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Field Tests and Improvement of a Sensor and Control Interface Module with Improved Compatibility for Greenhouse

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Abstract. *Number of greenhouses has been increased in many countries to control the cultivation conditions and improve crop yield and quality. Recently, various sensors and control devices, and also wireless communication tools have been adopted for efficient monitoring and control of the greenhouse environments. However, there have been farmers' demands for improved compatibility among the sensors and control devices. In the study, sensor and control interface modules with improved compatibility were developed and tested in field conditions. 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, fan, CO_2 generator, and window motor for ambient environment, and nutrient and water supply devices for root zone environment. For monitoring and control of greenhouse environment, sensors and control interface modules were fabricated using atmega128 as the mainboard with 8-channal relay for control, LCD for display and checking, zig bee for wireless communication, and the termite software for cording. The module was designed so that could send* *and receive data from computer and control a window opening and closing motor, a cooling & heating unit, ventilation fans through comparison operations of the measured and input setting values. Using the interface module and user computer, the operating conditions and the environmental conditions of the greenhouse were monitored, and the changes in temperature, humidity, light intensity, carbon dioxide, and other environmental parameters were confirmed in real-time, and also the environment setting values were easily changeable. Fabricated interface modules were tested in strawberry and chrysanthemum fields. The experiments were conducted five times and each experiment took about one hour. Optimal temperature, humidity and carbon dioxide conditions were checked whether it was maintained or not through the change of temperature, humidity, carbon dioxide artificially with sensor and control interface module that was developed. After confirming the maintenance of optimal growth conditions, table and graph were created by the result values and required time. For advancement of our sensor and control interface module, tuning, safety and emergency handle function was considered. First, since the malfunction and shorten the life of the product concerned by the resonance phenomenon in the greenhouse to prevent this phenomenon was ensuring the safety of products. Second, electrical safety certification was given by the electrical appliances safety certification system through the institute for safety assessment for safety of greenhouse sensor and control interface module Third, the module was controlled by the optimal safety conditions in the greenhouse through the disaster emergency response algorithms, such as hurricanes and earthquakes and torrential rains. It's also expected that resolving difficult to deal with greenhouse environmental programs and contributing to technical improvement of the control program related field and greenhouse environmental control system.*

Keywords. *Greenhouse, Environment monitoring, Control, Interface module, Compatibility*

Introduction

As of 2009, greenhouse area was 97,300 ha, 2.9% increase from 94,508 ha in 2007 in Korea (KSIS, 2012). Crop growth and quality is influenced by various environmental factors, and sensors and actuators have been adopted in greenhouses to improve the cultivation efficiency. When a ZigBee wireless communication technology was applied, crop yield and quality was improved (Wang et al., 2006; Garcia et al., 2009). Greenhouse environment can be divided into three groups: outside ambient condition, inside ambient condition, and inside root zone condition. Commercial sensors and actuators are usually not compatible each other, because manufacturers would have some specific interface protocol. Basically the input and output signals are different only in range, type, and communication method.

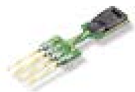
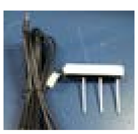
Various research has been conducted to monitor and control greenhouse environments in-situ or remotely. Simple case is that the greenhouse video-stream is sent to the user (Simon et al., 2009). A hybrid control system composed of physical elements and software component (Akira et al., 2005). It is necessary to develop systems with sufficient adaptability and mobility according to the environment of a user (Seo et al., 2009). A wireless sensor network with a tree topology structure is composed of a central controller and six wireless sensor parts such as temperature, humidity, and illumination (Jian, 2010). For communication, the CAN bus protocol has been applied to link greenhouses (Ma et al., 2010; XUE et al., 2006; Zhiwei, 2011). Although various research has been conducted to improve monitoring and control of greenhouse environments, low compatibility among the devices is one of the issues to be solved.

This study was conducted to fabricate and test a sensor and control interface module with improved compatibility. Our target was to interface most of the commercialized sensors and actuators.

