents and the receive address signals. These enablement signals enable the control unit to transmit the action field of the received command to the terminal units 18 and to receive messages from those terminal units 18 responding to the action field of the command and to transfer the received messages to the reading control center 12.

In accordance with another feature of the invention, the transmissions from the meter terminal units are often rather weak signals. Accordingly, it has been found to be advantageous to provide

control units which are distributed in position around the power distribution system so as to place every meter terminal unit 18 within a reasonable distance of a control unit which can receive limited power meter terminal unit data messages. However, since the control unit messages are not weak in power, it is not necessary to provide a number of distributed position control units for transmitting messages to the terminal units 18.

Accordingly, it is a feature of the invention to provide a plurality of control units, using only one of the control units to recognize a match between the transmit address field provided by the address buffer and the transmit address signals of the command to generate a transmit enable signal and to transmit commands to the terminal units 18, while another one or more of the plurality of control units is operable in response to a match between the receive address field and the receive address signals to generate a receive enable signal and then to receive the messages from the terminal units 18 and to transmit those messages to the reading control center 12.

The control units in such a system are preferably arranged in a set of control units which operate together to process the same command, and additional sets of the control units may be connected to the common channel of the reading control center 12 and to the power line 24.

It is another feature of the invention that the terminal units 18 may be arranged in a plurality of separate groups, with each group connected to a separate power line 24, with at least one control unit being connected to each of the separate power lines to serve a separate group of the terminal units 18, but all of the control units may be connected to the reading control center on a common channel. The control units are all operable to receive commands from the reading control center at one frequency on the common channel, but the separate control units are operable to respond to the commands by sending messages to the reading control center on the common channel at different frequencies so as to provide for simultaneous transmission of messages from the various control units to the reading control center. The reading

control center 12 is operable to receive and recognize the messages transmitted at the different frequencies from the separate control units.

As previously explained above, it is a very important feature of the invention that the control unit 14 is operable to substantially simultaneously receive a command through the receiver 200, and transmit an earlier received command to the meter terminal units 18 through the transmitter 208, and to receive messages at receivers 209 from the terminal units 18 responding to an earlier transmitted command, and to transmit messages back to the reading control center 12 through the transmitter 202. These substantially simultaneous operations are sometimes characterized as "interlacing".

CLAIMS:

1. A control unit (14,FIG.1) for an automatic meter reading system of the type which also includes a reading control center (12) for sequentially transmitting commands and receiving messages representative of measurement data and a plurality of meter terminal units (18) for recording data at the sites where the data is available and for transmitting that data over a power line (24) in the form of data messages in response to commands,

said control unit (14) being operable for relaying the commands and messages between the reading control center (12) and the meter terminal units (18),

said control unit (14) including a first receiving means (200,FIG.2) for receiving commands over a voice grade communication line (16) from the reading control center (12), a first transmitting means (208) for transmitting commands corresponding to received commands over a power line (24) to the meter terminal units (18), a second receiving means (209) for receiving data messages from the meter terminal units (18) over the power line (24),

Claim 1 (continued)

a second transmitting means (202) for transmitting to the reading control center (12) data messages corresponding to the data messages from the meter terminal units (18), data processing and decoding means (204,206) for decoding and processing and switching commands and messages between said first receiving means (200) and said first transmitting means (208) and between said second receiving means (209) and said second transmitting means (202),

characterized in the provision that

said data processing and communicating means (204,206) is operable to substantially simultaneously

(a) operate said first receiving means (200) to receive a currently received command within a group of commands from the reading control center (12) and

(b) operate said first transmitting means (208) to transmit an earlier received command within the same group of commands to the meter terminal units (18) when an earlier command has been received and

Claim 1 (continued)

(c) operate said second receiving means (209) to receive messages from the terminal units (18) responding to a single earlier transmitted command within the same group of commands when an earlier command has been transmitted and

(d) operate said second transmitting means (202) to transmit to the reading control center (12) the messages from the meter terminal units (18) responding to the single earlier transmitted command.

