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Module of Measuring Temperature and Relative Humidity

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Abstract

The module was designed using PIC16F877A microcontroller, PIC16F877A microcontroller is the heart of the whole system which reads the digital equivalent of relative humidity (RH) and ambient temperature (T) with the help of on chip 10-bit analog to digital converter (ADC) and capture compare pulse width (CCP) modulations. The LM 35 sensor is used for measured ambient temperature and HS1101LF sensor is used for measured the relative humidity. The measured parameters are displayed on LCD 16x2, sent to PC server using serial connection (RS232). The Pc server software is designed as the graphical user interface(GUI) using C sharp Language. It receives the measured parameters, decoded, display it on (GUI), stored in data base file, secure data base and sends to clients through TCP/IP Protocol.

Keywords: *PIC16F877A microcontroller, PC server, clients, graphical user interface, data base file.*

1. Introduction

The module play very important role in the industrial field and can be found in most of the current industries like gas fields, cement factories, oil refineries, pharmaceutical companies, weather stations and many more. It is focuses on increase the accuracy of measurement, send data in network (through TCP/IP Protocol), store data in data base file, decrease the cost and support the local industries. The main functions of this module its gathering data from LM 35 temperature sensor and HS1101LF relative humidity sensor and then sending data into PC server using serial communication (RS 232 Port).

The server provides receiving data, decoding data, formatting and displaying in graphical user interface (GUI), saving in data base file, and then sending to clients using TCP/IP socket. The clients receive and display in GUI.

The whole system its divided into three sub systems collecting data using DAS board, Receive and transmit data (server program), receive data (client program).

The big picture of whole system, it's appearing in figure 1.

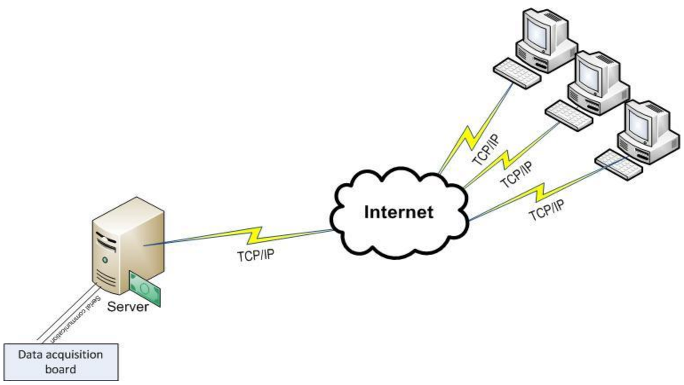

Figure 1: System Block Diagram

2. Materials and Methods

2.1 Data Acquisition System (DAS)

Its most important part of whole system , DAS can take multiple forms and have many levels of complexity, but they consist mainly of the same elements, usually arranged according to the basic configuration shown in the following figure(2), DAS is used to measure, record and display the all parameters.

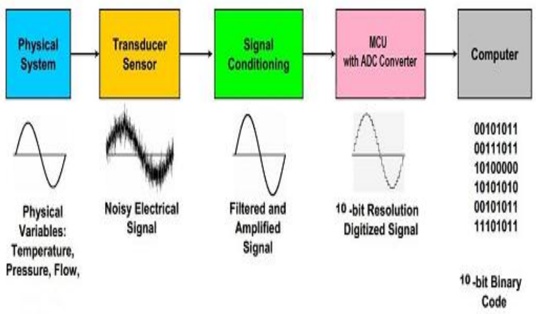

Figure 2: Data Acquisition System

The physical system which its represents the temperature and relative humidity.

The transducer (or sensor) used for transform the information signal into electrical signals.

2.2 LM35 Temperature Sensor

The LM35 is precision integrated circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature + 10.0 mV/˚C. The features of LM35 sensor is low cost, low output impedance 0.1Ω for 1 mA, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies 4 to 30 volts, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1˚C in still air, the basic centigrade temperature sensor connection appear in figure 3.

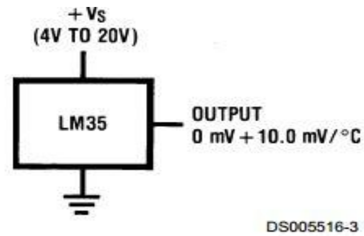

Figure 3: Basic Centigrade Temperature Sensor (+2 to +150˚C)

2.3 HS1101LF Relative Humidity Sensor

The HS1101LF sensor based on a unique capacitive cell is useful in all applications where humidity compensation is needed.

The features of relative humidity sensor is fast response time and very low temperature coefficient , Suitable for linear voltage or frequency output circuitry, High reliability and long term stability .

