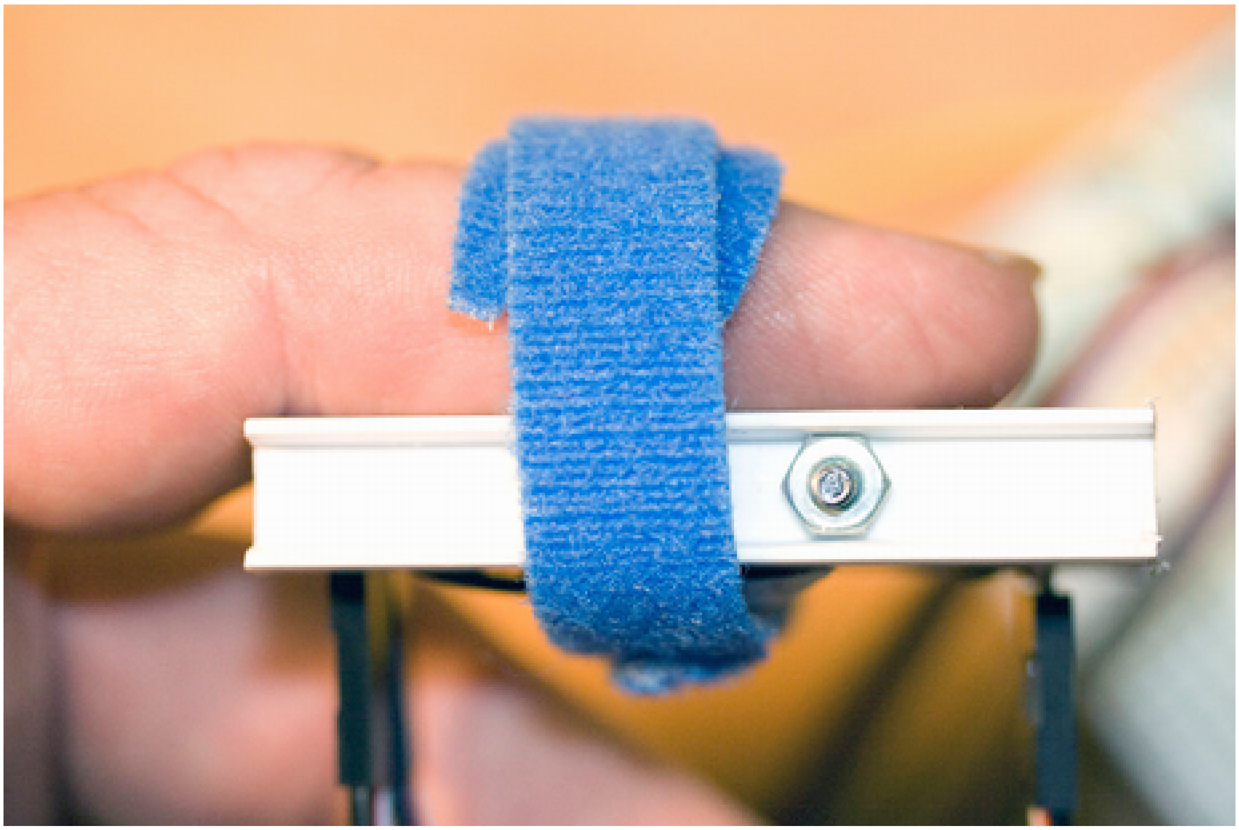
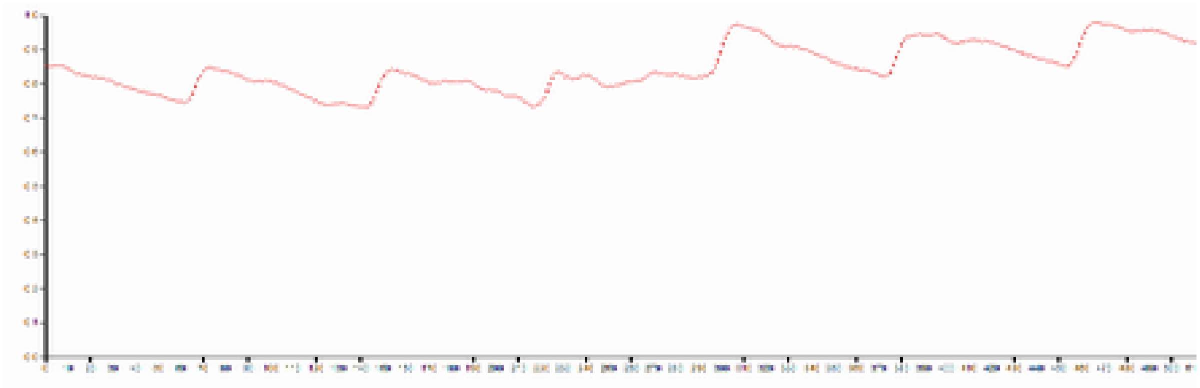
The Life Saver

The Life Saver from Boutique Engineering is an extremely low cost and portable health monitoring and diagnostic system designed for routine use in harsh field conditions. The Life Saver is designed to be low enough in cost to be considered a personal health monitor and to be routinely stocked in large quantities for use as a triage tool in mass injury situations.



