ABSTRACT

AN INFRARED DEVICE TO MEASURE THE EYEBLINK FOR THE STUDY OF CLASSICAL CONDITIONING

By
Alka Patel

The classically conditioned eyeblink response is studied by various groups to study neurological functions. This is a form of associative learning that has many features to help diagnose and learn about neurological diseases. Electromyogram traditionally is used to detect eyeblinks for this experimentation in human. However, EMG can be expensive and difficult to use. It involves the utilization of electrodes and produces only an indirect measure of eyelid closure. The goal of the project was to develop an infrared device to detect eyeblinks and replace the EMG. The project involved two major components, a hardware and a software component. The hardware segment included emitters and detectors to collect the signal and electronics for signal conditioning. The software stored, displayed and processed the data. The aim of this study was to have an inexpensive and facile way of detecting eyeblinks

To prove the reliability and validity of the signal, a small pilot study was conducted where both EMG and infrared were monitored continuously. The signal from the infrared was compared to the EMG signal in terms of reliability, validity and quality of the signal. The pilot study indicated that the infrared signal quality is better than the EMG. The pilot study also proved the infrared signal to be valid and reliable. The system's main goal was to replace EMG system with instrumentation that was less expensive but still reliable.

AN INFRARED DEVICE TO MEASURE THE EYEBLINK FOR THE STUDY OF CLASSICAL CONDITIONING

By
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APPROVAL PAGE

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This thesis is dedicated to my parents
Thank you for your enormous support throughout my life

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CHAPTER 1

INTRODUCTION

1.1 Objective

In modern science, the classically conditioned eyeblink response is a growing method of experimentation to study neurological functions. This is a form of associative learning that has many features to help diagnose and research neurological diseases. The goal of this project was to develop an infrared device to detect an eyeblink for human subjects. This project also aimed at developing a program in the LabVIEW programming language, which would collect and process the signal from the infrared device. The purpose was to develop an apparatus that is less expensive, easier to use and more reliable than the currently used method of the Electromyogram (EMG) which is used at Neurobehavioral Research Laboratory at the Veterans Affairs NJ Health Care System.

The electromyogram has been used to detect an eyeblink. In our lab, although reliable, EMG is expensive because it requires a costly amplifier and electrodes. Also, if EMG electrodes are not placed properly, the signal to noise ratio is low; therefore the use of EMG has been expensive and inefficient. The infrared has also been used in research as a way of detecting eyeblinks. The infrared system used by most researchers utilizes a pair of an emitter and a detector placed in front of the eye[15,1]. There was a comparison done between the detecting methods infrared and EMG. They discovered that both of these methods are reliable and can be utilized to detect eyeblinks[1]. Also there is commercially available product from San Diego Instruments, which utilizes the single emitter/detector pair placed in front of the eye. The purpose of this project was to build an infrared system that is more reliable, facile and is an improvement upon the existing infrared systems. An infrared system does not require any physical contact between the body and the system thus rendering it safer. An EMG system requires patient isolation from ground faults, which also adds to its cost. If it is successful, the infrared system can provide an inexpensive and more efficient way of detecting eyeblinks. At VA NJ Health Care System in East Orange, there is an existing system, which utilizes EMG to detect eyeblink to study classical conditioning. The details of the system will be provided in the later sections. The aim of the project was to improve this system by replacing the EMG with an infrared signal detection instrumentation.

The requirements for the hardware components were to detect an eyeblink through sets of infrared emitters and detectors. The hardware part also involved building of signal conditioning electronics such as the high pass and low pass filters to remove the noise. The gain was provided electronically to maximize the quantization of the A/D conversion card. The software portion of the project required a program in LabVIEW programming language, which provided A/D conversion, display and storage of the signal. The signal was compared with the conventional EMG signal.

