Health Monitoring Nano -Wear System for Astronauts

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Abstract- *This paper discusses the novel sensor technology which aims at monitoring health status to improve comfort and efficiency of astronauts as well as to eliminate catastrophic failure to the individual and mission. Continuous ambulatory monitoring of vital signs will enable proactive personal health management and better treatment of astronauts. It proposes to develop a low-weight, non-invasive, fully-interconnected Nano system to be worn underneath the spacesuit without the complexity of multi-wire and Multi-locations for mapping crewmembers' health status. It can sense more than 7 vital parameters such as heart rate, electrocardiogram (ECG), Blood Pressure (BP), Respiration, Sp02, radiation, Phonocardiogram (PCG), Body Temperature for both extra and intra-vehicular activities with the help of nuclear battery. In this system, all parameters' signals can be processed by MSP430F2274 and displayed through TMS320 DSP controller with Novel architecture to meet space requirements.*

Keywords: Multi-locations, 7 parameters, sensor, Nuclear Battery, Nano, Microcontroller.

1 Introduction

Life of the flesh is in the blood [1]. Definitely the abnormalities & the disease will be reflected (will have variations) in the flow of blood. The pain and abnormalities in the body is due to the obstruction of blood in the blood vessels in the affected area that are sensed by the brain through our nervous system.

1. 1 Existing Health Monitoring Devices

There exists a large variety of situations in which noninvasive and continuous monitoring of physiologic and related parameters are extremely useful in a remote setting. Remote telemedicine [2], in-home care [3], patient transport (ambulance, aircraft [4]), military use, emergency worker monitoring (first responders) [5], as well as in- and out-of-hospital clinical monitoring [6-9], cardiac monitoring, sleep studies, clinical trials of medications) are but a few. For space applications [10], these include extravehicular activities (EVA), launch and deorbit, exercise in microgravity, physiologic research, and unexpected medical events.

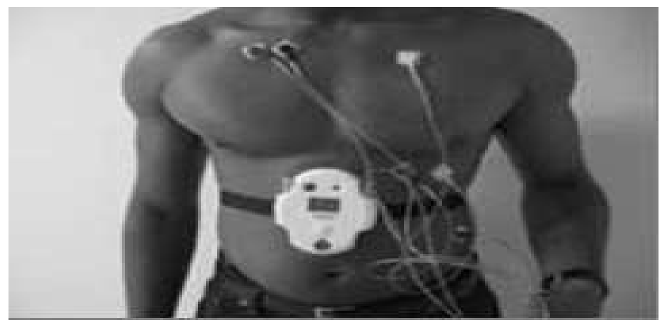

Fig. 1.1 Existing multisensory placements

Many of these applications require a rugged device, capable of daily use in an extreme environment due to pressure (hyperbaric, hypobaric), vibration (shuttle launch), radiation (on-orbit), temperature and humidity (emergency workers) or other environmental factors.

This automatic reflecting diagnostic system is bulky, expensive and it takes a professional medical doctor fluent with meridian points to interpret the results. Therefore, in the late 1990s, a lot of research was done in Taiwan to come up with a testing system that incorporated Dr. Volla's technology and the Traditional Chinese Meridian points and acupuncture, in a small enough packages that are affordable for the average person and also the results are interpretable to the average person. The bioelectric current, which is released by the meridian and the acupoint in the human body, can be read by the sensor connected to the computer and be statistically analyzed and correlated with the millions of clinical data records of the Data Center and the resulting report will be sent back to the computer. With the data being accumulated and revised continuously, the resulting report will be more and more precise and accurate. We give below some of the physiological parameter specifications that are in the existing health monitoring systems.

Fig1.2 Automatic reflecting diagnostic system

Table 1.1 Sensor Specifications

Parameter	**Sensor/Device**	**Range**	**Accuracy**
ECG (Lead II and V5)	Button electrodes	-	12bit
Respiration (Body-Impedance)	Button electrodes	-	12bit
Temperature (Skin)	FM50	-40C … +125C	+/-0.5C
Activity 2 x (2-axis Acceleration)	ADXL210E	+/-10g	2mg
SpO2 (Pulse Oximeter)	Nonin Xpod 3011	70…100%	+/-4 digits
Pulse Rate (Pulse Oximeter)	Nonin Xpod 3011	18… 300 pulses per min.	+/-3 digits
Blood Pressure (Cuff, Auscultatory)	Accutracker II	-	1mmHg

1.2 Disadvantages of existing systems

All these systems are bulky and during diagnosis we need an assisstant for measurements and some experts to interpret the results. More over in these systems, the person has to be in the lying position for ECG and for BP measuers the hand of the person should be at rest.