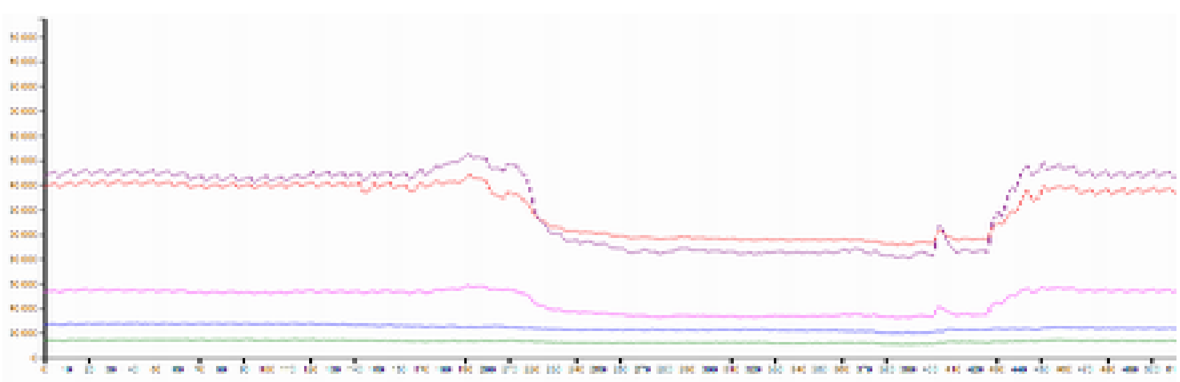
Diffuse Optical Spectroscopy (DOS)

If you have ever shined a flashlight through your hand you noticed that your skin is not completely opaque. The light that glows through your hand is a demonstration of light *diffusing* through tissue. The light does not travel in a straight line, unattenuated as in air. The light that emerges from the tissue is affected by the various chemical components including important metabolic markers. Diffuse Optical Spectroscopy (DOS) exploits this phenomenon to determine the metabolic state of the tissue being measured. DOS works by shining light through the skin and analyzing the light that passes back out through adjacent skin. In scientific literature, particularly useful wavelengths of light have been identified for the use of measuring the presence of absence of important metabolic markers, including oxygenated and deoxygenated hemoglobin.



By analyzing the light that passes through the skin, we can determine the varying absorption rates of the marker wavelengths over time and therefore the varying state of the blood and tissue. The above image shows the varying level of light from a red LED that pass through the skin. The absorption rate cyclically changes as each heartbeat generates a compression wave that temporarily increases the density of the blood. Each sawtooth rise signifies a heartbeat. The edges can be counted to produce an accurate pulse rate monitor.

We have tested a number of wavelengths under varying physical conditions and believe we can track changes in pulse, oxygenation and hydration with our extremely low cost device. The graph below shows the impact of applying and then removing a tourniquet to restrict blood flow. If we were to completely cut off the flow of blood we would expect the pulse to stop and the oxygen level to drop as it is metabolized by adjacent tissue. The valley in the chart shows readings during the period when the tourniquet was applied. The sawtooth pulse pattern is indeed attenuated while the tourniquet is applied. For safety reasons the tourniquet was only moderately tightened so some pulse remains. Not all wavelengths were equally attenuated, indicating that this is not a simple blockage of the light path but change in the transmission of specific wavelengths due to changes in the state of the tissue. The red line indicates change in oxygenation. The magenta and purple IR wavelengths are probably indicating changes in hydration but we do not have access to clinical equipment needed to confirm our analysis.



Studies have indicated that monitoring of pulse, oxygenation and hydration is effective for monitoring overall condition in emergency situations. While we do not expect our device to replace $100K patient monitors, the availability of a reasonably informative, easy to use status monitor could be a game changer. Our device provides both a stand-alone status display that can be used for personal diagnosis or triage and easy connection to centralized medical monitoring systems through commodity smartphones and tablet devices. This provides a wide range of possibilities for improving the management of mass injuries in battlefield, natural disaster or terrorist situations where large numbers of victims may need to be treated over a large geographic area.