2. A control unit (14,FIG.1,FIG.2) as claimed in Claim 1,

further characterized in that

the control unit operates such that when there is an earlier received command transmitted to said meter terminal units (18) that earlier command is the earlier command received by the control unit (14) immediately prior to the reception of the command currently received from the reading control center (12), and the messages received from the terminal units (18) are in response to the immediately preceding command transmitted to those terminal units (18), and said signal processing means comprises a data convertor (204) and an information processor (206).

3. A control unit (FIG.3,FIG.4) as claimed in Claim 1 or in Claim 2,

further characterized in the provision of

a clock pulse generator (224,FIG.4) for providing timing pulses to all of the other components of the control unit, said control unit being operable to receive commands from the reading control center in the form of a serial train of data pulses, means (226) for providing a train of timing pulses to said clock generator (224) derived (at 204,FIG.3) from the data pulses received from the reading control center (12) through said first receiving means (200) for controlling the operation of said clock means (224) to thus synchronize the operation of said control unit to the incoming train of data pulses from the reading control unit (12).

4. A control unit (FIGS. 3,4) as claimed in Claim 3,

further characterized in the provision that said control unit is operable to receive commands transmitted from the reading control center in a serial train of digital pulses at a uniform pulse rate which is used to synchronize the control unit clock (224), said control unit being operable to operate said first transmitting means (208) to transmit commands to said meter terminal units (18) in a serial bit format at the same pulse rate as the incoming commands from said reading control center (12), said control unit being operable to operate said second receiving means (209) to receive response messages from said meter terminal units (18) and to operate said second transmitting means (202) to transmit data messages to the reading control center (12) at the same pulse rate as the commands from the reading control center (12) and in serial digital pulse format.

5. A control unit (FIGS.3,4) as claimed in any one of the preceding claims 1, 2, or 4,

further characterized in the provision that said data processing and communicating means (204,206,FIG.2) comprise a communicator (204) and a data processor (206), said data processor (206) including a computer (210,FIG.3), first and second storage means (in 211) within said computer (210) for storing first and second commands received from the reading control center (12,FIG.1), decode means (230,216,210) responsive to the address and function code field portions of the commands received from the reading control center (12,FIG.1) to effect the transfer of those received commands to terminal units (18) corresponding to the address and function code fields recognized by said decode means the contents of which identifies at least one terminal unit and to enable said control unit to transfer messages to the reading control center (12) from those terminal units (18) which recognize the function code and an address in the action field of commands received by the terminal units (18), said first receiving means (200) and said

Claim 5 (continued)

data processing and decoding means (204,206) being operable to transfer sequentially received first and second commands from the reading control center (12) into said first and second storage means (at 211,FIG.3) respectively, said first receiving means (200) and said data processing and communicating means (204,206) being operable to generate a system synchronizing clock signal (at 226,224,FIG.3,FIG.4) each time a character is received from the reading control center (12) to effect the synchronous storage of the commands in said first and second storage means (at 211) and the transmission of commands from said control unit to the terminal units (18) and the transfer of messages from the terminal units (18) to the reading control center (12) through said control unit, first and second counter means (within 211,FIG.3), each associated with a respective one of said first and second storage means (in 211) and each responsive to the clock signal for counting the characters of commands received by said control unit, and control means (in 210) responsive to counts in said first

Claim 5 (continued)

and second counter means to effect the generation of control signals at prescribed counts of said first and second counter means to selectively identify said first and second storage means and control the time of storage of the first and second commands in the selectively identified first and second storage means and to control the time of transmission of the first and second commands from said first and second storage means to the terminal units (18) and to further control the time of reception and the transfer of messages from the terminal units (18) to the reading control center (12).

