Food Engineering Progress
Vol. 8, No. 2. pp. 135~140 (2004.5)

연구노트

Development of Multi-purpose Agricultural Controller and Its Operation Program

S. H. Kwon, Y. K. Chang and J. K. Chun
Department of Food Science and Technology, Seoul National University

Abstract

A controller for the automation of agricultural and food processes was designed with an 8 bit microcontroller, TMS73C161, and it was fabricated with three printed circuit boards (PCB); main, display and actuator PCB. The controller provided multiple functions to perform measurements of process variables (temperature, humidity, and illumination), and display and control them through 7-segment LED and 10 actuator relays. The operation program of the controller was developed to carry out real time monitoring and perform both stand alone and local control modes. It consisted of several subroutines to perform diverse applications. The multi-purpose controller was installed to a crop-culturing greenhouse in the field, and its performance successfully tested, including data acquisition, automatic environmental control and the real time monitoring of the green house system state.

Key words: process controller, circuitry design, real time monitoring, green house, automation

Introduction

Automation is an essential technology that allows food processors to improve their competitiveness, particularly in rural communities with severe labor shortages. In practice, communities have experienced several difficulties with process automation that need to be resolved, these being technological support and the high cost of installation. Many attempts have been made by several workers to design food process controllers using a microcontroller containing a CPU, ADC and numerous I/O ports in a single chip (Jun and Chun, 1992, 2000; Kim and Chun, 1993). The installation costs of automation devices have been reduced by the use of simplified food process controllers. Cho (1993) successfully applied the simplified food process a controller to a small scale greenhouse for the automation of environment control and the application of chemicals in a greenhouse. Furthermore, the controller could be operated in the stand alone state, with its own operation program residing within its programmable ROM, and it was used to acquire environmental variables, such as temperature, humidity and light intensity. Thus, the feasibility of versatile applications of the process controllers based on microcontroller technology are high in the fields of agricultural and food processing.

In order to enhance the economic feasibility of the controller, an improved controller, equipped with multi-purpose functions, is needed for its application to various processes and systems in rural communities, such as drying, crop cultivation, food fermentation, rice cake and storage systems for agricultural commodity.

The maintenance of an automation system is another bottle neck in the practice of automation, particularly in rural area where technical maintenance systems are rare. Therefore, our aim was to design a multi-purpose agricultural process controller, with practical and economical strengths. The object of this work was to manufacture a Printed Circuit Board (PCB) capable of being replaced with a new one should functional failure occur in the field. Attempts were also made to develop a transferable operation program able to be moved between applications.

Corresponding author: Jae-Kun Chun, Professor, Department of Food Science and Technology, School of Agricultural Biotechnology College of Agriculture and Life Sciences Seoul National University, San 56-1, Sinlim9-dong, Kwanak-gu, Seoul, Republic of Korea.
Phone: 02-880-4851, Fax: 02-873-5095
E-mail: chunjae@snu.ac.kr

Materials and Methods

Microcontroller chip and major electronic parts

The major components used in the design of the controller were a microcontroller, TMS73C161 (Texas Instrument, USA), MC6850 (communication chips, Motorola., USA), MAX232 (RS232C level driver, Maxim, USA), ADG506A (multiplexer, Analog Devices., USA), 30825F (relay, Matsushita. Japan) and GP1U50 (infrared receiver, Sony, Japan).

Sensors

A thermistor (1 kΩ, -20~60 ± 0.5°C, Dong-Kwang Electronics, Korea) and humidity sensor (SY-HS-200, Hybrid type, 990~2940 mV, 30~90 ± 1% RH, Sam-Young Electronics, Korea) were used as the measurement probes for the temperature and humidity, respectively, and a silicon photodiode (330-730 nm, 0-2000 Lux, Model S1133, Hamamatsu Co., Japan) as the illumination sensor. The fabricated sensors were used after calibration, according to the method of Jun and Chuns (2000).

Design tools of circuitry and PCB

An OrCAD R3.02 (OrCAD System, USA) and CADSTAR 386 V 7.3 (RACAL REDAC, U.K.) were the design tools for the circuit and Printed Circuit Board, respectively.

Programming tools

An emulator adaptor board (Young Tec., Korea) was used, along with a piggy back, to develop the operation program of the controller. C language was used to develop the programs of the monitoring computer. A bi-directional communication program between the monitoring computer and the controller, developed by Choi and Chun (1996), was used with a minor modification.

