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Design of Simplified Food Process Controller based on One Chip Microcontroller

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Abstract

A simplified food process controller(SFPC) based one-chip microcontroller was designed and built to perform measurement and control of process in a real time. An eight bit microcontroller, TMS73C85, was used as a CPU of the SFPC to provide 6 analog inputs for the measurements of temperature, humidity, lightness, event count and one reserved channel, and 6 digital channels to generate control signals. The circuits for sensors of temperature, humidity, lightness, event counter, and actuator control were included on the SFPC board. A LED display for monitoring of the food process and a key system for local setting of control point were provided with a real time clock using 60 Hz AC source. Six relays having 1 kWh capacity were implemented in the SFPC board to operate 6 actuators. The SFPC was installed to a pilot-scale food processing facility having a ventilation fan, a heater and a humidifier to verify its performance. The temperature and humidity were measured with errors of 1°C and 2%RH, respectively. The temperature in a food processing room(space of 15 m^3) was controlled within 2°C.

Key words: one chip microcontroller, process controller, data acquisition, food process automation

Introduction

Automation technology is becoming of economical and technical importance in food industries. Factory automation by a programmable logic controller(PLC) has been constructed for data acquisition and control(Kao, 1987; Cook, 1995). Although price of the PLC is lowering, the investment for this modern system still remains as a heavy financial burden for food processors of small and medium scale factories. There are so many cases where unit operations or equipments can be automated with a few I/O and control points. In these consequences, microprocessors have been widely used as the customized process controller, but its interfacing technology to food process was unfamiliar to food engineer (Chun, 1993; Kim, 1993). The recent technical advances in microcontroller have solved the interfacing difficulty because the complex and sophisticated electronic circuit for the expansion of I/O ports and ADC (Analog-Digital-Converter) was included in one-chip. The on-chip ADC is so convenient tool that interfacing technology can be applicable to food processes where data acquisition and control are needed. Several application cases of one chip microcontroller to food processes have been reported; Takjoo fermentation(Kim, 1993), Kimchi(Choi, 1996) and methane fermentation (Chun, 1992; Chun, 1993).

In this study, the design and application technologies of a simplified food process controller, SFPC, were described.

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Materials and Methods

Materials

One chip microcontroller, TMS73C85(Texas Instrument, 1990) was used as the CPU of the SFPC together with other electronic parts as listed in Table 1.

Table 1. Part list of the major electronic components of the SFPC

Part	Use	Specification
OP-AMP	Amplifying signal of sensors	LM324
Multiplexer	Multiplexing of sensors	4051
Photointerrupt	Sensing of interrupt signal	EE-SJ5 (OMRON)
Transistor	Buzzer and switching	C1008Y
Transistor	Power amplifying	D882-Y
Zener diode	Power supply of sensors	2.4V
Crystal	Device system clock	4MHz
Relay	Control of actuator	12V DC
7805, 7905	Voltage regulator	+5V and -5V regulator

Methods

Circuit design and developing tools

The circuitry of the SFPC was designed with CAD (Or-CAD, USA). A developing tool of the SFPC consisted of an emulator, EVM73C00(Metro Co., Korea), ADP73CXX, ICE-XX and piggy back chip, SE73CPXX.

Sensors

Thermistor(1kΩ, Tong-Kwang Sensor Co., Korea) was used as a thermometer probe for the range of −10 to 50°C. Thermistor type humiduty sensor (Shinygi Co., Model RHU-201, Korea) was adopted to measure the humidities ranging from 0 to 98%RH. Cds cell(D1160-11) and silicon photodiodes (330-730 nm, Model S1133, Hamamatsu Co., Japan) were used for the light switch and illumination sensor to measure from 0 to 2,000 Lux. The temperature and humidity sensors were calibrat-ed on the con-ventional method and the light sensor was calibrated by a Lux-meter(LI-185, Takemura Elec. Co., Japan).

Printed Circuit Board(PCB)

A PCB of the SFPC was fabricated by a PCB supplier(Zeus Co., Korea) and used as a main board of the SFPC.

Targeting food facility

The SFPC was installed to the food processing facility to measure the environmental variables (temperature and humidity) and control them to their set points. The food processing facility has a space of 15 m^3 where equipped with two electrical heaters(0.5 and 1 kW, 220VAC), a fan(110VAC, 30W), a humidifier(Ultrasonic, 0.5kW, 110VAC), 2 illumination lighting bulbs(Tungsten, 60W, 200VAC) and 10 relays(1A, 220VAC) for actuators.