2. Proposed Novel System

It is a simple, pocket size, inexpensive, and a tiny battery-powered instrument. It consists of Wireless network system with *a single location* for the sensors to include 8 parameters that can process all the data and transmit them either simultaneously or individually to a display system worn on the wrist of the astronauts or in the ground control. *Our system is an excellent* one as it needs *zero preparation* for measurements during diagnosis.

2.1 Significant Location & Sensor Module

The *significant organ* of the blood flow is the *unique heart* in our human body. We have the smooth flat surface of the chest (*upper sternum*) as the significant location for the sensors, which is more suitable even in *life threatening situations* when blood circulation is limited to torso and head without any time delay of minimum 15seconds as usual in the existing health monitoring systems for the blood to reach diagnosis locations namely finger & wrist [11]

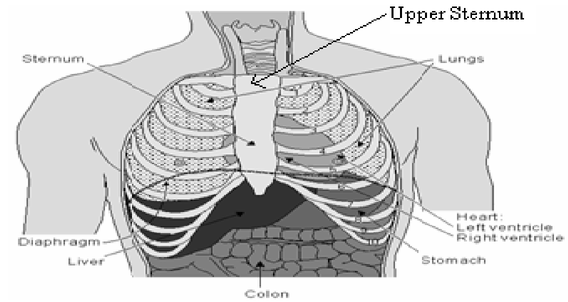

Fig 2.1.1 Upper Sternum for sensor location

In our novel system all the sensors are placed on *a single circular disc with angle specifications for each sensor*. Each sensor has a protective lid on its top so that, during the usage of an individual sensor , the mixing of other sensors' signals can be avoided.The ECG copper fill sensors are provided with adjustable extension holders with scale measurement. Under this circular disc all the signal processing circular discs are kept one below the other with microcontroller for signal processing. There is a button system for the projection of each individual sensors during its usage

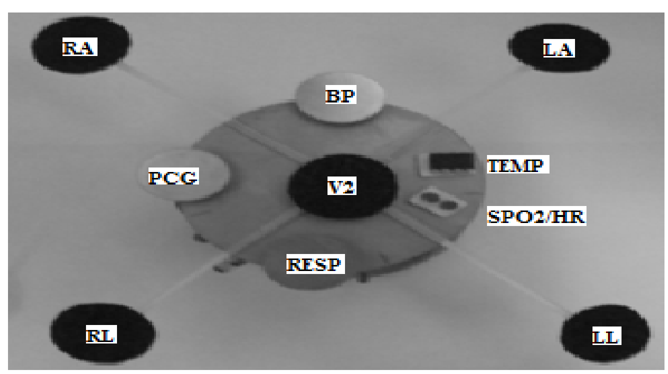

Fig 2.1.2 Top View with Sensors

The sensor system can be firmly and compactly fixed on the chest at all times throughout the journey both in & out of the space shuttle if needed. The sensor operation for a specific diagnosis can be triggered and controlled by remote system of either the individual astronauts in the shuttle or ground control station. The description of each parameter and its function in our novel system is dealt below.

2.2 ELECTROCARDIOGRAM

An electrocardiogram is an instrument that measures the *electro-mechanical activity* of the heartbeat. With each beat, an electrical impulse (or wave) travels through the heart. This wave causes the muscle to squeeze and pump blood from the heart. The ECG (Electrocardiogram) sensor measures *cardiac electric potential waveforms* (voltages produced during contractions of the heart).

2.2.1 Problem Identification:

Normally in the surface of the heart, muscle *action potential* is 20mV. It withstands up to 150-300ms at a frequency of 0.05-100Hz. As, the *action potential in the surface of the chest is only 1mV,* we need a *highly sensitive single located sensor instead of 5 electrodes that are located* at *different parts* of the body namely chest, hands and legs to pickup the signals of RA, LA, LL, RL and V2.

The sensor in our proposed system is a set of non-contact *bio potential copper fill capacitive type electrodes* [11] placed at the top circular disc with angle specifications to pick up signals of leads I, II, III, aVR, aVL, aVF and V_2. *In our novel system the person need not lie down.*

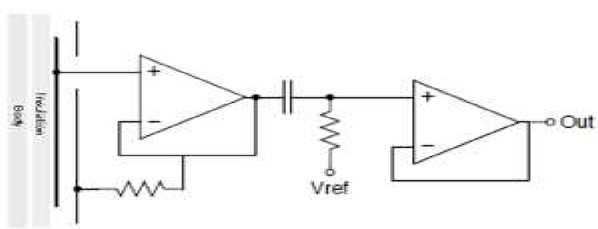

Fig 2.2.1 Copper fill capacitive type electrodes with amplifier unit

2.3 RESPIRATION

Respiratory rate is the *number of breaths* a human being takes *per minute*. It is usually measured when a person is at rest by counting the number of times the chest rises per minute. The Ultra-Piezo Sensor generates a small voltage signal from the *normal expansion and contraction* of the chest or abdominal wall. This voltage is immediately passed through an electronic filter before the respiratory signal is applied onto a physiological monitoring or recording system.

