Alternative Designs Report
Vital Signs Monitor
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Client #
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The core body temperature biosensor will consist of a thermistor placed under the armpits of the chest strap (region 1 of Figure 1). As a current runs through the thermistor, the resistance will be monitored and wirelessly transmitted using the Bluetooth transmitter (BT in Figure 1) to the Microsoft Surface tablet.

![Figure 1: Chest strap](image)

Once received by the tablet, the group’s LabVIEW program will calculate the patient’s body temperature, as seen in Figure 2, and display it.

![Figure 2: LabVIEW calculation of core body temperature](image)

Region 2 of Figure 1 represents the pressure sensitive ECG stethoscope. Positioned over the heart, the stethoscope will eliminate the need to apply electrodes to the patient’s extremities. The stethoscope will detect the pressure of each heartbeat and wirelessly transmit the information using the Bluetooth transmitter. Once transmitted to the tablet, the group’s LabVIEW program will determine the patient’s heart rate based on the incoming data. This stethoscope will also double as a respiration rate sensor by detecting the expansion and compression of the chest as respiration occurs in the patient. A grounded power source will be attached to the back of the chest strap to power each biosensor.

An additional wrist strap with two connecting finger straps will incorporate a blood oxygen sensor, blood glucose sensor, and a fall detection device. The fall detection device will be located on the wrist (region 3 of Figure 3) and consists of a triple axis accelerometer to detect abnormal three dimensional motions. The accelerometer will send information to the tablet through the Bluetooth wireless transmitter and the group’s LabVIEW program will determine if the motion is normal or abnormal. Region 5 of Figure 3 represents the blood oxygen sensor, monitored with spectroscopy by shining an LED on the surface of the finger and measuring the
tissue reflectance. The data will then be wirelessly sent to the tablet using the Bluetooth transmitter embedded in the wrist strap. Region 4 of Figure 3 represents the blood glucose biosensor which will incorporate near-infrared spectroscopy and analysis of the tissue reflectance in order to determine the concentration of glucose. The absorbance data will be sent to the tablet using the Bluetooth transmitter where the group’s LabVIEW program will compare the absorbance graph to an absorbance graph of the same wavelength in pure water. This comparison will determine the percentage of glucose in the body based on the decrease in absorbance measured. A grounded power source will be embedded in the wrist strap to power each biosensor.

**Figure 3: Wrist and finger straps**

A store bought scale will be incorporated into the system separately to measure the patient’s weight and wirelessly transmit the data to the tablet.
The Vital Signs Monitor system should consist of two interfaces. One being a strap around the patient, and the second being a mobile tablet, preferably the Microsoft Surface as it can run LabVIEW for data processing. These interfaces will communicate via Bluetooth. A microcontroller will need to be implemented on the receiving end of the Bluetooth signal to sort the data before being processed.

The strap will be around the center of the body of the patient, preferably at sternum level all the way around, and will contain most of the sensors incorporated into the system as well as the Bluetooth transmitter and a power source. This strap will be elastic enough to fit onto different upper body shapes yet strong enough not to break or tear if overstretched in any direction. All of the sensors on the main strap need to be in contact with skin therefore the inner surface must contain openings for each sensor and the outer surface of the material must be relatively smooth as to not create issues with clothing of the patient. Also, electric circuits need to be incorporated so the material must be a good insulator to protect the patient from possible shorts of the circuit. All of the wiring will be in between the material and connect to the both the power source and transmitter. Numerous sensors will be placed on this central strap; however, not all sensors will have maximal usage on this strap and will need placement in other parts of the body.

Around the core strap apparatus will be the sensors that need to collect data from the core of the body i.e. ECG, stethoscope, respiration rate monitor, and core body temperature as well as the Bluetooth transmitter and power source preferably in the form of batteries as they are easy to replace and don’t require the hassle of having to remember to plug it in. The ECG sensor will be a two-lead collecting signal variety with both leads at different ends of the strap. This will greatly enhance the mobility of the patient as multiple lead ECG sensors that require other wires leading to other extremities won’t be necessary. An electronic stethoscope makes the most sense as the signal can be transmitted and amplified easily. Incorporation of a 3M™ Littmann® Electronic Stethoscope Model 3200 would be adequate as it has Bluetooth transmittance already built into the device and eliminates noise, but the Master Classic II™ Stethoscope model would suffice and is more cost effective but doesn’t have built in Bluetooth. A respiration rate monitor will be in the form of a piezoelectric strip located on the front side of the strap which will detect movement of the ribcage which signals the patient is inhaling. Lastly, the core body temperature will be taken directly in the middle of the strap as that’s where the middle of the core of the body. Sensors that need to be away from the central strap are the blood oxygen sensor, fall detection, and weight of the patient.

Fall detection monitor can be an accelerometer on one arm as a person is falling the usually flail their arms. A downside to this is that the accelerometer could break if the patient falls on the sensor while throwing their arms out to catch their fall. Prior to a fall, a person usually exerts concentrated pressure on a specific point on their feet as they are off-balance; therefore, the fall detection device can be a shoe insole with a separate Bluetooth transmitter and power source. Blood oxygen will need to be taken from a thin area of skin as dictated by pulse oximetry techniques. There are 5 places on the body where this can be: earlobe, finger, palm, sole and toe. To keep continuity with the feet, a pulse oximeter can be attached to the insole near the toes on the sole which is actually a better location for a pulse oximeter. Finally, weight of the patient will need a separate device which incorporates a Bluetooth transmitter, power source, and a scale.
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My interpretation of how best to organize the sensors falls into a model of simplicity. As any engineer should know, the less complicated something is, the less things that can break. Thus, my sensor organization will start with the basic chest strap, and diverge a little from there.

