Optimal Design

Near Infrared Imaging System

Team 4
Barbara Adu-Baffour
Amir Nasser Bigdeli
Albert Pham

Client Contact:
Qing Zhu, PhD
Professor
University of Connecticut, Electrical and Computer Engineering Department,
New InfoTech Building, Unit 2157, Storrs, CT
Telephone: 860-486-5523
Email: Qing.Zhu@uconn.edu
1 Optimal Design Project 4

1.1 Introduction

The project to be designed aims to create a near-infrared imaging system using laser diodes for imaging biological tissues as requested by the client Dr. Zhu. Although there are similar products on the market for this task, this design presents a cheaper, more portable and more user and patient friendly option. Referring to alternate designs proposed, this approach contains a combination of the different desirable aspects of the designs that fits the client’s requests. The design is based on the analysis of the optical properties of pertaining to cancerous tissues such as hemoglobin concentration, blood $O_2$ saturation, and tissue light scattering and absorption, as seen in Fig.1 below

The primary concept behind the NIRIS for imaging biological tissue stems from the discovery that the transmission and absorption of near-infrared light by biological tissue can provide information about hemoglobin concentration changes.

![Absorption spectra of oxygenated and deoxygenated hemoglobin and water.](image)

Figure 1.0: Absorption spectra of oxygenated and deoxygenated hemoglobin and water.

By employing several wavelengths and frequency modulation of input signals, blood flow, volume, and oxygenation can be quantified using Beer-Lambert equation [1] which seen below in eqn.1

\[
\text{Equation 1.0: } OD = -\log \frac{I}{I_0} = \mu_a LD_{PF} + G
\]
OD is the optical density of the tissue
I is the detected intensity of light, \( I_0 \) is the incident intensity of light
\( \mu_a \) is the absorption coefficient
\( L \) is the distance travelled from source to detector
\( D_{PF} \) is the difference path length factor (accounts for extra total distance travelled through tissue due to scattering)
\( G \) is the geometry factor of the tissue

The device will provide multiple inputs from a probe of 10 centimeter in diameter that contains multiple laser diodes. The client wants the diodes to be able to operate at two different optical wavelengths, 780nm and 830nm, and the probe to potentially contain up to eight different laser diodes. To operate at these wavelengths the system will be operating in accord with the International Commission on Illumination (CIE) at IR-A infrared radiation or near-infrared wavelengths.

The device will have each of the laser diodes modulated at different frequencies to enable a spatial coding system and an optical detector channel will be designed with this device to detect signals from all the laser diodes and reveal their spatial locations. The device will have a system that would be able to identify the states of the laser diodes in either an “on” or “off” state. The device will have phototransistors as photodetectors placed next to each laser diode to detect the back-scattering off of biological tissue, and ultimately convert that analog signal into an electrical signal. An amplifier will be incorporated into the design to strengthen the signal from the photodetectors for proper processing through a data acquisition device, which will be connected to a computer and monitored with LabVIEW software. This software will programatically detect the states of each diode and separate multiple frequencies that might be detected by the phototransistors. Separate signals will be plotted on a graph that is displayed on an interactive user interface. Prior to conversion of analog to digital signals, signals from photodetector are filtered to remove any noise using a bandpass filter.

1.2. Hardware

1.2.1 Laser diode Circuit

The first component to implement would be the laser diodes. There will be two laser diodes used each operating at different wavelengths. These two diodes will also operate at two different modulated frequencies to ultimately differentiate between the two, but that is a problem to be solved later. At this point we are only concerned with supplying the laser diodes with adequate current to operate when necessary and not provide currents beyond its maximum ratings. If current ever surpasses the laser diodes maximum current capabilities the diodes burn out. Since operating in the small milliamps range the precision of the current is very important.

The laser diodes need to be chosen because the entire circuit is based off of creating a condition that is optimal for the diodes to operate correctly. The diodes are within the same family from Optnext with the first, HL7301MG, operating at 730 nm, and the second, HL8337MG, operating at 830 nm. These two are chosen for two reasons they both operate at the same operating current which makes it easier to produce one current line to operate both diodes.
The second reason is that they are both created with the same diode orientations. This makes it possible to place either circuit in any location that is viable for one diode to operate and have both be able to function properly. Figure 2.0 shows the HL8337MG laser diode which are the same traits found within the HL7301MG diodes. Now the design scheme for the circuit will be discussed to properly power these two diodes.

