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(54) POINT OF USE DIGITAL ELECTRIC ENERGY APPARATUS WITH REAL-TIME DUAL CHANNEL METERING

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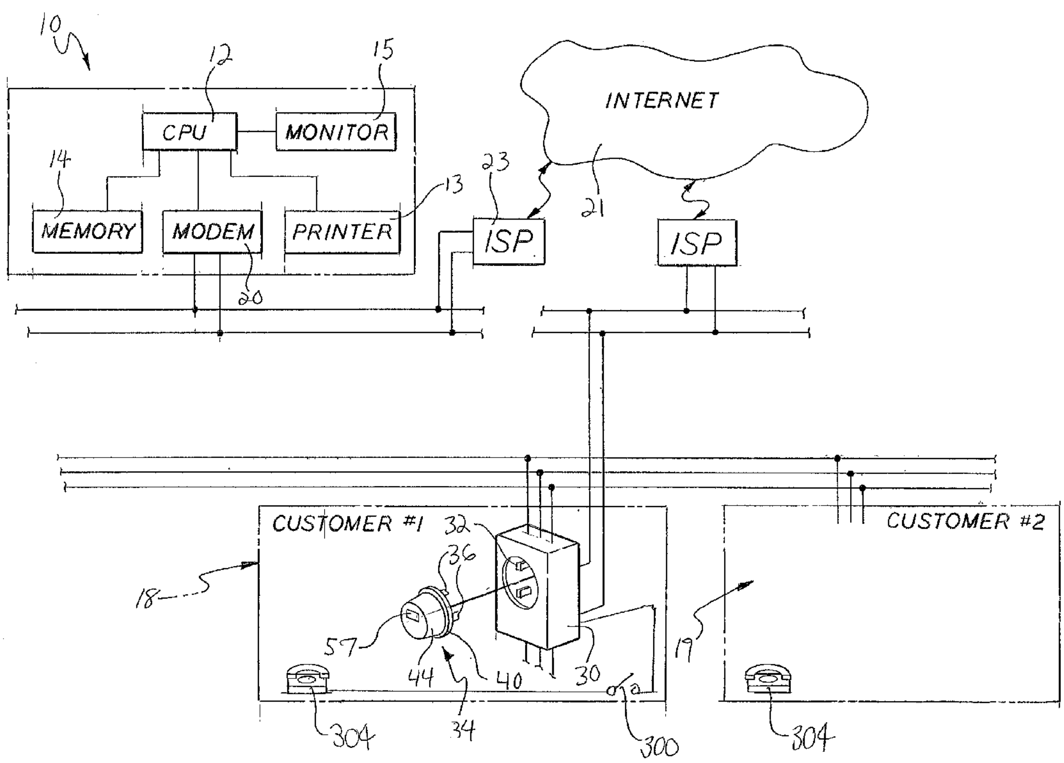
(52) **U.S. Cl.** **702/61**

(57) **ABSTRACT**

An apparatus and method for measuring electric power consumed at a use site includes voltage and current sensors on each site conductor which are sampled at a sample interval to generate sampled voltage and current signals. The voltage and current signals are converted to digital values which are used to directly calculate power consumption values. The digital voltage and current magnitude values are stored in a memory either prior to or subsequent to the power consumption calculations.



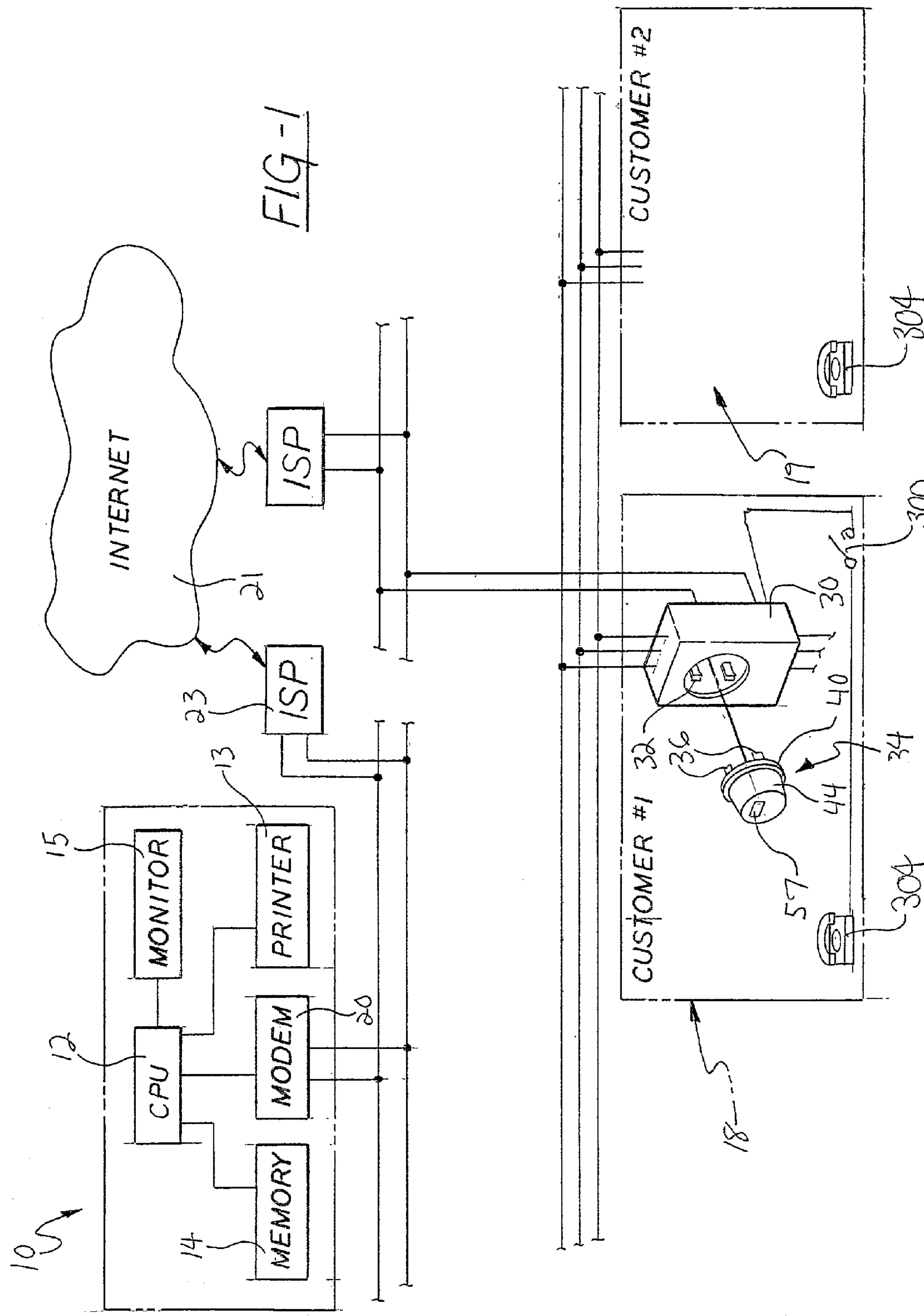

INTERNET
ISP
ISP
MONITOR
CPU
PRINTER
MODEM
MEMORY
CUSTOMER #1
CUSTOMER #2
10
12
13
14
15
17
18
20
21
23
30
32
34
36
40
44
57
300
304
304

FIG-1

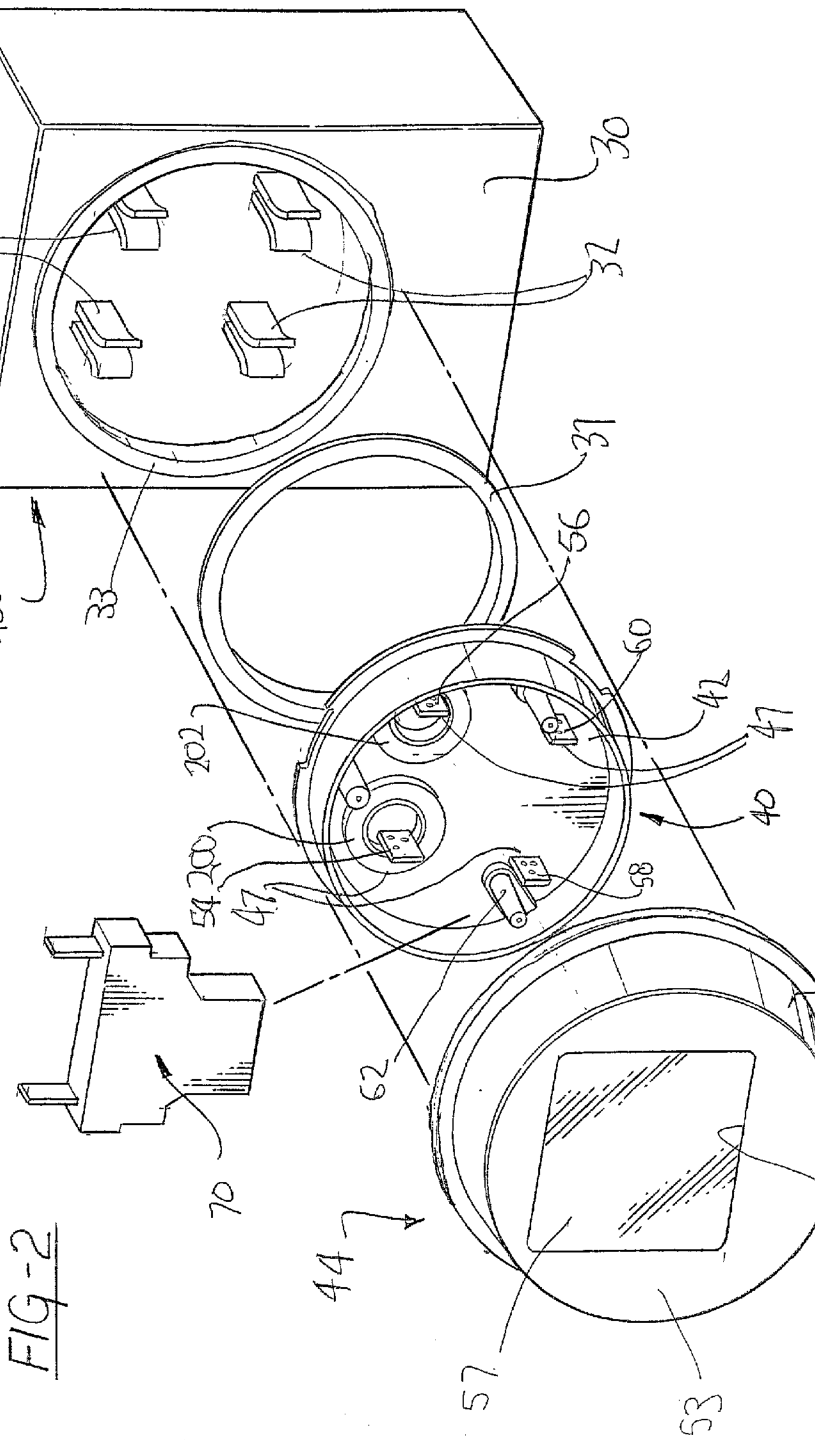


FIG-2

FIG-3

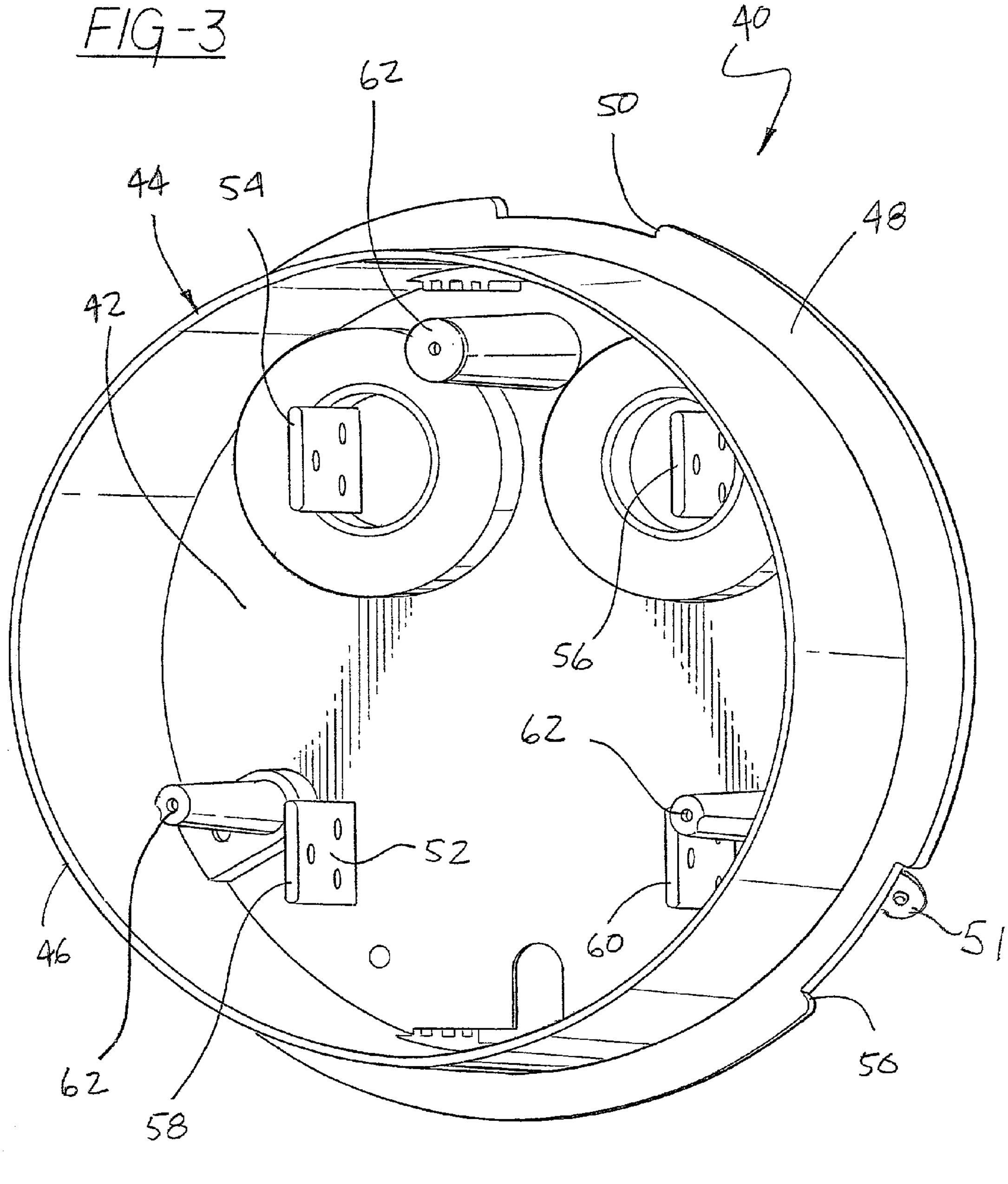
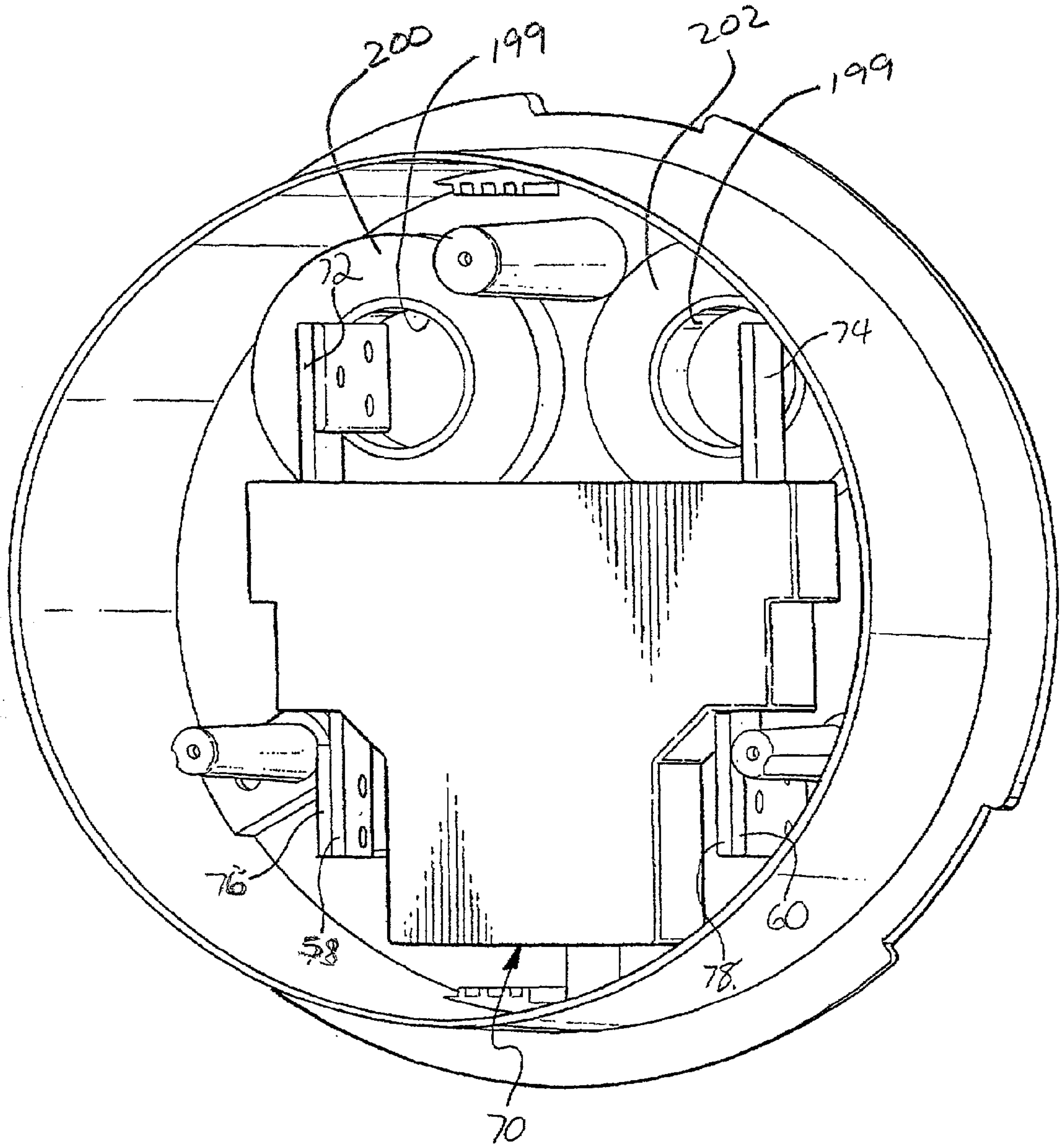