Results and Discussion

Design of the measurement modules

The circuitries of the measuring modules were designed using the above mentioned sensors, similarly to the method of Jun and Chun (2000). The circuits for the humidity and light measurements were designed according to the method of Cho (1993). The temperature measuring module was modified to a multiplex with 16 temperature probes.

Developing of multi-purpose controller circuit

Port allocation of TMS73C161

For the design of the controller, the microcontroller should be interfaced with various external devices, such as sensors, keys, relays and so on, as listed in Table 1.

The circuitry of the allocated port for the controller is schematically shown in Fig. 1.

Table 1. The hardware devices to be interfaced by the microcontroller, and the number of In/Output bits allocated, with their electrical properties

Function	Device	Number of bit or port required	Specification
	Temperature	16 analog channels	1kΩ, -20~60 ± 0.5
Measurement sensor	Humidity	1 analog channel	990~2940mV, 30~90 ± 1% RH
	Photoenergy	1 analog channel	0-2000Lux, 330-730nm,
Analog input	Multiplexer	4 digital inputs	High/low logic
Communication	RS232C	11 digital in/outputs	High/low logic
Display	LED	14 outputs	High/low logic
Actuator	Relay	10 outputs	High/low logic
IR Receiver	Remote control	1 interrupt	High/low logic
Key Input	Toggle Key	1 digital input	High/low logic
Alarm buzzer	Buzzer	1 digital output	High/low logic
Detection of Power failure	AC electric source	1 digital input	High/low logic

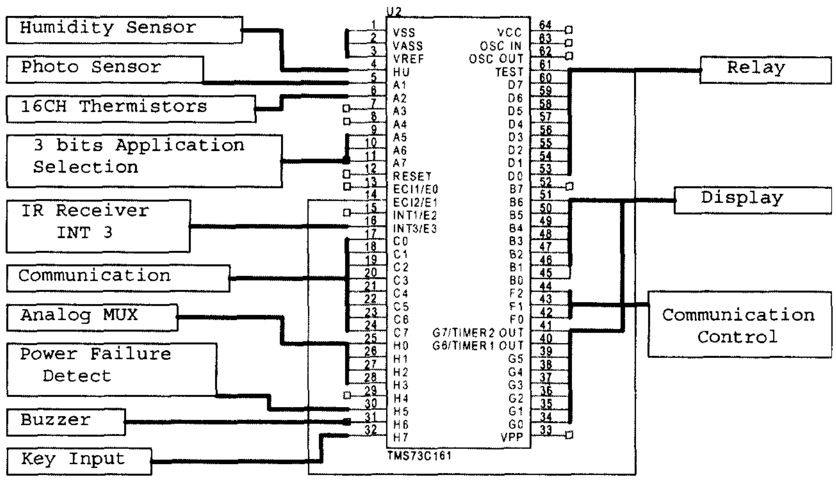


Fig. 1. The schematic port-allocation of the microcontroller for the multi-purpose agricultural controller.

The majority of the design was principally similar to that of the simplified food process controller developed by Jun and Chun (2000). However, in this work an infra red (IR)-remote controller was included to carry out the remote control of several hazardous operations, such as application of chemicals inside the greenhouse through the wireless remote IR communication. The multiplexer was implemented in the temperature measuring circuit to carry out a selective multi-channel measurement.

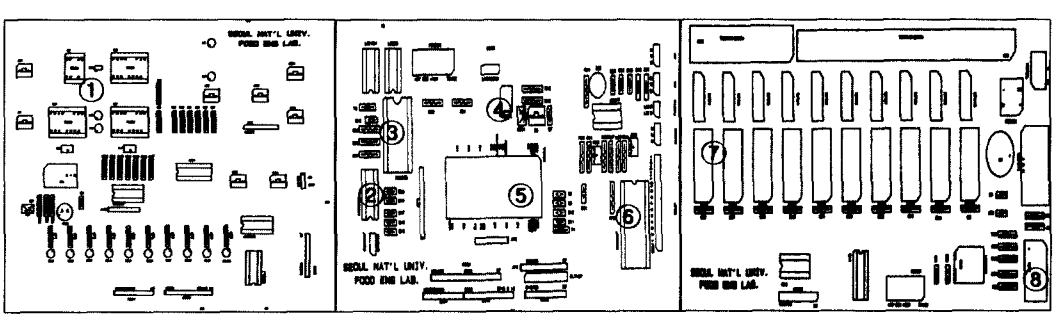
In addition, the controller was designed to use a 3-bit dip switch to select one of the eight different main routines. The agricultural multi-purpose controller could cover the measurement of environmental variables; establish the set point of process variables, control actuators and alarm of power failure. Thus, this controller could be applied to eight different purposes through the setting of the 3-bit dip switch or function selection switch.