1.2 Background Information

1.2.1 Chronic Fatigue Syndrome

The eyeblink conditioning is used to study many brain related diseases such as Parkinson's Disease, Alzheimer's Disease, Chronic Fatigue Syndrome (CFS) and aging[2,4,5]. The eyeblink conditioning system is used to study classical conditioning in CFS patients at the Neurobehavioral Research Laboratory at the Veterans Affairs NJ

Health Care System in East Orange. CFS is a disease characterized by intense and prolonged fatigue that, influences patients' daily activities for more than 6 months[7]. CFS patients feel severe fatigue, which hinders the normal activities, or they are easily exhausted without obvious cause. Other symptoms associated with CFS are sore throat, joint pain, poor sleep, headache, tender lymph nodes, and difficulties with concentration and memory. CFS is difficult to diagnose since the symptoms are similar to many other diseases. In order to diagnose CFS, all other medical conditions associated with the symptoms have to be eliminated. There is no known treatment or cure available for CFS because the cause of the disease is not well understood. However, patients find it quite helpful to treat the symptoms. The aetiology is controversial even though both biological and psychological factors have been suggested[3,7].

In the United States, CFS is diagnosed largely in women. Most CFS patients are 25 to 45 years old even though there are some adolescents and children affected by this illness[1]. However, CFS is found in people of all ages, races, social and economic classes from many countries around the world. Since there is no specific test to diagnose CFS, no one really knows how many people are actually affected by this illness. However, the Centers for Disease Control and Prevention (CDC) estimates that as many as 500,000 people in the United States have CFS or CFS like conditions[7]. Since very little is known about CFS, many scientists are investigating the facts about this disease.

1.2.2 Infrared Radiation

Infrared light has been used to detect many physiological signals in biomedical engineering. It is utilized to detect eyeblinks for the classical conditioning study in this project[1]. Infrared light is invisible electromagnetic radiation with wavelengths that lie within the range of 0.70 to 1000μm. Thus, infrared rays occupy the portion of electromagnetic spectrum with a frequency less than that of visible light and greater than that of most radio waves. The name infrared means 'below the red,' or lower frequency (longer wavelength). Infrared radiation is thermal or heat radiation. Sir William Herschel first discovered infrared in 1800. He was attempting to determine the part of the visible spectrum with the minimum heat associated in connection with astronomical observations he was making. In 1847, A. H. L. Fizeau and J. B. L. Foucault showed that infrared radiation has the same properties as visible light. These properties include the capabilities of being reflected, refracted and capable of forming an interference pattern[6,8].

There are many applications of infrared radiation. Many of these applications are similar to visible light applications. Thus, the spectrum of the infrared light can be used in chemical analysis the way visible spectrum is used. The temperature of an object at a distance can be observed by infrared radiation analysis. Radiometers operating in the infrared range serve as the basis for many instruments, such as heat seeking devices in missiles and devices for spotting and photographing persons or objects in the dark. The medical use of infrared radiation includes a simple heat lamp to the technique of thermal imaging (thermography). A thermograph of a person can show areas of the body where temperature is different compared to normal, thus indicating a medical problem. Recently, scientists have been interested in the field of infrared astronomy. Infrared astronomy consists of sending infrared sensors aloft in balloons, rockets, and satellites to study the infrared radiation reaching the earth from other parts of the solar system.

Infrared radiation is thus used in a wide range of applications due to its properties of reflection, refraction, and absorption etc[6,8].

Infrared is reflected in different amounts depending on the surface. The eye and skin both have different amount of reflection of infrared radiation. Thus, the movement of the eyelid can be detected by the infrared radiation. When an infrared beam is put on the eye, the eye will reflect specific amount of infrared and the skin of the eyelid will reflect a different quantity of infrared light. These differences in reflections produce a signal, which indicates an eye blink. When using infrared devices on humans, the safety becomes a big concern. The US government has safety standards for Maximal Permissible Exposure of infrared. This will be further discussed in a later section.

1.2.3 Classical Conditioning

Classical conditioning represents one of the most basic forms of learning in which a neural stimulus is paired with a stimulus that is known to generate a specific behavioral response. Learning any task requires one to associate two stimuli. For example, if you smell a perfume on somebody, the next time you smell the scent, you will remember that person previously using the scent. Thus, you associated the smell with a specific person. The concept of learning through classical conditioning is studied by many people to learn about the learning process in different diseased conditions.

Ivan Pavlov, a Russian scientist, was studying salivary secretions in dogs when they were fed. When food was placed in the dog's mouth, the dog would salivate. Over time he realized that the dog would salivate with other stimuli also. The presence of the plate or anything that was presented with the food would cause the dogs to salivate. Even the person who brought the food caused them to salivate. The dog, over time, learned to associate the other stimuli with the food. Thus, the dog would salivate even in the absence of the food[16].