6. A control unit (FIGS.3 and 4) as claimed in Claim 5,

further characterized in the provision of

a memory (212) within said information processor (206) and interconnected with said computer (210) for storing sub-routine programs for execution by said computer (210), one of said sub-routine programs being an interrupt sub-routine entered upon receipt of a command from the control center (12) when a resulting interrupt signal is caused to be applied to said computer (210), said interrupt sub-routine directing entry to other ones of the sub-routine programs to thereby cause said substantially simultaneous operation of said first and second receiving means (200,209) and said first and second transmitting means (208,202), said communicator (204) being operable for coupling said computer (210) through said second receiving means (209) and said second transmitting means (202) for causing the reception of messages from the terminal units (18) and storage of those messages in the store (211) of said computer (210) and for causing the transmission of

Claim 6 (continued)

messages from the store (211) of said computer (210) to the reading control center (12) through said second transmitting means (202) and for sequentially transferring commands received from the reading control center (12) through said first receiver into said store (211) of said computer (210) as directed by the program of sub-routines, said communicator (204) being operable to provide the aforementioned interrupt signal to said computer (210) at prescribed intervals as commands are received from the control center (12) to affect entry by said computer (210) into the interrupt sub-routine with each interrupt signal whereby the interrupt routine program is carried out to selectively direct entry into the other sub-routines for execution to thereby carry out the substantially concurrent reception and transmission of commands and messages being transferred between the control center (12) and terminal units (18).

7. A control unit (FIGS.3,4) as claimed in Claim 6,

further characterized in the provision that said computer (210) is operable to append control unit status information to all messages from the terminal units (18) at the time that those messages are transmitted from said control unit to the reading control center (12).

8. A control unit (FIGS.3,4) as claimed in Claim 6,

further characterized in the provision that said computer (210) is operable in response to a predetermined command from the reading control center (12) for responding with a message to the reading control center containing only control unit status information but having the same format as other messages transmitted to the reading control center (12).

9. An automatic meter reading system (FIG.1) for reading the measurement of a commodity over a power line incorporating a plurality of control units as claimed in any one of the preceding claims 1,2,4,6,7, or 8,

further characterized in that the system comprises a plurality of addressable terminal units (18,FIG.1) connected to the power line, each of said terminal units (18) being substantially instaneously responsive to commands received thereby which contain a recognizable address to transmit messages representative of measurement data onto the power line; a reading control center (12) having a common channel for transmitting commands and receiving messages and being operable to transmit commands each having at least transmit and receive address fields which identify at least one of said control units (14) and further having an action field identifying at least one terminal unit; each of said control units (14) being connected to the common channel of said reading control center (12) and to the power line (24) for selectively transferring

Claim 9 (continued)

commands and messages between said reading control center (12) and said terminal units (18), each of said control units including,

communication means (204,FIG.3) for receiving commands from said reading control unit (12) and for communicating messages thereto,

address means (230,216) for providing transmit and receive address signals representative of transmit and receive addresses unique to a control unit,

means (in 210) for selectively comparing the contents of the transmit and receive address fields in commands received by said communication means (204) with the transmit and receive address signals provided by said address means (230,216), said means for selectively comparing being operable to generate a transmit enable signal when there is a matching of the transmit address field contents and transmit address signals and to generate a receive enable signal when there is a match between the receive address field contents and the receive address signals to thereby selectively enable one

Claim 9 (continued)

control unit to transmit the action field of the received command to said terminal units (18) and to receive messages from those terminal units (18) responding to the action field of the command and to transfer the received messages to said reading control center (12).

10. An automatic meter reading system as claimed in Claim 9,

further characterized in the provision that only one of said plurality of control units (14) is operable upon the recognition of a match between the transmit address field contents and transmit address signals to generate a transmit enable signal and to transmit commands to said terminal units (18), and another one of said plurality of control units (14) is operable in response to a match between the receive address field contents and the receive address signals to generate a receive enable signal and then to receive the messages from said terminal units (18) and to transmit those messages to said reading control center (12).