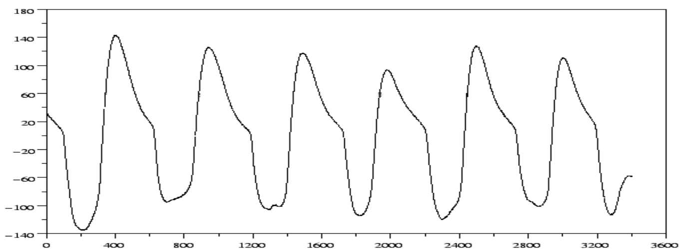

Fig 2.3.1 Continuous Respiration signal

Since the sensor *generates a voltage* when stressed by breathing, *no battery* is required for operation. This system is convenient, non-constraining, comfortable and durable for sleep disorder testing also.

Fig 2.3.1 Ultra Piezo Sensor

2.4 BLOOD PRESSURE

Blood pressure (BP) is the *pressure exerted* by circulating blood, upon the walls of blood vessels, and is one of the principal vital signs. During each heartbeat, BP varies between a *maximum* (systolic) and a *minimum* (diastolic) pressure.

Arterial hypertension may have adverse effects. Persistent hypertension is one of the risk factors for strokes, heart attacks, heart failure and arterial aneurysms and is the leading cause for chronic renal failure. Even moderate elevation of arterial pressure leads to shortened life expectancy.

Our proposed system is a *chest based continuous and non-invasive* method of monitoring and measuring blood pressure with display of *continuous graph of systolic and diastolic readings every second*. The design of continuous method provides a better monitoring of rise and falls in the blood pressure values. This device can be used so that the risk of higher and lower blood pressure can be eliminated and suitable precautionary measures can be adopted before the condition gets critical.

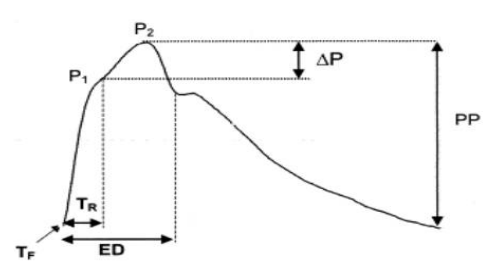

Fig 2.4.1 Analysis of Blood Pressure Curve

2.5 HEART RATE

Heart rate is the number of heartbeats per unit of time, typically expressed as *beats per minute* (bpm).

The *R wave to R wave interval* (*RR interval*) is the inverse of the heart rate.Heart rate is measured from the chest (apex of heart), which can be felt with one's hand or fingers.

In our method the heart rate (HR) is readily calculated from the ECG as follows:

HR = 1,500/RR interval in millimeters,

HR = 60/RR interval in seconds,

or HR = 300/number of large squares between successive R waves.

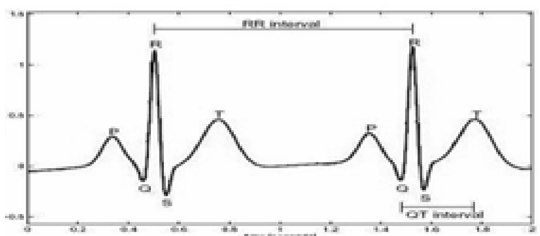

Fig 2.5.1 Heart Rate Analysis

2.6 TEMPERATURE

As a precision CMOS temperature sensor, the *FM50* is cost effective for *accurate, low power;* temperature monitoring applications. Output voltage versus temperature is extremely linear. With no load, the supply current is typically 130µA. For normal operation, the load on V_{OUT} should be 100KΩ or less.

In a typical application, a remotely mounted FM50 is monitored by a microcontroller unit (MCU) with an analog A/D converter input. Alternatively, the FM50 can drive a comparator with a high-impedance input.

Accuracy is typically $\pm 0.5^oC$ at room temperature, and better than $\pm 2^oC$ from 0 to 75^oC. FM50 is available in a 3-pin SOT-23 package.

