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Chest Worn Pulse Oximeter Integrating NI-USRP with GPS Disciplined Clock Transceiver

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Abstract—This paper presents the chest worn pulse oximeter with integrated universal software radio peripheral (USRP) with the global positioning systems (GPS) disciplined clock transceiver from the National Instruments. It illustrates the respiratory cardio monitoring using the flexible reflective pulse oximeter with ECG. The gathered cardio respiratory data assessed by the microcontroller and the output is sent through to the remote monitor display by means of wireless system. The device also incorporates an early warning feature to alert then both the user and also the person being monitored. The GPS device is included for tracking and to determine the present location of the client in case of an emergency situation. The output is then transmitted and also displayed to a web based server via radio frequency (RF). A complete hardware prototype model is designed, developed, tested, and implemented thus validated the proposed scheme. The statistical assessment method is then integrated where the parameters gathered are evaluated.

Keywords**— Electrocardiogram, Global positioning system (GPS), NI-USRP Transceiver, Pulse oximeter, RF**

I. Introduction

Health is a big concern nowadays due to the existence of different diseases affecting to peoples body. Another constituent to health problems is the extent of unsafe environment of today and because these problems arise especially on remote areas, the health technologies are becoming vital and necessary. The need for improving health paves the way to the solution for incurable diseases back then and now has made it way in early detection and prevention of certain diseases. The health monitoring from the stationary in hospitals became dynamic in such a way that patients are able to walk around the hospital safely. As ordinary people become aware of the danger in their health and hence; the health monitoring outside the hospital has becoming vital. Another constituent to health problems is the extent of unsafe environment of today. Some examples are the mountains where man hikers in this present generation, habitually participate in trekking the said environments. Also, working on environments such as mining pits where miners tend to delve in the pits surrounded by toxic and/or flammable gases. A whiff of these gases will tend affects the miner's physiological characteristics. Another instance also is that would be in fires where firemen are exposed to toxic fumes and gases made by burning synthetic materials. In these situations, both medical and personal cases as mentioned are likely to have monitoring to enhance their safety cases. An integrated device that is efficient in monitoring the conditions of the users is therefore helpful when the need arises. It will raise the chances of being in a more precarious situation wherein fatality is inevitable. Like what it is always said, prevention is better than cure. This paper is organized as it follows: Section II briefly presents the details of the chest worn pulse oximeter integrating the NI USRP with GPS disciplined clock transceiver used in this research paper. Section III is devoted to the experimental results, which are then carried out in order to verify the effectiveness of proposed method by means of the prototype model. Conclusion ends the paper at section IV.

II. Methodology

The figure below (Fig. 1) shows the major components of the constructed prototype. The sensors, ECG probes, and pulse oximeter shown in figure 1, provide the necessary data processed by the microcontroller (PIC18F4520). The GPS module receives signal through the GPS antenna & sends the data to the MCU. The data will be transmitted through the XBEE RF module transceiver to transceiver connected to a unit, once the data string to be sent is complete. The data will then be displayed in the web-based server.

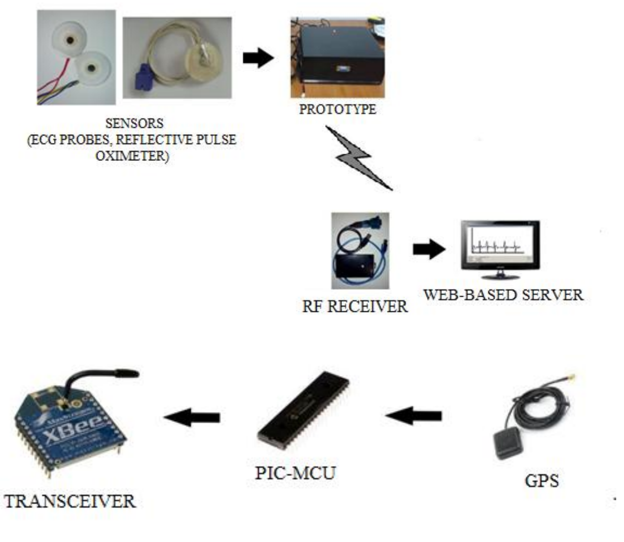


Fig. 1. General block diagram of the system.