FIG-4



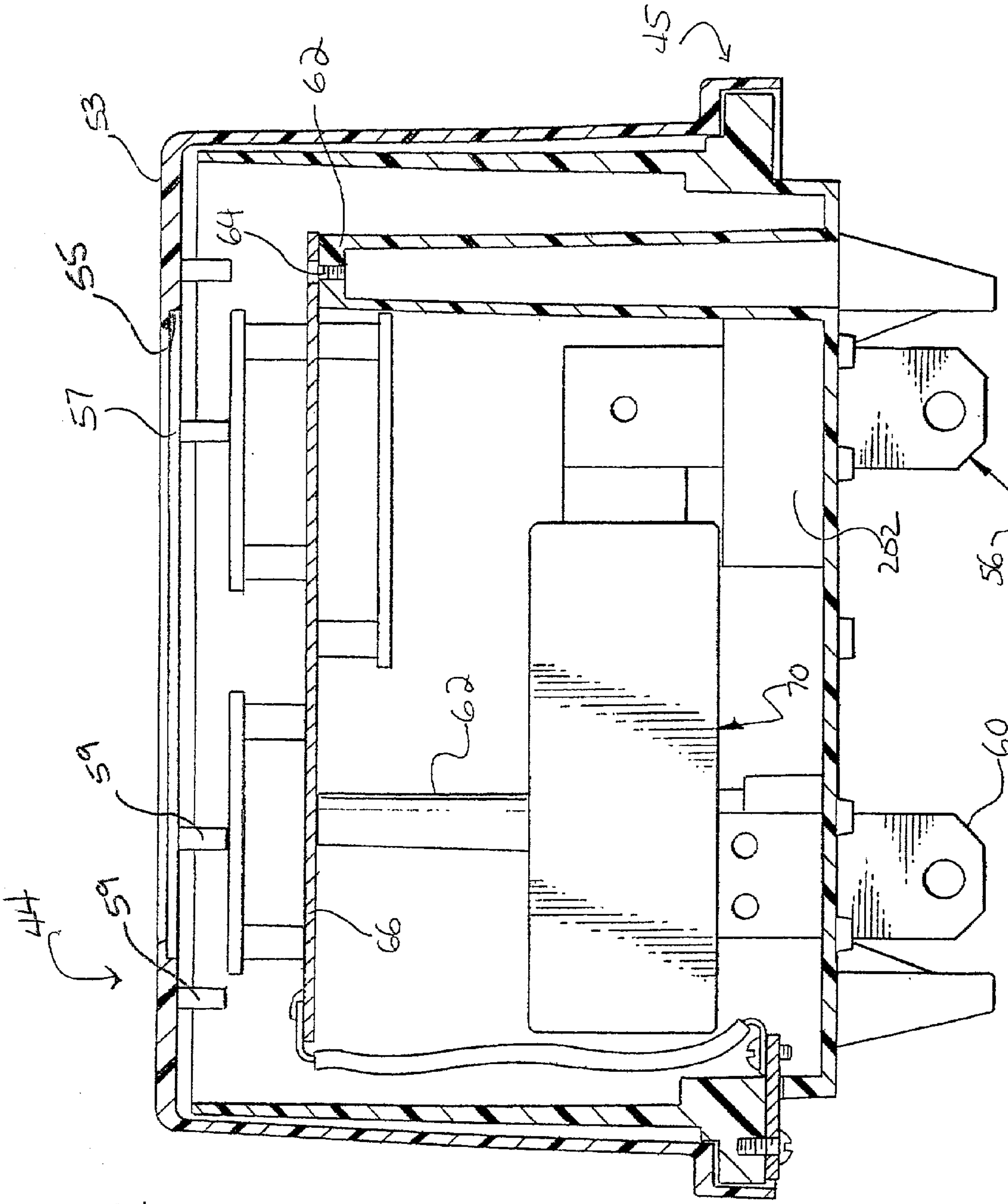
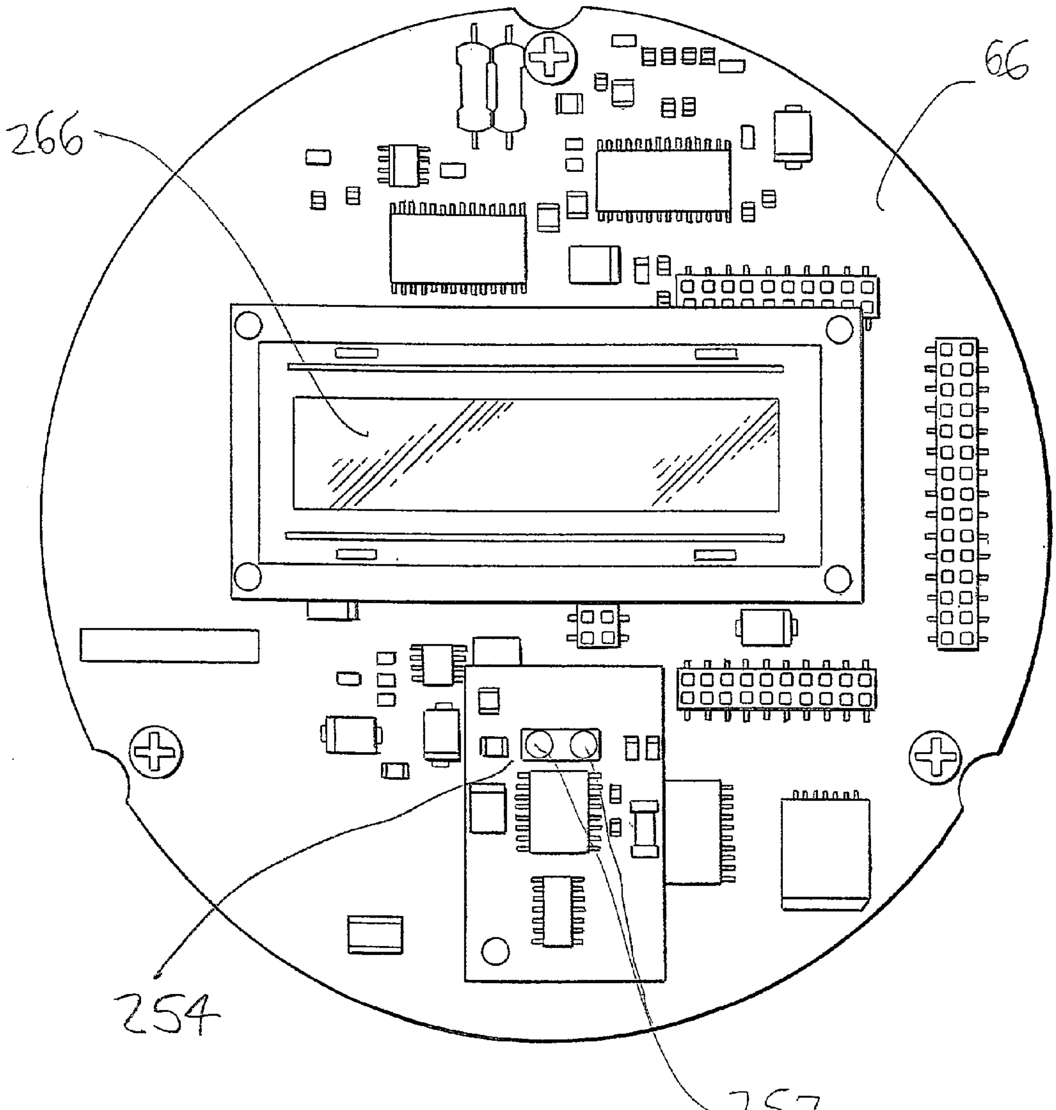


FIG-5

FIG-6



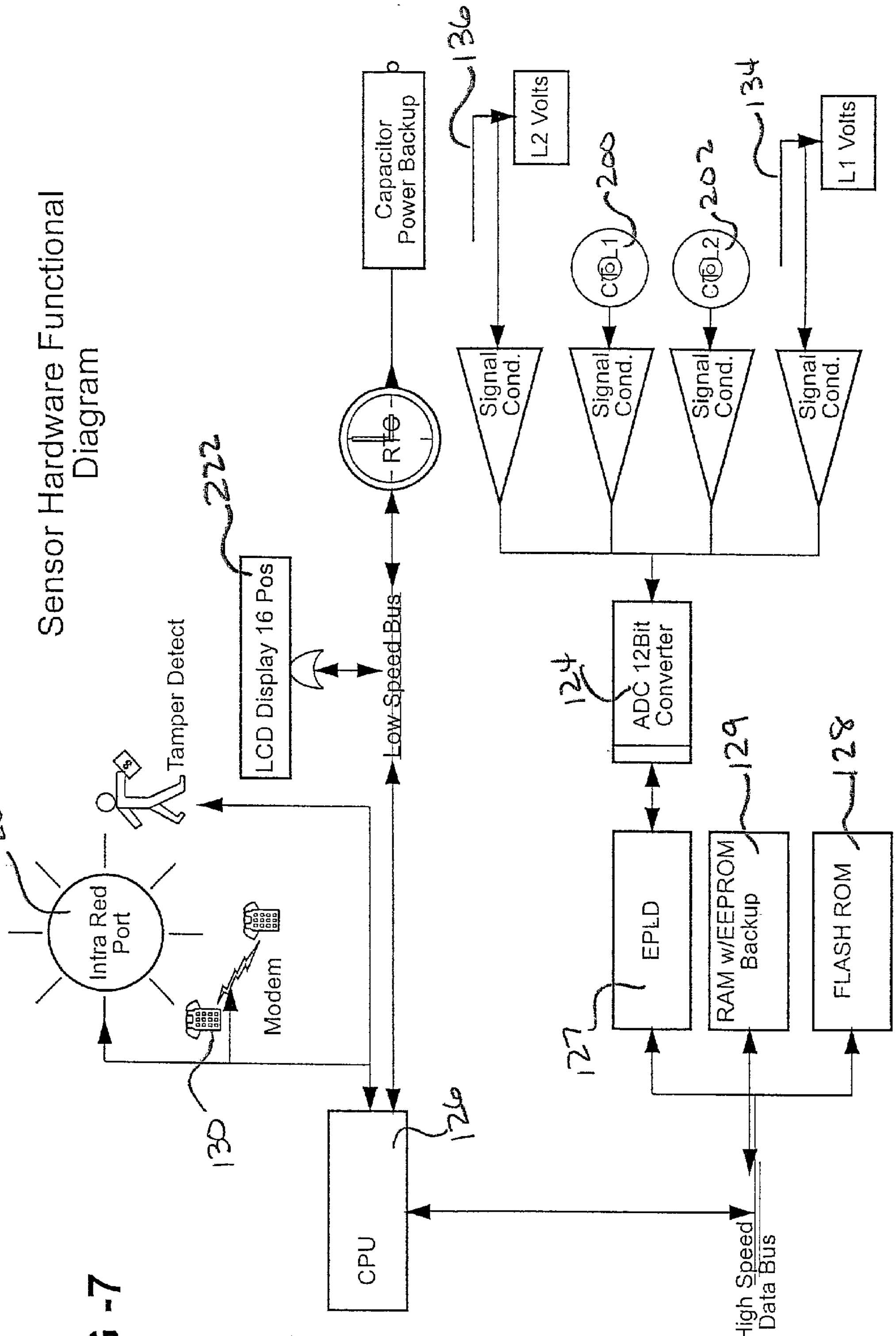

Sensor Hardware Functional Diagram
Capacitor Power Backup
136
L2 Volts
200
CT L1
202
CT L2
134
L1 Volts
Signal Cond.
Signal Cond.
Signal Cond.
Signal Cond.
RTC
222
LCD Display 16 Pos
Low Speed Bus
Tamper Detect
254
Intra Red Port
Modem
130
CPU
126
124
ADC 12Bit Converter
129
128
127
EPLD
RAM w/EEPROM Backup
FLASH ROM
High Speed Data Bus