![Figure 2.0: Laser Diode](image)

In this design scheme two types of power sources are used an AC component and a DC component. In order to introduce the two signals implementation of a bias tee is necessary. Figure 3.0 demonstrates an example of how a bias tee is configured.

![Figure 3.0: Bias tee](image)

The bias tee takes a radio frequency signal (RF) which is the AC signal and a DC signal and is able to separate the two signals using an inductor which filters out the AC component and the capacitor filters out the DC component of the signal. This is true due to the behavior of a capacitor and an inductor. A capacitor blocks direct current while allowing alternating current to pass, while an inductor blocks alternating current and allows direct current to pass. Using these ideas connecting a DC supply to node DC within the figure and an AC signal to node RF will combine the two signals in node RF+DC. Essentially this takes the DC component and inserts it into the AC signal. The design of a bias tee is dependent on the frequency of the signal being passed through. For the capacitor component the frequency follows equation 2.0.
Equation 2.0: \( X_c = \frac{j}{\omega c} \)

\( X_c \) is the impedance of the capacitor, \( \omega \) is the frequency in radians per second, and \( c \) is the capacitor value. Bias tees are usually designed for transmission line environments with a characteristic impedance of 50 ohms to 75 ohms. The \( X_c \) impedance is then chosen to be much less than 50 ohms. In a design example 30 ohms was chosen for \( X_c \) in comparison to transmission line's 50 ohms. Changing equation 2.0 to frequency in hertz now the capacitor value can be obtained.

Equation 2.1: \( 30 \text{ ohms} = \frac{j}{2\pi \times 50 \text{ ohms} \times c} \)

Solving for \( c \) within equation 2.1 yields a value of 3.537nF. This value will be used for the design scheme.

Now examining the inductor component the inductor value can be obtained by examining equation 3.0.

Equation 3.0: \( X_L = j \omega L \)

\( X_L \) is the impedance for the inductor, \( \omega \) again like in the case of the capacitor is the frequency in radians per second, and \( L \) is the inductor value. Unlike the case of the capacitor the impedance for the inductor must be much greater than the transmission line impedance. For this design scheme \( X_L \) is chosen to be 70 ohms. Again changing equation 3.0 to frequency in hertz equation 3.1 will ultimately yield an appropriate value for the inductor.

Equation 3.1: \( 70 \text{ ohms} = 2\pi \times 50 \text{ ohms} \times L \)

Solving for the inductor value \( L \) yields 222.817 mH. This inductor can now be placed into the bias tee configuration.

Having the bias tee this takes care of the incoming signal. This signal is now needed to be fed into the laser diodes. Note though like previously mentioned huge variations in current beyond the diode's operating point will compromise the diode. It is necessary to create a constant current source to make sure that the diode does not take in more current then it can handle. Precision constant current sources however are very expensive ranging in the hundreds of dollars. A cheaper alternative is necessary where the current supplied from this system is still as stable as possible.

Instead of searching for current sources an alternative idea can be used where a constant voltage source is used to create a constant current. A basic law is ohm's law which relates voltages to current and resistance. Ohm's law is represented in equation 4.0.

Equation 4.0: \( V = I R \)

\( V \) within the equation is the voltage value, \( I \) the current, and \( R \) the resistance. Knowing that the system has a constant voltage and also knowing a desired constant current a resistor can be used to create a resistance that meets these two requirements.
For a voltage regulator a chip, LM317, is chosen. The LM317 is an integrated three-terminal adjustable linear voltage regulator. This chip can be seen in Figure 4.0.

![Figure 4.0: LM317 Voltage Regulator](image)

Considering the type of voltage coming into the $V_{in}$ pin being a combination of an AC and DC signal the voltage will be fluctuating. This particular chip though provides a voltage change of 1.25 volts between the $V_{out}$ pin and the Adjust pin. This voltage does not fluctuate. Using this knowledge in addition to knowing the operating current of the diodes these pieces of information can be fed into equation 4.0. Ohm's Law and an appropriate resistor can be selected to provide a constant current of 75 mA. Examining equation 3.1,

$$\text{Equation 4.1:} \quad 1.25 \text{ volts} = 75 \text{ mA} \times R$$

$R$ is our resistor value and when solved for provides 16.667 ohms.

