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Supervisory Control and Data Acquisition for Air Conditioning System

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Abstract- This paper, Supervisory Control and Data Acquisition (SCADA) for an Air-Conditioner using Visual Basic, illustrates the application of SCADA devices not only for industry but also for the home. As a SCADA master unit, the personal computer provides a graphical user interface (GUI) and automatically regulates the managed air conditioning system in response to sensor inputs. The AT89SC51 microcontroller is applied for a Remote Telemetry Unit (RTU). This controller serves as a local collection point for gathering reports from temperature sensors and delivering commands to control relays for the actuators in both indoor and outdoor unit. The communications network, RS 232 protocol connects the SCADA master unit to the RTUs of the system. The engineering software tools, Visual Basic and Assembly language, are used to develop GUI and communication protocol between personal computer and microcontroller.

Indexed Terms- Supervisory Control and Data Acquisition (SCADA), graphical user interface (GUI), AT89SC51 microcontroller, Remote Telemetry Unit (RTU)

I. INTRODUCTION

Supervisory Control and Data Acquisition (SCADA) is a real-time industrial process control system used to centrally monitor and control remote or local industrial equipment such as motors, valves, pumps, relays, sensors, etc. SCADA is the combination of telemetry and Data Acquisition.

Previously without SCADA software, an industrial process was entirely controlled by PLC, CNC, PID & micro controllers having programmed in certain languages or codes. These codes were either written in assembly language or relay logic without any true animation that would explain the process running. It is always easy to understand the status of the process if it is shown with some animations rather than written codes. Hence SCADA software came to existence with some exclusive features and it became internal part of automation system.

SCADA is not just hardware but also software. It’s a concept. It’s a system as a combination of special hardware, software and protocols. SCADA is used to control chemical plant processes, oil and gas pipelines, electrical generation and transmission equipment, manufacturing facilities, water purification and distribution infrastructure, etc. For example, in a SCADA system, a PLC can be used to control the flow of cooling water as part of an industrial process. At the same time the supervisor can use the Host control function to set the temperature for the flow of water. It can also have alarms and can record the flow of water temperature and report back to supervisor.

The RTUs and PLCs are responsible for data collection such as meter readings, equipment status etc and communicate back to the SCADA system. This data can be stored in a database for later analysis or monitored by a supervisor to take appropriate actions if required.

SCADA systems typically implement a distributed database, commonly referred to as a tag database, which contains data elements called tags or points. A point represents a single input or output value monitored or controlled by the system. Points can be either "hard" or "soft". A hard point is representative of an actual input or output connected to the system, while a soft point represents the result of logic and math operations applied to other hard and soft points. Most implementations conceptually remove this distinction by making every property a "soft" point that can equal a single "hard" point in the simplest case. Point values are normally stored as value-timestamp combinations; the value and the timestamp when the value was recorded or calculated. A series of value-timestamp combinations is the history of that point. It's also common to store additional metadata with tags such as path to field device and PLC register, design time comments, and even alarming information. The quality and comfort of the indoor environment depends largely on temperature and fresh air indoors. Therefore, temperature of indoors must be independent than climate condition. The indoor condition such as heat, coldness and fresh air can change necessity. There are easy ways to reduce heat entering indoors and stay comfortably cool using air conditioner. A successful and speedy measurement for staying determined temperature needs air conditioning equipment containing requiring heater and cooler process.

The block diagram of SCADA Air Conditioning System implemented is shown in Fig. 1. Air conditioning system is designed and constructed by using 8051 microcontroller which also interfaces with Personal Computer based on Visual Basic (VB) software. The air conditioning system will be controlled from Personal Computer with the help of 8051, and this type of data acquisition system is so-called SCADA system, contrary to the one constructed in market by using different type algorithm. Controlling of environment temperature, heat, coldness process, speed of electric fan is done by PC control according to the database and user's settings. All of the parameter such as temperature, electric fan control and louver position can be controlled in GUI of personal computer.