Materials and Methods

Commercial sensors and actuators were surveyed through websites and magazines. They were generally different in input power (e.g., 12, 5, and 3.3 V), output type (e.g., voltage, current, and pulse), output range (e.g., mV and V), and communication protocol (e.g., RS232, analog, and digital port). Considering the specifications, 9 different sensors were chosen for performance evaluation. 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 rate sensor (pulse, ISE1202 A), a water/temperature/EC sensors (SDI, GS3), an oxygen sensor (current, SS2118), a wind velocity sensor (voltage, SEN0170). To design and fabricate a sensor and actuator module, a 16-bit MCU (MICROCHIP, dsPIC33FJ) was selected. It could supply an input voltage of 24 V, and convert the level into 5 V and 3.3 V. For operating system, C-language based MPLAB IDE v8.90 was used. In a stationery condition, the sensors were interfaced and data were collected for 5 hours at a 1-Hz interval. Table 1 shows summarized specifications of the sensors selected in the study.

Table 1. Specifications of improved interface module.

Contents	Picture	Company	Model name	Specification
Temperature & humidity sensor		SENSIRION	SHT75	Input power: DC 2.4 to 5.5V Output type: SCK, DATA (Digital) Humidity measurement range: 0 to 100%RH Temperature measurement range: -40 to120℃
Temperature & humidity sensor		MICOMST	HT-01DV	Input power: DC 2.3 to 5.5V Output type: 0V~5V Humidity measurement range: 0 to 100%RH Temperature measurement range: -20 to 100℃
Illuminance sensor		HANJIN DATA	BH1750FVI I2C	Input power: DC 3 to5V Output type: I2C(SCL, SDA,ADDR) Measurement range: 0-65535lux
CO2		SOHATECH	SH-300-ND	Input power: DC 7 to 12 V Output type: 0 to 3V, UART communication Measurement range: 0 to 3,000/5,000/10,000ppm
Flow sensor		DAESHIN	(ISE1202)A Type	Input power: DC 5 V Output type: pulse Measurement range: 1 to 30 L/min
Water content/ temperature/EC		DECAGON	GS3	Input power: DC 3.6 to 15 Output type: Digital Output way: serial TTL, 3.6V level, SDI 12
O2 sensor		SENKO	SS2118	Output type: 90±20μA in air Measurement range: 0 to100%
Temperature		DIWELL	DTS-L300-V2	Input power: DC 2.4 to 3.6V Output type: SPI Temperature measurement range: -30 to 300℃
Wind speed sensor		DFROBOT	Anemometer Kit [EN0170]	Input power: DC 12 to 24V Output type: 0 to 5V

