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# Development of Microcontroller Base Automatic Level of Discomfort Index Measurement using Thom Model

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## ABSTRACT

Many of scientific researchers used data collected from meteorology to compute for the level of discomfort index for prediction but no attempt by scientist in third world nations, Nigeria inclusive to measure level of discomfort index directly. In this paper attempt was made to measure level of discomfort index using Thom model directly. In this model, dry and wet temperatures are required. The dry and wet thermometer was designed using microcontroller and Thom model equation was embedded inside the microcontroller. The system uses dry and wet temperature developed using semiconductor temperature sensors (LM35) for computing discomfort level of the room or/and hall in question. Other material require in the system are multiplexer (CD4052), analog to digital converter (ADC0804), microcontroller (AT80S52) and intelligent display unit (Hitachi's LCD HD44780). An assembly language was written to take in data and compute for the Thom model. The temperature measurement using LM35 for dry and wet was completely in agreement with convention built using mercury in glass thermometer in Steven Screen in The Federal University of technology, Akure meteorological garden. Also, the output of the discomfort level index was in agreement with computed data for each set of measurement by equipment.

**Keywords:** *discomfort level, dry and wet thermometer, embedded system, microcontroller*

## 1. INTRODUCTION

The heat balance, between the human body and the environment, is a complicated combination of temperature, humidity, wind force and a variety of radiations. There is a great number of empirical formulae (bio-meteorological indices), that have been provided up till now, and which can express the scale of comfort and discomfort of the human being, in relation with the weather conditions.

In this paper the "Discomfort Index" (DI) which has been proposed by Thom (1959) was used and is expressed by the following formula:

$$DI = 0.4\,(Ta + Twb) + 4.8 \qquad (1)$$

where: Ta, Twb, are the dry and wet temperatures respectively.

This index is as good as others for practical application and it has been used for similar purposes by other investigators [1~5]. Furthermore this empirical formula has been based upon the feeling of comfort or discomfort, of a great number of people, with similar adaptative reactions to the environmental conditions.[6]

The temperature and humidity conditions, which in each case determine the values of DI and because of which man feels comfort or discomfort are graduated as follows in Table 1.[6]

This graduation (Table 1) relates to healthy and young people, office workers, and people who work in air conditioned buildings.

**Table l**. Categories of the Discomfort Index.

| Level Discomfort Index | Condition of room |
|---|---|
| DI<21 | comfort for man. |
| 21< DI< 24 | the 10% of the total population feels discomfort |
| 24<DI<26 | the 50% of the total populationfeels discomfort |
| DI>26 | the 100% of the total populationfeels discomfort |

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In order to achieve this automatic measurement of level of discomfort consists of dry and wet temperature sensors using LM35, multiplexer (CD4052), analog-to-digital converter (ADC0804), microcontroller (AT80S52) and intelligent display unit (Hitachi's LCD HD44780) as shown in figure 1, were connected together to make up the system. Also, an assembly language was written to read dry and wet temperature, and internally computed for the level of discomforted index.

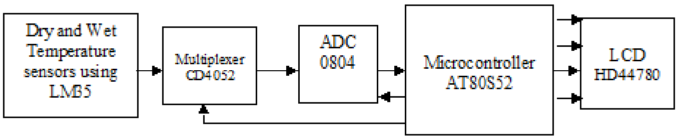


**Figure 1:** The Block Diagram of Automatic Level of Discomfort Index Measurement Instrumentation System

## 2.0 SENSOR CONSTRUCTION

### 2.1 Precision Centigrade Temperature Sensor Design

The LM35Z or LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. As shown in figure 2 shows the simple connection of LM 35 at reference voltage $V_s$ and connect is for the range of temperature from +2 $^oC$ to 150 $^oC$. Advantage of using LM35 is that it doesn't require external component for calibration or trimming. It has accuracies of ±0.5 $^oC$ at room temperature and ±0.75$^oC$ over full temperature range of sensor. The sensor sensitivity is +10mV/$^oC$. The LM35's low output impedance, linear output, and precise inherent calibration make readout and control circuitry especially easy. It required single power supply of voltage range from 4 V to 30 V. Its energy save since draw only 60 µA from its supply, it has very low self-heating, less than 0.1 $^oC$ in still air and with low impedance output, 0.1 Ω for 1mA load.