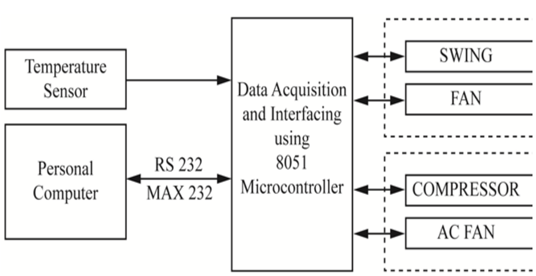

Fig.1 System Block Diagram of SCADA for Air Conditioning System

II. HARDWARE COMPONENTS

The proposed air conditioning system consists of temperature sensor, analog to digital converter (ADC0809), microcontroller AT89S51, RS 232 serial communication, MAX 232, stepper motor and asynchronous AC motor. The main components of the system are described as follows.

A. Temperature Sensor

The temperature sensor is assembled one with various parts and thermistor devices according to the required applications. Its electric characteristics are the same as those of thermistor devices. Variable types of sensor can be utilized for detecting or controlling temperature because its operating temperature range is wide from -50◦C to +300◦C. Standard temperature sensor is available in accordance with the applications such as measurements of liquid, atmosphere and surface temperature.

Not only must external temperature sensors inform the passengers about the outside temperature, they must also pass on the necessary information to the air-conditioning system or the engine control system. External temperature sensors mounted behind the front bumper, on the mirror or another part of the bodywork is completely exposed to the elements. They must be able to withstand moisture, heat, frost, road salt and high pressure washing. Moisture could slowly creep from critical parts such as material junctions up to the sensor head and cause it to fail. The NTC can be protected only if it is part of a completely sealed system.

Fig. 2 Temperature Sensor

For this reason, cabled sensors are recommended, so that the connector is not located near any moisture. If the connector is molded directly onto the external temperature sensor, the connector must be absolutely watertight. No moisture must get to the sensor prior to the mounting of the connector. The junction of the plastic to the metal contacts can never be absolutely moisture-tight. The NTC should be completely encapsulated and bonded to the cable. This is the only way to obtain a really watertight design. The temperature sensor for air conditioning system is shown in Fig. 2.

B. Analog to Digital Converter (ADC0809)

The ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals.

The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL outputs. The design of the ADC0809 has been optimized by incorporating the most desirable aspects of several A/D conversion techniques. The ADC0809 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications. The ADC0809 operates ratio metrically or with 5 V DC or analog span adjusted voltage reference with 0V to 5V input range. It is 8-channel multiplexer with address logic and standard hermetic or molded 28-pin DIP package. It is equivalent to MM74C949-1.

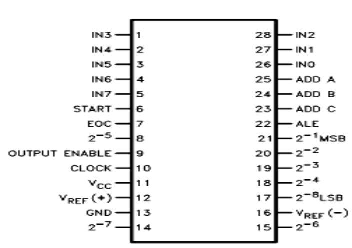

Fig. 3 Pin Diagram of ADC0809 Converter

C. Microcontroller AT89S51

The AT89S51 is a low-power, high-performance CMOS 8-bit microcontroller with 4K bytes of In-System Programmable Flash memory. The device is manufactured by using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with In-System Programmable Flash on a monolithic chip, the Atmel AT89S51 is a powerful microcontroller, which provides a highly flexible and cost-effective solution to many embedded control applications.

The AT89S51 provides the following standard features: 4K bytes of Flash, 128 bytes of RAM, 32 I/O lines, watchdog timer, two data pointers, two 16-bit timer/counters, a five-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.

In addition, the AT89S51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The idle mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next external interrupt or hardware reset.

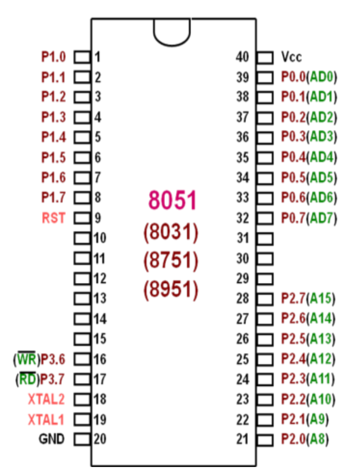

Fig. 4 Pin Configuration of AT89S51 Microcontroller

III. IMPLEMENTATION OF THE SYSTEM

In order to meet the software requirements of SCADA system, Visual Basic programming language is used for Graphical User Interface (GUI) in PC, the master unit of a SCADA and assembly language is used for Remote Telemetry Unit (RTU). For hardware portion, temperature sensing circuit with ADC to interface AT89S51 microcontroller, stepper motor driver circuit, relay driver circuit for actuators and RS 232 interface circuit using MAX232 IC are constructed and tested step by step.