11. A system as claimed in Claim 10,

further characterized in that

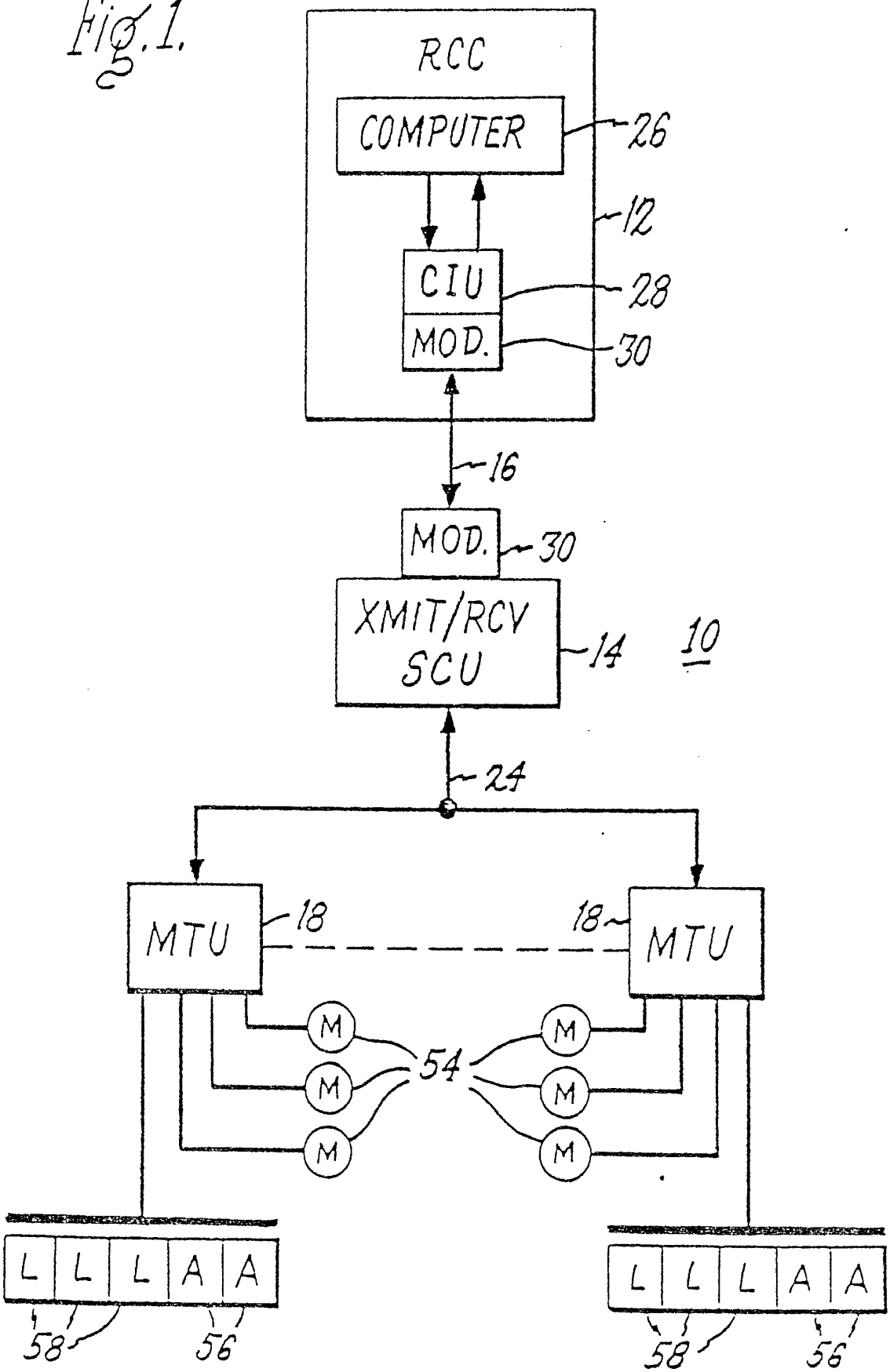
said plurality of control units (14) comprises a set, and the system further includes additional sets of said control units (14) connected to the common channel of said reading control center (12) and to the power line (24).