The HS1101LF it connects with timer 555 in a stable circuit as shown in figure (4).

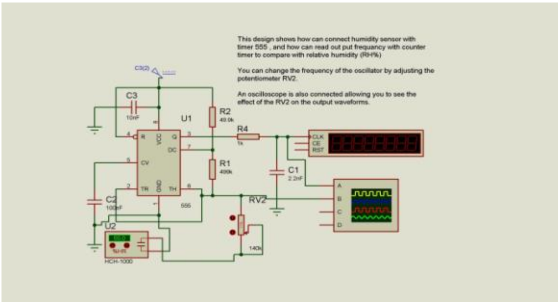

Figure 4: HS1101LF Sensor Connected as Variable Capacitance

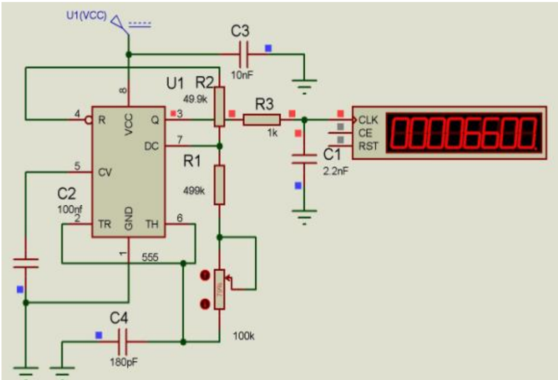

Figure 5: The Output Frequency when HS1101LF Sensor is equal 180 pf and Relative Humidity 55%

This circuit is the typical a stable design for timer 555.

The HS1101LF used as variable capacitor, is connected to the TRIG and THRES pin. Pin 7 is used as a short circuit pin for resistor R2.

The HS1101LF equivalent capacitor is charged through R1 and R2 to the threshold voltage (approximately 0.67Vcc) and discharged through R1 only to the trigger level (approximately 0.33Vcc) since R2 is shorten to ground by pin 7.

Since the charge and discharge of the sensor run through different resistors, R1 and R2, the duty cycle is determined by:

$$T_{hig} = C@RH \times (R1 + R2) \times Ln\,2$$
$$T_{low} = C@RH \times R1 \times Ln\,2$$
$$F = \frac{1}{T_{low} + T_{hig}} \qquad (1)$$

Where:

C@HR means the capacitance at relative humidity.

T_{hig} the duty cycle for high pulse.

T_{low} the duty cycle for low pulse .

From data sheet of HS1101LF sensor the relation between output frequency and relative humidity it consider in table (1).

Table1

RH (%)	0	5	10	15	20	25	30	35	40	45	50
Fout (Hz)	-	-	7155	7080	7010	6945	6880	6820	6760	6705	6650
RH (%)	55	60	65	70	75	80	85	90	95	100	
Fout (Hz)	6600	6550	6500	6450	6400	6355	6305	6260	6210	-	

The relation between relative humidity and output frequency are calculated using Matlab, figure (6) show the result

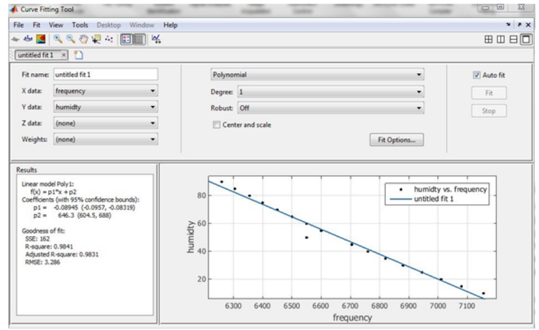

Figure 6: Relation between Relative Humidity and Output Frequency

Equation (2) consider the relation between relative humidity and output frequency

$$RH = 565.1 - 0.076725 \times Freq \qquad (2)$$

2.4 Signal Conditioning

The signal conditioning provides power supplies for whole system such as LCD, Max 232 , micro controller, timer 555 and all other peripherals , it amplify the output signal from LM35 and filter or digitized the sensor signal , that means the main function of signal condition is to provides output signal which is easy to capture with an analog input board .

2.5 Micro Controller Unit

PIC16F877A microcontroller contains of 10 bit analog to digital converter (ADC module) which it is used for convert analog signal from LM35 sensor into digital signal, and Capture/Compare/PWM (CCP) modules which it is used for capture the output pulses from HS110LF sensor .

A/D conversion is ratio operation, where input signal is compared with reference voltage and converted into fraction which it is then represent as codec digital number.

