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Evaluation of a Sensor and Control Interface Module for Monitoring of Greenhouse Environment

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Abstract. *Protected horticulture in greenhouses and plant factories has been increased in many countries due to the advantages of year-round production in controlled environment for improved productivity and quality. For protected horticulture, environmental conditions are monitored and controlled through wired and wireless devices. Various devices are used for monitoring and control of spatial and temporal variability in crop growth environmental conditions. Recently, various sensors and control devices, and also wireless communication tools have been adopted for efficient monitoring and control of the greenhouse environments. Sensing parameters may include light intensity, temperature, humidity, CO_2, wind, and rain for ambient environment, and EC, pH, and nutrient contents for root zone environments. Control devices may include lamp, heater, cooler, humidifier, dehumidifier, fan, CO_2 generator, and window motor for ambient environment, and nutrient and water supply devices for root zone environment. One of the major problems in those sensing and control devices is low compatibility among the units, due to company and/or user customized specifications of type (e.g., voltage, current, and pulse), range (e.g., 0~20 mA, 0~5 V, and 0~12 V), and communication protocol (e.g., analogy, digital, and RS-232) of input and output signal. To solve these problems and improve the compatibility, a sensor and interface module was fabricated. In this paper, the developed sensor and control interface module was evaluated for* *commercially available various sensors and control devices. First, commercially available sensors and control devices were surveyed, and several units were selected considering the type, range, and communication protocol of input and output signal. Then performance of the developed sensing and control interface module was evaluated in farmers' fields and a test bed. The sensing and interface module would be improved through practical feasibility tests in different greenhouses.*

Keywords. *Precision agriculture, Protected horticulture, Greenhouse, Environment monitoring, Environment control, Compatibility*

Introduction

Protected horticulture in greenhouses and plant factories are becoming more popular due to advantages of year-round crop production in controlled cultivation environment for improved crop yield and quality. Environmental factors are ambient conditions (i.e., light, temperature, humidity, CO_2, precipitation, and wind) and root conditions (i.e., nutrients and pH). Various sensors and control devices have been adopted by farmers for those environmental factors. Control devices (i.e., actuators) are lamps, heater and coolers, CO_2 generators, humidifiers and dehumidifiers, and fans for ambient conditions, and water and nutrient suppliers. One of the most serious problems is the low compatibility among the sensors and actuators. Most manufacturers implement company-specific communication protocol to access the sensor signal and activate the actuator ports, although the inputs and outputs of the sensors and actuators are mostly current and voltage. In the study, a sensor and control interface module was designed, and the performance was evaluated.

Materials and Methods

First, sensors and actuators commercially available for greenhouse environment management were surveyed from manufacturers' websites and magazines. Although there were various sensors and actuators, they could be classified into several groups by type (e.g., voltage, current, and pulse), rang e (e.g., 0~20 mA, 0~5 V, and 0~12 V), and communication protocol (e.g., analogy, digital, and RS-23 2) of input and output signal. Considering the differences, nine sensors were chosen. They were a temperature and humidity sensor (Voltage, HT-01DV), a temperature sensor (I2C, SHT75), an illuminance sensor (I2C, SHT75), a carbon dioxide sensor (voltage, SH-300-ND), a flow sensor (pulse, ISE1202 A), a nutrient temperature and EC sensors (SDI, GS3), an oxygen sensor (current, SS2118), and a wind velocity sensor (voltage, SEN0170). Then, a sensor and actuator interface module was designed and fabricated (Figure 1). A 16 bit MCU (MICROCHIP, dsPIC33FJ) was selected for the purpose. It could provide a device input voltage of 24 V from the power supply unit, a DC/DC conversion (LM22675), and voltage division to 5V and 3.3 V by LDO (S1117). The 24 V input voltage could be divided into different sensor and actuator relay activation levels (e.g., 5 or 3.3 V). The system operation program was developed using MPLAB IDE v8.90 (C language). Finally, the performance of the module was evaluated using the selected sensors. Temperature sensors with different communication methods (voltage, SPI, I2C type) and humidity sensors with different communication methods (voltage, I2C type) were tested. Sensor data were collected for 5 hours at an 1 Hz interval.

Results and discussion

Figure 1 shows the sensor and control interface module designed in the study. It could interface sensors through different communication methods: SPI 2 channels, I2C 2 channels, pulse input 4 channels, analog voltage 4 channels, analog digital 4 channels, and SDI 1 channel, and the interface module could be expanded through CAN communication protocol. Supplied 24 V was divided into 3.3, 5, and 12 V using an adjustable voltage regulator. Generally, the module showed favorable results, interfacing the sensors and actuators without recognized errors. For example, when temperature and humidity sensors with different output ranges and communication protocols were tested, the output values were same (Table 1). The developed prototype module will be tested in various farming conditions, and possible problems will be solved for improved compatibility.