12. A system as claimed in Claim 11, further characterized in the provision that one of said control units (14) in at least one of the sets of control units is utilized only for transmitting commands to said terminal units (18) and the remainder of the control units (14) in each set is utilized only for receiving and transmitting messages from the associated terminal units (18) to said reading control center (12).

13. A system as claimed in any one of the preceding claims 10, 11, or 12 comprising a plurality of separate groups of terminal units (18) with each group connected to a separate power line (24), at least one of said control units (14) being connected to each of said separate power lines to serve a separate group of said terminal units (18), and

further characterized in the provision that said reading control center (12) is operable to transmit commands at a first frequency on a common channel and to simultaneously receive messages on said common channel at a plurality of frequencies which are different from said first frequency, said control units (14) respectively serving said different groups of terminal units (18) being operable to receive commands from said reading control center (12) at said first frequency and to respond by sending messages to said reading control center (12) on said common channel at different ones of said different frequencies so as to provide for simultaneous transmission of messages to said reading control center (12).

Fig. 1.



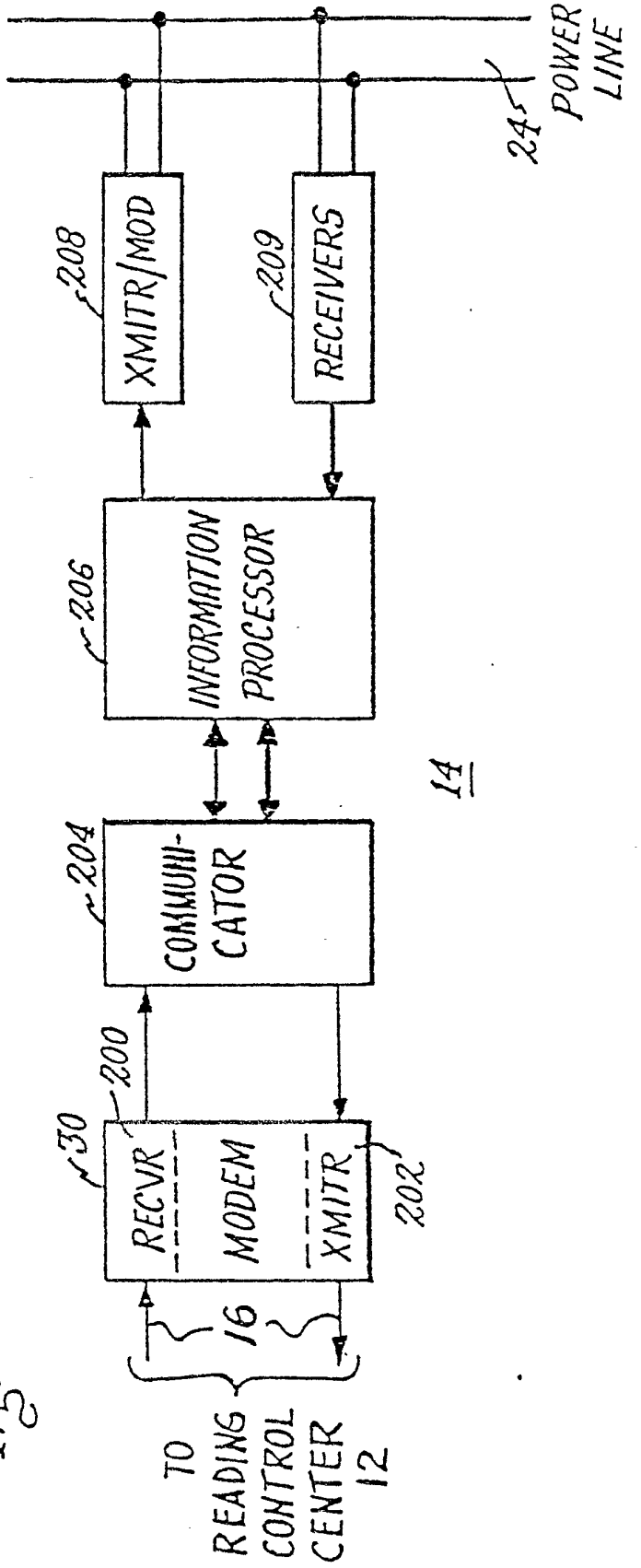

POWER LINE
24
208
XMITR/MOD
209
RECEIVERS
206
INFORMATION PROCESSOR
14
204
COMMUNI-CATOR
200
30
RECVR
MODEM
XMITR
202
16
TO READING CONTROL CENTER 12

