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Automatic Ventilation Control System for Energy Efficient buildings using CO_2 Sensors

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***Abstract*—** In this paper, the proposed work states automatic control strategy for ventilation systems in energy-efficient buildings. To maintain indoor CO_2 in the comfort zone to the accurate level and minimum ventilation rate is the main design goal of automatic ventilation controller. The system uses CO_2 as the main indicator of human comfort. The intelligent system as compared to traditional ON/OFF or fixed ventilation system gives better results in energy saving and also provide high indoor air quality. The technical notes provide the block diagram description and the importance using AVR Microcontroller. The KEIL µVision3 makes Embedded C Programming much easier than KEIL µVision2.

***Keywords*—** AVR controller, LCD, Sensor, CO_2 Predictive model, KEIL µVision3

I. INTRODUCTION

Currently most of people tend to spend most of their time in the interior of the building, e.g. at home, offices and hospitals, in schools and universities. That is why breathing fresh indoor air is vital for our health [1, 12], [2, 13]. Ventilation is considered to be one of the most important factors for maintaining acceptable indoor air quality in any space. It is used to introduce outside air, control temperature and remove excessive moisture, odors, smoke, heat, dust, airborne bacteria, and carbon dioxide. However, ventilation consumes energy in terms of electrical fan power as well as cooling and heating energy. Energy production also affects negatively on our environment and contributes to CO2-emissions to the atmosphere.[3,11]

Many types of ventilation systems encounter problems to control minimum supply air and thus to consume minimum amount of energy. But a ventilation system based on registration of increasing CO_2 concentrations can facilitate in solving the given problem. Such a technology called CO_2 based demand control ventilation (DCV).[4,11]

The experience and field studies have shown that the level of carbon dioxide in any space can be a reliable indicator and quite a cheap instrument of the air quality and ventilation rate. That is why CO2 is used as an indicator of air quality in demand controlled ventilation systems.[5,11]

CO2-based demand controlled ventilation system controls the amount of supply outdoor fresh air in a building depending on a number of people and their activity. People are the main source of CO2 in a building [12]. If a number of people in a room is doubled, the CO2 level will accordingly double. If one or few people leave a room, the level of CO2 will proportionally decrease. Hence to sense the presence of person IR sensor is used and, Thus DCV saves energy solely by not heating or cooling unnecessary amount of outdoor air. The benefits of such a ventilation system are maximal when a number of people continuously changes in a building, in the extreme climate conditions or when the electricity cost is quite high.[4, 10]

II. PROPOSED WORK

The proposed work is to study and implement Automatic Ventilation Control for Energy Efficient Buildings with CO2 Predictive Model. The objective of the proposed work is a predictive model is used to forecast the indoor concentration, which is mainly related to the human generation, outdoor air quality and air flow rate. [10]

The proposed intelligent control system is used to automatically find the optimal overall ventilation rate based on the real operating conditions. The overall ventilation rate includes both natural ventilation and mechanical ventilation. The natural ventilation system works all the time. Only if the indoor concentration exceeds the set point or the minimum ventilation rate per person cannot be satisfied, the mechanical ventilation systems are activated. It can be seen that only natural ventilation is used before 5:00 am, and both natural ventilation and mechanical ventilation are utilized after 5:00 am in this simulation scenario. The natural ventilation is implemented by opening the window, and in the simulation the window is assumed to open in a
fixed angle so that the natural ventilation rate can be set as a constant value for 24 hours.[10]

Although natural ventilation rate is very small as compared to the mechanical ventilation rate, it is helpful to reduce the energy consumption. It can be observed that the energy consumption is reduced after combining the natural ventilation system with the mechanical ventilation system.

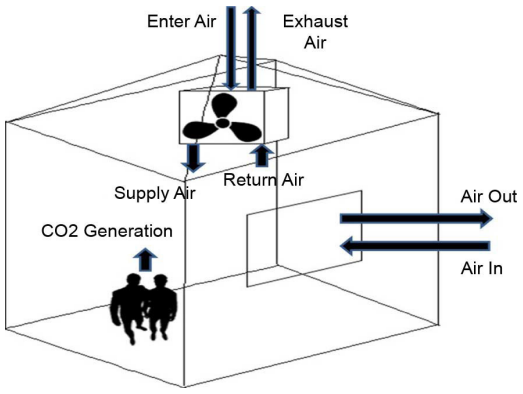


Figure.1. Predictive Model

A predictive model is used to forecast the indoor concentration, which is mainly related to the human generation, outdoor air quality and air flow rate. Fig.1. represents a building with both natural ventilation and mechanical ventilation systems. Natural ventilation is implemented by opening the window, and air fans are used to control the mechanical ventilation rate by adjusting the speed. Outdoor air can be drawn into a mixing box by an outdoor air fan and damper, and it is mixed up with the partial return air. The supply air fan is utilized to pull the mixed air through the supply duct into the building as the supply air. The air goes to return air inlets after passing through the building. The return air has two ways out: some of it is exhausted to outdoor directly, while the rest is sent back to the mixing box and mixed up with the outdoor air[6, 10].

