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Remote controlling and monitoring of HVAC system over Internet

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In this study, internet-controlled heating ventilating and air-conditioning (HVAC) system has been proposed with programmable sleeping time and automatic operation mode, three steps fan speed unit, adjustable fan angle, a remote control device with an LCD and a web based control unit. A low cost microcontroller (MC) to control HVAC system and a PC as an Internet server are used. The system has three different control units (remote control by a hand-device, keypad control mounted on HVAC, and web based control). Each control unit has same menu options for users. A data acquisition board provides communication between server and MC. A webcam is used to monitor HVAC parameters and room environment remotely over the Internet. The system uses HTTP protocol to control devices. Proposed web based control method remotely works for long distance. As HVAC systems have high voltage, driver circuits with opto-couplers have been used for safety of the system.

Keywords*:* HVAC, Remote access, Remote monitoring, Web based control

Introduction

Internet technology[1-5] has made it possible to develop better control methods for air conditioners (ACs). Studies are available on microcontroller (MC) based heating ventilating and air-conditioning (HVAC) control systems. Rutman *et al*[6] presented temperature control of an office using ELECTRE II method. Lute & Paassen[7] controlled temperature of a space using an estimation-based system with MC. Hamdi & Lachiver[8] developed fuzzy logic controllers for HVAC system. Singh *et al*[9] presented another considerable study on application of fuzzy modelling technique to fan-coil unit of an HVAC system. Wei & Dage[10] developed an intelligent climate control system for automobiles based on heat sensing. Gertig *et al*[11] developed a programmable digital thermostat system consisting of heating, ventilating and fan speed units and MC controlling HVAC using relays. Infrared (IR) waves were substituted for ultrasonic voice waves because the effects of environmental parasites[12]. Recently, remote control systems for HVAC systems have been used widely over short distances. Web based control methods for HVAC systems are able to deal with an environment such as lighting control and security control using Internet and a PC as a home-server. Lin *et al*[13] presented user development platform for an embedded web server and an approach of access to traditional equipments having no Internet interface. Park[14] presented a next generation AC system including both remote control system over Internet and telephone. Lin & Broberg[14] also presented a web controlled HVAC system. Changhong *et al*[16] presented a web-based remote control service (WBRCS) system.

This study presents sleeping mode control and remote control (RC) hand devices and monitoring of a HVAC system over Internet.

Developed System

HVAC has been controlled from following three points: i) A control panel mounted on HVAC; ii) An IR RC device; and iii) A web based control system providing remote access over Internet. Each of these control points has same user friendly and multi-functional menu options.

Hardware Structure

Main Board Circuit

Main board circuit consists of a MC, HVAC driver circuits, a LCD, a heat sensor, an IR sensor and control keys (Fig. 1). PIC16F877 MC used to control main board circuit, has 8 analog/digital converters, 5 external interrupt inputs and 33 I/O lines. A heat sensor measures room temperature. An optic-isolator and a triac are used for heating-ventilator driver circuit. A transistor is also used for triggering optic-isolator and triac. Thus, main

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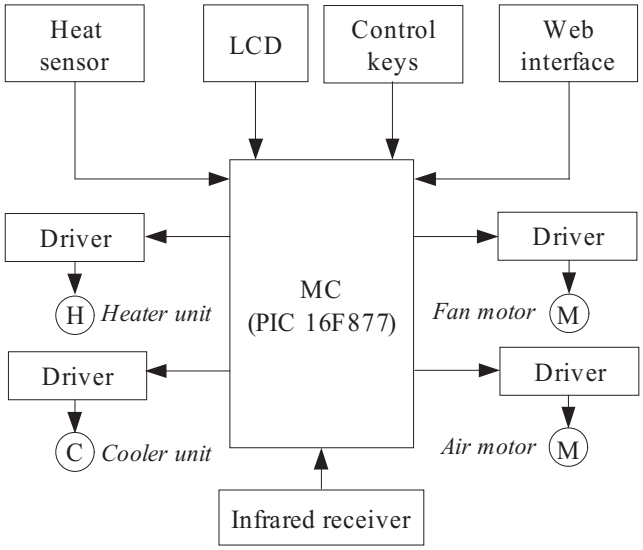