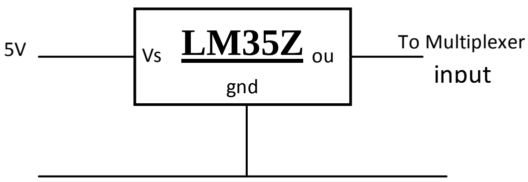


**Figure 2:** LM35z Sensor connection

### 2.2 Wet Junction Construction

The wick of the wet junction is made by passing three lengths of cotton sewing machine thread over the LM35Z junction or neck (Figure 2) and binding them, not too tightly, with another length of the same thread. The six ends of the threads, which pass over the junction that has been glued with aradiate and two lengths of the binding thread form the wick (figure 2).[7]

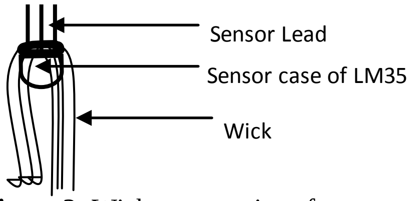


**Figure 3:** Wick constructions for wet temperature sensor

## 3.0 CIRCUIT DESCRIPTION

### 3.1 Criteria for Choosing a Microcontroller

The basic criteria for choosing a microcontroller suitable for the application are:

The first and foremost criterion is that it must meet the task at hand efficiently and cost effectively. In analyzing the needs of a microcontroller-based project, it is seen whether an 8- bit, 16-bit or 32-bit microcontroller can best handle the computing needs of the task most effectively. Among the other considerations in this category are:

(a) **Speed:** The highest speed that the microcontroller supports.

(b) **Packaging:** It may be a 40-pin DIP (dual inline package) or a QFP (quad flat package), or some other packaging format. This is important in terms of space, assembling, and prototyping the end product.

(c) **Power consumption:** This is especially critical for battery-powered products.

(d) The number of I/O pins and the timer on the chip.

(f) How easy it is to upgrade to higher – performance or lower consumption versions.

(g) **Cost per unit**: This is important in terms of the final cost of the product in which a microcontroller is used.

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The second criterion in choosing a microcontroller is how easy it is to develop products around it. Key considerations include the availability of an assembler, debugger, compiler, technical support. Here midepack complier and proteus was used simulation before it was built in real life.

The third criterion in choosing a microcontroller is its ready availability in needed quantities both now and in the future. Currently of the leading 8-bit microcontrollers, the 8051 family has the largest number of diversified suppliers. By supplier is meant a producer besides the originator of the microcontroller. In the case of the 8051, this has originated by Intel several companies also currently producing the 8051.

Thus the microcontroller AT89S52, satisfying the criterion necessary for the proposed application is chosen for the task. [8,]

## 3.2 Basic Description of Microcontroller AT89S52

The 8051 family of microcontrollers is based on an architecture which is highly optimized for embedded control systems. It is used in a wide variety of applications from military equipment to automobiles to the keyboard. Second only to the Motorola 68HC11 in eight bit processors sales, the 8051 family of microcontrollers is available in a wide array of variations from manufacturers such as Intel, Philips, and Siemens. These manufacturers have added numerous features and peripherals to the 8051 such as I2C interfaces, analog to digital converters, watchdog timers, and pulse width modulated outputs. Variations of the 8051 with clock speeds up to 40MHz and voltage requirements down to 1.5 volts are available. This wide range of parts based on one core makes the 8051 family an excellent choice as the base architecture for a company's entire line of products since it can perform many functions and developers will only have to learn this one platform.

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry- standard 80C51 instruction set and pinout. 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 AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. In addition, the AT89S52 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 con-tents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

The basic architecture of AT89C51 consists of the following features:

- Compatible with MCS-51 Products
- 8K Bytes of In-System Programmable (ISP) Flash Memory
- 4.0V to 5.5V Operating Range
- Fully Static Operation: 0 Hz to 33 MHz
- 256 x 8-bit Internal RAM
- 32 Programmable I/O Lines
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Full Duplex UART Serial Channel
- Low-power Idle and Power-down Modes
- Interrupt Recovery from Power-down Mode
- Watchdog Timer
- Fast Programming Tim
- Flexible ISP Programming (Byte and Page Mode) [8,9,10]

## 3.4 Sensor Selector Unit

Since two input signal source are available CD4052 differential 4 channel multiplexer IC was used to select input one by one and is address by microcontroller and output signal of the multiplexer fed into the input of ADC0804, the output from ADC is send to port 3 (P3) of AT89S52 controller. It sample the data every 1 s.

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## 3.5 Analog-to-digital Conversion (ADC0804)

The ADC0804 is compatible with microprocessors. It is a 20-pin IC that works with 5 V supply. It converts the analogue input voltage to 8-bit digital output. The data bus is tri-state buffered. With eight bits, the resolution is 5V/255 = 19.6 mV.

