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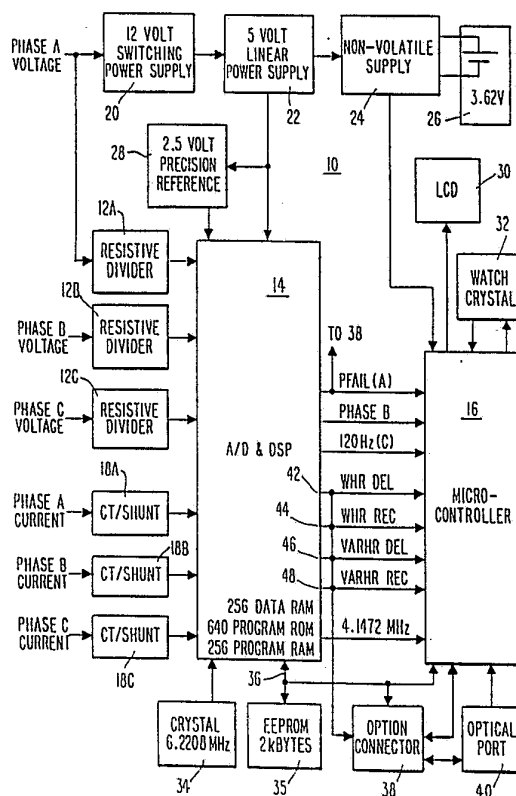
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(54) Title: METHOD AND APPARATUS FOR ELECTRONIC METER TESTING

## (57) Abstract

Methods and apparatus for electronically displaying metered electrical energy are disclosed. A first processor (14) receives voltage and current signals and determines electrical energy. The first processor (14) generates an energy signal representative of the electrical energy determination. A second processor (16), connected to said first processor, receives the energy signal and generates a display signal representative of electrical energy information. A display (30) is connected to receive the display signal and displays the electrical energy information. In a first embodiment it is preferred for the first processor (14) to determine units of electrical energy from the voltage and current signals and to generate an energy signal representative of the determination of such units and the rate at which the units are determined. In another embodiment the first processor determines and displays watt units, apparent reactive energy units and the rate at which such units are determined. The display (30) may provide energy flow direction information.



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# METHOD AND APPARATUS FOR ELECTRONIC METER TESTING

## Field of Invention:

The present invention relates generally to the field of electric utility meters. More particularly, the present invention relates to both electronic watthour meters and  
5 meters utilized to meter real and reactive energy in both the forward and reverse directions.

## Background of the Invention:

Techniques and devices for metering the various forms of electrical energy are well known. Meters, such as  
10 utility power meters, can be of two types, namely, electro-mechanical based meters whose output is generated by a rotating disk and electronic based meters whose output component is generated electronically. A hybrid meter also exists, wherein an electronic register for providing an  
15 electronically generated display of metered electrical energy has been combined, usually optically, to a rotating disk. Pulses generated by the rotating disk, for example by light reflected from a spot painted on the disk, are utilized to generate an electronic output signal.

20 It will be appreciated that electronic meters have gained considerable acceptance due to their increasing reliability and extended ambient temperature ranges of operation. Consequently, various forms of electronic based meters have been proposed which are virtually free of any  
25 moving parts. In the last ten years several meters have been proposed which include a microprocessor.

Testing of electronic meters has always been a problem. A special mode of register operation known in the industry as the test mode has been available to ease register

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testing, however, little has been done to improve overall meter testing. Electronic meters have the potential of providing faster test times, multiple metering functions and calibration of the meter through software adjustment.

5 However, implementing such functions can be expensive and complicated.

Presently, electric utility companies can test mechanical meters with a piece of test equipment which can reflect light off a metered disk to detect a painted spot as  
10 the disk rotates. An alternative form of testing mechanical meters is disclosed in U.S. Patent Number 4,600,881 - LaRocca et al. which describes the formation of a hole in the disk. A light sensitive device is placed in a fixed position on one side of the disk. As the disk rotates, and the hole passes  
15 over the light sensitive device, a pulse is provided indicating disk movement.

Since electronic meters preferably do not contain rotating disks, such simple testing techniques cannot be utilized. Consequently, a need exists for an electronic meter  
20 having a relatively simple means of testing the meter.

Summary of the Invention:

The previously described problem is resolved and other advantages are achieved in a method and apparatus for electronically displaying metered electrical energy are  
25 disclosed. A first processor receives voltage and current signals and determines electrical energy. The first processor generates an energy signal representative of the electrical energy determination. A second processor, connected to said first processor, receives the energy signal and generates a  
30 display signal representative of electrical energy information. A display is connected to receive the display signal and displays the electrical energy information. In a first embodiment it is preferred for the first processor to determine units of electrical energy from the voltage and  
35 current signals and to generate an energy signal representative of such units and the rate at which the units are determined. In this embodiment it is also preferred for

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the second processor to generate, in response to the energy signal, a disk signal representative of a rate of disk rotation equivalent to a traditional electromechanical meter and display signals are representative of the total number of units, the rate at which units are determined and the rate of equivalent disk rotation, wherein the display includes separate indicators for each display signal. In another embodiment the first processor, in concurrently determining units of electrical energy, determines watt units, apparent reactive energy units and the rate at which such units are determined, wherein the watt units, the apparent reactive energy units and the rate at which such units are determined are displayed. In still another embodiment, the first processor meters multiple types of electrical energy and generates energy signals. A first converter is provided for converting an electrical output signal to light. The second processor, connected to the first converter, generates an output signal in response to the energy signals, wherein the generation of the output signal includes the multiplexing of the energy signals into the output signal. In a still further embodiment, the display provides energy flow direction information.

It is preferred for the display to be a liquid crystal display containing a plurality of visible annunciators. It is especially preferred for the second processor to generate the display signal so that select annunciators are made visible at select times. In this fashion it is possible to provide an energy usage indicator equivalent to that of a rotating disk. It is especially desirable for the display signal to be generated so that the annunciators provide a forward and reverse energy flow indication at a rate faster than an equivalent disk rotation rate. In an especially preferred embodiment, three annunciators are located on the display for providing the above indications of electrical energy direction. In that embodiment, the annunciators are arranged in a line. The first annunciator is arrow shaped and indicative of the

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reverse direction and the third annunciator is arrow shaped and indicative of the forward direction. It is also preferred for the energy signal to be provided to the second processor at a given data rate. In such an embodiment it is especially preferred for the second processor to include a data rate display member for displaying on the display the rate at which data is being provided to the second processor. In such an embodiment, the direction and both the rate at which data is provided to the second processor and a signal mimicking the rate of disk rotation can be displayed. Indicators for each quantity are provided.

#### **Brief Description of the Drawings:**

The present invention will be better understood, and its numerous objects and advantages will become apparent to those skilled in the art by reference to the following detailed description of the invention when taken in conjunction with the following drawings, in which:

Fig. 1 is a block diagram of an electronic meter constructed in accordance with the present invention;

Figs. 2A-2E combine to provide a flow chart of the primary program utilized by the microcontroller disclosed in Fig. 1;

Fig. 3 is a front elevation of the liquid crystal display shown in Fig. 1;

Fig. 4 is a diagrammatic view of select annunciators of the liquid crystal display shown in Fig. 3;

Fig. 5 is a schematic diagram of the optical port shown in Fig. 1; and

Fig. 6 is a schematic diagram of certain command buttons contained in the meter.

#### **Detailed Description:**

A new and novel meter for metering electrical energy is shown in Fig. 1 and generally designated 10. It is noted at the outset that this meter is constructed so that the future implementation of higher level metering functions can be supported.

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Meter 10 is shown to include three resistive voltage divider networks 12A, 12B, 12C; a first processor - an ADC/DSP (analog-to-digital converter/digital signal processor) chip 14; a second processor - a microcontroller 16 which in the preferred embodiment is a Mitsubishi Model 50428 microcontroller; three current sensors 18A, 18B, 18C; a 12V switching power supply 20 that is capable of receiving inputs in the range of 96-528V; a 5V linear power supply 22; a non-volatile power supply 24 that switches to a battery 26 when 5V supply 22 is inoperative; a 2.5V precision voltage reference 28; a liquid crystal display (LCD) 30; a 32.768 kHz oscillator 32; a 6.2208 MHz oscillator 34 that provides timing signals to chip 14 and whose signal is divided by 1.5 to provide a 4.1472 MHz clock signal to microcontroller 16; a 2 kbyte EEPROM 35; a serial communications line 36; an option connector 38; and an optical communications port 40 that may be used to read the meter. The inter-relationship and specific details of each of these components is set out more fully below.

It will be appreciated that electrical energy has both voltage and current characteristics. In relation to meter 10 voltage signals are provided to resistive dividers 12A-12C and current signals are induced in a current transformer (CT) and shunted. The output of CT/shunt combinations 18A-18C is used to determine electrical energy.