2.7 Sao2

This paper presents a prototyped novel *chest-based* Pulse Oximetry system. It reports on test results from comparative trials with a commercially available finger-based Pulse Oximetry system using several human subjects. In our chest based novel system a *reflective sensor* is used where the LEDs and photodiode are mounted *beside each other at the center of the sensor circular disc*. Initially, a simple sensor arrangement is realized by mounting a bi-colour LED (SMT660/910) and a blue enhanced PIN silicon photodiode (PDV-C173SM) onto a PCB board. This enabled the optimal gap size between both components to be experimentally determined during later testing. The main circuit consists of two amplifier stages (figure 2.7.1). In the trans-impedance amplifier stage the PIN photodiode is placed across both inputs. In the second stage a DC offset removes a large DC component of the photodiode signal before further amplification. Two readings are taken by a 12-bit ADC module when one LED is switched on. The ADC readings are distinguished by the MCU *into two signal pairs* (red and infrared).

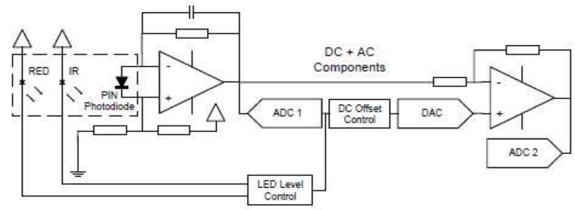

Fig 2.7.1 Input front end circuit and LED control of the single-chip Pulse Oximeter design using the MSP430.

Each *signal pai*r is processed by the MCU to calculate the current for the individual LED and the required DC offset. The *LED current* is used to control the *illumination of tissue* with the aim to obtain the largest possible peak-to-peak amplitude in the amplified photodiode signal. ADC readings of the second amplifier output produce a red and infrared *peripheral pulse graph* (*PPG*). The baseline of both raw PPG signals varies and sudden signal distortions and baseline shifts are mainly induced by motion artefacts (breathing, movements of the sensor on the chest, etc.). The noise in both PPG signals differs from subject to subject and also depends on the environment (ambient light, electromagnetic interferences (EMI)). The DC residuals and noise in both raw signals are reduced through filtering with a high and low pass digital filter.

2.8 Phonocardiograph

A Phonocardiogram or PCG is a *plot of high fidelity recording of the sounds and murmurs* made by the heart with the help of the machine called phonocardiograph, or "*Recording of the sounds made by the heart during a cardiac cycle*." The *sounds* are thought to result from *vibrations created by closure of the heart valves*. There are at least two: (i) when the atrio ventricular valves close at the beginning of systole (ii) when the aortic valve closes at the end of systole. It allows the detection of sub audible sounds and murmurs and makes a permanent record of these events. In contrast, the ordinary stethoscope cannot detect such sounds or murmurs, and provides no record of their occurrence.

A *piezo electric heart sound transducer* is used to pick up the *vibrations of the four heart valves*. The PCG is then interfaced to the display unit for processing after which the *frequency spectrum and time period analysis* is done. The PCG along with its data is provided on the screen for detecting the disorders associated with the heart Valves. The technique of phonocardiography has evolved continuously to grab an important role in the proper and accurate diagnosis of the defects of the heart. This technique, though seemingly quite reliable, is quite difficult to master. As with the stethoscope, it requires highly educated professionals to read the PCG signal. [12]

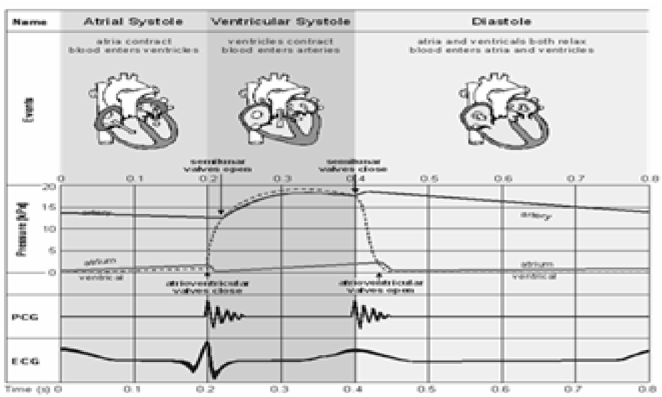

Fig.2.8.1 Cardiovascular signals comparison

3. Signal Processing and Transmission

A small *base unit* powers the entire system by *nuclear battery* and signal processing is done using MSP430F2274 and with the help of *wireless transmitter* like *zigbee* the data is sent to either *TMS320 based receiver* or other external device for display.