A presentation regarding DOS is available on YouTube. A link is provided below in the references section. The speaker in this video is Ben Margolis. The research was conducted as part of a Harvey Mudd College research clinic and was sponsored by Beckman Laser Institute and Medical Clinic at the University of California in Irvine.

Our Device

An ideal DOS instrument would be able to provide precise readings of any wavelength of interest. Unfortunately, sensors of that type are neither cheap nor portable. LEDs inherently emit light within a narrow range of wavelengths. A large variety of low cost LED are available which emit light in a rainbow of “colors” including specific visible and infrared (IR) wavelengths which are suitable for DOS. The low cost TAOS TSL237 light sensor responds to a wide range of wavelengths, including those suitable for DOS, with a very fast detection rate. By shielding the skin and sensor from ambient light and cycling through a number of LEDs so the sensor is only exposed to one emitter at a time we are able to use a single TSL237 to detect the transmission level of five different wavelengths of visible and IR light at a rate of several hundred samples per heartbeat, allowing us to meaningfully plot and analyze changes in the transmission rates of each wavelength over time.

We used a Parallax Propeller Activity Board to control the system and to provide voltage regulation. In this prototype the Propeller microcontroller was used to cycle through the LEDs, capture the TSL237 readings and transmit the data to a notebook computer via USB. While not included in this prototype, the Propeller chip is capable of analyzing the data to provide stand-alone display of heart rate and other key data. The Propeller chip is also capable of directly controlling SD cards for long term logging of data.

We envision packaging the Life Saver as a finger clip similar to those used with modern heart rate monitors. A finished circuit board including LEDs, sensor, microcontroller, SD card holder and USB connector could be shrunk down to approximately 1” x 2.25” x 0.25”, easily fitting within the finger clip package. A LIPO battery of the same size would provide many hours of operation and could be recharged through the USB cable. A bluetooth transceiver could be added to the package at modest additional cost to support wireless data transfer from the instrument.

The device would have several output LEDs providing a simple, intuitive, stand-alone user interface that could be used with essentially no training. A green LED would indicate that the subject had readings in the normal range. Orange would indicate mild stress and red would indicate high stress. A blue LED would indicate possible dehydration and the need to drink water. Patterns of blinking would be used to signal “call for help” to the user and to convey specific information when reported to trained personnel.

When connected to a device such as smartphone, tablet or notebook computer it is easy to display real time data visualization displays like the accompanying charts to first responders and triage personnel. This provides a useful subset of the information available from standard medical monitoring equipment at a tiny fraction of the cost and with extreme portability. The smart device’s camera and radio (cell or wifi) can be used to provide visual and data diagnostic information to remote medical personnel for advanced evaluation. Each Life Saver would have an embedded serial number and stand-alone data capture so one smart device could be shared among multiple Life Saver patients. A standard USB hub would allow simultaneous connection of multiple Life Save devices or the smart device could be passed from patient to patient and the stand-alone SD storage used to avoid gaps in data collection.

State of Development

The product submitted for this microMedic 2013 Contest is a proof of concept demonstration of the product’s core technologies. This unit also demonstrates our ability to rapidly develop and demonstrate complex systems in a short period of time by fully exploiting modern electronic components and system technology. This product was conceived and developed by two people working 500 miles apart but forming one virtual lab by means of modern data sharing and transportation systems. The entire timeline from product concept to working product was approximately four weeks of very part time work. This prototype uses physically large and easy to assemble components to allow rapid development. Standard, relatively low density PCB fabrication techniques would reduce the product size by an order of magnitude. Both this prototype and a envisioned compact production version use common, off-the-shelf components (COTS) for everything but packaging to keep costs low and speed the development cycle.

The retail cost of the components used in our prototype cost approximately $60 and includes essentially all the components needed for our envisioned product except for the battery and finger clip packaging. There are many variables still to be evaluated, but it seems reasonable to estimated a finished cost of less than $75 at modest quantities.

Project Team

Boutique Engineering is a father and son team collaborating on the development of integrated hardware and software systems for niche markets.

Benjamin Margolis: Boutique Engineering Chief Scientist and Principal Engineer. Ben holds a BS in Engineering with Honors from Harvey Mudd College (2010), and has a strong technical background in basic sciences and multiple engineering disciplines - including control systems and optics. He is principal of Six Pearls, an engineering consultancy, and chief engineer for a stealth mode medical device company. Ben has previously invented a hemostatic bandage currently being commercialized by RevMedX. Ben did undergraduate research related to diffuse optical spectroscopy for Beckman Laser Institute, a leading medical research institute based out of UC Irvine.

