DEVELOPMENT OF WIRELESS SENSOR NODE FOR MONITORING INDOOR AIR QUALITY

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Abstract – **This paper presents the application of Wireless Sensor Node in the Development of Wireless Sensor Node for Indoor Monitoring. Two major parameters qualify the indoor air quality except polluted gas, are air temperature and relative humidity. The LM35DZ temperature sensor and A0545 basic humidity sensor are used to measure air temperature and relative humidity in percentage. Functions of sensor node are transferring data from sensor to data handler. In these project, three sensor nodes are developed and each node consists of Microcontroller (PIC16F877), Transceiver and Sensor. This microcontroller programmed to read the temperature and relative humidity of workspace every hour for one day. For research and development purposes the system implemented at Research Assistance Laboratory (Sensor Node 1), Mechatronics and Consumer Laboratory (Sensor Node2) and Advance Signal Processor Laboratory (Sensor Node3), Faculty Electrical Engineering, MARA University of Technology Malaysia.**

Keywords: **Microcontrollers, Transceiver, Analog-digital conversion**

1.0 INTRODUCTION

A sensor node also known as a 'mote' (in North America), is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. The objective is developing sensor node that is one part of this project to monitor percentage of indoor relative humidity. This system will monitor values of temperature and humidity by using microcontroller for every hour until the end of monitoring day (1 day).

1.1 Sensor Node

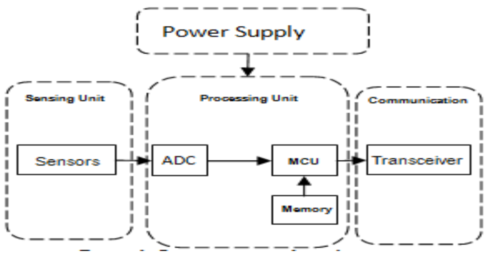


Figure 1.0: Basic sensor node architecture

The architecture sensor node consists with four basic components sensing unit, a processing unit, a transceiver unit, and a power unit [1]. The function of sensing unit to converts type of energy element such as heat which is the sensors will produced analog signal base on the observed phenomena into an electrical signal. This signal fed into processing unit and ADC part will converted the analog signal from sensor into digital signal. The processing unit manage the procedures of sensor that have make using PIC programmer and fed into transceiver system for transmitting data. Continuous power supply are important for wireless sensor node, power unit may be supported by power scavenging such as battery, ac adaptor or solar panel. The design of such sensor nodes is driven by the following factors:

• Size – Reducing physical size has always been one of the key design issues. Therefore, the goal is to provide powerful processor, memory, radio and other components while keeping a reasonably small size, dictated by a specific application.

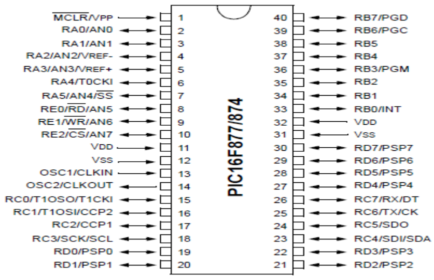
• Flexibility – To facilitate experimentation these devices should be very flexible in programmability and should have an expensive set of hardware and software sensor interfaces to accommodate different sensing technologies.

1.2 Processing Unit

A microcontroller is a functional computer system-on-a-chip. A microcontroller controls the operation of the entire sensor node. Among its many tasks, it must be programmed to alert the rest of the sensor's circuits when it decides to enter the active mode. It must take readings from all available transducers and decide whether it is necessary to send a message with these readings in it.

It is a type of microprocessor emphasizing high integration, low power consumption, self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor. Generally MCU possesses integration of CPU as computing, memory, a clock oscillator, ROM and RAM memories, and general purpose I/O ports, special hardware features [2].

In this project, PIC16F877 were used as microcontroller. The PIC16F877 contained all the basic features such as 10-bit multi channel ADC converter, power saving SLEEP mode, low power consumption, high speed CMOS FLASH/EEPROM technology, and Universal Synchronous Asynchronous Receiver Transmitter with 9-bit address detection [4]. Figure 1.1 shows the basic diagram of PIC. Table 1 and table 2 shows the Specification of PIC 16F877 and pin description that been used.