The simple linear relationship between ADC input and ADC output is given by:

$$\frac{ADC\_Result}{1023} = \frac{V_{in}}{V_{ref}} \qquad (3)$$

The PIC16F877A MCU has two pins for reference voltage (Vref + and Vref-) and the Vref is calculated as:

$$V_{ref} = V_{ref+} - V_{ref-} \qquad (4)$$

By default the maximum output voltage from LM35 = 1.5 volt and the minimum output is 0.2 volt ,according to the connection in Figure (3) .

To improve the accuracy, we used an external reference voltage Vref + =2.5 volt and Vref - = GND . and non inverting amplifier with gain 1.3 to increase the maximum analog input voltage to 1.95 volt.

So the Maximum ADC result is:

(1.95/2.5)x 1023 = 798

and the resolution is:

Resolution = (log (ADC Result) / log2) (5)

(log798/log 2) = 9.6

and each step corresponds:

(1.95/978) = 0.00199 Volt

The CCP configured as capture mode that capture every rising edge of the pulses. When capture its occurred the TMR1 value is saved in CCPR1H:CCPR1L registers, the interrupt request flag bit, CCP1IF is set.
The interrupt flag must be cleared in software,
If another capture occurs before the value in register CCPR1 is read, the old captured value is overwritten by the new value.

2.6 Module Hardware

The circuit diagram of the Module is shown in Figure (7), The LM35 sensor is connected to non inverting amplifier with gain =1.3 and then connected to PORTA at channel 0 , HS1101LF sensor is connected with timer 555 in a stable mode as shown in figure (4) , external reference voltage Vref+ is connected to PORT A at channel3 and Vref− is connected to PORT A at channel2 ,battery is connected with 7805 regulator and then supply the micro controller , LCD 16x2 is connected to PORT B ,MCU send data serially from PIN C6 is connected to max 232 for convert TTL level to serial level , A 16MHz crystal is connected between the OSC1 and OSC2 pins. Also, an external reset push button is connected to the MCLR input to reset the microcontroller when required.

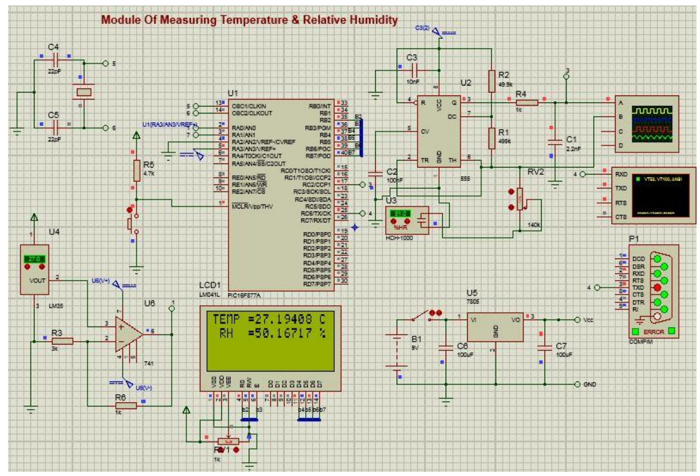

Figure 7: Hardware Connections and shows the Result after Module Run

2.7 Software Description

2.7.1 Microcontroller Firmware

The program starts with initialize the main components (LCD display, CCP module, A/D converter).
The CCP1 module check if the second rising edge it is captured from train input pulse ,while it captured then disable interrupts and clear flag (CCPIF) until complete the processing . in the interrupt services routine (ISR) the period between the two rising edge pulses are calculated (P = t2 - t1) , in the main program function the relative humidity are calculated according equation (1),and A/D start to convert analog signal into digital ,the A/D conversion is calculated according equitation (3).
For displaying the gathered data, it must be converting into string data and then sends to LCD. Data sent to the Pc server through serial interface, Figure (8) shows the Flow chart of the microcontroller firmware.

