APPARATUS FOR DETERMINING THE ANGULAR POSITION, SPEED AND/OR DIRECTION OF ROTAY OBJECTS

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ABSTRACT

This paper describes a capacitively reading apparatus for determining the angular orientation, speed and/or direction of rotary objects such as shaft, dial hand, counter wheel and the like.

The apparatus consists of sensing device and circuit accompanying with said sensing device. The sensing device is provided by arranging many stationary electrodes lying substantially on a surface of a stationary plane member and by arranging rotary electrode lying substantially on a surface of rotary objects to be monitored, in which said rotary electrode is in confronting relationship to some stationary electrodes so as to cons-truct unique capacitors according to the angular position of rotary objects. The angular position of said rotary electrode is determined by sets of stationary electrodes which are in confronting relationship to rotary electrode. A carrier signal is generated by scanning device while scanning said stationarelectrodes, whose periods are in corresponding relationship to said stationary electrodes, respectively. The periods of carrier corresponding to the angular position of said rotary electrode is modulated by a modulation signal generated by detecting device according to said rotary electrode. This apparatus is applied to automatically monitor any kind of storage tank, as well as to automatically read the conventional utility meters such as Watthour meters, Gas meters, Water meters, etc..

1. INTRODUCTION

There has been considerable effort expended in providing means and apparatus for remotely reading the angular position of rotary objects at a distance, for example, through telephone line and the like. There are four categories in remotely monitoring the angular position of rotary objects; photoelectric cell; mechanically sliding contact; magnetic field; and electric field. The sensing device using the electric field is a desirable thing because the information can be transferred from one point to another another point by electric field without physical contact between them.

The theory of the sensing device for this paper is described in the paper (4). In this paper a detailed description for a capacitively reading apparatus which consists of sensing device and electronic circit accompanying with the sensing device is presented.

2. CAPACITIVELY SENSING DEVICE

The capacitively sensing device consists of rotary electrode lying substantially on a surface of rotary objects to be monitored and an array of many stationary electrodes lying substantially on a surface of stationary member whose surface is parallel to the circumferential path defined by said rotary electrode.

In this exemplary embodiment, a fan-shaped rotary electrode is arranged on the cross-sectional surface of a counter wheel of cyclometer in order to show how to remotely read the indicating number of counter wheel by this principle. This rotary electrode is monitored to identify the angular position of rotary objects, the indicating number of counter wheel for this example. The central angle of said rotary elect trode is selected to be 72 degrees for a clear illustration.

Many stationary electrodes are arranged on a stationary member in a circular array which is ,in use, positioned in confronting relationship to said rotary electrode to be monitored in order to form said sensing device. Sensing device in Fig. 1 is the plan view of said sensing device. Each number designated outside the circle is corresponding to each of said stationary electrodes. The numbers assigned on the cylindrical surface are designated inside the circle. This device can be used as a sensing device to monitor said rotary electrode, but a sensing device with improved advantages can be obtained by interconnecting said stationary electrodes to each other in a particular mode, as shown in Fig.1. Every other stationary electrode is designated by A, C, D, and E, respectively, in the clockwise direction. Each of these five stationary electrodes is connected to every two other stationary electrode in the same direction.

These five stationary electrodes have a wire to be connected to said electronic circuit, respectively.

Therefore, 5 wires instead of 10, the number of said stationary electrodes, are needed for said sensing device with 10 stationary electrodes to be connected to said electronic circuit. Each indicating number of counter wheel is identified from two of these five wires. Table 1 shows the corresponding relationship between the set of two wires and the indicating number of counter wheel, which is obtained from said sensing device. Thus, the indicating number of counter wheel, the angular position of rotary objects, is determined from said stationary electrodes without physical connection between the rotary objects and the measuring device.

3. CIRCUIT CONFIGURATION

The functional block diagram of the electronic circuit accompanying with said sensing device is shown in Fig. 2. The functions of the apparatus of Fig. 2 are to generate a carrier signal whose periods are corresponding to each of the number assigned on the surface of counter wheel, the angular position of rotary objects, to generate a modulation signal according to the indicating number counter wheel and to generate a modulated output signal which can be transmitted through two-wire transmission line. The modulated output signal is the carrier whose periods corresponding to the indicating number of counter wheel are modulated with said modulation signal.

This remotely reading apparatus consists of five stages: power/line interface; sensing device: scanning device: detecting device: and output device.