Picture 1.1: Basic Diagram of PIC

TABLE 1
SPECIFICATION OF PIC

	PIC16F877
Operating Frequency	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	8K
Data Memory (bytes)	368
EEPROM Data Memory	256
Interrupts	14
I/O Ports	Ports A,B,C,D,E
Timers	3
Capture/Compare/PWM Modules	2
Serial Communications	MSSP, USART
Parallel Communications	PSP
10-bit Analog-to-Digital Module	8 input channels
Instruction Set	35 instructions

TABLE 2
SELECTIVE PIN

Pin Name	DIP Pin	Description
OSC1/CLKIN	13	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	Oscillator crystal output
MCLR/Vpp	1	Master Clear (reset), input or programming voltage input. This pin is an active low RESET to the device.
RA0/AN0	2	Bi-directional I/O port where, RA0 an option be an analog input 0
RA1/AN1	3	Bi-directional I/O port where, RA1 an option be an analog input 1
RA2/AN2/Vref-	4	Bi-directional I/O port where, RA2 an option be an analog input 1 or negative analog reference voltage.
Vdd	11 or 32	Positive supply
Vss	12 or 31	Ground reference
RB7/PGD	40	Input/Output pin (with interrupt-on-change) or in-circuit debugger pin
RC7/RX/DT	26	Can be USART Asynchronous Receive or Synchronous Data
RC6/TX/CK	25	Can be USART Asynchronous Transmit or Synchronous Clock

1.3 Sensing Unit

The sensing unit consists of a set of sensors. Sensors are equipped with an analog or digital output reading sensor values [3]. Analog output requires the use of an ADC also included in the sensing unit. Microcontroller Unit typically have an integrated ADC, which can be used.

Sensor is hardware devices that produce measurable response to a change in a physical condition like temperature and humidity of the area to be monitored. The constant analog signal sensed by the sensors is digitized by an Analog-to-digital converter and sent to controllers for further processing. Characteristics of sensor node are small size, use very low energy, operate in high volumetric densities, be autonomous and operate unattended and be adaptive to the environment. In this project, 2 types of sensors were used, there are LM35DZ temperature sensor and A0545 basic humidity sensor.

The LM35DZ is precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35DZ's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. The LM35DZ is operating voltage from 4 to 30 volts. Figure 1.1 show basic diagram of temperature sensor and pin description that been used.

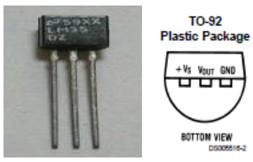


Figure 1.1: Temperature sensor and pin that used

Typical output produce proportional with linearization centigrade, +10.0 mV/ ºC. The detection temperature is shown in equation 1.

$$Temp\,(^{\circ}C) = \frac{V_O}{+10.0mV\,/\,^{\circ}C} \tag{1}$$

The A0545 Basic humidity sensor was deployed to measure humidity at the outdoor or indoor places. The A0545 Basic humidity sensor include capacitive sensing element for sensing and measure relative humidity. The CMOS process ensures provided highest reliability and excellent long-term stability. The output in term of voltage 10-90% of V_{CC} represents the proportional to 0-100% of relative humidity. Figure 1.2 shows the relationship between output voltage with 5 V of V_{CC} and possible relative humidity might be measure and Figure 1.2 shows relationship between output voltage and relative humidity of A0545 Basic.

The possible output and can be translate into basic mathematical form as:

$$Y = mX + C \tag{2}$$

Where *m* is represent the slope and *C* the y-intercept, therefore as refer the basic linear polynomials that form is

$$Y = 0.04x + 0.5 \quad (3)$$

$$V_{out} = 0.04(RH\%) + 0.5 \quad (4)$$

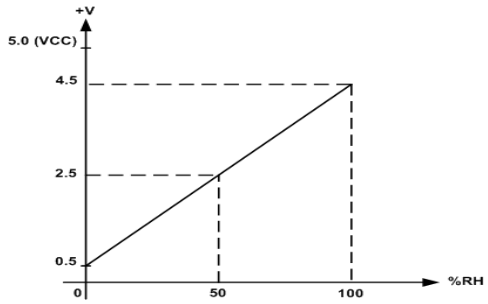


Figure 1.2: Relationship between output voltage and relative humidity.