Results and Discussion

Port allocation of TMS73C85

In order to design the SFPC, 45 I/O pins of TMS-73C85 were allocated for their uses upon the characteristics of ports. Six pins of analog inputs (Port A) were primarily allocated for the interface to sensors. Two pins; C0, C1 of Port C were used for key inputs. All pins of Port B and 6 pins from G0 to G5 of Port G were allocated for a 7-segment LED displayer. High voltage output of Port H was set for the activation signals for relays. The complete schematic drawing of the port allocation was shown in Figure 1.

Circuitry of real time clock

For the real time clock for the SFPC, electrical power source(60 Hz, 100V AC) was used for the standard pulse signal by adopting the zero cross

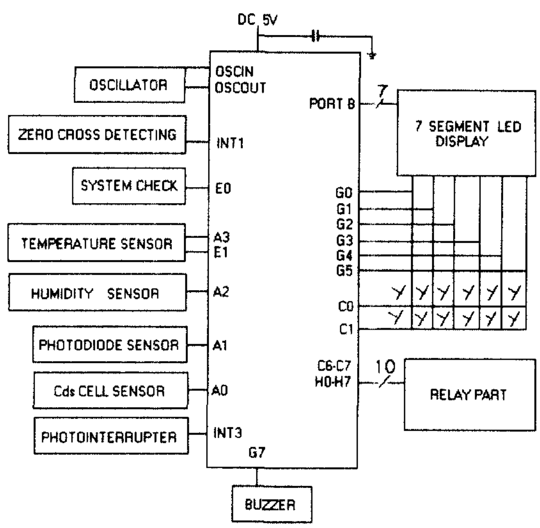

Fig. 1. The port allocation of I/O port of TMS73C85 for SFPC.

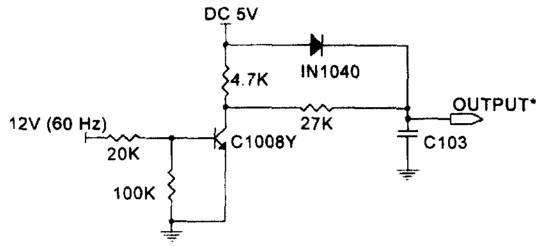

Fig. 2. The circuitry of the real timer.

detection circuitry as shown in Figure 2. The pulse signal was sent to one of the interrupts, INT1 of the microcontroller, by which 1/60 sec of time unit was accomplished.

Temperature measurement circuit

A multi-channel temperature measuring circuit was designed with an analog multiplxer, 4051, and a Wheatstone bridge consisting of thermistor(1kΩ) to obtain voltage difference between thermistor probe selected by the multiplexer and standard voltage of 2.4V supplied across a zener diode. The output signal of the bridge was amplified by an amplifier, LM324, via a voltage follower as shown in Figure 3. The gain control was provided to adjust the output of the measured signal to be in the range of 0 to 5VDC and interfaced to A2 pin of Port A.

Humidity measurement circuit

The oscillatory circuit for the humidity sensor was designed to supply 1 kHz AC of 700 mV as appeared in Figure 4.

Lightness measurement circuitry

Two light sensing circuits were prepared; one for a light operating switch and the other for the measurement of light energy. A Cds photo-cell was used for the light switch and a silicon photodiode was used as the component of a light sensor working under the wavelength ranges of 320 to 730 nm as shown in Figure 5. The electrical current through two parallel photodiodes was proportional to the light energy absorbed, and the output current was passed a register and amplified with LM324 op-amp to obtain output voltage ranging from 0 to 5VDC.

LED display circuit

As shown in Figure 2, Port B and G were used for the dynamic LED dispolayer which could display measured data in two-digit format along with the

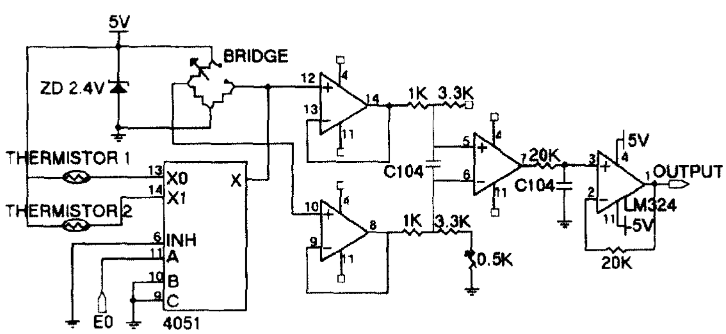

Fig. 3. The multi-channel thermometer circuit.