First processor 14 is connected to receive the voltage and current signals provided by dividers 12A-12C and shunts 18A-18C. As will be explained in greater detail below, processor 14 converts the voltage and current signals to voltage and current digital signals, determines electrical energy from the voltage and current digital signals and generates an energy signal representative of the electrical energy determination. Processor 14 will always generate watthour delivered (Whr Del) and watthour received (Whr Rec) signals, and depending on the type of energy being metered, will generate either volt amp reactive hour delivered (VARhr Del)/volt amp reactive hour received (VARhr Rec) signals or

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volt amp hour delivered (VAhr Del)/volt amp hour received (VAhr Rec) signals. In the preferred embodiment, each transition on conductors 42-48 (each transition from logic low to logic high and vice versa) is representative of the measurement of a unit of energy. Second processor 16 is connected to first processor 14. As will be explained in greater detail below, processor 16 receives the energy signal(s) and generates an indication signal representative of the energy signal(s).

10 In relation to the preferred embodiment of meter 10, currents and voltages are sensed using conventional current transformers (CT's) and resistive voltage dividers, respectively. The appropriate multiplication is accomplished in a new integrated circuit, i.e. processor 14. Although described in greater detail in relation to Fig. 1, processor 14 is essentially a programmable digital signal processor (DSP) with built in analog to digital (A/D) converters. The converters are capable of sampling three input channels simultaneously at 2400 Hz each with a resolution of 21 bits and then the integral DSP performs various calculations on the results.

Meter 10 can be operated as either a demand meter or as a so-called time of use (TOU) meter. It will be recognized that TOU meters are becoming increasingly popular due to the greater differentiation by which electrical energy is billed. For example, electrical energy metered during peak hours will be billed differently than electrical energy billed during non-peak hours. As will be explained in greater detail below, first processor 14 determines units of electrical energy while processor 16, in the TOU mode, qualifies such energy units in relation to the time such units were determined, i.e. the season as well as the time of day.

All indicators and test features are brought out through the face of meter 10, either on LCD 30 or through optical communications port 40. Power supply 20 for the electronics is a switching power supply feeding low voltage



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linear supply 22. Such an approach allows a wide operating voltage range for meter 10.

In the preferred embodiment of the present invention, the so-called standard meter components and register electronics are for the first time all located on a single printed circuit board (not shown) defined as an electronics assembly. This electronics assembly houses power supplies 20, 22, 24 and 28, resistive dividers 12A-12C for all three phases, the shunt resistor portion of 18A-18C, oscillator 34, processor 14, processor 16, reset circuitry (not shown), EEPROM 35, oscillator 32, optical port components 40, LCD 30, and an option board interface 38. When this assembly is used for demand metering, the billing data is stored in EEPROM 35. This same assembly is used for TOU metering applications by merely utilizing battery 26 and reprogramming the configuration data in EEPROM 35.

Consider now the various components of meter 10 in greater detail. Primary current being metered is sensed using conventional current transformers. It is preferred for the current transformer portion of devices 18A-18C have tight ratio error and phase shift specifications in order to limit the factors affecting the calibration of the meter to the electronics assembly itself. Such a limitation tends to enhance the ease with which meter 10 may be programmed. The shunt resistor portion of devices 18A-18C are located on the electronics assembly described above and are preferably metal film resistors with a maximum temperature coefficient of 25 ppm/°C.

The phase voltages are brought directly to the electronic assembly where resistive dividers 12A-12C scale these inputs to processor 14. In the preferred embodiment, the electronic components are referenced to the vector sum of each line voltage for three wire delta systems and to earth ground for all other services. Resistive division is used to divide the input voltage so that a very linear voltage with minimal phase shift over a wide dynamic range can be obtained.

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This in combination with a switching power supply allows the wide voltage operating range to be implemented.

It will be appreciated that energy units are calculated primarily from multiplication of voltage and current. The specific formulae utilized in the preferred embodiment, are described in greater detail in co-pending application, Attorneys Docket No. B900250/ABME-0008, filed concurrently herewith and incorporated herein by reference. However, for purposes of Fig. 1, such formulae are performed in processor 14.

The M37428 microcontroller 16 is a 6502 (a traditional 8 bit microprocessor) derivative with an expanded instruction set for bit test and manipulation. This microcontroller includes substantial functionality including internal LCD drivers (128 quadraplexed segments), 8 kbytes of ROM, 384 bytes of RAM, a full duplex hardware UART, 5 timers, dual clock inputs (32.768 kHz and up to 8 MHz), and a low power operating mode.

During normal operation, processor 16 receives the 4.1472 MHz clock from processor 14 as described above. Such a clock signal translates to a 1.0368 MHz cycle time. Upon power fail, processor 16 shifts to the 32.768 KHz crystal oscillator 32. This allows low power operation with a cycle time of 16.384 kHz. During a power failure, processor 16 keeps track of time by counting seconds and rippling the time forward. Once processor 16 has rippled the time forward, a WIT instruction is executed which places the unit in a mode where only the 32.768 kHz oscillator and the timers are operational. While in this mode a timer is setup to "wake up" processor 16 every 32,768 cycles to count a second.

While power supply 20 can be any known power supply for providing the required direct current power, a preferred form of power supply 20 is described in detail in copending application ABB-0010, filed concurrently herewith and which is incorporated herein by reference.

Consider now the main operation of processor 16 in relation to Figs. 2A-2E and Fig. 3. At step 1000 a reset

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signal is provided to microcontroller 16. A reset cycle occurs whenever the voltage level  $V_{dd}$  rises through approximately 2.8 volts. Such a condition occurs when the meter is powered up.

5           At step 1002, microcontroller 16 performs an initialize operation, wherein the stack pointer is initialized, the internal ram is initialized, the type of liquid crystal display is entered into the display driver portion of microcontroller 16 and timers which requires  
10 initialization at power up are initialized. It will be noted that the operation of step 1002 does not need to be performed for each power failure occurrence. Following a power failure, microcontroller 16 at step 1004 returns to the main program at the point indicated when the power returns.

15           Upon initial power up or the return of power after a power failure, microcontroller 16 performs a restore function. At step 1006, microcontroller 16 disables pulses transmitted by processor 14. These pulses are disabled by providing the appropriate signal restore bit. The presence  
20 of this bit indicates that a restore operation is occurring and that pulses generated during that time should be ignored. Having set the signal restore bit, microcontroller 16 determines at step 1008 whether the power fail signal is present. If the power fail signal is present, microcontroller  
25 16 jumps to the power fail routine at 1010. In the power fail routine, the output ports of microcontroller 16 are written low unless the restore bit has not been set. If the restore bit has not been set, data in the microcontroller 16 is written to memory.

30           If the power fail signal is not present, microcontroller 16 displays segments at step 1012. At this time, the segments of the display are illuminated using the phase A potential. It will be recalled that phase A potential is provided to microcontroller 16 from processor 14. At 1014,  
35 the UART port and other ports are initialized at 1016, the power fail interrupts are enabled such that if a falling edge is sensed from output A of processor 14, an interrupt will

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occur indicating power failure. It will be recalled that processor 14 compares the reference voltage VREF to a divided voltage generated by the power supply 20. Whenever the power supply voltage falls below the reference voltage a power fail  
5 condition is occurring.

At step 1018, the downloading of the metering integrated circuit is performed. It will be appreciated that certain tasks performed by microcontroller 16 are time dependent. Such tasks will require a timer interrupt when the  
10 time for performing such tasks has arrived.

At 1022, the self-test subroutines are performed. Although no particular self-tests subroutine is necessary in order to practice the present invention, such subroutines can include a check to determine if proper display data is  
15 present. It is noted that data is stored in relation to class designation and that a value is assigned to each class such that the sum of the class values equals a specified number. If any display data is missing, the condition of the class values for data which is present will not equal the specified  
20 sum and an error message will be displayed. Similarly, microcontroller 16 compares the clock signal generated by processor 14 with the clock signal generated by watch crystal 32 in order to determine whether the appropriate relationship exists.

25 Having completed the self-test subroutines, the ram is re-initialized at 1024. In this re-initialization, certain load constants are cleared from memory. At 1026, various items are scheduled. For example, the display update is scheduled so that as soon as the restore routine is completed,  
30 data is retrieved and the display is updated. Similarly, optical communications are scheduled wherein microcontroller 16 determines whether any device is present at optical port desired to communicate. Finally, at 1028 a signal is given indicating that the restore routine has been completed. Such  
35 a signal can include disabling the signal restore bit. Upon such an occurrence, pulses previously disabled will now be

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considered valid. Microcontroller 16 now moves into the main routine.

At 1030, microcontroller 16 calls the time of day processing routine. In this routine, microcontroller 16 looks at the one second bit of its internal and determines whether the clock needs to be changed. For example, at the beginning and end of Daylight Savings Time, the clock is moved forward and back one hour, respectively. In addition, the time of day processing routine sets the minute change flags and date change flags. As will be appreciated hereinafter, such flags are periodically checked and processes occur if such flags are present.