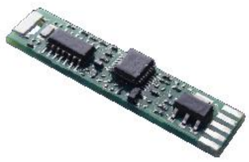


Figure 1.3: Humidity Sensor

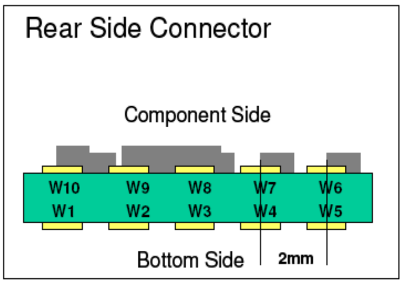


Figure 1.4: Pin of Humidity Sensor

TABLE 3
SELECTIVE PIN HUMIDITY SENSOR

Pin	Function
W8	GND
W9	Analog Out
W10	Vcc +

1.4 Communication

In order to transmit data from sensor nodes to data handler, radio system as wireless communication devices was a main role to enable transmission data through air [6].

The NT-R07A data transceiver module adopting RF integrated circuit with super heterodyne working mode and SAW resonance. Its features are stability and strong ability of anti-jamming. It is widely used at some spot of industrial control that has high requirement.

TABLE 4
TECHNICAL SPECIFICATIONS

Working voltage	5.0VDC
Operating range	50m
Transmission rate	9600bps
Working frequency	315MHz- 433.92MHz

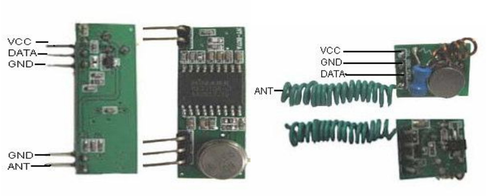


Figure 1.5: Transceiver NT-R07A

1.5 PICBASIC PRO Compiler

PICs microcontroller supports several programming language such likes assembly language which is using hardware instruction set dependable on the amounts of instructions sets for each PICs family, PICBasic and PICBasic Pro as High-Level Language (HLL) to use write PICs program with easier and quicker and, the other alternative HLL which is support to program PICs microcontroller family is using C/C++ language [5]. Figure 1.6 illustrates the stages in the development process for the program of a simple embedded system.

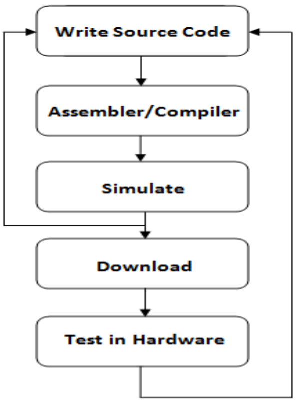


Figure 1.6: Flow of Software Development

PICBasic Pro language was selected for programming by using CodeDesigner Lite with PICBasic Pro compiler. CodeDesigner Lite is an advanced Windows based integrated development environment (IDE) for microcontroller especially for PICs chip family. The software equipped all user requirements for programming and with the advance features support such likes PICBasic/PICBasic Pro statement sensitive, auto compiler, reduce time spent hunting down errors, quickly navigate error lines and much more.

With CodeDesigner Lite capabilities to compile the human interactive language (PICBasic Pro language) into machine code which is microcontroller understand each command/codes from users. When the code was successful compile without any errors, the CodeDesigner Lite software generate the hexadecimal file which contained machine code with different bit length according to PICs family. In this case, the PICkit2 programmer software was opted as interfacing software between machine code and internal memory program of PIC. This software automatically detected the type of PIC that used.

2.0 METHODOLOGY

2.1 Hardware

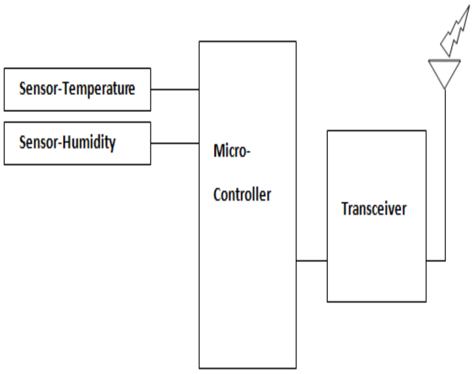


Figure 2.0: Overview Hardware Sensor Node

Sensor node is node in wireless sensor network that is able to performing some processing, gathering sensory information and communicating with other connected nodes in the network. The sensor nodes are designed and implemented to perform the air quality monitoring using temperature (T) and relative humidity (RH) at the same time. Figure 2.0 illustrate the overview flow of hardware sensor node. Each sensor node consists of same hardware configuration and three unit of sensor node was developing to monitor the laboratory room.

Each sensor nodes contained of two sensor that is LM35DZ temperature sensor and A0545 Basic humidity sensor. PIC as microcontroller was received the analog signal from both of sensor through the internal integration ADC hardware on the microcontroller and transmit the analyzed data by transceiver device. Figure 2.1 illustrate circuit design for overall sensor node and Figure 2.2 show the PCB layout after convert using PCB designer.

