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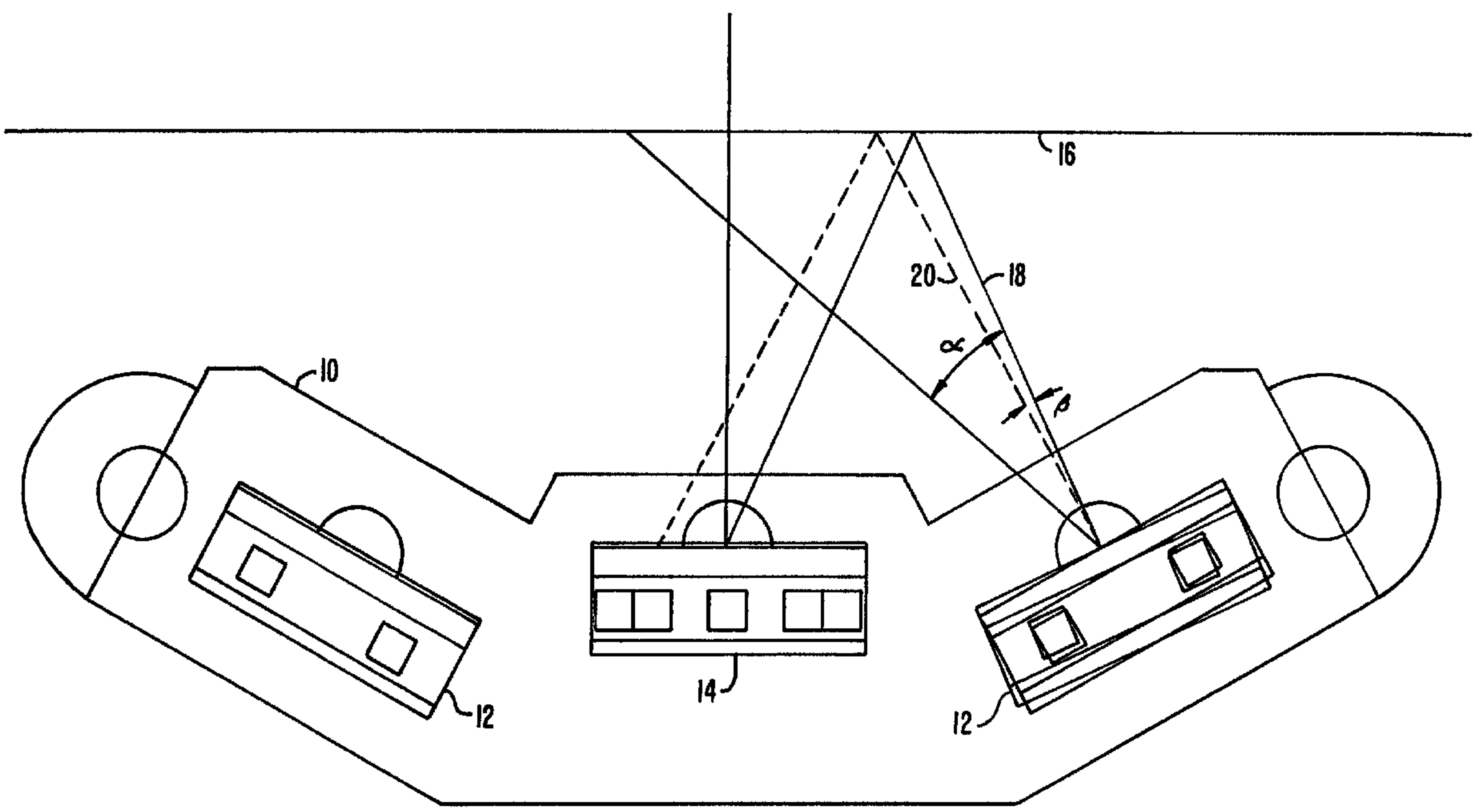

(57) Abrégé/Abstract:
Apparatus recording information about angular motion of a rotatable disk (16). The disk (16) has regions with differing properties with respect to electromagnetic energy. The apparatus includes first means (12) emitting a first sequence of electromagnetic energy pulses in a first direction toward the disk. The first emitting means are adjacent a first side of the disk. The apparatus also includes second means (12) emitting a second sequence of electromagnetic energy pulses is a second direction toward the disk, the second emitting means also being adjacent the first side of the disk. The first and second sequences of electromagnetic energy pulses reflect from the first side of the disk in different areas, the areas being separated in the direction of rotation of the disk. Photosensitive means (14) receive the electromagnetic energy pulses from both the first and second emitting means at a single point and generate a signal in response to the received electromagnetic energy pulses. A controller (U3) processes the signal to determine the number of rotations of the disk, and the direction of rotation of the disk.

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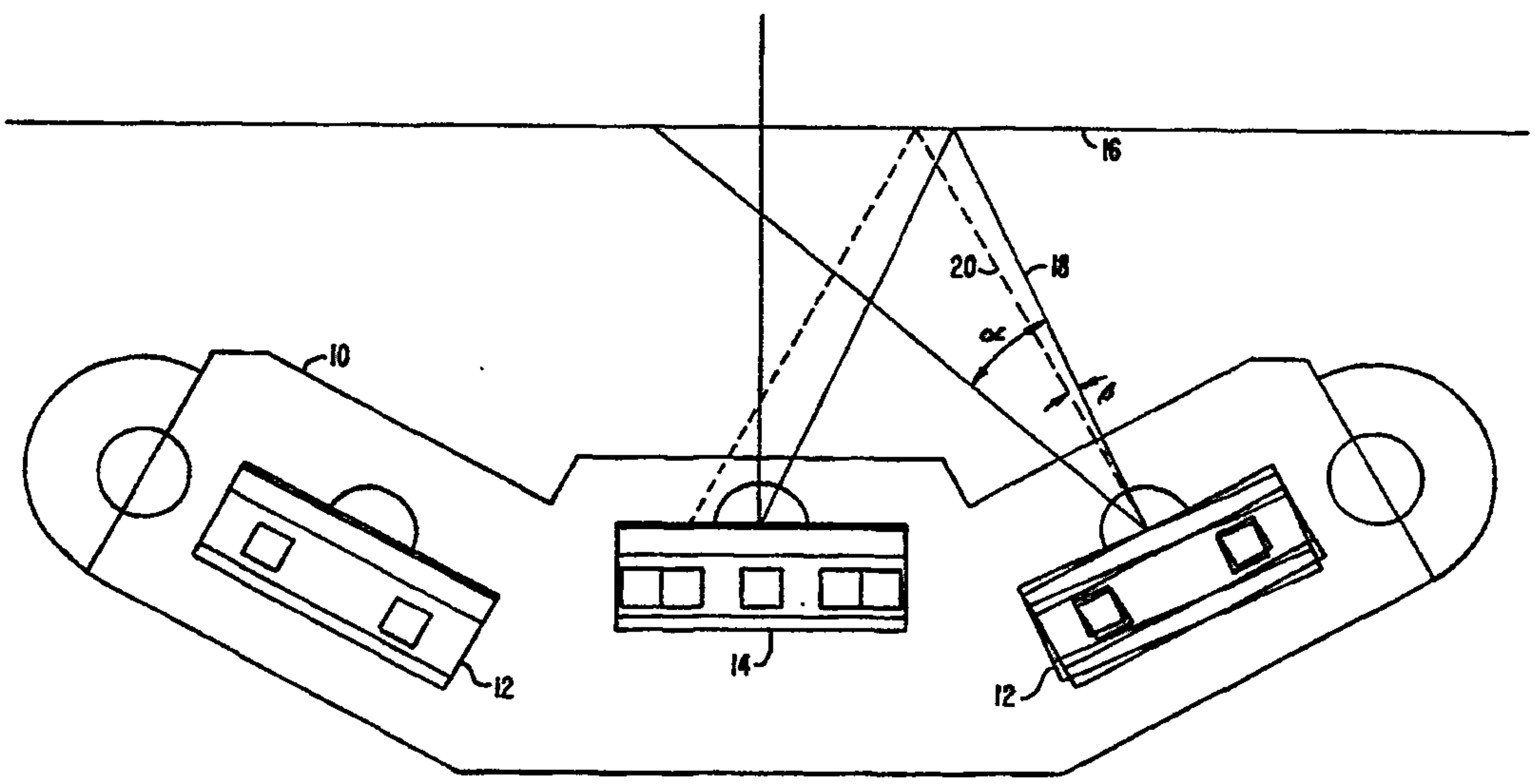

