Design and Development of Low Cost and Portable Microcontroller Based Hygrometer

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Abstract: *The hygrometer is widely used in air conditioner, humidity data logger, humidifier & dehumidifier etc. The aim of this research work is to design and development of a low cost, portable microcontroller based hygrometer. The hygrometer has been designed using the sensor module HSM-20G. The sensor operates in capacitive principle, i.e. changes in relative humidity (RH) of the surrounding air cause a change in dielectric constant of the polymer film leading to a change of sensor capacitance. The module converts this capacitance change into analog voltage. The HSM-20G sensor provides analog voltage for both temperature and humidity. The sensor is connected with PIC16F876A microcontroller, which converts the analog voltage into digital and display the result into 16 X 2 alphanumeric LCD display. The program is written in C language using mikro C PRO. The measuring accuracy of the humidity reading of our designed meter is negligible.*
Keywords: Hygrometer, microcontroller, relative humidity, sensor capacitance, LCD display, and C program.

I.   Introduction

Hygrometry is the part of physics, which deals with the measurement of the amount of water vapour present in a given volume of air. Condensation of this aqueous vapour present in the atmosphere is responsible for various phenomena like formation of clouds, fogs, rains, snows, hails, etc [1]. The capacity of air to hold water vapour is limited and is controlled by temperature only. If the air in any place and time contains the maximum amount of water vapour that it can hold, it is said to be saturated, otherwise it is unsaturated [2]. Dew point is the temperature at which water vapour actually present in the air just reaches saturation. We may, therefore, define dew point as that temperature at which the pressure of water vapour actually present in the atmosphere is equal to the saturation pressure of water vapour corresponding to dew point. Knowledge of dew point enables us to find out the pressure of water vapour actually present in the atmosphere. For example, dew point today is 20 at a particular place at the time of observation. From Regnault's chart, it is found that the saturation pressure of water vapour at 20 ^{0}C is 17 mm. Hence today at the particular place, the pressure of water vapour actually present in the atmosphere is 17 mm [3].

The term 'humidity' signifies the dampness or wetness of the atmosphere due to its holding of water vapour. It is the concentration of water vapor in the air. The concentration can be expressed as absolute humidity, specific humidity, or relative humidity [4]. Relative humidity (R.H.) or hygrometric state of air is defined to be the ratio of the quantity of water vapour actually present in a certain volume of air at a particular temperature to the quantity of water vapour that would be required to saturate the same volume of air at the same temperature [5]. So

$$\text{R.H.} = \frac{\text{Mass of water vapour actually present in any volume of air at } \theta\ ^0\text{C}}{\text{Mass of water vapour necessary to saturate the same volume of air at } \theta\ ^0\text{C}}$$

Since pressure of water vapour is proportional to the amount of water vapour present in a given volume of atmosphere, we may define relative humidity as

$$\text{R.H.} = \frac{\text{Pressure of water vapour actually present in the air at } \theta\ ^0\text{C}}{\text{Pressure of water vapour necessary to saturate the air at } \theta\ ^0\text{C}}$$

Since the saturation vapour pressure of water at dew point is the actual pressure of water vapour contained in the atmosphere at a particular temperature, so relative humidity can be written as

$$\text{R.H.} = \frac{\text{Saturation vapour pressure at the dew point}}{\text{Saturation vapour pressure at the temperature } (\theta\ ^0\text{C)} \text{ of the air}}$$

Relative humidity is generally expressed as a percentage and is calculated by applying any of the above equation. For example, if f denotes the saturation vapour pressure at the dew point and F the saturation vapour pressure at the temperature of air, then,

$$\textbf{R.H.} = \frac{f}{F} \times 100\%$$

The feeling of dampness or dryness depends upon the factor 'Relative humidity'. A low relative humidity encourages evaporation and, therefore, the air will appear dry and high value of it will discourage evaporation, and the air will appear damp. This is why wet clothes are found to dry up more quickly if relative humidity of the atmosphere is low [6].

The hygrometric state of the air or its relative humidity is of great service in weather forecasting. Dew point predicts minimum temperature at night. Information regarding relative humidity is necessary by the Public Health Department, as germs of certain diseases multiply very quickly in moist atmosphere. Proper humidity necessary for health and comfort can be produced artificially. The humidity of the air in refrigerators storing meat must not exceed a definite value, otherwise the meat deteriorates; artificial seasoning of timber takes place under pre-arranged value of air humidity. Tobacco deteriorates unless the air in the storeroom has a specified humidity. Thus, it is very important to measure the relative humidity [7]. Table-1 shows the specification of the designed temperature and humidity monitor.