The inbuilt clock generator circuit produces a frequency of about 640 kHz with R1 = 10 kilo-ohms and C4 = 150 pF, which connected timing components. The conversion time obtained is approximately 100 micro-second. The functions of other pins are given below:

Pin 1 (CS): The active low chip-select pin.

Pin 2 (RD): This active-low pin enables the digital output buffers. When high, the 8-bit bus will be in Hi-Z state.

Pin 3 (WR): This active-low pin is used to start the conversion.

Pin 9 (Vref/2): This is optional input pin. It is used only when the input signal range is small. When pin 9 is at 2 V, the range is 0-4.0 V, i.e. twice the voltages applied to these pins. The analogue input can range from 0 to 5 V.

Pin 6 (V+), Pin 7 (V-): The actual input is the difference in voltages applied to these pins. The analogue input can range from 0-5 V.

Pin 5 (INTR): This is an active-LOW interrupt, or halt pin.

Pins 11-18 ($DB_7$-$DB_0$): These are the three-state buffered digital outputs.

Pin 8 (A GND): This ground connection for the input analog voltage.

Pin 10 (D GND): This ground for the device and digital outputs. [11]

## 3.6 Intelligent Liquid Crystal Display Unit

The Hitachi's LCD HD44780 standard requires 3 control lines as well as either 4 or 8 I/O lines for the data bus. The user may select whether the LCD is to operate with a 4-bit data bus or an 8-bit data bus. If a 4-bit data bus is used the LCD will require a total of 7 data lines (3 control lines plus the 4 lines for the data bus). If an 8-bit data bus is used the LCD will require a total of 11 data lines (3 control lines plus the 8 lines for the data bus).

The three control lines are referred to as **EN**, **RS**, and **RW**.

The **EN** line is called "Enable." This control line is used to tell the LCD that you are sending it data. To send data to the LCD, in program should make sure this line is low (0) and then set the other two control lines and/or put data on the data bus. When the other lines are completely ready, bring **EN** high (1) and wait for the minimum amount of time required by the LCD datasheet (this varies from LCD to LCD), and end by bringing it low (0) again.

The **RS** line is the "Register Select" line. When RS is low (0), the data is to be treated as a command or special instruction (such as clear screen, position cursor, etc.). When RS is high (1), the data being sent is text data which should be displayed on the screen. To display the any letter and digit on the screen you would set RS high.

The **RW** line is the "Read/Write" control line. When RW is low (0), the information on the data bus is being written to the LCD. When RW is high (1), the program is effectively querying (or reading) the LCD. Only one instruction ("Get LCD status") is a read command. All others are write commands, so RW will almost always be low.

Finally, the data bus consists of 4 or 8 lines (depending on the mode of operation selected by the user). In this project an 8-bit data bus is used, the lines are referred to as DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7.

Before intelligent liquid crystal display can be really to use it must be initialize and configure. The first instruction to send must tell the LCD whether the communication will be an 8-bit or 4-bit data bus. Other condition necessary for it to perform most is sent as shown in table 3. [9]

## 3.7 Circuit Descriptions and its Operation

The microcontroller is interfaced with the ADC with multiplexer inputs and call for the LCD mode display.

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Port details:

- Port 0: Interfaced with the LCD data lines.
- Port 1: Interfaced with the ADC data lines, LCD Control lines and multiplexer address
- Port 2: not used
- Port 3: Interfaced with the ADC data lines

**Table 3:** LCD Command Codes

| Code (Hex) | Command to LCD Instruction Register |
|---|---|
| 1 | Clear display screen |
| 2 | Return home |
| 4 | Decrement cursor (shift cursor to left) |
| 6 | Increment cursor (shift cursor to right) |
| 5 | Shift display right |
| 7 | Shift display left |
| 8 | Display off, cursor off |
| A | Display off, cursor on |
| C | Display on, cursor off |
| E | Display on, cursor blinking |
| F | Display on, cursor blinking |
| 10 | Shift cursor position to left |
| 14 | Shift cursor position to right |
| 18 | Shift the entire display to the left |
| 1C | Shift the entire display to the right |
| 80 | Force cursor to beginning to 1st line |
| C0 | Force cursor to beginning |
| 38 | 2 lines and 5x7 matrix |

The system consists of temperature sensors for dry and wet using LM35 having 10 mV/$^{o}$C as sensitivity. These sensors are connected to the multiplexer input in which microcontroller sample it every time. From the multiplexer output link to the ADC0804 with was developed on successive approximation method. The ADC0804 is microprocessor compatible; the 8-bit digital output is connected to the port 3 (P3) of AT80S52 to takes in data. Internally the microcontroller takes in dry- and wet- temperature, and computed for the discomfort level index. The LCD is connected to the microcontroller through P0 to display dry- and wet- temperature, and discomfort level index using 2 lines and 16 characters LCD.