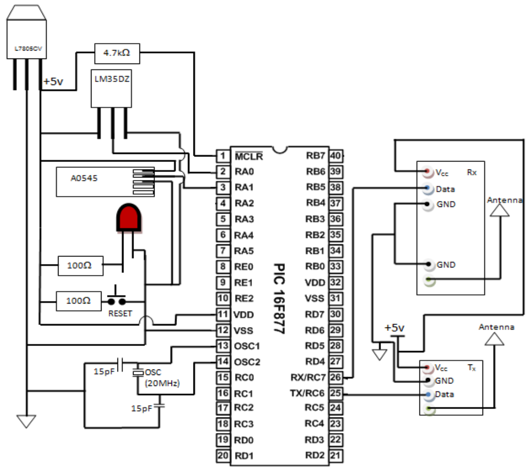


Figure 2.1: Circuit Design for Sensor Node

Only a few pin that deployed to monitor the signal flow from other devices such from sensors and communication device. The analog port of microcontroller which is AN0 and AN1 was selected as input to obtained signal from sensors and inject the signal into internal ADC block system. With 10-bit resolution digital data from ADC was analyzed by centre processing unit and send to the USART Asynchronous transmitting block to customize the data into 8-bit, no parity and one stop bit with travelling speed 9600 boudrate.

A crystal or ceramic resonator is connected to the OSC1 and OSC2 pin in order to establish oscillation. PIC16F877 oscillator design requires the parallel cut crystal method in order to oscillate the correct frequency. The higher capacitance selection can increase the stability of oscillator and also increase that start-up time or wake-up time. The value of frequency oscillator should be defined in the header of program tools if deployed different with default. For developing sensor nodes by deployed PIC16F877 microcontroller, HS crystal oscillator with 15 pF for both C1 and C2 was opted.

The AN0 on PIC16F877 microcontroller was used as an analog input without any external circuit between sensor and microcontroller unit. The 10-bit resolution of ADC initializing, able to detect as low as 4.888 mV and applied +5 V as a reference voltage and capable to analyzed the lowest linearization signal from temperature sensor.

The AN1 of pin 3 PIC16F877 microcontroller was deployed as input pin to receive analog signal from A0545 Basic relative humidity sensor. The same concept deployed here, to measure the environment relative humidity as temperature sensor.

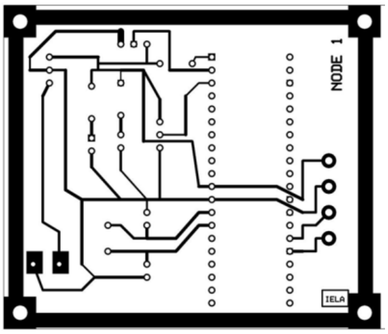


Figure 2.2: PCB Layout for Sensor Node

2.2 Software

Three sensor nodes were developed to monitor environment air quality including environmental of temperature and humidity as a main sensor to monitor quality air contaminant.

All sensors consists same system flow which is programmed into embedded microcontroller system of PIC16F877 and only different part is in time controlled scheduled and data types that contained integration information with recognized codes for base station. Figure 2.3 illustrate overview program flow chart sensor node.

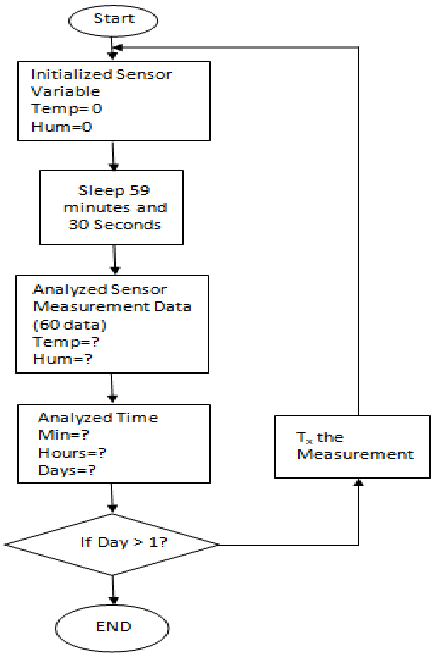


Figure 2.3: Sensor node overview program flow chart.

Before the sample data taken from ADC, each variable that hold measurement from sensors set into zero. Again, the microcontroller set into sleep mode condition up to 59 minutes and 30 seconds.

