

# SKIN COLOR MONITOR

*Midsemester Report*

October 22, 2008



THE UNIVERSITY  
*of*  
**WISCONSIN**  
M A D I S O N

Team:

Amy Lenz, Vincent Mi, Brooke Sampone, Grant Smith

Advisor:

Walter F. Block, Ph.D.

Client:

John G. Webster Ph.D.

# SKIN COLOR MONITOR

## *Midsemester Report*

### Abstract

Menopause is the final stage in the overall reproductive system of most women. Menopausal onset usually occurs between the ages of 35 and 55 in most women. Menopause poses as a nuisance to most women and causes the instantaneous sensation of heat, sweating, flushness, and increased heart rate. Doctors and researchers are attempting to develop ways to monitor hot flashes in order to develop therapeutic drugs and other methods of treatment for hot flashes. Currently, the devices that are being utilized to monitor hot flashes are inconveniently large, uncomfortable for the wearer, and, at times, unreliable. As a design team, we are trying to overcome these downfalls by creating a skin color monitor that is designed in an aesthetically pleasing manner with comfort, size, and ease of use playing significant roles in the design process. As the housing and circuitry have already been implemented in some particular fashion by previous design teams, our goal is to perfect these aspects by designing tests which will accurately display how and why the final device should be used to monitor skin color changes in menopausal women.

### Design Statement

As directed by our client, Professor John Webster, the objective for this semester is to improve upon an already existing skin color monitor. The device uses a colored LED and a photodiode to detect color changes in woman's skin due to hot flashes experienced during menopause. The purpose of the device is to record sudden color changes resulting from hot flashes for the analysis during research and testing of pharmaceutical menopausal drugs. Compliance with FDA standards is also important, because the device is meant to be worn continuously to optimize the amount of data that can be recorded. As a result, the device needs to be small and esthetically pleasing to be concealed under clothing. Continuous use requires the device to run on a battery that will last for one day with readings recorded every ten seconds. In order to properly detect hot flashes, it needs to be worn on the chest or upper arm region where the greatest occurrence of blushing has been proven. Overall, the device needs to be compact (less than 6 cm x 6 cm x 1 cm), comfortable and inexpensive, less than seven dollars to produce.

### Motivation

A common symptom of menopause in women is hot flashes. Hot flashes are the sudden onset of warmth that causes the skin to blush and the body to sweat. During menopause, the depletion of primary oocytes cause a hormone called follicle stimulating hormone, FSH, to respond to the ovarian and uterine cycles as they cease activity. Consequently, lowered levels of estrogen and progesterone confuse the hypothalamus causing the body to register at a higher temperature than

normal (Martini, 2006). With a disillusioned high body temperature the heart increases activity to promote blood flow. However, in order to increase blood flow the blood vessels dilate to allow saturation of tissues in the capillary beds. The elevated blood flow within the capillary beds is what causes the flushness color of the skin. As a result, heat is lost from the surface of the skin which is meant to lower the body temperature. However, the woman was at a stable body temperature so therefore she experiences chills after the incidence of a hot flash.

Women in Westernized cultures experience hot flashes during menopause over eighty-five percent of the time. Possible ways to minimize occurrences is to take hormone replacement drugs; however, these have been proven to increase risks for breast cancer (Webb, 2007). In contrast, non-westernized cultures such China, Japan and Pakistan have hot flash occurrence rates below twenty percent. The significant decrease is thought to be due to the presence of phytoestrogens in their diets (WebMD Health, 2000). Phytoestrogens are plant-derived chemicals commonly found in soy which mimic the chemical properties of estrogen in the body. Though it is not our duty to research why hot flashes occur, it is our goal to provide a device for research purposes to better document their episodes.