Fabrication of the multi-purpose controller

For the practical application of the multi-purpose controller, the layout of the IC chips, including the microcontroller on the PCB, was designed as shown in Figure 3, Three PCB-layouts were the main, display and actuator PCBs, as shown in Fig. 2.

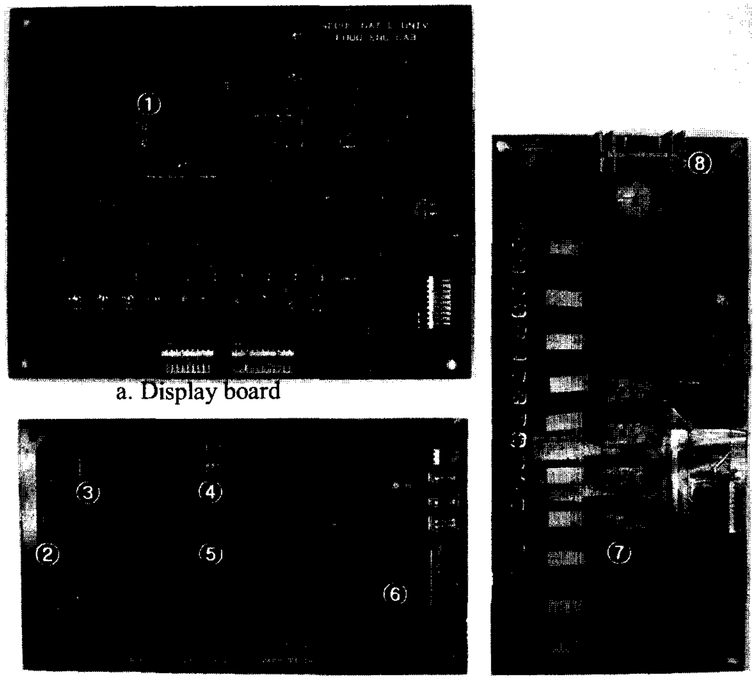
The pictures of the constructed controller PCBs are shown in Fig. 3.

The PCBs were connected using cables that can be replaced in case of malfunction in any one of the three boards. Accordingly, the technical maintenance problem in rural communities could be resolved with the replaceable spare boards.



a. Display board b. Main board. c. Actuator board

Fig. 2. The layouts of the Printed Circuit Boards of the multi-purpose agricultural controller. ① 7 segment LED ② MAX232 ③ MC6850 ④ 3-bits dip switch ⑤ TMS73C161 ⑥ ADG506A ⑦ relay module ⑧ battery backup



b. Main board c. Actuator board

Fig. 3. Pictures of the constructed controller, consisting of three PCBs. ① 7 segment LED ② MAX232 ③ MC6850 ④ 3-bits dip switch ⑤ TMS73C161 ⑦ ADG506A ⑧ relay module ⑨ battery backup.

Development of control program

The operation program for the multi-purpose controller was composed of one mainoperation program, which can select one of eight main routines, seven subroutines and three interrupt routines. In the selection of the main routine, the program could branch into one of the six main routines, according to the selected state of the dip switch; and thus, the multi-purpose functions were achieved. The overall flow chart of the controller program is shown in Fig. 4.

As indicated in the flow chart, seven subroutines and 3 interrupt routines were used within the main routine. The relevant program routines for the controller are listed in Table 2.

