DEVELOPMENT OF A MODULAR ENVIRONMENT MONITORING SYSTEM FOR GREENHOUSE

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ABSTRACT

In Korean agriculture, an automatic environment control system for greenhouse is essential to save labor and to increase the quality of products.

The existing environment monitoring systems have weighed on greenhouse growers and researchers because of their high cost and difficult applications.

Many sensors are widely used for monitoring the greenhouse environment, but most of commercial sensors are expensive and not suitable for use in greenhouses. Thus, the development of an environment monitoring system for exclusive use in greenhouses is essential.

The objective of this study was to develop modular environment monitoring systems, which are low-cost, reliable and easy-to-use.

The results showed that the sensors for indoor and outdoor environments and nutrient solution had the ranges and accuracies appropriate for use in greenhouses. Also the modular environment systems developed showed a satisfactory performance in terms of stability and reliability in the measurement and acquisition of the greenhouse environment data.

Key Word : Environment control system, Greernhouse, Monitoring system

INTRODUCTION

In greenhouse, an automatic environment control system is essential to save labor and to increase the quality of products. An environment control system for greenhouse consists of environment monitoring system and driving systems with various controllers and actuators.

The existing environment monitoring systems have weighed on greenhouse growers because of their high cost and difficult applications. Also in order to analyze the relation between environment data and plant growth, an environment monitoring system for exclusive use in greenhouse is essential.

The objectives of this study were to develop low-cost and inexpensive sensors which are adequate in greenhouses, and to develop modular monitoring systems which are suitable for data acquisition and communication with host computer and for stepwise extension of environment monitoring systems.

MATERIAL AND METHODS

Sensors

Temperature, humidity and light-intensity sensors A semiconductor temperature sensor was developed. The principle is that the voltage between the base and the emitter of transistor changes with temperature. Since the output of sensor is the current(μA) proportional to absolute temperature(K), a circuit for signal conditioning circuit could designed.

An electrical-resistance humidity sensor was developed. This sensor was made of gold electrodes on ceramic base and porous polymer layer, whose electric conductivity changes with humidity. The sensitivity, reliability and durability of this type of humidity sensor are excellent.

A photo-diode light-intensity sensor was developed. The linearity between incident light intensity and output current, the response and reliability are excellent. The dark current, output variation, and temperature coefficient are relatively small.

Fig 1 shows the shape of the temperature sensor developed, and the relative humidity and light intensity sensors developed also have the similar shape.

Wind direction, wind velocity and rainfall sensors A wind direction sensor using conductive plastic potentiometer was developed.

A wind velocity sensor which generates pulses proportional to wind velocity was developed. The sensor generates pulses by the reed switch as the magnet rotates.

A rainfall sensor which collects rain in a bottle cell and generates pulses was developed. Every time when the bottle cell is filled with rainfall, the sensor generates one pulse. The smaller the bottle cell, the more accurately the rainfall can be measured.

Fig. 2 shows a photograph of the sensors for wind direction, wind velocity and rainfall developed.

Nutrient solution sensors The acidity(pH) of nutrient solution is the H+ ion concentration and it is used as a criterion which determines if the solution is acid or alkaline. A glass-polarity acidity sensor, which has a good time response and can easily be connected to electronic circuits, was developed.

The electrical conductivity(EC) is widely used as an index which estimates the content of various nutrients in the nutrient solution. A 4-ring polarity EC sensor, which generates alternating current to two outer polarities, was developed. The voltage drop across the two inner polarities was measured.

In order to measure the dissolved oxygen (DO) in nutrient solution, a galvanic-cell DO sensor was developed. The galvanic-cell sensor produces current proportional to oxygen concentration in nutrient solution.

Fig. 3 shows a photograph of the nutrient solution sensors.

Environment Monitoring System

Modular monitoring subsystems Fig. 4 shows the block diagram of the environment monitoring system consisted of the sensors and modular monitoring subsystems. The modular monitoring subsystems were developed using one-chip microcomputers(MC6805) for monitoring data from the sensors. The one-chip microcomputers used in this study have an A/D converter, digital input and output ports.