The most widely researched example of classical conditioning is that of eyeblink conditioned response[2]. Classical conditioning of eyeblink has been demonstrated in two paradigms: delay and trace. In a delay paradigm, the conditioned stimulus (CS) is presented alone for a set amount of time and then with the unconditional stimulus (US). In the trace paradigm, the CS is given alone for some time and then there is an US presented. There is a gap between the CS and US where no stimuli are present

In classical conditioning, the US causes the automatic or natural response. In Pavlov's experiment, the presence of food is the US. For the human eyeblink conditioning, the US is the puff of air that causes the eye to blink. The natural response of the eyeblink to the US is known as the unconditional response (UR). The salivation of the dog is the UR in Pavlov's experiment. The second stimulus, which is presented with the US, is known as CS. The dish used for the food or the person who brought food is CS in Pavlov's experiment. Whereas, in the eye blink conditioning, the audio tone presented with the puff of air is the CS. Over time, one learns to associate the US and CS when presented together many times. This association will cause a UR with the presentation of CS. This response is known as conditional response (CR).

This type of associative learning is used to study many neurological diseases. Eye blink conditioning is used to study Parkinson's disease, Alzheimer's disease, and chronic fatigue syndrome[2,3,4]. Since eye blink conditioning will require a specific neural substrate to acquire the CR, it is used to research and understand these diseases and the complex mechanisms of the brain.

1.2.4 Current System

There are many experimental apparatus for studying eye blink conditioning. The current system is used to detect eyeblinks via EMG. The goal of the project was to replace the EMG with an infrared device. Once the infrared device was constructed it was compared with the EMG system by running a pilot study using the EMG system. The EMG system consists of three main components: a computer, a hardware component, and the patient interface[7]. A software program is used to control the hardware component. Through a digital output port, the program controls the generation and delivery of the audio stimuli and the puff of air to the patient. The protocol for the classical conditioning experiment uses a tone of 800 Hz for 500ms as a CS and a puff of air for 50ms as the US. An electronic amplifier is used to measure the physiological signals of EMG, ECG and respiration. The data of the signal is transferred from the amplifier to the computer via an Analog to Digital (A/D) converter for storage and further processing[10].

The hardware component generates and controls the audio tone, which is delivered to the subject through a set of headphones. The two different stimuli were generated using the controlling software program and output from the computer through a D/A converter. The output from the D/A converter is passed through an audio amplifier (Model 200 David Clark, Worchester MA). Aviation headphones (Model H10-50 – David Clark, Worchester, MA) were used since these provide large attenuation to ambient noise. The audio amplifier provides final gain and also matches impedance to the headphones. The audio sound levels were calibrated using a sound meter (Model 33-2050-Radio Shack/Tandy Corporation, Fort Worth, TX)[10].

A puff of air is used as an US with the tone. The US has to be consistent and reliable so that it always provides a stimulus with the same intensity. The puff of air is delivered to the eye via a small armature placed 1cm directly in front of the eye. The generation of the puff of air initiates with an air tank with a high precision regulator. The regulator is set at 5 PSI for this stimulus. The regulated air is passed through a filter (Model 9933-11- BX / Balston Inc. –Lexington, MA) to remove small particles. This filtered air is then passed through a computer controlled solenoid valve (Model ET – 2-12 – H- Clippard Instrument Laboratory – Cincinnati, OH). This solenoid opens to fill a small reservoir of a fixed volume (0.0007 cu. ft.). A second computer controlled solenoid valve opens to deliver the puff of air to the eye. The air is delivered to the eye through tygon tubing to the small armature in front of the eye[10]. The armature is placed properly in front of the eye for the puff to be most effective.

The physiological signal of EMG is recorded to detect the eye blink in the eyeblink conditioning system. EMG is a measurement of an electrical potential created by the motor units when the muscle is contracting. Three surface electrodes are utilized to sense the EMG. One is placed above the eye, one below the eye and a third ground is placed on the neck. These electrodes measure the electrical potential created from these muscles when the eye is blinking. A third ground electrode is placed on the neck. The EMG signal is amplified through a battery operated differential amplifier (Model 2283FT, UFI – Morro Bay, CA). The amplifier gain set at 1000 and a low pass filter with cut-off frequency of 10 Hz was used for signal conditioning. A high pass filter at 0.15 Hz cut off frequency was used to remove the DC drift. The filters and amplifier provide the signal to be conditioned and amplify it so that it is easier to work with. Thus, EMG provides a measure of electrical activity of the eye which in turn provides the knowledge of the characters tics of the eyeblink.