(57) Abstract

Apparatus recording information about angular motion of a rotatable disk (16). The disk (16) has regions with differing properties with respect to electromagnetic energy. The apparatus includes first means (12) emitting a first sequence of electromagnetic energy pulses in a first direction toward the disk. The first emitting means are adjacent a first side of the disk. The apparatus also includes second means (12) emitting a second sequence of electromagnetic energy pulses in a second direction toward the disk, the second emitting means also being adjacent the first side of the disk. The first and second sequences of electromagnetic energy pulses reflect from the first side of the disk in different areas, the areas being separated in the direction of rotation of the disk. Photosensitive means (14) receive the electromagnetic energy pulses from both the first and second emitting means at a single point and generate a signal in response to the received electromagnetic energy pulses. A controller (U3) processes the signal to determine the number of rotations of the disk, and the direction of rotation of the disk.

PULSE INITIATOR DEVICE

BACKGROUND OF THE INVENTION

This invention relates to a device and method for monitoring the angular motion of a rotatable disk, and specifically a device and apparatus for monitoring and deriving power consumption information from the rotatable disk in a standard watt-hour meter.

As is well known in the art, one type of widely used watt-hour meter employs a horizontally disposed rotatable disk which rotates in response to the consumption of electrical energy. Also included in such watt-hour meters are a plurality of dials which electro-mechanically record the number of rotations of the rotatable disk, thereby keeping track of power consumption. In the past, various alternatives to electro-mechanically recording power consumption have been employed to increase the accuracy of the measurement as well as to provide remote sensing capabilities. For example, systems have been designed which use electromagnetic energy (EM) to monitor rotations of the disk by means of the detection of a non-reflective mark on the surface of the disk, or the transmission of the energy through an aperture in the disk. The EM source is usually mounted on the watt-hour meter structure so that its emitted energy impinges upon the surface of the disk. A sensor is positioned so that when the mark, or aperture, passes the EM source, the sensor detects the resulting drop-off in reflected energy, or the transmission of energy through the disk. Some sort of processing circuitry then derives and accumulates energy consumption data from the resulting signal. This data may then be communicated to remote locations by various techniques, including encoded transmission over power lines, or infrared transmission. Examples of such systems are described in U.S. Patent No. 4,399,510 to Hicks, U.S. Patent No. 4,301,508 to Anderson, et al., and U.S. Patent No. 4,350,980 to Ward.

Some systems have been developed which have the ability to determine not only the number of rotations, but also the direction of rotation of the disk. This capability is desirable for the detection of unauthorized access to and tampering with power monitoring equipment. Two such systems are described in U.S. Patent No.

4,678,907 to Lipski et al., and U.S. Patent No. 4,321,531 to Marshall. Each of these systems employs two photosensitive sensors and associated circuitry to determine the direction of rotation. While such systems have proven to be effective in some applications, the present invention has the advantage of achieving the same capability using only one sensor.

SUMMARY OF THE INVENTION

An apparatus for recording information about the angular motion of a rotatable disk disposed in a first structure is provided. The disk has regions with differing properties with respect to electromagnetic energy. The apparatus includes first means for emitting a first sequence of electromagnetic energy pulses in a first direction toward the disk. The first emitting means are mounted on the first structure adjacent a first side of the disk. The apparatus also includes second means for emitting a second sequence of electromagnetic energy pulses in a second direction toward the disk, the second emitting means also being mounted on the first structure adjacent the first side of the disk. The first and second directions are such that the first and second sequences of electromagnetic energy pulses reflect from the first side of the disk in different areas, the areas being separated in the direction of rotation of the disk. Photosensitive means are mounted on the first structure so that they can receive the electromagnetic energy pulses from both the first and second emitting means at a single point. The photosensitive means generate a signal in response to the received electromagnetic energy pulses. A controller coupled to the photosensitive means then processes the signal to determine the number of rotations of the disk, and the direction of rotation of the disk.

In one embodiment of the invention, the first and second emitting means comprise infrared emitting diodes (IREDs), and the photosensitive means comprise a photo diode. Regions on the first side of the disk have differing reflective properties with respect to infrared energy. The controller is coupled to the IREDs causing them to emit infrared pulses in a particular sequence. The pulses reflect from the first side of the disk and are received by the photo diode which generates a signal, the characteristics of which depend upon the regions from which the infrared pulses are reflected. In a particular embodiment, the first structure comprises a standard watt-hour meter.

It should be understood that the invention can be configured not only in a reflective mode as described above, but also in a transmissive mode. In such an embodiment, the first and second emitting means would be disposed on the opposite side of the rotatable disk from the photosensitive means, the first and second emitting means being spatially separated in the direction of rotation of the disk. Instead of a non-reflective, radiation-absorbing region, the disk would have at least one aperture through which the photosensitive means could sense pulses of electromagnetic energy from the first and second emitting means.

A method for deriving information about the rotation of a rotatable disk using an embodiment of the above-described apparatus is also provided. Electromagnetic energy from the first emitting means is reflected from the first side of the disk and received by the photosensitive means at a first point. A first signal pulse corresponding to the received electromagnetic energy is then generated. Electromagnetic energy from the second emitting means is then reflected off of the disk and received by the photosensitive means at the same point. A second signal pulse corresponding to the received electromagnetic energy is then generated. These steps are repeated, generating a pulse train comprising the first and second signal pulses. The pulse train is then processed to determine the number of rotations of the disk, and the direction of rotation of the disk. For a particular application, the pulse train repetition period and pulse durations are constrained in accordance with the sampling theorem Nyquist rate, depending on the maximum rate of rotation of the disk and its reflective (or transmissive) features.

A further understanding of the nature and advantages of the present invention may be realized by reference to the remaining portions of the specification and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 depicts an assembly designed according to the present invention adapted for mounting in a standard watt-hour meter.

Figs. 2a-2g show various views of the assembly of Fig. 1.

Fig. 3 is a schematic diagram of a particular embodiment of the present invention.

Fig. 4 is a state diagram illustrating the operation of a particular embodiment of the present invention.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Fig. 1 depicts an assembly designed according to a particular embodiment of the present invention. A housing 10 is adapted for mounting in a standard watt-hour meter. Two infrared emitting diodes (IREDs) 12 are mounted in housing 10 on either side of a photo diode 14. IREDs 12 are mounted so that the infrared energy emitted from each IRED reflects off of the surface of a rotatable disk 16 and is received by photo diode 14. The infrared energy from each IRED 12 reflects off of slightly separated areas on the bottom surface of disk 16. The areas are separated in the direction of rotation of the disk.

