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A Study on the Design of Water Pollution Alarm System with Solar Cell

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Abstract

As the industry has been growing rapidly, the problem of environmental pollution has been on the rise seriously. In this paper, we used solar cells at the power supply unit of the equipment, which has been sold at present, for measuring the quality of water in order to complement the problem.

Also, to get rid of the inconvenience that the examiners must go the job site, check and collect the polluted water we set the goal at designing the water pollution alarm system which measures the quality of water automatically using one-chip microprocessor and materializing the program.

Nomenclature

I	: output current	R_{Sh}	: parallel resistor
I_{PH}	: photo current	V_{OC}	: open voltage
I_0	: saturation current of the diode	I_{SC}	: short current
q	: electric charge	FF	: Fill Factor
V	: voltage	V_m	: maximum output voltage
K	: boltzmann constant	I_m	: maximum output current
T	: temperature	P_{in}	: photovoltaic energy radiated
R_S	: series resistor	$S_1(t), S_2(t)$	: signal

1. Introduction

Recently, the development of semiconductor elements among electrical and electronic industries has been accelerated and as the industries grow, the environmental pollution has been become a matter of grave concern. Many instruments measuring the quality of water, due to the development of technologies, has been on sales but some of these which are portable are used in laboratories or research centers of environmental problem and others which are not portable are installed at enterprises which provide water purification processing system. This measurement method is that the examiners with measuring instruments go to the field and test the quality of water there or pick the sample of the water and back to the inspection office to examine it.

In this paper, to solve these inconvenient problems we presents the device, which is easy to be installed anywhere and also transmits the state of water to the managers at inspection offices to be checked.

This system has solar cells, which transform photovoltaic energy to electric energy, for drive power supply and it is operated by the program in a one-chip microprocessor PIC(Peripheral Interface Controller).

2. The definition and characteristic of the technology of the solar cell

2.1 The definition of solar cell technology

The solar cell is the product of new technology which transforms unlimited and nonpolluting photovoltaic energy to electric energy. The basic principle of the solar cell, which is a generation element, is that as the photovoltaic irradiates the solar cell consisting of the P-N junction, the pairs of electron-hole are excited by the light energy of larger wavelength range than the width of forbidden band of the semiconductor and electrons and holes move and then each of N layer and P layer is electrified negative or positive. The electromotive force is generated by this photovoltaic effect and the current flow across the outer load[1]-[3],[6].

2.2 The characteristic of solar cell technology

The solar cell, comparing to other batteries, doesn't need high cost of fuel or make less air pollution and wastes because of using clean photovoltaic energy by transforming it to electric energy directly. It doesn't make mechanical vibration or noise because it is an element of semiconductor. Also, it is easy to yield the generation capacity and needs short time to be set up. It is available for the generation of power in movable or fixed form. The generation efficiency of solar cell is identical in wide range of use from the small power source of the calculator to that of houses or factories. The life of solar cell is more than 20 years, the period from installation until exchange is longer enough, comparing to others. The construction of solar cell system is rather simple and is easy to be checked and repaired. On the contrary, the price of solar cell is very expensive and it is very affected by outer circumstance and needs

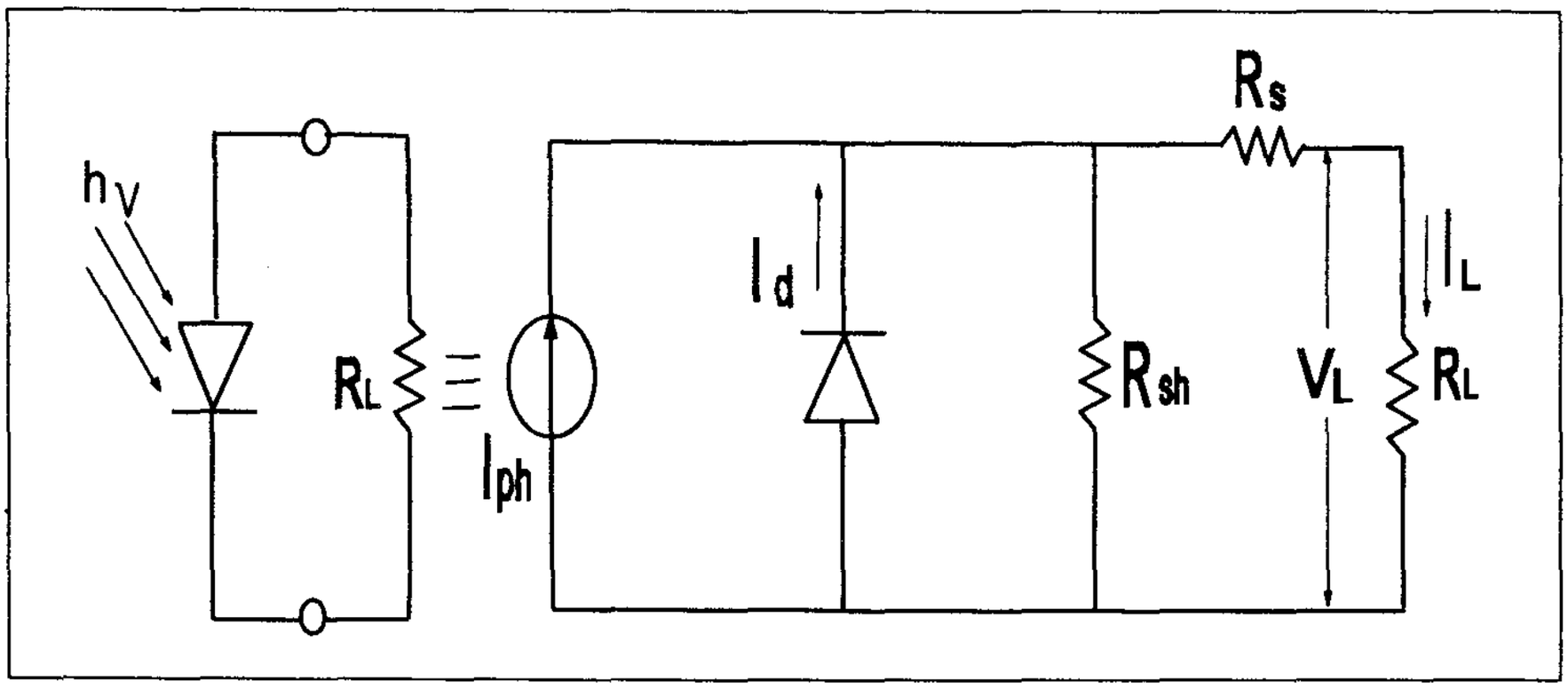


Fig. 1. Equivalent circuit of solar cell

wide areas for installing the solar modules due to its weak energy density. The transformation efficiency of crystal solar cell is about 13% and that of amorphous solar cell is about 7%[4]. The electric amount of the output of solar cells depends on the meteorological conditions, particularly the radiation and reaching degree of light during a day. For A.C. application solar cells must require inverters because its output is in form of D.C. and also it needs power storage system such as batteries because it doesn't have any function of accumulating the output power.