Each parameters' sensor is connected to a signal processing circular disc (with on / off button) kept one below the other sensors disc. Data in each signal processing disc is transmitted to the display unit worn on the wrist or to remote ground control unit

Fig 3.1 Lateral View of Signal Processing Unit

3.1 Nuclear Battery

In our novel system we use *3V nuclear battery* for many reasons.In space applications; nuclear power units offer *advantages over solar cells, fuel cells and ordinary batteries.*

Fig 3.1.1 Nuclear Battery

When the satellite orbits pass through *radiation belts* such as the Van- Allen belts around the Earth that could *destroy the solar cells*. Operations on the moon or Mars where long periods of *darkness require heavy batteries* to supply power when solar cells would not have access to sun light.

Space missions in opaque atmospheres such as Venus, where *solar cells would be useless* because of lack of light. At distances far from the Sun, for long duration missions where fuel *cells, batteries and solar arrays would be too large and heavy*. Heating the electronics and storage batteries in the deep cold of space at −245°C is a necessity. So in the future it is ensured that these *nuclear batteries will replace all the existing power supplies due to its incredible* advantages over the other. It is quite sure that the future will be of '*Nuclear Batteries'* because of the applications which require a *high power, a high life time, a compact design over the density, an atmospheric conditions-independent power supply*. NASA is on the hot pursuit of harnessing this technology in space applications.

3.2 Mixed Signal Microcontroller MSP430F2274

The Texas Instruments MSP430 family of ultra low power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture combined with *five low power modes* is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers and constant generators that attribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 ms.

The MSP430F2274M series is an ultra low-power mixed signal microcontroller with two built-in 16-bit timers, a universal serial communication interface, 10-bit A/D converter with integrated reference and data transfer controller (DTC), two general-purpose operational amplifiers in the MSP430F2274M devices and 32 I/O pins. Typical applications include sensor systems that capture analog signals, convert them to digital values and then process the data for display or for transmission to a host system. Stand-alone RF sensor front end is another area of application. *Available in Military Temperature (–55°C/125°C) Range.*

3.3 Zig bee

Zig Bee is a specification for a suite of *high level communication protocols* using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs), such as wireless light switches with lamps, electrical meters with in-home-displays, consumer electronics equipment via short-range radio needing low rates of data transfer. The technology defined by the Zig Bee specification is intended to be *simpler and less expensive* than other WPANs, such as Bluetooth.

Zig Bee is targeted at radio-frequency (RF) applications that require a *low data rate, long battery life, and secure networking.* Zig Bee is a low-cost, low-power, wireless mesh networking standard. The *low cost* allows the technology to be widely deployed in wireless control and monitoring applications. The *low power-usage* allows longer life with *smaller batteries*. The *mesh networking* provides high reliability and more extensive range.

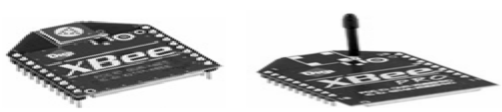

Fig 3.3.1 Zig Bee Module

The software is designed to be easy to develop on small, inexpensive microprocessors. The radio design used by Zig Bee has been carefully *optimized for low cost* in large scale production. It has few analog stages and uses digital circuits wherever possible.

3.4 TMS320 DSP controller

The TMS320C672x is the next generation of Texas Instruments' C67x generation of high-performance 32-/64-bit floating-point digital signal processors. The TMS320C672x includes the TMS320C6727, TMS320C6726, and TMS320C6722 devices. *C67x+ is an enhanced* version of the C67x CPU used on the C671x DSPs. It is compatible with the C67x CPU but offers significant improvements in speed, code density and floating-point performance per clock cycle. *The Efficient Memory System* maps the large on-chip 256K-byte RAM and 384K-byte ROM as unified program/data memory. Development is simplified since there is no fixed division between program and data memory size as on some other devices. *Universal Host-Port Interface (UHPI)* is a parallel interface through which an external host CPU can access memories on the DSP. Multichannel Audio Serial Ports (McASP0, McASP1, McASP2) - Up to 16 Stereo Channels I2S.

The flexibility of this line of processors has led to it being used not merely as a co-processor for digital signal processing but also as a main CPU. Newer implementations support standard IEEE JTAG control for boundary scan and/or in-circuit debugging.

3.5 Receiver and display Unit

Fig 3.5.1 Novel TMS320 DSP based Multipara System

Using TMS320C6727 the display of the ECG curve, continuous BP curve, Sao2, oxygen level, PCG, body temperature, heart rate, respiration radiation effect of space can be mounted on the wrist of the individual astronauts & the ground control center as well.

4. Conclusion

The proposed novel integrated wireless single location sensor system is without the complexity of multi-wire and multi-locations. It can acquire more than 7 vital parameters simultaneously or single parameter of our choice. The signal processing and simultaneous mapping is done using TMS320C6727 DSP controller with a novel wrist watch type display.

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