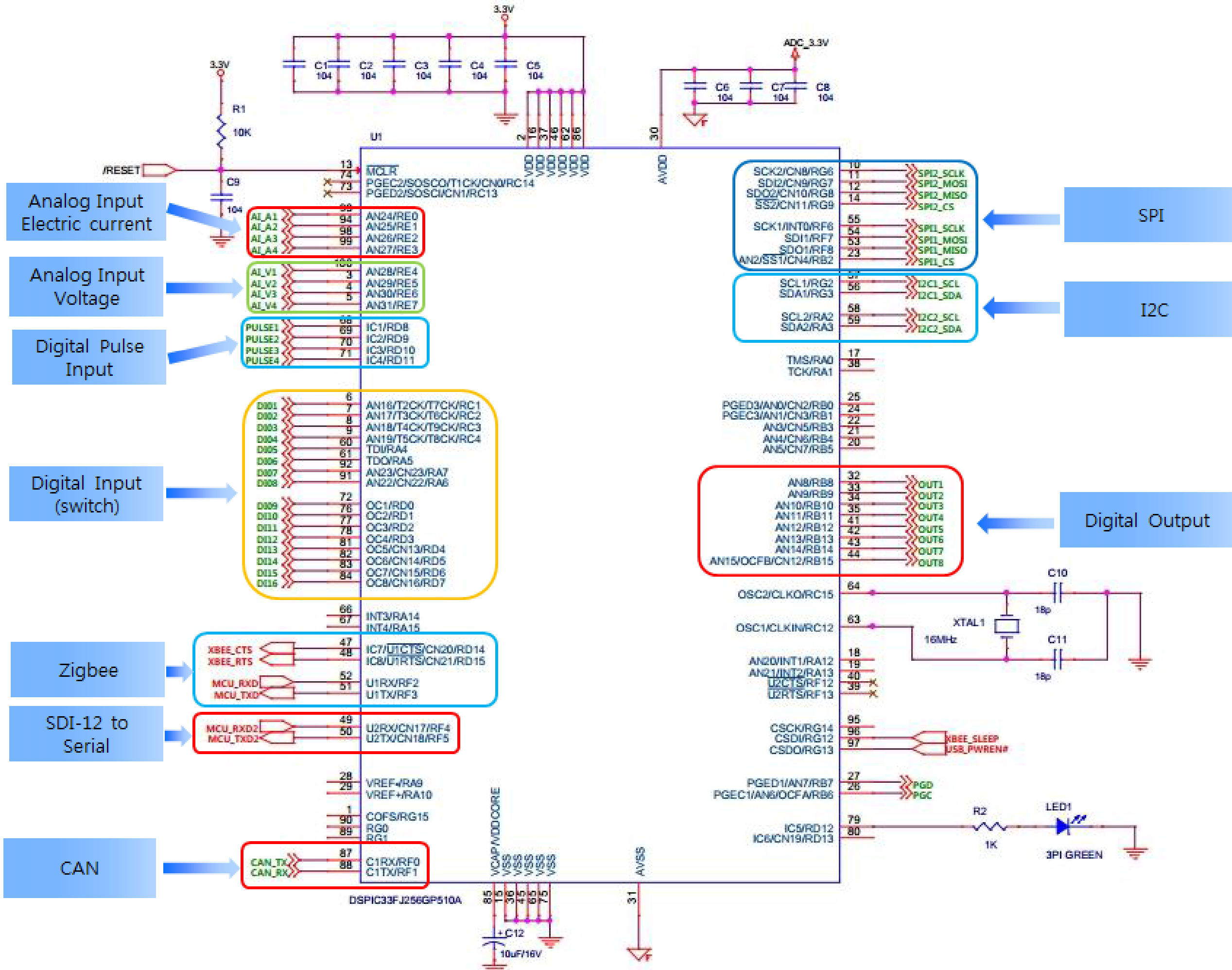


Figure 1. Circuit diagram of the MCU part (MICROCHIP, dsPIC33FJ).