It will be noted that there are two real time interrupts scheduled in microcontroller 16 which are not shown in Fig. 2, namely the roll minute interrupt and the day interrupt. At the beginning of every minute, certain minute tasks occur. Similarly, at the beginning of every day, certain day tasks occur. Since such tasks are not necessary to the practice of the presently claimed invention, no further details need be provided.

At 1032, microcontroller 16 determines whether a self-reprogram routine is scheduled. If the self-reprogram routine is scheduled, such routine is called at 1034. The self-reprogram typically programs in new utility rates which are stored in advance. Since new rates have been incorporated, it will be necessary to also restart the display. After operation of the self-reprogram routine, microcontroller 16 returns to the main program. If it is determined at 1032 that the self-reprogram routine is not scheduled, microcontroller 16 determines at 1036 whether any day boundary tasks are scheduled. Such a determination is made by determining the time and day and searching to see whether any day tasks are scheduled for that day. If day tasks are scheduled, such tasks are called at 1038. If no day tasks are scheduled, microcontroller 16 next determines at 1040 whether any minute boundary tasks have been scheduled. It will be understood that since time of use switch points

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occur at minute boundaries, for example, switching from one use period to another, it will be necessary to change data storage locations at such a point. If minute tasks are scheduled, such tasks are called at 1042. If minute boundary  
5 tasks have not been scheduled, microcontroller 16 determines at 1044 whether any self-test have been scheduled. The self-tests are typically scheduled to occur on the day boundary. As indicated previously, such self-tests can include checking the accumulative display data class value to determine whether  
10 the sum is equal to a prescribed value. If self-tests are scheduled, such tests are called at 1046. If no self-tests are scheduled, microcontroller 16 determines at 1048 whether any season change billing data copy is scheduled. It will be appreciated that as season changes billing data changes.  
15 Consequently, it will be necessary for microcontroller 16 to store energy metered for one season and begin accumulating energy metered for the following season. If season change billing data copy is scheduled, such routine is called at 1050. If no season change routine is scheduled,  
20 microcontroller 16 determines at 1052 whether the self-redemand reset has been scheduled. If the self-redemand reset is scheduled, such routine is called at 1054. This routine requires microcontroller 16 to in effect read itself and store the read value in memory. The self-redemand is then reset.  
25 If self-redemand reset has not been scheduled, microcontroller 16 determines at 1056 whether a season change demand reset has been scheduled. If a season change demand reset is scheduled, such a routine is called at 1058. In such a routine, microcontroller 16 reads itself and resets the demand.  
30 At 1060, microcontroller 16 determines whether button sampling has been scheduled. Button sampling will occur every eight milliseconds. Reference is made to Fig. 6 for a more detailed description of an arrangement of buttons to be positioned on the face of meter 10. Consequently, if  
35 an eight millisecond period has passed, microcontroller 16 will determine that button sampling is scheduled and the button sampling routine will be called at 1062. If button

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sampling is not scheduled, microcontroller 16 determines at 1064 whether a display update has been scheduled. This routine causes a new quantity to be displayed on LCD 30. As determined by the soft switch settings, display updates are  
5 scheduled generally for every three-six seconds. If the display is updated more frequently, it may not be possible to read the display accurately. If the display update has been scheduled, the display update routine is called at 1066. If a display update has not been scheduled, microcontroller 16  
10 determines at 1068 whether an annunciator flash is scheduled. It will be recalled that certain annunciators on the display are made to flash. Such flashing typically occurs every half second. If an annunciator flash is scheduled, such a routine is called at 1070. It is noted in the preferred embodiment  
15 that a directional annunciator will flash at the same rate at which energy determination pulses are transmitted from processor 14 to processor 16. Another novel feature of the invention is that other annunciators (not indicative of energy direction) will flash at a rate approximately equal to the  
20 rate of disk rotation in an electro-mechanical meter used in a similar application.

If no annunciator flash is scheduled, microcontroller 16 determines at 1072 whether optical communication has been scheduled. It will be recalled that  
25 every half second microcontroller 16 determines whether any signal has been generated at optical port. If a signal has been generated indicating that optical communications is desired, the optical communication routine will be scheduled. If the optical communication routine is scheduled, such  
30 routine is called at 1074. This routine causes microcontroller 16 to sample optical port 40 for communications activity. If no optical routine is scheduled, microcontroller 16 determines at 1076 whether processor 14 is signaling an error. If processor 14 is signaling an error,  
35 microcontroller 16 at 1078 disables the pulse detection, calls the download routine and after performance of that routine, re-enables the pulse detection. If processor 14 is not

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signaling any error, microcontroller 16 determines at 1080 whether the download program is scheduled. If the download program is scheduled, the main routine returns to 1078 and thereafter back to the main program.

5           If the download program has not been scheduled or after the pulse detect has been re-enabled, microcontroller 16 determines at 1082 whether a warmstart is in progress. If a warmstart is in progress, the power fail interrupts are disabled at 1084. The pulse computation routine is called  
10 after which the power fail interrupts are re-enabled. It will be noted that in the warmstart data is zeroed out in order to provide a fresh start for the meter. Consequently, the pulse computation routine performs the necessary calculations for energy previously metered in places that computation in the  
15 appropriate point in memory. If a warmstart is not in progress, microcontroller 16 at 1084 updates the remote relays. Typically, the remote relays are contained on a board other than the electronics assembly board.

          All data that is considered non-volatile for meter  
20 10, is stored in a 2 kbytes EEPROM 35. This includes configuration data (including the data for memory 76 and memory 80), total kWh, maximum and cumulative demands (Rate A demands in TOU), historic TOU data, cumulative number of demand resets, cumulative number of power outages and the  
25 cumulative number of data altering communications. The present billing period TOU data is stored in the RAM contained within processor 16. As long as the microcontroller 16 has adequate power, the RAM contents and real time are maintained and the microcontroller 16 will not be reset (even in a demand  
30 register).

          LCD 30 allows viewing of the billing and other metering data and statuses. Temperature compensation for LCD 30 is provided in the electronics. Even with this compensation, the meter's operating temperature range and the  
35 LCD's 5 volt fluid limits LCD 30 to being triplexed. Hence, the maximum number of segments supported in this design is 96. The display response time will also slow noticeably at



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temperatures below -30 degrees celsius. For a more complete description of the generation of a display signal for display 30, reference is made to co-pending application, Attorneys Docket No. B900250/ABB-0008, filed concurrently herewith and  
5 incorporated herein by reference.

The 96 available LCD segments, shown in Fig. 3, are used as follows. Six digits (.375 high) are used for data display and three smaller digits (.25 high) for numeric identifiers. In addition to the numeric identifiers, there  
10 are seventeen alpha annunciators that are used for identification. These are: PREV, SEAS, RATE, A, B, C, D, CONT, CUM, RESETS, MAX, TOTAL, KV /, \, -\, R, and h. The last five annunciators can be combined to produce: KW, KWh, KVA, KVAh, KVAR, or KVARh, as shown. Three potential  
15 indicators are provided on the LCD and appear as light bulbs. These indicators operate individually and are on continuously when the corresponding phase's potential is greater than 57.6 Vrms, and flash when the potential falls below 38.4 Vrms. "TEST" "ALT", and "EOI" annunciators are provided to give an  
20 indication of when the unit is in test mode, alternate scroll mode, or an end of a demand interval has occurred. Six (6) pulse indicators 200-210 are also provided on LCD 30 for watt-hours and an alternate quantity (VA-hours or VAR-hours).

Pulse indicators 200-210 are configured as two sets  
25 of three, one set for indicating watts and another set for indicating VARhours. Each set has a left arrow, a solid square, and a right arrow. During any test, one of the arrows will be made to blink at the rate microcontroller 16 receives pulses from processor 14 while the square will blink at a  
30 lower rate representative of a disk rotation rate and in a fashion which mimics disk rotation. It will be noted that signals necessary to flash indicators 200-210 are generated by processor 16 in energy pulse interrupt routines. The left arrow 200 blinks when energy is received from the metered site  
35 and the right arrow 204 blinks when energy is delivered to the metered site. The solid square 202 blinks at a Kh rate equivalent to an electro-mechanical meter of the same form,

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test amperes, and test voltage. Square 202 blinks regardless of the direction of energy flow. The rate at which square 202 blinks can be generated by dividing the rate at which pulses are provided to processor 16. Consequently, testing can occur  
5 at traditional rates (indicative of disk rotation) or can occur at faster rates, thereby reducing test time. Indicators 206-210 operate in a similar fashion, except in relation to apparent reactive energy flow.

These pulse indicators can be detected through the  
10 meter cover using the reflective assemblies (such as the Skan-A-Matic C42100) of existing test equipment. As indicated above, the second set of three indicators indicate apparent reactive energy flow and have the tips of arrows 206 and 210 open so that they will not be confused with the watt-hour  
15 indicators.