With all the proper components for the laser circuit they are taken and integrated together to produce our laser design schematic which is represented in Figure 5.0.

![Figure 5.0: Laser Diode Schematic](image)
V1 is the DC voltage source set at 12 volts. V2 is the AC voltage source with an amplitude of 1 and frequency of 730 hz. They are both fed into the bias tee with the proper capacitance and inductance values. This is than taken and fed into the LM317. Knowing the different of voltages between V_out and Adjustable nodes the proper resistance is placed in between to generate the desired current powering the laser diode D1.

Taking Figure 4.0 and running it through a transient time analysis to test for the current at node D1 produces figure 5.1.

![Figure 5.1: Current Feeding into Diode vs Time](image)

The first thing to note is that our desired current is 75 mA however the produced current is actually in the 77 mA range. This is due to the tolerances within the components that cannot really be accounted for. Usually built components come with certain range in which the true value can be related to. This is fine however considering 77 mA is considerably close to the desired 75 mA. The second point of interest is that the produced current is not constant. The current feeding into the diode does fluctuate. However it only fluctuates between 77.846 mA and 77.830 mA. This fluctuation is very small and negligible as long as it continues to operate within this range.

1.2.2 Photodetector

A photodetector is a component that takes optical signals and converts it into electrical signals. There are many different types of photodetectors including photodiodes, phototransistors, and photoresistors. With this design the type of photodetector being used is the Avalanche Photodiode (APD). The most important factor of using an avalanche photodiode over other photodetectors is that the APD provides a greater level of sensitivity. Also the APD has a self amplification which amplifies the initial received signal. A big disadvantage to the APD is
that because it is so sensitive it creates a higher level of noise than other types of photodetectors. This would require filter devices to be used to remove as much noise from the signal as possible.

The APD’s structure is more complicated than that of ordinary photodiode devices. It consists of four layers, the n+, p, un-doped, and p+ regions. Light is absorbed through the undoped region which is a relatively thick region. An example of the layers of an avalanche photodiode can be seen in figure 6.0.

The avalanche region occurs between the n+ and p regions. When light enters the undoped region it causes generation of hole-electron pairs. Under the action of the electric field the electrons then migrate towards the avalanche region. Here the electric field causes the velocity of the electrons to increase which creates collisions with the crystal lattice. This effect creates further hole electron pairs. This process allows a single electron created by light in the undoped region to produce many more electrons with the collisions with the crystal lattice. This in fact is how the self amplification of the APD works.

The specific APD necessary would be either one made of Silicon or a combination of Indium, Gallium, and Arsenide because these two are able to operate within the limits of the laser diodes of 700-900 nm. The downside to using these two types of APDs are that the level of multiplication of the self amplification is lower than that of Germanium, however Germanium can only operate from 800-1700 nm which excludes the 730 nm diode.

1.2.3 Amplifier and Filter

The signal coming from the avalanche photodiode needs to be amplified to levels where the data acquisition unit can interpret. The signals are of low amplitude even with the amplification from the APD so needs to be further amplified. Also it is important to note that the signals are current values so a current amplifier needs to be utilized. After some consideration a
basic bipolar-junction-transistor (BJT) amplifier will be used. Specifically a Common-emitter amplifier. Figure 7.0 is a schematic for the designed common-emitter amplifier.

![Common-Emitter Amplifier](image)

**Figure 7.0: Common-Emitter Amplifier**

Not yet having exact signals from the Laser diode circuit V1 is introduced as a sample signal. The input capacitor C1 removes any constant component of the input which is our DC component. The resistors R2 and R3 bias the NPN transistor so that it will remain in an active mode for the entire range of our input. The output is an inverted copy of the AC-component of the input that is amplified by the ratio R4/R5. Which in the chosen case is 10. To calculate the actual current gain provided by the current-emitter amplifier equation 5.0 is used.

\[ \beta = A_i = \frac{i_{out}}{i_{in}} \]

The current \( i_{in} \) is found between R2 and R3 running directly into the transistor. The current \( i_{out} \) is found running through R4 at our \( V_{out} \) node.