The P1.0 and P1.1 are used to address multiplexer CD4052 to select the sensor in such that when P1.0 and P1.1 are low select dry temperature sensor and P1.0 is high and P1.1 is low pick up wet temperature sensor. In each case of selecting sensor the following operation must be accomplished. (see figure 4)

The data conversion by the ADC0804 through microcontroller will be carryout by grounding pin 1 (CS) and the pin 3 (WR) of ADC0804 is connected P1.5 send a low-to-high pulse to start conversion. P1.5 of AT80S52 keeps monitoring the pin 5 (INTR) of ADC0804; If INTR is low, the conversion is finished or if the INTR is high, keep polling until it goes low. After the INTR has become low, and pin2 (RD) of ADC0804 is connected P1.7 send a high-to-low pulse to the RD pin to get the data out of the ADC804.

In order to display data on intelligent liquid crystal display the following action to carryout:

For Writing data to the LCD is done in according to following steps;

1) Set R/W bit to low (connected P1.2 to R/W of LCD)
2) Set RS bit to logic 0 or 1 (instruction or character) (connected P1.3 to RESET of LCD)
3) Set data to data lines (if it is writing)
4) Set EN line to high (connected P1.4 to enable of LCD)
5) Set EN line to low

and to Read data from data lines the following steps need to be taken;

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1) Set R/W bit to high (connected P1.2 to R/W of LCD)

2) Set RS bit to logic 0 or 1 (instruction or character) (connected P1.3 to reset of LCD)

3) Set data to data lines (if it is writing)

4) Set EN line to high (connected P1.4 to enable of LCD)

5) Set EN line to low [9]

# 4 CALIBRATION AND TESTING

The figure 4 shows completed schematic circuit diagram of level discomfort index. When connecting an LM35 to an ADC804. Since the ADC804 has 8-bit resolution with a maximum of 256 steps and the LM35 produces 10 mV for every degree of temperature change, the input ($V_{in}$) of the ADC804 was condition to produce a output ($V_{out}$) of 2560 mV full-scale output. Therefore, in order to produce the full scale $V_{out}$ of 2.56 V for the ADC804, the input was set to Vref/2 = 1.28. This makes $V_{out}$ of the ADC804 correspond directly to the temperature as monitored by the LM35. The reference voltage was generated using three diode of IN4148 with 100 ohms resistor in series and 1 kilo-ohms pot was connected across it as shown on the figure 4. Adjusting pot until the value is equal to 1.28 V. The voltage was fed into input of ADC0804 at of 10 mV per step increase the result shown on table 4.

**Table 4:** Input voltage and corresponding output of ADC0804 and LCD

| Vin (mV) | ADC0804 output | LCD display Output |
|---|---|---|
| 0 | 00000000 | 000 |
| 10 | 00000001 | 001 |
| 20 | 00000010 | 002 |
| 30 | 00000011 | 003 |
| 40 | 00000100 | 004 |

From table 4 above it shows that input corresponded to excepted output.

The two thermometers using LM35Z has sensor built for the job was tested and compared against a good quality Mercury-in-glass thermometer as the standard when it insert inside heating water until it boil. The reading was given in the table 5 below:

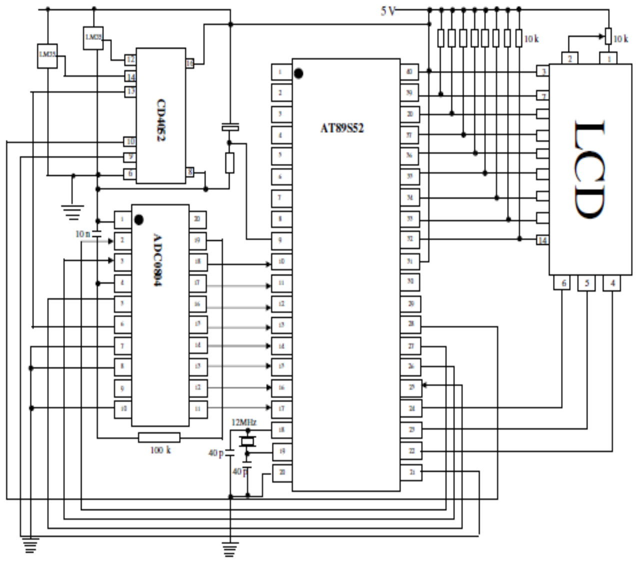


**Figure 4:** Complete Schematic Circuit for Discomfort

**Table 5.** Standardization of the Developed Dry and Wet Thermometer

| Time of reading in minutes | Hg-in-glass thermometer, $T_{Hg}$ (°C) | Dry unit thermometer $T_D$ (°C) | Wet unit (without wick) thermometer $T_W$ (°C) |
|---|---|---|---|
| 0 | 27.5 | 27.4 | 27.5 |
| 2 | 32.3 | 32.3 | 32.4 |
| 4 | 41.7 | 41.7 | 41.6 |
| 6 | 57.2 | 57.3 | 57.2 |
| 8 | 69.1 | 69.2 | 69.1 |
| 10 | 78.3 | 78.3 | 78.4 |
| 12 | 88.9 | 88.9 | 88.9 |
| 14 | 92.8 | 92.8 | 92.8 |
| 16 | 98.6 | 98.5 | 98.7 |

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## 5 RESULTS AND DISCUSSION

There is no stable environment where the temperature relatively constant therefore, is not easy to check for repeatability of the thermometry system but it was checked for correctness in the value reading with standard mercury in glass thermometer these was in shown on table 6 above therefore it was found that correlation of Dry thermometer unit was 0.99 and for Wet thermometer unit was 0.99 against standard mercury in glass thermometer. The correlation were much closed to unity therefore, the sensor linearity for two systems were very good for the job. Also the table 6 shown the data collected by built instrument and computed value of DI corresponding with display value on the instrument at FUTA meteorology observatory were compared. The values were in completely in agreement with each other, which are also confirmed correctness and accuracy of the instrument.

## 6 CONCLUSION

The instrument found so useful in determine the level of discomfort in a hall, poultry house, in factories, room etc and also to determine dry and wet temperature during practical period that usually carryout by the mercury-in-glass thermometer. Since accuracy and the precision is very encouraging and error from sensor end is minimized. Also, the linearity of the sensor within the range of interest that is between +2$^o$C to +150$^o$C is great advantage compare with any other temperature sensing element that are exponentially in nature such as thermistor and digital display unit remove error reading when mercury-in-glass thermometer are used. The correlation between the built and mercury-in-glass thermometer was found to be 0.99, which is very close to unity as shown in table 6. This shown a very good agreement and so very useful to determine level discomfort automatically using exit Thom Model.

**Table 6:** DI measurement at FUTA meteorology observatory on 23-12-2010 using Delta T Instrument compare with the Developed

| **T** | **S** | | **D** | | **DIS** | **DID** |
|---|---|---|---|---|---|---|
| | **Dry** | **Wet** | **Dry** | **Wet** | | |
| | **$T_D$** | **$T_W$ ($^o$C)** | **$T_D$** | **$T_W$ ($^o$C)** | | |
| 6 | 28.3 | 20.4 | 28.4 | 20.3 | 21 | 21 |
| 7 | 27.4 | 19.3 | 27.4 | 19.4 | 21 | 21 |
| 8 | 29.1 | 21.2 | 29.0 | 21.2 | 22 | 22 |
| 9 | 29.3 | 24.8 | 29.3 | 24.8 | 24 | 24 |
| 10 | 29.1 | 26.1 | 29.1 | 26.1 | 24 | 24 |
| 11 | 30.0 | 27.5 | 30.0 | 27.5 | 25 | 25 |
| 12 | 30.2 | 28.4 | 30.4 | 28.3 | 25 | 25 |
| 13 | 30.2 | 28.4 | 30.2 | 28.4 | 25 | 25 |
| 14 | 32.0 | 30.8 | 32.0 | 30.8 | 27 | 27 |
| 15 | 32.1 | 30.0 | 32.1 | 30.0 | 27 | 27 |
| 16 | 30.0 | 29.6 | 30.0 | 29.6 | 26 | 26 |
| 17 | 29.1 | 27.4 | 29.1 | 27.4 | 25 | 25 |
| 18 | 29.0 | 27.2 | 29.0 | 27.2 | 24 | 24 |
| 19 | 27.0 | 25.0 | 27.0 | 25.1 | 23 | 23 |
| 20 | 28.0 | 25.5 | 28.0 | 25.4 | 23 | 23 |

**T** = Time of the day from 6.00am to 20.00pm

**S** = Standard

**D** = Developed

**DIS** = Discomfort level computed from Standard

**DID** = Discomfort level computed from Developed

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