FIG -7

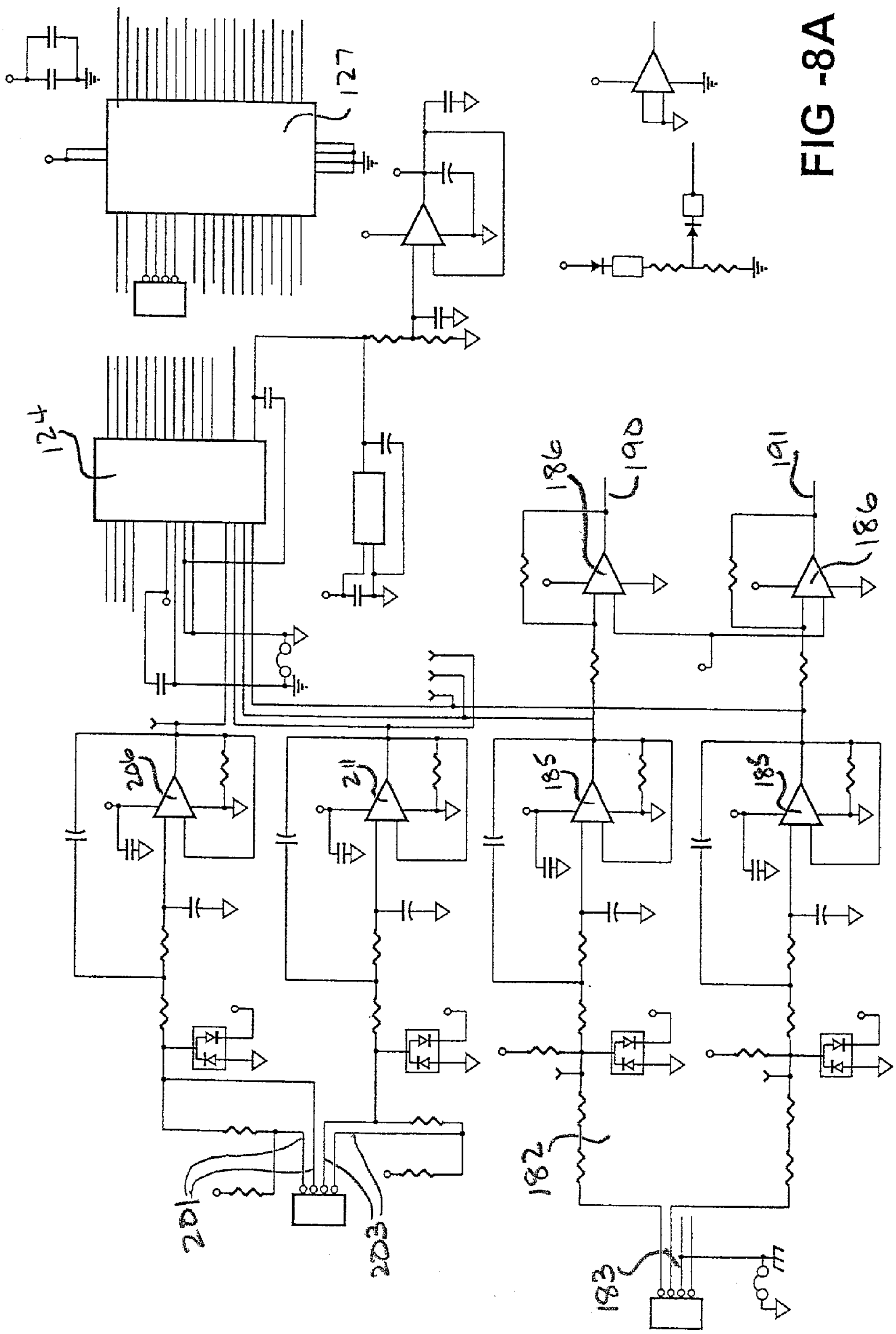


FIG -8A

FIG -8B

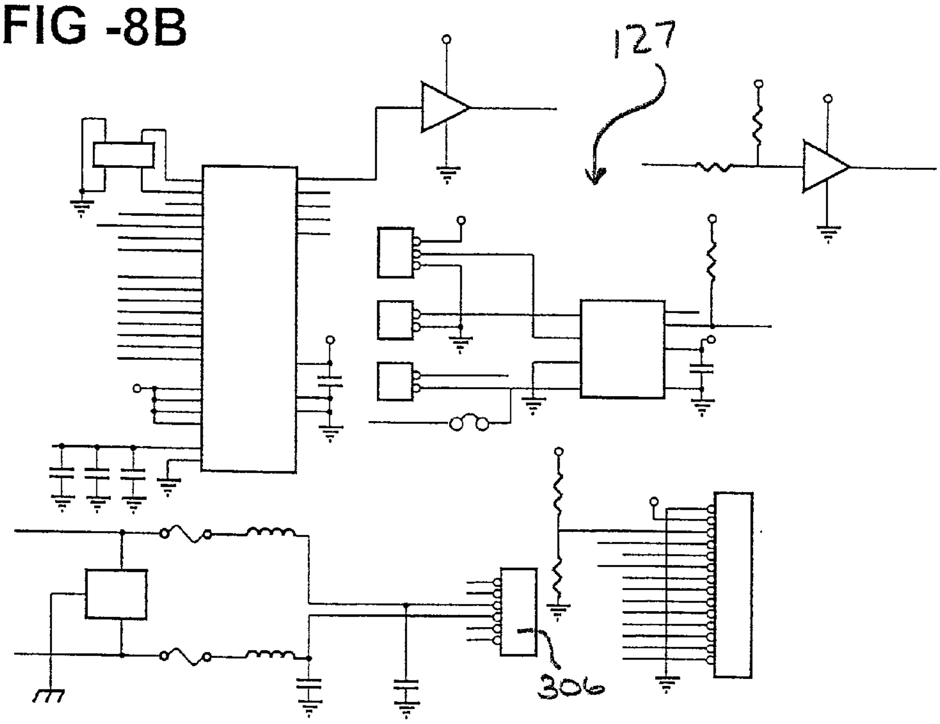


FIG -8C

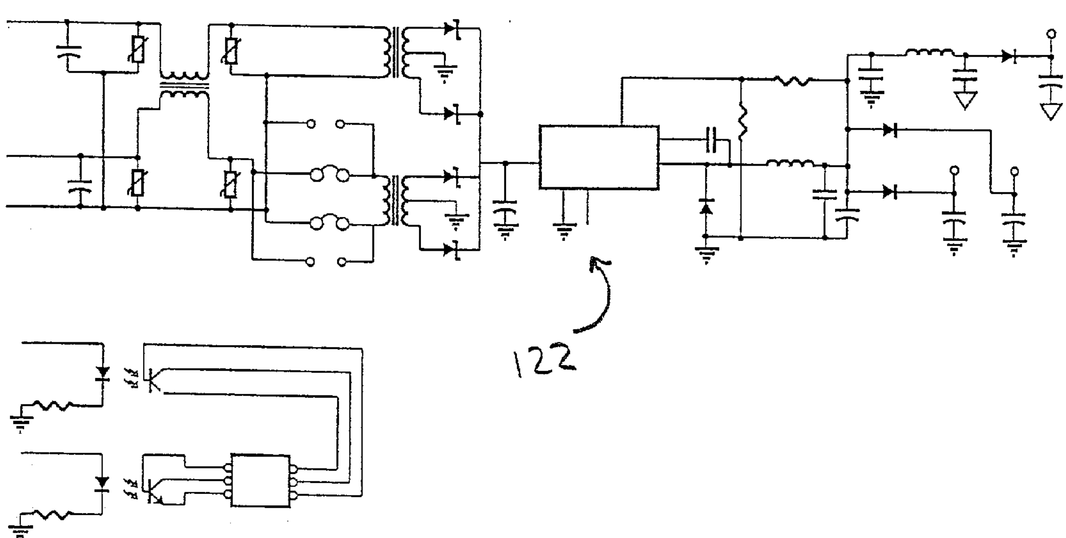


FIG -8D

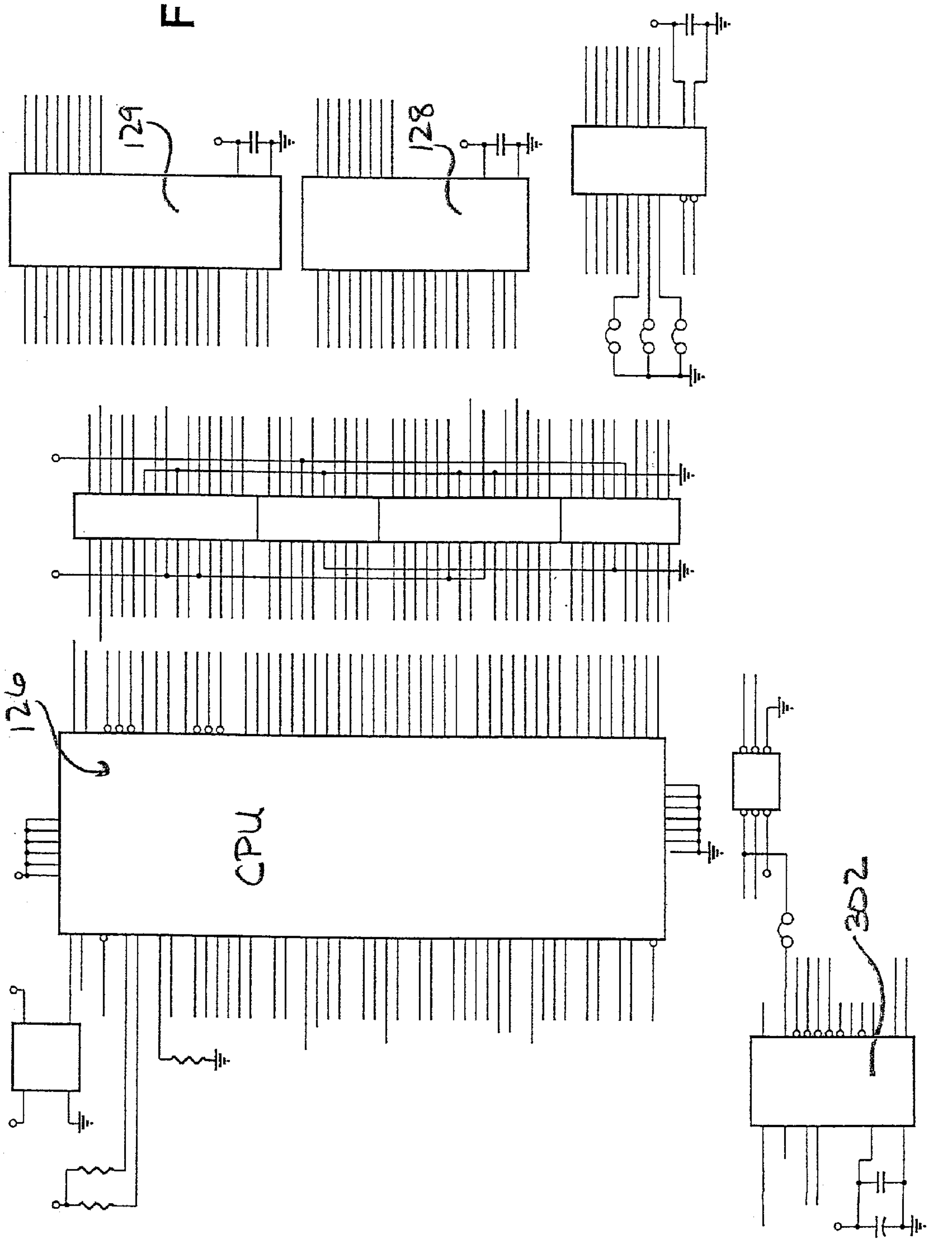


FIG -9A

Sensor Software Flow Chart

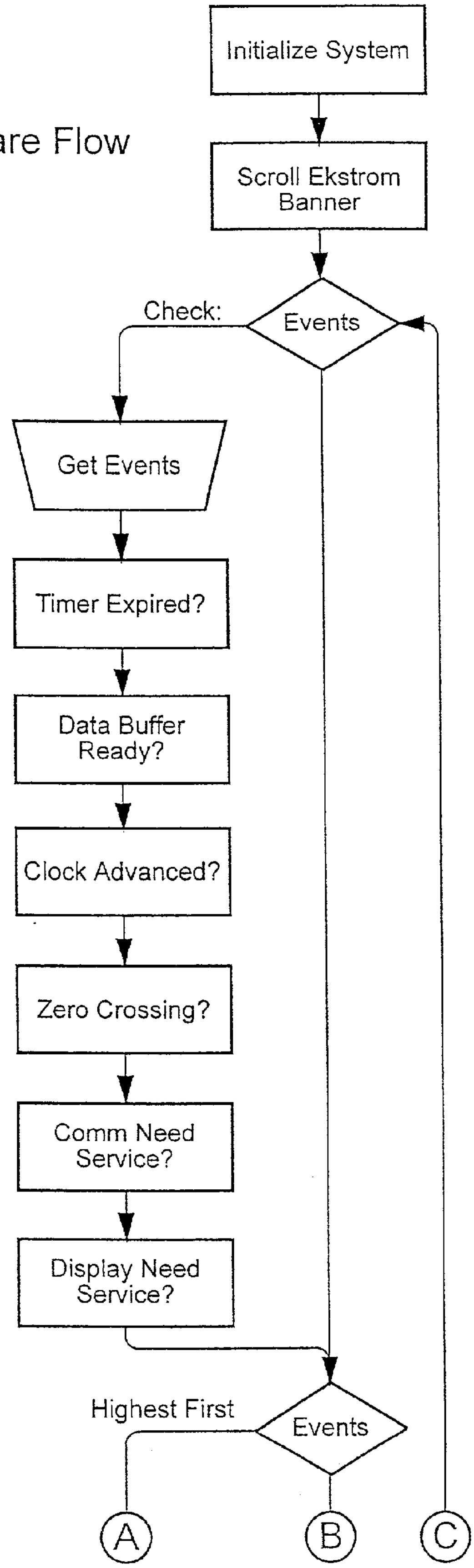
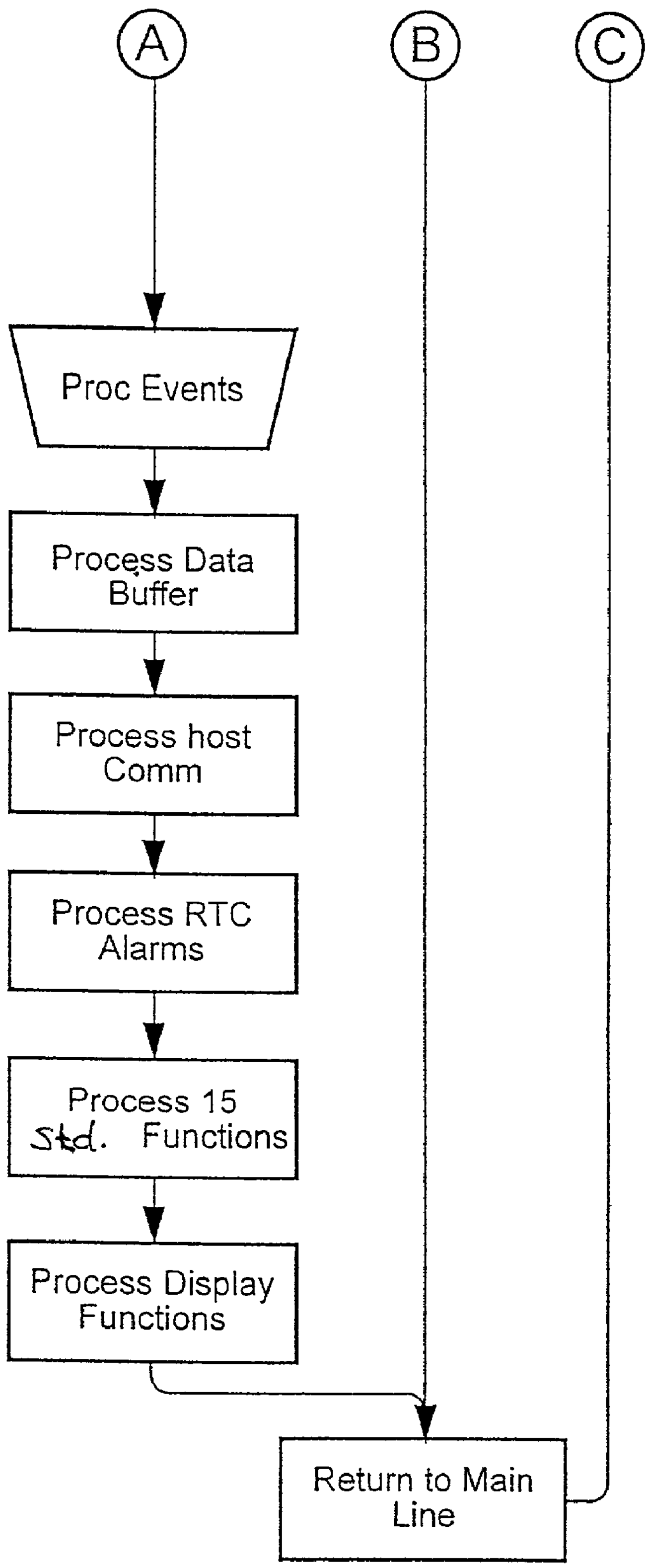


FIG -9B


A
B
C
Proc Events
Process Data Buffer
Process host Comm
Process RTC Alarms
Process 15 Std. Functions
Process Display Functions
Return to Main Line

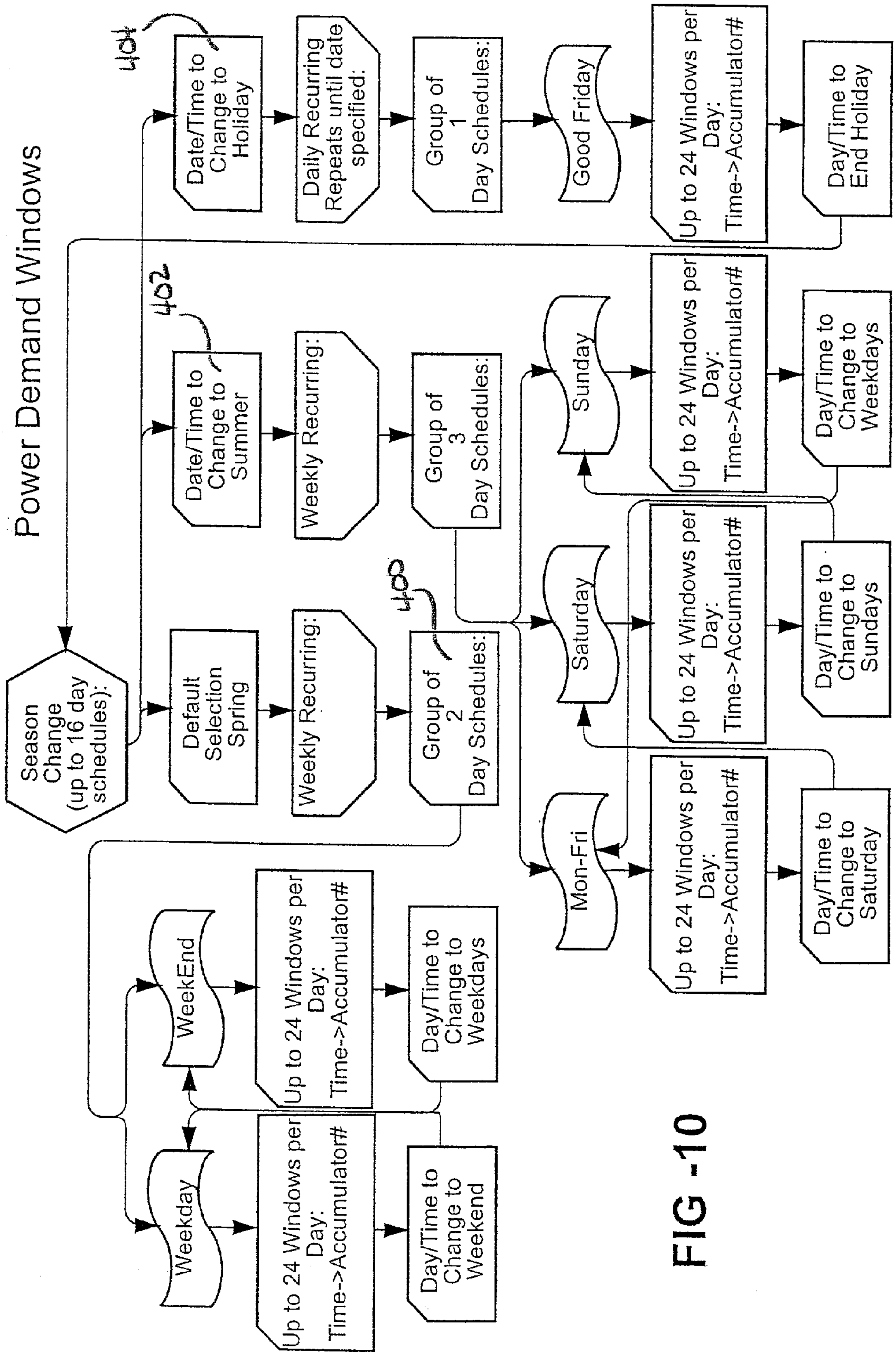

Power Demand Windows
Season Change (up to 16 day schedules):
Default Selection Spring
Weekly Recurring:
Group of 2 Day Schedules:
400
Date/Time to Change to Summer
402
Weekly Recurring:
Group of 3 Day Schedules:
Date/Time to Change to Holiday
404
Daily Recurring Repeats until date specified:
Group of 1 Day Schedules:
Good Friday
Up to 24 Windows per Day: Time->Accumulator#
Day/Time to End Holiday
Sunday
Up to 24 Windows per Day: Time->Accumulator#
Day/Time to Change to Weekdays
Saturday
Up to 24 Windows per Day: Time->Accumulator#
Day/Time to Change to Sundays
Mon-Fri
Up to 24 Windows per Day: Time->Accumulator#
Day/Time to Change to Saturday
WeekEnd
Up to 24 Windows per Day: Time->Accumulator#
Day/Time to Change to Weekdays
Weekday
Up to 24 Windows per Day: Time->Accumulator#
Day/Time to Change to Weekend