Power/line interface consists of resonant circuit and on/off switch. When there is a need to read an utility meter with this apparatus , an interogation signal together with DC power is sent from a central facility to the meter through 2-wire transmission line. The interogation signal is detected by the filtering operation of power/line interface and causes a magnetic relay or an electronic on/off switch to be turned on in order for DC power to be supplied to the meter. The transmission line is used to collect the meter readings, as well as to supply the interogation signal and DC power to the meter to be monitored.

The scanning device consists of oscillator, counter, demultiplexer, multiplexer, and amplifier. Oscillator generates signal to be supplied to the sensing device through demultiplexer and at the same time, to the first counter.

The first counter is used to determine how many periods of the input signal to be applied to each of said stationary electrodes during selected for input. The second counter selects each channel of demultiplexer for input and of multiplexer for output whenever one period of signal is arrived from the first counter.

Therefore, some periods of output signal from the first counter are corresponding to each set of channels, in other words, each set of stationary electrodes for input and output. The output from the first counter is converted to the sinusoidal waveform by the bandpass filter, as shown in fig.3B. The sinusoidal waveform is used as a carrier for transmitting the indicating number of counter wheel to a central facility through 2-wire transmission line.

While said stationary electrodes are scanned for the input and output signals, the maximum output signal is obtained from the set of stationary electrode which is in confrontring relationship to said rotary electrode to be monitored for the indicating number of counter wheel. The output signal is amplified so as to have an enough magnitude and then applied to level detector. The level detector dis-tinguishes the signal corresponding to the indicating number of counter wheel from noise. A few periods of output signal from the level detector is selected by period selector and then applied to bandpass filter so as to be converted into sinusoidal waveform, as shown in Fig. 3D. This waveform is used as a modulation signal. The fundamental frequency of said modulation signal is usually different from said carrier. The carrier and the modulation signal are simultaneously applied to a modulator from which a modulated output signal is obtatined. This modulated output signal, shown in Fig. 3E, is transmitted to a central facility through 2-wire transmission line.

When the modulated signal, as shown in Fig.3E, is recieved at the central facility, the indicating number of counter wheel is identified by the modulated periods of the carrier. Thus, the angular position of rotary objects is automatically read at a distance without mechanical contact with the rotary objects.

Another preferred feature of the present sensing technique is to provide a sensing device having an improved sensitivity by means of connecting said rotary electrode to said electronic circuit.

One approach to connect said rotary electrode to sadi electronic circuit is to make both the female and the male for the rotary objects conductive. A rotary objects usually rotates on a shaft, and then the female is fixed to the rotary objects. Therefore, the conductive female is connected to said rotary electrode and the conductive male is to connected to said electronic circuit, as shown in Fig. 4. There exists a complete, but sliding mechanical contact between said conductive female and said conductive male. However, as a worst case, a complete mechanical contact between the female and the male may not exist. Then the conductive female and the male can be considered as a coaxial capacitor, as shown in Fig. 5. The capacitance of the coaxial system is defined by,

$$Ccx = K/(Log(b) - Log(a))$$

, where K is a proportional constant, a is the radius of the conductive male and b is the radius of the conductive female.

Because the radius of the male is nearly equal to that of the female for the rotary objects to be monitored, the capacitance Ccx may be considered as infinity. In other words, there exists an electrically complete connection between the conductive female and the conductive male. When an input is applied to some of said stationary electrodes and an output is measured at the conductive male, or vice versa, the maximum output signal is obtained more than twice that of the sensing device being scanned only by said stationary electrodes.

Electronic circuit accompanying with said sensing device can be implemented by using microcomputer and an A/D converter. Fig.5 shows the another exemplary embodiment of the capacitively reading apparatus according to the present techniques.

The accuracy of the apparatus of Fig.2 depends on how exactly the level detector distinguishes the signal from the noise and how many stationary electrodes is arranged in the circular array. In the circuit of Fig. 5, the accuracy is improved by the wordlength of A/D converter. Detecting function of Fig. 2 is implemented by the averager, A/D converter and a single-chip microcomputer.

The averager converts the output of amplifier into DC level signal while one set of said stationary electrodes is selected for the input and output signals. If the maximum output signal is obtained from the averager at the maximum capacitance between the in-put and the output terminals and is adjusted to be equal to the maximum dynamic range for the input of 8-bit A/D converter, then the resolution being obtained from the microcomputer-based apparatus is approximately evaluated in the following;

$$resolution = 360/N/2**B \quad degree/bit$$

This high resolution is superior to any other apparatus being manufactrued at the same price.