## Current Devices

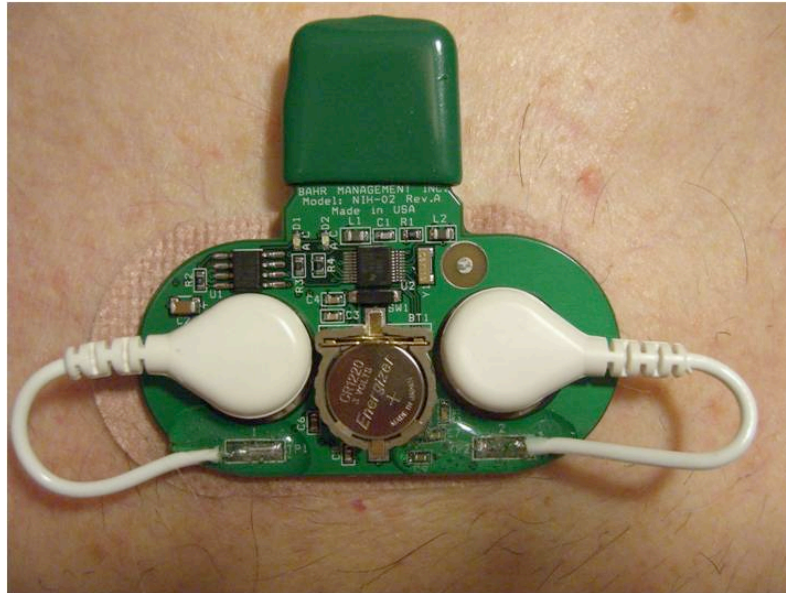
Several devices exist which can detect hot flashes. A simple example is that of a journal. A woman can use a journal as a personal monitoring device. For instance, when a woman feels she is about to experience a hot flash, she would note it in the journal. In the journal she would record the time and duration of the hot flash, along with any specific symptoms she experiences. Although this is a simple and cost effective way to monitor hot flashes, several problems are associated with this system. Subjectivity and unreliability are the two major issues. The data recorded is based solely on the individual woman's perception. Also, there is a greater chance for missed recordings. If a woman has a hot flash at night, she is not likely to record this hot flash. Thus, this method is not accurate enough for monitoring hot flashes.



**Figure 1.** The BIOLOG can be programmed to specifically monitor hot flashes in several different ways. (Hot Flash, 2007)

Another device which could be used to monitor hot flashes is the BIOLOG which is produced by UFI (Hot Flash, 2007). This is a flexible device which can be programmed to monitor many different aspects of choice. For instance, it could be programmed to monitor temperature changes. However, this device does not fit the project design specifications. The device itself costs roughly \$2200 while the software is an additional \$2000. Also, the device is too large and

bulky weighing approximately 200 grams. Although its function is ideal, the physical aspects do not coincide with the project's objectives.



**Figure 2.** The skin conductance device is used to measure the change in conductivity of the skin while a woman experiences a hot flash. (J. G. Webster, personal communication, 2008)

The device that the client is currently using to monitor hot flashes is a skin conductance device. This device employs electrodes and circuitry to analyze the change in skin conductance. When a woman sweats, the conductivity of her skin changes. This data can be recorded using a data recorder. The peaks in the data show when a hot flash occurred. To be sure that the data is analyzed correctly, a woman also makes note of when she believes she is having a hot flash so the data is not skewed by exercise or any other vigorous activity that may cause the woman to sweat. Although this device can accurately measure hot flashes, the client hopes to analyze a different aspect of hot flashes, that of color changes.

