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Development of an Indoor Environment Monitoring System with Secure Digital (SD) Card Storage

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Abstract—**Demand of indoor environment monitoring system is increasing especially in science laboratories, hospital wards and farm incubators. In this work, a low cost indoor environment monitoring system with secure digital (SD) card storage is presented. The system developed uses an 8-bit microcontroller with an on-chip 10-bit analog-digital-converter (ADC) as the system core and monitors three environmental parameters i.e. temperature, humidity and brightness.**

I. Introduction

CONSTANT monitoring of environmental parameters such as temperature, humidity and brightness is important for facilities such as science laboratories, hospital wards and farm incubators. Conventionally these environment parameters are human measured using mechanical sensors. Error and inconsistency due to human factor reading are often unavoidable. Modern electronics based indoor environment monitoring system has been researched and implemented for a long time to allow greater automation and saving in human labor [1]. This work aims to develop a low cost environment monitoring solution using commercial off-the-shelf electronics components. This work also explores the possibility of interfacing with Secure Digital (SD) cards for greater flexibility in data storage.

Overview of the entire system is first presented in Section II; followed by design considerations concerning the hardware and software modules in Section III and Section IV. Finally results and system performance are discussed in Section V.

II. System Overview

The block diagram of the indoor monitoring system developed is shown in Fig. 1. The system basically comprises of five major components which are 8-bit microcontroller, sensors, SD card, Liquid Crystal Display (LCD) screen and push buttons.

The Microchip PIC18F4620 [2] 8-bit microcontroller is the main component of the system. It is responsible to capture sensor data, process and store data, and provides user interface. This system is able to measure three environment conditions which are temperature, humidity and brightness. All parameters are automatically measured by the sensors within an arbitrary time interval determined by user. Measured data are stored into a SD card. This work can support two file systems i.e. File Allocation Table (FAT)-12 and FAT-16, which allows the user to use any SD card with a maximum storage of 2 Giga Bytes (GB). A Java program is written for the user to access, analyze and export the historical data recorded in the SD card. A JHD 162A (2-row × 16-character) LCD screen is responsible to display program menu, system status and sensor readings. Finally, push buttons are included in the system to allow easy menu navigation.

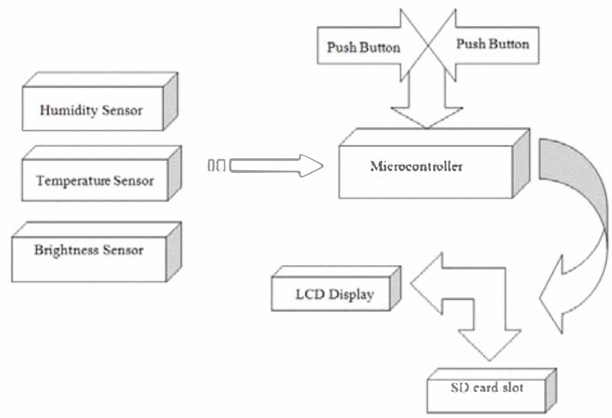

Fig. 1. Indoor monitoring system block diagram.

III. Design Considerations of Hardware

Hardware used in this work can be divided into three individual circuits:

A) Main circuit
B) Sensor circuit
C) SD card circuit

The system can be powered using any conventional laboratory 9~12V DC power supply or a single PP3/9V battery.

A. Main circuit

The main circuit consists of voltage regulators, microcontroller, LCD module and push buttons. A list of components used in the main circuit is shown in Table I.

The main voltage regulator in this system is LM7805, which converts incoming 9V into constant 5V as required by the microcontroller. Feature of a LM7805 includes internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. Another voltage regulator in the system, LM1117-3.3 has similar protection feature as LM7805 but it supplies 3.3V, which is needed by the SD card circuits.

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The microcontroller used in this circuit is a Microchip PIC18F4620, an 8-bit microcontroller which runs on a 10MHz crystal. This specific model of microcontroller is chosen due to several reasons: i) on-chip 13-channel 10-bit resolution ADC, which eliminates the need of external ADC chips, ii) huge program memory (64KB), which is necessary for FAT file system, and iii) vast available software resources i.e. free libraries and C compiler such as Hi-Tech C.