Now comparing the current at these two nodes should give the current gain of the amplifier. Figure 7.1 shows a DC transient analysis of the amplifier comparing \( i_{in} \) to \( i_{out} \).
Figure 7.1 confirms the validity of the amplifier. With the chosen values within the circuit in figure 7.0 it was calculated to produce a gain of 10. Analyzing the circuit and comparing the two currents $i_{in}$ and $i_{out}$ plugging the values of the analysis into equation 5.0 produces Figure 7.1. Which demonstrates that $\beta$ is equal to 10, our expected gain. Now when knowing the exact signal provided from the laser diode circuit in the future these component pieces can be adjusted to properly achieve a gain necessary to produce understandable results.

Having the amplifier to amplify the signal it is time now to consider the noise being transmitted with the signal. Using an avalanche photodiode comes with a system that is noisier then normal. It is important to use a filter and attempt to filter out this noise. Using Filterlab a filter design software by Microchip a fourth order active filter was implemented that captured the desired frequencies. The modulated signals are between 700 and 800 Hz so an active band-pass filter is designed allowing frequencies from 650 Hz to 900 Hz to pass. This range allows for signals from the modulated frequencies to pass and it also prevents noise from 60 Hz level naturally found from land line wires to be filtered out. Anything not laying within 650 Hz to 900 Hz is not of value towards this design. The active design can be seen in figure 8.0.
An AC analysis is done of the filter to see its waveform. This analysis can be seen in figure 8.1.

As per the program frequencies between 650 Hz and 900 Hz are allowed to pass through with all other frequencies rejected. This removes a large portion of the noise within the hardware components and allows for software filters to have a cleaner signal to analyze and filter. This signal now is sent to the data acquisition device which starts the software analysis of the laser diode signals.
1.2.4 Data Acquisition Device

In order to analyze the signal being generated by the photodetectors, the NIRIS will be connected to a National Instruments Data Acquisition Device, Model PXI-5114. This specific device is a high-speed digitizer featuring two 250 MS/s simultaneously sampled input channels, each with 8-bit resolution, 125 MHz bandwidth, and up to 256 MB of memory [4]. The whole circuit is integrated into a 3U peripheral component interconnect (PCI) extension for instrumentation (PXI). The unit is ideal for a wide range of application areas including communications, scientific applications, military/aerospace, and consumer electronics. The optimal design will utilize the PXI-5114 for its digitizing abilities. To fully utilize this device, it is important to understand how it digitizes the analog signal and sends to as a readable format to LabVIEW for further analysis.

Bandwidth describes the difference between limiting frequencies within which the input signal can pass through the system with minimal amplitude loss — from the input at the tip of the probe or test fixture to the output data [8]. In the case of the NIRIS design, the bandwidth will be the signal that will be sent to the PXI-5114 from the circuit through a BNC connection. The limiting frequencies that determine the bandwidth include both a high and a low frequency that are specified as the frequency (in Hz) at which a sinusoidal input signal is attenuated to 70.7% of its original amplitude. This point is known as the -3 dB point. Figure 9.0 below shows a graphical representation of this point.

![Figure 9.0: -3 dB Point](image)

Another aspect of the signal to understand is flatness. Flatness is an effect on the acquired waveform that is frequency dependent [8]. As the frequency rises, the amplitude slowly falls toward the 3 dB cutoff point of the bandwidth. When signals are composed entirely of frequencies below this cutoff point, the measured signal can appear slightly different than the input signal. The higher frequency components of the signal are attenuated more than the lower frequency components, changing the overall signal. Flatness describes how well the analog front end passes signals of different frequencies. A maximally flat front end passes all frequencies with the same amount of attenuation, so the measured signal looks like the input signal.
However, in the real world, as the frequency rises, the measured input signal slowly falls toward the –3 dB point.

Once the fundamentals of the signal is understood, such as the bandwidth and the flatness effect, it is important to look into how the digitizer would interpret the input signal, and whether it will be able to read it at all. This concern is addressed by the resolution of the digitizer. Resolution is the smallest input voltage change a digitizer can capture. Resolution can be expressed in bits (LSB), in proportions, or in percent of full scale. For example, a system has 12-bit resolution, one part in 4,096 resolution, and 0.0244% of full scale. Resolution limits the precision of a measurement. The higher the resolution (number of bits), the more precise the measurement. An 8-bit ADC, such as the PXI-5114 used in this design, divides the vertical range of the input amplifier into 256 discrete levels. With a vertical range of 10 V, the 8-bit ADC cannot ideally resolve voltage differences smaller than 39 mV. In comparison, a 14-bit ADC with 16,384 discrete levels can ideally resolve voltage differences as small as 610 µV.