The spread of the infrared "beam" from each IRED is roughly 25° from the center of the beam as shown by angle α in the figure. Fig. 1 also illustrates the effect that a slight misalignment of the right IRED has on the angle of incidence of the reflected infrared energy. Solid line 18 represents the center axis of the infrared energy beam for the preferred mounting angle, and dashed line 20 represents the center axis of the beam for a 4° rotation in the mounting angle (angle β). The preferred mounting angle sets up an angle of approximately 28.8° between the center axis of the infrared energy beam and the vertical. As is shown in the figure, the center axis of the reflected energy deviates only slightly from the center of photo diode 14, even with a substantial misalignment. Thus, this configuration ensures that even if either, or both, of the IREDs are misaligned, infrared energy of sufficient intensity will reach the photo diode to enable proper operation. Figs. 2a-2g show various views of housing 10 of Fig. 1.

Fig. 3 is a schematic diagram of a particular embodiment of the present invention. The anodes of IREDs 12 are pulsed by NPN driver transistors Q1 and Q2 under the firmware timing control of a microcontroller U3. The network comprising resistors R12, R18, R19, and thermistor RT1 determines the drive current level for IREDs 12, with RT1 providing compensation for the variation of IRED output irradiance with temperature. The photo diode 14 receives input in the form of infrared energy reflected from a rotatable disk (not shown). Output current pulses from photo diode 14 are then conditioned by a two stage ac-coupled operational amplifier circuit 22 with a decision threshold set by a voltage divider comprising R27, R35, and R29. The resulting output is received by a comparator embedded in microcontroller U3. The comparator output is a logic high for high amplitude pulses which exceed the decision threshold, and a logic low for low amplitude pulses which do not exceed the decision threshold.

Firmware in microcontroller U3 implements a periodic sequence of drive pulses and state machine logic for processing, tracking, and decoding the power consumption information contained in the reflected infrared energy. The firmware determines disk rotational direction and accumulates the result as encoded registration of accumulated energy consumption, matching the external watt-hour meter's electro-mechanical register.

The operation of the above-described embodiment is as follows. IREDs 12 are periodically pulsed in sequence. Sequence timing is determined by the microcontroller's crystal oscillator 13 which is stable with respect to initial tolerance, temperature, and aging to within $\pm$ 500 parts per million. The resulting range of periods is 976.1 μs to 977.1 μs, with a preferred period of 976.6 μs. During each period, the left IRED is turned on first for a first interval. Both IREDs are then held off for a second interval. Then the right IRED is turned on for a third interval. The duration of the first interval is 17.28 μs to 17.30 μs, with a preferred duration of 17.29 μs. The duration of the second interval is 0 to 1.018 μs, with a preferred duration of 1.017 μs. The duration of the third interval is 19.32 μs to 19.34 μs, with a preferred duration of 19.33 μs. Finally, both IREDs are held off for the remainder of the period, the duration of this interval being 939.0 μs when the other intervals are the preferred durations. The output of photo diode 14 follows this pulse sequence yielding high amplitude output current pulses when receiving reflected energy from the shiny metal disk surface; and receiving much lower amplitude pulses when receiving reflected energy from a specially installed stripe of infrared absorbing paint along a particular radius on the disk's bottom surface. As the disk rotates during normal power consumption (i.e., in a counterclockwise direction), the stripe's leading edge passes through the left IRED's reflecting area, and then through the right IRED's reflecting area. As disk rotation continues, the stripe's trailing edge clears the left IRED, and then the right IRED, so that their radiated energy once again reflects off of the shinier metal disk surface to the photo diode. Due to the input sequence of pulses, the pulse train which appears at the output of the photo diode has well defined characteristics which are recognized and processed by the controller. Under exceptional conditions (e.g., tampering), the meter disk rotates in the reverse or clockwise direction. In such cases, the radiation-absorbing stripe passes over the right IRED first. The characteristics of the resulting pulse train are distinctly different from those of the pulse train produced under normal conditions. Upon the occurrence of such an event, the controller is able to determine the direction of rotation of the disk due to the predictable variations in the photo diode signal.

It should be understood that the invention can be configured not only in a reflective mode as described above, but also in a transmissive mode. In such an embodiment, the two IREDs would be disposed on the opposite side of the rotatable disk from the photosensitive device, the IREDs being spatially separated in the direction of rotation of the disk. Instead of a radiation-absorbing stripe, the disk would have at least one aperture through which the photo diode could sense the infrared pulses from the IREDs. In a transmissive embodiment, the firmware would be suitably altered to recognize and process infrared pulses in a complementary manner with respect to the reflective embodiment described above. The present invention may also be adapted to recognize fractional rotations of the disk using multiple radiation-absorbing stripes or transmissive apertures.

It should also be understood that the interval durations discussed above represent only one embodiment of the invention. Interval durations can vary widely for different applications. For example, not only can the interval between the pulsing of the two IREDs be of zero duration, but these pulses can theoretically overlap. As long as the sampling rate is chosen so that the microcontroller can determine from which IRED a particular pulse is coming, it is not necessary to insert a positive interval between the two pulses. The maximum sampling rate is limited by such factors as the rise and fall times of the optoelectronic devices, amplifier settling times, and the amount of microcontroller time available.

The durations of the IRED pulses can also deviate substantially from the specific values of the above-described embodiment. Factors to be considered when determining interval durations for a specific application are the size of the features of the rotatable disk, the reflective (or transmissive) properties of the disk, and the maximum rotational rate of the disk. As mentioned above, the pulse train repetition period and pulse durations are constrained in accordance with the sampling theorem Nyquist rate, depending on these factors.

Correct operation of the photo diode over the range of meter types, electronic component parameter variation, and operating conditions (e.g., temperature, mounting alignment, and the 20 to 30 year operational life), depends on the proper choice of the decision threshold level. The threshold level is chosen so that it lies between pulse amplitudes estimated for the worst case (i.e., least reflective) shiny metal disk surface and the worst case (i.e., most reflective) infrared-absorbing stripe.

Fig. 4 is a state diagram illustrating the operation of the embodiment of Fig. 3 according to the firmware. When power is supplied to the invention, the circuitry comes up initially in state 5. State transitions occur according to the events L and R. The event L represents that the left IRED has been energized and a photo diode output pulse which exceeds the decision threshold was registered. The event R represents an equivalent event for the right IRED. L\R represents the occurrence of both events L and R, while a bar over this symbol represents the non-occurrence of the event. State changes do not occur where there is no change in the output pulse train.

The firmware code represented by the state diagram of Fig. 4 is included in Appendix A.

While the invention has been particularly shown and described with reference to a specific embodiment thereof, it will be understood by those skilled in the art that the foregoing and other changes in the form and details may be made therein without departing from the spirit or scope of the invention.