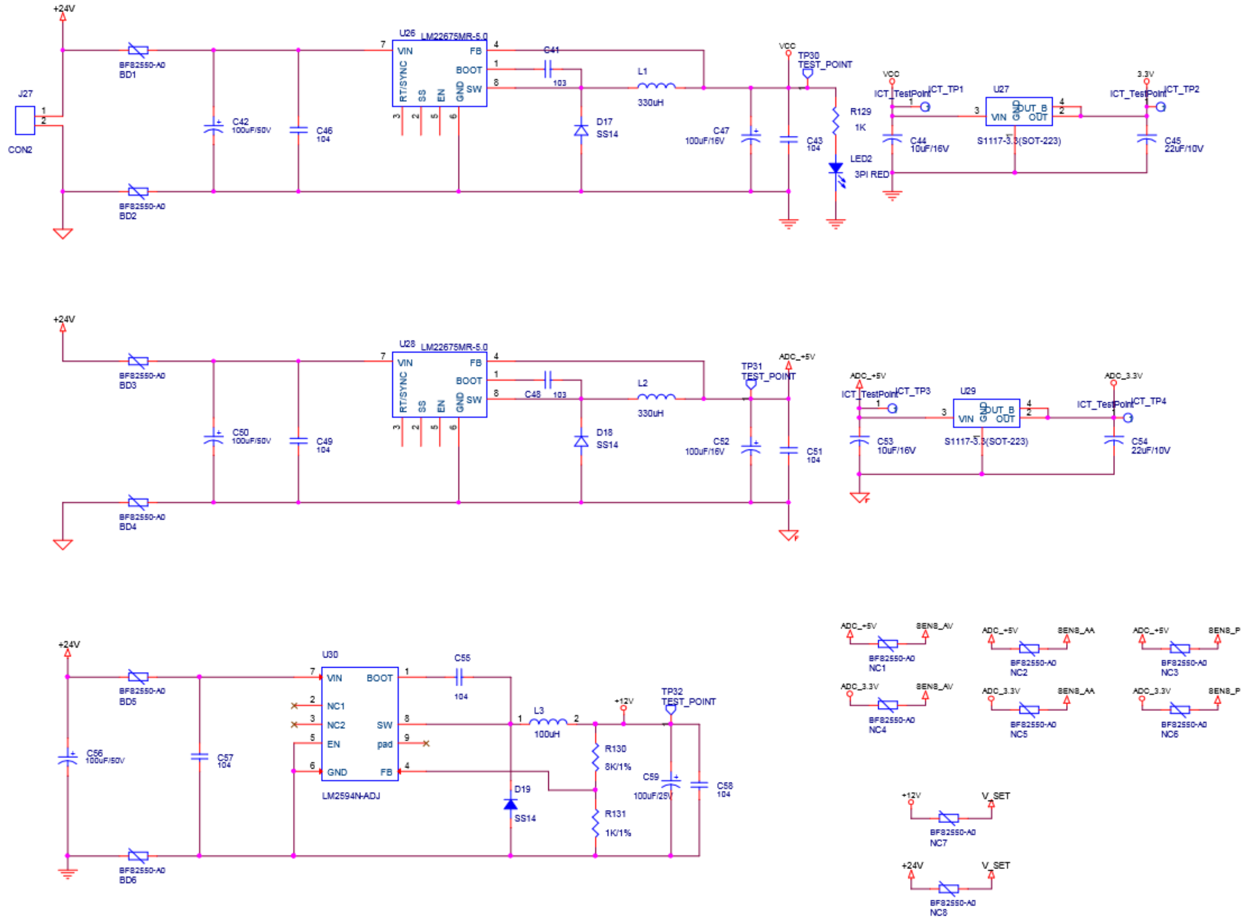


Figure 2. Circuit diagram of the power division part (24V, 12V, 5V, 3.3V).

Management software program was coded using LabVIEW as shown in Figure 4. CAN communication device confirmation panel as a file open/close and quit function was located on the top left. Sensor channel selection and sensor value graph panel were located on the top right. Output part that could show values of each sensor channel was located on the lower left. Manual/automatic control display function key as a control part was located on the lower right.

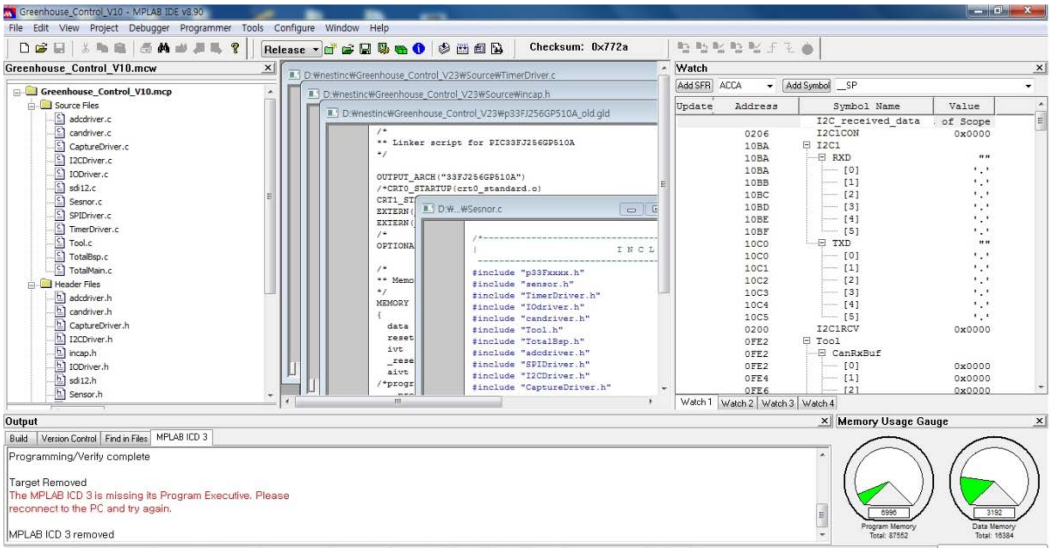


Figure 3. Coding of the operating system (MPLAB IDE v8.90).

