Alternative Designs
Near Infrared Imaging System

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Alternative Design 1

The first alternative design deals with making our system portable by programming all filters and analytic functionality onto a microcontroller. This microcontroller will be packaged into a box with the near-infrared laser imaging system and an LCD screen to display the user interface. In terms of marketing, this design is highly beneficial for its application in clinical use. Potential clients, such as hospitals, favor devices that can easily be transported from one room to another. Portability means less equipment to deal with and more time to work with, and that is exactly the business model that fits into the ecosystem of a hospital-like environment. Our original design would require a separate data acquisition device to process the signal from analog to digital, and then send that digital signal to a computer. From there, further processing would need to be done by LabVIEW with the guidance of the user. With a portable device such as an integrated microcontroller, the data acquisition and all following processing can be done in one independent unit.

There are some advantages and disadvantages to this design. One major advantage is portability. Due to the nature of the device, it will be very light and easy to carry from one location to another. The operability of the device will on par with the original computer-based design. Another advantage is its marketability. In terms of aesthetic appearance, a portable tablet-like device is in-line with current technological trends. Portable devices have been outselling their stationary counterparts for the past three years, and it seems as if this pattern is not going to change anytime soon. One last advantage, and a very big one at that, is the cost. For our client specifically, this advantage does not hold true, since they already have a data acquisition device that will be able to handle our original stationary design. When considering a broader market, beyond our intended client, it is important to note that many hospitals and
clinical environments do not house industry standard data acquisition devices, such as the National Instruments one. Not having LabVIEW, on the other hand, is not an issue, due to the fact that LabVIEW supports the creation of standalone executable programs.

The microcontroller in question is the ARM926EJ-S CPU Board, as seen in the Figure 1.

![ARM926EJ-S CPU Board](image)

The onboard Linux drivers support LCD frame buffers and touchscreen capability, giving this specific piece of hardware very high potential. Optimally, an LCD touchscreen will be used in tandem with the microcontroller to output the user interface, giving the client a keyboard-less and intuitive design to work with. This all adds to the usability of the product.

In terms of costs, the microcontroller itself would retail at $120. The LCD touchscreen (capacitive) would cost roughly $200. That would be it for the additional costs of this alternative design, due to the fact that LabVIEW has a software development kit (SDK) specially targeted to ARM microcontrollers. This would mean the program would still be coded in LabVIEW, but with slight modifications to the user interface and with a little less functionality. This reduced functionality though does not impose on the intended functionality of the program, since all
signal analysis VI’s are included in the LabVIEW microcontroller SDK. And if this doesn’t suffice, LabVIEW has a C Code Generator module that will port our algorithms to any ARM processor.

Ultimately, the greatest downfall to this design is the limited timeline of the project. Seeing as how the circuit for the near-infrared imaging system isn’t completed, budgeting time for both the completion of the main circuit and the integrated microcontroller doesn’t seem feasible. If there were no time constraints or if the team was bigger, such a design would be a great alternative, and possibly the best overall design for the product itself. Comparatively though, the cost benefits of this design match those of the original design, but in different terms. This design excels at being marketable and high-end, whereas the original design is much simpler and more targeted towards the intended client rather than a broad range of potential clients.

**Alternative Design 2**

The 2nd alternative design would be implemented within the filtering aspect of our near infrared imaging system. As with any transmitted signal there will be a noise associated with the desired signal. Even if noise reduction techniques are used the noise level can never really be reduced to zero. With this fact to get a readable or clean signal a method would be to take the signal and clean it up by filtering out noise. An easy example of an unwanted signal would be the 60 Hz frequency given off by land line power. To combat this unnecessary signal the total signal is taken and placed through a filter to filter out the 60 Hz frequency. Originally the plan was to take the transmitted signal from the laser diodes and allowing a software interface to filter out the signal. This alternative design removes the filtering done by the software and instead uses
hardware within of the near infrared imaging system to filter the noise out before sending the data to the computer.

There are two basic types of filters that can be used within circuit design. The Low-pass filter and the High-pass filter. The low-pass filter allows low frequencies to pass while the high-pass filter allows high frequencies to pass. They both can be built using a resistor in series with a capacitor. The type of filter produced would depend on the orientation of these two components and the exact frequencies filtered out is dependent on the values of the resistor and capacitor. A simple low-pass 1st order filter can be seen in figure 1.0.