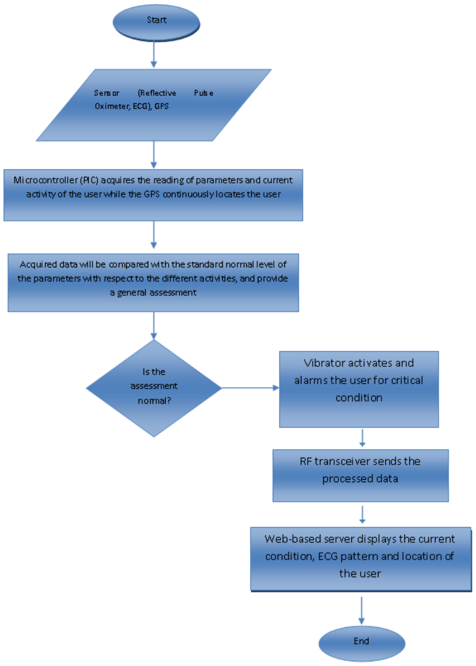


Fig. 2. Software process flow chart.

The figure 2 above represents the software flowchart of the research study. Upon startup, the sensors are activated to gather data and will be sending to the microcontroller unit to be processed and send wirelessly to a monitor. The data is then displayed to a web based server inclusive of the user's pulse rate, oxygen saturation level, ECG pattern, and his/her location. The data will be gathered from the user through reflective pulse oximeter & ECG sensors then the microcontroller will evaluate and assessed the gathered data whether the individual parameters are normal and will correlate and do the overall assessment to provide finding of the real-time status of the user. If the status of the user is normal, the data will be transmitted without notifying the user but if the over-all assessment shows that the status of the user is not on its normal state.

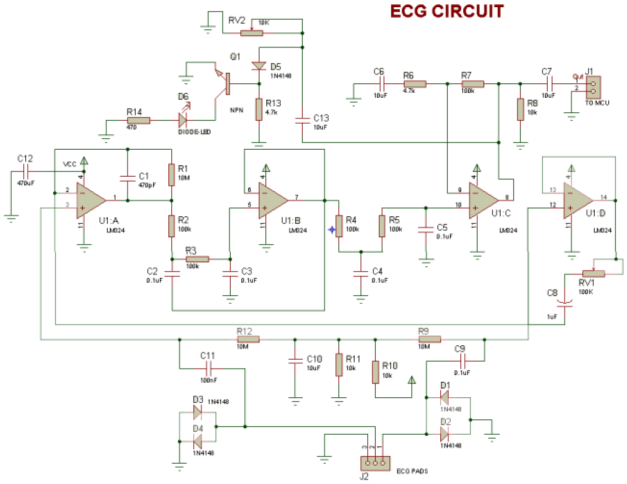


Fig. 3. Schematic diagram of the ECG.

The figure above shows the schematic diagram of ECG. The main components used were the LM324 op amp which handles the data acquisition and the amplification of the gathered voltage reading from the pulses.

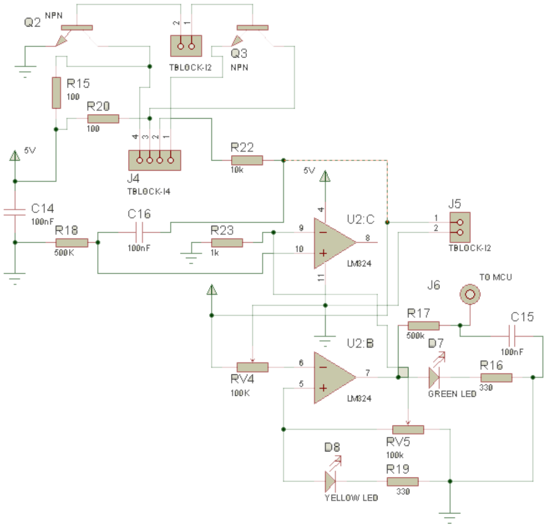


Fig. 4. Schematic diagram of the pulse oximeter.

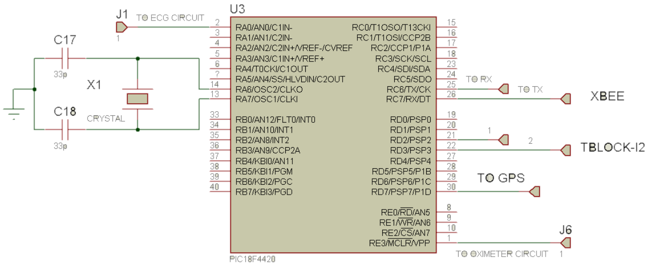
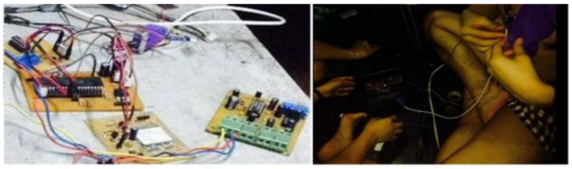
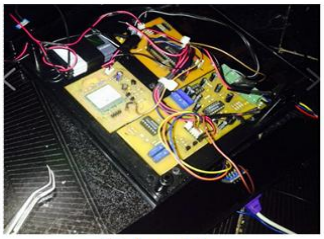


Fig. 5. Schematic diagram of the MCU connections.