CHAPTER 2

SYSTEM INTRODUCTION

2.1 Overview of the System

Infrared is not a new concept for detection of motion in different materials and tissues[15]. It has been used in various applications to sense the motion in the biomedical industry and other industries as well. The surface dependent properties of reflection and refraction allow the detection of motion.

The infrared system for eye blink conditioning consists of two major components. The major component of the system is the hardware design. The hardware design incorporates a circuit that does the detection of the signal and some signal conditioning. The detection is monitored by infrared emitters and detectors, which are mounted on the side of a pair of glasses. Six emitters and seven detectors are mounted on the glasses (See Appendix D for the illustration of the glasses). The movement of the eyelashes and eyelids due to eye blink causes the change of reflection of the infrared; this change causes a signal that is picked up by the detectors. This signal is then passed through a voltage reference to bring the signal to baseline and a high pass filter and a low pass filter to remove a significant portion of the noise and improve the signal to noise ratio. The signal detected is low in amplitude so it requires some amplification. A non-inverting amplifier was built to provide the gain to the signal. The reference voltage, high pass filter, low pass filter and the amplifier were built on a quad operational amplifier.

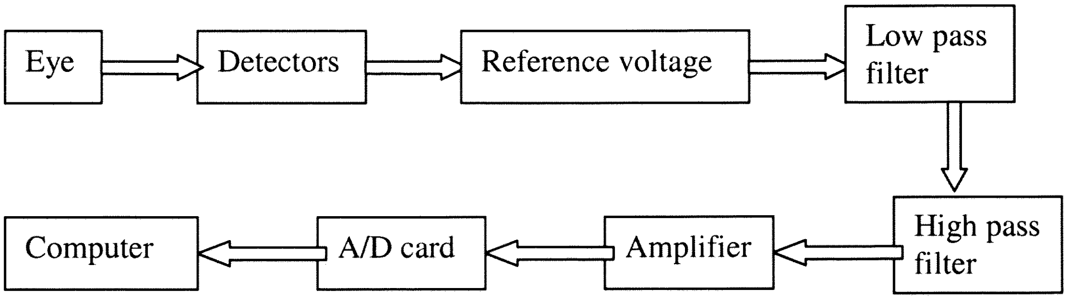


Figure 2.1 Block diagram of the hardware portion of the Infrared System

The signal from the hardware is fed to a computer via a 12-bit analog to digital converter card. The converted digital signal is processed further through a program in LabVIEW. This program saves the data in the computer and plots the data for visualizing purposes. The signal is further processed to find the maximum and minimum of the peaks in the signal. It also involves saving and plotting the puff of air markers and EMG from the current system for comparison. The data saved on the computer can be further processed off-line. The processing can involve calculating mean, duration and latency.

2.2 Hardware Design

2.2.1 Electronics

The hardware segment of the system can be divided into five stages. The first stage is the interface of infrared emitters and detectors with the eye. It also involves the electronics of the emitters and detectors. An infrared emitter gives off infrared rays, which can be reflected according to the surface they encounter. The emitters used in this system is a high output infrared LED from Radio Shack (Model 276-143c). This LED has radiant power of 16mW, forward voltage of 1.2V, forward current of 100mA and viewing angle to half intensity of 45 degrees at 25 degrees Celsius. An infrared detector detects the voltage difference. The detectors are 1mA phototransistor Fairchild infrared detectors (Model 512-L14Q1, Mouser electronics). Both detectors and emitters are mounted on the side of a pair of glasses. These LEDs are utilized to detect the movement of the eyelids from the side. The emitters and detectors are wired in series which sums all the voltage changes to increase the sensitivity of detection. The emitters and detectors both have resistors associated with them that optimize their performance. The resistors are standard quarter watt carbon film resistors. The values were chosen to control the intensity of infrared rays. Similarly, the value of this resistor for the detectors is chosen to optimize the performance of the detectors. After careful evaluation of different resistance value, a best performance yielding value has been chosen (See Figure 2.2 for the circuit diagram of the emitters and detectors interface).