A. PC Software Implementation

The VB's software is designed to operate air conditional control system. VB's window is made up of boxes. Each box contains information related to configurable parameters needed for configuring. For the PC application, a source code VB file will be used. The VB file has multiple configurable items in it. Each item is broken up into sections relating to the specific area for which the code will be used. The section contained in VB files are: RS232, COM port setting, sensor data and display section. PC's serial data acquisition interfaces require the sending and receiving of ASCII data to operate. To communicate with the serial port using visual basic, the MSComm control must be utilized to allow serial data transfer via a serial port.

B. User Interface Window

In this research, the program is constructed to control air conditional system. This program is arranged step by step or procedurally and it consists of a series of steps that take place one after another. The programmer decides the condition under which a procedure takes place, how often it takes place and when the program stops. This program has been implemented using Microsoft Visual Basic (V- 6.0).

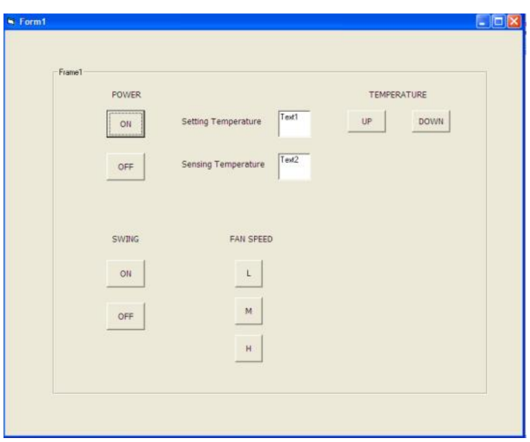

Fig. 5 Graphical User Interface for Air Con Control

System

The user interface displays the setting temperature, the sensing temperature, swing ON/ OFF and the fan speed of the air conditional system as shown in Fig.5. In this system, the temperature sensors are used to sense the condition of room.

C. Software Development for the system

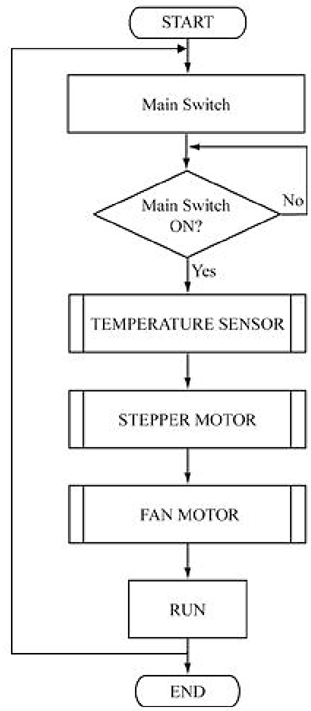

Fig. 6 Main Flowchart of the System

For software development for SCADA air-conditioning system, the assembly language for AT89S51 microcontroller is used to develop a control process for temperature sensing system, stepper motor, variable speed fan motor and compressor. The main control process is shown in Fig. 6.

D. Software Development for Temperature Sensing

The temperature sensed by the room temperature sensor is greater than or equal to setting temperature by GUI from PC, the compressor and cooling fan in outdoor unit of the air-conditioning system will be run automatically, otherwise it will be shutdown.

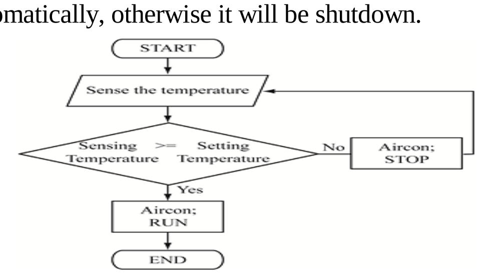

Fig. 7 Flowchart of Temperature Sensing

E. Software Development for Indoor Fan Control

The indoor fan can be switched ON and OFF and its speed can be changed by three kinds of switches- low, medium and high in GUI from PC. If one of three switches is in ON condition, the other two switches will be OFF.