Referring to Fig. 4, it will be seen that annunciators 200-204 are positioned along a line, wherein annunciator 202 is positioned between annunciators 200 and 204. As time progresses, processor 16 generates display  
20 signals so that, when energy is flowing in the forward direction, annunciator 204 always flashes. However, annunciators 200 and 202 can be made to flash selectively, to create the impression that energy is flowing from left to right. When energy is flowing in the reverse direction, the  
25 reverse is true. Annunciator 200 flashes continuously, and annunciators 202 and 204 flash selectively to mimic energy flowing from right to left.

Meter 10 interfaces to the outside world via liquid crystal display 30, optical port 40, or option connector 38.  
30 It is envisioned that most utility customers will interface to LCD 30 for testing of the meter, some utilities will desire an infrared LED, such as LED 112, to test the meter calibration. Traditionally, electronic meters have provided a single light emitting diode (LED) in addition to an optical  
35 port to output a watthour pulse. Such designs add cost, decrease reliability and limit test capabilities. The present invention overcomes these limitations by multiplexing the

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various metering function output signals and pulse rates over optical port 40 alone. Meter 10 echoes the kh value watthour test output on optical port 40 anytime the meter has been manually placed in the test mode (the TEST command button in Fig. 5 has been pressed) or alternate scroll mode (the ALT command button in Fig. 5 has been pressed). While in these manually initiated modes, communication into processor 16 through optical port 40 is prevented. It is noted that in the preferred embodiment, the ALT button is capable of being enabled without removal of the meter cover (not shown). To this end a small movable shaft (not shown) is provided in the meter cover so that when the shaft is moved the ALT component is enabled. Consequently, removal of the meter cover is not necessary in order to test the meter.

Referring now to Fig. 5, optical port 40 and reset circuitry 108 are shown in greater detail. Optical port 40 provides electronic access to metering information. The transmitter and receiver (transistors 110 and 112) are 850 nanometer infrared components and are contained in the electronics assembly (as opposed to being mounted in the cover). Transistors 110 and led 112 are tied to UART include within microcontroller 16 and the communications rate (9600 baud) is limited by the response time of the optical components. The optical port can also be disabled from the UART (as described below), allowing the UART to be used for other future communications without concern about ambient light. During test mode, optical port 40 will echo the watthour pulses received by the microcontroller over the transmitting LED 112 to conform to traditional testing practices without the necessity of an additional LED.

Meter 10 also provides the ability to be placed in the test mode and exit from the test mode via an optical port function, preferably with a data command. When in a test mode initiated via optical port 40, the meter will echo metering pulses as defined by the command transmitted on the optical port transmitter. This allows the multiplexing of metering functions or pulse rates over a single LED. In the preferred

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embodiment, such a multiplexing scheme is a time based multiplexing operation. The meter will listen for further communications commands. Additional commands can change the rate or measured quantity of the test output over optical port 40. The meter will "ACK" any command sent while it is in the test mode and it will "ACK" the exit test mode command. While in an optically initiated test mode, commands other than those mentioned above are processed normally. Because there is the possibility of an echoed pulse confusing the programmer-readers receiver, a command to stop the pulse echo may be desired so communications can proceed uninterrupted. If left in test mode, the usual test mode time out of three demand intervals applies.

The data command identified above is called "Enter Test Mode" and is followed by 1 data byte defined below. The command is acknowledged by processor 16 the same as other communications commands. The command places meter 10 into the standard test mode. While in this mode, communications inter-command timeouts do not apply. Hence, the communications session does not end unless a terminate session command is transmitted or test mode is terminated by any of the normal ways of exiting test mode (pressing the test button, power failure, etc.), including the no activity timeout. Display 30 cycles through the normal test mode display sequence (see the main program at 1044, 1060 and 1064) and button presses perform their normal test mode functions. Transmitting this command multiple times causes the test mode, and its associated timeout counter, to restart after each transmission.

The data byte defines what input pulse line(s) to processor 16 should be multiplexed and echoed over optical port 40. Multiple lines can be set to perform a totalizing function. The definition of each bit in the data byte is as follows:

bit0 = alternate test pulses,  
bit1 = alternate delivered pulses,  
bit2 = alternate received pulses,

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bit3 = whr test pulses,  
bit4 = whr delivered pulses,  
bit5 = whr received pulses,  
bits 6 and 7 are unused.

5           If no bits are set, the meter stops echoing pulses.  
This can be used to allow other communications commands to be  
sent without fear of data collision with the output pulses.  
While in this mode, other communications commands can be  
accepted. The test data can be read, the meter can be  
10 reprogrammed, the billing data can be reset or a warmstart can  
be initiated. Since the Total KWH and Maximum Demand  
information is stored to EEPROM 35, test data is being  
processed in memory areas and functions such as demand reset  
and warmstart will operate on the Test Mode data and not the  
15 actual billing data. Any subsequent "Enter Test Mode Command"  
resets the test mode data just as a manual demand reset would  
in the test mode.

          This command also provides the utility with a way  
to enter the test mode without having to remove the meter  
20 cover. This will be beneficial to some utilities.

          While the invention has been described and  
illustrated with reference to specific embodiments, those  
skilled in the art will recognize that modification and  
variations may be made without departing from the principles  
25 of the invention as described herein above and set forth in  
the following claims.

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Claims

What is claimed is:

1. Apparatus for electronically displaying metered electrical energy, said electrical energy comprising voltage and current characteristics, wherein voltage and current signals representative of said voltage and current characteristics are provided, said apparatus comprising:

a first processor, connected to receive said voltage and current signals, for determining units of electrical energy from said voltage and current signals and for generating an energy signal representative of said units and the rate at which said units are determined;

a second processor for receiving said energy signal, for generating in response to said energy signal a disk signal representative of a rate of equivalent disk rotation and for generating display signals in response to said energy signal, said display signals being representative of said units, said rate at which said units are determined and said rate of equivalent disk rotation; and

a display, connected to receive said display signal, for displaying said units, said rate at which said units are determined and said rate of disk rotation, concurrently.

2. The apparatus of claim 1, wherein said energy signal is further representative of the direction of energy flow, said display signal being further representative of said direction, said display comprising a direction indicator for indicating the direction of energy flow in response to said display signal.

3. The apparatus of claim 2, wherein said annunciators are sized and located on said display so that said rate at which said units are determined, said rate of disk rotation and the direction of energy flow can be concurrently monitored.

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4. The apparatus of claim 1, wherein said display comprises a liquid crystal display, wherein said display comprises a plurality of visible annunciators.

5       5. The apparatus of claim 4, wherein said second processor generates said display signal whereby select annunciators are made visible at select times.

6. The apparatus of claim 5, wherein certain of said annunciators are arrow shaped.

10       7. The apparatus of claim 6, wherein said annunciators are selectively made visible such that rotation of a disk is mimicked.

8. The apparatus of claim 7, wherein one of said annunciators is made visible at the rate at which said units are determined.

15       9. The apparatus of claim 8, wherein said second processor generates said disk signal representative of a rate of disk rotation in relation to said rate at which said units are determined.

20       10. The apparatus of claim 9, wherein said second processor generates said disk signal by dividing the rate at which said units are determined by a desired value.

25       11. The apparatus of claim 9, wherein said plurality of annunciators comprises first, second and third annunciators, wherein said first, second and third annunciators are positioned along a line, wherein said second annunciator is positioned between said first and third annunciators.

30       12. The apparatus of claim 11, wherein said first and third annunciators are arrow shaped, wherein first and third annunciators can be made visible at said rate at which said units are determined and can be made visible at said rate of disk rotation and wherein said second annunciator can be made visible at said rate of disk rotation.

35       13. The apparatus of claim 1, further comprising a light converter for converting light to an electrical signal, said light converter connected to said second processor.

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14. The apparatus of claim 13, wherein said second processor is capable of generating and receiving communication signals through said light converter, wherein said second processor is capable of echoing portions of said energy signal  
5 through said light converter.

15. Apparatus for electronically displaying metered electrical energy, said electrical energy comprising voltage and current characteristics, wherein voltage and current signals representative of said voltage and current  
10 characteristics are provided, said apparatus comprising:

a first processor, connected to receive said voltage and current signals, for concurrently determining units of electrical energy from said voltage and current signals, wherein said units of electrical energy comprise watt units  
15 and apparent reactive energy units and for generating an energy signal representative of said units and the rate at which said units are determined;

a second processor for receiving said energy signal, for generating display signals in response to said energy  
20 signal, said display signals being representative of said watt units and said apparent reactive energy units and said rate at which said units are determined; and

a display, connected to receive said display signals, for displaying said watt units, said apparent  
25 reactive energy units and said rate at which said units are determined, whereby multiple meter functions are concurrently displayed.