Table-1: The specification of designed temperature and humidity monitor.

Features	Specifications
Main voltage	220V, 50Hz
Temperature ranges	5 ^{0}C-60 ^{0}C
Temperature accuracy	$\pm 1.0^0$C
Humidity sensor	HSM-20G
Humidity ranges	20 to 95%
Humidity accuracy	$\pm 5\%$ RH

II. Methodology

To design a system, the first attempt has been taken is to design the block diagram of the desired system. The block diagram of the complete units consists of several blocks. Fig. 1 shows the complete block diagram of the designed humidity monitor. The roughly operation of this device is that when the on off button is pressed by the user, the device will activated and LCD will display both the reading of humidity level with temperature level and also that the readings is displayed by output measured by the sensor continuously . The device will stop operating as the on/off button is pressed once again. The device will need a battery 0f 9V but the voltage regulators will regulate the voltage to 5V for device usage. In order to load the program in the microcontroller used which is PIC16F876A, MPLAB was used for this Portable humidity Reader. This software will load all program made into internal memory of PIC16F876A. Once the HEX file was created in the MPLAB, this file will then be loaded into PIC16F876A using PIC Kit2. To ensure the sensor works in the specified range, detailed programming must be taken into consideration since the sensor is sensitive towards vapor produced by exhalation or water heater. The programming is modified so that the LCD display the reading will continuously measure by Humidity sensor. There are many reasons for choosing HSM-20G as our humidity sensor. In this circuit designed, a diode (IN4007) is use to protect the circuit from wrong polarity supply. Few capacitors is used to stabilizes the voltage at the output side of the voltage supply from the 9V battery. The LED is a green LED from over current which might burn LED. MCLR, RB6 and RB7 need to be connected to the USB in circuit programmer to program the PIC microcontroller. At the same time, RB3 need to be pull down to 0V to disable low voltage programming, because the programmer is using high voltage programming. The PIC16F876A will gather all analogue data senses by the humidity sensor and converted into digital output and shows through thee LCD. The process is infinity loop operation as according to the programming loaded earlier into the PIC microcontroller [8].
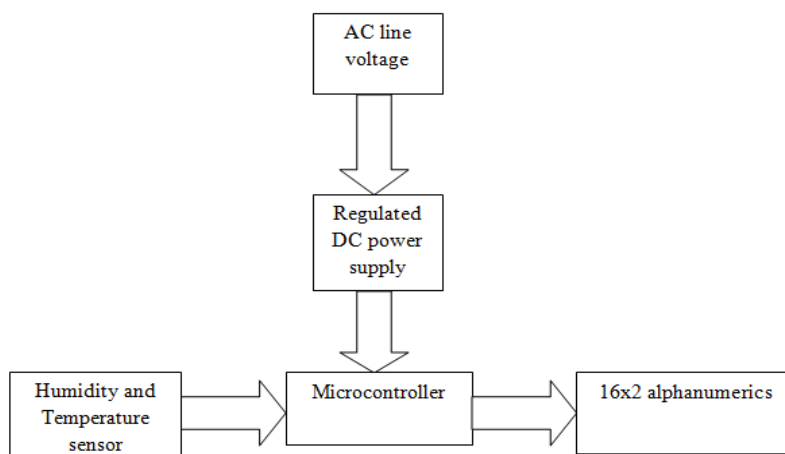
Fig. 1: Simplified block diagram of the developed system.

III. Design and Circuit Description

3.1 HSM-20G Humidity Sensor Module

The module of HSM-20G is essential for those applications where the relative humidity can be converted to standard voltage output. Humidity sensor is device consisting of special plastic material whose characteristics change according to the amount of humidity in air. Basically, this sensor senses the amount of water vapor in air. For this research work, analogue input sensor we used. HSM-20G is essential for the objectives and applications where the reading in terms of relative humidity was converted into standard voltage output. The applications include humidifiers and dehumidifiers, air conditioner, humidity data loggers and automotive climate control [9, 10]. Table-2 shows the specification of the HSM-20G humidity sensor.

Table-2: The specification of the HSM-20G humidity sensor.