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Appendix A

Firmware Listing

```
                                      .FORM
323                             ;************************************************************
323                             ;       P I   S t a t e   M a c h i n e
323                             ;
323                             ;        Sample current PI input, flag PI sensor tamper
323                             ;        If input has changed, execute the state machine.
323                             ;************************************************************
323 0203 9FD2                         LD      B,#PORTLP         ;Reg b => PI Sensor
323 0205 72                           IFBIT   PISENSE,[B]       ;PI Sensor already on?
323 0206 BD0B6C                       RBIT    PITMP,ESTAT       ;Yes - Flag it for tamper report
323 0209 9FD0                         LD      B,#PORTLD         ;Reg b => PI IREDs on this port
323 020B 7D                           SBIT    IREDL,[B]         ;Turn on left IRED and wait
323 020C 64                           CLR     A                 ;Reg a will accumulate result
323 020D A0                           RC                        ;Carry will temp store result
323 020E 9FD2                         LD      B,#PORTLP         ;Reg b => PI Sensor
323 0210 B8                           NOP                       ;Wait 10µsec for valid output
323 0211 B8                           NOP
323 0212 B8                           NOP
323 0213 B8                           NOP
323 0214 72                           IFBIT   PISENS,[B]        ;Read result
323 0215 8A                           INC     A                 ; and save it
323 0216 72                           IFBIT   PISENS,[B]        ;Read result
323 0217 8A                           INC     A                 ; and save it
323 0218 72                           IFBIT   PISENS,[B]        ;Read result
323 0219 8A                           INC     A                 ; and save it
323 021A 9FD0                         LD      B,#PORTLD
323 021C 6D                           RBIT    IREDL,[B]         ;Turn off left IRED
323 021D 7C                           SBIT    IREDR,[B]         ;Turn on right IRED and wait
323 021E 9301                         IFGT    A,#1              ;0-1 => off, 2-3 => on
323 0220 A1                           SC                        ;Carry has left IRED result
323 0221 64                           CLR     A                 ;Reg a will have right IRED result
323 0222 9FD2                         LD      B,#PORTLP
323 0224 B8                           NOP                       ;Wait 10µsec for valid output
323 0225 B8                           NOP
323 0226 B8                           NOP
323 0227 B8                           NOP
323 0228 72                           IFBIT   PISENS,[B]        ;Read result
323 0229 8A                           INC     A                 ; and save it
323 022A 72                           IFBIT   PISENS,[B]        ;Read result
323 022B 8A                           INC     A                 ; and save it
323 022C 72                           IFBIT   PISENS,[B]        ;Read result
323 022D 8A                           INC     A                 ; and save it
323 022E 9FD0                         LD      B,#PORTLD
323 0230 6C                           RBIT    IREDR,[B]         ;Turn off right IRED
323                                   .FORM
323 0231 9301                         IFGT    A,#1              ;0-1 => off, 2-3 => on
323 0233 02                           JP      L10
323 0234 64                                   CLR     A
323 0235 02                                   JP      L20
323                             L10:
```

```
                                     LD      A,#1
323                        L20:                               ;Reg a has new sample
323 0238 A8                          RLC     A                ;Reg a has new sample
323 0239 9600                        XOR     A,#TYPEPI*(PIL!PIR) ;Set correct logic sense
323 023B 9F3C                        LD      B,#INPI          ;Reg b => Saved PI Input
323 023D 82                          IFEQ    A,[B]            ;Is new reading a change?
323 023E 22A1                        JMP     PIDONE           ;  No - Skip further service
323 0240 A6                          X       A,[B]            ;  Yes - Store new value
323 0241 9847                        LD      A,#L(TBPI)       ;Base of table of PI States
323 0243 BD3D84                      ADD     A,PISTAT         ;Compute table index
323 0246 A5                          JID                      ;Branch to correct state
323                        TBPI:
323 0247 86                          .BYTE   L(CCW1)          ;State 0:  PI CCW1
323 0248 69                          .BYTE   L(CW1)           ;State 1:  PI CW1
323 0249 8E                          .BYTE   L(CCW2)          ;State 2:  PI CCW2
323 024A 71                          .BYTE   L(CW2)           ;State 3:  PI CW2
323 024B 55                          .BYTE   L(PIC)           ;State 4:  PI Center
323 024C 4D                          .BYTE   L(PIX)           ;State 5:  PI Initial
323                        PIX:                               ;State 5:  Initial PI machine state
323 024D                             TSTST   4,(PIL!PIR)
323 024D 9803                        LD      A,#(PIL!PIR)
323 024F 82                          IFEQ    A,[B]
323 0250 BC3D04                      LD      PISTAT,#4
323 0253 22A1                        JMP     PIDONE
323                        PIC:                               ;State 4:  Center PI Machine State
323 0255                             TSTST   0,PIR
323 0255 9802                        LD      A,#PIR
323 0257 82                          IFEQ    A,[B]
323 0258 BC3D00                      LD      PISTAT,#0
323 025B                             TSTST   1,PIL
323 025B 9801                        LD      A,#PIL
323 025D 82                          IFEQ    A,[B]
323 025E BC3D01                      LD      PISTAT,#1
323 0261                             TSTST   5,0
323 0261 9800                        LD      A,#0
323 0263 82                          IFEQ    A,[B]
323 0264 BC3D05                      LD      PISTAT,#5
323 0267 22A1                        JMP     PIDONE
323                                  .FORM
323                        CW1:                               ;State 1:  Clockwise 1 PI State
323 0269                             TSTST   3,PIR
323 0269 9802                        LD      A,#PIR
323 026B 82                          IFEQ    A,[B]
323 026C BC3D03                      LD      PISTAT,#3
323 026F 224D                        JMP     PIX
323                        CW2:                               ;State 3:  Clockwise 2 PI State
323 0271                             TSTST   1,PIL
323 0271 9801                        LD      A,#PIL
323 0273 82                          IFEQ    A,[B]
323 0274 BC3D01                      LD      PISTAT,#1
```

```
                                        LD      A,#(PIL!PIR)
323 0279 B9                             IFNE    A,[B]
323 027A 22A1                           JMP     PIDONE
323                             PLSCW:                          ;Count (pulse) a clockwise hole
323 027C 9F3E                           LD      B,#HOLCW
323 027E AE                             LD      A,[B]
323 027F 8A                             INC     A
323 0280 A6                             X       A,[B]
323 0281 BC3D04                         LD      PISTAT,#4
323 0284 22A1              R            JMP     PIDONE
323                             CCW1:                           ;State 0:  Counter-clockwise 1 PI State
323 0286                                TSTST   2,PIL
323 0286 9801                           LD      A,#PIL
323 0288 82                             IFEQ    A,[B]
323 0289 BC3D02                         LD      PISTAT,#2
323 028C 224D                           JMP     PIX
323                             CCW2:                           ;State 2:  Counter-clockwise 2 PI State
323 028E                                TSTST   0,PIR
323 028E 9802                           LD      A,#PIR
323 0290 82                             IFEQ    A,[B]
323 0291 BC3D00                         LD      PISTAT,#0
323 0294 9803                           LD      A,#(PIL!PIR)
323 0296 B9                             IFNE    A,[B]
323 0297 22A1              R            JMP     PIDONE
323                             PLSCCW:                         ;Count (pulse) a counter-clockwise hole
323 0299 9F3F                           LD      B,#HOLCCW
323 029B AE                             LD      A,[B]
323 029C 8A                             INC     A
323 029D A6                             X       A,[B]
323 029E BC3D04                         LD      PISTAT,#4
323                             ;       jmp     PIDone
323                             PIDONE:
```

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An apparatus for recording information about the angular motion of a rotatable disk disposed in a first structure, the disk having regions with differing properties with respect to electromagnetic energy, the apparatus comprising:

first means for emitting a first sequence of electromagnetic energy pulses in a first direction toward the disk, the first emitting means being mounted on the first structure adjacent a first side of the disk;

second means for emitting a second sequence of electromagnetic energy pulses in a second direction toward the disk, the second emitting means being mounted on the first structure adjacent the first side of the disk and separated from the first emitting means in the direction of rotation of the disk, the first and second directions being such that the first and second sequences of electromagnetic energy pulses reflect from the first side of the disk in different areas, the areas being separated in the direction of rotation of the disk;

photosensitive means mounted on the first structure so that the photosensitive means can receive the electromagnetic energy pulses from both the first and second emitting means at a single point, the photosensitive means being for generating a signal in response to the received electromagnetic energy pulses; and

a controller coupled to the photosensitive means for processing the signal to determine the number of rotations of the disk, and the direction of rotation of the disk, the controller also being for synchronizing the first and second sequences of electromagnetic energy pulses such that each electromagnetic energy pulse from the first emitting means is followed by an electromagnetic energy pulse from the second emitting means.