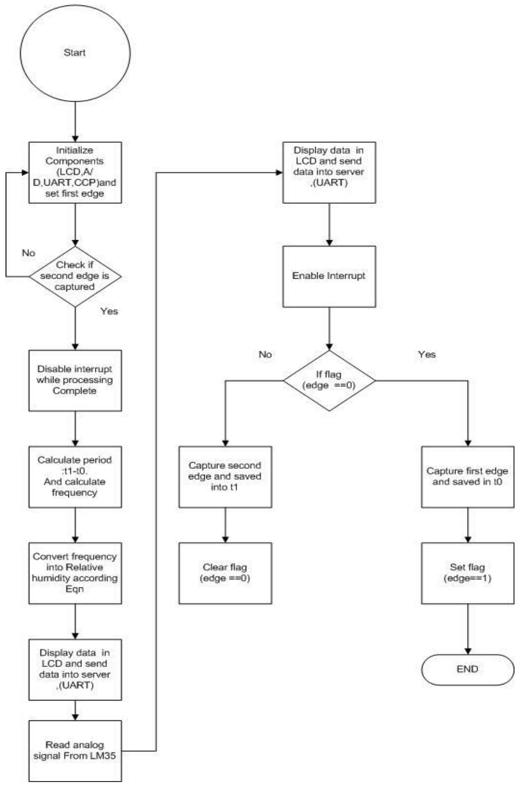

Figure 8: Flow Chart of the Microcontroller Firmware

The microcontroller sent data as string format, including temperature and relative humidity via serial interface connection to the Pc server, Figure (9) shows the protocol of sending data, the size of message format or (packet) is 6 bytes.

H	Relative humidity data	T	Temperature data

Figure 9: Message format

The server receives string data or (packet) and it provide filter for the packet (separate temperature data from relative humidity data), display the parameters in GUI, it helps the user to monitor and access to the data base.

The server communicate to the clients through TCP/IP protocol, the communication start with client request, and server listen to the port, server accept connection, the client send query, the server process query and sends back to the client, the client sends an acknowledgement, this procedure its repeated until the client or server close the connection, figure (10) shows the flow chart of server program.

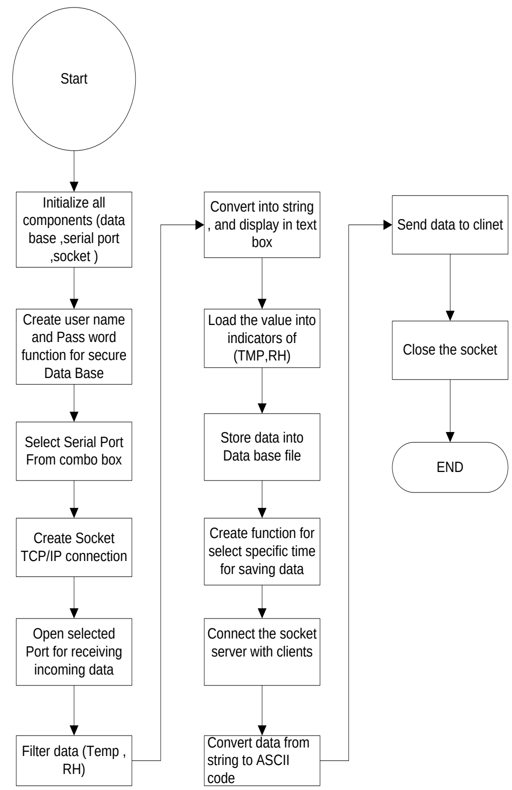

Figure 10: Flow Chart of Server Software

The client initiates the communication by send query to server, wait until server sends response it receive the packet from server as ASCII data, it converts data to string ,provide filter(separate temperature data from relative humidity data), display the parameters in GUI, figure(11) shows the flow chart of client program .

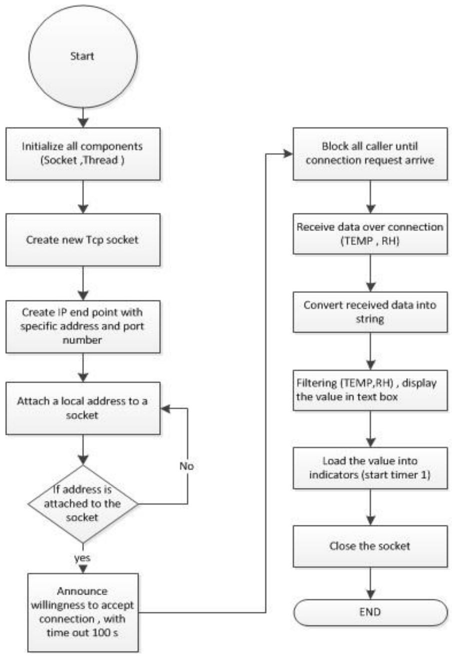

Figure 11: Flow Chart of Client Software

3. Client Server Configuration

The Server

listen (at some port number).
if a connection attempt to connect
is sensed accept connection request.
process query (send response).
close connection.

The Client

request connection.
send query.
receive response.
close connection.

4. Results

The module is designed with high accuracy in measurements, the accuracy in temperature is ±0.5 ˚C and in relative humidity is ±1.5%.

Table2 shows the result of module compared with ideal state of sensors.