16. The apparatus of claim 15, wherein said display comprises a liquid crystal display, said display comprises a  
30 plurality of visible annunciators, wherein certain of said annunciators are arrow shaped.

17. The apparatus of claim 16, wherein said second processor generates said display signal whereby select annunciators are made visible at select times.



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18. The apparatus of claim 15, wherein said second processor generates in response to said energy signal a disk signal representative of a rate of disk rotation in relation to said rate at which said units are determined

5 19. The apparatus of claim 18, wherein said second processor generates said disk signal by dividing the rate at which said units are determined by a desired value.

20. The apparatus of claim 19, wherein said plurality of annunciators comprises first and second sets of  
10 first, second and third annunciators, wherein set of said first, second and third annunciators are positioned along a line, wherein said second annunciator is positioned between said first and third annunciators.

21. The apparatus of claim 20, wherein said first  
15 and third annunciators in each of said first and second sets are arrow shaped, wherein first and third annunciators can be made visible at said rate at which said units are determined and can be made visible at said rate of disk rotation and wherein said second annunciator can be made visible at said  
20 rate of disk rotation.

22. The apparatus of claim 21, wherein said first and third annunciators of said first set have a solid arrow shape and wherein said first and third annunciators of said second set have an open arrow shape.

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23. Apparatus for electronically displaying metered electrical energy, said electrical energy comprising voltage and current characteristics, wherein voltage and current signals representative of said voltage and current characteristics are provided, said apparatus comprising:

a first processor, connected to receive said voltage and current signals, for metering multiple types of electrical energy from said voltage and current signals and for generating energy signals representative of said multiple types of electrical energy;

a first converter for converting an electrical output signal to light; and

a second processor, connected to said first converter, for receiving said energy signals, for generating said output signal in response to said energy signals, wherein the generation of said output signal comprises multiplexing said energy signals into said output signal.

24. The apparatus of claim 23, wherein said first converter comprises a light emitting diode.

25. The apparatus of claim 23, wherein said second processor generates said output signal by time multiplexing said energy signals, whereby energy signals resulting from different meter functions can be transmitted from said first converter.

26. The apparatus of claim 23, wherein said second processor multiplexes only certain of said energy signals in response to a control signal.

27. The apparatus of claim 23, further comprising a second converter for converting light into an electrical signal

28. The apparatus of claim 27, wherein those portions output by said second processor are determined by a communication signal transmitted to said second processor through said second converter.

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29. The apparatus of claim 23, wherein said first processor generates said energy signals so that said energy signals are further representative of the rate at which each of said multiple types of electrical energy are metered.

5           30. The apparatus of claim 29, wherein said second processor generates said output signal by time multiplexing said energy signals, whereby the rate at which each of said multiple types of electrical energy are metered can be transmitted from said first converter.

10           31. The apparatus of claim 30, wherein said second processor generates, in response to said energy signals, disk signals representative of a rate of disk rotation in relation to said rate at which each of said multiple types of electrical energy are metered.

15           32. A method for electronically displaying metered electrical energy, said electrical energy comprising voltage and current characteristics, wherein voltage and current signals representative of said voltage and current characteristics are provided, said method comprising the steps  
20 of:

determining units of electrical energy from said voltage and current signals and generating an energy signal representative of the determination of said units and the rate at which said units are determined;

25           generating in response to said energy signal a disk signal representative of a rate of disk rotation in relation to said rate at which said units are determined;

generating a display signal in response to said energy signal and said disk signal, said display signal being  
30 representative of said units, said rate at which said units are determined and said rate of disk rotation; and

displaying said units, said rate at which said units are determined and said rate of disk rotation, concurrently.

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33. A method for electronically displaying metered electrical energy, said electrical energy comprising voltage and current characteristics, wherein voltage and current signals representative of said voltage and current characteristics are provided, said method comprising the steps of:

concurrently determining units of electrical energy from said voltage and current signals, wherein said units of electrical energy comprise watt units and apparent reactive energy units and generating an energy signal representative of the determination of said units and the rate at which said units are determined;

generating a display signal in response to said energy signal, said display signal being representative of said watt units and said apparent reactive energy units and said rate at which said units are determined; and

displaying said watt units, said apparent reactive energy units and said rate at which said units are determined, whereby multiple meter functions are concurrently displayed.

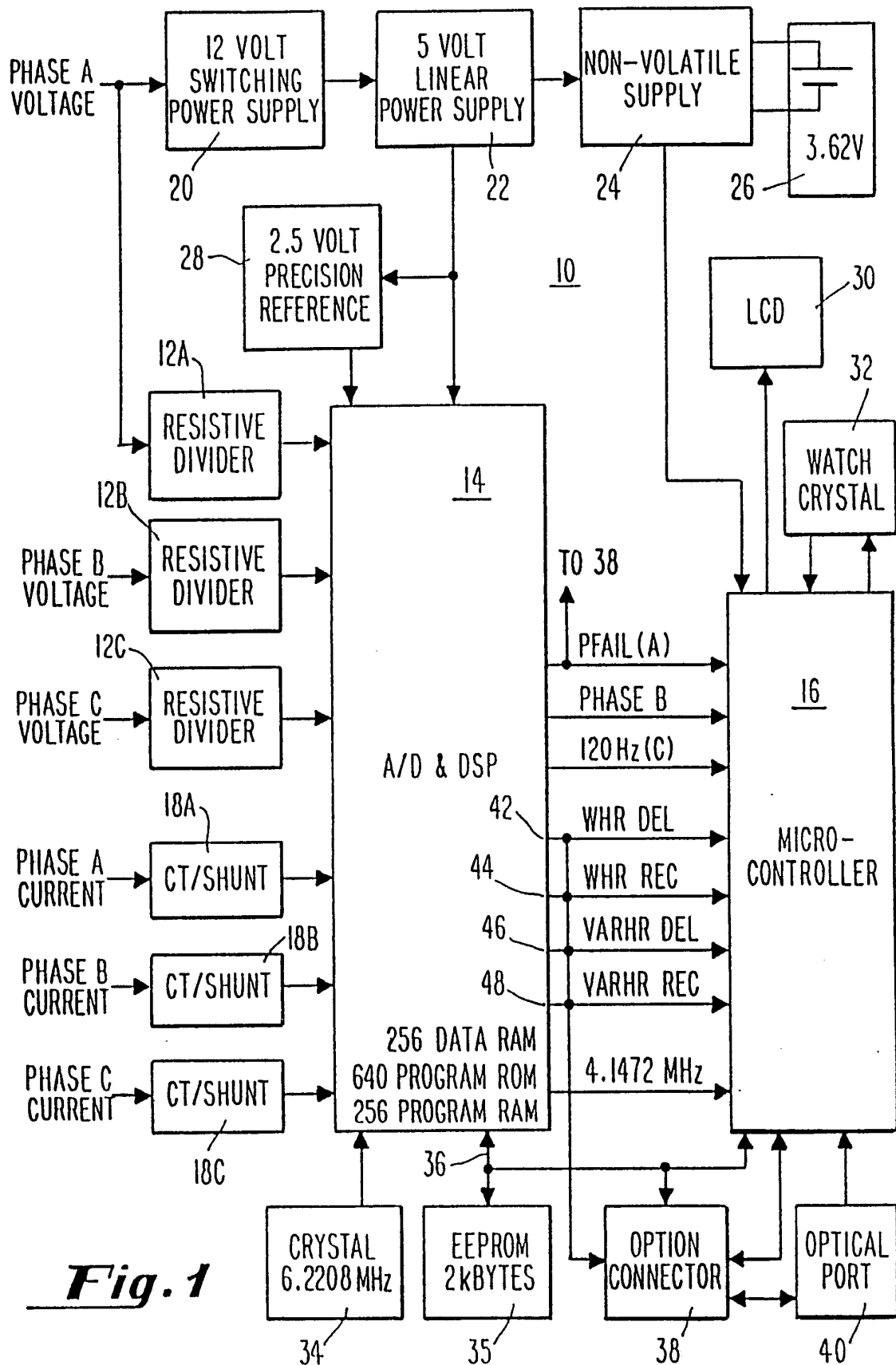
34. A method for electronically displaying metered electrical energy, said electrical energy comprising voltage and current characteristics, wherein voltage and current signals representative of said voltage and current characteristics are provided, said method comprising the steps of:

metering multiple types of electrical energy from said voltage and current signals and for generating energy signals representative of said multiple types of electrical energy;

generating said output signal in response to said energy signals, wherein the generation of said output signal comprises multiplexing said energy signals into said output signal; and