FIG -10

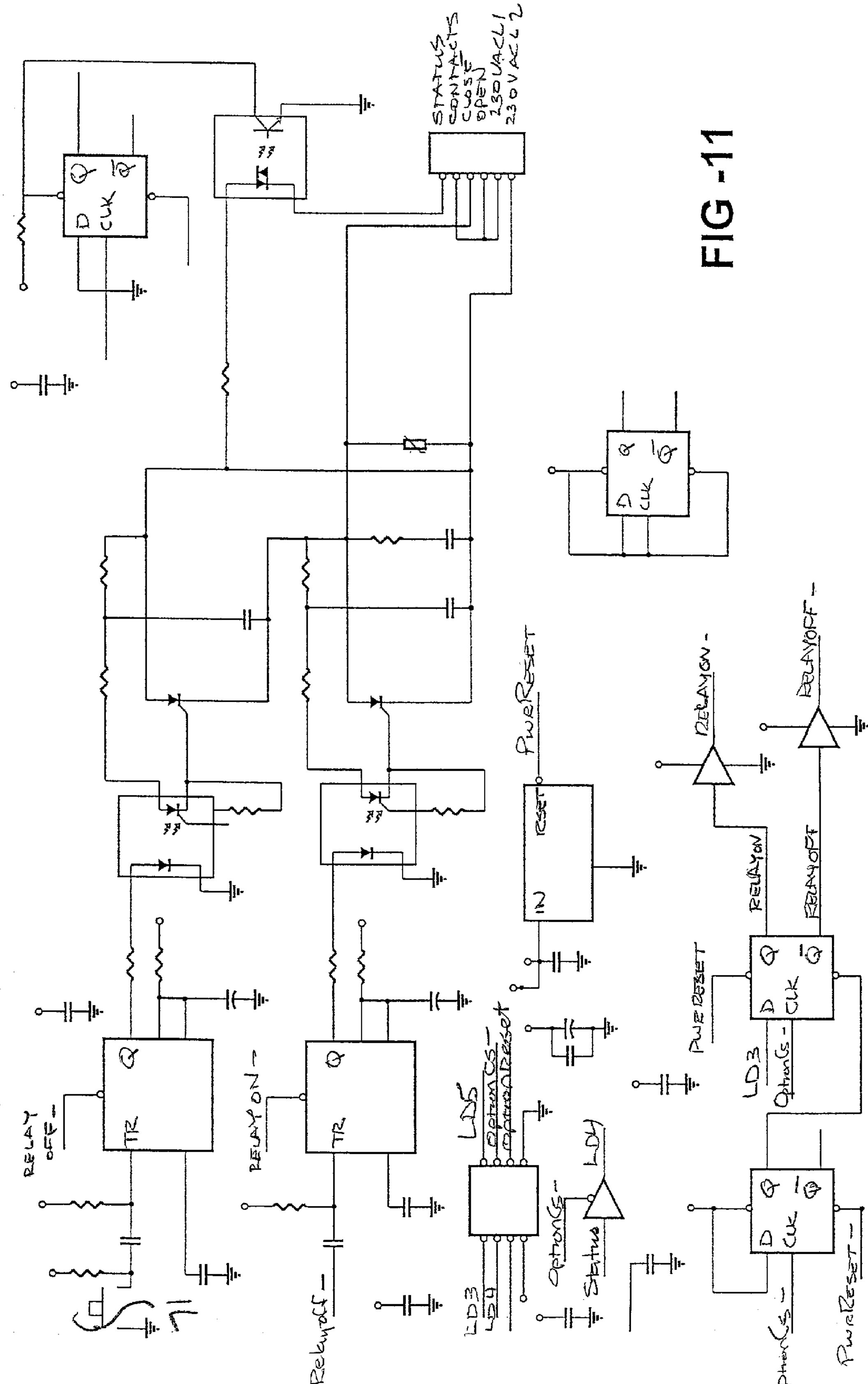

STATUS
CONTACTS
CLOSE
OPEN
230VACL1
230VACL2
RESET
IN
PWRRESET
RELAYON-
RELAYOFF-
RELAYON
RELAYOFF
LD3
LD4
LD5
OptionCS-
Status

FIG -11

FIG -12

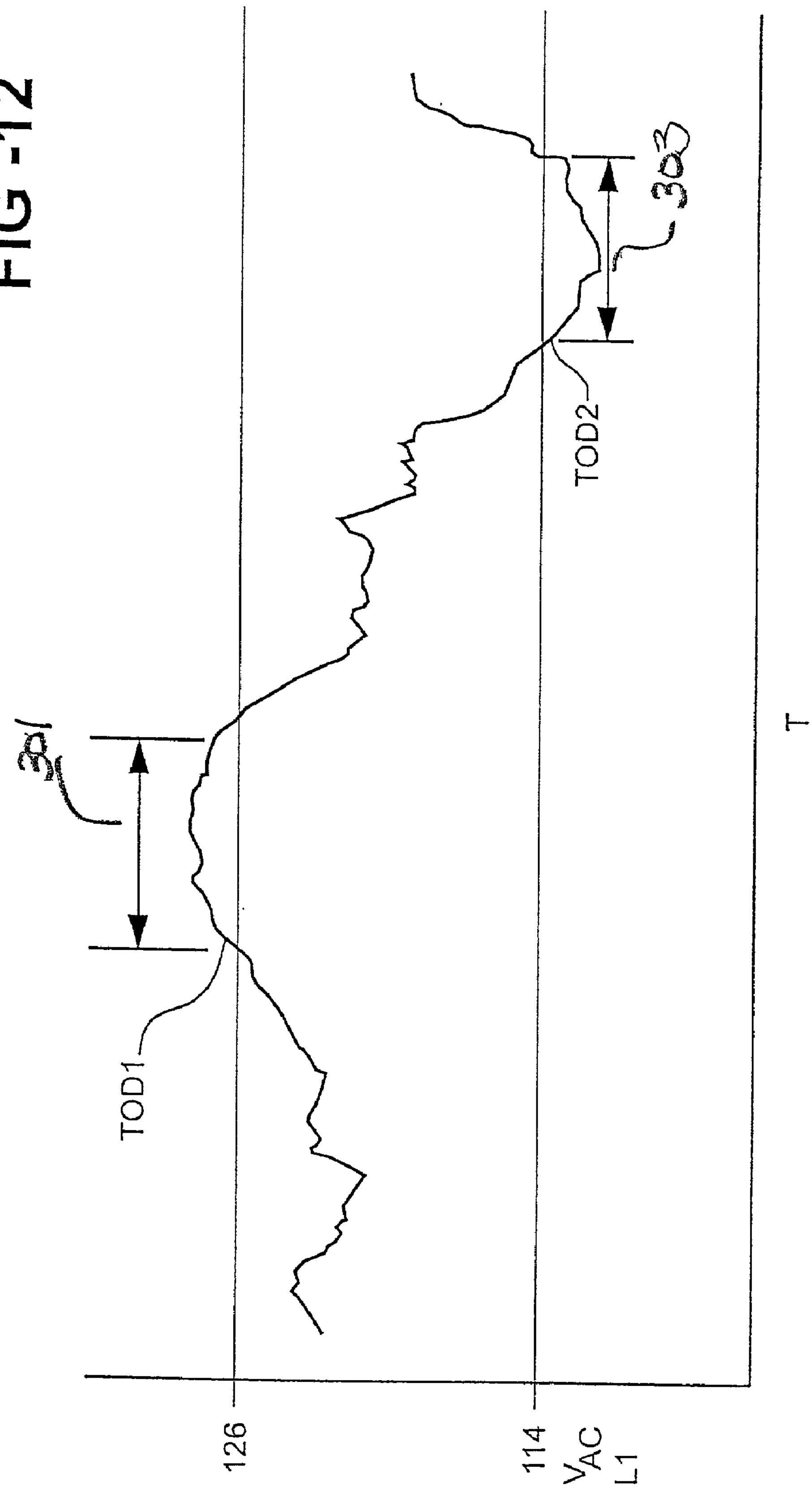


FIG -13

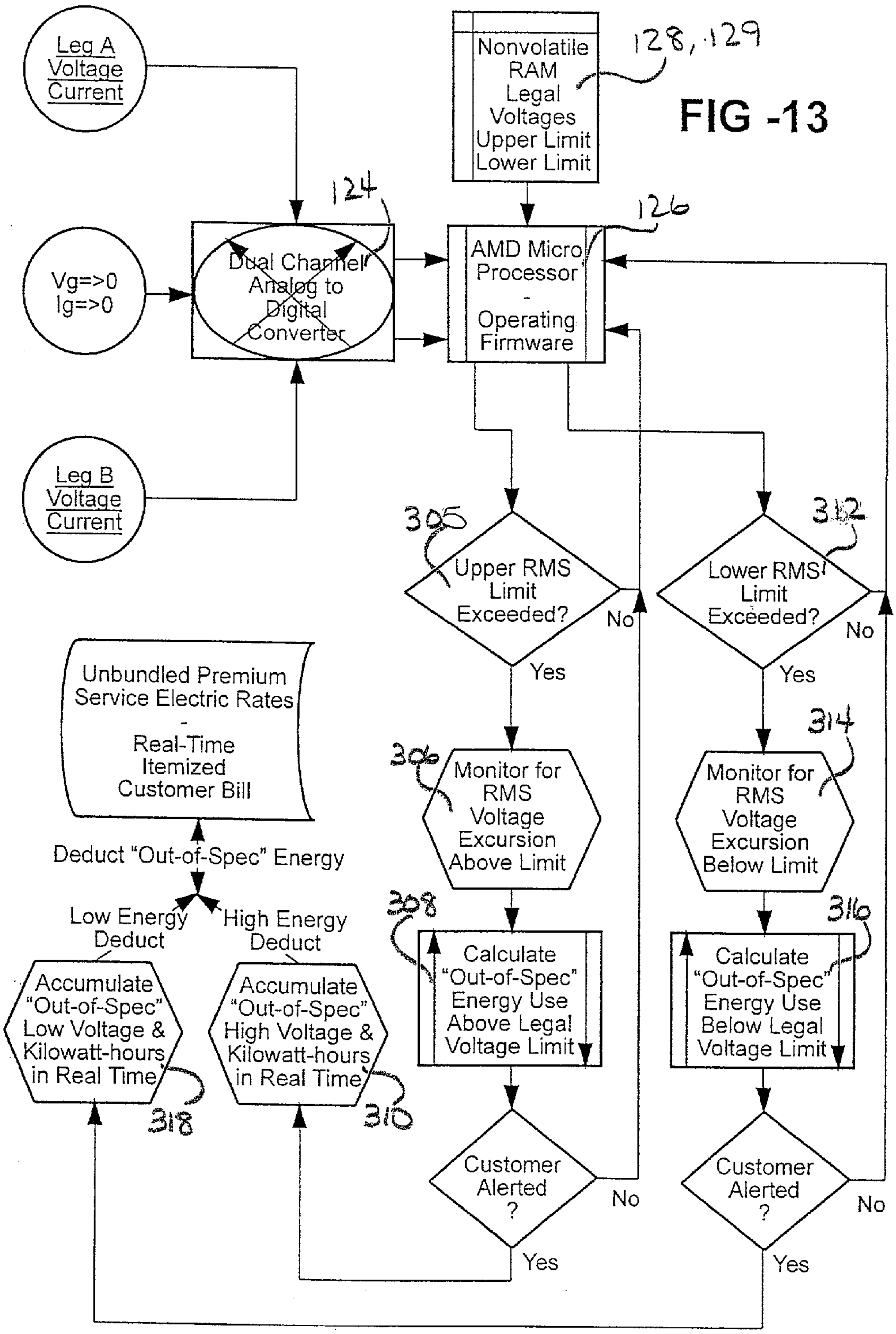
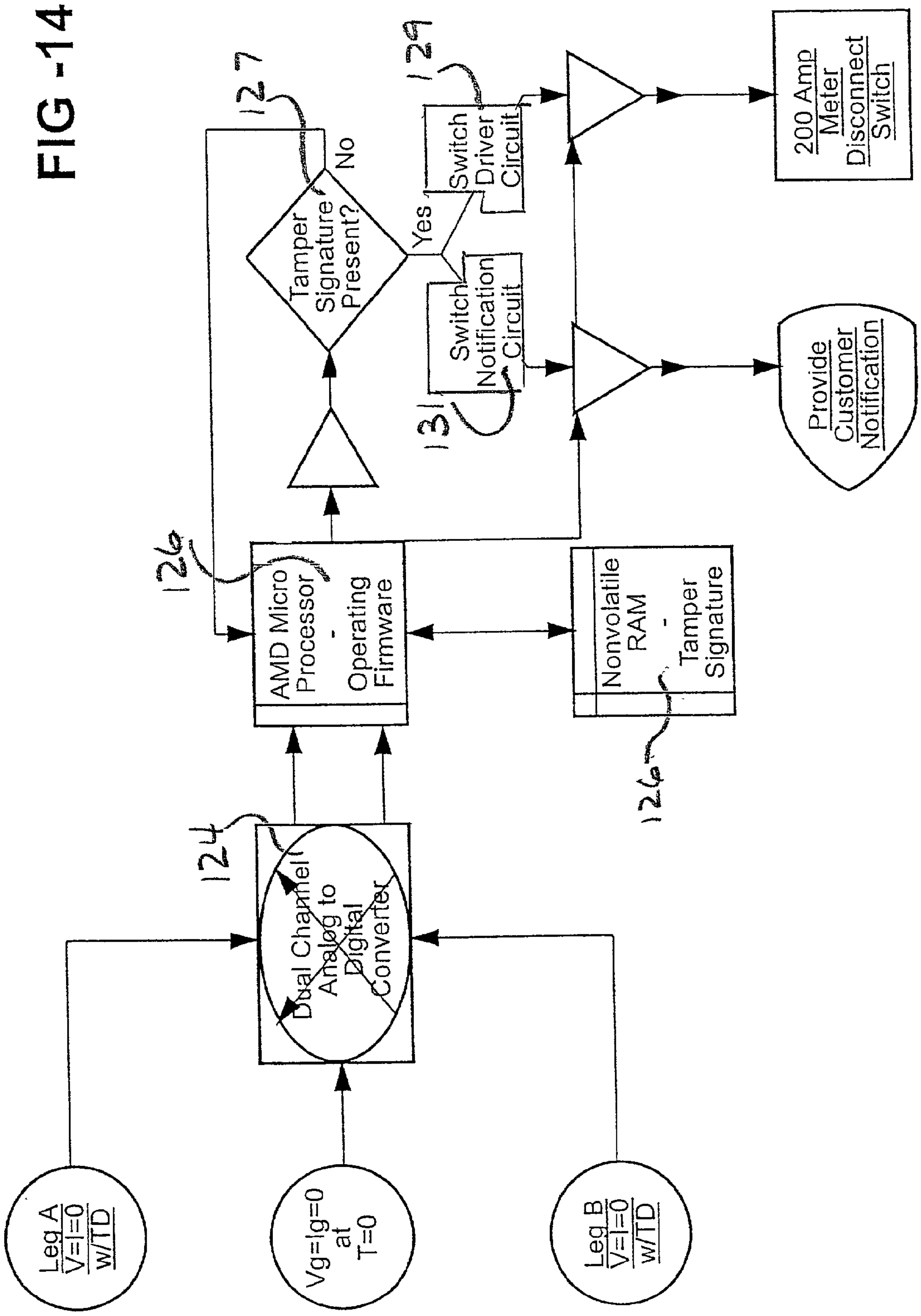