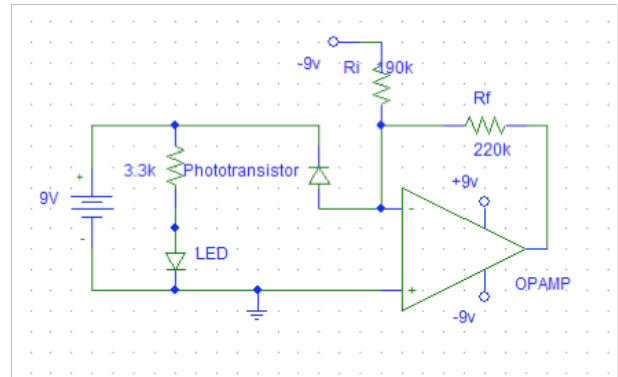
## Previous Semester's Work

This project is in its third semester of work. The project initially began in fall 2007. The fall 2007 team designed the basic housing and setup of the skin color monitor. The housing was made of rigid, black polycarbonate. The polycarbonate housing had a cylindrical shape and measured 3.8 x 1.4 centimeters. Two small holes were cut at 45° angles from the central vertical position in the housing. One hole was for the LED and the other for the phototransistor. A blue LED was chosen despite finding research that indicated a red LED would have the greatest reflectance. The team spoke with Kevin Eliceiri, senior information processing consultant in the graduate school division of molecular biology at the University of Wisconsin – Madison. Eliceiri is also the director of the Laboratory for Optical and Computational Instrumentation. He suggested the team use blue LEDs because it is the wavelength least absorbed by the skin. The red LED, as tested by the team, showed the voltage differences between different colors of paper were not as great as they were with the blue LED (Ginter, Ho, Kurkiewicz, & Yuen, 2007). A

basic circuitry was implemented which included a  $200\Omega$  resistor used to control the voltage across the LED and a reverse biased phototransistor. As the phototransistor detected light, some leakage passed through a  $1\text{ M}\Omega$  resistor. Finally, an acrylic shield was placed on the bottom of the device to prevent the movement of the skin in relationship to the LED and phototransistor.



**Figure 3.** Image of the sensor and housing design developed by the fall 2007 design team. (Ginter, Ho, Kurkiewicz, & Yuen, 2007).



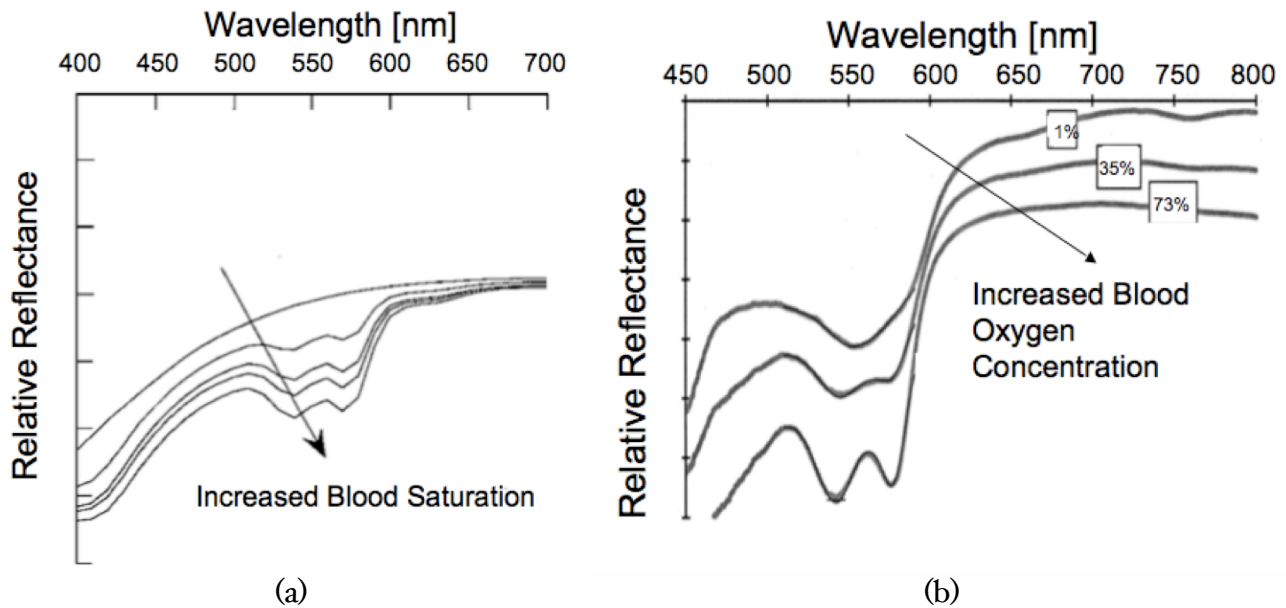
**Figure 4.** Circuitry designed by the spring 2008 design team. (Mosher, Offutt, & Vasys, 2008).

