LOW POWER WIRELESS MONITORING SYSTEM DUAL POWERED BY PIEZOELECTRIC TRANSDUCERS AND SOLAR CELLS

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ABSTRACT

In weather analysis, it is important to monitor certain parameters such as temperature and relative humidity. It is also ideal to make use of autonomous-power automatic weather stations. The available technology in the country regarding long distance weather monitoring systems can be improved in its ability to transmit information between the monitoring devices and the base station and in synthesizing a cost-efficient method for regulating the power consumption of each device. One vital issue to be considered is the power source because batteries of wireless network systems require maintenance which is not convenient for monitoring stations located in remote areas such as mountains and other rural areas. This paper addresses these concerns by using a low-cost and low-power consuming wireless communication system for a better means of sending data from the node to the station and by creating a systematic method for sending and receiving data using self-harvesting energy sources that specifically provide low- power consuming sensors in order to save space, energy, and costs. The group designed a Wireless Sensor Network (WSN) in weather monitoring. It is powered-up by two energy-scavenging sources – piezoelectric transducers and solar cells. Each sensor node is composed of energy scavengers, microcontroller, temperature and relative humidity sensors and Zigbee. After the conducted study, the designed energy harvesting system using piezoelectric transducers and solar panel was able to power up the wireless sensor node. A scheduled sleep, read, and transmit/ receive modes was successfully designed to minimize the current consumption of the node. The base station is the interface between the hardware and the software. The data received is logged by a program developed using LabVIEW. Then, the data would be sent through a GSM Module and will be published in the Web.

Key Words- NI LabVIEW, Piezoelectric Transducers, Solar Cells, Wireless Sensor Network (WSN), Zigbee

1. INTRODUCTION

In weather analysis, it is important to monitor certain parameters such as temperature and relative humidity. It is also ideal to make use of autonomous-power automatic weather stations. However, it is significantly expensive and has large power consumption. At the time this study was conducted, the available technology in the country regarding long distance monitoring systems is relatively lacking in its ability to transmit information between the monitoring device and the station and in synthesizing a cost-efficient method for regulating the power that is required. Another issue would be the power source itself, because batteries of wireless network systems are constantly requiring maintenance which would inevitably cause delays and some loss of data which is not convenient for automatic stations that could be located in mountains and rural areas. This paper address these concerns by using a low-cost and low-power wireless communication system for a better means of sending data from the node to the station. It also creates a systematic method for sending and receiving data and uses self- harvesting energy sources that specifically provide low- power consuming sensors in order to save space, energy, and costs.

2. DESIGN CONSIDERATIONS

The most significant part of the project is the energy scavenging system which is composed of piezoelectric transducers and solar panel. Piezoelectric transducers are mainly used as sensors but this project focused on its use as an energy scavenger (Arms et al., 2005). The solar panel is a widely used energy scavenging tool has been studied for so many years. The importance of this project is to use both scavenging tools to integrate to a system that could run autonomously or with very little maintenance.