Fig. 1—Block diagram of main board

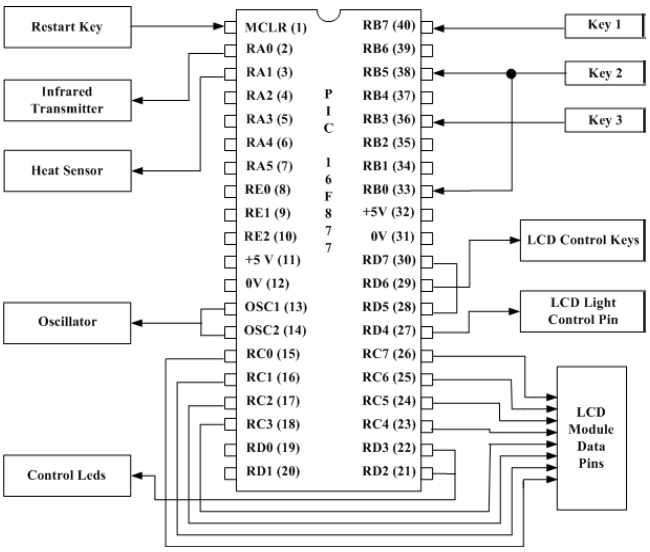

Fig. 2—Remote control hand-device circuit

board control circuit has been isolated from power circuit. Driver circuit of fan motor consists of control pins, semiconductor switch, opto-coupler and a triac. Motor can be operated in three optional modes by means of changing trigger angle of triac. Driver belonging to air-orientation control unit consists of MC control pins, transistors and a stepper motor. This control unit is used to emit air blown by a fan motor according to a pre-determined angle. Stepper motor instead of limitation switch is used for control operation. Position information of stepper motor is stored in EEPROM memory of MC, in order to utilize it again when AC is turned on again.

Remote Control Hand-Device

RC hand device consists of LM35 temperature sensor, PIC16F877 MC, 2x16 LCD, IR led and control keys. Multi functional control is executed with control keys using LCD as menu (Fig. 2).

Data Acquisition Board

A data acquisition (DAQ) board, PowerDAQ PD2-MFS-8-500/16DG (United Electronics Company) is used to communicate server and HVAC. An expansion module (PD-BNC–16) is used for connecting circuits to DAQ board. Multifunctional DAQ board has an integrated digital signal processor, which collects data simultaneously without any hardware or software unit.

Hardware Implementation

MC controls HVAC system. Main board circuit including MC, HVAC driver circuits, LCD, heat sensor, IR sensor and control keys have been designed (Fig. 3). A PC configured as server is used to control HVAC system over web. Data transfer between server and HVAC system are provided via DAQ board. Besides, control keys and remote control hand-device can control the system.

Software Structure

In order to design three identical control units for HVAC system, several programming languages and packet programs are used as follows:

Client Side

Any special hardware or software unit installation is not required on client side to control HVAC system over web, because server executes all operations. Internet connected PC with a browser program is enough. Simple web pages, which do not include any Java applet or ActiveX control, are designed as interface. HTML based forms were used in pages to input parameters, so web pages can be loaded quite fast.

Server Side

Apache 2.0.48 web server was installed due to open source coding, independence of operating system, fast and safe communication. Also, a membership system using secured databases was prepared. MySQL Server 5.0 software was used to execute database connections and operations.