In the figure 4, it shows the schematic diagram of the pulse oximeter. The main components used were LM324 op amp that handles the acquisition of data from the photo diode IR LED pair. It then sends the data to the microcontroller unit. On the figure 5, it shows here the schematic diagram of the microcontroller unit. The unit is used for storage and also analysis of the data gathered by the ECG and pulse oximeter circuits.



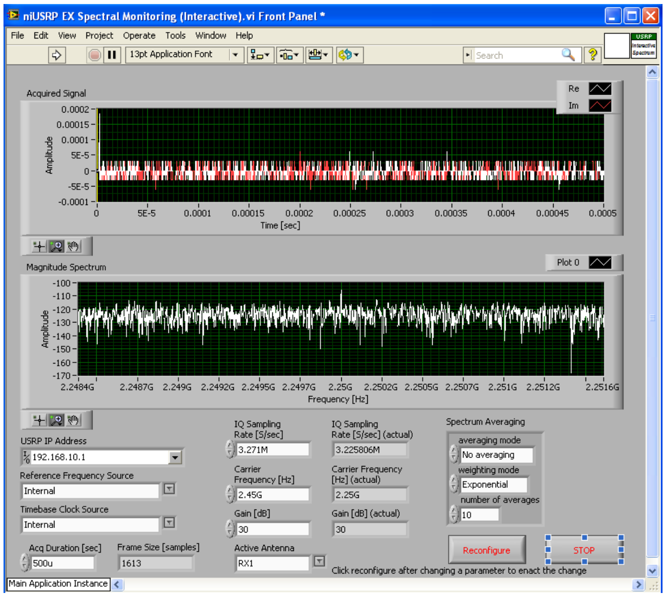
(a) Integration of GPS (b) Testing



(c) Assembly

Fig. 6. Construction and testing of the hardware prototype model.

III. Experimental Results


niUSRP EX Spectral Monitoring (Interactive).vi Front Panel *

USRP IP Address: 192.168.10.1
Reference Frequency Source: Internal
Timebase Clock Source: Internal
Acq Duration [sec]: 500u
Frame Size [samples]: 1613
IQ Sampling Rate [S/sec]: 3.271M
IQ Sampling Rate [S/sec] (actual): 3.225806M
Carrier Frequency [Hz]: 2.45G
Carrier Frequency [Hz] (actual): 2.25G
Gain [dB]: 30
Gain [dB] (actual): 30
Active Antenna: RX1
Spectrum Averaging
averaging mode: No averaging
weighting mode: Exponential
number of averages: 10

Click reconfigure after changing a parameter to enact the change

Fig. 7. Output waveform and data gathered via NI USRP.

The NI USRP showed the carrier frequency in the magnitude spectrum used by the XBee RF module for which is 2.25 GHz (actual) and the gain in dBm is -109 with an equivalent power level of 125.8925 picowatts.

Fig. 8. ECG waveform (test subject is steady).

The obtained waveform of the ECG shows the normal electrical activity of the heart. Based on the component of a normal ECG waveform, which are the variables P, Q, R, S, T and U waves, the acquired waveform is in accordance with the characteristics of a normal ECG waveform. The data will be gathered from the user through reflective pulse oximeter & ECG sensors then the microcontroller will evaluate and assessed the gathered data whether the individual parameters are normal and will correlate and do the overall assessment to provide finding of the real-time status of the user. If the status of the user is normal, the data will be transmitted without notifying the user but if the over-all assessment shows that the status of the user is not on its normal state. The researchers conducted a testing to obtain 10 samples. The researchers then considered setting up in validating the data gathered by the sensor; steady and after the certain activity, the researchers used pulse oximeter to get the standard measurement of the pulse rate and the oxygen saturation level. To further validate the ECG output, the researchers consulted a doctor to compare the ECG outputs of the device and the clinical ECG machine. The result is then certified by the doctor, stating that the device produced similar waveform with the clinical ECG machine. The researchers conducted a testing and obtained 10 samples. The researchers then considered setting up in validating the data gathered by the sensor; steady and also after the certain activity, the researchers used a pulse oximeter to get the standard measurement of the pulse rate and also the oxygen saturation level. To further validate the ECG output, the researchers consulted a doctor to compare the ECG outputs of the device and the clinical ECG machine. The results are then certified by the doctor stating that the device produced similar waveform with the clinical ECG machine.