III. INTRODUCTION TO EMBEDDED SYSTEMS

Embedded system is a combination of software and hardware designed and programmed to perform one/more particular task(s). The hardware is designed for specific application and then software is embedded in this hardware to perform the task. Both software and hardware are dedicated to that particular application. The heart of the system is either processor or controller. Processor / controller may be general purpose or special purpose that controls whole system [7, 8].

There may be more than one processor/controller if system is complex. It may be possible that there is one general purpose processor / controller and one or more special purpose processors / controllers. For example in 3G (or 4G) cell phones there is one general purpose processor that handles user commands, memory and display etc. And there are special purpose processors like DSP for voice communication and network management, display controller to generate real and reach images on color LCD screen.

An embedded system is a special-purpose system in which the computer is completely encapsulated by or dedicated to the device or system it controls. Physically embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, or the systems controlling nuclear power plants. In terms of complexity embedded systems can range from very simple with a single microcontroller chip, to very complex with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

IV. BLOCK DIAGRAM

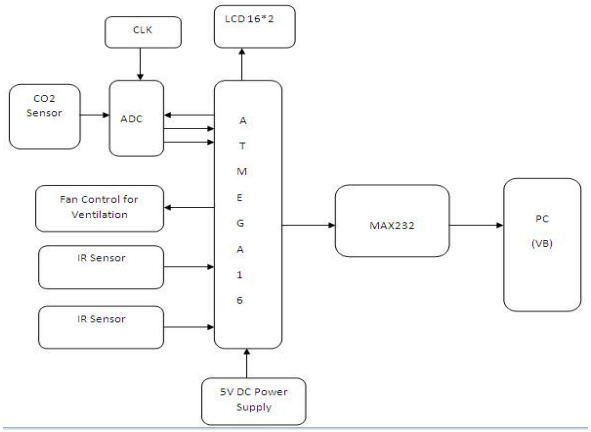


Figure.2. Block diagram automatic ventilation system

The generalized block diagram of project is shown as above. The block AVR microcontroller

1. AVR
2. Power supply
3. LCD
4. Sensors
5. PC interface

The Atmega16 controller from Microchip Company is from AVR series. At the slave part the sensor CO will be interface to microcontroller. The output of CO sensor is analog which is given to the ADC which is inbuilt in AVR. The LCD used is 16 X 2 which is used for display of the sensor data. The DC motor which resembles the FAN will be interface to microcontroller through L293 driver IC. The L293 driver IC is interface for boosting of current. The IR sensor is used for counting the persons IN and Out. The data will be passed to PC using serial communication.

The person would be counted and FAN will be controller and according to the percentage of the CO2 the FAN speed will be controller.

A) Block Diagram Description

Working of proposed ventilation system is as follows:

1) Firstly, CO2 concentration in the atmosphere is sensed by CO2 sensor which is then converted to digital form and provided to micro-controller.
2) Main function of microcontroller is to compare CO2 level and maintain the CO2 concentration to desired level.
3) The CO2 level is then graphically represented using Mat Lab simulation tool. Max232 is a PC interface.

PIR (Passive infrared sensor) and IR (infrared sensor) continuously provide information about occupancy and the number of people in the room to the microcontroller.
All the information regarding occupancy is displayed on LCD display.

The microcontroller is such programmed that the CO2 level and ventilation is controlled in order to save excessive amount of power consumption.

This Project mainly consists of Power Supply section, Microcontroller section, LCD display section, ADC 0804 section, Motor section and Relay section.

1) Microcontroller Section

This section forms the control unit of the whole project. This section basically consists of a Microcontroller with its associated circuitry like Crystal with capacitors, Reset circuitry, Pull up resistors (if needed) and so on. The Microcontroller forms the heart of the project because it controls the devices being interfaced and communicates with the devices according to the program being written.[12]

Microcontroller

A Micro controller consists of a powerful CPU tightly coupled with memory RAM, ROM or EPROM), various I / O features such as Serial ports, Parallel Ports, Timer/Counters, Interrupt Controller, Data Acquisition interfaces-Analog to Digital Converter (ADC), Digital to Analog Converter (ADC), everything integrated onto a single Silicon Chip.