Software Application

The system consists of three different parts to write three separated software (DAQ board software, main

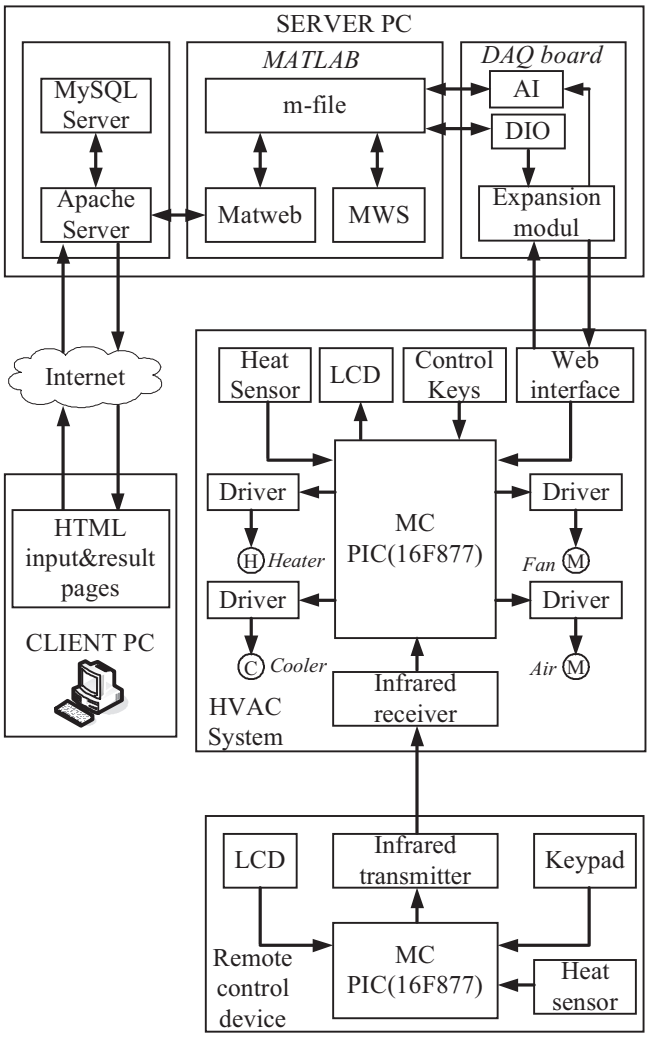

Fig. 3—Block diagram of designed system

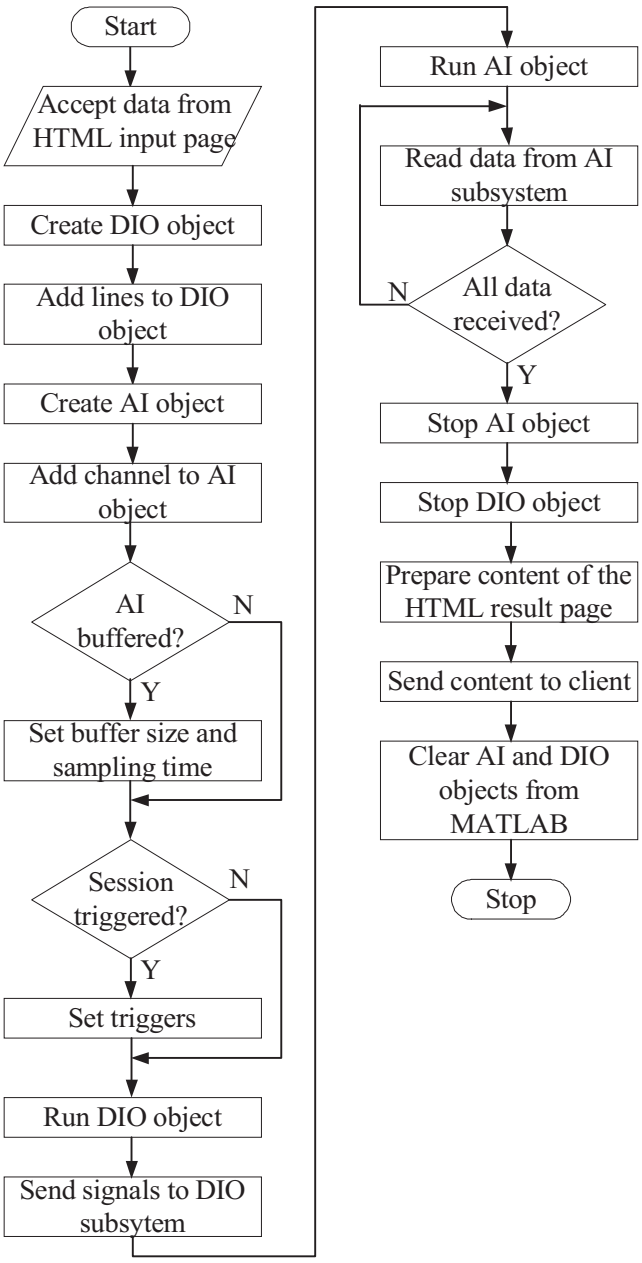

Fig. 4—A simplified flow chart of software developed in m-file

board software and RC hand-device software). MATLAB packet program was used to program DAQ board and to establish server/client connection. Main board and RC hand-device units are in Assembly language. MC controls main board. Operations namely desired level of temperature (5-40°C), three optional levels of fan speed of HVAC system, desired value of blowing angle of fan (15-75°), sleeping mode programming (max. 96 h interval) using timer are performed using control keys mounted on HVAC and LCD can show all operational steps.

Data acquisition toolbox is used for implementation of programmed DAQ board. Web server toolbox is used to send or receive data over web. A common MATLAB m-file has been prepared to perform all tasks (Fig. 4). The m-file performs following operations: i) Transfers data and other commands sent by client over web to MATLAB environment; ii) Creates analog input or digital output objects, then add channels to these objects and sets configuration; iii) Activates digital output subsystem of DAQ board using digital output object; iv) Receives data from analog input subsystem of DAQ board and then transfers them to MATLAB environment by means of analog input object; v) Converts information about operation results to appropriate format to send client PC; vi) Prepares content of HTML result page and then send it to client PC; and vii) Clear all created objects and