Characteristics	HSM-20G
Input voltage range	DC 5.0-0.2 V
Output voltage range	DC 1.0-3.0 V
Measurement Accuracy	5%RH
Operating current(Maximum)	2mA
Operating RH range	20 to 95%(100%RH intermittent)
Temperature range	0c to 50c
Long term stability(typical drift per year)	1.5%
Time response(63% step change)	1 min

3.2 Low voltage power supply

Microcontroller and other electronic components, which are used in designing humidity monitor, require a dc voltage (+5V). A regulated dc power supply is designed for this purpose. The complete circuit of a regulated dc power supply is shown in Fig-2 using a 7805 IC as a voltage-regulating device. The power supply is a combination of three sections [11, 12], namely: bridge rectifier, a capacitor filter and IC voltage regulator.

3.1.1 Bridge rectifier: The bridge rectifier converts the step-down transformer's secondary ac voltage into pulsating dc voltage.

3.1.2. Capacitor filter: The pulsating dc voltage is applied to the capacitor filter. This filter circuit reduces the pulsations in the rectifier dc output voltage and the output voltage is 9V.

3.1.3 IC voltage regulator: The IC voltage regulator provides regulated output and C2 is used to improve transient response. Although voltage regulators can be designed using op-amp, it is quicker and easier to use IC voltage regulators [13, 14]. In this design a positive fixed voltage regulator L7805 is used. The voltage regulation curve for designed low voltage power supply is shown in Fig-3.
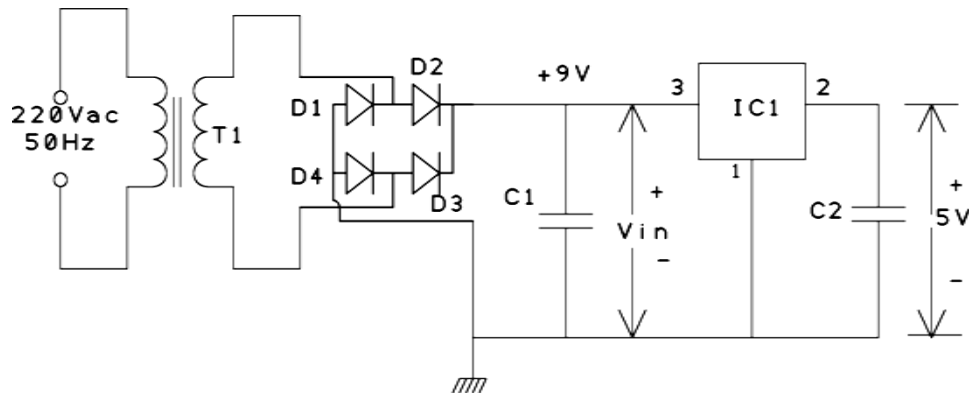
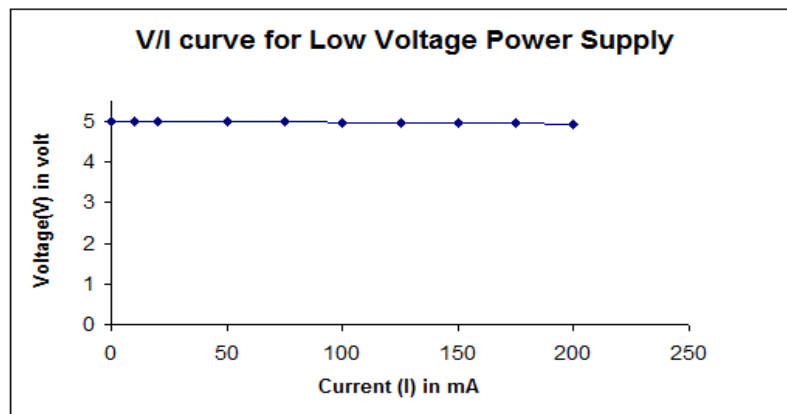**Fig. 2** Schematic diagram of low voltage regulated power supply

Fig.3 Voltage regulation Curve for Low Voltage Power Supply

3.3 Microcontroller

A microcontroller is a microcomputer in a single chip. A controller is used to control some process or aspect of the environment. As the process of miniaturization continued, all of the components needed for a controller were built right onto one chip. A microcontroller is a highly integrated chip, which includes on one chip, all or most of the parts needed for a controller. The microcontroller could be called a "one-chip-solution" [15]. In this work, a PIC16F876A microcontroller has been used, which converts the analog voltage into digital and display the result into 16 X 2 alphanumeric LCD display.