Leg A
Voltage
Current
Vg=>0
Ig=>0
Leg B
Voltage
Current
Dual Channel
Analog to
Digital
Converter
124
Nonvolatile
RAM
Legal
Voltages
Upper Limit
Lower Limit
128, 129
AMD Micro
Processor
-
Operating
Firmware
126
Upper RMS
Limit
Exceeded?
305
No
Yes
Lower RMS
Limit
Exceeded?
312
No
Yes
Monitor for
RMS
Voltage
Excursion
Above Limit
306
Monitor for
RMS
Voltage
Excursion
Below Limit
314
Calculate
"Out-of-Spec"
Energy Use
Above Legal
Voltage Limit
308
Calculate
"Out-of-Spec"
Energy Use
Below Legal
Voltage Limit
316
Customer
Alerted
?
No
Yes
Customer
Alerted
?
No
Yes
Unbundled Premium
Service Electric Rates
-
Real-Time
Itemized
Customer Bill
Deduct "Out-of-Spec" Energy
Low Energy
Deduct
High Energy
Deduct
Accumulate
"Out-of-Spec"
Low Voltage &
Kilowatt-hours
in Real Time
318
Accumulate
"Out-of-Spec"
High Voltage &
Kilowatt-hours
in Real Time
310

FIG -14


Leg A
V=I=0
w/TD
Vg=Ig=0
at
T=0
Leg B
V=I=0
w/TD
Dual Channel
Analog to
Digital
Converter
124
AMD Micro
Processor
-
Operating
Firmware
126
Nonvolatile
RAM
-
Tamper
Signature
126
Tamper
Signature
Present?
127
No
Yes
Switch
Driver
Circuit
129
Switch
Notification
Circuit
131
200 Amp
Meter
Disconnect
Switch
Provide
Customer
Notification

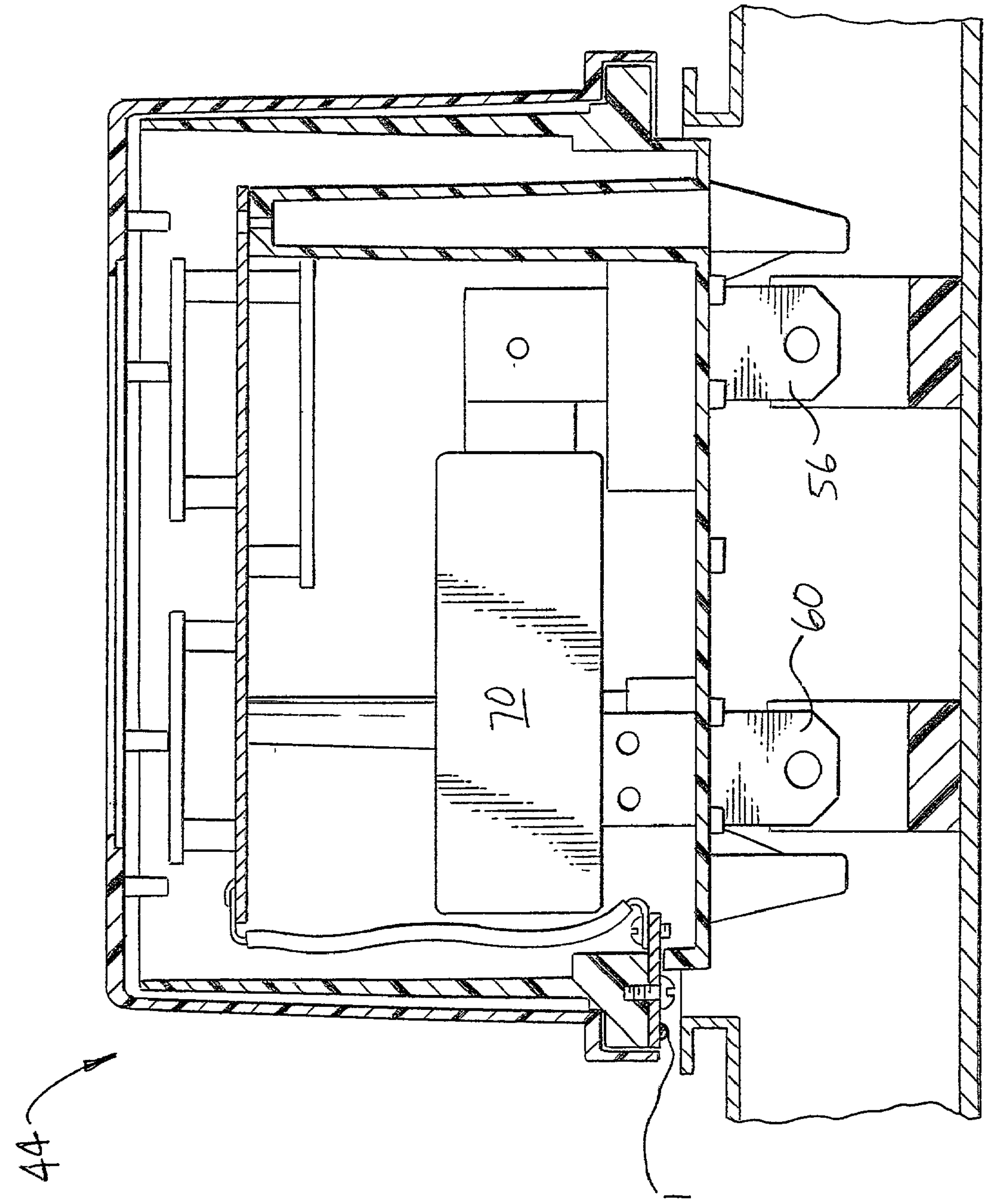


FIG-15

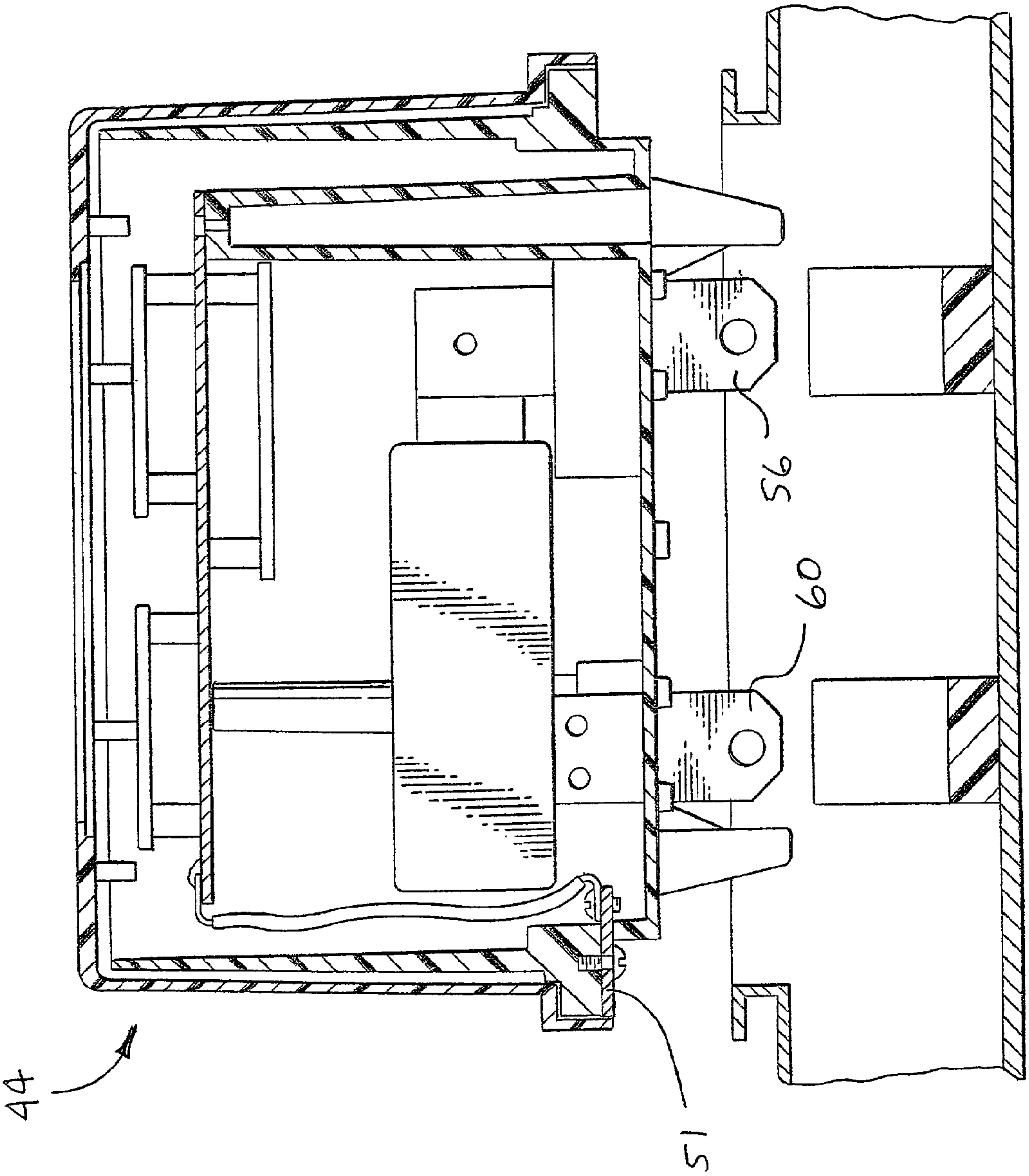


FIG-16

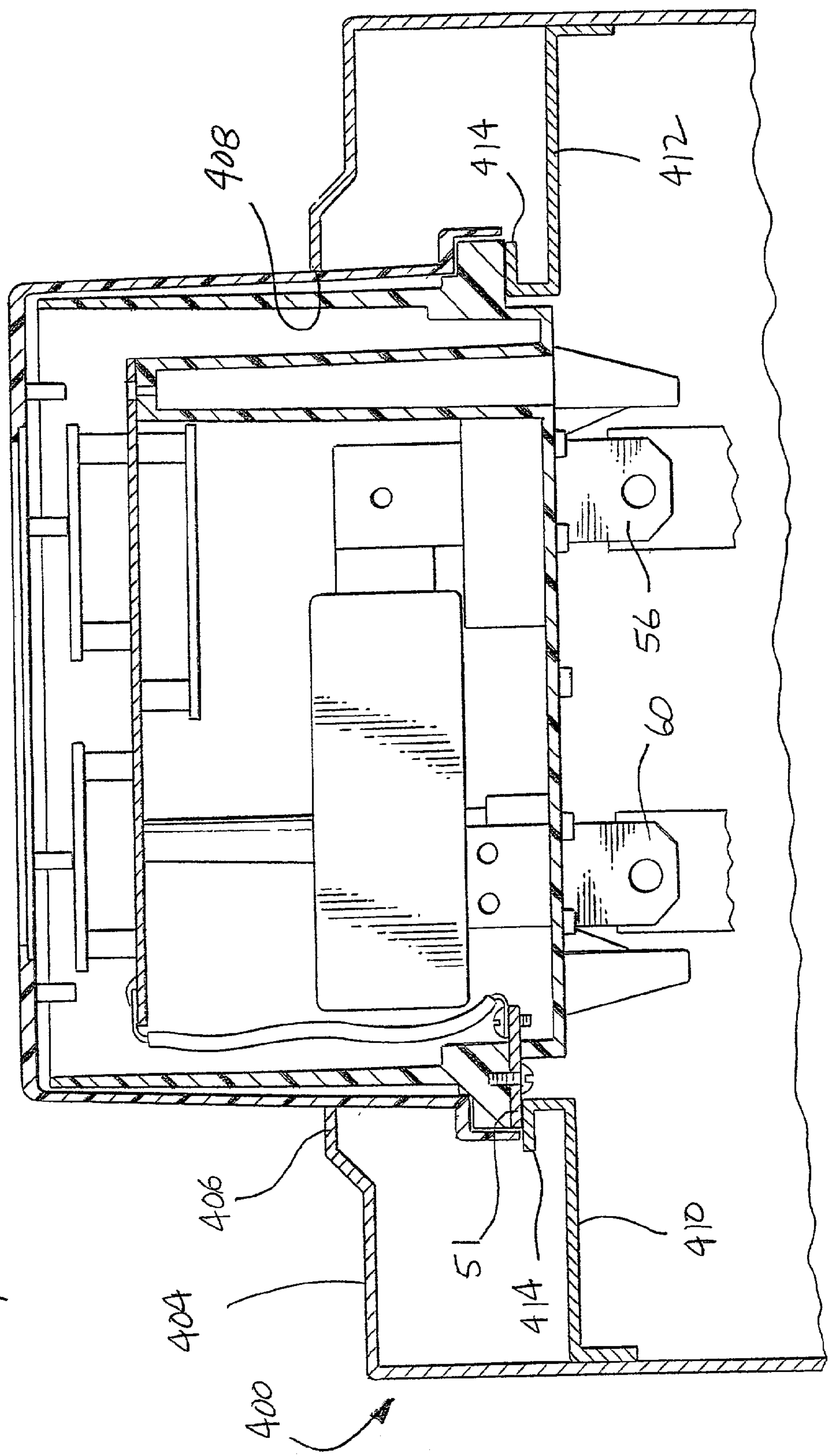


FIG-17

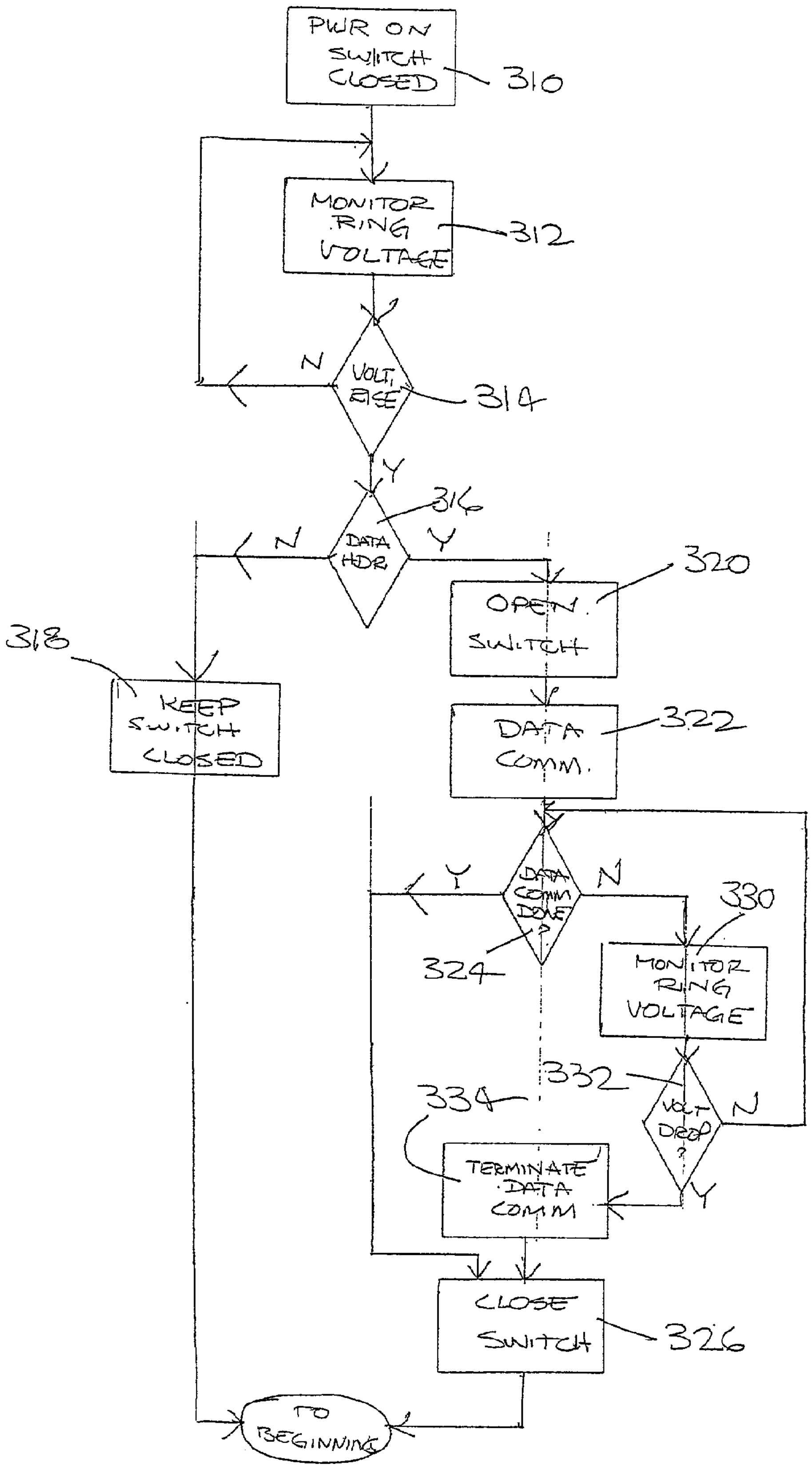

PWR ON SWITCH CLOSED
310
MONITOR RING VOLTAGE
312
N
VOLT. RISE
314
Y
316
N
DATA HDR
Y
320
OPEN SWITCH
318
KEEP SWITCH CLOSED
DATA COMM.
322
Y
DATA COMM DONE ?
N
330
324
MONITOR RING VOLTAGE
332
334
VOLT DROP ?
N
TERMINATE DATA COMM
Y
CLOSE SWITCH
326
TO BEGINNING