In order to have standard RS-232C communication with the main computer, digital output ports in the microcomputers were used and a UART IC(MC6850) circuit was added.

Modular subsystems carry out the function of monitoring with four seven-segment LEDs and four pilot LEDs which are used to display the selection of measurand.

Software for the modular environment subsystems was programmed with an assembly language appropriate for the one-chip microcomputers. The software consists of the subroutines for initialization, key-in, mode-change, measuring, monitoring and communication.

Fig. 5 shows the flow chart of the algorithm of measuring, displaying and communicating data for the modular monitoring subsystems.

Integrated environment monitoring system The modular monitoring subsystems with the sensors for indoor and outdoor environments and nutrient solution were connected to a main computer to make an integrated environment monitoring system.

In order to collect, display and analyze all data from modular monitoring subsystems, the main computer program was developed using high level language 'C'. The software has the functions of data collecting, saving, graph drawing, data analyzing and communicating with monitoring subsystems.

Because the main computer(IBM PC compatible) used in this study, has four serial ports for multiple RS-232C communication, the software for multiple communication was also developed.

Fig. 6 shows a photograph of the integrated environment monitoring system which consists of the sensors and modular monitoring subsystems for greenhouse application.

Performance Test The performance tests on the sensors and modular monitoring subsystems developed were carried out. The sensors and modular subsystem for the indoor environment were tested in a constant temperature-and-humity chamber and in a greenhouse for the period of one month.

The wind direction and wind velocity sensors for the outdoor environment were tested in a simple wind tunnel made for this study, and the rainfall sensor was tested with simulated rainfall.

The sensors for nutrient solution were tested with the standard solutions made for this study.

RESULTS

The results of the evaluation tests on the sensors and modular monitoring subsystems developed were satisfactory in terms of range and accuracy for greenhous applications as shown in Table 1.

Modular environment monitoring subsystesms were convenient for the extension of the environment monitoring system according to the need of the greenhouse growers since they were independent of each other.

The integrated environment monitoring system including RS232C communication between modular monitoring subsystems and main computer also functioned well as expected. Fig. 7 shows a sample CRT display of the measured data at an instant of time.

CONCLUSIONS

Sensors necessary for monitoring the indoor and outdoor environments and nutrient solution were developed. And modular environment subsystems for collecting and displaying data, and communicating with the main computer were also developed.

The sensors and modular monitoring subsystems developed showed satisfactory performance in terms of measuring range, accuracy and reliability.

The integrated environmental monitoring system including communication between modular subsystems and main computer functioned as well.

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Table 1. Performance of the environmental monitoring system developed.

Sensors		Range	Accuracy	Output Signal
Indoor environment	Temperature	-10 ~ +50℃	< ± 0.2℃	4~20mA
	Relative Humidity	10 ~ 90%RH	< ± 3 %RH	4~20mA
	Light Intensity	0 ~ 2000 μ mol/m^{2}s	< ± 45 μ mol/m^{2}s	4~20mA
Outdoor environment	Wind Direction	0 ~ 360°	< ± 6°	0 ~ 5V DC
	Wind Velocity	0.7 ~ 10.0 m/s	< ± 0.65 m/s	pulse signal
	Rainfall	3 mm ~	< ± 0.3 mm	pulse signal
Nutrient Solution	Acidity(pH)	1 ~ 14 pH	< ± 0.2 pH	4~20mA
	Elec. Conductivity	0 ~20 mS/cm	< ± 0.1 mS/cm	4~20mA
	Dissolved Oxygen	0 ~ 20 ppm	< ± 0.5 ppm	4~20mA

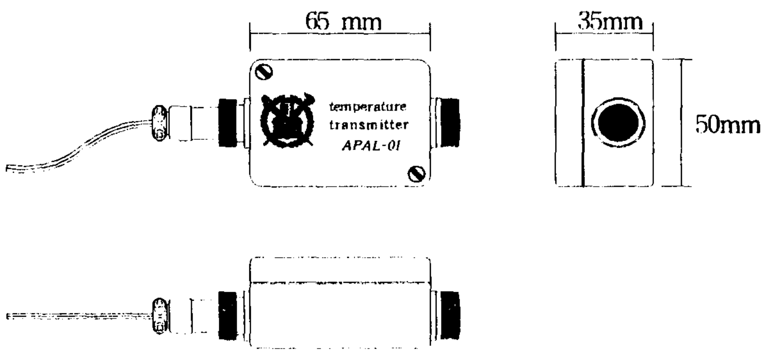

Fig. 1 Temperature sensor developed.