The spring 2008 team worked to improve the circuitry and modified the housing. They chose to use a dome shape as the housing while using the same materials. This shape was chosen due to the aesthetics and durability. The size measured 3.65 x 1.59 centimeters. One major change this team implemented was a way to eliminate specular reflection. To do this they placed the LED at an angle perpendicular to the base of the housing. The phototransistor was inserted at a  $45^\circ$  angle away from the LED. Another significant change in their design was the circuitry. This was accomplished by including a differential amplifier. They used an LED branch, a phototransistor branch, and an op-amp branch (Mosher, Offutt, & Vasys, 2008). As the phototransistor received light from the LED, current leaked through. The current entered the op-amp which allowed for detection on a scale sensitive to skin colors. The team performed tests to rationalize why using a phototransistor was better than using a photocell. They found that the phototransistor was more sensitive to light than the photocell.

## Making Design Choices

Although a large portion of the actual design efforts had been completed prior to the commencement of this semester, some choices remained to be made, particularly a lot of component selection. Design choices include housing size, acrylic covering positioning, and illumination technique. Component selection refers to justification and choice of LEDs, photosensors, and power supply. The most critical aspect of measuring skin color is deciding what wavelength(s) to apply and how to apply them. Methods employed by similar products

currently use either lasers, fiber optic cables, or LEDs. Fiber optics and lasers allow for a narrower range of wavelengths to be applied and are thus more sensitive and more accurate with regard to determining changes in skin color; however both of these methods are incredibly costly, upwards of \$200 would be a gross underestimate. LEDs also emit a specific range of wavelengths and although the beam is not as directed or specific, it can still provide a reflectance value containing information about the skin's color. LEDs come in many shapes, sizes and colors, so how is the decision made as to which one is best fit for detecting hot flashes. The primary effector of color change during a hot flash is increased blood flow to the epidermal capillaries. Wavelengths near 550 nm are most sensitive to change in the blood concentration in the skin (Figure 5a). Other colors are more reflective, but deeper penetrating, such as red and infrared wavelengths. It may be possible to use multiple LEDs concurrently or a single multicolored LED; however, this would require the use of gratings to make the photodiodes specific to the information yielded from each color (blue~blood oxygen, green~blood concentration of skin, red~melanin (Figure 5b). (Shimada, Sratonnikov) Thus concludes the discussion of light sources and photosensors.



**Figure 5.** Plots of skin reflectance at various wavelengths in reaction to changes in blood saturation (a) and blood oxygen concentration (b). (Sratonnikov)

Another important aspect of the design is the housing, including the acrylic surface. The clear surface provides a medium for photon propagation while preventing skin displacement that would otherwise interfere with color measurements. By placing the acrylic on the outside of the main housing, the device is slightly easier to manufacture, and by placing it inside, the device is less susceptible to stray rays of light entering around the edges which are liable to throw off the desired sensory readings. The housing itself need only be large enough to contain the power supply, LED(s), photodiode(s), and necessary circuitry. Larger housing may provide greater ability to disguise the device if it were designed to be worn openly. Smaller housing would allow it to be discretely concealed under clothing. The power supply will effect the choice of housing

size as well as LED. An inexpensive watch battery provides ample power for the entire circuit and is quite small. Two watch batteries would allow the circuit's op amp to have both positive and negative offsets. Overall, the selection of components and final design choices leave room for improvement previous semester's models.

The circuit can also be improved. A low pass filter can be used to improve the consistency of the measurements since only a .2 Hz sampling frequency is desired. Similarly, a routine that conserves power can be applied. Because the device only samples once every five seconds, the LED and associated scaling and storing electronics only need to be powered for brief intervals around when the measurements are made. By adding an alternating aspect the device can be powered for less than one twentieth of its operational life span. It is likely that the light itself causes minor biological reactions on the skins surface, so a constant light source might reduce this potential problem. Either way, the circuit definitely needs to filter noise as evidenced by previous semesters' inability to collect consistent, stable measurements during their experiments.

## Final Design Choice

Although there are many options present, for the sake of simplicity and practicality, our group plans to continue improving on the single LED design used by previous semesters. Our reasoning is based on the fact that implementing more than one LED or other light source would introduce a much greater level of complexity to the project, including much more involved data analysis and circuitry, more interference considerations, and sensor wavelength filtering. Most of which is beyond our scope and abilities. Also, testing and results as indicated by previous semesters of design teams show promising results using just one LED. This design choice will also keep production and prototyping costs to a minimum.