It does not mean that any micro controller should have all the above said features on chip, Depending on the need and area of application for which it is designed, the ON-CHIP features present in it may or may not include all the individual section said above. Any microcomputer system requires memory to store a sequence of instructions making up a program, parallel port or serial port for communicating with an external system, timer / counter for control purposes like generating time delays, Baud rate for the serial port, apart from the controlling unit called the Central Processing Unit.

INTRODUCTION OF AVR:

Micro-Controller- Microcontroller is the heart of this circuit. The microcontroller used is AVR, ATMEGA32 from ATMEL company. The MOSFET IRF224 will be used as driver for driving DC motor. The sensing of speed for DC motor will be done using optical encoder .The output of sensor will be given as feedback to the microcontroller. For every one rotation of motor one interrupt signal will be send to microcontroller. The required speed can be entered through keypad. LCD 16 X 2 or 20 x4 will be attached to microcontroller. The HMI will be displayed on LCD.The crystal will provide required for the microcontroller.

BRIEF HISTORY OF AVR:

ATMEGA32:The AVR is a Modified Harvard architecture 8-bit RISC single chip microcontroller (µC) which was developed by Atmel in 1996. The AVR was one of the first microcontroller families to use on-chip flash memory for program storage, as opposed to One-Time Programmable ROM, EPROM, or EEPROM used by other microcontrollers at the time.

WHY AVR?-AVRs have been used in various automotive applications such as security, safety, power train and entertainment systems. Atmel has recently launched a new publication "Atmel Automotive Compilation" to help developers with automotive applications. Some current usages are in BMW, Daimler-Chrysler and TRW

System Semiconductor, Inc produces the M3000 Motor and Motion Control Chip, incorporating an Atmel AVR Core and an Advanced Motion Controller for use in a variety of motion applications.

The New 32-Bit AVRs In 2006 Atmel released microcontrollers based on the new, 32-bit, AVR32 architecture. They include SIMD and DSP instructions, along with other audio and video processing features. This 32-bit family of devices is intended to compete with the ARM based processors.

Due to lot of features in built it is very cost effective and easy to build a controller.

TECHNICAL DETAILS OF AVR

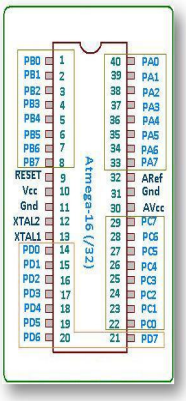
- High-performance, Low-power AVR® 8-bit Microcontroller
- Advanced RISC Architecture
- 131 Powerful Instructions – Most Single-clock Cycle Execution
- 32 x 8 General Purpose Working Registers
- On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
- 32K Bytes of In-System Self-Programmable Flash
- Endurance: 10,000 Write/Erase Cycles
- In-System Programming by On-chip Boot Program

- True Read-While-Write Operation
- 1024 Bytes EEPROM\
- Endurance: 100,000 Write/Erase Cycles
- 2K Byte Internal SRAM
- Programming Lock for Software Security
- JTAG (IEEE std. 1149.1 Compliant) Interface
- Boundary-scan Capabilities According to the JTAG Standard
- Extensive On-chip Debug Support
- Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface

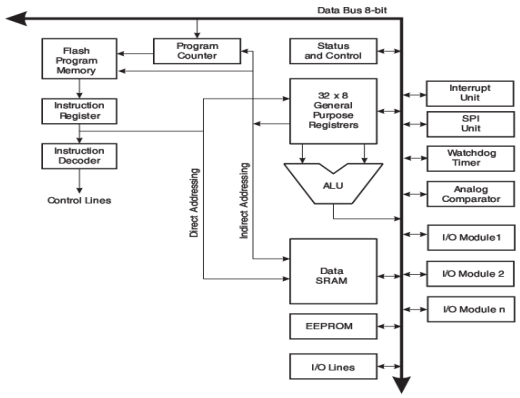
PERIFERAL FEATURES

- Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
- One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and CaptureMode
- Real Time Counter with Separate Oscillator
- Four PWM Channels
- 8-channel, 10-bit ADC
- 8 Single-ended Channels
- Byte-oriented Two-wire Serial Interface
- Programmable Serial USART
- Master/Slave SPI Serial Interface
- Programmable Watchdog Timer with Separate On-chip
- Oscillator
- On-chip Analog Comparator
- Special Microcontroller Features
- Power-on Reset and Programmable Brown-out Detection
- Internal Calibrated RC Oscillator
- External and Internal Interrupt Sources
- Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
- I/O and Package
  -32 Programmable I/O Lines
- 40-pin PDIP, 44-lead TQFP, and 44-pad QFN/MLF
- Operating Voltages
  – 2.7 - 5.5V for ATmega32L
  – 4.5 - 5.5V for ATmega32
- Speed Grades
  0 - 8 MHz for ATmega32L
  – Active: 1.1 mA
  – Idle Mode: 0.35 mA
  – Power-down Mode: < 1 µA

PHYSICAL PORT



ARCHITECTURE



NECESSITY OF MICROCONTROLLERS

Microprocessors brought the concept of programmable devices and made many applications of intelligent equipment. Most applications, which do not need large amount of data and program memory, tended to be costly. The microprocessor system had to satisfy the data and program requirements so, sufficient RAM and ROM are used to satisfy most applications .The peripheral control equipment also had to be satisfied. Therefore, almost all-peripheral chips were used in the design. Because of these additional peripherals cost will be comparatively high.

Bulky: On comparing a board full of chips (Microprocessors) with one chip with all components in it (Microcontroller).
Debugging: Lots of Microprocessor circuitry and program to debug. In Micro controller there is no Microprocessor circuitry to debug. Slower Development time: As we have observed Microprocessors need a lot of debugging at board level and at program level, where as, Micro controller do not have the excessive circuitry and the built-in peripheral chips are easier to program for operation. So peripheral devices like Timer/Counter, Parallel programmable port, Serial Communication Port, Interrupt controller and so on, which were most often used were integrated with the Microprocessor to present the Micro controller .RAM and ROM also were integrated in the same chip. The ROM size was anything from 256 bytes to 32Kb or more. RAM was optimized to minimum of 64 bytes to 256 bytes or more.

Microprocessor has following instructions to perform:

1. Reading instructions or data from program memory ROM.
2. Interpreting the instruction and executing it.
3. Microprocessor Program is a collection of instructions stored in a Nonvolatile memory.
4. Read Data from I/O device
5. Process the input read, as per the instructions read in program memory.
6. Read or write data to Data memory.

7. Write data to I/O device and output the result of processing to O/P device.

2. POWER SUPPLY SECTION

This section is meant for supplying Power to all the sections mentioned above. It basically consists of a Transformer to step down the 230V ac to 9V ac followed by diodes. Here diodes are used to rectify the ac to dc. After rectification the obtained rippled dc is filtered using a capacitor Filter. A positive voltage regulator is used to regulate the obtained dc voltage.

The power supplies are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronics circuits and other devices. A RPS (Regulated Power Supply) is the Power Supply with Rectification, Filtering and Regulation being done on the AC mains to get a Regulated power supply for Microcontroller and for the other devices being interfaced to it. A power supply can by broken down into a series of blocks, each of which performs a particular function. A d.c power supply which maintains the output voltage constant irrespective of a.c mains fluctuations or load variations is known as "Regulated D.C Power Supply".

For example a 5V regulated power supply system as shown below:

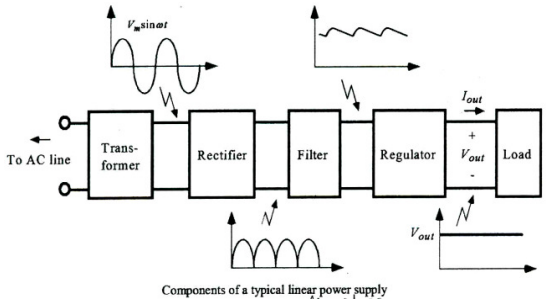


Figure.3. Block Diagram of the Power Supply

3. LCD DISPLAY SECTION

This section is basically meant to show up the status of the project. This project makes use of Liquid Crystal Display to display / prompt for necessary information. Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal.

An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. One each polarizers are pasted outside the two glass panels. These polarisers would rotate the light rays passing through them to a definite angle, in a particular direction When the LCD is in the off state, light rays are rotated by the two polarisers and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent.

When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarizers, which would result in activating / highlighting the desired characters.

The LCD's are lightweight with only a few millimeters thickness. Since the LCD's consume less power, they are compatible with low power electronic circuits, and can be powered for long durations. The LCD s doesn't generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD's have long life and a wide operating temperature range.