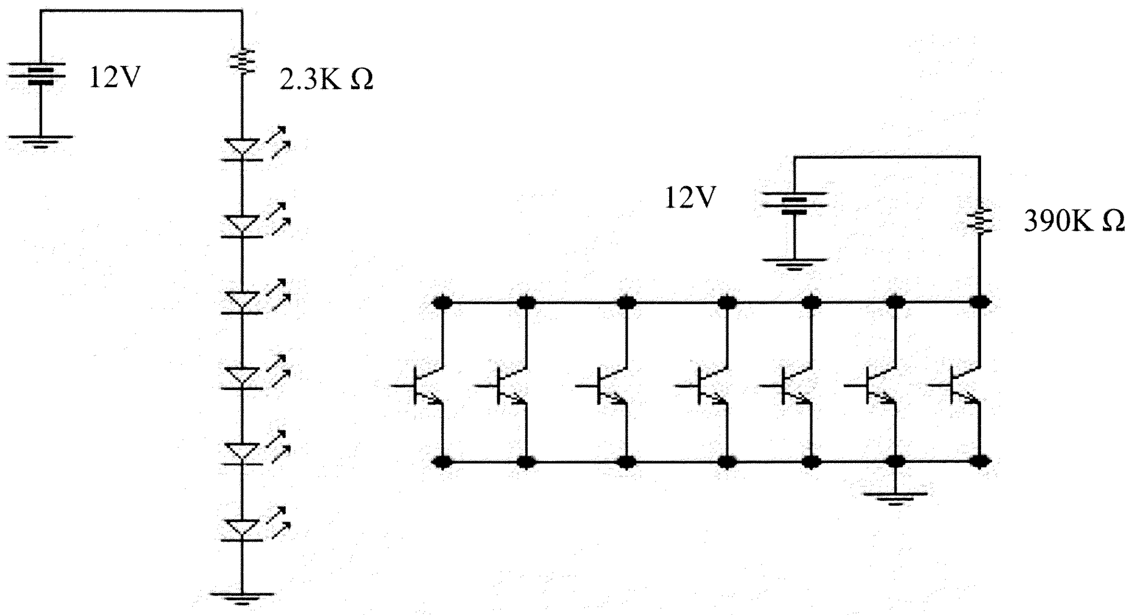


Figure 2.2 Circuit diagram of the emitters and detectors interface

The next four stages of the hardware portion are constructed on a quad operational amplifier. A quad operational amplifier contains four independent operational amplifiers. This was utilized since the signal conditioning electronics had four stages, which required four operational amplifiers. Thus, it would be appropriate to use a quad operational amplifier, which has four independent operational amplifiers on one chip instead of four individual operational amplifiers. This quad operational amplifier consists of four independent high gain operational amplifiers that are internally compensated. It operates over a wide range of voltages and is compatible for both single or dual- ended power supply applications. When provided with proper external components, an operational Amplifier (op amp) could be configured to perform a variety of operations such as addition, subtraction, multiplication, integration and differentiation[9]. An op amp has high input impedance, low output impedance, extremely high gain and large bandwidth. An op amp provides flexibility of building a filter, attenuator, amplifier, and other signal conditioning devices. The infrared system uses a quad op amp (Model 276-1711, Radio Shack) to construct a voltage reference, high pass filter, low pass filter and gain amplifier. A voltage reference is used to bring the signal to baseline and the filters are used to remove the noise embedded in the signal. The detailed characteristics these electronics will be discussed below.

The signal collected from the detectors is passed through a circuit of voltage reference adjustment. In applications requiring higher stability and low noise, a device known as voltage reference is used. This device generates a stable and clean voltage that is insensitive to variation in the power supply voltage. A voltage reference provides a dc voltage whose purpose is to serve as a reference for the whole circuit (See Figure 2.3 for the circuit diagram of the voltage reference). If one wants to compare, it is similar to a tuning fork in a musical instruments.