Development of monitoring program of the agricultural controller

To allow communication of the multi-purpose controller with a monitoring computer, a monitoring program was developed to access the control word of the 8250 UART and 8259 PIC using C language. One serial communica-

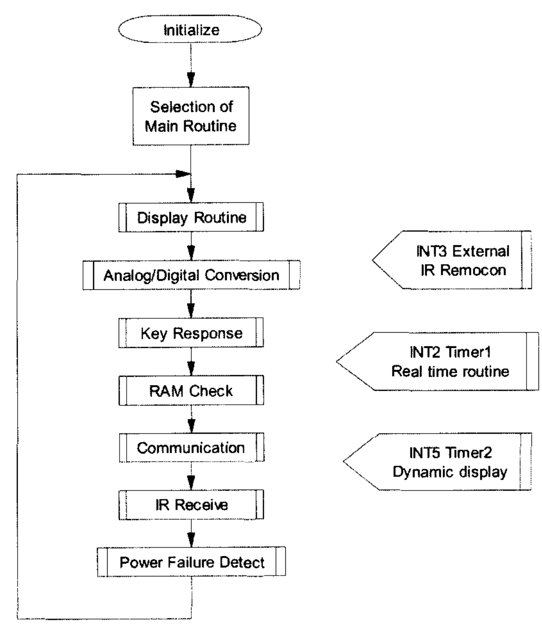


Fig. 4. The overall flow chart of the main program of the agricultural multi-purpose controller.

Table 2. Routines of the program, and their functions within the controller

Routines of Program	Functions
Initialization routine	RAM clear, SP set, port initialize
	Write initial value into RAM
	Initialize communication
	Read multipurpose data
Main routine #1	Mushroom cultivation
Main routine #2	Flower cultivation
Main routine #3	Soybean sprout culture
Main routine #4	Koji fermentation
Main routine #5	Rice cake process
Main routine #6	further application
Subroutines	
Display routine: Display of measured data and set point of control	
A/D conversion routine: A/D conversion of signal from sensors	
Control routine: Control of temperature, humidity and lightness	
Key response routine: Response to key input and branch to key table	
RAM check routine: Compare set value and relay status with previous state	
Infrared receive routine: Response to remote controller	
Power check routine: Detection of power failure	
Interrupt routines	
External interrupt 3: Receive signal from remote controller	
Internal interrupt 2: Real time clock, flag set for timer blink	
Internal interrupt 5: LED digit shift, 7 segment on/off key check	

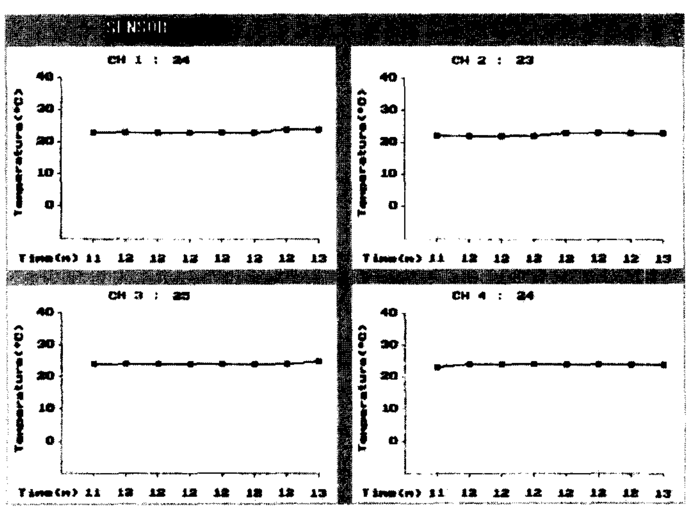


Fig. 5. The screen display of temperatures acquired from four measurement channels.

tion port (COM1) of a microcomputer was used for the bi-directional communication at a rate of 4800 bauds. The acquired data was displayed on the monitor screen of the microcomputer, and stored to the hard disk. The monitoring screen provided several icons for easy acknowledgment of the state of the working control relays. Operators can perform remote-control of the multi-purpose controller using a mouse or the pull-down menu bar of the monitoring PC program (see Fig. 5).

Performance of the multi-purpose agricultural controller

The performance test of the multi-purpose agricultural controller was conducted through the on-line monitoring of the temperature state at four different locations in the greenhouse in the field. The acquired temperatures were successfully displayed on the monitor screen of a microcomputer communicating with the controller, as shown in Fig. 5.

Although the controller was tested using a monitoring subroutine, it could be applied to various applications, according to the program residing in the EPROM. Therefore, more versatile application programs are expected to be developed by the users.

The cost of the multi-purpose controller was lower than $200, which was reasonably economical for food processors and farmers in rural communities to purchase as an automation device.

Acknowledgements

This study was supported by the Technology Development Program for Agriculture and Forestry, Ministry of Agriculture and Forestry, and partially by the Brain Korea 21 Project, Ministry of Education and Human Resources Development, Republic of Korea.

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