FIG 18

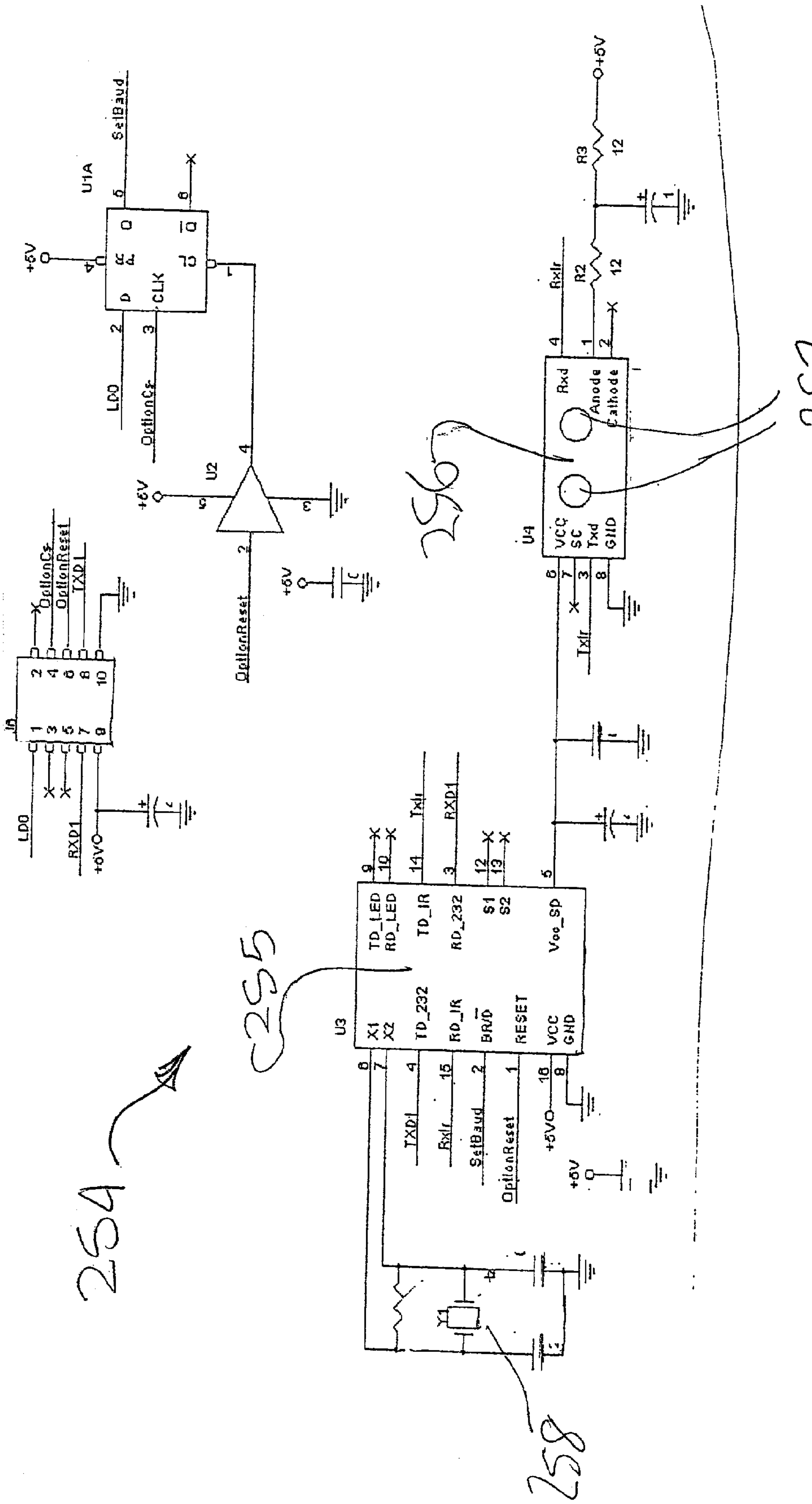

U1A
SelBaud
CLK
LD0
OptionCs
OptionReset
U2
+5V
TXD1
RXD1
U3
TD_LED
RD_LED
TD_IR
RD_232
S1
S2
Vcc_SP
X1
X2
TD_232
RD_IR
BR/D
RESET
VCC
GND
RxIr
TxIr
U4
Rxd
Anode
Cathode
SC
Txd
R2
R3
Y1
254
255
256
257
258

FIG. 19

POINT OF USE DIGITAL ELECTRIC ENERGY APPARATUS WITH REAL-TIME DUAL CHANNEL METERING

CROSS REFERENCE TO CO-PENDING APPLICATION

[0001] This application claims the benefit of the filing date of co-pending provisional U.S. Patent Application Serial No. 60/235,122, filed Sep. 25, 2000 and entitled POINT OF USE DIGITAL ELECTRIC ENERGY MEASUREMENT, CONTROL AND MONITORING APPARATUS.

BACKGROUND

[0002] The present invention relates, in general, to apparatus for measuring and controlling the supply of electric energy at a use site.

[0003] In the electric utility industry, watthour meters are typically employed to measure electric power used at a building or home site. A socket housing is mounted on a convenient wall of the residence or commercial building and contains pairs of line and load terminals which are respectively connected to the electric utility line conductors and the building load distribution conductors. The terminals typically receive blade contacts on a plug-in watthour meter to complete an electric circuit through the meter between the line and load terminals.

[0004] Plug-in socket adapters and socket adapters/extenders, both hereafter referred to simply as socket adapters, are designed to plug into the meter socket housing terminals. Such socket adapters are employed to convert a ringless style socket to a ring style socket or to extend the mounting position of the jaw terminals in the socket outward from the socket for mounting various electrical equipment, such as test devices or survey recorders, in the socket. The watthour meter is then plugged into jaw contacts carried within the socket adapter. The socket adapter jaw contacts are connected, either integrally or via separate electrical connections, to blade terminals extending rearwardly of the socket adapter housing for plug-in engagement with the socket terminals or jaw contacts.

[0005] Meter reading personnel periodically inspect each meter site and record utility meter readings, either visually or by using a probe to retrieve power usage data stored in solid state memory of the watthour meter.

[0006] To increase data collection efficiency and reliability, watthour meters are now available with interface equipment designed to permit remote interrogation of the meter and transmission of electric power usage data. Utility meters located at each customer site are connected in data communication to a central billing facility via various communication methods, including power line signal transmission, dedicated signaling lines, use of the public telephone switching network, and radio frequency signal transmission.

[0007] Prior automatic meter readers sense the instantaneous voltage and currents applied to a use site. These instantaneous values are measured at a sampling interval and digitized. The digital instantaneous sample values representative of the instantaneous voltage and current at each sample interval are stored in a memory. Subsequent calculations are performed on the sampled voltage and current values.

[0008] However, prior automatic meter readers average the voltage and current data over each sampling interval to obtain an average voltage and current which is considered representative of the instantaneous voltage and current during the entire sampling interval. It is these average values which are used in calculating power consumed at the use site, such as total kilowatt hours, etc. However, this leads to a lower measurement accuracy due to the averaging.

[0009] Thus, it would be desirable to provide an electric energy measurement apparatus which provides a higher measurement accuracy than that possible using prior automatic meter reading techniques.

SUMMARY OF THE INVENTION

[0010] The present invention is an electric energy measurement apparatus which is capable of measuring instantaneous voltage and current at a use site and then using digitized instantaneous voltage and current values to calculate total power consumed and other power values, including kilowatt hours, with a high degree of measurement accuracy.

[0011] In one aspect, the electric energy measurement apparatus and method include voltage and current sensors for measuring the voltage and current on each of at least two power conductors at the use site. The instantaneous voltage and current values measured by the voltage and current sensors are sampled at a sampling interval and the sensor outputs converted to digital values which are stored in a memory for each sample.

[0012] Simultaneous with or subsequent to the storing of the digital voltage and current values in the memory, the digital voltage and current values are used in power calculations to generate power values, such as total kilowatt hours consumed at the use site on each conductor or phase during the sampling interval. These power calculations are totaled over any time period to determine the total power consumed at the use site. This provides a more accurate power measurement which overcomes the less than accurate averaging measurement techniques employed in prior art automatic meter readers.

[0013] The digital voltage and current values are stored for each leg or phase of electric power supplied to the use site. This enables power calculations to be performed on each phase for separate power consumption values.

[0014] The measurement apparatus is capable of downloading the stored power calculation values to the remote site for further processing and/or analysis at any time so as to conserve memory space, etc.

BRIEF DESCRIPTION OF DRAWINGS

[0015] The various features, advantages and other uses of the present invention are more apparent by referring to the following detailed description and drawing in which:

[0016] **FIG. 1** is a schematic diagram of an electric energy management apparatus according to the present invention;

[0017] **FIG. 2** is an exploded, perspective view showing the electric energy management apparatus according to the present invention mountable in a watthour meter socket;

[0018] **FIG. 3** is a perspective view of the electric energy management apparatus without the internal circuit board, the disconnect switch and the shell;

[0019] **FIG. 4** is a perspective view of the electric energy management apparatus shown in **FIG. 3** including the optional disconnect switch;

[0020] **FIG. 5** is a side elevational view of the housing of the electric energy management apparatus with a portion of the sidewall of the housing removed to show the internal components of the electric energy management apparatus of the present invention;

[0021] **FIG. 6** is a front elevational view of the circuit board of the electric energy management apparatus shown in **FIG. 5**;

[0022] **FIG. 7** is a block diagram of the major components of the electric energy management apparatus at one customer use site;

[0023] **FIGS. 8A, 8B**, **8**C, and **8**D are detailed schematic diagrams of the circuitry of the electric energy management apparatus mounted on the circuit board shown in **FIGS. 5 and 6**;

[0024] **FIGS. 9A and 9B** are flow diagrams of the electric energy management apparatus control program;

[0025] **FIG. 10** is a flow diagram of the power demand windows control sequence of the present electric energy management apparatus;

[0026] **FIG. 11** is a schematic diagram of the disconnect switch control circuitry used with the optional disconnect switch shown in **FIG. 4**;

[0027] **FIG. 12** is a graph depicting out-of-specification voltages;

[0028] **FIG. 13** is a flow diagram of the "out-of-spec" energy detection sequence;

[0029] **FIG. 14** is a flow diagram depicting the tamper detection sequence;

[0030] **FIG. 15** is a side elevational view of the electric energy management apparatus depicting a partially removed position of the housing from the meter socket;

[0031] **FIG. 16** is a side elevational view, similar to **FIG. 15**, but showing the housing blade terminals in a fully separated position with respect to the socket jaw contacts;

[0032] **FIG. 17** is a side elevational view of a meter installation depicting the electric energy measurement apparatus of the present invention mounted in a ringless style meter socket;

[0033] **FIG. 18** is a flow diagram of the telephone interrupt and non-interrupt control sequence; and

[0034] **FIG. 19** is a diagram of the optical communication circuit.

DETAILED DESCRIPTION

[0035] Referring now to the drawing, there is depicted a point of use, digital, electrical energy measurement, control and monitoring apparatus for use at individual utility customer sites which has connectivity through a global telecommunication network to a centralized computer control system.

Central Utility

[0036] As shown in **FIG. 1, a** central utility company site is depicted generally by reference number **10**. The central utility site **10** may be the central business office of the utility, a generating station, etc., where utility billing information is accumulated, tabulated and recorded. A central processing unit **12** is located at the central site **10**. The central processing unit **12** may be any suitable computer, such as a mainframe, a PC, a PC network, workstation, etc., having the capacity of handling all of the utility company customer billing transactions and/or the remote data communications described hereafter. The central processing unit **12** communicates with a memory **14** which stores, identification data specific to each utility customer, as well as other data regarding the power usage of each customer. The memory **14** may include both hard disc storage memory and on-board memory. Although high voltage, electrical power distribution lines denoted generally by reference number **16** for a three-wire, single-phase electrical system, are shown as extending between the central utility site **10** to each utility customer **18**, **19**, etc., it will be understood that the electrical power distribution lines **16** may extend from a separate electrical power generating site with appropriate voltage transformations to each customer site, and not directly from the central utility site **10**. Further, it will be understood that the electrical power distribution lines **16** may provide three-phase power to any customer site.

[0037] As shown in **FIG. 1**, various input and output devices, such a keyboard, printer(s) **13**, display terminals or monitors **15**, etc., may also be connected to the central processing unit **12** as is conventional. In addition, one or more modems **20** are connected to the central processing unit **12** at the central utility site **10** and to a conventional telephone wiring network denoted generally by reference number **22**. The telephone wiring network **22** may be conventional telephone wires, as well as fiber optics, satellite, microwave, cellular telephone communication systems and/or combinations thereof. The modem **20**, which may be any conventional modem, functions in a known manner to communicate data between a processor and the telephone network.

[0038] Also stored in the memory **14** are the various software control programs used by the central processing unit **12** to automatically communicate with the electrical energy management apparatus at each utility customer **18**, **19** as described hereafter. The memory **14** also stores the power usage data for each utility customer **18**, **19** as well as various billing routines utilized by a particular utility company.

[0039] Generally, the software control program stored in the memory **14** is a menu driven database capable of handling multiple simultaneous calls to a number of remote apparatus at the customer sites **18**, **19**. The control program stores each customer's power usage in accumulated KWH and KVA, for example, and instantaneous voltage, current and power factor measurements. Also, the control program generates periodic summary printouts via the printer **13**.

[0040] The control program enables the utility to remotely program each energy management apparatus from the central site **10**. Such programmable features include time, date and year data, a multi-level security code for communication access, receive call and originate call modes, line voltage quality set points, start and end times for multiple demand billing period intervals, i.e., three intervals in each 24 hour period, the date, time and duration of a communication window for communication with the central site **10**, etc.

[**0041**] Various main system menu screens may be generated by the CPU **12** to enable communication with any of the remote units. Further details concerning the generation and use of such menu screens can be had by referring to U.S. Pat. No. 5,590,179, the entire contents of which are incorporated herein by reference.

[**0042**] According to a unique feature of the present automatic meter reader apparatus, CPU **12** communicates with a global telecommunications network that is separate from the conventional telephone line network **22** through an interface including a modem connection **20** to an Internet service provider (ISP) **20** which communicates with a worldwide telecommunications network, such as the Internet or world wide web. The CPU **12** can generate an appropriate identification number (I.D.) or address for any of the remote units. This I.D. can be transmitted by the ISP **20** through the Internet **21** to any of the individual use sites **18**, **19**, etc.

Remote Utility Customer

[**0043**] As shown in **FIGS. 1 and 2**, a plurality, such as tens or even hundreds or thousands of utility customer sites **18**, **19**, are connected to the electrical power distribution network **16** at remote locations of varying distances from the central utility company site **10**.

[**0044**] As is conventional, each utility customer site **18**, as shown in **FIG. 1**, includes a conventional utility meter socket **30** having a plurality of internally mounted jaw contacts or terminals **32** which are connected to the single-phase three-wire line conductors of the electrical distribution network **16**. Although not shown in **FIG. 1**, the separate jaw terminals **32** in the socket **30** are connected to the individual service or load conductors at each utility customer site **18**. In a conventional application, the socket **30** is mounted at a suitable location at the utility customer site **18**, such as on an exterior wall, with the load conductors extending from the socket **30** to the building wiring circuits.

Remote Unit

[**0045**] A digital, electric energy management apparatus (hereafter "remote unit") **34** is provided for recording, measuring, controlling and monitoring electrical power usage at a particular customer site **18**. The remote unit **34** has a plurality of outwardly extending, blade-type, electrical terminals **36** which electrically engage the jaw contacts or terminals **32** in the socket **30**.

[**0046**] As shown in **FIGS. 1 and 2**, and in greater detail in **FIGS. 3, 4** and **5**, the remote unit **34** of the present invention, in a preferred embodiment, includes a base denoted generally by reference number **40**. The base **40** is snap-in connectable in the meter socket **30**. However, according to the present invention, the base **40** includes internally mounted electrical energy measurement and telecommunication circuits as described in greater detail hereafter. The use of the base **40** to house the automatic meter reading circuitry is a preferred embodiment of the present invention. It will be understood, however, that such electrical energy measurement and control circuitry, as described hereafter, can also be mounted at each customer site **18**, **19** by other means, such as in an enclosure separate from a standard watthour meter and the meter socket.