Fig. 1 shows the equivalent circuit of solar cell using photovoltaic effect. In ideal case, the characteristic of voltage-current, as radiated, Is

$$I = I_{Ph} - I_0\left[\exp\left(\frac{qV}{nKT}\right) - 1\right] \quad (1)$$

But in actual case, the resistor in series R_s and the parallel resistor R_{Sh} are added. The equation (1) is rewritten as the equation (2).

$$I = I_{Ph} - I_0\left[\exp\left(\frac{q(V+IR_S)}{nKT}\right) - 1\right] - \frac{V+IR_S}{2} \quad (2)$$

where, I is output current, I_{Ph} photo current, I_0 saturation current of the diode, n diode constant, K boltzmann constant and q is a electric charge. Fig. 2 is shown the characteristic of maximum output voltage and maximum power point of solar cell.

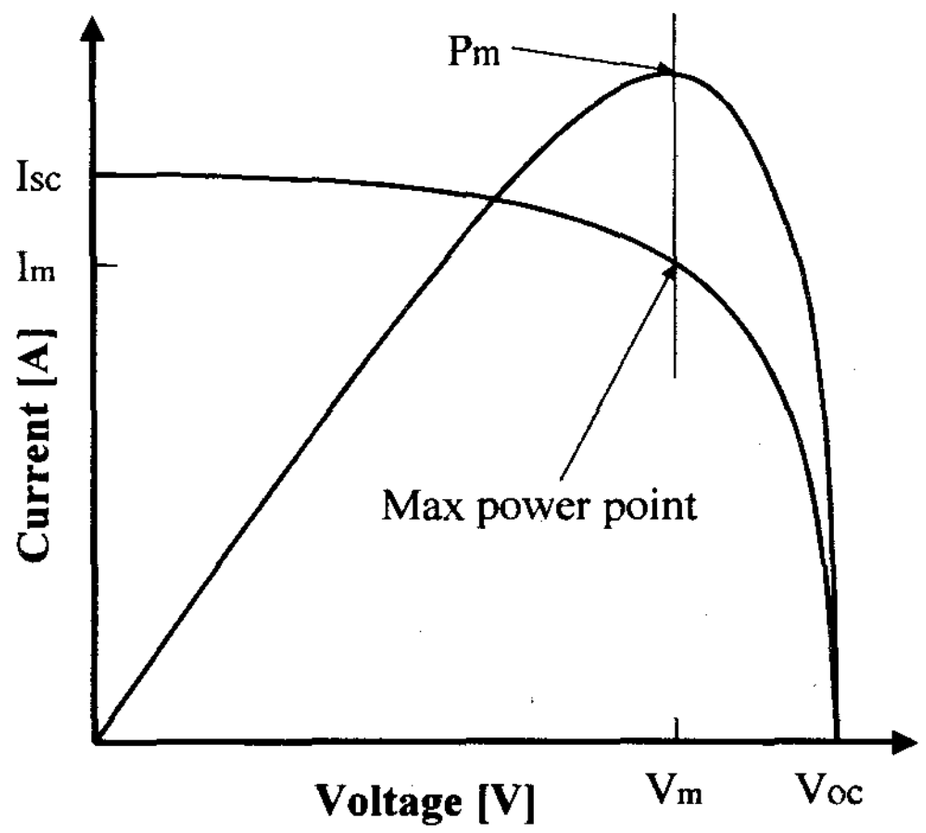


Fig. 2. Maximum output voltage and maximum power point of cell

The 3 variables of Fig. 2, open voltage V_{OC}, short current I_{SC}, and Fill Factor FF, are the parameters related to the transformation efficiency of energy.

$$V_{OC} = \frac{nKT}{q} \ln\left(\frac{I_{Ph}}{I_0} + 1\right) \quad (3)$$

First, the open voltage is the equation (3) and the short current is the equation (4).

$$I_{SC} = I_{Ph} - I_0[\exp\left(\frac{qIR_S}{nKT}\right) - 1] \quad (4)$$

The fill factor is defined as the equation(5).

$$FF = (V_m \times I_m) / (V_{OC} \times I_{SC}) \quad (5)$$

where, V_m is the maximum output voltage and I_m is the maximum output current. The energy transformation efficiency of the solar cell is the value of dividing the maximum electric energy obtained from the solar cell by radiation energy. Its value is as follows.

$$\eta = \frac{V_m \times I_m}{P_{in}} = \frac{V_{OC} \times I_{SC}}{P_{in}} \times FF \quad (6)$$

where, P_{in} is the photovoltaic energy radiated.

2.3 The characteristic of solar cell temperature

Because the solar system installed in the buoy with transparency PVC(thickness-3mm).

In the sun, the buoy grew up temperature. From photovoltaic module, the optimum voltage of compensated and uncompensated temperature equation shown as follow.

2.3.1 Compensated temperature

$$V_m(t) = V_m \times [1 + \dot{\gamma}(t-25) - \dot{\delta}(100-L)] \quad (7)$$

V_m : Optimum voltage at the standard condition [V]

$V_m(t)$: Optimum voltage at the optional test condition [V]

$\dot{\gamma}$: Temperature coefficient of optimum voltage (-0.00462/℃)

$\dot{\delta}$: Irradiance coefficient of optimum voltage 0.000094 / (㎽/㎠)

α : Duty ratio

$\alpha = \frac{V_m(t) - V_i}{V_m(t)}$ (V_i : Output voltage of solar cell [V])

t : Temperature(effected by transducer compensate)

$t = ((V_0 - 1) \times (140/4)) - 40$ (V_0 : Output voltage transducer)

2.3.2 Uncompensated temperature

$$V_m(t) = V_m \times [1 + \dot{\gamma}(t-25) - \dot{\delta}(100-L)] \quad (8)$$

t : Atmosphere temperature

The main characteristics of a photovoltaic module used in the field are as indicated below :

Open circuit voltage	: 20 [V]
Short circuit current	: 600 [mA]
Voltage at load	: 18 [V]
Current at load	: 550 [mA]
Maximum power	: 12 [W]

Fig. 3 is showed maximum output power with insolation and temperature.