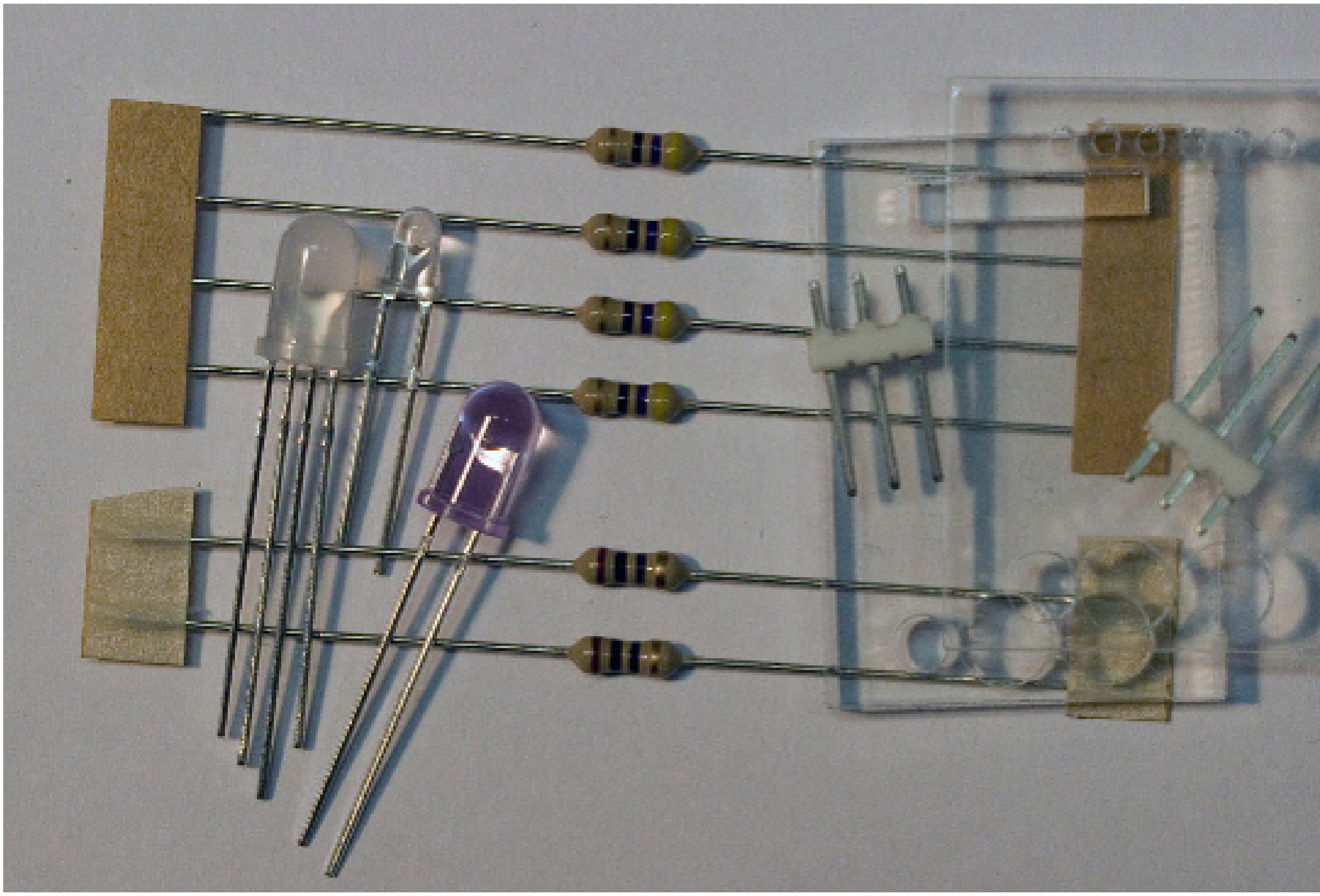
Albert Margolis: Boutique Engineering Project Manager and Chief Technician. Al holds a BS in Information Systems from Golden Gate University (1980) and an MBA in Telecommunications Management from Golden Gate University (1982). Al has held a variety of software development and hardware integration positions in banking, insurance and telecommunications. Al is founder of Hobby Engineering a distributor of STEM education products.

Construction / Bill Of Material

This development prototype is extremely simple and was intended mainly as a platform to test the feasibility of using commodity LED and sensors for Diffuse Optical Spectroscopy. No formal drawings were prepared. No materials were special ordered for this project. The majority of materials were acquired from Hobby Engineering inventory and the rest were available in Al Margolis's custom project supplies.