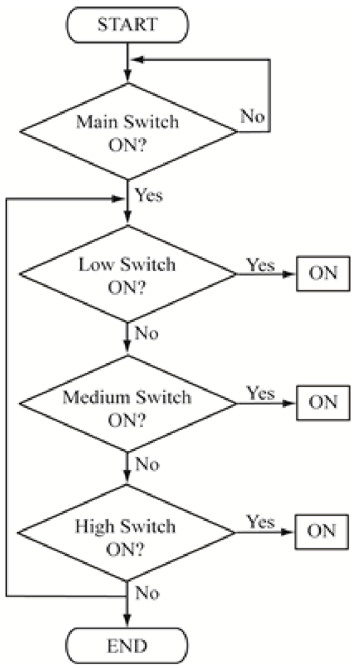

Fig. 8 Flowchart of Indoor Fan Control

F. Software Development for Stepper Motor Control

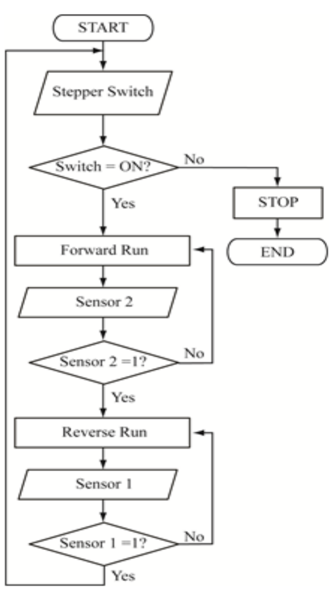

Fig. 9 Flowchart of Stepper Motor Control

The stepper motor control process for swing function includes main ON/OFF and automatic forward and reverse running mode. If the main switch is ON condition, the stepper motor will run in forward direction until sensor 2 is High state. The stepper motor will run in reverse direction once the sensor 1 is High state. The flow chart of the stepper motor for swing function is shown in Fig. 9.

IV. TESTS AND RESULTS

The main engineering software tool used in this research work is Proteus 7 professional. Each portion of SCADA Air-conditioning system, especially for the control process between 8051 Microcontroller and actuators, is developed and tested in Proteus simulator. Some critical simulations, tests and results are described as follows.

A. Simulation Test for Stepper Motor Control

The simulation circuit for stepper motor control by AT89S51 microcontroller is shown in Fig. 10. If the input switch is HIGH state, the microcontroller will produce a PWM and stepper motor will run and otherwise it will stop.

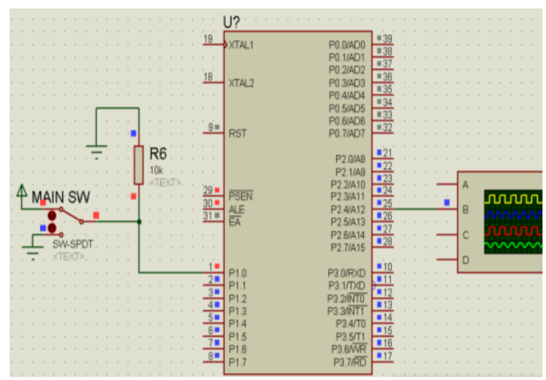

Fig. 10 Simulation Test for Stepper Motor Control Circit

The main function of microcontroller for stepper motor control is to produce PWM that is suitable for stepper motor speed. The 8051 microcontroller provides a PWM which is frequency 5 Hz and 50 % duty cycle. The waveform of PWM is shown in Fig. 11. According to testing results, this PWM can run the stepper motor in suitable speed for swing function of indoor unit fan.

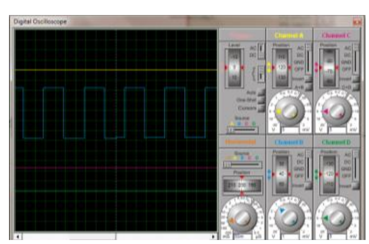

Fig. 11 PWM Waveform of Stepper Motor Driven

Signal

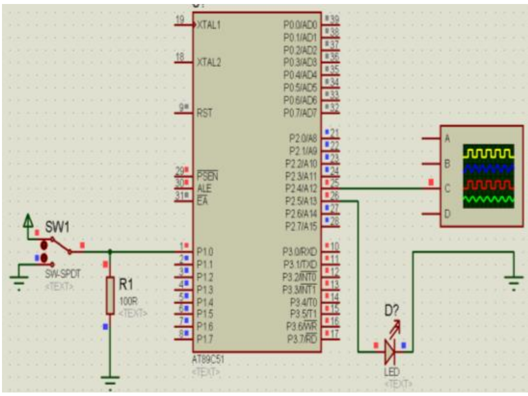

Fig. 12 Simulation for Forward and Reverse Rotation of Stepper Motor

For driving the stepper motor in forward and reverse rotation, the pin 26 of port 2 produces the control signal, low and high, in turn automatically. When this pin is in high state, the stepper motor will rotate in forward rotation for 15 seconds. And then, the pin 26 will be again in low state in result of reverse rotation of stepper motor. The simulation test of stepper motor rotation is shown in Fig. 12.