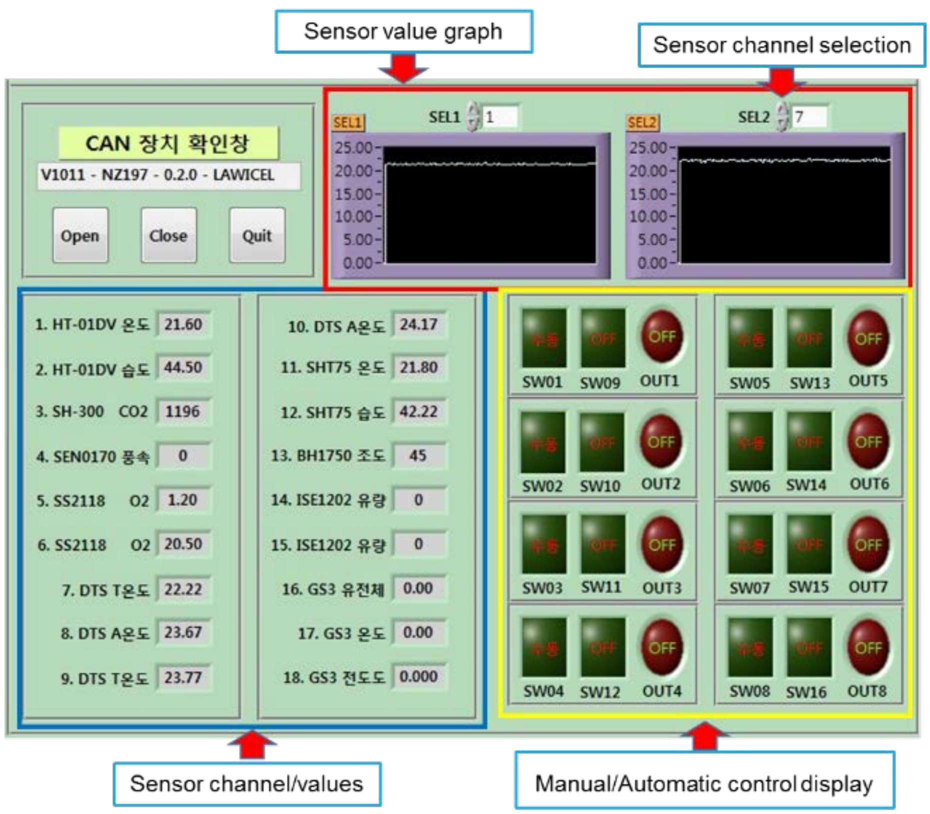


Figure 4. Developed sensor and actuator monitoring program.

Results and discussion

Averages and standard deviations were compared. Output of the temperature sensors showed similar values and they were not statistically significantly different. Also, the output of the humidity sensors showed very similar values and they were not statistically significantly different. The results indicated that the developed module could interface different sensors with improved compatibility and similar performance.

Figure 8. Internal structure of the fabricated sensor and actuator interface module.

Table 2. Measurements of the temperature sensors using the developed interface module.

	3.3V, voltage HT-01DV	3.3V, SPI DTS-L300-V2	5V, I2C SHT175
Temp. mean (℃)	22.80±0.34[a]	22.78±0.25[a]	22.79±0.17[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 3. Measurements of the humidity sensors using the developed interface module

	3.3V, voltage HT-01DV	5V, I2C SHT175
Humidity. mean (℃)	67.35±1.26[a]	67.27±0.95[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

Temperature control

Figure 9 shows the results of the comparison tests. Performance of the developed module and commercial control unit was evaluated in a plant factory. The average and standard deviation of temperature using the commercial unit were 20.51°C and 1.05°C. Those of the developed module were 19.96°C and 0.28°C. The mean values were not statistically significantly different ($p < 0.05$).