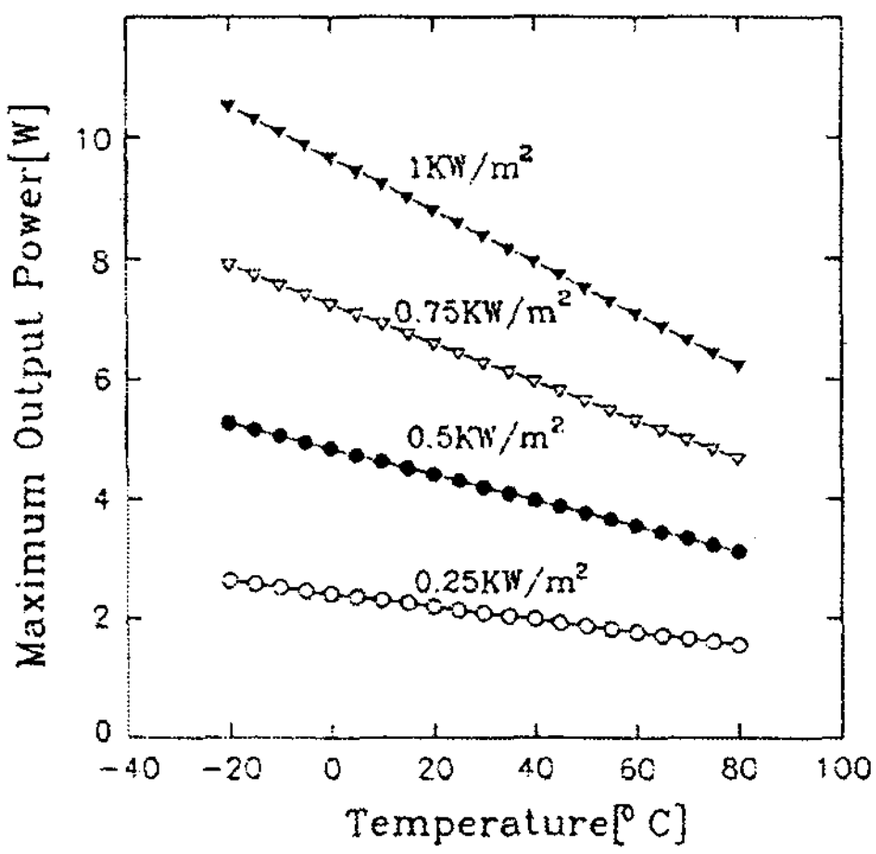


Fig. 3. is represent temperature characteristic with solar cell

3. Principal of Communication

The coding method of basically digital information is that NRZ(Non Return to Zero) method regulates constant voltage during 1 bit. The main technical of NRZ communication are positive voltage compare to bit value 1 and negative voltage compare to bit value 0. The advantage of NRZ method is easy to realize. And disadvantage of it has problem to discriminate the starting and ending parts of from one to one bit. The relation equation of NRZ is represented as follow.

$$S_1(t) = \begin{cases} A : -\frac{T}{2} \le t \le \frac{T}{2} \\ 0 : \text{otherwise} \end{cases} \quad (9\text{-a})$$

$$S_2(t) = \begin{cases} -A : -\frac{T}{2} \le t \le \frac{T}{2} \\ 0 : \text{otherwise} \end{cases} \quad (9\text{-b})$$

And then the signal S_1, S_2 are used to recognize the ID(Identification).

4. Configuration of the Controller System

4.1 The inner structure of one-chip microprocessor (PIC)

The inner parts of PIC16C57 are divided into CPU, EPROM, RAM, I/O and Counter unit. CPU which is composed of ALU, INSTRUCTION DECODER and REGISTER is the main part reading the instructions from EPROM and performing them. PIC16C74 has ALU of 8 bits and working registry inside as shown in Fig. 4. In Other processors, working registry called by accumulator operates as a main part in all arithmetics. The data for the voltage of water alarm system go to the working registry, to be calculated, and the results are written to data memory. At this time arithmetic and logic algorithms influence only 3 flags which are CARRY, DIGIT CARRY and ZERO located in STATUS