2. The apparatus of claim 1 wherein the photosensitive means comprises a photo diode.

3. The apparatus of claim 1 wherein the first and second emitting means comprise infrared emitting diodes and the electromagnetic energy pulses comprise infrared energy pulses.

4. The apparatus of claim 1 wherein the controller is coupled to the first and second emitting means so as to control the first and second sequences of electromagnetic energy pulses, thereby generating a third sequence of electromagnetic pulses.

5. The apparatus of claim 4 wherein the third sequence comprises:

(1) a first pulse for a first interval from the first emitting means;

(2) a second pulse for a third interval from the second emitting means;

(3) a fourth interval during which the first and second emitting means are off; and

(4) repeated cycles comprising (1) through (3).

6. The apparatus of claim 5 wherein the first and third intervals overlap.

7. The apparatus of claim 1 wherein the regions on the first side of the disk have differing reflective properties with respect to electromagnetic energy, and the signal generated by the photosensitive means has characteristics dependent upon the reflective properties of the regions from which the electromagnetic energy pulses are reflected.

8. The apparatus of claim 7 wherein the first and second emitting means, and the photosensitive means are mounted on a housing, the photosensitive means being mounted on the housing between the first and second emitting means, the housing being mounted on the first structure.

9. The apparatus of claim 8 wherein the first structure is a standard watt-hour meter.

10. The apparatus of claim 9 wherein the rotatable disk is disposed in a substantially horizontal plane, and the housing is mounted in the standard watt-hour meter below the rotatable disk.

11. The apparatus of claim 1 wherein the disk has at least one aperture through which the electromagnetic energy pulses from the first and second emitting means are transmitted.

12. The apparatus of claim 11 wherein the photosensitive means is mounted on the first structure on the opposite side of the disk from the first and second emitting means.

13. An apparatus for recording information about the angular motion of a rotatable disk disposed in a first structure, a first side of the disk having regions with differing reflective properties with respect to electromagnetic energy, the apparatus comprising:

a housing mounted on the first structure adjacent the first side of the disk;

first means mounted on the housing for emitting a firsts sequence of electromagnetic energy pulses in a first direction toward the disk;

second means mounted on the housing for emitting a second sequence of electromagnetic energy pulses in a second direction toward the disk, the first and second directions being such that the first and second sequences of electromagnetic energy pulses reflect from the first side of the disk in different areas, the areas being separated in the direction of rotation of the disk;

photosensitive means mounted on the housing so that the photosensitive means can receive the reflected electromagnetic energy pulses from both the first and second emitting means at a single point, the photosensitive means being for generating a signal in response to the received electromagnetic energy pulses, the signal having characteristics dependent upon the reflective properties of the regions from which the electromagnetic energy pulses are reflected; and

a controller coupled to the photosensitive means for processing the signal to determine the number of rotations of the disk, and the direction of rotation of the disk, the controller also being for synchronizing the first and second sequences of electromagnetic energy pulses such that each electromagnetic energy pulse from the first emitting means is followed by an electromagnetic energy pulse from the second emitting means.

14. The apparatus of claim 13 wherein the photosensitive means comprises a photo diode.

15. The apparatus of claim 13 wherein the first and second emitting means comprise infrared emitting diodes, and the electromagnetic energy pulses comprise infrared energy pulses.

16. The apparatus of claim 13 wherein the controller is coupled to the first and second emitting means so as to control the first and second sequences of electromagnetic energy pulses, thereby generating a third sequence of electromagnetic energy pulses.

17. The apparatus of claim 16 wherein the third sequence comprises:

(1) a first pulse for a first interval from the first emitting means;

(2) a second pulse for a third interval from the second emitting means;

(3) a fourth interval during which the first and second emitting means are off; and

(4) repeated cycles comprising (1) through (3).

18. The apparatus of claim 17 wherein the first and third intervals overlap.

19. The apparatus of claim 13 wherein the photosensitive means is mounted on the housing between the first and second emitting means.

20. The apparatus of claim 13 wherein the first structure is a standard watt-hour meter, the housing being adapted for mounting in the standard watt-hour meter.

21. The apparatus of claim 20 wherein the rotatable disk is disposed in a substantially horizontal plane, and the housing is mounted in the standard watt-hour meter below the rotatable disk.

22. An apparatus for recording information about the angular motion of a rotatable disk disposed in a first structure, the disk having at least one aperture through which the electromagnetic energy is transmitted, the apparatus comprising:

first means for emitting a first sequence of electromagnetic energy pulses, the first emitting means being mounted on the first structure adjacent a first side of the disk;

second means for emitting a second sequence of electromagnetic energy pulses, the second emitting means being mounted on the first structure adjacent the first side of the disk and separated from the first emitting means in the direction of rotation of the disk;

photosensitive means mounted on the first structure on the opposite side of the disk from the first and second emitting side of the disk from the first and second emitting means so that the photosensitive means can receive the electromagnetic energy pulses transmitted through the at least one aperture from both the first and second emitting means at a single point, the photosensitive means being for generating a signal in response to the received electromagnetic energy; and

a controller coupled to the photosensitive means for processing the signal to determine the number of rotations of the disk, and the direction of rotation of the disk, the controller also being for synchronizing the first and second sequences of electromagnetic energy pulses such that each electromagnetic energy pulse from the first emitting means is followed by an electromagnetic energy pulse from the second emitting means.

23. The apparatus of claim 22 wherein the photosensitive means comprises a photo diode.

24. The apparatus of claim 22 wherein the first and second emitting means comprise infrared emitting diodes and the electromagnetic energy pulses comprise infrared energy pulses.

25. The apparatus of claim 22 wherein the controller is coupled to the first and second emitting means so as to control the first and second sequences of electromagnetic energy pulses, thereby generating a third sequence of electromagnetic energy pulses.

26. The apparatus of claim 25 wherein the third sequence comprises:

(1) a first pulse for a first interval from the first emitting means;

(2) a second pulse for a third interval from the second emitting means;

(3) a fourth interval during which the first and second emitting means are off; and

(4) repeated cycles comprising (1) through (3).

27. The apparatus of claim 26 wherein the first and third intervals overlap.

28. The apparatus of claim 22 wherein the first structure is a standard watt-hour meter.

29. A method for deriving information about the rotation of a rotatable disk, a first side of the disk having regions with differing reflective properties with respect to electromagnetic energy, the method comprising the steps of:

(1) reflecting a first sequence of electromagnetic energy pulses from a first emitting means from the first side of the disk;

(2) receiving the reflected first sequence of electromagnetic energy pulses from the first emitting means at a first point with a photosensitive means;

(3) generating a first signal pulse with the photosensitive means corresponding to the received first sequence of electromagnetic energy pulses from the first emitting means;

(4) reflecting a second sequence of electromagnetic energy pulses from a second emitting means from the first side of the disk, the second sequence being synchronized with the first sequence such that each electromagnetic energy pulse from the first emitting means is followed by an electromagnetic energy pulse from the second emitting means;

(5) receiving the reflected second sequence of electromagnetic energy pulses from the second emitting means at the first point with the photosensitive means;

(6) generating a second signal pulse with the photosensitive means corresponding to the received second sequence of electromagnetic energy pulses from the second emitting means;

(7) repeating steps (1) through (6), thereby generating a pulse train comprising the first and second signal pulses; and

(8) processing the pulse train to determine the number of rotations of the disk, and the direction of rotation of the disk.

30. The method of claim 29 wherein the photosensitive means comprises a photo diode.

31. The method of claim 29 wherein the first and second emitting means comprise infrared emitting diodes and the electromagnetic energy comprises infrared energy.