Figure 10.0 below shows the block diagram for the PXI-5114 [4].
In above image, we can see both BNC channels, CH 0 and CH 1. Using one of these channels, the analog signal will be transmitted from the photodetectors into the digitizer. From the analog in path, the signal will be transferred to the 8-bit 250 MS/s analog-to-digital converter (ADC). An ADC is a device that converts a continuous quantity to a discrete digital number. As described before, resolution is an important factor of the ADC. Due to the fact that the signal is decimated after it goes through the ADC, the type of ADC used in the PXI-5114 is most likely a Sigma-Delta ADC (or a Delta-Sigma ADC). Figure 11.0 below shows the block diagram for such a ADC [4].

Figure 11.0: Block Diagram Sigma-Delta ADC

Such an ADC oversamples the desired signal by a large factor and filters the desired signal band. Generally, a smaller number of bits than required are converted using a Flash ADC after the filter. The resulting signal, along with the error generated by the discrete levels of the Flash, is fed back and subtracted from the input to the filter. This negative feedback has the effect of noise shaping the error due to the Flash so that it does not appear in the desired signal frequencies. The decimation process that follows the ADC reduces the sampling rate, filters off unwanted noise signal and increases the resolution of the output.

The PXI-5114 provides two independent digitizer input channel signal conditioning paths. Each path provides a choice of 50 Ω input impedance or 1 MΩ input impedance, as shown in the following Fig. 12.0.
The PXI-5114 provides noise filtering on the analog signal before it is sent to the ADC. It has a 20 MHz noise filter that limits the bandwidth of the signal path through both the 1 MΩ and 50 Ω signal paths. This filter is intended to reduce noise when the signal content is 20 MHz or less. Figure 13.0 shows a typical frequency response of the noise filter [4].

![Figure 13.0: Noise Filter](image-url)
Having this intermediary noise filter within the overall noise conditioning pathway provides a cleaner signal for the ADC. This cuts out a lot of the noise that would have otherwise unnecessarily showed up in the digitized signal. This doesn’t mean that there isn’t a need for filters before the signal gets transmitted to the PXI device itself. There are many other sources of interference that have to be dealt with, such as white noise and pink noise. Getting the signal as clean as possible for analysis in LabVIEW is the main goal of all these filters. Besides acting as the digitizer, the PXI-5114 will also act as an intermediary between the signal generated by the photodetectors and the signal read by the data acquisition device and sent to the computer.

1.2.5 LabVIEW

The optimal design for the NIRIS involves extensive analysis of the signal from the photodetectors in LabVIEW software. The user interface will also reside within this program as a standalone VI. Much of the analysis that needs to be done on the signal include filtering, graphing, and recording the vital data.

The programming language of LabVIEW is called “G”. This language will allow the programmer to visually program a series of instructions, including gathering data from the data acquisition device, filtering it through a Butterworth Filter VI, and outputting it on graphs that make up part of the user interface. The main component involved in gathering data from the PXI-5114 is the DAQ Assistant Express VI [6]. Within this VI, the programmer can select the appropriate input channel from the PXI card, adjust input variables such as the type of input (i.e. voltage or current), and can calibrate the PXI itself. Figure 6 below shows the main DAQ Assistant window in which the programmer adjusts all the necessary settings. Other sampling variables which can be fine-tuned from within the DAQ Assistant manager window include timing settings such as the acquisition mode, the number of samples to read, and the sampling rate. The output of the DAQ Assistant Express VI is a two-dimensional array of type doubles containing the time variable and the signal variable.

The resulting array fetched from the DAQ Assistant Express VI will be fed directly into a graph for the user to visualize the “unfiltered” data. Technically, the data was filtered before it was processed by the DAQ, but without loss of generalization it is possible to label this data as unfiltered. A Waveform Graph will be able to graph the raw signal in real time due to the fact that the whole program will be put into a while loop, stopping only when the user requests it to. The raw signal will also be branched into a Butterworth Filter. Using the Filter Express VI [7], the programmer can select the Butterworth Filter and specify specific cutoffs. Due to the nature of the project, the main type of filter being used will be a bandpass filter. The client requires one or more signals to be detected by the photodetector, sent to the DAQ, and analyzed in LabVIEW. For this reason, a bandpass filter will be used to isolate the specific frequencies at which the
signal is being gathered at. Figure 14.0 below shows how LabVIEW uses point-by-point analysis in its Filter Express VI [8].