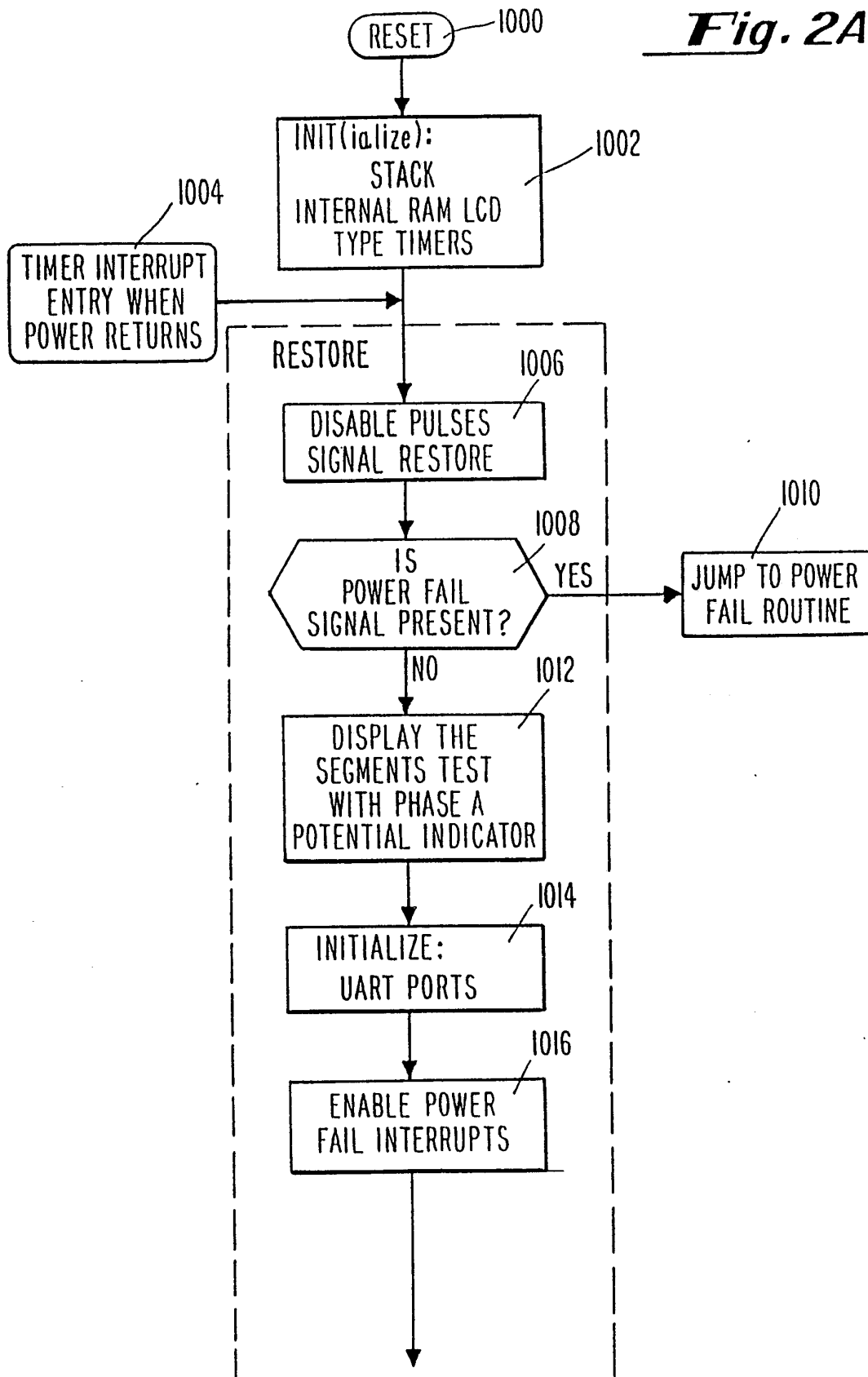
converting said output signal to light.

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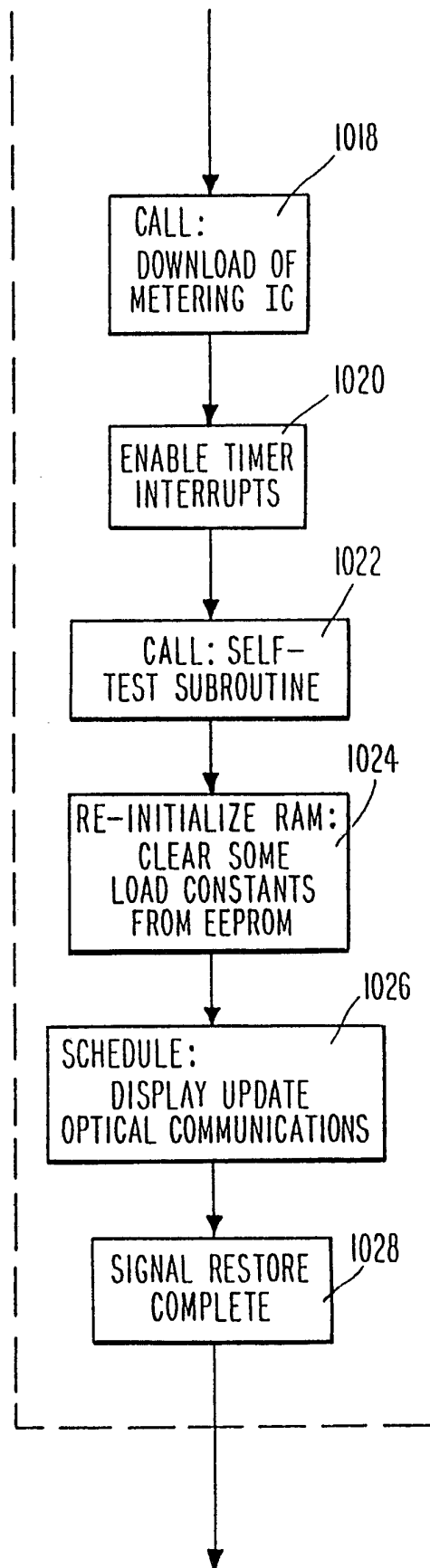