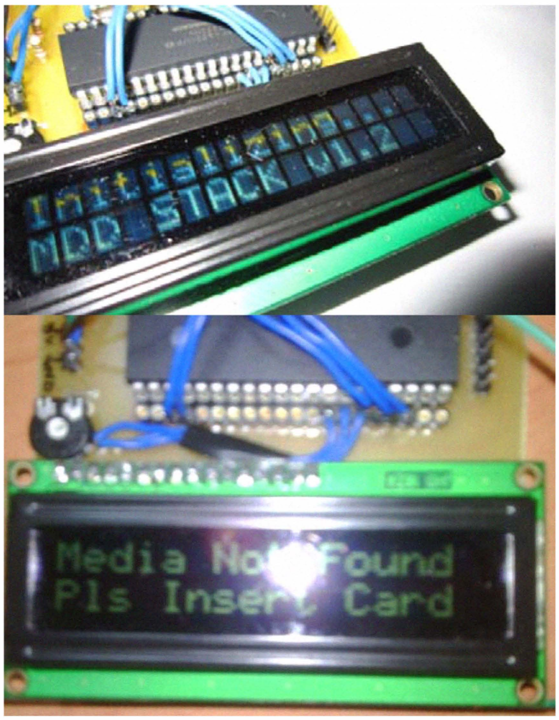

Fig. 2. LCD displaying a) System status b) Error message

TABLE I

COMPONENTS LIST	
Capacitor (Ceramic)	0.1µF × 4 20pF × 2
Light Emitting Diodes (LED)	Orange × 1 Blue × 1
Resistor	1kΩ × 6
Crystal Oscillator	10MHz
Voltage Regulator	LM7805 × 1 LM1117-3.3 × 1
LCD module	JHD162A × 1
Microcontroller Unit	PIC18F4620 × 1
Level shifter	MC74VHCT125A × 1
Push button	2-pin × 4
Temperature sensor	LM35 × 1
Humidity sensor	HSM-20G × 1
Brightness sensor	NORP-12 × 1

The LCD panel used in this work (JHD162A) can display 16 characters on each of the 2 rows available. Content displayed includes program menu, latest system status, error message and sensor data. Interfacing of the LCD is done via the RS232 port. Examples of LCD display output are shown in Fig. 2.

Two-pin push buttons are installed in the system to provide system operation control such as *reset*, *start*, *stop*, and *menu navigation*. Push buttons are connected to the microcontroller via 1kΩ pull-up resistors.

B. Sensor circuit

This work is capable of sensing three environmental parameters which are temperature, humidity and brightness. All sensors used are analog, continuous time type. The output values are of analog voltage levels, which will be sampled and converted into digital values by the on-chip ADC.

1) Temperature sensor: LM35 is used as the temperature sensor. This sensor requires 5V voltage supply. The reasons LM35 is chosen are: i) linear output voltage, ii) does not require external calibration, and iii) low current consumption (60µA) which leads to low self-heating.

2) Humidity sensor: HSM-20G by Cytron Technologies is used as the humidity sensor [3]. This sensors works under 5V voltage supply and draws 1 to 2 mA of current. The output voltage is linear and ranges between 1 to 3V.

3) Brightness sensor: NORP-12 light dependent resistor (LDR) is used as the brightness sensor due to several reasons: compact in size, affordable, wide resistance range and low power consumption. LDR is a sensor which resistance decreases when exposed to visible light. Unlike the temperature and humidity sensor, which provides active linear output voltage, LDR sensor is passive type and requires different circuit configuration as in Fig. 3. Additional resistor is paired with the LDR to form a voltage-divider circuit. ADC pin is then connected to the center node for voltage sampling.

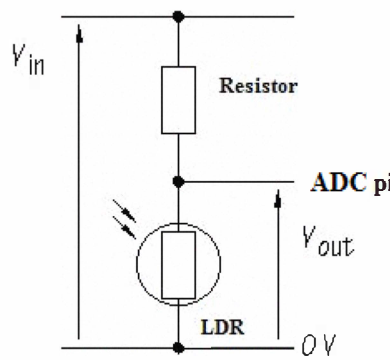

Fig. 3. LDR sensor interface to the microcontroller.

C. SD card circuit

SD card slot in this work is fed with 3.3V DC voltage generated by LM1117-3.3 voltage regulator in the main circuit. Direct interfacing between SD card and the microcontroller is not possible due to mismatch in voltage level (5V vs. 3.3V). Hence an additional level shifter IC (MC74VHCT125A CMOS buffer) is required to perform the 5V↔3.3V voltage level conversion. The circuit configuration is shown in Fig. 4. SD card interface can operate in two different modes: SD card mode and SPI mode. In this work, SPI is chosen as only 3 wires are needed compared to 6 wires required by SD card mode [4]. Although SD card mode provides higher data transfer rate, such speed is not required in this system.