[**0047**] In general, the remote unit **34** includes a two-part housing formed of the base **40** having a base wall **42** and a shell **44** which are releasably joined together by a snap-in and rotate connection. As described hereafter, a plurality of electrical terminals **34** are mounted in the base **40**. The electrical terminals **47** are provided in the base **40** in any number, type and arrangement depending upon the electrical power service for a particular application. By way of example only, the electrical terminals **47** are arranged in the base **40** in a first pair of line terminals **54** and **56** and a second pair of load terminals **58** and **60**.

[**0048**] A peripheral flange **48** is formed on the base **40** which mates with a similarly formed flange **33** on the watthour meter socket or housing **30** for mounting the remote unit **34** to the watthour meter socket **30**. A conventional seal or clamp ring **62**, such as a seal ring disclosed in U.S. Pat. No. 4,934,747, the contents of which are incorporated herein by reference, is mountable around the mating flanges **48** and **33** to lockingly attach the remote unit **34** to the socket **30** and to prevent unauthorized removal of or tampering with the remote unit **34**.

[**0049**] It will also be understood that the remote unit **34** and the socket **30** may be configured for a ringless connection. In this type of connection, not shown, the cover of the socket **30** is provided with an aperture which is disposable over the remote unit **34**. The cover is locked to the socket **30** enclosure after the remote unit **34** has been inserted in the socket **30** and through the aperture in the cover.

[**0050**] The base **40** and the base wall **42** has generally circular configuration centered within an integrally formed annular side wall **44** which terminates in an outer edge **46**. The flange **48** projects radially outward from the sidewall **44** at the general location of the base wall **42**. A plurality of circumferentially spaced notches **50** are formed in the flange **48** for reasons which will be described in greater detail herein.

[**0051**] At least one and preferably two ground tabs **51**, only one of which is shown in **FIG. 3**, are mounted on the exterior surface of the base wall **42** and have an radially outer end which is positioned within one of the notches **51** as shown in **FIG. 3**. The ground tabs **51** are adapted to engage a ground connection in the meter socket **30**, as is conventional and as is described in greater detail hereafter.

[**0052**] The shell **44** has a generally cylindrical configuration formed of a sidewall **45** and an end wall **53**. An annular flange **47** projects radially from one end of the sidewall **45** as shown in **FIGS. 2 and 5**. The flange **47** has a stepped shape formed of a radially extending leg and an axially extending leg. The flange **47** overlays the flange **48** on the base **40** and receives the sealing ring **37** thereover as described above.

[**0053**] A plurality of arcuate slots **49**, such as three slots **49** by way of example only, are formed in the radially extending leg of the flange **47**. A generally L-shaped lock arm **51** projected interiorly from the radially extending leg of the flange **47** along one inside edge of each slot **49**, as shown in **FIG. 5**. The L-shaped lock arm **51** is alignable with one of the notches **51** in the base **40** when the shell **44** is joined to the base **40**. Rotation of the shell **44** relative to the base **40** causes the lock arm **51** to slide underneath the bottom edge of the flange **48** on the base **40** to lock the shell **44** to the base **40**.

[**0054**] It will be understood that alignable apertures may be formed in the flange **47** of the shell **44** and the flange **48** of the base **40** in the rotated, locked position for receiving a seal member, such as a conventional watthour meter seal ring, not shown, to lockingly attach the shell **44** to the base **40** and to provide an indication of tampering with the remote unit **34** after the remote unit **34** has been mounted on the socket **30**.

[**0055**] As also shown in **FIGS. 1 and 2**, and in greater detail in **FIG. 5**, the end wall **53** of the shell **44** is provided with an aperture **55** which has an under notch or undercut formed about the periphery of the aperture **55** as shown in **FIG. 5**. The aperture **55** is adapted for receiving a transparent cover **57**, formed, by example, of Lexan, and having a notched peripheral edge which fits within the undercut formed about the periphery of the aperture **55**. A plurality of posts **59** project inwardly from the undercut surrounding the aperture **55** in the end wall **53** of the shell **44** and are adapted to engage apertures formed about the periphery of the cover **57** to align and mount the cover **57** to the end wall **53**. Fasteners, such as lock nuts, not shown are mountable over the posts **59** to lock the cover **57** in the end wall **53**.

[**0056**] Although not shown in **FIG. 5**, portions of the transparent cover **57** are masked or blacked out to provide separate windows, one for the display **222** and one for the opto-communication port **134**.

[**0057**] A plurality of apertures **52** are formed in the base wall **42** at the normal jaw contact positions of a watthour meter. For the single phase remote unit **34** described herein by way of example only, four apertures **52** are formed in the base wall **42** and respectively received the line blade terminals **54** and **56** and the load blade terminals **58** and **60**. The blade terminals **54, 56, 58** and **60** have one end portion disposed interiorly within the base **40** extending away from one side of the base wall **42** and an external portion, shown in **FIG. 5**, which projects exteriorly of the opposed surface of the base wall **42** and adapted to slidably engage the jaw contacts **32** in the watthour meter socket **30**.

[**0058**] Although not shown, one of the apertures formed in the exterior portion of each blade terminal **54, 56, 58** and **60** can receive a lock member, such as a cotter pin, conventionally used in watthour meters, to fixedly secure each blade terminal **54, 56, 58** and **60** to the base wall **44**.

[**0059**] A plurality of bosses **62**, such as three bosses by way of example only, are formed on the base wall **42** and project therefrom to co-planar upper ends as shown in **FIG. 5**. Each boss **62** can be solid or hollow, but has an upper end bore **64** adapted to receive a fastener, such as a screw, for securing a circuit board **66** containing the remote unit **34** circuitry thereon. Thus, the bosses **62** form a support for the circuit board **66** as shown in **FIG. 5**. This spaces the circuit board **66** above the blade terminals **54, 56, 58** and **60** as well as above an optional disconnect switch **70**.

Disconnect Switch

[**0060**] The provision of a disconnect switch **70** is optional in the remote unit **34** of the present invention. However, the disconnect switch **70** provides valuable features when used in the tampering detect sequence described hereafter. The disconnect switch **70** may also be remotely controlled by the central utility site **10** to control the power at a particular customer site.

[**0061**] The disconnect switch **70** can be of conventional construction in that it includes two switchable contacts, which are adapted to be respectively connected between one line and one load blade terminal, such as blade terminals **54** and **58** and **56** and **60**.

[**0062**] To this end, the disconnect switch **70** is provided with a pair of line terminals **72** and **74** which project outwardly from one side of the housing of the disconnect switch **70** and a pair of load terminals **76** and **78** which project from an opposite edge or surface on the disconnect switch **70**. The terminals **72** and **74** are adapted to be disposed in registry with the load blade terminals **54** and **56** extending through the base wall **42**. Suitable fasteners, such as rivets, are employed to securely and electrically connect the terminals **72** and **74** to the load blade terminals **54** and **56**, respectively. Likewise, the load terminals **74** and **78** are disposed in proximity with the load blade terminals **58** and **60** and are secured thereto by means of suitable fasteners as described above. In this manner, the disconnect switch **70** can be easily mounted in the base **42** without interfering with the circuit board **66**.

[**0063**] Although the disconnect switch blade terminals **72, 74, 76** and **78** have been described as being separate from the blade terminals **54, 56, 58** and **60** in the base **40**, it will be understood that the disconnect terminals **72, 74, 76** and **78** can be integrally formed as a one piece, unitary structure with the blade terminals **54, 56, 58** and **60** to form a generally L-shaped blade terminal projecting from the disconnect switch **70** which has an end portion, similar to the blade terminals **54, 56, 58** and **60**, which is slidingly engagable through one of the apertures in the base wall **42**.

[**0064**] **FIG. 11** depicts the control circuitry for the disconnect switch **70** which is mounted on a circuit board attached to the bottom surface of the circuit board **66** facing the disconnect switch **70**. The disconnect switch control circuitry includes a pair of flip-flops which remember the state of an internal relay in the disconnect switch **70**. The flip-flops enable the disconnect switch **70** contacts to be switched to the last state after power is reapplied to the remote unit **34** after a power interruption, removal of the remote unit **34** from the meter socket **30**, etc.

[**0065**] The disconnect switch **70** may be controlled by a signal from the central site **10** to either "on" or "off" states as dictated by the electric utility. The signal will be received by the circuit and cause the flip-flops to switch states in accordance with the on or off signal. At the same time, a push button **71**, shown in **FIG. 11**, is mounted at a convenient location on the shell **44** and the base **42** to enable a customer, after receiving appropriate instructions from the electric utility, to manually reset the disconnect switch **70** to the "on" state.

Remote Unit Circuitry

[**0066**] A general block diagram and the circuitry of the major components of the remote unit **34** which are mounted in the base **40** at each utility customer site **18** is shown in

FIGS. **7**, **8**A-**8**D and **19**. The circuit includes a power supply **122**, voltage and current sensing circuit, an analog to digital conversion circuit **124**, a central processing unit and associated logic **126**, memories **128** and **129**, a telephone communication modem **130**, an opto-communication port **254**, and a clock. The details of these major components will now be described.

[**0067**] As is conventional, the electrical power distribution network **16** from the central utility company generating site typically carries 240 VAC. A single-phase, three-wire power distribution network **16** is shown in **FIGS. 1 and 2** with three wires connected to the electrical power distribution network **16** at each utility customer site **18**. Each line **134** and **136** carries 120 VAC RMS with respect to neutral or ground wire.

[**0068**] The power supply **122**, shown in **FIG. 8**C, provides regulated, low level DC power at the preferred ±DC levels required by the electronic components used in the circuit **120**.

[**0069**] The circuit **120** also includes a voltage sensing network denoted in general by reference number **180** in **FIG. 8A**. The voltage sensing network receives 120 VAC RMS 60 Hz input from the utility lines. One set of voltage inputs including voltage lead line connections **182** and **183** are between one lead line and neutral; while the other pair of inputs **184** and **183** is between the other lead line conductor and neutral. The voltage lead **182** is input to a combination of series connected, differential amplifiers **185**, **186** which have a settable gain of 1/100, for example. The output of the differential amplifiers is input to an A/D converter **124**. The other line connection **184** is input to a similar combination of differential amplifiers thereby resulting in two separate voltage inputs as shown by reference numbers **190** and **191** in **FIG. 8A** which are connected to other inputs of the A/D converter **124**. The differential amplifiers **186** provide an instantaneous voltage corresponding to the lead line voltage present on the conductors **182**, **183** and **184** which is within the input range of the A/D converter **124**. It should be understood that the input voltages supplied to the A/D converter **124** are instantaneous voltages.

[**0070**] The current sensing network of the circuit **120** includes first and second current transformers **200** and **202**, respectively, as shown in FIGS. **3**-**5**. The current transformers **200** and **202** each include a high permeability toroid which is disposed around a circular wall **199** surrounding each of the line blade terminals **54** and **56**, respectively, in the base **40**. The circular wall **199** is preferably a continuous or discontinuous annular member or members which are fixedly disposed on the base **40**. Preferably, the wall **199** is integrally formed with and extends from the plane of the base **40**.

[**0071**] The walls **199** provide a center support for the toroidal current transformers **200** and **202** to fixedly mount the current transformers **200** and **202** on the base **40**. This fixes the position of the current transformers **200** and **202** with respect to the inner disposed blade terminals **54** and **56**, respectively. Once the meter is calibrated, the magnetic flux between of the current transformers **200** and **202** and the current flowing through the blade terminals **54** and **56** remains fixed thereby increasing the accuracy of the electric power measurement of the meter as compared to prior art automatic meter reader devices in which the current transformers are not held in a fixed position and are capable of movement with respect to the blade terminals.

[**0072**] The current transformers **200** and **202** are precision, temperature stable transformers which provide a ±10 volt output voltage signal in proportion to the instantaneous current flowing through the line conductor. The electrical conductive coil of each current transformer **200** and **202** maybe covered by a protective insulating coating, with the conductive coil leads or outputs extending therefrom.

[**0073**] The outputs **201** from the current transformer **200** are input through a conditioning circuit to an amplifier **206**. The output of the differential amplifier **206**, which represents the scaled instantaneous current in the line conductor **134**, is supplied as an input to the A/D converter **124** as shown in **FIG. 8A**.

[**0074**] A similar signal conditioning circuit is provided for the current transformer **202**. The output leads **203** from the current transformer **202** are supplied to a differential amplifier **211**. The output of the differential amplifier **211** is also supplied as a separate input to the A/D converter **124**.

[**0075**] The A/D converter **124** includes internal sample and hold circuits to store continuous voltage and current signal representations before transmitting such instantaneous voltage and current representations to other portions of the circuit **120**, as described hereafter.

[**0076**] The twelve bit output from the A/D converter **124** is connected to an electronic programmable logic device (EPLD) **127**, shown in **FIG. 8**A, which stores the instantaneous line voltages and currents and performs at least an initial kilowatt hour (KwH) calculation at the sample rate of the A/D converter **124** on each link. This gives a real time, dual channel power measurement since the power on each separate 120 VAC line and on the 240 VAC line is separately calculated. This avoids the averaging employed in prior power metering devices and provides greater power measurement accuracy.

[**0077**] The individual line voltages and currents as well as the calculated KwH are accumulated for a predetermined time period, before the data is transmitted through a high speed data bus to a central processing unit **126**. The central processing unit **126**, in a preferred embodiment which will be described hereafter by way of example only, is a 16 bit microcontroller, Model No. AMI86ES, sold by Analog Devices. The microcontroller **126** executes a control program stored in the flash memory **128**, or backup EEPROM memory **129**, as described hereafter, to control the operation of the circuit **120**. Clock signals from a real time clock circuit **127**, in **FIG. 8**B, are supplied to the processing unit **126** and other circuit elements.

[**0078**] The microcontroller **126** also drives a display means **222**, such as a liquid crystal display, for consecutively displaying for a brief time interval, for example, the total kilowatt hours (KwH) total KVA total and KVA reactive, date, time, individual line current and voltage, and average power factor. The display **222** can be mounted, for example, at a suitable location on the circuit board **66**, for easy visibility through the transparent cover **57** mounted in the end wall of the shelf **44**. The display **222**, in a preferred embodiment, contains 16 characters divided into significant digits and decimal digits.

[0079] Referring now to **FIGS. 9A and 9B**, there is depicted a flow diagram of the sequence of operation of the control program executed by the CPU **126**. After initialization, the CPU **126** executes a number of steps to initialize various registers and to set up to receive voltage and current data. Maintenance routines are also executed to determine if any of the components, such as the communication channels, the display **226**, etc., need service. If any maintenance or time event, such as a zero crossing of the voltage or current waveforms is detected, the CPU **126** executes the detected event step in a priority order from high to low as shown in **FIG. 9B** which depicts an exemplary priority order of event processing.

Tamper Detection

[0080] The remote unit **34** of the present invention is provided with a unique tamper detection circuit which not only detects at least one or more different types of tamper events; but is capable of recording the time of day and the total duration of the tamper event as well as optionally taking action such as switching the disconnect switch **70** to an open condition thereby preventing any further application of electric power through the disconnect switch **70** to the customer site **18**, **19** when the remote unit **34** is reinserted into the socket **30**.

[0081] The base **40** of the remote unit **34** is provided with at least one and, preferably, two ground tabs **51**, one being shown in **FIG. 3**, which extend radially along the back surface of the base wall **42** into one of the notches **50** on the flange **48** surrounding the base wall **42**. Each ground tab **51** is positioned to engage a ground connection in the socket **30** to complete a ground circuit from the remote unit **34** through the socket **30** to earth ground.

[0082] The tamper detection sequence of the present invention is based on the mounting relationship of the blade terminals **54**, **56**, **58** and **60** in the jaw contacts **32** in the socket **30** and the connection between the ground tabs **51** and the mating ground tabs in the socket **30**. In addition, the voltage and currents of each of the two legs or phases of power supply to a customer use site **18** as well as the voltage and current of the center ground or neutral connection are continuously monitored as part of the tamper detection.

[0083] Since the blade terminals **54**, **56**, **58** and **60** extend a distance, such as approximately ½ inch, into the jaw contacts **32** in the socket **30** when in the full mounted position shown in **FIG. 5**, any attempt to remove the remote unit **34** from the socket **30** will initially cause the ground tab **51** to separate from the mating ground tab in the socket **30** in a timed sequence before the blade terminals **54**, **56**, **58** and **60** completely separate from the respective jaw contacts **32** and shown in **FIGS. 15 and 16**.

[0084] In a normal operating state when the remote unit **34** is securely mounted in the socket **30**, the voltage on the first and second legs will equal approximately 120 VAC, and the voltage and current on the ground leg will be zero. The current in the first and second legs will be greater than zero.