![Figure 1.0: 1st order RC low-pass Filter](image)

With a low pass filter from the input voltage we first have a resistor then a capacitor which feeds to ground. The signal would be produced between the resistor and capacitor with reference to ground. An example of a high-pass filter can be seen in figure 1.1. The high-pass filter is similar to a low-pass filter however the order of the components are simply swapped.

![Figure 1.1: 1st order RC high-pass Filter](image)
With these two filters in combination a third type of filter can be produced. This filter will be the filter implemented into the circuit design. This is a band-pass filter. Figure 1.2a demonstrates how a band-pass signal is constructed.

![Figure 1.2a: Band-pass Filter](www.allaboutcircuits.com/vol_2/chpt_8/4.html)

A band-pass filter has a low-pass filter component in addition to a high-pass filter section. This allows for a particular frequency range to be accepted through the filter with all other frequencies rejected from the signal. Figure 1.2b shows how a band-pass filter works.

![Figure 1.2b: Band-pass Filter signal](www.allaboutcircuits.com/vol_2/chpt_8/4.html)

Figure 1.2b demonstrates how a band-pass filter works on a graph of magnitude transfer versus the frequency. The bandwidth of the filter is just the different between the upper and lower cutoff frequencies respectively $F_H$ and $F_L$ within the graph. With this band-pass filter component
values can be chosen to specifically cut out the 60 Hz land line frequency by having a higher lower cutoff frequency then 60 Hz. Also knowing the modulated signals that will go through the signals the specific frequency range can be chosen to filter out everything else which should be noise.

Benefits to a filter built within the circuit instead of using a software filter would relate to timing issues. The circuit takes an AC signal and directly filters the noise out of this signal before sending to the computer. If relying on a software filter the signal would have to be received by the PC which involves an Analog to Digital conversion before any filtering can be done. Also another important benefit would be the ability of the circuit to filter out noise before amplifying the signal. If the data isn't filtered before being amplified, when it is amplified this would include an amplified version of the noise with the signal. Drawbacks to having a circuit filter instead of a software filter are that the filter values are set unless components are physically changed. With a software filter the restrictions of the filter range can easily be changed by modifying the formula used to filter the signal.

**Alternative Design 3**

The third design option involves changing the type of photodetector used. Phototransistors will be used to collect backscattered light from the laser diodes instead of avalanche photodiodes. Phototransistors are a type of photodetector that contains an internal gain. Similar to photodiodes, they take optical signal from a light source (laser diodes in this case) and converts it into an electrical signal. Here, light striking the base of the phototransistor replaces what would ordinarily be voltage in the case of a regular transistor. The phototransistor amplifies variations in the light striking it. This internal gain is a desired property of the phototransistor since the signals involved are of small magnitudes.
In terms of cost, the phototransistor is a more economical alternative than avalanche diodes and photomultiplier tubes. An additional advantage of phototransistors is that in comparison to another self amplifying unit, the avalanche photodiode, the phototransistor produces a lower level of noise. One of the main disadvantages of the phototransistor is the fact that it does not have a particularly good high frequency response. This occurs because of the large capacitance associated with the base-collector junction. This junction is designed to be relatively large to enable it to pick up sufficient quantities of light.

In this design, a common-emitter phototransistor will be used in conjunction with an amplifying circuit (Fig. 1) to generate an output that transitions from a high state to a low state when light in the near-infrared range is detected by the phototransistor. The wavelength range for light in the near-infrared region is about 650 nanometers (nm) to 1100 nm. The output is created by connecting a resistor between the voltage supply and the collector pin of the component. The output voltage is read at the terminal of the collector. It is called an amplifier circuit because the current generated in the phototransistor when light is detected is very small. However, the phototransistor has an internal amplifier which magnifies this current to useful levels.
Since the design requires the detection of two different frequencies, the phototransistor will be operated under active mode. In the active mode the base connection of the transistor is left open or disconnected because it is not required. If the base of the phototransistor is used to bias the transistor, the collector current flow would mask any current flowing from the photo-action itself. This is unwanted because we want the photo-action from the laser diodes to control the transmitted signal not current from the collector of the transistor.

For operating conditions, the bias conditions are quite simple. The collector of an n-p-n transistor is made positive with respect to the emitter of a p-n-p transistor. In this mode, the phototransistor will generate a response proportional to the light received by the component up to a certain light level. When the amount of light surpasses that level, the phototransistor becomes saturated and the output will not increase even as the light level increases. This mode is useful in applications where it is desired to detect two levels of inputs for comparison.