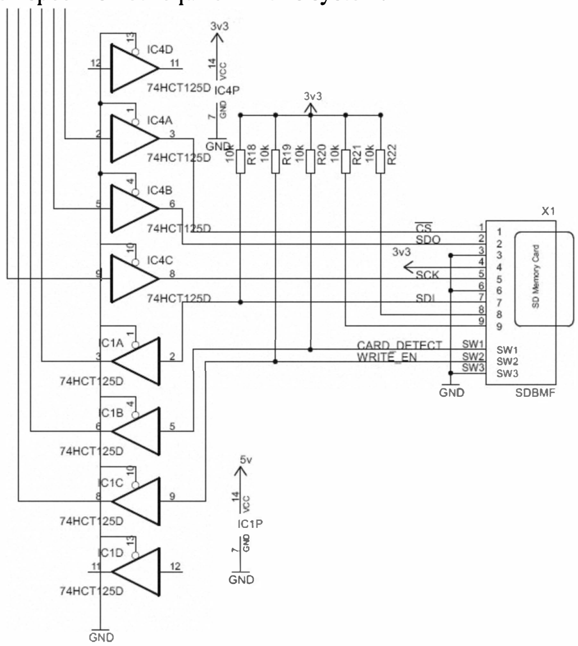

Fig. 4. SD card-microcontroller interface.

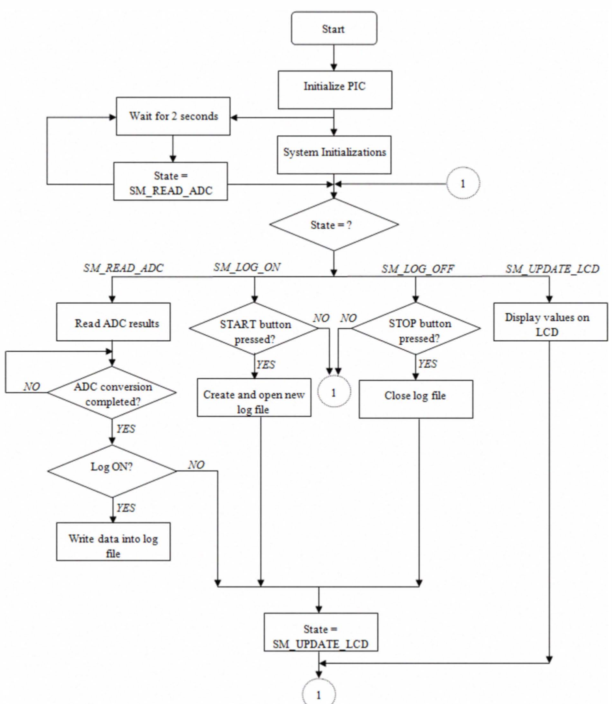

Fig. 5. Microcontroller main program flow chart.

IV. Design Considerations of Software

Embedded software used to program the microcontroller is developed using C language whereas the GUI windows front end program for data processing is developed using Java.

A. *Microcontroller program*

Development of the microcontroller program in this work is done using Hi-Tech C compiler. This compiler can compile ANSI-C codes into HEX code that can be programmed into microcontroller program memory. Main program for the microcontroller is illustrated using flow chart in Fig. 5.

B. *File System*

The library of Microchip Microchip Memory Disk (MDD) file system is used to provide an interface to FAT-12 and FAT-16 disks. With all extra functions disabled except *file search*, *write* and *programming* functions, the MDD file system alone requires approximately 21kB of program memory.

C. *Java-based GUI front end*

A Java-based GUI front end is designed to open the data file recorded in the SD card. This program allows user to access and analyze the measured data via a convenient user interface. Java language is chosen due to the portability of Java code across different operating systems. A snapshot of the Java GUI front end is shown in Fig. 6. The program layout is partitioned into three parts: i) table panel which displays the three sensor parameters, ii) digital clock panel for time reference, and iii) buttons panel for program functions. The program also provides chart plotting feature to export high quality charts derived from the sensor data.

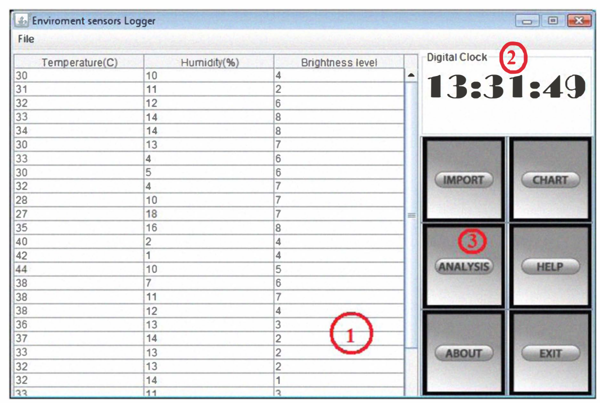

Fig. 6. Java-based graphical user interface.