3.3.1 Peripheral Features of PIC16F876A microcontroller
- Timer 0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler,can be incremented during Sleep via external crystal/clock
- Timer 2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
- Capture is 16-bit, max. resolution is 12.5 ns
- Compare is 16-bit, max. resolution is 200 ns
- PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI™(Master mode) and I2C™ (Master/Slave).
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection.
- Parallel Slave Port (PSP) – 8 bits wide with external RD, WR and CS controls (40/44-pin only).

3.3.2 AnalogFeatures of PIC16F876A microcontroller
- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
- Two analog comparators
- Programmable on-chip voltage reference(VREF) module
- Programmable input multiplexing from device inputs and internal voltage reference
- Comparator outputs are externally accessible

3.3.3 Memory organization

There are three memory blocks in each of the PIC16F87XA devices. The program memory and data memory have separate buses so that concurrent access can occur and is detailed in this section. The EEPROM data memory block is detailed in "Data EEPROM and Flash Program Memory". Additional information on device memory may be found in the PIC micro® Mid-Range MCU Family Reference Manual (DS33023).

3.3.4 Analog to digital converter module

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the 40/44-pin devices. The conversion of an analog input signal results in a corresponding 10-bit digital number. The A/D module has high and low-voltage reference input that is software selectable to some combination of VDD, VSS, RA2 or RA3. The A/D converter has a unique feature of being able to operate while the device is in Sleep mode. To operate in Sleep, the A/D clock must be derived from the A/D's internal RC oscillator.

3.4 Software details

Single microcontroller is used to do all the functionality of the humidity monitor. A program is developed in modular form using MPLAB IDE (Integrated Development Environment). Hex file generated using MPASM assembler. Hex file then downloaded to microcontroller using a PIC programmer. Fig. 4 shows the flow chart of the developed system.
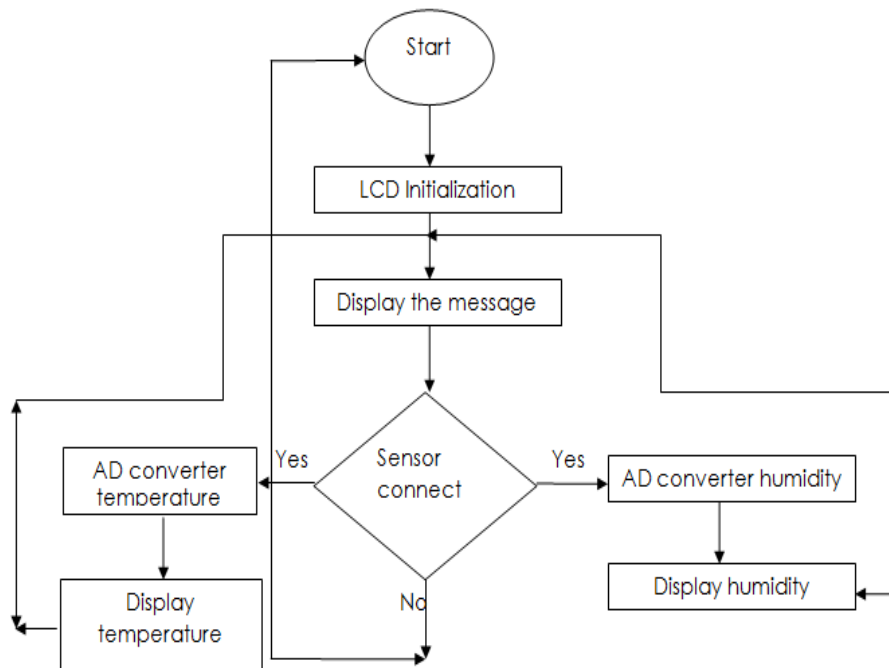

Fig. 4 The flow chart of the developed system.

3.5 LCd Display

To display the temperature and relative humidity of air, a monitor is used. A monitor is an electronic device that shows information on the screen when we type. This is called outputting information. The system displays the result into 16 X 2 alphanumeric LCD display.