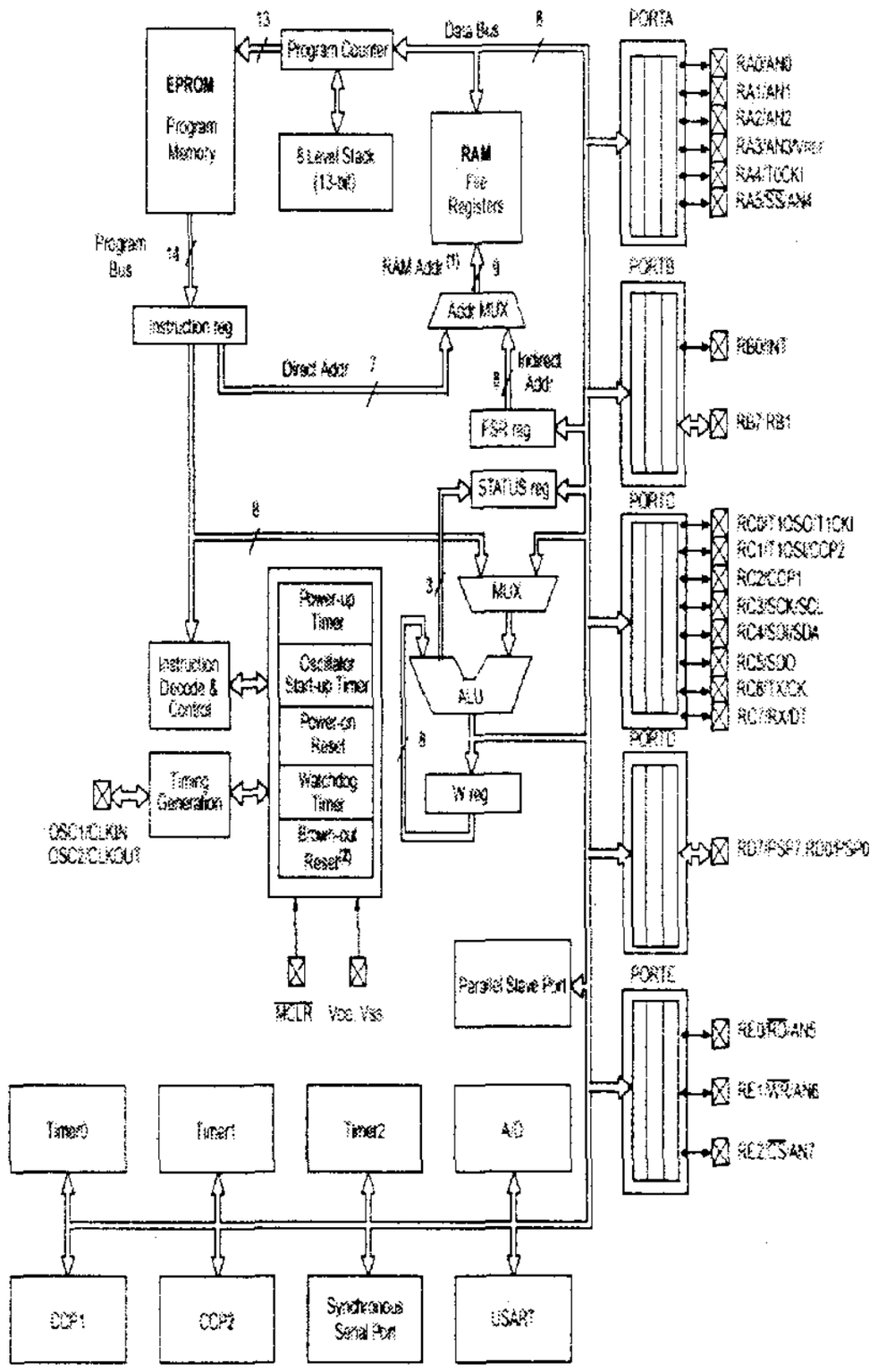


Fig. 4. The block diagram of PIC

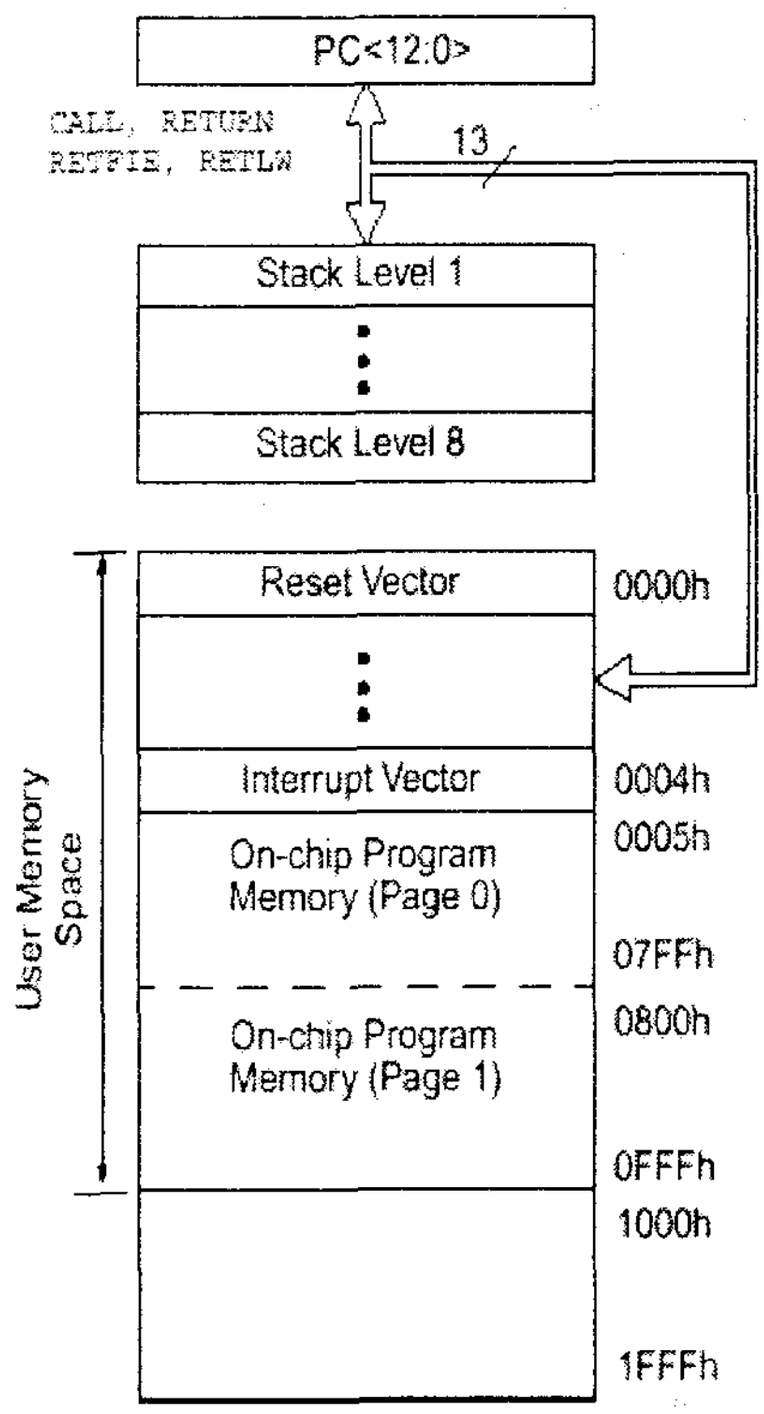


Fig. 5. structure of program memory

registry. Fig. 4 shows this principle mentioned above.

4.2 The structure of memory

PIC16C74 has the program memory of 4K word consisted of 14 bits inside as shown in Fig. 5. To address this program memory PC is composed of 13 bits and 8 registries among STACK registry are composed of 13 bits, too.

4.3 Simulation of solar cell

The operation characteristics of the solar cell array (LG siltron, 18V, 600mA) applied In