B. Simulation Test for Temperature Sensing Unit

Instead of temperature sensor, the potentiometer is used to provide changing analog voltages into 8 bits ADC. The clock for ADC 0808 is provided by function generator. The simulation test of ADC 0808 and AT89S51 microcontroller interfacing is shown in Fig. 13.

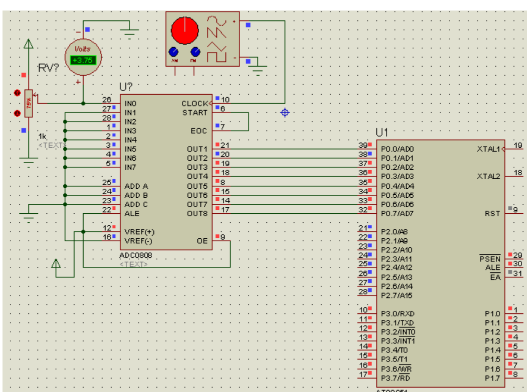

Fig. 13 Simulation of Temperature Sensing Unit

C. Workbench Testing

The MAX232N IC is used for interfacing the main control circuit and personal computer. The interfacing test for main controller and PC is shown in Fig. 14.

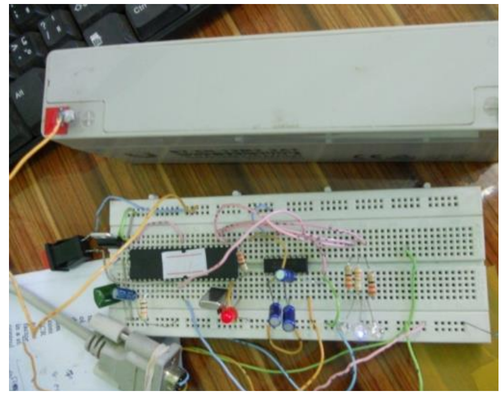

Fig. 14 Interfacing Test for PC and Main Controller

The control circuit of DC motor and stepper motor is tested as mentioned in Fig. 15.

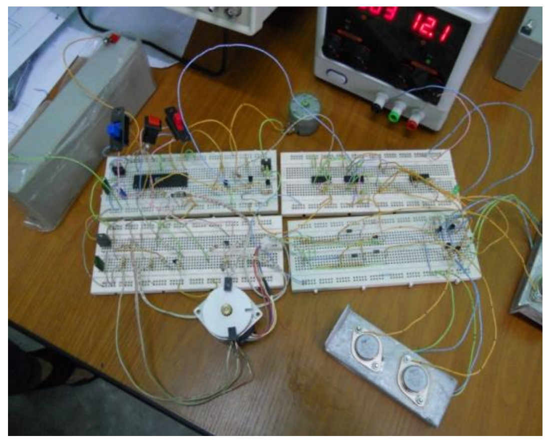

Fig. 15 Testing of Control Circuit for Stepper Motor and DC Motor

V. CONCLUSION

Supervisory Control and Data Acquisition (SCADA) system is a sophisticated automation, data acquisition and data logging tool as well as a control option during operation, thus facilitating operators to effect parameter changes based on actual real time data available at his finger tips. The facility to view key process parameters like, temperature, operation of compressor, swing, fan speed, allows the operating personnel to analyze and instantaneously take corrective action. The optimized utilization of equipment running time manifests as reduced energy consumption. The real time consumption trend helps in overall optimization, leading to energy savings.

The exploit of modern materials and equipment with the implementation of appropriate algorithms produce modern air-conditioning systems that belong to the energy saving this systems with maximum performance, which save energy and protect the environment. A system for monitoring and control provides management and visualization of the object and display the current value of significant parameters.

With the stored data in the system, it is possible to detect the problems with the On/Off controllers applied to the air conditioning system. The program embedded in the microcontroller can be changed as the user require without needing to change the design of air conditioning parts.

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