3.6 Complete Circuit Diagram
Fig. 5 represents the schematic diagram of the developed temperature and relative humidity monitoring system.
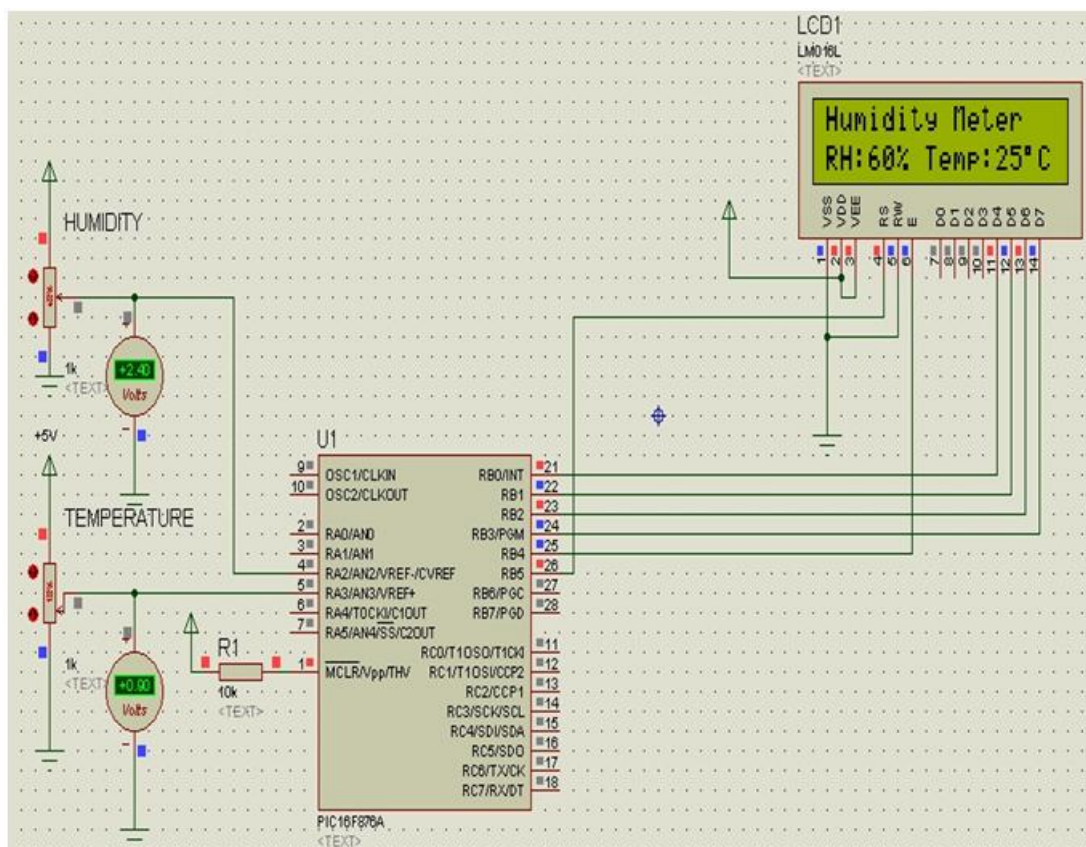

Fig. 5: The schematic diagram of the developed hygrometer.

IV.   Results and Discussion

The design of this work was planned in step-by-step and systematic way. At first the whole system was outlined in a block diagram and then the different parts of the circuits of the block was designed and tested. Finally the whole system of the designed system was developed and following data's have been obtained. Table-4 represents the variation of experimental temperature with standard temperature, while Table-5 represents the variation of experimental relative humidity with standard relative humidity.

Table 4: Comparison of temperature designed meter and temperature of Standard **meter.**

No of obs.	Temperature in designed meter ^{0}C	Temperature in Standard meter ^{0}C	Error in %
01	26	26.4	1.5
02	27	27	0
03	27	27	0
04	27	27	0
05	27	28	3.5

Table 5: Comparison Of Humidity Of Designed Meter And Humidity Of Standard **Meter.**

No of obs.	Humidity in Designed meter (RH %)	Humidity in Standard meter (RH %)	Error in %
01	69	69.5	0.71
02	66	66.1	0.15
03	62	62.5	0.80
04	61	61.7	1.13
05	61	61.3	0.48

V.   Conclusion

The designed system has been tested and the desired performance has been obtained. Although there was little deviation of experimental result with standard result, more or less good result had been obtained. The most important advantage of this system is that it can store monitored data and this data can be used for further purposes.

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