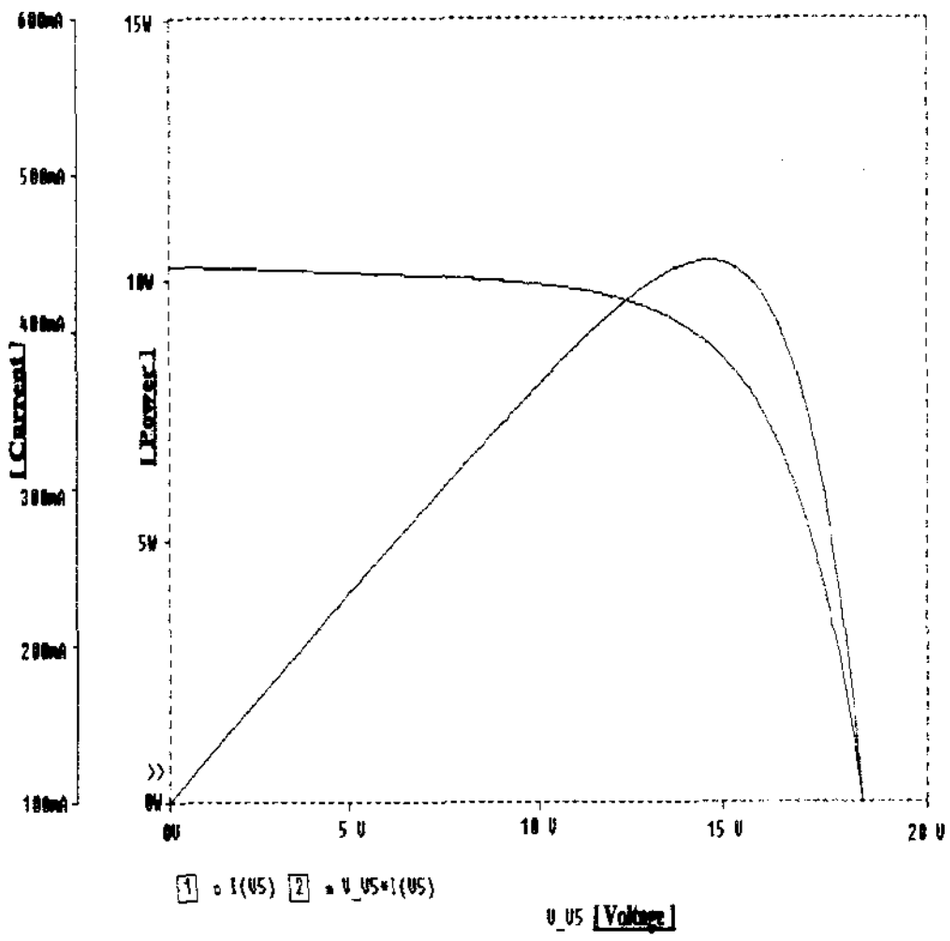


Fig. 6. The Characteristic curve of voltage-current and power of solar cell

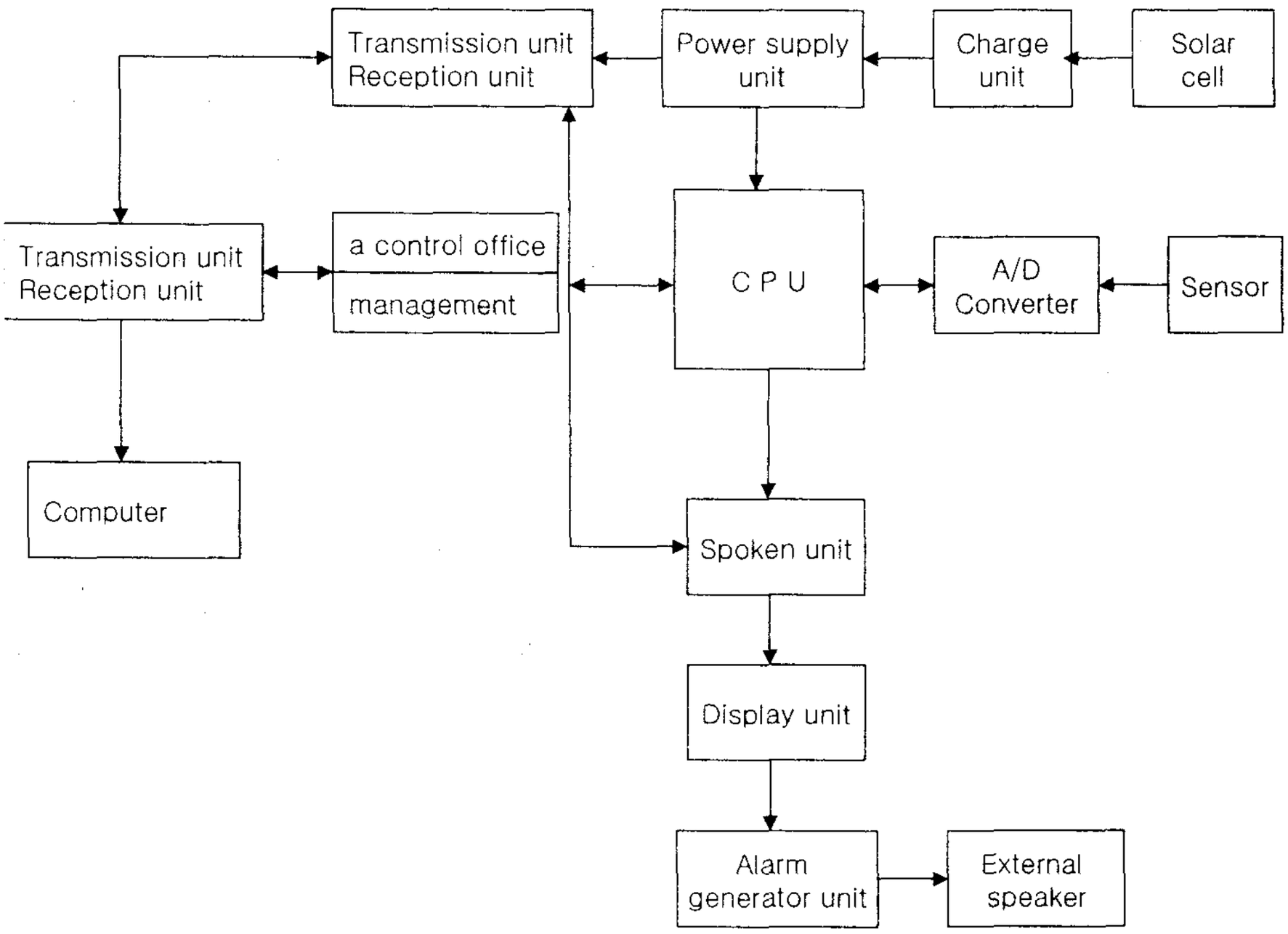


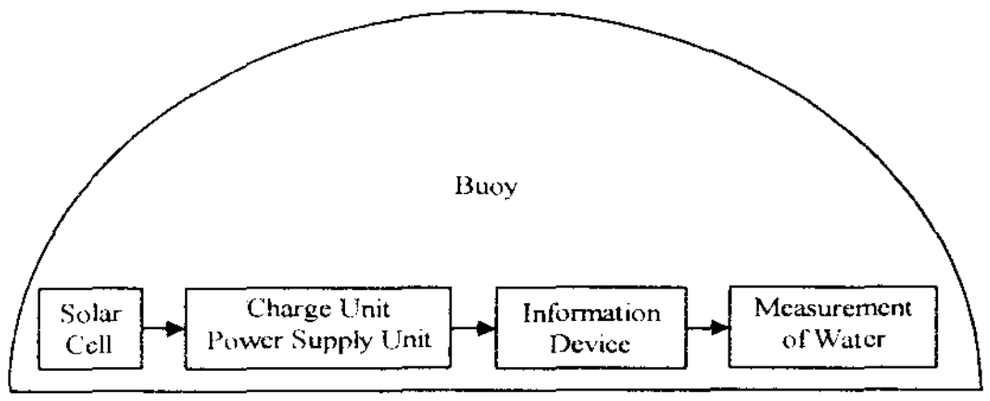
Fig. 7. The block diagram of water pollution alarm system

this experiment, the waveform of simulation on signal detection and that of actual experiment are shown in Fig. 6.

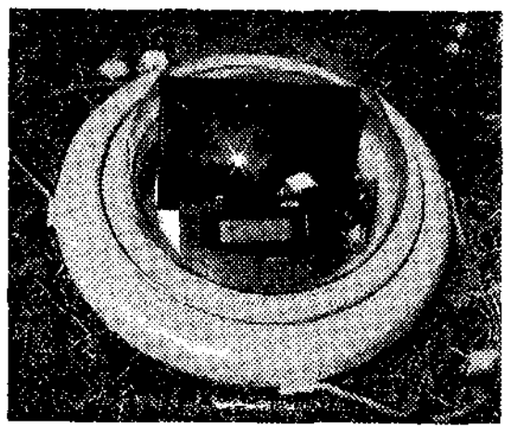
5. Experimental and discussion

5.1 Water pollution alarm system

The block diagram of water pollution alarm system is shown in Fig. 7. The buoy of water quality alarm system is supposed to be installed on the surface of water and the informative device transmits data to inspectors and offices through wire or wireless communication. The power supply driving this system, charge unit, and an instrument measuring the quality of water consist of the system.