The chest strap will be sweat resistant, elastic, soft, wearable material on the side closest to the body. On the other side, facing away from the patient however, there will be a few “rails” of open electrically conductive strips running parallel to each other throughout the length of the strap. (See Figure 1) There will be another soft elastic thin secondary layer designed to cover and protect the user, and these open wires from each other. The purpose of these striped wires will be to provide a ground, a power source, and a data channel. Connecting to each of these wires will be a box to which the chest strap originates. This box will be worn such that it will lie between the scapulae, and not impede any daily function of the user. This box will provide power and ground along two of the three parallel stripes. The third will be a data wire used to communicate between sensors and the main strap computer. These boxes will then take all of the data (communicated via a wired connection), consolidate it into a signal, and communicate via a Bluetooth chip to whatever base station or LabVIEW enabled device of one's choosing. The rails will provide power, and a means of communicating to the chest strap box, which will carry the brunt of the data processing load.

The sensors then will be used by clipping in between the two separate layers such that conducting pins will connect and provide power to each individual sensor (see Figure 2). A third pin will then be used to communicate the single channel of data to the box. Communicating multiple sources of data on a single wire can be accomplished using the 1-Wire communication protocol developed by Dallas Semiconductors, or the I2C communication bus developed by Phillips. Either communication method is compatible with Arduino microcontrollers via existing API, however I2C is built into the existing library possibly making it easier to use. Each sensor will be programmed to handle its own input, translate it into a language communicable via this single wire that can provide, and then communicate to the main box on the chest strap back. This reliable method of data transfer will offer built in support for a variable amount of sensors (if two temperature sensors are needed for example) because each sensor will have its own unique serial number so the same type of data won’t confuse the microcontroller. The main box will then take each of the sensors data, and prepare it for interpretation by the existing circuitry, and LabVIEW. Ultimately the presence of three wires in the strap may or may not be necessary, dependent on whether we use this communication method or not. Since it is low power and low speed, the novelty of minimizing the expose wires will need to be addressed.

This system is efficient for several reasons. It will be cheaper to produce, lighter, user friendly, and customizable. It will be cheaper to produce because each sensor will be small, and lack complicated communication relay, or batteries. Due to the lack of batteries in each device, the total weight of all sensors will be minimized, adding to the comfort of the user. The modular nature of each sensor means that replacement of faulty parts is simple. Either replaces the main battery, or a cheap sensor module, not both. Diagnosing such problems will be incredibly easy since either all parts are powered, or just one is not relaying data, or no data is being interpreted, but power is being sent to them. Troubleshooting will essentially be reduced to ensuring the proper contacts are maintained, and placing the sensors (which by attaching via clips, are variable in their placement) in the proper locations. From there, it would be easy to isolate which, if any, parts are not working. Since the wires run across the entirety of the strap, sensor position can be adjusted for any patient by clipping each of them wherever they may be...
optimally positioned on their body. Finally it is customizable by allowing doctors to purchase only specific sensors. Each one will be self-contained, and will be able to run independently of other sensors.

Temperature sensor

This small device will clip on the chest strap and preferably be placed in the armpit. This is the closest location for core body temperature that will be accessible to the chest strap. The inside of the clip will have three contacts for the power, ground and data transmission. This sensor will be the simplest to develop communication for. A thermistor placed in contact with the inside of the armpit will ensure constant contact and an accurate data reading. This thermistor will change in resistance as temperature changes. This change in resistance can be sensed by the microcontroller, which can then interpret, and perform a simple calculation to convert the signal to degrees. Alternatively the raw resistance data can be communicated and be calculated by LabVIEW itself. Since there will only be one number (either resistance or temperature) this sensor will only take a small amount of bandwidth.

Blood Oxygen monitor

This sensor will be designed the most complicatedly and differently from the others. A blood oxygen monitor needs two different LEDs to shine through a thin portion of the patient’s skin, usually the fingertip. A detector then picks up the light that has shined through the patient and an absorbance curve is plotted. These two curves are then compared to obtain a reading on the oxygen content of the blood. In this design, it would be sensible to place a sensor box on the patients back, and have a wire that contains the clip with two LED’s and the two photo sensors snaking up under the shirt to the patients earlobe. This similarly thin area of the body also serves as a good location for pulse oximetry. The two different LED absorbance curves can then be relayed to the sensor module itself. Because of the more complicated dual channel input, all of the necessary calculations will be performed locally before blood oxygen content data is transmitted to the main chest strap box.

Fall detector

In interest of keeping as many sensors as close to the chest strap as possible (to remove the hassle of peripheral devices), my design for fall detection relies on using a piezoelectric sensor attached directly to the strap. When one falls not only do the arms move rapidly in an attempt to save oneself, but the actual act of falling will be accompanied by a detectable bump. It is this bump that my detector will aim to log. Following a similar clip design as all of the above devices, the inside will have a piezoelectric buck to detect knocks. A buck works by producing a small voltage difference whenever the sensor detects a jarring motion. This device may also make use of an internal clock (stored in the main box) for the purposes of logging frequency and times fallen.

Stethoscope

For a stethoscope sensor, it would make most sense to use a contact microphone that will be placed on the chest over the lungs. Normally a contact microphone is not very high quality and may produce a tinny noise. However since the input we are looking for will be directly bone conductive, and also very near the sensor; one can hope that this won’t be an issue. If needed, further signal processing one can filter out unwanted noise.
References