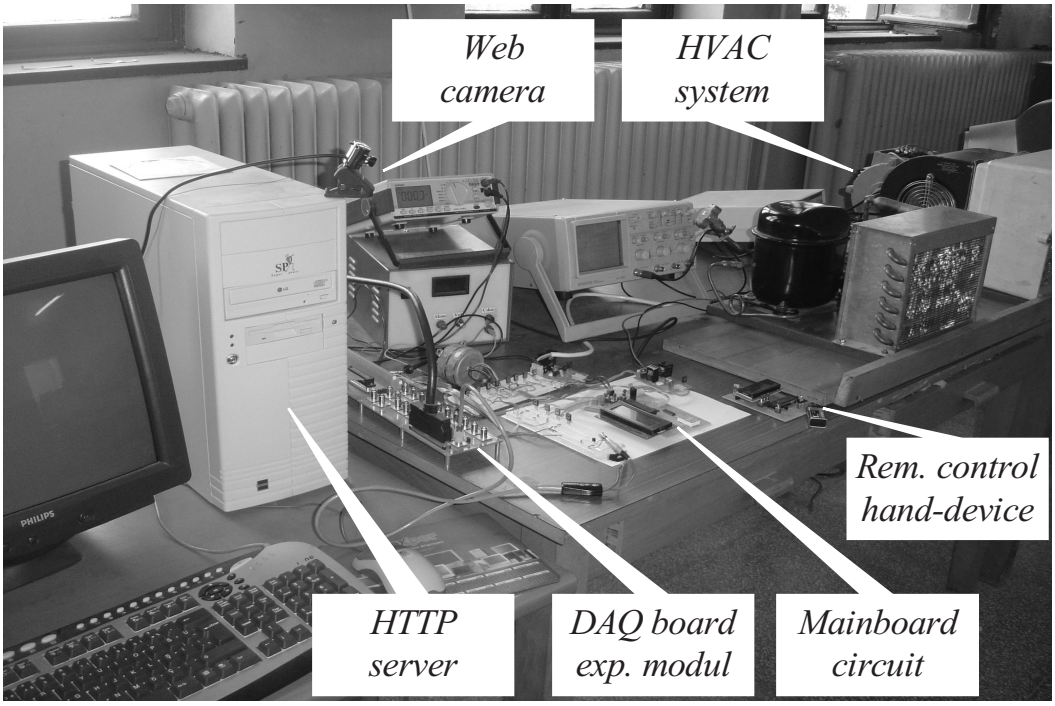

Fig. 5—General view of developed system

variables from MATLAB environment after completion of application.

All controls of control panel mounted on HVAC system can also be performed by RC hand-device. Three control keys of hand-device can be used to execute multi-functional operations in menu format on LCD. The hand-device uses 9 V battery and it passes to sleeping mode automatically to decrease energy consumption when it is not in use > 1 min.

Experimental Study using Developed System

Developed HVAC system is designed and implemented at Electrical Machines and Energy Control Group Research Laboratory, Gazi University, Turkey (Fig. 5). Three control units are as follows:

Web based Control Operation

Simplified HTML input and output pages have been designed to control HVAC system over web. Main page includes required control commands and other links as follows: i) *Open WebCam* — When user clicks on this link, a connection establishes between client PC and web camera mounted on server, so HVAC system is remotely monitored on the screen; ii) *Measure at Room Temperature* — This command ensures to measure actual temperature value of environment where HVAC system is placed; iii) *Set Sleeping Mode* — HVAC system can be programmed to a sleeping time using this command. At the end of sleeping time, HVAC sets to sleeping mode automatically; iv) *Set Fan Speed* — Fan speed of HVAC system can be adjusted in three optional levels using this command; v) *Set Fan Angle* — This command ensures to set blowing angle of fan; vi) *Set Temperature* — Temperature value of environment can be set to a desired level between 5°C and 40°C using this command; and vii) *Return Default Settings* — This command ensures to reset the system. After this operation, all parameters modified previously by user are set to default values.

User who wants to control the system must enter username and password in "member entrance page" firstly. User selects a desired value and then clicks "submit" button on HTML input page. This button activates a form embedded in the page. The form uses POST method. The "action" tag is used in this method to select program, which will sent data entered over the form. Value of "action" tag has been given as "cgi-bin/matweb.exe". Thus, "matweb.exe" application runs after clicking on "submit" button on HTML pages. The "matweb.exe" application is a component of MATLAB WebServer toolbox and it ensures to run m-file determined in "mlmfile" area of the form. Additionally,

parameters on the form are transferred into m-file as a variable by means of "matweb.exe" and "matlabserver.exe" (MWS) applications. Finally, all operations discussed under software structure are executed by m-file.

Control Operation With Control Keys on Main Board

Control keys mounted on main board also control HVAC system. Users can modify fan speed using these keys. All operational steps while setting speed are displayed on LCD mounted on main board. Status of fan speed is seen on LCD. Likewise, users can set HVAC to sleeping mode. Timer of HVAC can be set using timers of MC. Moreover, users can also set blowing angle. All parameters adjusted are saved in EEPROM memory of MC, therefore in case of electricity is cut off, none of the parameters previously stored are lost.

Control Operation with RC Hand-Device

HVAC system is mostly controlled by a RC hand-device instead of control keys on main board. There are four control keys and an LCD on user friendly hand device. A LM35 heat sensor is mounted on hand-device. So, temperature value of environment can be seen easily without looking at LCD mounted on main board circuit. A timer has also been added to hand-device, thus users can learn actual time information. MC controlling main board of HVAC system receives signals sent by TSOP1136 receiver of RC device. Main problem in RC hand-devices with LCD is necessity of altering batteries frequently due to extreme energy consumption. It is minimized by setting status of hand-device to sleep mode automatically.