(a) Diagram of this system



(b) Appearance

Fig. 8. The diagram of this system and appearance

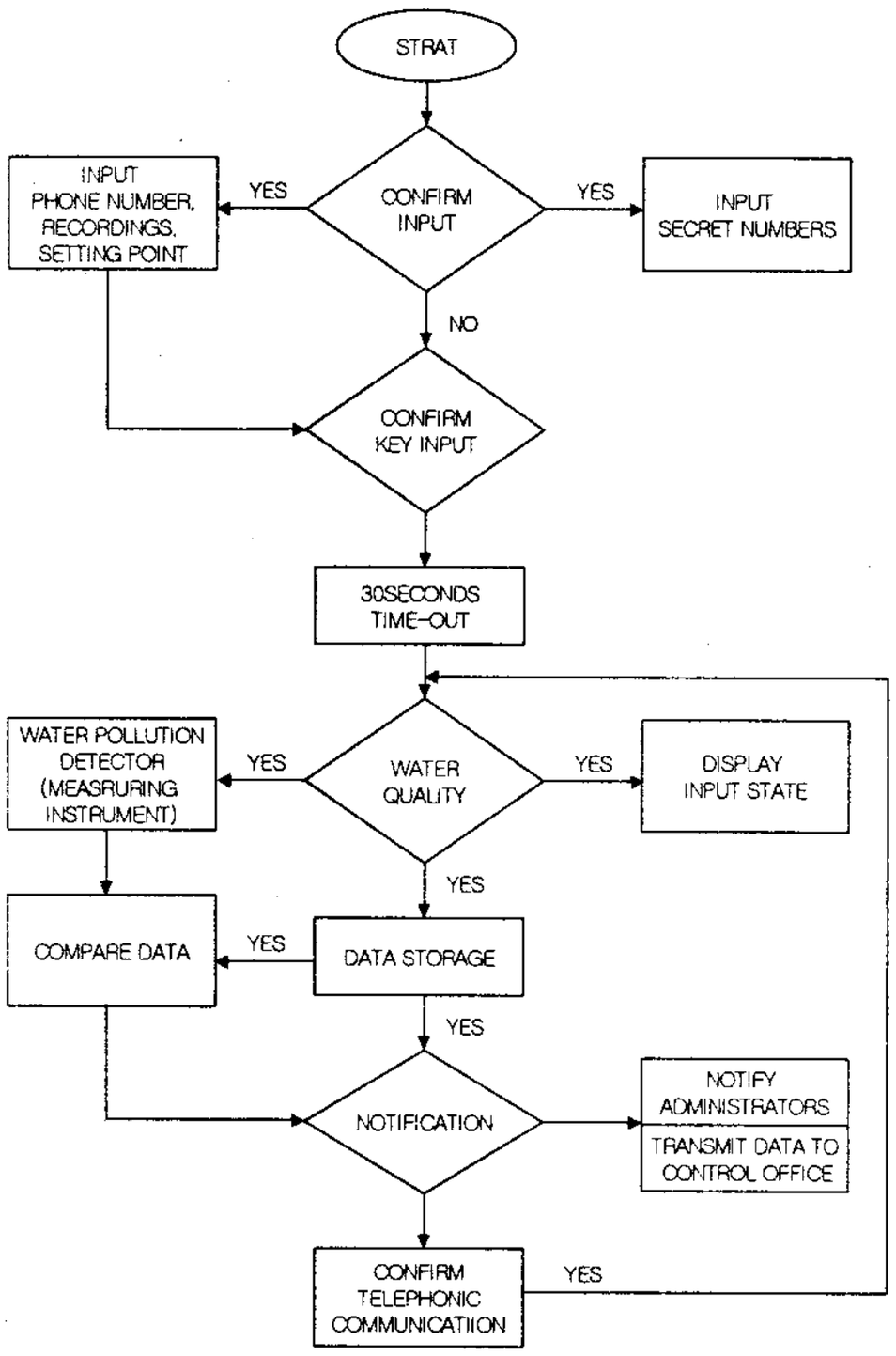


Fig. 9. The operation flowchart

Fig. 8 presents the composition of the water pollution alarm used in this paper. The buoy of this alarm system is supposed to be installed on the surface of water and data transmission is achieved through wire or radio. This system consists of the device, informing the quality of water to the managers at the inspection office, power supply unit, and charge unit and measuring devices.

The operation flowchart of the whole system is shown in Fig. 9. The system operates in 30 seconds after setting value is input. The measuring instruments compares measuring value to setting value and then informs the degree of water pollution to the inspection office in audio automatically.

5.2 The composition of the charge circuit system with solar cells

The composition of the charge circuit with

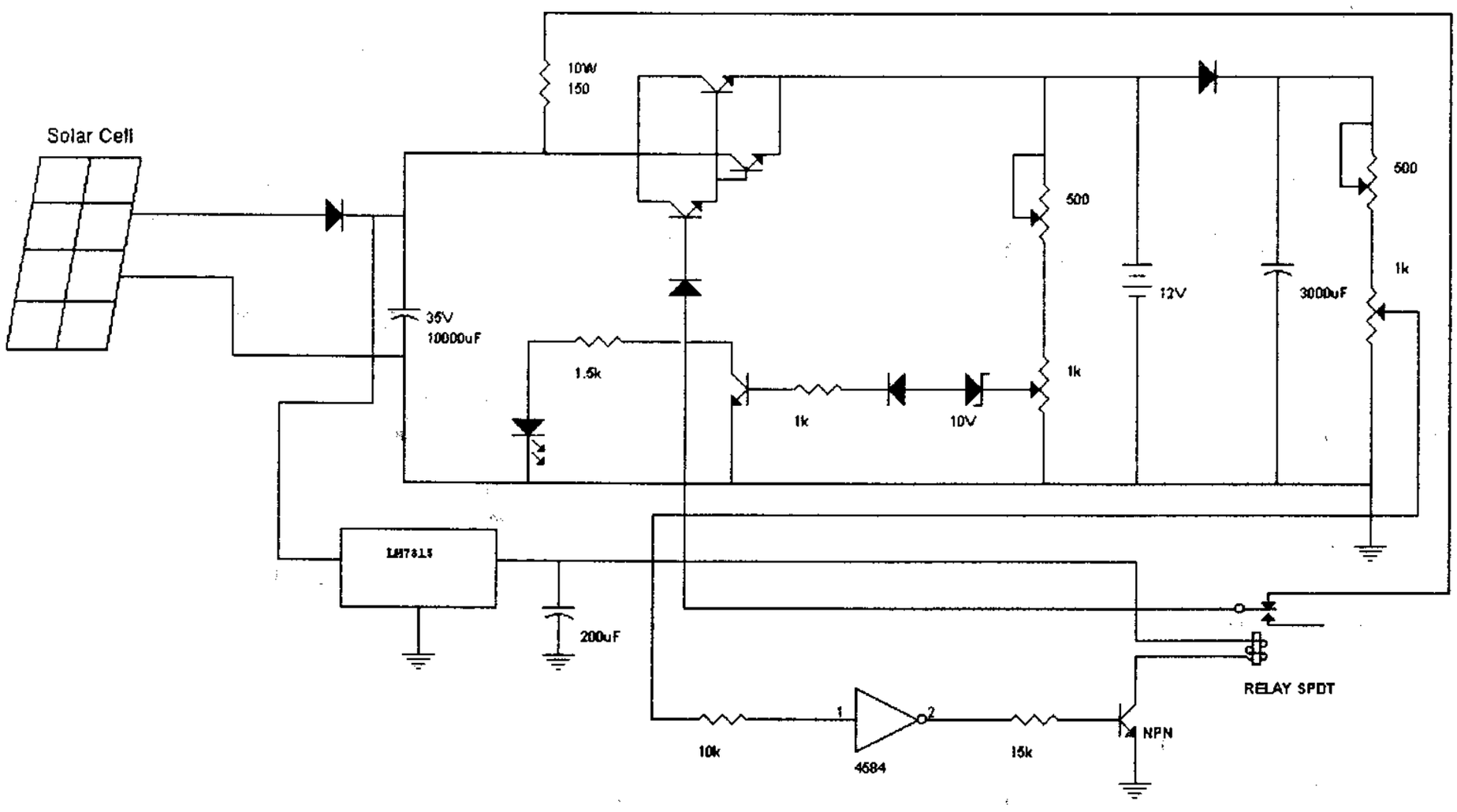
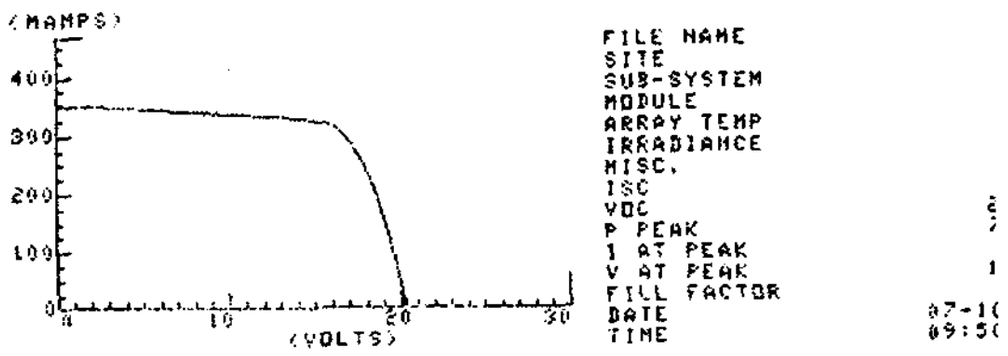
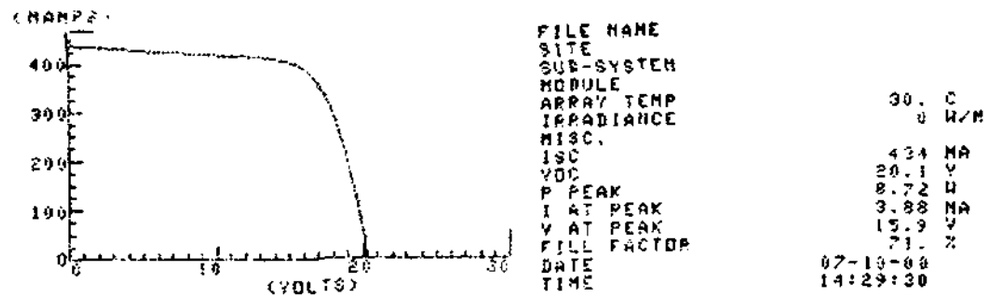