All data collection from temperature, humidity and air contaminants gas sensor was start from internal block system of ADC. The average conversation was deployed up to 60 times sample data to produced precise and accurate measurement data. The temperature measurement was the first conversation and channel 0 was set for LM35DZ temperature sensor and then second conversation is for A0545 Basic humidity sensor with channel 1. The register ADCON0 was set to $81 for temperature sensor and $89 for humidity sensor.

The ADCAN0 subroutine was called to start ADC conversation. Through the same register ADCON0, the status bit shows either the conversation was done or not. Minimum as 5 µs delayed was applied each time to check conversation. Each times conversation done from the ADCAN0 subroutine, the result store temporarily into related conversation variable with word size and repeated the conversation until 60 times. The final result divided with 60 for average calculations. After all conversation done for both temperature and humidity the time controlled state take place to control time and integrate conversation data with time calculation.

Data temperature and humidity monitoring scheduler transfer to base station every ten minutes approximately, to prevent interference between others sensor nodes before transfer to monitoring base station. Every information from sensor nodes transfer to base monitoring station for every one hour approximately. When the minutes variable more than one as one hour monitoring condition, the hour variable increase until it count to 24 as 24 hours monitoring status and increase the day variable until it count more than 1. In this indicate the complete monitoring was successful and shut down the process system. Figure 2.4 illustrate data monitoring state flowchart.

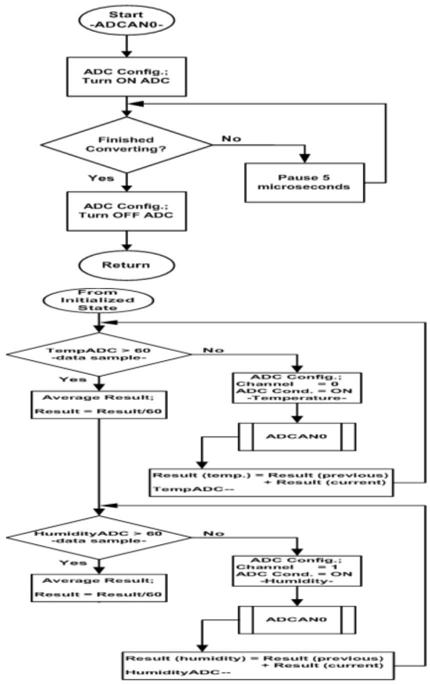


Figure 2.4: Data monitoring state flowchart

3.0 RESULT AND DISCUSION

3.1 Result

From figure 3.0 below shows the result for wireless sensor node in HyperTerminal. Each sensor node was transfer the result to HyperTerminal every hour and each sensor node have 10 minutes delay. The result that display by the HyperTerminal is in the resolution value and to determine the real value, Equation 5, 6 and 7 were used.

$$V_O = \frac{\text{Re}\,solution}{2^{10}-1} \times V_{CC} \qquad (5)$$

For Temperature

$$Temp\,(^O C) = \frac{V_O}{+10.0mV\,/^O\,C} \qquad (6)$$

For Humidity

$$RH(\%) = V_O(0.04) + 0.5 \qquad (7)$$

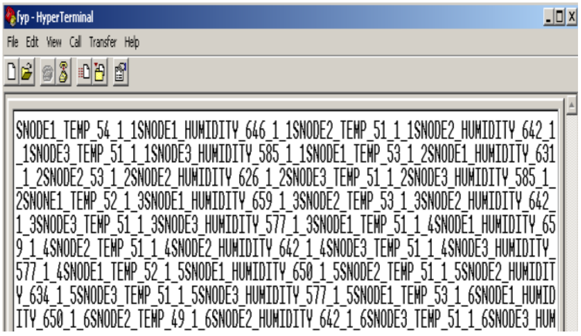


Figure 3.0: Result Display at HyperTerminal

The experiment work, the system has been tested at Research Assistance Room (Sensor Node 1), Mechatronics and Consumer Laboratory (Sensor Node 2) and Advance Signal Processor laboratory (Sensor Node 3), Faculty Electrical Engineering, MARA University of Technology Malaysia. Table 5, 6 and 7 show the degree of Celsius and the percentage of Relative Humidity every hour after converted from resolution value to real value. The percentage of Relative Humidity is increasing at the certain time from 65% to 71% for sensor node 1 and 2. Sensor node 3 gets a stable percentage of relative humidity. Air temperature for sensor node 1 and 2 were increasing at the first of monitoring until at one time. Air temperature is stable for sensor node 3.