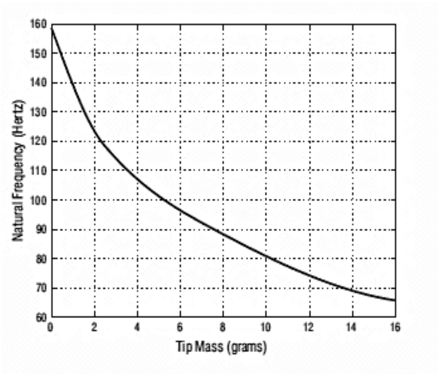

Fig. 1 Relationship of Tip Mass to Natural Frequency

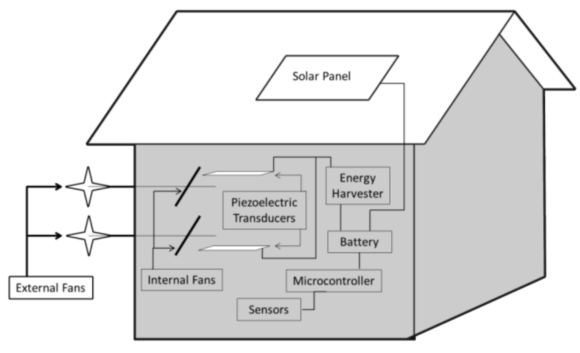

Fig. 2 Structure of Case

The solar panel used in this project is a basic panel with several cells in a small package. The piezoelectric transducer, on the other hand, is a bender-type that is actuated by subtle vibrations. Bender-types are very fragile but they can be used for a small system that has enough protection. And since the environment operates at different frequencies of vibration, the bender-types are tuned to a certain frequency that will optimize the energy gathered. The Figure 1 shows the relationship of tip mass to natural frequency piezoelectric transducer from Mide (2011). It shows the relationship of the tip mass or the tuning mass that is attached to the bender-type piezoelectric transducer to tune it to a specific frequency that will output a desired voltage. The whole process of identifying the correct configuration to tune the piezoelectric transducer is deduced from trial and error and basic algorithm based from the data sheet. In order to further improve the gathered energy, the transducers are connected in parallel to double the current gathered since the each node uses two piezoelectric transducers. In order to actuate the bender-types and at the same time, protect it from harsh conditions, the transducers are enclosed in a case and reacts from the internal fans connected to an external actuator fans. Figure 2 shows protective casing designed to place the components of the system.

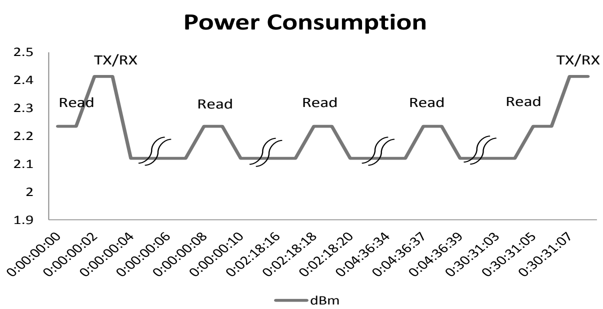

Fig. 3 Peripheral Schedule

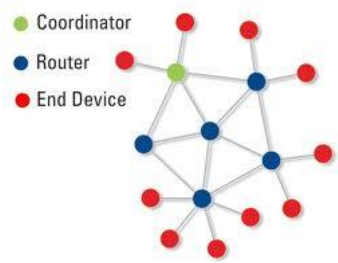

Fig. 4 Sample Zigbee Network

The load to be powered up by the energy scavengers is a low-power monitoring system, made up of sensors, microcontroller and a Zigbee module for transmission and reception of data. The sensors used (MCP9700 Temperature Sensors and HIH-5030 Relative Humidity Sensors) uses 6uA and 200uA of current respectively. The PIC18LF4620 microcontroller is one of Microchip's Nano-watt Technology that operates at 11uA and sleeps at 100nA (Microchip, 2011). Together with a Zigbee that operates at 40mA, the whole system is scheduled to read the sensors every 2 minutes and sends the average data recorded every 30 minutes and creating a system that consumes an average of 30uA. Figure 3 shows the peripheral schedule of the system that optimizes the system's current usage. The Zigbees are considered low cost and low power communications devices based from Digi International. There are 3 Zigbees used for this project: one is for the coordinator of the base station which is connected to the computer with a graphical user interface, another is for the router Zigbee which receives data from one sensor node, combine it with its own and send both data to the base station's coordinator, and lastly, an end device which only transmits data to the router. Figure 4 shows an example of how each types of Zigbee are connected to one another. There can only be one coordinator per network and there can be several router or end devices in use. Routers can communicate with one another but end devices could not; because of this, they use and require less power than routers. Then, for the interface of the hardware to the computer, a graphical user interface that can receive the data sent to the coordinator, record the collected data, graph the data, infer a conclusion using an algorithm, send the data through SMS and display the output online is made using National Instruments' LabVIEW that can do all those features using a single program.

3. DATA AND RESULTS

Table 1 shows the initial test results of the piezoelectric transducer used on its own. Without any tip mass, the PZT can reach around 3 volts V_{RMS} at around 30Hz of frequency when it is hit at a steady pace. Figure 5 is the average voltage output of a tuned piezoelectric transducer. By adding a weight on the PZT, the transducer is tuned and is able to reach even above 3 volts at a low frequency.