2/8

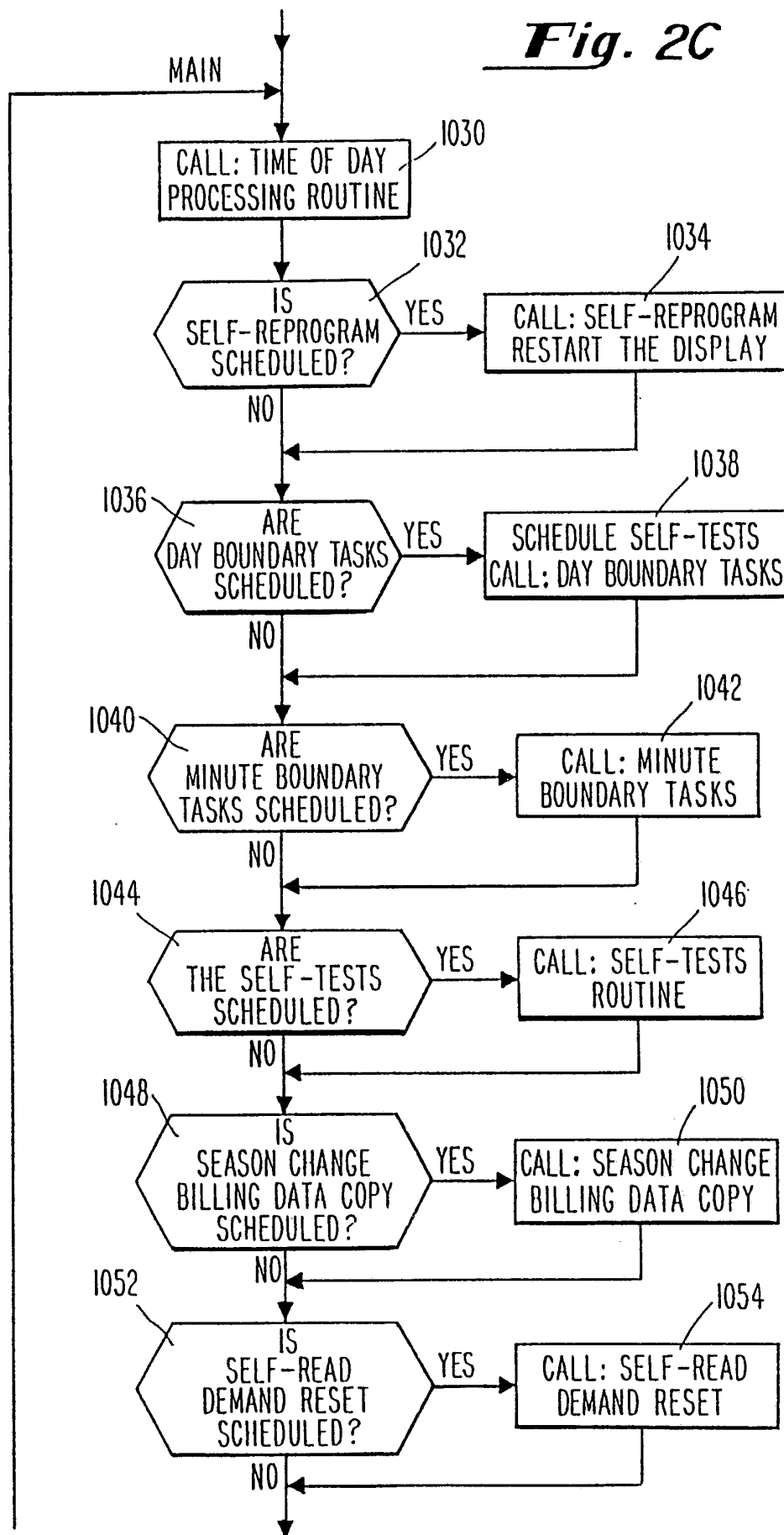
## MICROCONTROLLER FIRMWARE: MAIN LOOP

**Fig. 2A**

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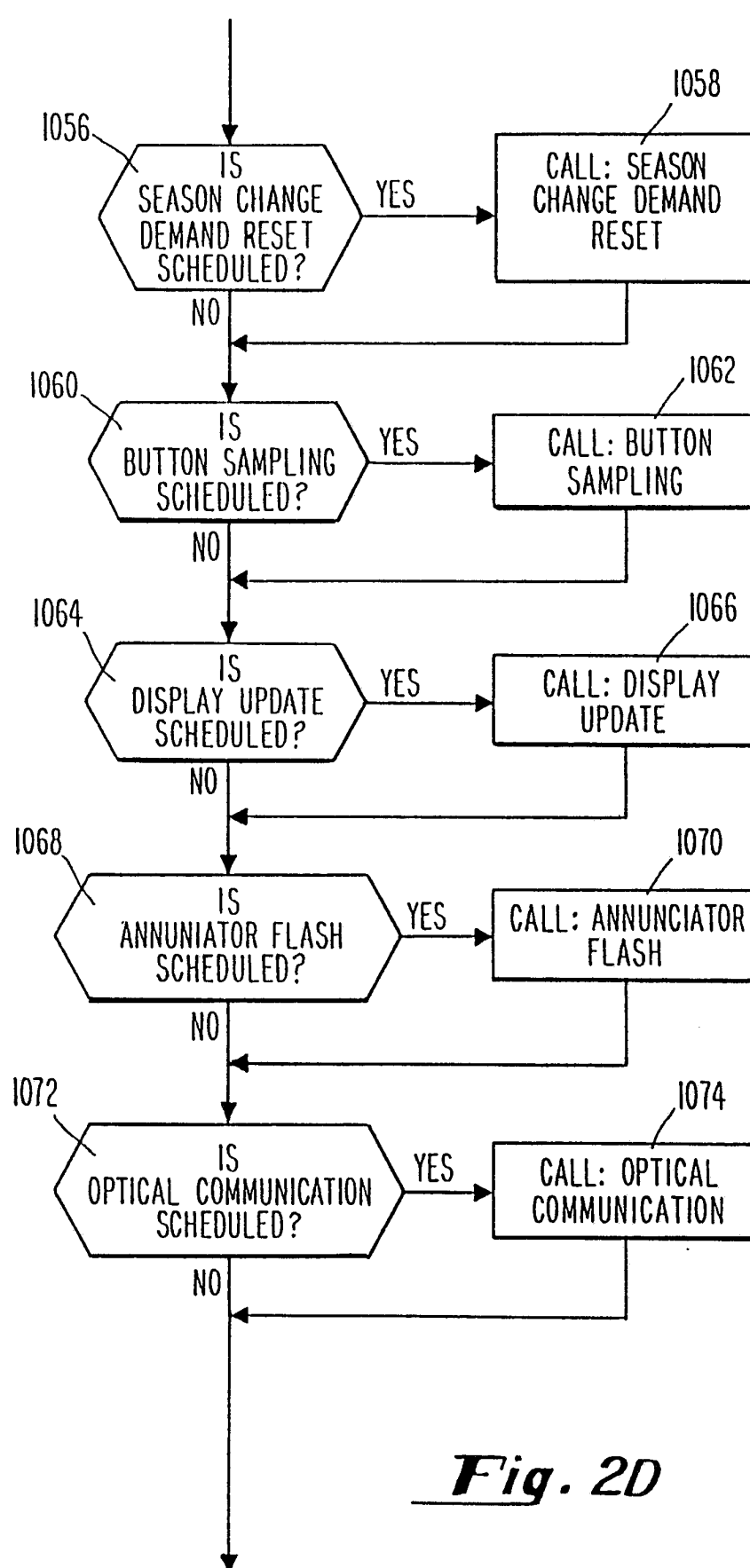
*Fig. 2B*

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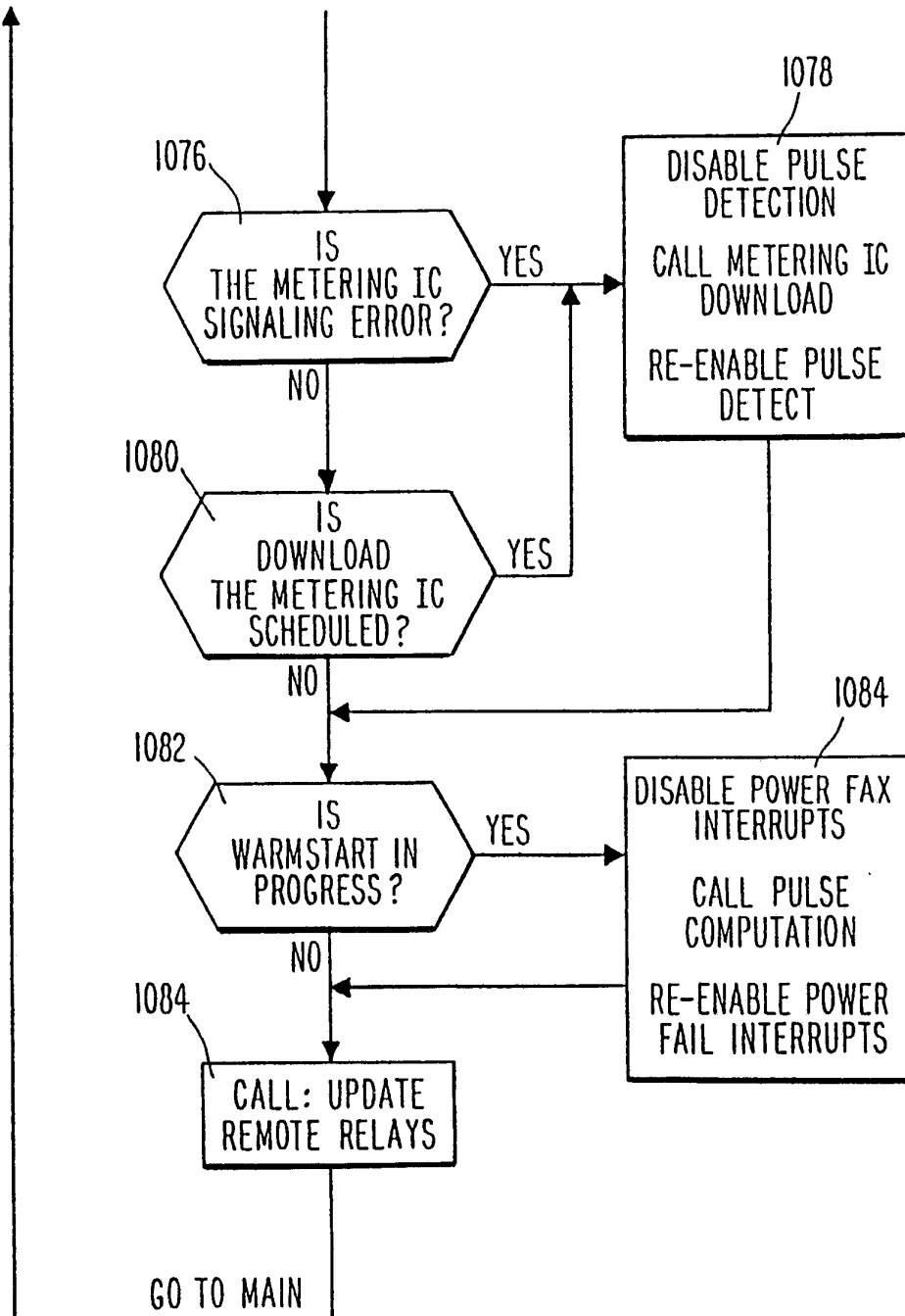
*Fig. 2C*