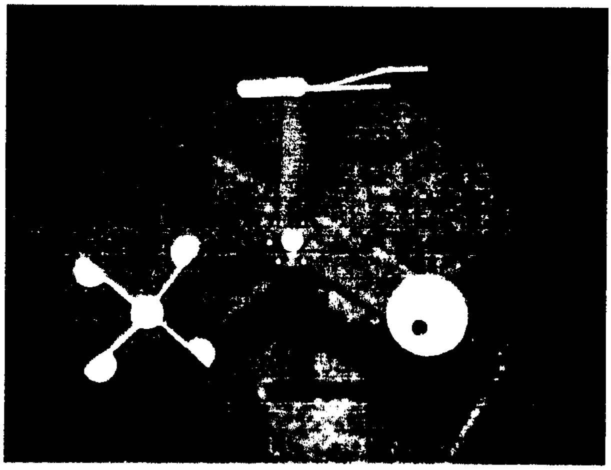

Fig. 2 Sesors of wind direction, wind velocity and rainfall developed.

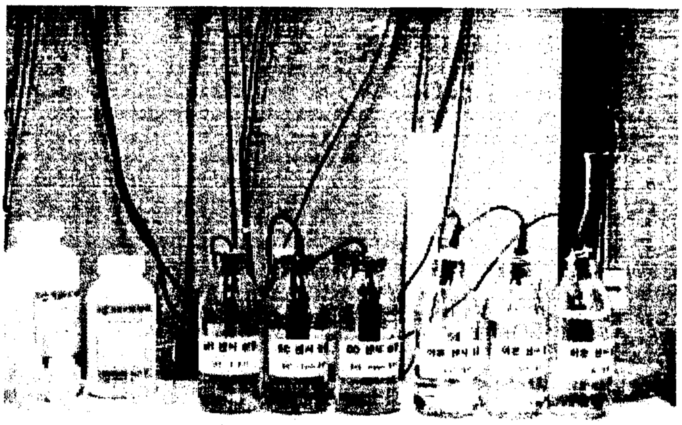

Fig. 3 Nutrient solution sensors.

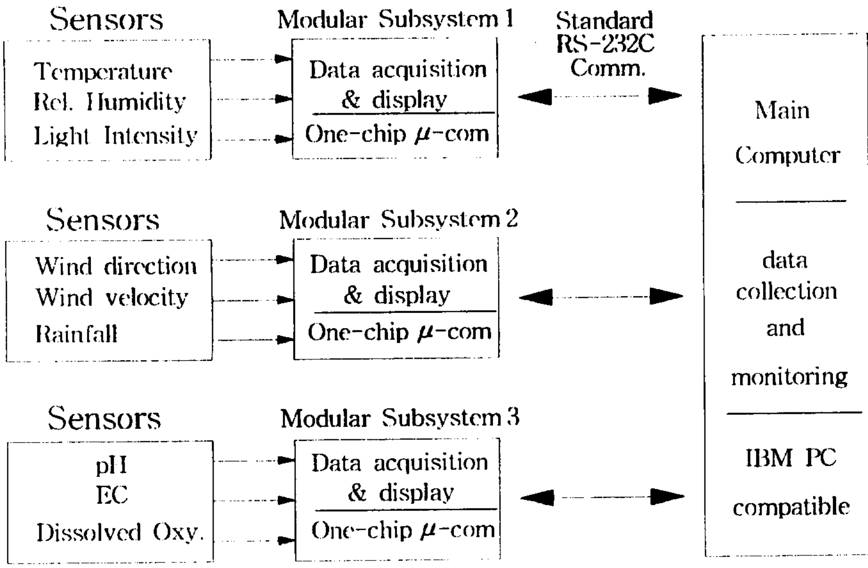

Fig. 4. Block diagram of the environemental monitoring system.