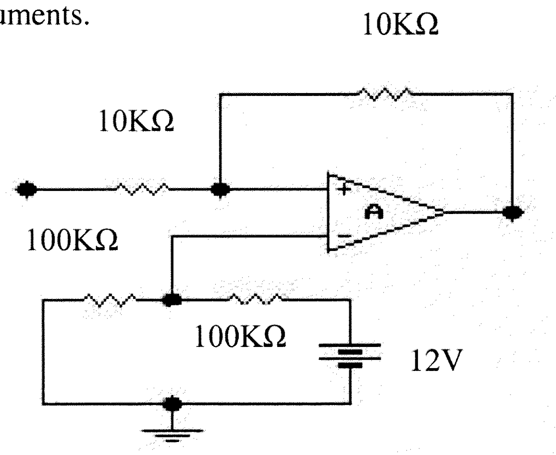


Figure 2.3 Circuit diagram of the voltage reference

In the infrared system, the baseline of the dc voltage lies at 6 volts; to bring the signal to baseline, it required the voltage reference. The range of the A/D card is ±10; thus, if the signal is at 6 volts, it only allows the signal amplification up to 10 volts. It was necessary to bring signal to baseline to provide the gain, which can create a high amplitude signal. Therefore, the signal was passed through a voltage reference and is brought down to baseline. A voltage reference is built on the quad op amp with a potentiometer, as to provide adjustment as necessary. Depending on the baseline, the potentiometer is adjusted for resistance to modify the baseline (See Figure 2.3). Next, the signal is put through filters to remove the unnecessary noise.

A filter is a device that is able to discriminate between the frequencies by passing signals in one frequency band while blocking signals outside the frequency band. For example, a lowpass filter allows lower frequency signal to pass while the higher frequencies are attenuated. A highpass filter does the opposite; it allows the high frequency signal to pass while attenuating the low frequencies. There are two types of filters, active filters and passive filters. A passive filter includes only the passive components of electronics such as resistor, capacitor, and inductors. In a passive filter the gain is always less than one and the output power is always less than input power. An active filter is a filter that includes an operational amplifier with external components. In active filters, output signal can exceed the input signal because of the gain provided through the operational amplifier. The main purpose of the filters is to remove the unwanted frequencies embedded in the signal[9].

A high pass filter is a circuit that is characterized by a frequency f_o called the cutoff frequency. In a high pass filter, all the frequencies higher than the cutoff frequency will pass through without any changes in amplitude, while, all the frequencies below the cutoff frequency are completely attenuated. This is only true for ideal filters, however in reality the cutoff does not decrease sharply so it does not always remove the exact frequency that is chosen as cutoff frequency[9]. The signal after the voltage reference is passed through an adjustable cutoff frequency high pass filter. A high pass filter is used to remove the very low DC noise.

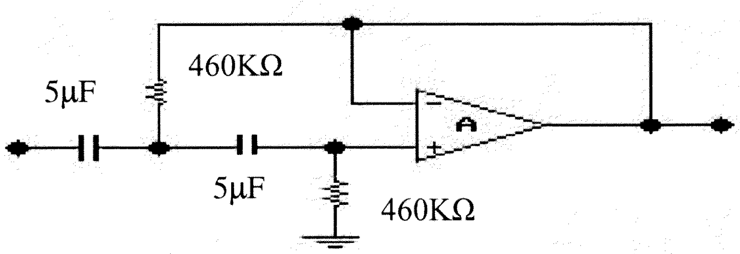


Figure 2.4 Circuit diagram of highpass filter

The resistors of the high pass filter are dual potentiometers. The values of the resistance are adjusted according to the need of the cutoff frequency. During the testing phase, the filter needed to be adjustable so that cutoff frequency could be changed according to the signal. The final value of 460K Ohms was determined for the highpass filter. The capacitors used for this filter are 5 μF polyester capacitors. The cutoff frequency is calculated by the values of the resistor and the capacitor. The formula used for this calculation is $F_o = 1/2\Pi RC$. The cutoff frequency is set to 0.069Hz in the high pass filter of the infrared system. The intention was to have a cutoff frequency of 0.05Hz; however, the values of the exact components needed were not available. Thus, using the available resistor and capacitor values the cutoff frequency of 0.069Hz was achieved. The intention of this cutoff frequency is to remove the DC noise that is merged with the signal[9]. For example, if the subject has an itch while the experiment is running, then there would be a noise due to the movement of the subject.