Fig. 10. Composition of the charge circuit system with solar cells



(a) AM



(b) PM

Fig. 11. The characteristic of voltage and current with solar cell

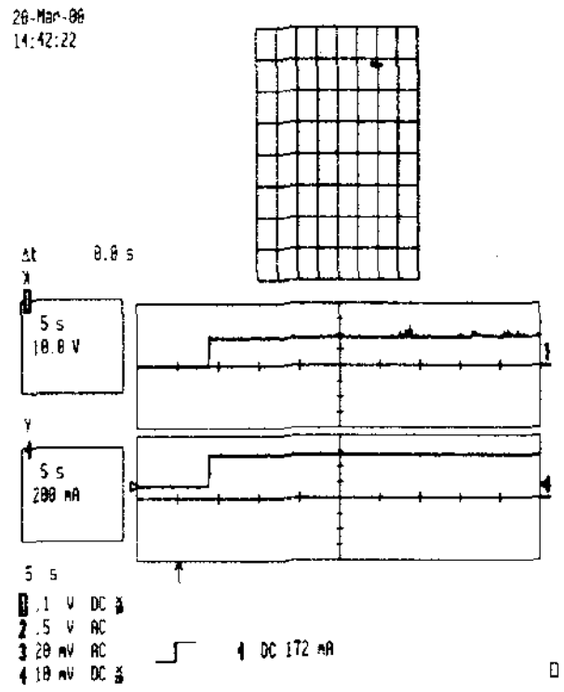
solar cells is shown in Fig. 10. The system in this paper consists of solar cell array(LG Siltron, 18V, 600(mA) 24cm×38cm), storage batteries(FNC 1240, 12V, 2.4AH), storage circuit unit, and on-and-off circuit unit. The LED(2V, 15mA) with high brightness was used as a load-operating identifying signal with at night.

Fig. 11 is showed the characteristic voltage and current with solar cell temperature. The solar cell power is increase at the P.M point.

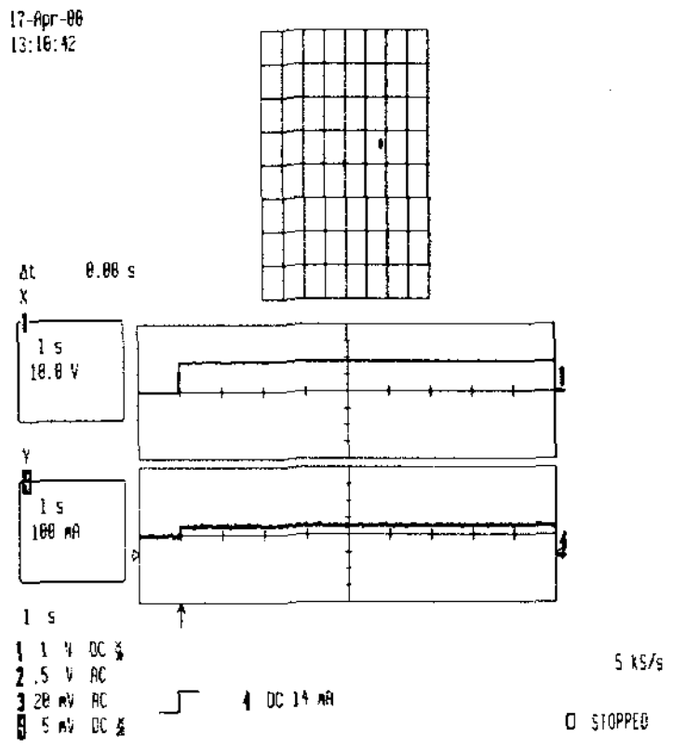
The buoy of this alarm system of the buoy of alarm system are presented the power track point(top), voltage(middle), current (below) with Fig. 12.

Regardless of time, alarm system was operated according to the amount of sunlight.

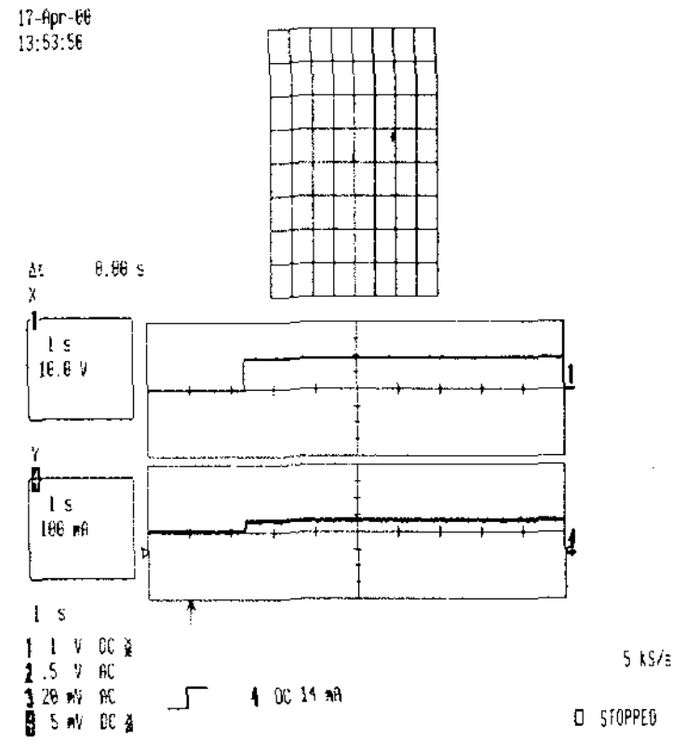
As Fig. 13, the top and down waveforms have represented input of RF module output waveform. The buoy operating signal turns on to right or not ID.