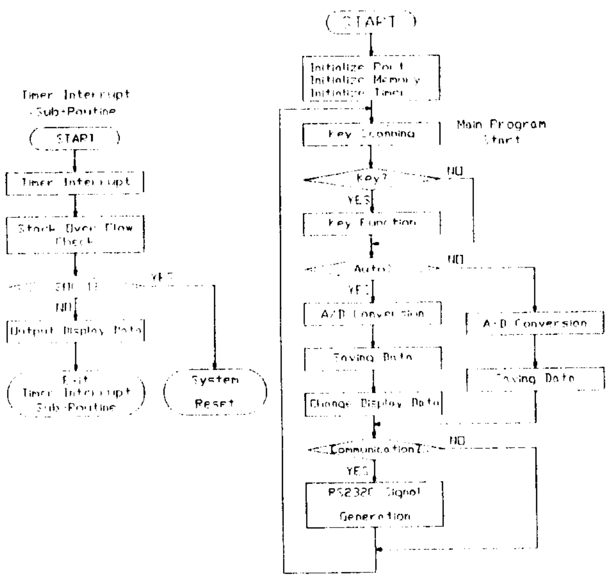

Fig. 5 Flow chart of the algorithm of measuring, displaying and communicating data for the modular subsystems.

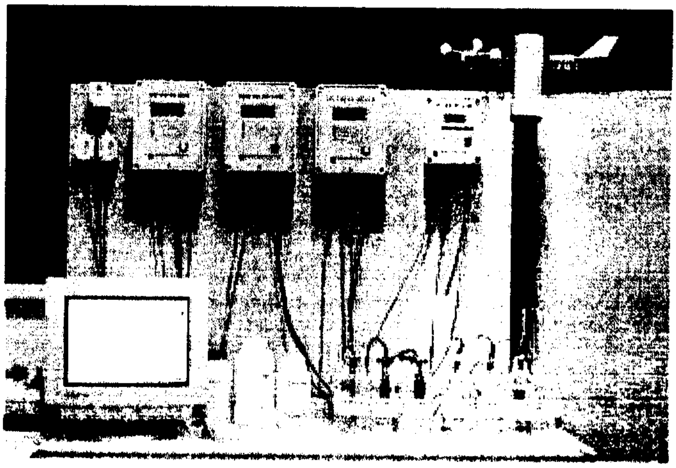

Fig. 6. Integrated environmantal monitoring system developed.

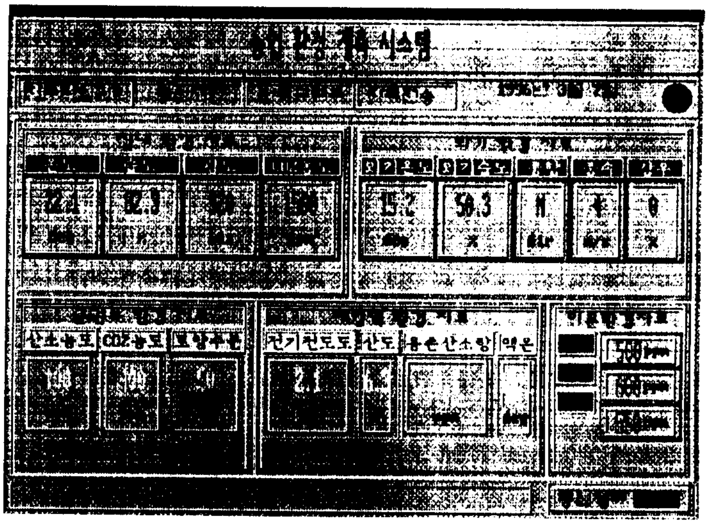

Fig. 7 A CRT display of the integrated environmental monitoring system.