![Diagram of Array-Based Analysis versus Point-by-Point Analysis](image)

**Figure 14.0: Array-Based Analysis versus Point-by-Point Analysis**

Point-by-point analysis is essential when dealing with control processes where high-speed, deterministic, point-by-point data acquisition is present. Any time resources are dedicated to real-time data acquisition, point-by-point analysis becomes a necessity as acquisition rates and control loops are increased by orders of magnitude. The point-by-point approach simplifies the design, implementation, and testing process, because the flow of the application closely matches the natural flow of the real-world processes that the application is monitoring and controlling. Point-by-point analysis is streamlined and stable, because it ties directly into the acquisition and analysis process.

Due to the fact that the range of frequencies is known but not the exact values, a for loop will be used to iterate through the entire range of possible frequencies to find which frequencies are currently being captured by the photodetector. This part of the program exhibits spatial coding properties, in the sense that the LabVIEW program will be able to tell which laser or lasers are turned on, and at which frequencies they are being driven at. Figure 15.0 below shows an overall flow chart of the processes described in the last two sections.
To maintain proper memory management, a divide-and-conquer algorithm will be used to find and isolate the frequencies of the powered lasers. This will make sure that the overall run time of the program is feasible and can keep up with the live signal feed. This will also make sure the space consumption of the program is well within the limits of LabVIEW’s memory allocation manager.

2 Realistic Constraints

2.1 Engineering Standards

The device will be required to provide multiple inputs from multiple laser diodes and as such it is important to know the states of each diode and what frequency each signal is being modulated at. This allows for special coding of the signals to enable target recognition of cancerous tissues. Also the device will have a filter that will sort out unwanted frequencies due
to powerlines and noise from laser diodes. This will enable the desired signals to be interpreted since wrong analysis can be fatal to patient if tumors are not detected properly.

### 2.2 Constraints

As with any project in the field of science and medicine, there are multiple realistic constraints that will affect the results and overall effectiveness of this project. Economic constraint is the major issue in this project due to the limited budget allocated. In regards to this project, many of the parts that are needed to construct the imaging probe, such as the laser diodes, current drive, and photodetectors considered in this design can be purchased commercially for a relatively low price. Other hardware requirements, such as the National Instruments Data Acquisition (DAQ) device and DC/AC power source, are already provided through the research laboratory. Software requirements such as LabVIEW, MultiSim and Filterlab are also provided. The majority of our economic constraints will depend heavily on the amount of prototypes we render, the amount of hardware instruments that are necessary to completely build the probe and also the cost of shipments of parts.

Environmentally, there are only a few constraints that we will have to deal with, specifically electronic or e-waste since the project does not have the use of radioisotope materials involved. The disposal of damaged components during the design is the only issue that has environmental issues and as such our completed project should be handled with care and done under environmentally compliant conditions. Sustainability and manufacturability are not going to be a problem due to the nature of the project. As of now, there are also no ethical constraints involved with laser imaging on biological tissue. Health and safety concerns would only be a problem if the project were to involve human test subjects. Test specimen to be used for the purpose of this project will be phantoms which have similar characteristics and optical properties as human tissue. No social or political constraints are associated with this project since live human test subjects are not used.

An operational constraint that has to dealt is the fact optical measurements can be easily contaminated by motion artifacts caused by patient or operator as well as relative motion of the probe and soft tissue during contact imaging which is similar to 1D ultrasound probes scanned in 2D to perform 3D imaging. Careful operation procedure and operator training are required to obtain good quality images using hand-held based optical devices over using bulky optical systems employing compression plates or circular geometry.