Table 1: Pulse rate validation

TEST	STEADY		AFTER ACTIVITY	
	PULSE RATE (BPM)	COMMERCIAL PULSE OXIMETER (BPM)	PULSE RATE (BPM)	COMMERCIAL PULSE OXIMETER (BPM)
1	78	77	125	119
2	79	79	135	120
3	74	76	120	111
4	76	77	125	120
5	75	73	135	110
6	76	78	125	100
7	76	76	110	115
8	79	80	125	112
9	74	73	110	119
10	76	78	114	125

Table 2: T-test using the chest-worn pulse oximeter and commercial pulse oximeter (steady)

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	76.7	76.3
Variance	5.344444	3.344444
Observations	10	10
Hypothesized mean difference	0	
Df	17	
t Stat	0.429119	
P(T<=t) one-tail	0.336613	
t Critical one-tail	1.739607	
P(T<=t) two-tail	0.673225	
t Critical two-tail	2.109816	

The researchers have the following findings after obtaining the testings: the obtained measurement of pulse rate (BPM)

Table 3: T-test using the chest-worn pulse oximeter and commercial pulse oximeter (after activity)

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	122.4	115.1
Variance	80.93333	50.76667
Observations	10	10
Hypothesized mean difference	0	
Df	17	
t Stat	2.011546	
P(T<=t) one-tail	0.030198	
t Critical one-tail	1.739607	
P(T<=t) two-tail	0.060397	
t Critical two-tail	2.109816	

Table 4: Oxygen saturation level validation

TEST	STEADY		AFTER ACTIVITY	
	SPO2 (%)	COMMERCIAL PULSE OXIMETER (% SPO2)	SPO2 (%)	COMMERCIAL PULSE OXIMETER (% SPO2)
1	98	98	98	97
2	99	98	98	96
3	99	98	98	98
4	99	99	98	96
5	99	98	99	97
6	99	98	99	96
7	98	99	99	96
8	99	99	99	97
9	99	99	99	98
10	99	99	99	96

using the chest worn pulse oximeter is in the range of 74-86 BPM when the person is steady or at rest while it increases to 98-145 BPM, as shown in Table 1, when the person conducts certain activity, in this case going up the stairs. The obtained measurement of oxygen saturation (% SPO2), as shown in Table 4 using the chest-worn pulse oximeter shows minimal difference when the person is steady or at rest compare when the person conducts the activity of going up the stairs. As compared then to the commercialized pulse oximeter, the chest worn pulse oximeter illustrates the insignificant difference in its measurement of pulse rate whether steady (Table 2) or after certain activity (Table 3) and oxygen saturation level whether steady (Table 5) and also after certain activity (Table 6). The researchers design considered the individual schematics; the pulse oximeter circuit, the ECG circuit. After assuring the functionality of both circuits through testing, the GPS is then integrated and it shows the assembly of circuits in its housing as it was illustrated in figure 6.

Table 5: T-test using the chest-worn pulse oximeter and commercial pulse oximeter (steady)

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	98.8	98.5
Variance	0.177778	0.277778
Observations	10	10
Hypothesized mean difference	0	
Df	17	
t Stat	1.405564	
P(T<=t) one-tail	0.088933	
t Critical one-tail	1.739607	
P(T<=t) two-tail	0.177866	
t Critical two-tail	2.109816	

Table 6: T-test using the chest-worn pulse oximeter and commercial pulse oximeter (after activity)

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	98.6	96.7
Variance	0.266667	0.677778
Observations	10	10
Hypothesized mean difference	0	
Df	15	
t Stat	6.182518	
P(T<=t) one-tail	8.77E-06	
t Critical one-tail	1.75305	
P(T<=t) two-tail	1.75E-05	
t Critical two-tail	2.13145	

IV. Conclusion

This paper has presented the chest worn pulse oximeter integrating NI USRP with GPS discipline clock transceiver. The proposed system uses the principle of electrocardiogram and pulse oximeter. Extensive experimental studies have been performed and carried out to further validate the study.

Results have clearly confirmed that the proposed method is remarkably effective. The measured parameters are obtained through chest worn pulse oximeter and the commercial pulse oximeter shows no significant difference as shown in the t-test performed, therefore the chest-worn pulse oximeter is accurate. The oxygen saturation can be accurately measured not only in the earlobe and fingertips also in the chest using the chest-worn pulse oximeter, then the pulse rate increases with physical activity while the oxygen saturation remains on the normal range of oxygen saturation. Also, the ECG waveform obtained from the prototype device and it shows normal condition as compared with the clinical ECG machine. The frequency used by XBee RF module is safe in accordance to the standard level under the range of 3 kHz to 300 GHz. The researchers would then recommend further study through the use of the computational intelligence such as fuzzy logic, genetic algorithm, neural network, and particle swarm optimization.

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