Changing the display size or the layout size is relatively simple which makes the LCD's more customer friendly.
The LCDs used exclusively in watches, calculators and measuring instruments are the simple seven-segment displays, having a limited amount of numeric data. The recent advances in technology have resulted in better legibility, more information displaying capability and a wider temperature range. These have resulted in the LCDs being extensively used in telecommunications and entertainment electronics. The LCDs have even started replacing the cathode ray tubes (CRTs) used for the display of text and graphics, and also in small TV applications. This section describes the operation modes of LCD's then describe how to program and interface an LCD to 8051 using Assembly and C.

LCD OPERATION

In recent years the LCD is finding widespread use replacing LED s (seven-segment LED s or other multi-segment LED s).This is due to the following reasons:

- The declining prices of LCDs.
- The ability to display numbers, characters and graphics. This is in contrast to LED which is limited to numbers and a few characters.
- Incorporation of a refreshing controller into the LCD, there by relieving the CPU of the task of refreshing the LCD. In the case of LED s, they must be refreshed by the CPU to keep on displaying the data.
- Ease of programming for characters and graphics.

LCD PIN DESCRIPTION

The LCD discussed in this section has 14 pins. The function of each pin is given in table.

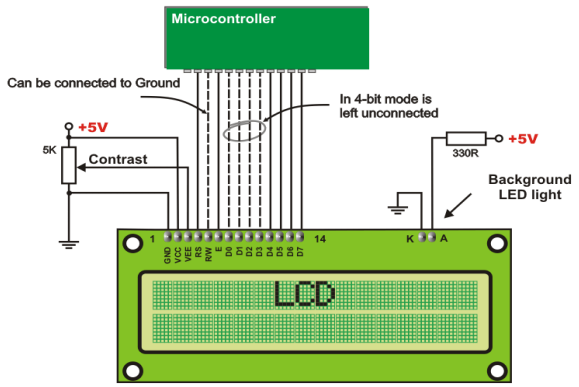


Figure.4.Connection of LCD with Microcontroller

The LCD can display a character successfully by placing the

a. Data in Data Register

Data corresponds to the ASCII value of the character to be printed. This can be done by placing the ASCII value on the LCD Data lines and selecting the Data Register of the LCD by selecting the RS (Register Select) pin.

b. Command in Command Register of LCD

Each and every display location is accessed and controlled by placing respective command on the data lines and selecting the Command Register of LCD by selecting the (Register Select) RS pin.[12]

4. SENSORS

To save energy, demand-controlled ventilation (DCV) is utilized to prevent the energy waste from ventilating an empty building [9]. Over the past decade, much work has confirmed the effectiveness of DCV in terms of energy savings. Sensorbased demand controlled ventilation (SBDCV) has two primary schemes:

1. CO_2 sensor-based DCV (CO_2 Sensor).
2. Occupancy sensor-based DCV (IR Sensor). [9]

The CO_2 concentration for indoor air can be directly measured by CO_2 a sensor, and it is verified that CO_2-DCV can save around 10% to 35% energy compared to the normal fixed ventilation control by different experiments [14]-[16]. Its limitations include the lack of accuracy for the CO_2 sensor and the needs for maintenance.[9]

Occupancy sensor-based DCV is a common strategy to achieve both high indoor air quality and energy savings[11]. It determines the ventilation rate according to the number of occupants and the minimum ventilation rate per person required by industry standards. Compared to the CO_2 sensor, the occupancy sensor with high accuracy has been existing and it can determine the exact number of people in the building directly. The limitation for occupancy sensor-based DCV lies in the variation and uncertainty of the minimum ventilation rate per person in different situations.[9]

This work provides a promising approach to designing more effective ventilation systems for increasing building energy efficiency by embedding a certain degree of intelligence into the control systems.

5. PC INTERFACE

Software used is:
*Keil software for C programming
*Express PCB for lay out design
*Express SCH for schematic design
* Embedded C

KEIL µVision3
What's New in µVision3?
µVision3 adds many new features to the Editor like Text Templates, Quick Function Navigation, and Syntax Coloring with brace high lighting Configuration Wizard for dialog based startup and debugger setup. µVision3 is fully compatible to µVision2 and can be used in parallel with µVision2.[13]
What is µVision3?

µVision3 is an IDE (Integrated Development Environment) that helps you write, compile, and debug embedded programs. It encapsulates the following components:

- A project manager.
- A make facility.
- Tool configuration.
- Editor.
- A powerful debugger.