Sensor node 1 was placed at Research Assistance Laboratory. Only the research assistance used this room, so the value of temperature and humidity is stable because just a few human used this laboratory. Sensor Node 2 was place at Mechatronics and Consumer Laboratory. Sometimes this laboratory was used as a class. The data of temperature and humidity were not stable because human body produces heat. This situation could affect the value of data. Advance Signal Processor (ASP) laboratory was monitored by Sensor Node 3. This laboratory almost closes so the temperature of this room decreases until 23°C. The percentage of relative humidity is stable.

TABLE 5
DATA WIRELESS SENSOR NODE 1

Hour	Sensor Node 1			
	Temp(Res)	Temp (°C)	Humidity(Res)	humidity
1	54	26.39	646	66
2	53	25.90	631	65
3	52	25.42	659	68
4	51	24.93	659	68
5	52	25.42	650	67
6	53	25.90	653	67
7	52	25.42	658	68
8	53	25.90	653	67
9	52	25.42	658	68
10	53	25.90	648	67
11	53	25.90	651	67
12	52	25.42	670	69
13	52	25.42	676	70
14	52	25.42	676	70
15	52	25.42	678	70
16	52	25.42	680	71
17	51	24.93	651	67
18	53	25.90	650	67
19	52	25.42	657	68
20	51	24.93	662	68
21	52	25.42	655	68
22	51	24.93	659	68
23	52	25.42	641	66
24	52	25.42	638	65

TABLE 6
DATA WIRELESS SENSOR NODE 2

Hour	Sensor Node 2			
	Temp(Res)	Temp (°C)	Humidity(Res)	humidity
1	51	24.93	642	66
2	53	25.90	626	64
3	53	25.90	642	66
4	51	24.93	642	66
5	51	24.93	634	65
6	49	23.95	642	66
7	51	24.93	651	67
8	53	25.90	651	67
9	53	25.90	659	68
10	55	26.88	667	69
11	55	26.88	675	70
12	55	26.88	667	69
13	55	26.88	659	68
14	55	26.88	651	67
15	53	25.90	659	68
16	55	26.88	667	69
17	55	26.88	667	69
18	53	25.90	651	67
19	53	25.90	651	67
20	53	25.90	651	67
21	53	25.90	651	67
22	53	25.90	626	64
23	49	23.95	618	63
24	51	24.93	618	63

TABLE 7
DATA WIRELESS SENSOR NODE 3

Hour	Sensor Node 3			
	Temp(Res)	Temp (°C)	Humidity(Res)	humidity
1	51	24.93	585	59
2	51	24.93	585	59
3	51	24.93	577	58
4	51	24.93	577	58
5	51	24.93	577	58
6	51	24.93	577	58
7	51	24.93	585	59
8	51	24.93	593	60
9	51	24.93	602	61
10	51	24.93	602	61
11	53	25.90	618	63
12	51	24.93	618	63
13	51	24.93	634	65
14	51	24.93	626	64
15	51	24.93	626	64
16	51	24.93	618	63
17	51	24.93	618	63
18	49	23.95	610	62
19	49	23.95	602	61
20	49	23.95	602	61
21	49	23.95	602	61
22	49	23.95	593	60
23	49	23.95	593	60
24	49	23.95	593	60

4.0 CONCLUSION

A hardware wireless sensor node for monitoring indoor air quality has been successful developed for monitor air temperature and humidity parameters. Covering average monitoring area, more than one sensor nodes were applied to monitor the indoor air quality at target places.

Hardware and software integrations to suit development as indoor air quality with WSN technology monitoring was performed and monitoring up to one day continuously which the system have been applied at Research Assistance Room (Sensor Node 1), Mechatronics and Consumer Laboratory (Sensor Node2) and Advance Signal Processor (ASP) laboratories (Sensor Node3), MARA University of Technology Malaysia.

5.0 FUTURE WORK

Alternatively, this project can be improve by designing the control of air quality by using microcontroller system. The temperature and humidity can be control to stabilize the comfort of room. The type of transceiver can be recommended to use in wireless sensor node model such as SRWF-508 Low Power Wireless Transceiver Data. SRWF-508, the low-power wireless transceiver data module is used as the wireless data transceiver in short-ranges but more then 50 m, with the small size, weight and power consumption and good stability and reliability. Besides that, analyse data will be design in coding PIC to improve this project, and the data automatically will display in real value such as degree Celsius of temperature and percent of relative humidity.

6.0 ACKNOWLEDGEMENT

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