Fig. 2

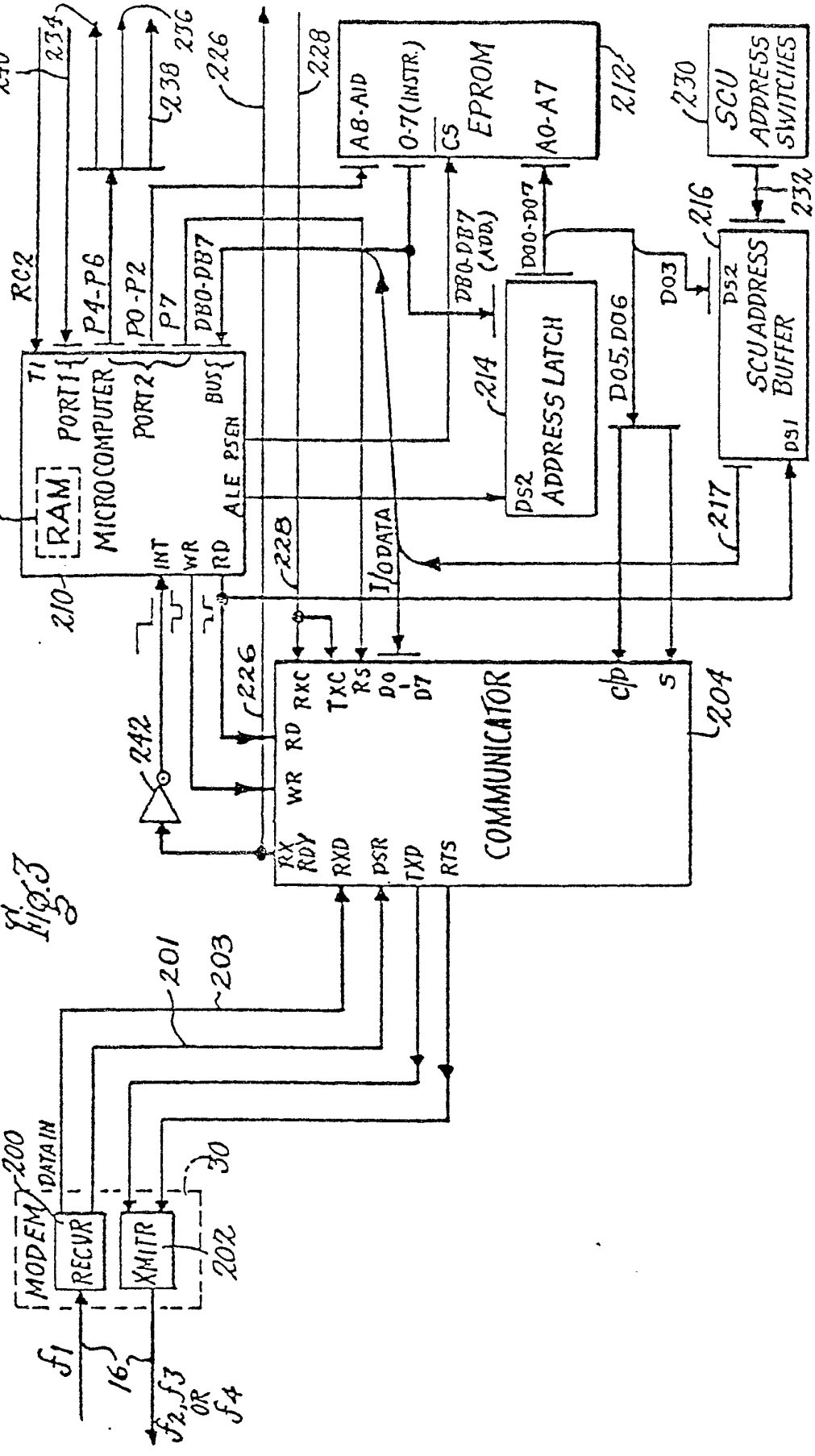

MODEM
DATA IN
RECVR
XMITR
f1
f2, f3 OR f4
16
30
200
201
202
203
COMMUNICATOR
RXRDY
RXD
PSR
TXD
RTS
RD
WR
RXC
TXC
RS
D0-D7
C/D
S
204
206
MICROCOMPUTER
RAM
211
210
T1
PORT1
PORT2
BUS
INT
WR
RD
ALE
PSEN
RC2
P4-P6
P0-P2
P7
DB0-DB7
226
228
234
240
238
236
242
I/O DATA
EPROM
212
A8-A10
O-7 (INSTR.)
CS
A0-A7
DB0-DB7 (ADDR)
214
ADDRESS LATCH
DS2
D05, D06
D03
DB0-DB7
216
SCU ADDRESS BUFFER
DS2
DS1
217
SCU ADDRESS SWITCHES
230
232