Furthermore, much larger output signal can be obtained from the sensing device having means for connecting said rotary electrode to said electronic circuit, because two stationary electrodes are drived by an input. In the exemplary configuration, the multiple-input OR gates are used for driving two stationary electrodes at the same time.

Microcomputer is used for implementing several function such as for controlling the scanning function, for determining the set of said stationary electrodes from which the maximum output signal is obtained, for generating the modulated output signal which can be transmitted to a central facility through 2-wire transmission line. Therefore, this apparatus can be employed to remotely read the indication of the conventional utility meters having a pointer-type indicator as well as a mechanical register set. Furthermore, the microcomputer-based apparatus can provide many other advantageous functions such as real time data collection, demand metering, demand limiting, time-of-use metering, prepaid metering, peak alert, standard modem signal generation, etc.

4. CONCLUSION

The apparatus for remotely determining the angular position, speed and/or direction of rotary objects have been descibed. It consists of sensing device and circuit accompanying with said sensing device. The sensing device is consists of rotary electrode lying substantially on a surface of rotary objects and many stationary electrodes lying substantially on a surface of a stationary plane member which is in parallel and confrontring relationship to said rotary electrode. This rotary electrode is to be monitored for determining the angular position of rotary objects.

The angular position of rotary objects is determined only by sets of stationary electrodes without any construction for mechanically or electrically connecting said rotary electrode to said electronic circuit.

However, the sensing device having an improved sensitivity is obtained by providing means for electrically connecting said rotary electrode to said electronic circuit.

The functional circuit diagrams accompanying with said sensing devices are dexcribed by showing the typical waveform be observed at various points on the diagrams.

The apparatus described in this paper can primarily be applied to automatically read, at a low price, the conventional indications such as the counter wheel of mechanical register, pointer hand, or rotary disc, etc..

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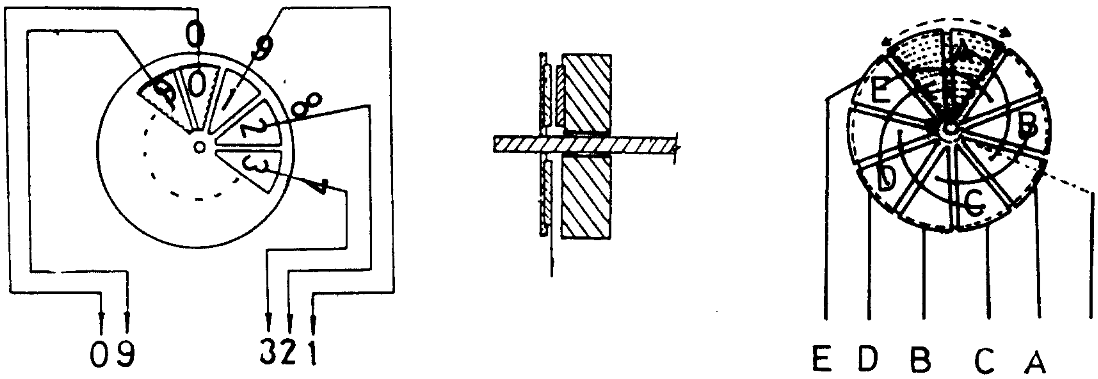

(A) (B) (C)

Fig. 1. Capacitively sensing devices

Table 1. The corresponsing relationship between the sets of stationary electrodes and the indicating number of counter wheel.