[0085] During a tamper event when the remote unit **34** is initially pulled from the socket **30**, as shown in **FIG. 15**, the ground tab **51** will separate from the mating ground connection member in the socket **30**. At this time, the ground current will equal zero while the voltage of the ground line will be greater than zero due to the loss of ground connection. However, the blade terminals **54**, **56**, **58** and **60** are still connected to the socket jaw contacts **32** such that current continues to flow through the first and second legs, i.e., i_{L1} and $i_{L2}>0$. Continued separation of the remote unit **34** from the socket jaws **32** will eventually completely separate the blade terminals **54**, **56**, **68** and **60** from the socket jaw contacts **32**, as shown in **FIG. 16**, such that the current flowing through the first and second legs will drop to zero.

[0086] This defines the tamper signature detected by the remote unit **34** of the present invention. Specifically, the tamper signature is the detection of a time delay between the time that the ground current equals zero and a ground voltage is greater than zero and a subsequent time occurrence of at least one of the first and second line and load currents equaling zero. In the case of a power outage, the ground voltage will not be greater than zero, so as to not constitute the tamper signature.

[0087] This sequence is depicted in **FIG. 14**. The microprocessor, after detecting a tamper signature in step **127** will generate and send a signal, labeled "tamper" in **FIG. 8**B, to the disconnect switch **70** which will cause the disconnect switch **70** to switch or remain in an open position the next time electric power is supplied to the disconnect switch **70** through the blade terminals. This signal is shown by reference number **129**. The CPU **126** also generates a notification signal **131** which can be transmitted back to the central site **10** to indicated to the utility that a tamper event has occurred. If the utility company chooses to contact the customer at the customer site at which a tamper event was detected, the utility company can notify the customer that tampering has been detected and provide the customer with the time of the start of the tamper detection as well as the total duration of the tamper event. Corrective action can now be easily taken by the utility to address the tamper event.

[0088] Upon reconnecting power to the offending customer site, the central site **10** can send a signal through the communication network described hereafter, to the customer site to set up the disconnect switch circuitry to reapply power to the disconnect switch **70** after the customer pushes pushbutton **71** on the remote unit **34**. This will cause the disconnect switch **70** contacts to switch to the closed state thereby reconnecting a circuit between the line and load blade terminals in the remote unit **34**.

[0089] The signal **131** also contains data relating to the time and date of the start of the detected tamper signature event as well as the time duration of the tamper event. The time and date of the start of the tamper event as well as the duration of the each detected tamper event can be stored in the memory of the remote unit **34** for later transmission to the central site **10** for tamper event recordation, analysis, etc.

[0090] Instead of a control program consisting of software instructions executed by a microprocessor, the above described tamper event detection method can also be implemented in a dedicated electronic circuit formed of electric current and voltage sensors and logic elements which can sense the line and ground circuit voltages and currents as well as a time separation between certain voltages and currents as described above. The outputs of such a circuit can be the "tamper" signal which can be transmitted by various means, such as power line communication, Rf communication, etc., to a central site **10**. The "tamper" signal can be applied directly to the disconnect switch **70** to automatically disconnect the supply of electric power to the meter site at which a tamper event has been detected.

[**0091**] In **FIG. 18**, the remote unit **34** of the present invention is shown mounted in a ringless style watthour meter socket **400** which includes a housing **402** and a cover **404**. A raised annulus **406** is formed in the cover **404** surrounding an aperture **408** through which the sidewall of the remote unit **34** extends.

[**0092**] Inner disposed mounting brackets **410** and **412**, which are fixedly mounted on the sidewalls of the socket housing **402**, extend inward to an inner flange end **414**. The inner flange end **414** is positioned to engage one of the ground tabs **51** extending radially outward on opposite diametric sides of the housing of the remote unit **34**. This completes a ground circuit through the internal circuitry of the remote unit **34** and the earth ground connection in the meter socket **400**.

[**0093**] The tamper event signature detection method and apparatus according to the present invention takes place in the same manner as that described above.

Remote Communications

[**0094**] A first communication feature of the remote unit **34** of the present invention is uninterruptible telephone service to the customer site **18**. The remote unit **34** intercepts calls by TCP/IP modem interface circuitry that permits the remote unit **34** to answer incoming calls from the central site **40** without detection by the customer, and, additionally, a courtesy transfer feature that automatically disconnects the remote unit **34** from the telephone line and prepares the remote unit **34** for a later retry when the customer picks up the handset on the telephone during a communication between the remote unit **34** and the central site **10**

[**0095**] The uninterruptible telephone service is achieved by connecting the TCP/IP modem interface circuit in series in the telephone(s) of the use site **18**. In this manner, the remote unit **34** can recognize and intercept the ring circuit to receive or transmit data to the central site **10**.

[**0096**] Initially, the CPU **126** detects a voltage rise before a voltage peak is reached in the ring circuit. The CPU **126** is programmed to recognize the TCP/IP data format from the central site **10**. Upon detecting the TCP/IP format, the CPU **126** routes the incoming telephone call to the appropriate part of the remote unit circuitry **120** for processing and prevents the incoming call from reaching the customer's telephone thereby preventing ringing of the customer's telephone.

[**0097**] At the same time, the CPU **126** monitoring the ring circuit for a voltage drop which occurs when the customer picks up the handset of one of its telephones. Upon detecting the voltage drop, the CPU **126** immediately disconnects the telephone ring connection through the modem **130** and switches the connection to the customer's telephone thereby allowing the customer to make an outgoing call without interruption from the remote unit **34**.

[**0098**] Referring now to **FIG. 18**, there is depicted the control program sequence for operation of the remote communication interface to the remote unit **34** and telephone service to the customer site **18**.

[**0099**] As shown in **FIGS. 1 and** 8D, the customer site **18** is provided with a switch **300** which is embodied internally within a programmable modem circuit **302** shown in **FIG. 8D**. The programmable modem **302** executes a firmware control program which maintains the switch **300** in the normally closed position for normal telephone communication on the telephone network conductors to and from the customer's telephone(s) **304**.

[**0100**] As shown in **FIG.** 8B, the tip and ring conductors of the telephone network are connected to a header or jack **306** which provides input connections to the modem **302** as shown in **FIG. 8D**. The switch **300**, shown in a pictorial representation in **FIG. 1**, is normally closed thereby providing a connection of the tip and ring circuits on leads **308** to the customer's telephone **304**. This is embodied in control step **310** in **FIG. 18**.

[**0101**] The modem **302** is programmed to continuously monitor the ring voltage in step **312** to detect a voltage rise from the nominal ring voltage associated with a non-call condition. Such a voltage rise is an indication of an incoming telephone call on the ring conductor. Upon detecting a voltage rise in the ring conductor or circuit in step **314**, the modem **302** then looks at the following data signals to detect a communication signal header format indicating a data communication signal from the central site **10**. As noted above, this communication format can be the standard Internet TCP/IP communication protocol.

[**0102**] If the data communication header format is not detected in step **316** following a detection of a voltage rise in step **314**, the modem **302** maintains the switch **300** in a closed position as shown in step **318** thereby allowing the normal incoming telephone call to be connected to the customer's telephone **304**. This allows the customer to conduct a normal two-way telephone call without interference from the remote unit **34**.

[**0103**] Alternately, if the modem **302** detects the data communication header format in step **316**, the modem **302** opens the switch **300** in step **320** and establishes data communication between the central site **10** and the remote unit **34** in step **322**.

[**0104**] The modem **302** continuously monitors the bidirectional data communication in step **324** to determine when the data communication is completed or finished. Upon completion of the data communication exchange, the modem **302** will reclose the switch **300** in step **326**.

[**0105**] As shown in **FIG. 18**, continuously during the data communication sequence, the modem **302** monitors the ring voltage which has previously risen to a voltage peak during a telephone or data communication. If the customer picks up the handset of the telephone **304** during the data communication sequence, the ring voltage will drop. The modem **302**, by continuously monitoring the ring voltage in step **330** will detect the voltage drop from the voltage peak in step **332**. Immediately upon detecting a voltage drop in step **332**, the modem **302** terminates the data communication between the remote unit **34** and the central site **10** in step **334** and recloses the switch **300** in step **326** to enable the customer to complete the telephone call.

[**0106**] The remote unit CPU will store a flag indicating that data communication was interrupted and will restart or reconnect the remote unit **34** with the central site at a later time or date to complete the data communication sequence which was interrupted.

[**0107**] The same non-interruptible telephone service to the customer also applies when the processing unit **126** initiates a data communication to the central site **10**. The modem **302** will initiate a telephone call which will drive the ring voltage to a high voltage level. The processor in the modem **302** will continuously monitor the ring voltage during the data communication to and from the central site **10** to detect a voltage drop which will occur if the customer picks up the handset of the telephone **304**. In a manner similar to steps **330**, **332**, **334**, and **336** in **FIG. 18** and described above, the processor in the modem **302** will immediately terminate data communication and reclose the switch **300** to enable the customer to complete a telephone call in a normal, non-interrupted manner. The processor of the modem **302** can supply a signal or flag to the processor **126** in the automatic meter reader **34** to indicate that data communication was interrupted. The automatic meter reader **34** will, at a later program time, reinitiate data communication to the central unit to retransmit all stored power values.

[**0108**] Another communication feature is the use of global network communications via TCP/IP protocol through the modem **302**. This enables each remote customer site **18**, **19**, etc., to exchange data with the central utility site **10** over a global network, such as the Internet **21**, in digitally encoded TCP/IP protocol at random time based intervals. The communication is two-way frequency programmable as well as duration programmable to permit communication flexibility. Each reader **34** will have an Internet address for unique communication with the central site **10**.

[**0109**] The modem **302** at each customer use site as well as the modem in the central site **10** provides one way of connection to a global telecommunication network, such as the Internet or World Wide Web. It will be understood that other interfaces or connections to the global telecommunication network may also be employed, such as a direct cable connection, direct subscriber line connection, etc.

[**0110**] Another communication feature is wireless communication via a cordless or wireless optical communications port **254**. An optical receiver, preferably an infrared receiver (IR) in the form of a pair of photodiodes or LED's **257** is mounted on the circuit board **66** and has a field of view through transparent cover **57** to receive optical or infrared signals from a wireless infrared programmer, not shown. The infrared programmer can be a hand held unit, computer lap top, or computer integrated infrared wand having an IR transmitter to enable a utility service person to program, upload and download information, connect and disconnect service via the disconnect switch **70**, and instantaneously obtain customer load profile, use and service interruption data.

[**0111**] The photodiodes **257** are mounted on an integrated circuit **256** which carries connections to the ASIC circuit **255** for controlling the transmit and receive data communication through the photodiodes **257** at a clock rate established by a crystal oscillator **258** input to the ASIC circuit **255**. Input and output leads are connected between the ASIC circuit **255** and the central processor **126**. The CPU **126**, under stored program control, is capable of receiving and decoding input signals received by the photodiodes **257** as well as transmitting data in the desired format through one of the photodiodes **257** to the external programmer.

[**0112**] The unique wireless communications port simplifies the construction of the remote unit **34** since a plug connection to an external programmer, as previously required, is no longer necessary.

Out-Of-Spec Power

[**0113**] As described above, an electric utility is required to deliver electrical power, particularly the voltage of such power, within a specified range of maximum and/or minimum voltages. For example, the supplied voltage cannot exceed 120 VAC RMS or be below 114 VAC RMS.

[**0114**] **FIG. 12** depicts an exemplary voltage versus time waveform of electrical power supplied to customer site **18**. TOD1 depicts the start of an out of range voltage excursion on leg or phase one of the electric power delivered to the customer use site **18**. The remote unit **34** detects the out of range excursion of the instantaneous voltage on leg one beyond the high voltage limit, and stores the time of day (TOD1) of the beginning of the out-of-spec voltage excursion as well as of the duration **301**, or the total length of time that the voltage is out-of-spec. This time duration is converted to kilowatt hours in real time as shown in **FIG. 13** to provide an indication of the amount of out-of-spec power which was delivered to a particular use site.

[**0115**] **FIG. 12** also depicts a low voltage out-of-spec excursion. The start time TOD2 and the duration **303** of this excursion are also detected and stored in the memory of the remote unit **34** and the kilowatt hours of low "out-of-spec" voltage is determined. In this manner, a utility can determine whether or not electric power was delivered to a particular use site outside of the required range.

[**0116**] As shown in **FIG. 13**, when a upper RMS voltage limit is exceeded on any of the lines in step **305**, the CPU **126** monitors the RMS voltage for the duration of the upper limit excursion in step **306**. The CPU **126** via the EPLD **27** calculates the "out-of-spec" energy use during the upper limit excursion in step **308**. This "out-of-spec" energy use is accumulated in kilowatt hours in real time in step **310**. A similar sequence is used when the lower voltage RMS limit is exceeded in step **312**. As described above, the CPU **126** monitors the RMS voltage during the lower limit excursion in step **314** and calculates the total "out-of-spec" energy use in kilowatts below the legal voltage limit in step **316**. The out-of-spec low voltage and kilowatt hours are accumulated in real time in step **318** for transmission to the cental site **10** for billing purposes.

Power Demand Windows

[**0117**] As describe above, the CPU **126** through the voltage and current detection circuitry **120** is capable of measuring and storing the instantaneous line voltages in the calculated KwH and other electric power parameters at each sample of the A/D converter **124**.

[**0118**] The CPU **126** operates on a demand window concept wherein each 24 hour day is divided into a plurality of intervals of any predetermined duration, such as 15 minutes, 30 minutes, 45 minutes, 60 minutes, etc. In each interval, the total KwH, KAV, average phase angle, and peak voltage and current variables are calculated and stored in the memory

128. This data can be transmitted to the central site at any time upon receipt of an interrogation signal from the central site **10** or on a time sequence initiated by the remote unit **34**.

[**0119**] This interval arrangement allows peak voltage and current excursions on any of the power lines at a customer site to be detected and reported. Previously, the average of the voltage and current supplied to a particular customer site were used thereby rendering the central utility incapable of detecting any peak voltages or currents.

[**0120**] As shown in **FIG. 10**, in order to provide different real time pricing for peak utility demand periods, week days, weekends, holidays, etc., the control program of the CPU **126** is provided with a plurality of discrete schedules, such as sixteen schedules by example only. Three of the schedules are shown in **FIG. 10**, again by example. The first schedule provides for regular time (non-daylight savings time) wherein the power usage data is stored and transmitted on a weekly basis. As shown in step **400**, the weekly data storage can also be subdivided into two different day schedules, one for week days and one for weekends. Up to twenty four windows per day are provided for each day schedule. At the end of any day schedule time period, the CPU **126** automatically switches to the other day schedule.

[**0121**] Similarly, the CPU **126** is programmed to automatically switch to a daylight savings time schedule as shown in step **402**. This can also be on a weekly recurring data reporting basis. This schedule is divided into three days schedules, by example only, covering the weekdays, (Monday-Friday), a separate Saturday schedule and a separate Sunday schedule. Each day schedule is subdivided into twenty four windows per day, with the sequence automatically switching to the next sequential day schedule at the completion of the then current day schedule.

[**0122**] Finally, a holiday schedule is depicted in step **404** which is provided on a daily basis.

What is claimed is:

1. An apparatus for measuring electric power usage at a use site comprising:

a current sensor and a voltage sensor coupled to at least one phase of electric power service to a use site for sensing current and voltage, respectively, of electricity passing to the use site, the sensors producing current and voltage signals indicative of sensed current and voltage;

means for sampling current and voltage signals at a sample interval and producing sampled current and voltage values;

an anlog-to-digital converter, acting on the current and voltage sampled signals, for producing a plurality of digital signals at predetermined sample intervals indicative of the magnitude of the sampled current and voltage; and

a processor, responsive to the plurality of digital current and voltage signals, for calculating an amount of electric power passing to the use site based on all of the sensed and sampled current and voltage values.

2. The apparatus of claim 1 further comprising:

a memory, coupled to the processor, for storing the sampled current and voltage digital values and the calculated power values over predetermined time periods.

3. The apparatus of claim 1 wherein:

one current sensor and one voltage sensor are coupled to each leg of electric power service to the use site; and

the processor, response to the plurality of the digital current and voltage signals on each phase of electric power, for calculating an amount of electric power passing to the use site on each phase.

4. The apparatus of claim 1 further comprising:

the processor having a remote data transmission capability for remotely transmitting the power values.

5. A method of measuring electric power consumed at a use site comprising the steps of:

separately sensing the voltage of each incoming power conductor to the use site;

separately sensing the current on each incoming power conductor to the use site;

sampling each voltage and current at a sample rate and outputting sample voltage and current values;

converting each sample voltage and current value to a digital voltage and current magnitude value; and

calculating power consumed at the use site using the digital voltage and current magnitude values.

6. The method of claim 5 further comprising the step of:

storing each of the digital magnitude voltage and current values in a memory either after or prior to power calculation.

7. The method of claim 5 wherein the step of calculating power consumption comprises the step of:

calculating total kilowatt hours consumed at the use site from the instantaneous voltage and current digital values.

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