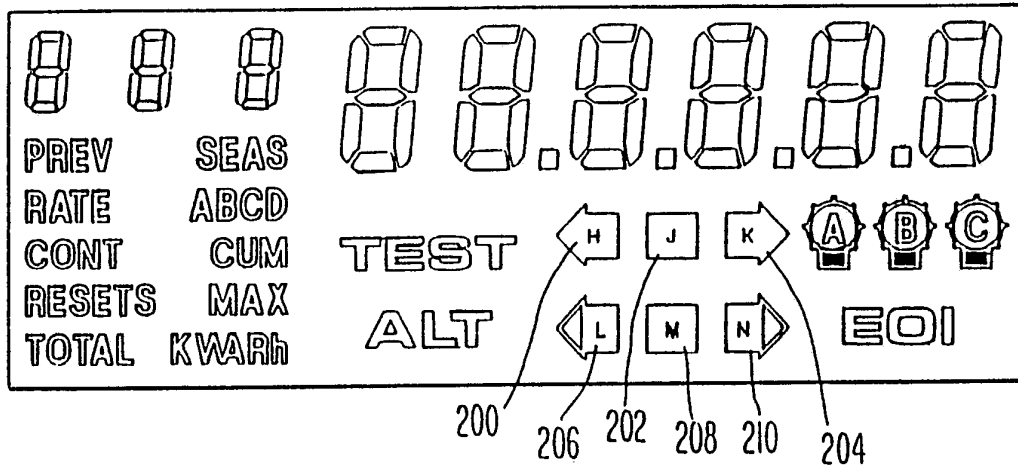
5/8

***Fig. 2D***

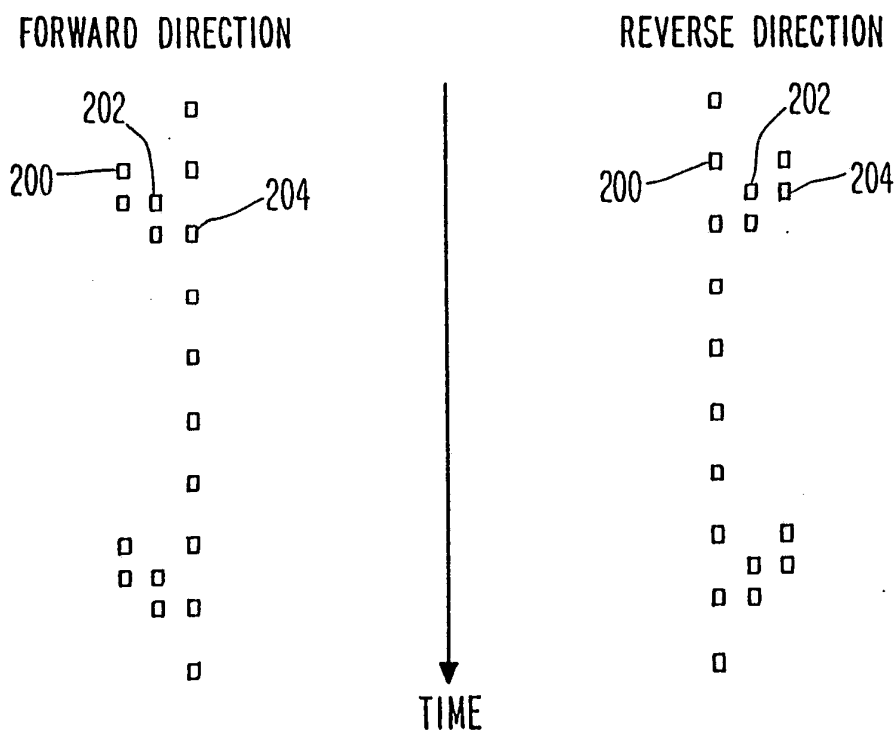
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Fig. 2E

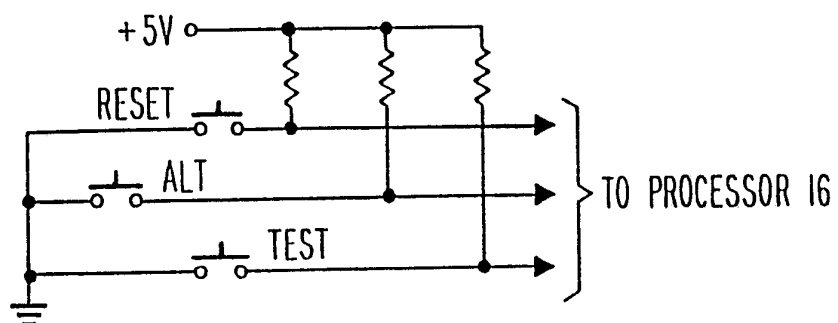
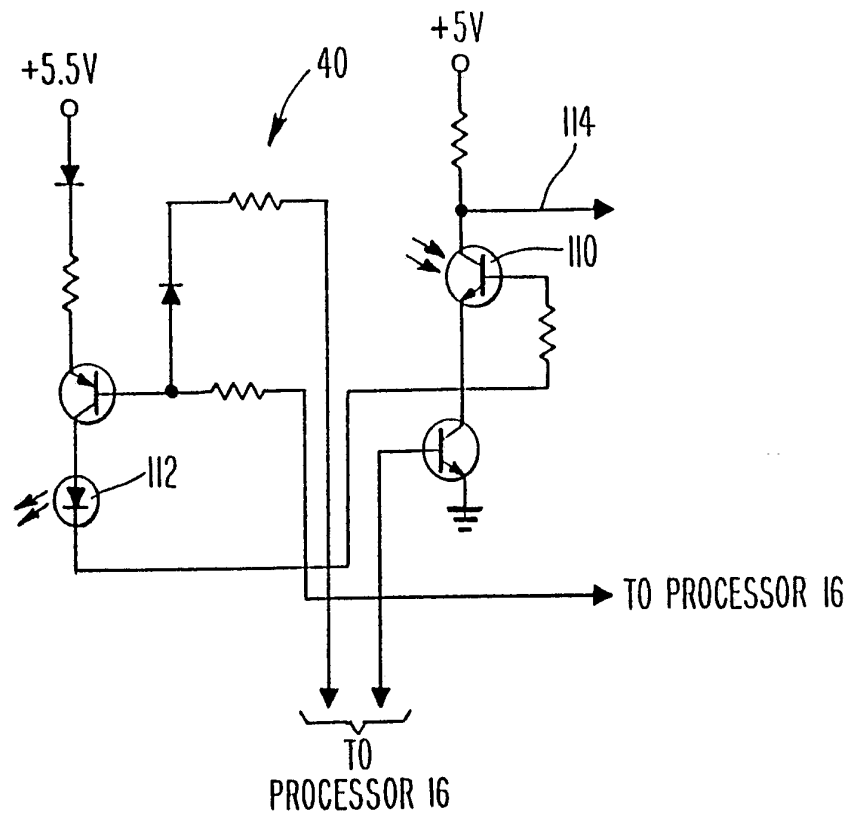
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***Fig. 3***



***Fig. 4***



## INTERNATIONAL SEARCH REPORT

PCT/US92/09632

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) :G01R 13/00, 13/14

US CL :324/142,141; 340/753,870.29

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 364/483,340/752,754,755,792,870.28; 324/103R,107,117R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<u>X</u> Y	US, A, 4,881,027 (JODER ET AL.) 14 November 1989, See Fig. 1; col. 3, line 53-col. 4, line 66.	<u>32</u> 1-22,29-31, & 33
Y	US, A, 4,884,021 (HAMMOND ET AL.) 28 November 1989, See col. 7, lines 57-68; col. 12, lines 3-68.	1-31 & 34
Y	US, A, 4,686,460 (STEVENS ET AL.) 11 August 1987, See col. 4, line 5-col. 5, line 50.	2-12, 15-22, & 33
Y	US, A, 4,509,128 (COPPOLA ET AL.) 02 April 1985, See col. 7, lines 46-48.	23,24,26, & 34
Y	US, A, 4,335,445 (NERCESSIAN) 15 June 1982, See col. 6, lines 1-4.	23-27,29- 31 & 34

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

05 JANUARY 1993

Date of mailing of the international search report

16 FEB 1993

 Name and mailing address of the ISA/US  
 Commissioner of Patents and Trademarks  
 Box PCT  
 Washington, D.C. 20231

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**INTERNATIONAL SEARCH REPORT**International application No.  
PCT/US92/09632**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,283,772 (JOHNSTON) 11 August 1981, See col. 8, lines 36-42.	1-34
A	US, A, 4,853,620 (HALDER ET AL.) 01 August 1989, See col. 3, lines 13-31.	1-34
A	US, A, 4,713,608 (CATILLER ET AL.) 15 December 1987, See col. 5, lines 18-30.	1-34

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US92/09632

## B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

- APS: 1.(340/ 870.28-870.29/CCLST) AND (MULTIPLEX?) AND (ENERGY OR WATT? OR VAR)  
2. (324/141/CCLS+ OR 324/142/142/CCLST) AND [LIGHT AND MULTIPLEX?] OR  
{APPARENT(W)POWER OR ENERGY OR WATT?}  
3. (324/141/CCLST OR 324/142/CCLST) AND [(DISK? OR DISC) AND POLARITY]