Table2

Temperature measured by module design in ˚C	Ideal temperature of LM35 in˚C	Error of temperature measured in ˚C	Relative Humidity measured by module designed in %	Ideal Relative Humidity of HS1101LF sensor in %	Error of measured Relative Humidity in %
25.41	25	0.41	19.52	20	0.48
30.30	30	0.30	31.12	30	1.12
35.19	35	0.19	41.6	40	1.6
40.07	40	0.07	51.4	50	1.4
44.96	45	0.04	60.43	60	0.43
50.34	50	0.34	69.37	70	0.63

The Pc server program is designed and proves all functions figure (12) shows the software server after run.

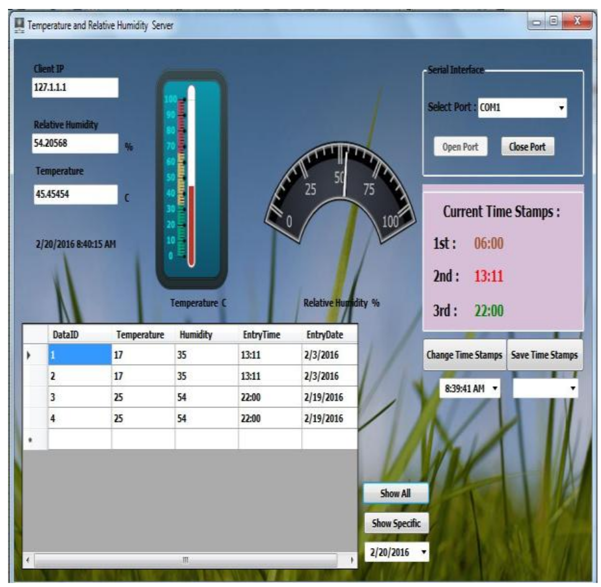

Figure 12: Server Program after Run

Figure (13) shows client program when it receives and display the data.

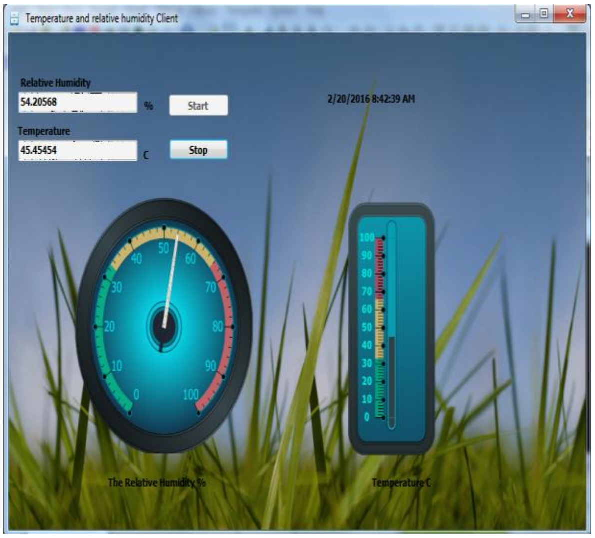

Figure 13: Client Program after Run

5. Discussion

The signal conditioning circuit is helped to increase the accuracy and resolution of measurement as shown the result in table 2, the accuracy of temperature measurement by module is 0.5 ˚C and that is the maximum accuracy of sensor from data sheet.

The resolution is increased from 8.2 bit to 9.6 bit, according equation (5).

In relative humidity the accuracy is = 1.5%, it depends on adjust the circuit of timer 555 with sensor. From data sheet of HS1101LF sensor when the capacitance value of sensor are = 180pf the corresponding frequency out is= 6600hz figure (5) shown this result.

Client server program are designed using C sharp language which it provides large library of modules such as (serial communication, converting data type, timers, TCP/IP Protocol,..). Data sent from MCU to PC through serial interface as 6 bytes(massage format) ,the server software receive data ,filter data , convert to string to display ,store data in database in specific time ,converting to ASCII , and then send to clients through TCP/IP protocol. The client program receive packet of data and display it in GUI.

Recommendations: This system can be use as standard platform, which can be replace the sensors with other sensors and also can modify the module by increasing number of sensors.

Future Work: Designing weather monitoring system by added some sensors to the system such as (atmospheric pressure, wind speed, wind direction, rain fall).

6. Conclusions

In this work, we have proposed a robust and cost effective system design that can suit local industries for data acquisition and signal processing.

This inexpensive module is designed with high accuracy of measuring temperature and relative humidity, the enhancements in accuracy depends of configurations of ADC module and CCP modules in microcontroller. Client and server programs are designed according requirements above and tested many times.

Applications and Advantages

1. Can be used in various industries to control the device based on different time.

2. This module reduces the human efforts or human interaction and thus it can work independently as an automated circuit.

Acknowledgments

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