The circuit consists of LEDs connected to I/O pins and ground with current limiting resistors and the TSL237 connected to 3.3VDC, ground and an I/O pin. Essential circuitry for the Propeller microcontroller, including power sourcing, was provided by the Propeller Activity Board. This simple circuitry was able to collect interesting data.

Parallax Propeller Activity Board (http://www.hobbyengineering.com/H4848.html)
TSL237 Light To Frequency Sensor
940nm IR LED (http://www.hobbyengineering.com/H1530.html)
880nm IR LED (http://www.hobbyengineering.com/H1982.html)
RGB visible light LED
3 - 47 ohm resistor (red and both IR LED current limiting)
(http://www.hobbyengineering.com/H1534.html)
2 - 10 ohm resistor (blue and green LED current limiting)
(http://www.hobbyengineering.com/H1091.html)
3 - 3-pin header pin assembly (http://www.hobbyengineering.com/H1057.html)
acrylic for base assembly
vinyl tape (insulation and to hold assembly together)
plastic girder & #4 screw/washer/nut (allowed adjusted of space between LEDs and sensor)



References

microMedic project number micro13AM309.

DOS Research Presentation by Ben Margolis
http://www.youtube.com/watch?v=O_T0fx4bOj0

Research paper discussing use of DOS measurements, primarily oxygenation, as a substitute for traditional patient monitoring in trauma situations.
http://www.ncbi.nlm.nih.gov/pubmed/19725738

http://www.hobbyengineering.com/On_Finger_Contest.jpg, Image of device on finger (high resolution)

http://www.hobbyengineering.com/Assembled_Contest.jpg. Image of device sensor assembly (high resolution)

http://www.hobbyengineering.com/LED_Parts_Contest.jpg Image of unassembled parts for LED module (high resolution)

```
''**********************************************
''*                                            *
''*  Author: Ben Margolis                      *
''*  Copyright (c) 2013 Ben Margolis           *
‘’*
‘’* This Propeller module sequences through 5 LEDS, reads the TSL237
‘’* writes the data out the USB serial port.
''**********************************************

CON
  _clkmode = xtal1 + pll16x
  _XinFREQ = 5_000_000
  NUM_LINES = 9
  NEXT_CNT_INCREMENT = 80_000_000 / 10   '10 Hz = 100 ms
  CNT_PER_WAVELENGTH = 80_000_000 / 200  '200 Hz = 5 ms
  Led_First_Pin = 0
  Led_LastPin = 4
  Sensor_Output_Pin = 17
  Sensor_Control_Pin = 14


OBJ
  pst  : "Parallax Serial Terminal"
  lfs  : "tsl230"

VAR
   long value
   byte line_num, WAVELENGTH
   long next_cnt


PUB go | old
  pst.start(115200)                         'start terminal
  lfs.Start(Sensor_Output_Pin, Sensor_Control_Pin,500,false)                   'start tsl230 light to
frequency sensor @ 1000 Hz = 1 ms

  dira[Led_First_Pin..Led_LastPin] := %11111                    'set LED pins as output
  next_cnt := cnt + NEXT_CNT_INCREMENT

  repeat
          if cnt >= next_cnt
          next_cnt := cnt + NEXT_CNT_INCREMENT   'wait for 100ms
```

```
#
# This Windows Python module reads data send by the Propeller microcontroller and
# displays a running graph of the TSL237 output for each of the 5 LEDs.
#


import serial
import io
import numpy
import threading
import time

NUM_READINGS = 512

class SerialPortReader(object):
    def __init__(self,port='COM5',baud=115200,
            delimeter=' ',newline=chr(13),new_plot=True,sio=None,ser=None):
    """
    The first few args are for creating a new serial port buffer.
    The sio and ser arguments allow for
    passing already opened buffers into the instance. For some reason, it took a
    while to start reading
    when opening a new buffer. I'm impatient.
    """
    if sio is not None:
    self.ser = None
    self.sio = sio
    elif ser is not None:
    self.ser = ser
    io.TextIOWrapper(io.BufferedRWPair(self.ser, self.ser), newline=newline)
    else:
    self.ser = serial.Serial(port, baud, timeout=1, interCharTimeout=1)
    self.sio = io.TextIOWrapper(io.BufferedRWPair(self.ser, self.ser), newline=newline)

    self.delimeter = delimeter

    self.setup_readings()

    self.__is_shut_down = threading.Event()
    self.__shutdown_request = False

    self.start_time = time.time()

    def setup_readings(self):
```

```
self.max_raw_readings = []
self.min_raw_readings = []
self.readings = []
self.analysis_readings = []

self.sio.readline()
self.sio.readline()
```

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