(a) The voltage and current from solar cell when sunny



(b) The voltage and current from solar cell when cloudy



(c) The voltage and current from solar cell with load of 5Ω when cloudy

Fig. 12. The experimental waves of PV module for the buoy of alarm system

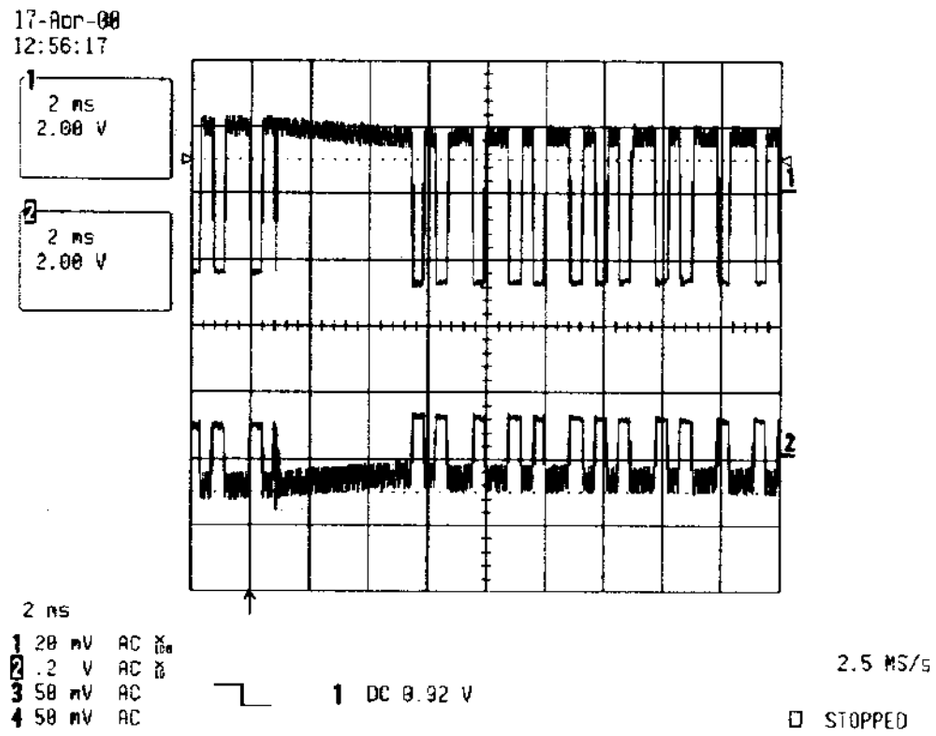


Fig. 13. The output waves of buoy RF sensor

The alarm system of water pollution described in this paper checks the ion density (PH), Dissolved Oxygen(DO) and the temperature of water by using the water pollution measuring instrument being sold at EASTEC and then if they exceeds the limit, informing system works and lets the managers at the inspection office know what happens. Fig. 14 is represented the controller of Water Pollution Alarm System.

6. Conclusion

This study is about working out the problems of conventional measuring and informing system of water pollution by designing this system described above with solar cells and PIC. The expectant effects are as follows. First, it is possible for the managers to deal with the matters happen promptly. Second, it can reduce personnel expenses. At last it is easy to set up anywhere water, we think, is polluted seriously. In the future, we are going to concentrate on the monitoring with a computer in order to supervise the state of water pollution from remote control offices in wireless communication.

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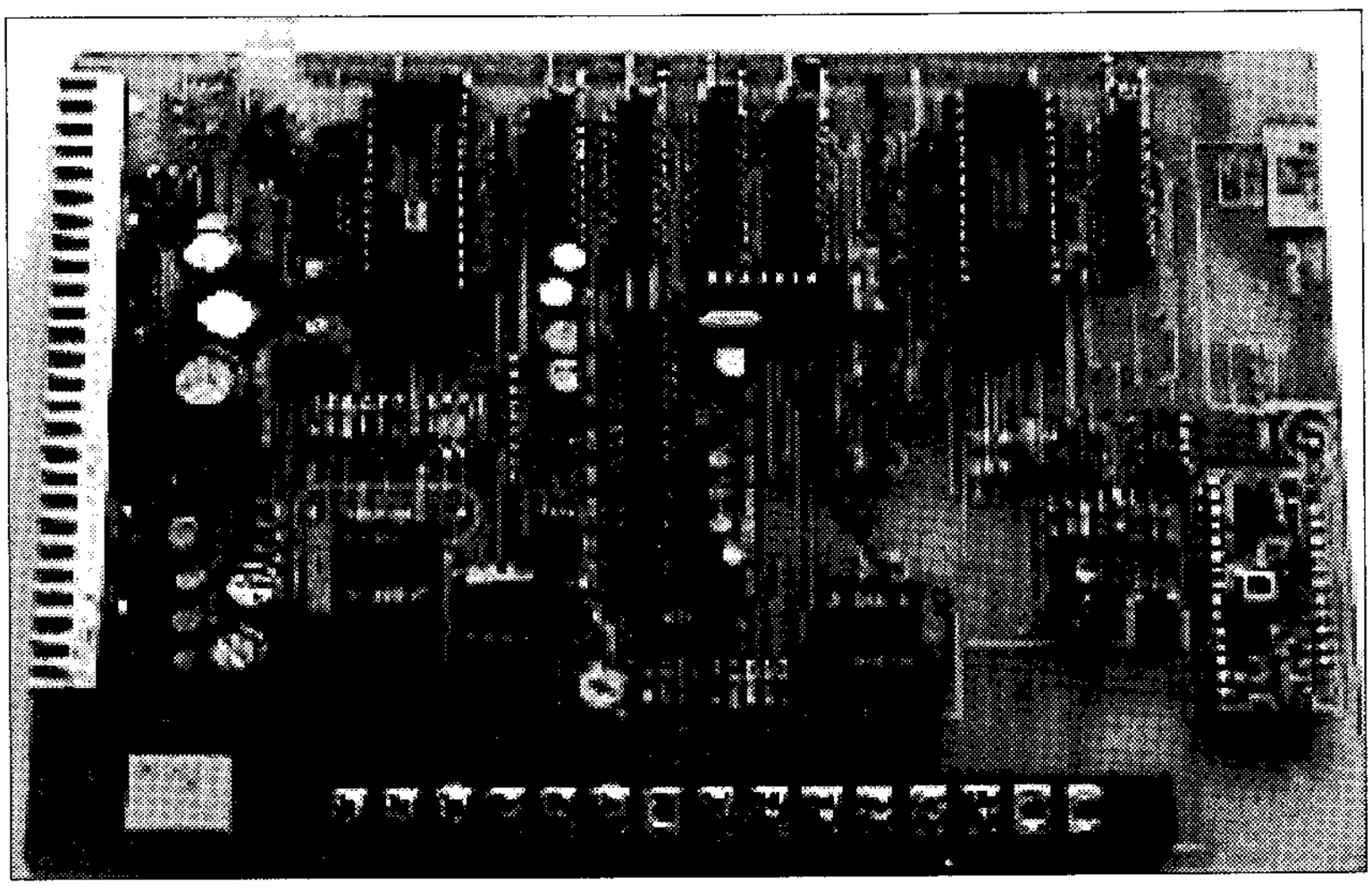

Fig. 14. The main controller PCB board

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