A low pass filter was also built on the same quad op amp. Low pass filter response is also characterized by a frequency f_o (cutoff frequency). In a low pass filter, all the frequencies below f_o are passed through with unchanged amplitude, while anything above the cutoff frequency is attenuated[9]. Similar to high pass filter, this is true only for an ideal filter. In reality, the cutoff frequency comes down slowly creating a slope. Thus, the fall off is not sharp and has a slope that will pass the frequencies immediately after the cutoff frequency. The signal from the high pass filter is fed to the low pass filter. Low pass filter's major purpose is to remove the high frequency noise embedded in the signal. There is noise from other electronics and electrical lines which cause the 60 Hz noise in the signal. One of the key functions of the low pass filter is to remove the 60-cycle noise.

The capacitors used for the low pass filter are 34nF polyester film capacitors The low pass filter also uses a double gang potentiometer, which allows the cutoff frequency to be adjustable (See Figure 2.5 for the circuit diagram of lowpass filter). The value was determined to be 436K Ohms for the resistors which would be optimal for wide range of subjects.

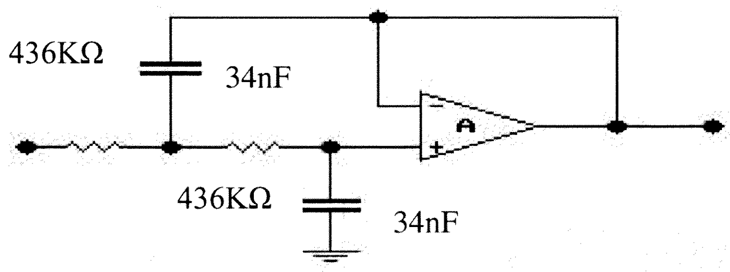


Figure 2.5 Circuit diagram of the lowpass filter

The cutoff frequency for the low pass filter is 10.73 Hz. The desired cutoff frequency for the low pass filter was 10Hz. However, the exact component values required to achieve this were not available. Thus, using the available components the cutoff frequency of 10.73Hz was achieved. In the evaluation of the circuit, it was difficult to see where the cutoff frequency should lie. Hence, it was important to have easily adjustable cutoff frequency.

The filtered signal from the low pass filter is very low in amplitude. For further processing, plotting and for storing purposes, the signal needs amplification. The signal is passed through an amplifier. An amplifier is built on the quad op amp that has an adjustable gain. It allows the signal amplitude to be multiplied by the ratio of gain resistors ($1+R_2/R_1$).

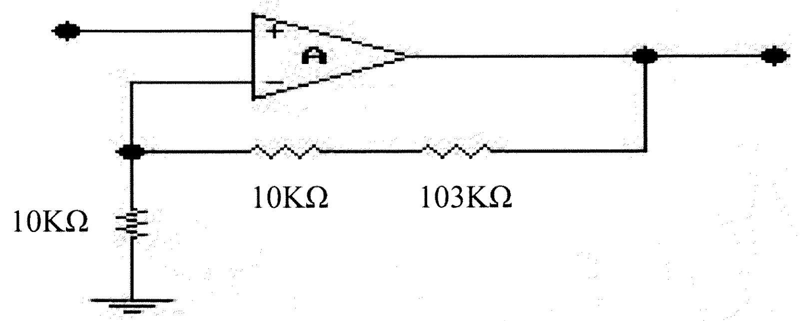


Figure 2.6 Circuit diagram of the amplifier

The amplifier has a gain that can be adjusted from 1 to 100 (See Figure 2.6 for the circuit diagram or the amplifier). This allows the gain to be adjusted according to the signal acquired from specific subject. For example, if a subject has a low signal that has peak amplitude of the signal below 2volts, then the gain is increased to increase the signal amplitude. Thus, 2volts is used as a threshold point; if the peak of the signal is below 2volts then the gain is increased. If the peak of the signal is above 2volts then the gain is not altered. This feature was necessary during evaluation since the signal characteristics were unknown. The intention was to acquire a gain that would work over wide range of subjects. After the evaluation a gain of 11.3 was acquired as the final gain that works over a wide range of subjects.