Conclusions

A fully integrated AC prototype has been designed and implemented. The system can be controlled by three different units (web based control, remote control by a hand-device and keypad control mounted on AC). All hardware system of AC was controlled by a PIC16F877 MC. A DAQ board inserted into PCI bus of web server has been used to control the system over web. If a user is connected to server from a client PC over web, a login page is sent to user for account authentication, and then a main control web page is displayed on client PC. Main control page includes forms to implement all operations. User selects desired operations, setup values, and submits form back to web server, having CGI program named *matweb.exe*. CGI program performs requested tasks and status of the system operation is reported back to the user. Current operational parameters of the system are measured by MC and displayed on LCD. Using web camera on LCD, these parameters are monitored online by one client PC at a time by taking into account Internet speed.

References

1 Zurowski, R, *The Industrial Information Technology Handbook* (CRC Press LLC, Florida) 2004, Chapter 20.

2 Azat A K M, Otieno A, Ghrayeb O & Anand N, Internet based experiments for physical laboratory set-up, in *Proc 2003 American Society for Engineering Edu Annual Conf & Exposition* (American Society for Engineering Education, Tennessee) 2003, 22-25.

3 Suman Y & Kharbanda V P, Internet diffusion in India and China -who holds the edge, *J Sci Ind Res*, **64** (2005) 339-346.

4 Colak I, Demirbas S, Irmak E, Sefa I & Bayindir R, Remote control of DC motor over the internet, in *Proc 3rd Int Conf Technical & Physical Problems in Power Engineering*, Ankara, Turkey, 2006, 216-218.

5 Lee J Y, Lee S, Kwangsoo K, Kim H & Kim C H, Process-centric engineering Web services in a distributed and collaborative environment, *Compu & Ind Engg*, **51** (2006) 297-308.

6 Rutman E, Inard C, Bailly A & Allard F, A global approach of indoor environment in an air-conditioned office room, *Build Environ*, **40** (2005) 29-37.

7 Lute P J & Paassen D V, Optimal indoor temperature control with the use of a predictor, in *Proc 3rd IEEE Conf on Control Applications*, Glasgow, Scotland, 1994, 1843-1848.

8 Hamdi M & Lachiver G, A fuzzy control system based on the human sensation of thermal comfort. *Proc 1998 IEEE Int Conf on Fuzzy Systems*, Anchorage, Alaska, 1998, 487-492.

9 Singh J, Singh N & Sharma J K, Complexity reduction in fuzzy modeling of fan-coil unit of HVAC system, *J Sci Ind Res*, **64** (2005) 420-425.

10 Wei K C & Dage G A, An intelligent automotive climate control system, in *Proc IEEE Int Conf on Systems, Man and Cybernetics*, Vancouver, British Columbia, Canada, 1995, 2977-2982.

11 Gertig A, Herron B, Mullins Z & Thomas J, *Programmable Digital Thermostat* (Department of Electrical and Computer Engineering Mississippi State University, USA) 2003, 1-23.

12 Kataoka S & Atagi K, Preventing IR interference between infrared waves emitted by high-frequency fluorescent lighting systems and infrared remote controls, *IEEE Trans Ind Appl*, **33** (1997) 239-245.

13 Lin T, Zhao H, Wang J, Han G & Wang J, An embedded web server for equipments. *Proc 7th Int Symp on Parallel Architectures, Algorithms and Networks*, Hong Kong, China, 2004, 345-350.

14 Park G, The remote control system for the next generation air conditioners, *IEEE Trans Consumer Electron*, **47** (2001) 168-178.

15 Lin P H & Broberg H, Internet based monitoring and controls for HVAC applications, *IEEE Ind Appl Mag*, **8** (2002) 49-54.

16 Changhong W, Fei T, Yufeng W & Guangcheng M, Web-based remote control service system, *Proc 2003 IEEE Int Symp on Industrial Electronics*, Rio de Janeiro, Brasil, 2003, 337-341.