32. The method of claim 29 wherein the first and second emitting means, and the photosensitive means are mounted on a housing adapted for mounting in a standard watt-hour meter.

33. The method of claim 32 wherein the rotatable disk is disposed in a substantially horizontal plane, and the housing is mounted in the standard watt-hour meter below the rotatable disk.

34. The method of claim 29 wherein the processing step is accomplished by means of a controller, the controller also pulsing the first and second emitting means, thereby causing the first and second emitting means to emit electromagnetic energy in a particular sequence.

35. The method of claim 34 wherein the sequence comprises:

(1) a first pulse for a first interval from the first emitting means;

(2) a second pulse for a third interval from the second emitting means;

(3) a fourth interval during which the first and second emitting means are off; and

(4) repeated cycles comprising (1) and (3).

36. The method of claim 35 wherein the first and third intervals overlap.

37. A watt-hour meter having a first structure, comprising:

a rotatable disk disposed within the first structure, the disk having regions with differing properties with respect to electromagnetic energy;

first means for emitting a first sequence of electromagnetic energy pulses in a first direction toward the disk, the first emitting means being mounted on the first structure adjacent a first side of the disk;

second means for emitting a second sequence of electromagnetic energy pulses in a second direction toward the disk, the second emitting means being mounted on the first structure adjacent the first side of the disk, the first and second directions being such that the first and second sequences of electromagnetic energy pulses reflect from the first side of the disk in different areas, the areas being separated in the direction of rotation of the disk;

photosensitive means mounted on the first structure so that the photosensitive means can receive the electromagnetic energy pulses from both the first and second emitting means at a single point, the photosensitive means being for generating a signal in response to the received electromagnetic energy pulses; and

a controller coupled to the photosensitive means for processing the signal to determine the number of rotations of the disk, and the direction of rotation of the disk, the controller also being for synchronizing the first and second sequences of electromagnetic energy pulses such that each electromagnetic energy pulse from the first emitting means is followed by an electromagnetic energy pulse from the second emitting means.

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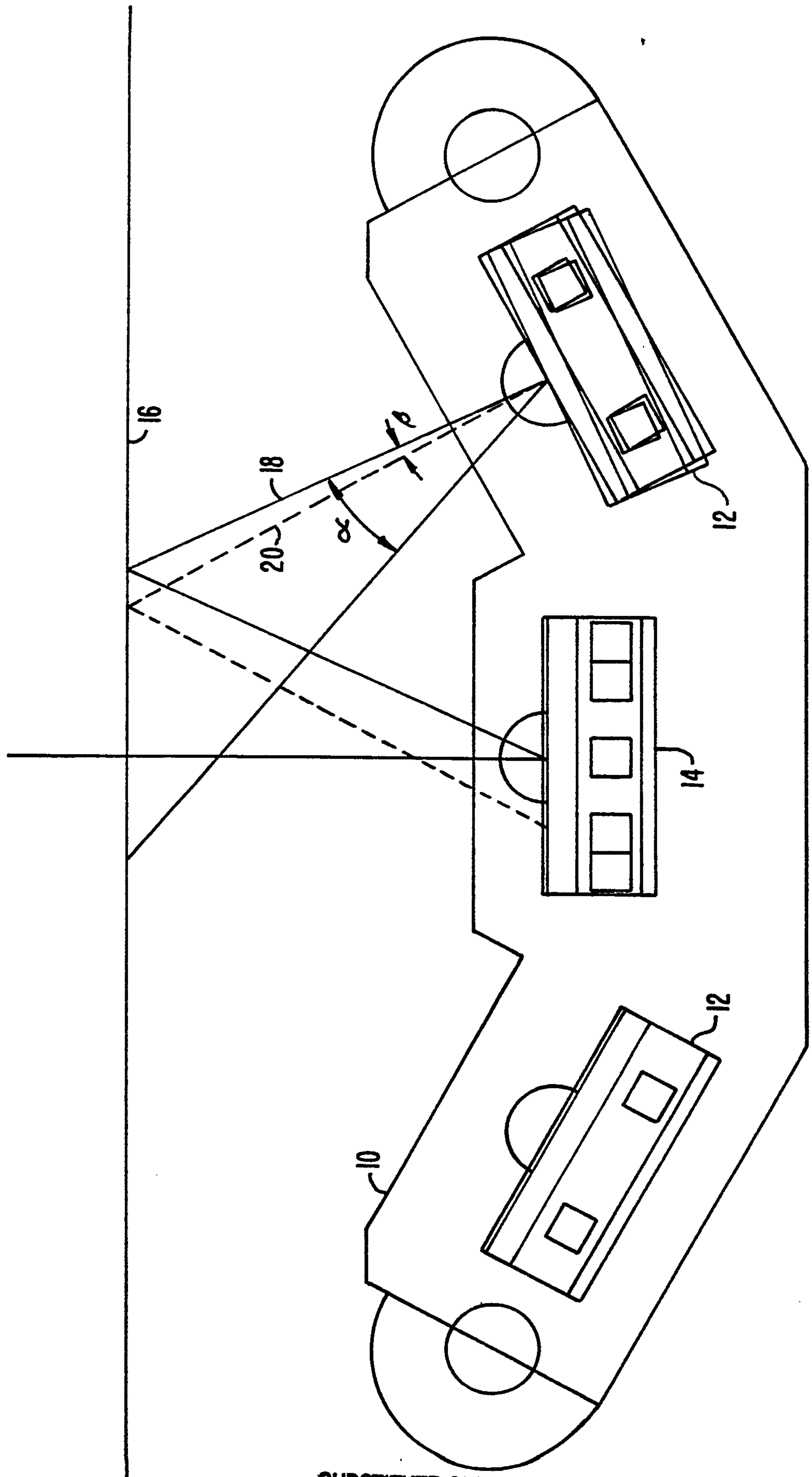


FIG. 1.

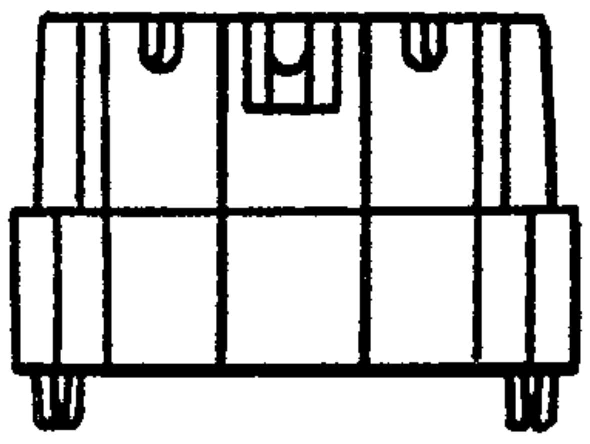


FIG. 2a.

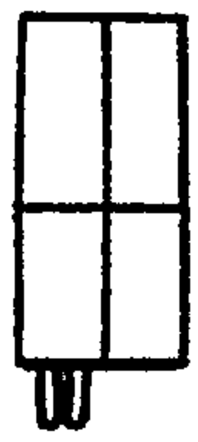


FIG. 2b.

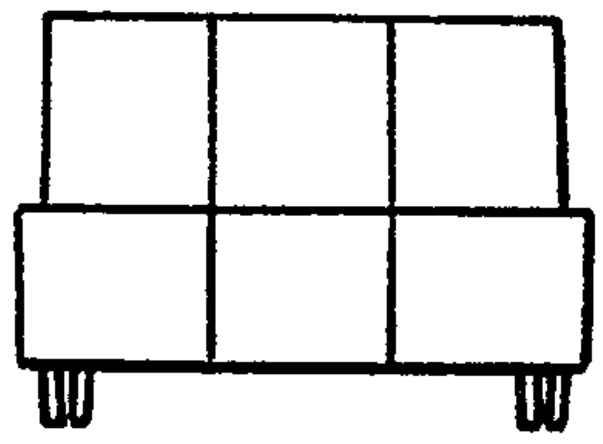


FIG. 2c.