Express PCB
Express PCB is a Circuit Design Software and PCB manufacturing service. One can learn almost everything you need to know about Express PCB from the help topics included with the programs given.
Details: Express PCB, Version 5.6.0

Express SCH- The Express SCH schematic design program is very easy to use. This software enables the user to draw the Schematics with drag and drop options. A Quick Start Guide is provided by which the user can learn how to use it.
Details: Express SCH, Version 5.6.0.

EMBEDDED C- The programming Language used here in this project is an **Embedded C** Language. This Embedded C Language is different from the generic C language in few things like

a) Data types

b) Access over the architecture addresses.

The Embedded C Programming Language forms the user friendly language with access over Port addresses, SFR Register addresses etc.

Embedded C Data types:

Data Types	Size in Bits	Data Range/Usage
unsigned char	8-bit	0-255
signed char	8-bit	-128 to +127
unsigned int	16-bit	0 to 65535
signed int	16-bit	-32,768 to +32,767
sbit	1-bit	SFR bit addressable only
Bit	1-bit	RAM bit addressable only
sfr	8-bit	RAM addresses 80-FFH only

Table.1. Embedded C Data Types

8051 project development cycle

1. Create source files in C or assembly.
2. Compile or assemble source files.
3. Correct errors in source files.
4. Link object files from compiler and assembler.
5. Test linked application.

The steps to develop 8051 project using keil are:

1. Click on the Keil uVision Icon on Desktop
2. Click on the Project menu from the title bar
3. Then Click on New Project
4. Save the Project by typing suitable project name with no extension in u r own folder sited in either C:\ or D:\
5. Then Click on save button above.
6. Select the component for u r project. i.e. Atmel……
7. Click on the + Symbol beside of Atmel
8. Select AT89C51 as shown below
9. Then Click on "OK"
10. Then Click either YES or NO……mostly "NO"
11. Now your project is ready to USE
12. Now double click on the Target1, you would get another option "Source group 1" as shown in next page.
13. Click on the file option from menu bar and select "new"
14. The next screen will be as shown in next page, and just maximize it by double clicking on its blue boarder.
15. Now start writing program in either in "C" or "ASM"
16. For a program written in Assembly, then save it with extension ". asm" and for "C" based program save it with extension " C"
17. Now right click on Source group 1 and click on "Add files to Group Source"
18. Now you will get another window, on which by default "C" files will appear.
19. Now select as per your file extension given while saving the file
20. Click only one time on option "ADD"
21. Now Press function key F7 to compile. Any error will appear if so happen.
22. If the file contains no error, then press Control+F5 simultaneously.
23. Then Click "OK".
24. Now Click on the Peripherals from menu bar, and check your required port as shown in fig below.
25. Drag the port a side and click in the program file.
26. Now keep Pressing function key "F11" slowly and observe.
27. You are running your program successfully[14]

RELEVANCE

The concentration for indoor air can be directly measured by a CO2-sensor, and it is verified that CO2-DCV can save around 10% to 35% energy compared to the normal fixed ventilation control.

The limitation of the ON/OFF control is that the overall ventilation rate cannot vary continuously, which has only two operation modes. Thus, the ventilation system using ON/OFF control can be considered as a discrete ventilation system. Based on [9], Sensor-based demand- controlled ventilation, it is difficult to find an optimal ventilation rate to maintain the indoor CO2 concentration just below the set point. To provide a high level of air quality comfort, the ON/OFF control system always chooses a higher ventilation rate at the cost of consuming more energy. The proposed intelligent control is applied to the continuous ventilation system whose ventilation rate can be changed continuously. The goal of the intelligent control system is to achieve the balance of the air quality comfort and power consumption.[11]

It can be observed that as compared with the ON/OFF control strategy, the indoor air quality is improved in intelligent control system. The overall uncomfortable time is reduced while the comfort level is improved. The simulation results indicate that the intelligent control system leads to better performances in scenarios of both sufficient and insufficient energy supplies[11]. The intelligent control system saves 15% electricity cost as compared to the ON/OFF control.

CONCLUSION

The project "Automatic Ventilation Control System for Energy Efficient buildings using CO_2 Sensors" has been successfully designed and tested. Integrating features of all the hardware components used have developed it. Presence of every module has been reasoned out and placed carefully thus contributing to the best working of the unit. Secondly, using

highly advanced IC's and with the help of growing technology the project has been successfully implemented.

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