Fig. 3

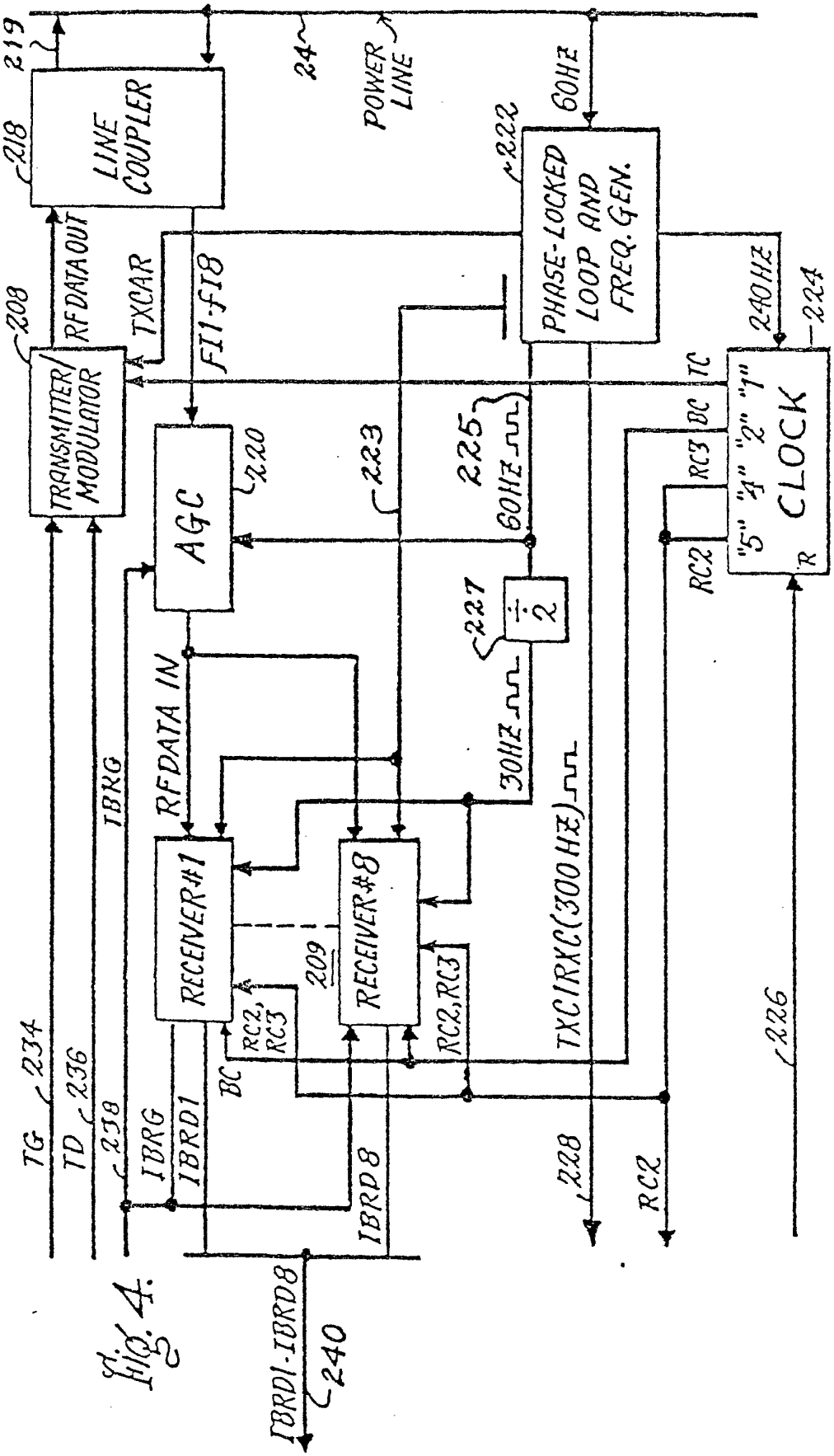

219
218
LINE COUPLER
24
POWER LINE
60HZ
222
PHASE-LOCKED LOOP AND FREQ. GEN.
240HZ
224
208
RF DATA OUT
TXCAR
FI1-FI8
TRANSMITTER/ MODULATOR
AGC
220
223
225
60HZ
TC
BC
RC3
RC2
"5" "4" "2" "1"
CLOCK
R
227
÷ 2
30HZ
RFDATA IN
IBRG
RECEIVER#1
RECEIVER#8
209
RC2, RC3
BC
TXC IRXC (300 HZ)
226
234
TG
236
TD
238
IBRG
IBRD1
IBRD8
228
RC2
IBRD1-IBRD8
240

Fig. 4.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US81/00385

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 3

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

U.S Cl. 340/151, 310A, 870.03, 163,147SY
INT. Cl.3 H04M 11/04, G08C 19/00, H04B 3/54

II. FIELDS SEARCHED

Minimum Documentation Searched 4

Classification System	Classification Symbols
US	340/151,150,163,870.02,870.03,310 R, 340/310A, 147 SY

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 5

III. DOCUMENTS CONSIDERED TO BE RELEVANT 14

Category *	Citation of Document, 16 with indication, where appropriate, of the relevant passages 17	Relevant to Claim No. 18
X,P	US, A, 4,204,195, Published 20 May 1980, Bogacki.	1-4
A	US, A, 4,114,141, Published 12 September 1978, Travis.	1-4
A	US, A, 4,127,845, Published 28 November 1978, Dansbach et al.	1-4
A	US, A, 4,012,734, Published 15 March 1977, Jagoda et al.	1-4

* Special categories of cited documents: 15

"A" document defining the general state of the art

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or 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

IV. CERTIFICATION

Date of the Actual Completion of the International Search 3	Date of Mailing of this International Search Report 3
17 June 1981	30 JUN 1981
International Searching Authority 1	**Signature of Authorized Officer 10**
ISA/US	James J Groody