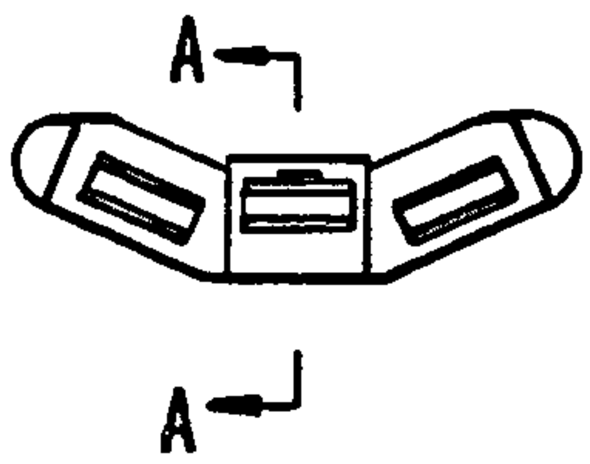


FIG. 2d.

SECTION A-A

FIG. 2e.

FIG. 2f.

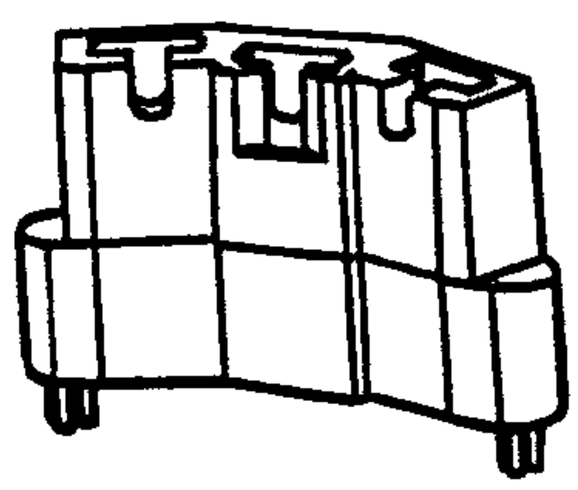
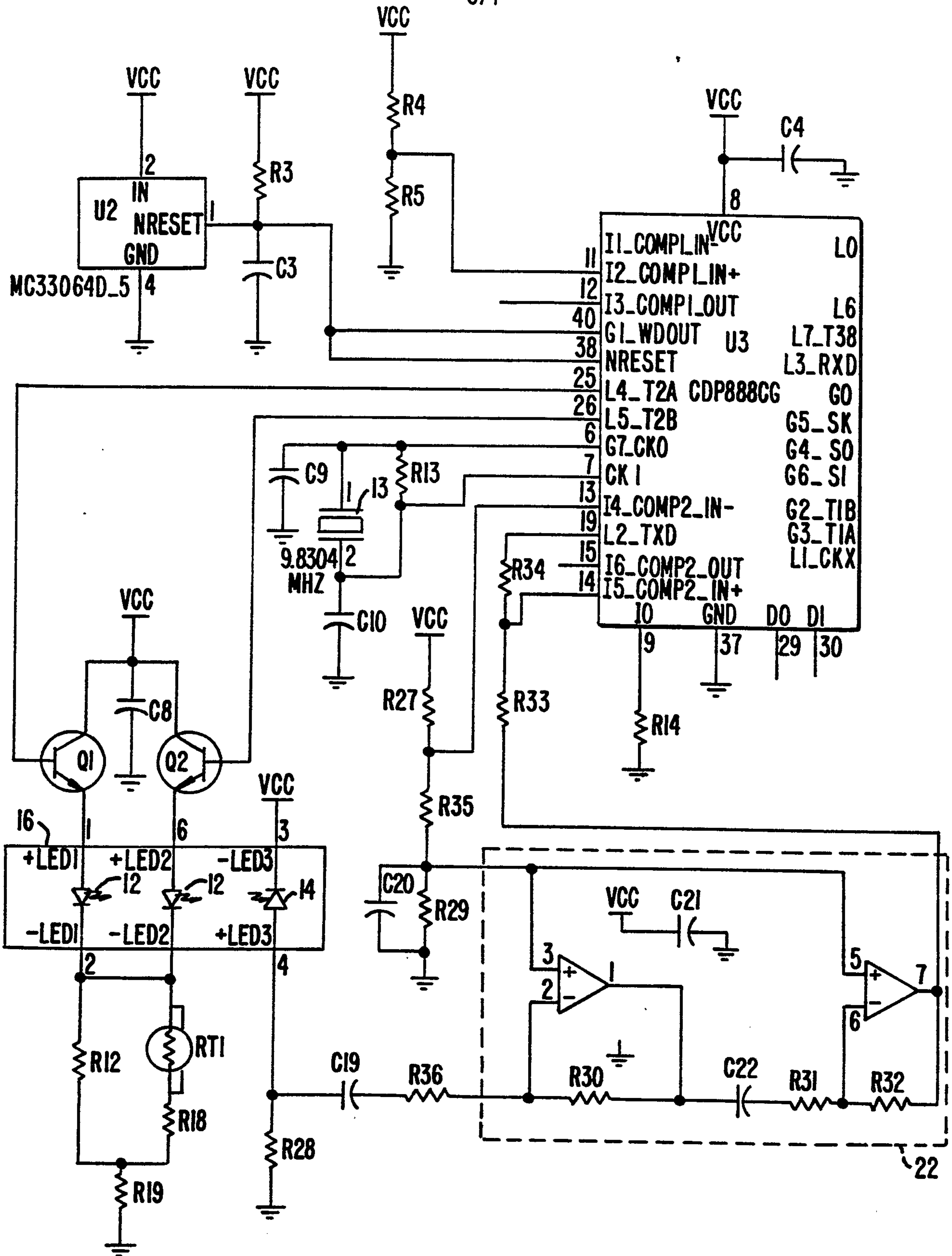