### 3 Safety Issues

Safety is the number priority in this design. To protect both user and patient this design will have all if its circuits housed in a plastic box for good thermal and electrical resistance and long-term. Also, no bare wires will be left to prevent electrical shocks to the user. All other electrical components will be protected from any potential interruptions such as physical harm.
Biological and chemical hazards will be prevented with this design since artificial tissues (phantoms) will be used. Also due to the non-invasiveness of near infrared imaging technology, health hazards due to infections from wounds created from needles. In comparison to other non-invasive imaging techniques such as mammogram, MRIs, PETs, etc., this design does not use radioisotopes and as such health complications related to radiation are avoided from multiple tests.

The possibility of overheating of the components is also considered which due to the change in current of laser diodes, power-line surges and spikes (transients). This issue will be addressed by using a heat sink in the form of a fan for dissipating heat. This fan together with all parts of the circuits will be put in the plastic housing mentioned above with vents for dissipation of the heat. This approach also prevents health hazards due to heat damage to the skin and eye and other electrical components of the design.

4 Impact of Engineering Solutions

The design of near infrared imaging system will have a huge impact in the tissue imaging world as it presents a new technique for non-invasive imaging that is cheaper and reduces health risks associated with other forms of imaging mentioned earlier. As the client conducts research in breast cancer, this device will provide a better form of probing into cancerous tissues since near infrared light can probe further centimeters into tissues compared to visible light. Since the design of the device is relatively cheaper, more laboratories and other low funded institutions and facilities to be able afford tissue imaging researches.

On a more social basis, this device when manufactured and used on a large scale will be of great benefit due to its advantage of implementing a more specific and more sensitive imaging technique exceeding that of x-ray mammography. This make near infrared imaging an important development in the means of screening for breast cancer. Screening demands a spatial resolution of a few millimeters or better in order that tumors can be distinguished from surrounding healthy tissue while they are still small in size before metastasis occurs and treatment becomes more difficult which can result in death. The use of this device will encourage more people especially women to see the doctors for early detection of tumors since the development of this design contribute to the better distinguishing between benign and malignant lesions, without a surgical biopsy.

The portability of this device allows easy transport from one place to another compared to available bulky optical imagers. This is a global advantage since a portable device will allow imaging to be done not only in hospitals and research laboratories but also in remote areas where access to such devices is impossible.

5 Life-Long Learning

Throughout the design process new knowledge has been acquired in many different areas, most of which do not involve direct passing on from teacher to student but through research and
time spent on building devices. Valuable knowledge on work ethics has been acquired and most importantly time management. Working as a team from different engineering tracks plays a very important aspect of our ability to work with people from different disciplines in industry and other non-related fields. As a team, the ability to interpret ideas, offer suggestions to improve designs, and delegate work is important to working successfully in the real world. This way knowledge is exchanged and better interaction with people occurs to allow project to be successful.

Understanding the motivation of the design was an important learning experience since device is to serve mainly for research into breast cancer. As design engineers we are responsible for taking the ideas the client is trying to convey and developing a device that meets all of the required needs which is a valuable tool to be used in the future as engineers. Also as design engineers, the knowledge of keeping in touch with the client on regular basis has been improved. This way the team is in a better position, knowing that we are doing exactly what the client requests.

Throughout the process lots of research was done to understand the basics of near infrared imaging and available devices on the market, which helped the team get a better understanding of what was to be done. The major knowledge is gained through the research done on circuit components and how they are to be integrated for a successful project implementation. Building of the circuits for the different components of the device will enable team members acquire and improve skills on implementing theoretical knowledge to practice. Skills in software coding and creating an appealing user interface have also improved since the project required a more complex code compared to previous codes done in class sessions.

Writing skills have improved during the period of senior design as result of the engineering reports to be written. This prepares students to work in industry and engineering research settings as all changes and relevant information are documented to allow relay data for repeating or improving designs. Public speaking skills have also developed and improved from in-class presentations and weekly meetings with project advisors. This also enables professional communication skills to be acquired and also to retain knowledge obtained from explaining to people.

6 References

[1] Figure.1 http://www.scholarpedia.org/article/Near_infrared_imaging (Accessed October 20, 2010)

http://www.medphys.ucl.ac.uk/research/borg/research/NIR_topics/imaging_exp.htm
(Accessed October 21, 2010)

[4] NI PXI-5114 - 250 MS/s, 8-Bit Digitizer/Oscilloscope,


[6] Using the DAQ Assistant to Automatically Generate LabVIEW Code,


[8] LabVIEW For Measurement and Data Analysis,