A second design goal our team has set is to redesign the current LED and photodiode housing. The current housing designs produced by previous design groups, although small, is still fairly large and bulky when worn on the body. Also, much of the housing consists of a large amount of excess acrylic material unnecessary for any structural or design purposes. We plan to reduce this excess material as much as possible, and reduce the overall size by about one half. This will most likely be done with the same acrylic material used last semester, and milling or drilling out the internal designs as needed. Our team is also currently considering using a rapid prototyping machine to quickly create many variations of our design if possible.

Finally, a reliable circuit for amplification of the signal has yet to be produced. The first semester design group did not use an amplifier during their tests, and focused on response of the photodiode. The second semester group did develop an amplifier, but the results have yet to be reproduced, and documentation shows great variability and unreliability in its implementation. We hope to improve on this design by implementing an improved and reliable circuit in place of the current circuit developed by the previous semester. The final design components of this circuit will depend on testing results as discussed in the next section.

## Planned Testing

A bulk of time this semester will be dedicated to testing, since many of the concepts of the design have already been developed by previous work, but the greatest problem seems to be in effective implementation of the designs. The results of the tests will then dictate component usage in our design such as LED color and intensity, circuit elements, and certain aspects of housing design.

The team has ordered various red, blue, and green LEDs to test their response on human skin. Although a test between various colors has already been done by previous semesters, variability in their LEDs posed a possible bias towards certain colors which had greater intensity than others. This testing, in addition to noted research on skin reflectance will hopefully provide us with sufficient information to make a final conclusive decision on LED color choice.

For the circuitry, most of the testing will be done during implementation as necessary. Currently a reliable circuit that provided necessary amplification does not exist. Photodiode output is expected to be in the range of millivolts (mV) and according to our requirements, needs to be amplified to the range of 1-5 V, which indicates a gain of almost 1000, which will need to be implemented through an amplifier. Also, noise will need to be reduced through low pass filters, and offset may need to be incorporated before amplification to avoid saturation of the signal.

Finally, we plan to test the reliability of the device and circuit elements by running by running the device for extended periods of time (about a week) to test for reliability. Last semester's team reports various LED and circuit element failures within the first 24 hours of operation and no conclusive reasons have been provided. Our team hopes to avoid the same issues through our reliability testing.

## Future Work

In our limited time, we are not able to implement all necessary steps to put a working device into production. There are many remaining aspects of the design we simply do not have the time, resources or ability to complete. Some of these design aspects include a printed circuit board, continued size optimization, a mechanism to attach the device to the body, data recording and analysis, and research for production. Our group hopes that our work this semester will be sufficient for future teams to continue to develop into the above noted aspects of the design.



# BIBLIOGRAPHY

- Ginter, B., Ho, J., Kurkiewicz, P., & Yuen, J. (2007). *Skin Color Monitor*.  
*Hot flash*. Retrieved October 9, 2008 from <http://www.ufiservingscience.com/HFMon1.html>
- Martini, F. H. (2006). *Fundamentals of Anatomy and Physiology*. San Francisco: Pearson Education Inc., Benjamin Cummings, p. 1061 & 1066.
- Mosher, R., Offutt, S., & Vasys, V. (2008). *Skin Color Monitor*.
- Shimada M., *et al.* 2001. Melanin and blood concentration in human skin studied by multiple regression analysis: experiments. *Physics in Medicine and Biology*. 46: 2385-2395.
- Sratonnikov, Alexander A. and Loschenov, Victor B. Evaluation of blood oxygen saturation in vivo from diffuse reflectance spectra. *Journal of Biomedical Optics* 6.4: 457-467.
- Webb, Sarah. (September 18, 2007). Hormone Replacement Therapy Linked to Breast Cancer. *Discover*. October 21, 2008, from <http://discovermagazine.com/2008/jan/hormone-replacement-therapy-linked-to-breast-cancer>
- WedMD Health. (February 9, 2000). Natural Alternatives to Hormone Therapy. *Medscape*. October 21, 2008 from <http://www.medscape.com/viewarticle/517977>