Input/output	AB	AC	AD	AE	BC	BD	BE	CD	CE	DE
Indicating number	3	4	0	1	5	6	2	7	8	9

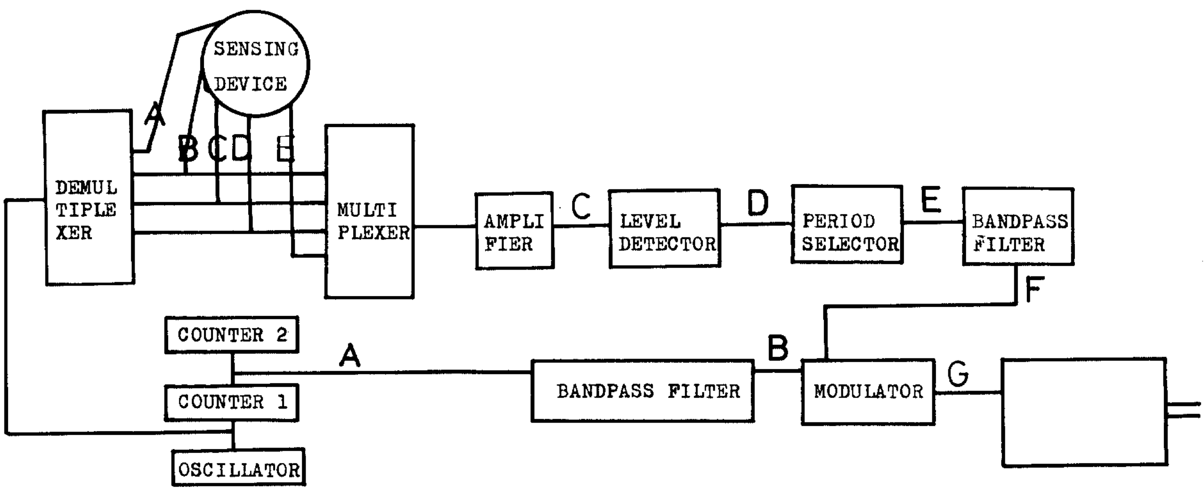

Fig. 2. Functional block diagram of the apparatus for this paper.

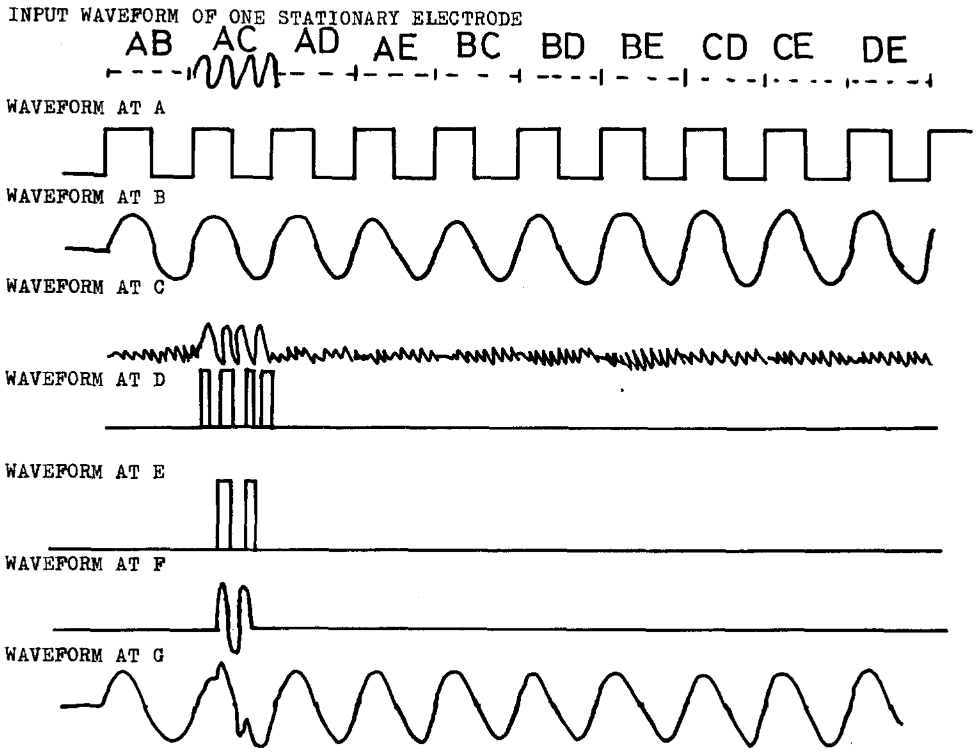

Fig. 3. Typical waveforms observed at various points of the circuit in Fig. 2 when the indicating number of counter wheel is 4.

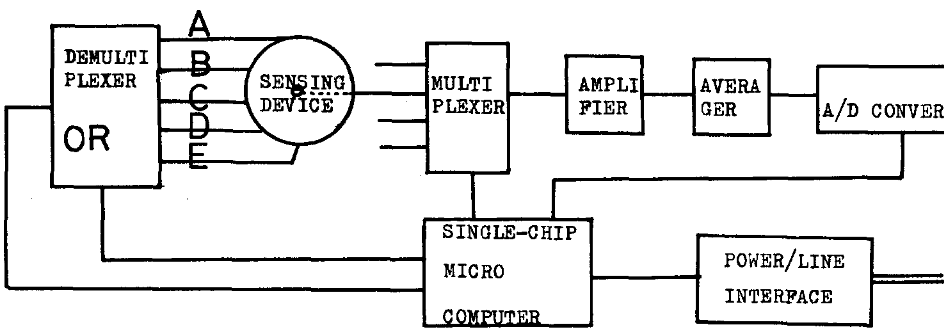

Fig. 4. Microcomputer-based apparatus having an improved sensitivity.