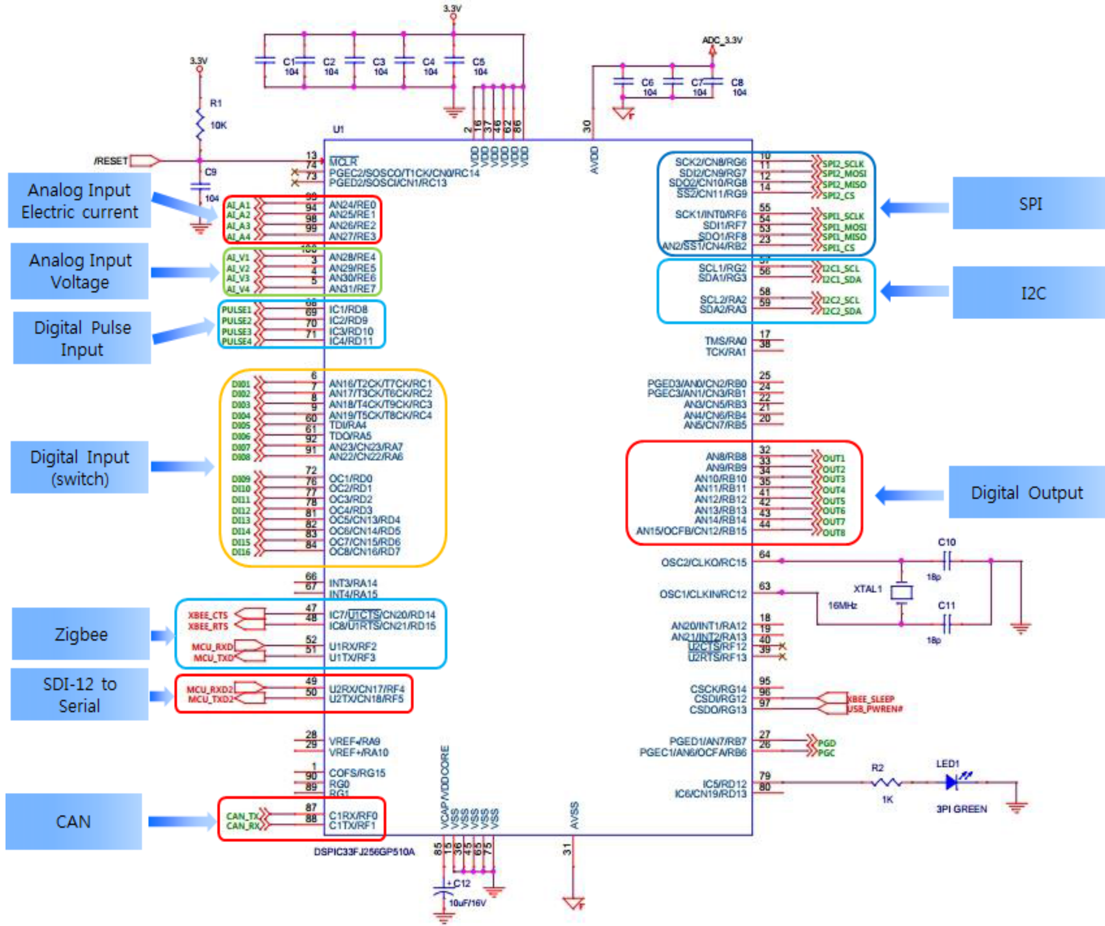

Fig 1. Fabricated sensor and controller interface module

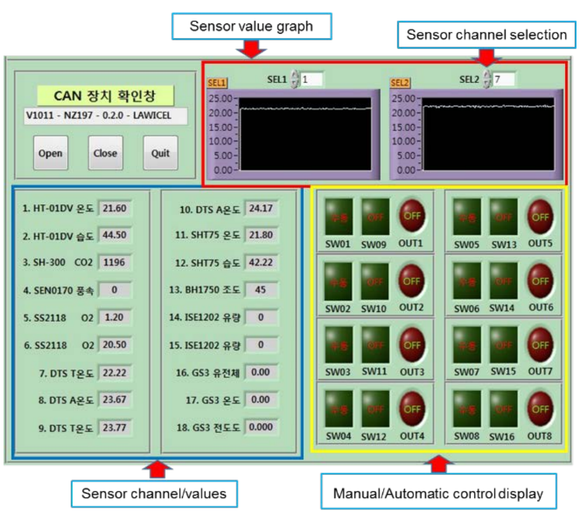

Fig 2. Sensor monitoring program

Table 1. Temperature sensing by method of communication

	3.3V, voltage HT-01DV	3.3V, SPI DTS-L300-V2	5V, I2C SHT175
Temperature (℃)	22.80 ± 0.34^{a}	22.80 ± 0.34^{a}	22.80 ± 0.34^{a}

1) Average ± standard deviation
2) Means with different superscript (a, b, c) are significantly different at $p<0.05$ by LSD's multiple range tests

Table 2. Humidity sensing by method of communication

	3.3V, voltage HT-01DV	5V, I2C SHT175
Humidity (%)	22.80 ± 0.34^{a}	22.80 ± 0.34^{a}

1) Average ± standard deviation
2) Means with different superscript (a, b) are significantly different at $p<0.05$ by LSD's multiple range tests