V. Results and Discussions

The system is able to sample three data channels (temperature, humidity and brightness) as shown in Fig. 7. For future expansion, the system can accommodate additional ten data channels. Data ranges that can be sensed by the system are summarized in Table II. The proposed system is fabricated on two-layer printed circuit boards (PCB). The system has three separate PCB i.e. microcontroller board, SD card board and sensors board as shown in Fig. 8. The different boards are connected using bus wires. Such modular design allows easy replacement of components in case of defect that might occur in the future.

During the development process, several design issues aroused. In order to prevent reinvention of wheels for future developers, these issues are discussed:

A. *Insufficient Microcontroller program*

Initially another microcontroller PIC18F4455 (24kB program memory) was proposed as the system core. However, as mentioned in section IV-B, embedding the MDD file system [5] alone already consumes 21kB of memory. The remaining memory space is insufficient for the authors to implement other system function. The issue was addressed by swapping to the PIC18F6420 model, which comes with 64kB of program memory.

B. *Lack of Real Time Clock (RTC)*

RTC can provide accurate time information for the microcontroller, which is an important feature. Microcontroller MSSP (Master Synchronous Serial Port) is needed to run I2C (multi-master serial single-ended computer bus) mode so that the microcontroller can be interfaced with RTC. PIC18F4620 only has one MSSP and the microcontroller is already running it with SPI mode (for SD card purpose). Since MSSP can only run in either SPI mode or I2C mode, therefore the RTC function is temporarily not implemented. For future upgrade, I2C mode can be realized with more programming effort i.e. using bit banging method.

C. *Difference in operating voltages of microcontroller and SD card*

The PIC18F4620 microcontroller is operating in 5V but the SD card is operating at 3.3V, which is explained earlier in Section III. To solve this problem, CMOS bus buffers (MC74VHCT125A) are inserted between microcontroller and SD card data pins to perform the 5V↔3.3V conversion.

TABLE II

SENSOR PERFORMANCE SUMMARY

Temperature	Tolerance range: 0 to 60 (°C)
Humidity	Tolerance range: 45 to 86 (% relative humidity) *Exposure to dryer: 45* *Exposure to water vapor: 86*
Brightness	Tolerance range: 4 to 98 (relative brightness level) *Enclosed completely: 4* *Direct 60W florescent bulb exposure: 98*

Fig. 7. Sensor data plotted into charts.

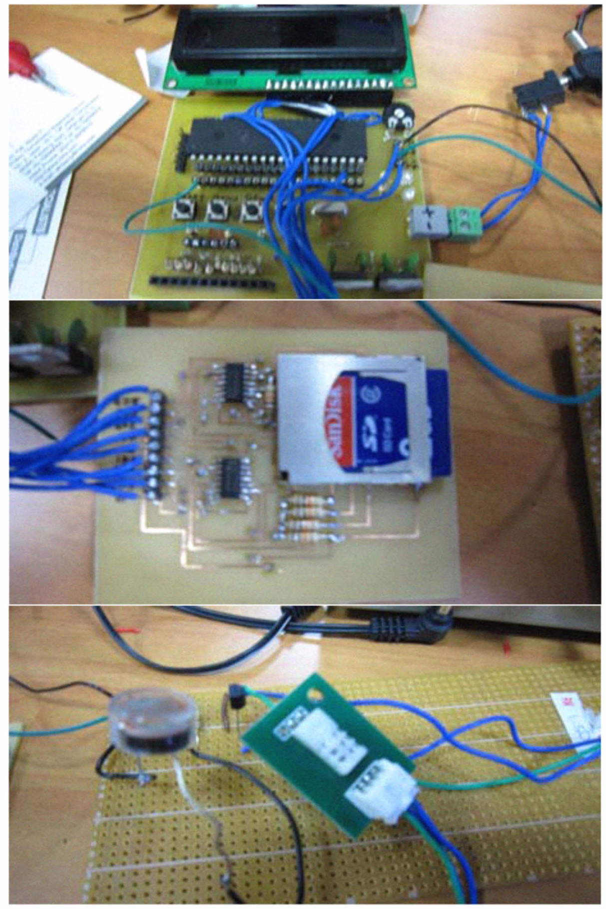

Fig. 8. a) Microcontroller board, b) SD card board and c) sensors board.

VI. CONCLUSION

A low cost indoor environment monitoring system with SD card storage is designed and tested successfully using commercial off-the-shelf electronic components. User can analyze the data stored in the SD card using the multi-platform compatible Java program developed. The designed system is able to trace and record temperature, relative humidity and brightness level accurately at constant time interval.

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