FIG. 2g.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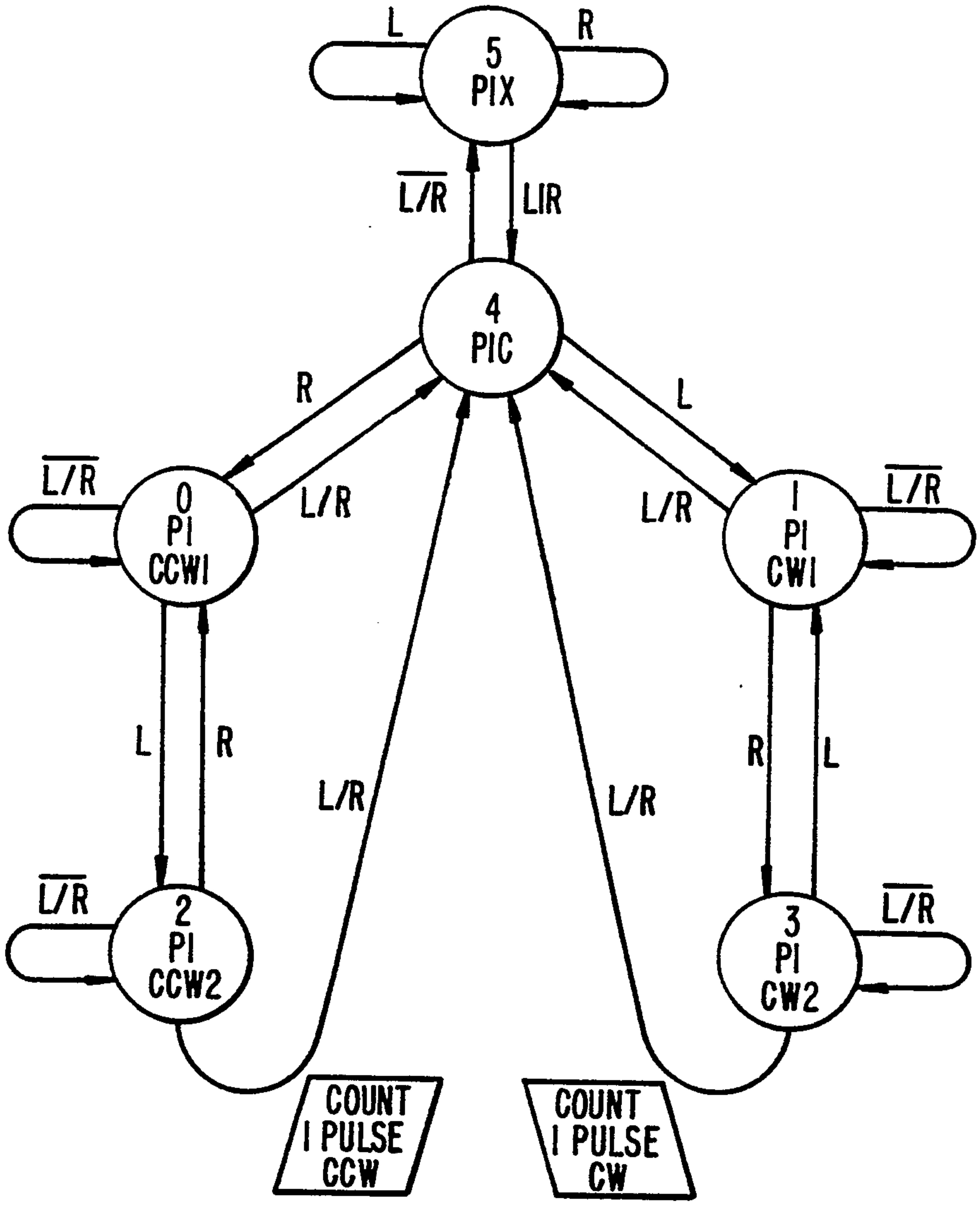
U2
IN
NRESET
GND
MC33064D_5
R3
C3
R4
R5
C4
U3
CDP888CG
I1_COMP1_IN-
I2_COMP1_IN+
I3_COMP1_OUT
G1_WDOUT
NRESET
L4_T2A
L5_T2B
G7_CKO
CK I
I4_COMP2_IN-
L2_TXD
I6_COMP2_OUT
I5_COMP2_IN+
IO
GND
DO
DI
L0
L6
L7_T38
L3_RXD
G0
G5_SK
G4_SO
G6_SI
G2_TIB
G3_TIA
L1_CKX
C9
R13
13
9.8304 MHZ
C10
R34
R27
R33
R14
C8
Q1
Q2
16
+LED1
+LED2
-LED3
-LED1
-LED2
+LED3
12
14
R35
C20
R29
C21
R12
RT1
R18
R19
R28
C19
R36
R30
C22
R31
R32
22

FIG. 3.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L/R
4
PIC
R
L
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L/R
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PI
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1
PI
CW1
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$\overline{L/R}$
L
R
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L
L/R
L/R
2
PI
CCW2
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PI
CW2
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$\overline{L/R}$
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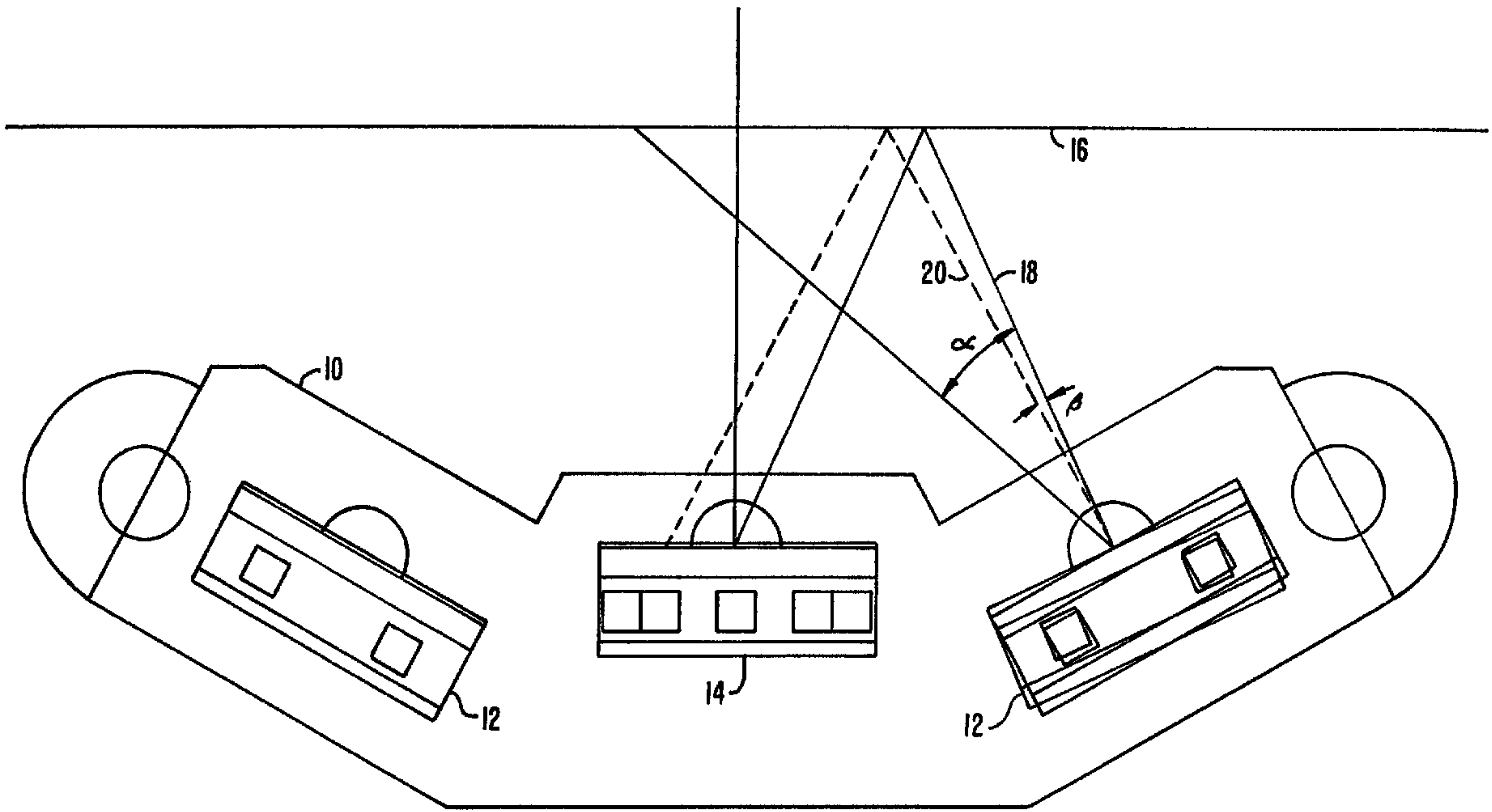
CCW
COUNT
1 PULSE
CW

FIG. 4.



16
20
18
α
β
10
12
14
12