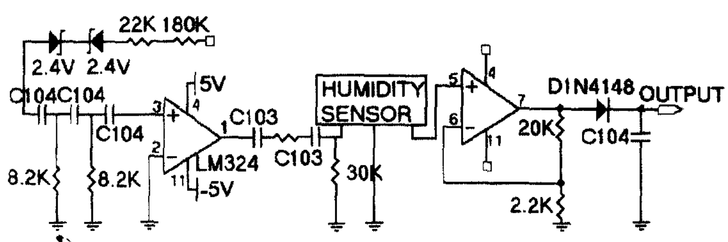

Fig. 4. The circuitry of the humidity measurement module.

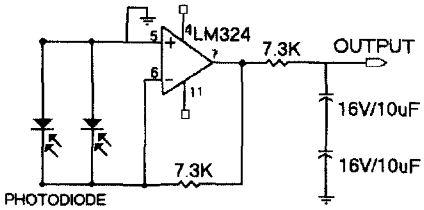

Fig. 5. The circuitry of lightness measurement module.

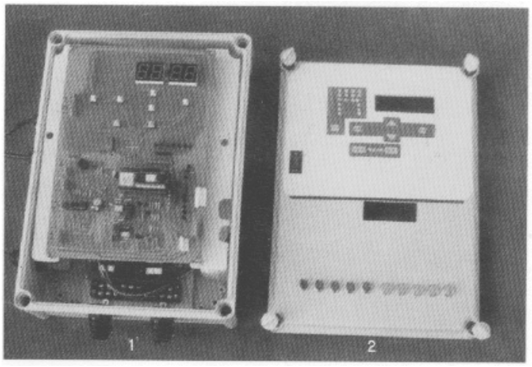

Fig. 6. Picture of the SFPC fabricated.
1: PCB of SFPC installed, 2: Panel of SFPC.

real process time.

Fabrication of SFPC and its performance

The circuitry of the SFPC was realized as a process controller on the PCB as shown in Figure 6.

The SFPC was successfully tested by the developing tools as previously described in Methods, after loading an operation program by using a piggy back chip. We could confirm functions of the data acquisition from the connected sensors, displaying the data on the LED display and activation of the relays with the output signals.

The accuracy of measuring temperature and humidity were ±1°C and ±2%RH, respectively. Figure 7 illustrates the temperature profiles constructed by the SFPC and the control curve of the temperature within error of ±2°C and indicates that it has worked in stable state.

The performance of the SFPC could be further enhanced and other application would be expanded to various processes upon the operation programs to be resided in EPROM. The uses of the function keys of the SFPC could make its task more

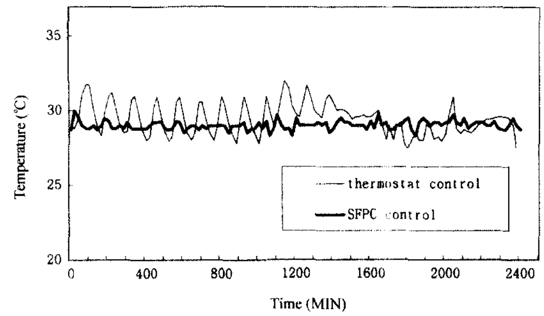

Fig. 7 Temperature profile of food processing room.

versatile. And the programming would be reported elsewhere.

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요 약

식품 공정의 공정변수의 계측과 제어를 수행할 수 있는 식품공정간이제어장치(Simplified Food Process Controller, SFPC)를 단일칩 microcontroller를 사용하여 설계, 제작하였다. SFPC의 CPU로는 TMS73C85을 사용하였고 6개의 아날로그 채널에는 식품공정 변수들의 계측을 위한 온도계, 습도계, 조도계, 계수기를 접속할 수 있도록 하였고, 1개의 여분 아날로그 채널과 제어기의 작동 신호를 출력하는 6개의 디지털 채널이 있도록 설계하였다. Thermistor 온도계, 습도계, 조도계의 계측회로를 설계하고 외부 인터럽터를 이용한 계수기 회로와 공정제어회로를 SFPC 기판상에 포함시켰다. 실시간 기준으로 식품공정의 계측치와 제어상태를 표시할 수 있도록 7 segment LED와 제어목표값을 설정 할 수 있도록 6개의 조작키와 6개의 1 kWh 용량의 릴레이를 갖도록하였다. 제어장치의 실시간 시계로는 60 Hz 전원을 zero cross detecting 회로에서 발생한 신호를 외부 interrupt 신호로 사용하여 설계하였다. 제작된 제어장치 SFPC 는 전열히터, 환풍기, 증습기가 설치된 15 m^{3}의 실험용 식품가공에 설치하여 성능시험을 수행한 결과 온도에서 1°C, 습도에서 2%RH 의 오차를 보였으며 온도제어결과 실온을 2°C 오차 범위 내로 유지 할 수 있었다.

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