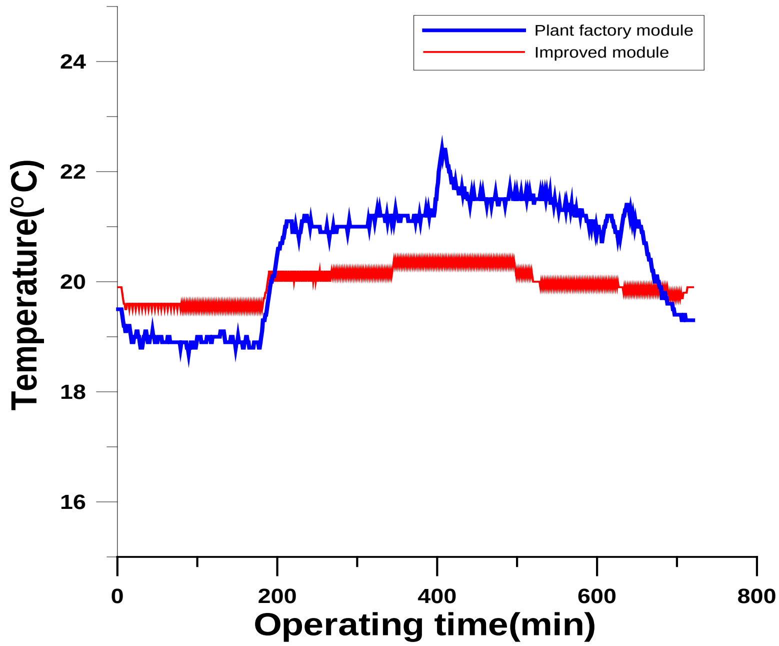


Figure 9. Results of measurement the temperature in plant factory.

Humidity control

Figure 10 shows the results of the comparison tests for humidity control. The average and standard deviation of humidity using the commercial unit were 65.94% RH and 1.25% RH. Those of the developed module were 66.7% RH and 0.9% RH. The mean values were not statistically significantly different ($p < 0.05$).

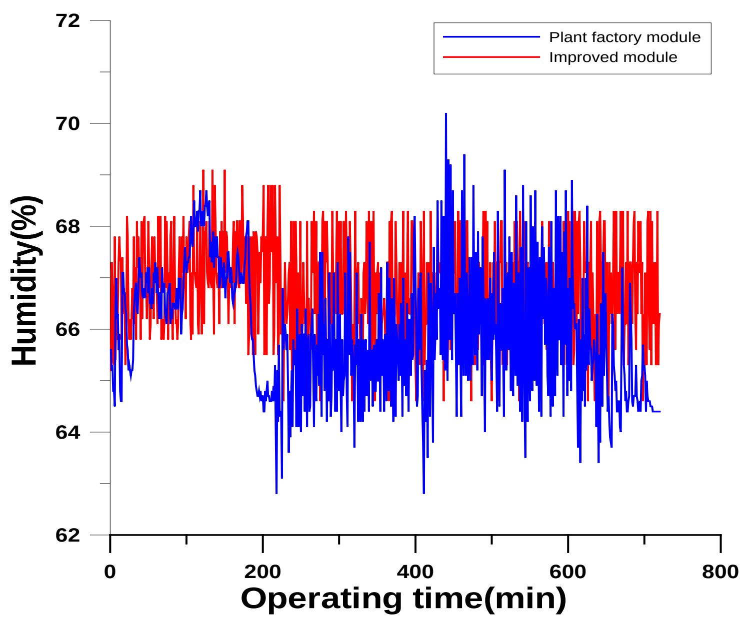


Figure 10. Results of measurement the humidity in plant factory

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