Table 1. PZT Initial Test Results

Trial	Frequency (Hz)	Operating Voltage (V)
1	31	3.25
2	29	3.04
3	27	3.41

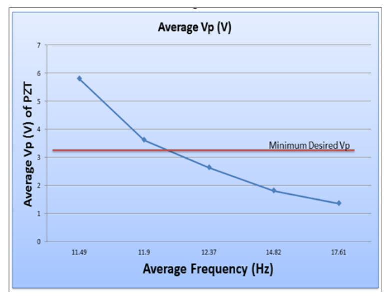

Fig. 5 Average Voltage Output

Figure 6 is the results of the comparison between the input voltage and the output voltage of the PZT energy harvester. The input voltage is the voltage that the PZT transducers generate, and as the data indicates, even if the PZT produces different voltages at different frequencies, the energy harvester is able to maintain an output voltage at around 3.3 volts. Figure 7 indicates the time it would take for the energy harvester to reach a constant voltage of around 3.3 volts.

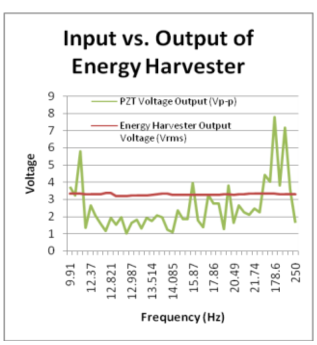

Fig. 6. Comparison of the voltage level detected at the input and output of the PZT Energy Harvester

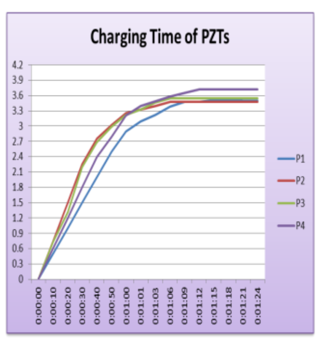

Fig. 7 Charging time of the PZTs in order to obtain a constant 3.3 volts and above from the energy harvester

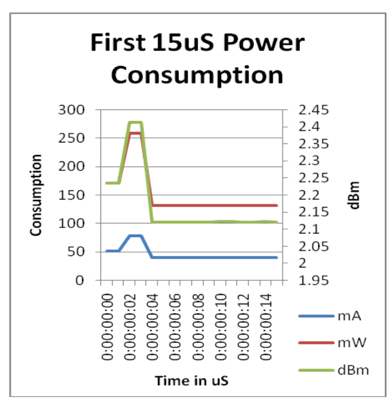

Fig. 8 Power Consumed by WSN

Table 2. Average Voltage Levels Measured at the PZT Energy Harvester Output

	PZT Energy Harvester Output		
	Vrms	Iout (mA)	mW
6:00 AM	3.3	0.001	0.0033
12:00 NN	3.22	0.0009	0.002898
6:00 PM	3.29	0.00089	0.002928
12:00 AM	3.23	0.005846	0.002616

Table 3. Average Voltage of the Solar Panel

	Solar Panel Output		
	Vrms	Iout(mA)	mW
6:00 AM	2.45	0.083	0.20335
12:00 NN	3.66	0.135	0.4941
6:00 PM	3.07	0.038	0.16885
12:00AM	0.035	0.055	0.001925

Table 4. Current Input and Output from the Battery

	Input (mA)	Output(mA)
6:00 AM	0.084	0.1353
12:00 NN	0.1359	0.1354
6:00 PM	0.03889	0.1342
12:00 AM	0.060846	0.135

Fig. 8 shows the immediate shift of power consumed by the wireless sensor network in the first 15uS after starting up. The node consumes 50.3mA (166mW or 22.2dBm) when it reads the analog sensors; 78.6mA (259.05mW or 24.1dBm) when the XBee transmits/Receives; and 40mA (132mW or 21.2dBm) during sleep mode. In the integration of the energy sources to the system, Table 2 shows the measured output voltage and current and the computed output power from the energy harvester at different times of the day. Meanwhile, Table 3 shows the average output voltage measured at the solar panel at different times of the day. Table 4 shows the current input and output of the battery at different times of the day. From the test results there are times when the input at the battery is not enough to power the 0.041mA load of the system, but the battery is still able to power up the whole system. Readings were recorded by WSN every 2 minutes. The nodes were able to supply the data to the base station for the GUI to record. For the temperature reading and relative humidity reading, the formula to convert the value read by the Analog-to-Digital converter (ADC) of the microcontroller was computed based from the datasheet. Since both of the sensors have linear output with respect to the changes in temperature and humidity, the equations used for the two sensor readings are as follows:

Temperature Sensor:

$$T = \frac{(Raw\ ADC) * 3.3V}{1024\ steps} * 100 = T^{o}C$$

(Equation 1)

Relative Humidity Sensor:

$$RH = \frac{(Raw\ ADC) * 3.3V}{1024\ steps} - 25 = \%RH$$

(Equation 2)

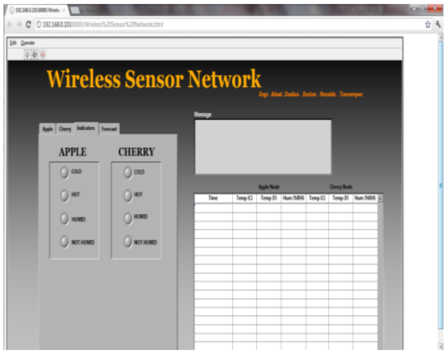

Fig. 9 Front Panel/ GUI Published Online

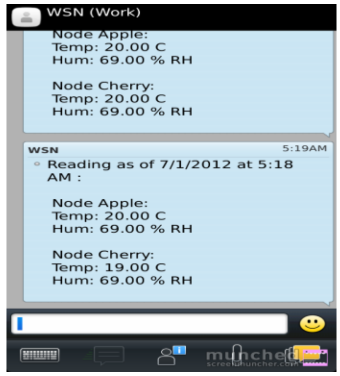

Fig. 10 SMS Message received

Figure 9 shows the whole GUI used for data-logging and web publishing. It is integrated with the SMS system and has several tabs to see the graphical output of each station—Apple Station (node 1) and Cherry Station (node 2), indicators if the readings are within the average temperature and relative humidity range, and a rough estimate of the forecast based on the sensor readings. The GUI can be viewed online only when the GUI is running or when it is logging data because it was published using the LabView Server. The URL of the online GUI is: http://192.168.0.103:8000/Wireless%20Sensor%20Network.html. SMS application was constructed using LabVIEW. The message received includes the time when the data was retrieved and the values of the sensors. All these details are finally concatenated at to create the message. The graphical user interface only displayed the list panel for the COM port as well as the input panel for the desired destination mobile numbers. String of data or the message template as well as the multiple destination mobile numbers are stored in the Labview program. Messages can be sent to as many destination numbers as desired as long as the location is entered in the program. Figure 10 shows the SMS message received by a cellphone after the data is processed by the system. SMS message is received at around the same time the data was received from the base station, as indicated by the cellular phone.

4. CONCLUSION & RECOMMENDATIONS

The designed energy harvesting system using piezoelectric transducers and solar panel was able to power up the wireless sensor node. Using low power sensors, Zigbee Transmitter, and PIC18LF4620 microcontroller, the wireless sensor node operated at an average of 0.141mA or 147.4mAh which integrated well with the energy harvesting system. A scheduled sleep, read, and transmit/ receive modes was successfully designed to minimize the current consumption of the node. And each node was scheduled when to receive or transmit data so that the furthest node was able to send the sensor readings to the nearest node from the base station before it sends both readings to the base station. At the base station, the data logging system using LabView is able to receive and record the data upon reception. It also provides a live update on the web- server as long as it is running. The system is also programmed to automatically send an SMS through the GSM module to several dedicated numbers and numbers that can be inputted by the user. Several points were noted to cater improvement for the future studies concerning any material or method used in this study. In using Piezoelectric transducers, it is important to consider that the connection, either in series or parallel, affects the output of the transducers. PIC18LF4620 is a good microcontroller for low power applications. It also provides larger room for any changes or additional storage for data or room functions. Zigbees require little time configure and are able to act as a coordinator, router, or an end device. Several types of Zigbees are available in the market depending on the need of the system.

5. REFERENCES

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