2.2.2 Analog to Digital Converter

The signal collected from the detectors and filtered with the electronics is an analog signal. The signal needs to be digital for it to be stored and processed further in the computer. The computer used was an IBM compatible Pentium III PC. The digital computer cannot store and process a continuous time signal. The signal must be sampled and the samples can be stored and processed in the computer. An Analog to digital (A/D) converter card can perform the sampling and conversion of an analog signal to digital signal. The computer controls an A/D card, where the user provides the sampling rate for the conversion. The sampling rate must satisfy the sampling theorem, which states that the sampling rate must be at least twice the highest frequency present in the signal[12]. The sampling rate of 100 samples/sec was chosen for the infrared system. The infrared signal has frequency range of 3 to 7 Hz; thus the sampling rate of 100 samples/sec satisfies the sampling theorem. The rate chosen is higher than required but the intentions for the signal processing were to calculate durations and latencies. Thus, it was necessary to have a high resolution as to be accurate on the latencies and duration measures.

The A/D converter performs two functions on the analog signal. One is the sampling operation described above and the other is the quantization operation. The computer cannot store the amplitude of the signal in volts; it can only store the points as zeros and ones (binary number). Therefore, the signal must be converted into binary form[12]. The A/D card used for the infrared system is National Instrument 12 bit A/D card. This card uses successive approximation method of conversion. The card has a resolution of 12 bits over a range of ± 10 volts. The digital signal after the conversion through an

A/D card is stored and processed through a software program in the LabVIEW programming environment.

2.3 Software Design

2.3.1 Introduction to LabVIEW

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) is a programming language based on graphical representations and the notion of data flow programming. This programming language is widely accepted by the industry, academic institutions, and research laboratories around the world for data acquisition and processing. The three primary components of this programming language are data acquisition, data analysis, and data visualization. LabVIEW contains functions that perform particular applications. This has a great advantage to the scientists and engineers since it cuts down the time they need to spend on the development of the application. The functions of LabVIEW are called Virtual Instruments (VIs). VIs allow recording, processing which involves mathematical functions, and visualization of the incoming data. LabVIEW contains a library with all the function available according to categories and subcategories. The VIs contain input and output ports, which allows the user to input necessary parameters for the function they want to execute. Thus, a particular VI can do a very difficult mathematical function when provided with the input parameters and the signal[11].

2.3.2 System Configuration

LabVIEW programming environment has two interfaces. There is a front panel, which is also known as the user interface. The front panel consists of the plots of the data and other input parameters that are to be altered by the user. The major purpose of the front panel is for the user to visualize the performance of the program and to alter the user parameters when necessary. There is also a block diagram panel, where the actual program exists. This panel contains all the VIs that are connected to perform the desired functions in the program. The VIs are connected with wires through which data flow takes place[11].

The digital signal is input to the LabVIEW program, where it is plotted for visualizing and stored in the computer. The signal is also input to a loop where the VIs are connected to find threshold and duration of the peaks of the signal. The beginning of the program is assembled to set the parameters for communications between the software and the hardware of the system (refer to Appendix for detailed program code). The AI configuration VI allows the programmer to set up channel specifications and buffer size[11]. There were three channels used in this program; one is used for EMG, the second for air puff delivery marker and the third for infrared signal. Buffer size is the storage location where the data is continuously acquired and retrieved. If the rate at which data is retrieved is slower than the rate at which it is acquired the buffer will fill up. When buffer fills up, LabVIEW over writes the data. Therefore, the buffer size should be chosen carefully to prevent such problems. For this program, the buffer size was set to1000 scans. The sampling rate of 100 samples/sec is chosen. Thus, every second 100 samples are placed in the buffer. The scan rate at which LabVIEW acquires data from the buffer is set to infinite. Thus, it acquires all the samples in the buffer. Therefore, the buffer size was not a vital parameter since every second all the data will be acquired by the program. The size of 1000 scans was chosen just to have a buffer size that was larger than the sampling rate and the scan rate of acquisition from the buffer.

The next VI in the program is AI start, which sets the rate at which the data is placed in the buffer. The AI start VI sets up the sampling rate, which is specified by the programmer[11]. The sampling rate must satisfy the sampling theorem which states that the sampling rate should be twice the highest frequency embedded in the signal. The sampling rate chosen for the infrared system is 100 samples per second meaning 100 samples are stored per each second. The frequency of the infrared signal is calculated from the duration measures which provided period (T) of the signal. The frequency of the signal is 1/T. The frequency of infrared signal is between 3 to 7 Hz so the sampling rate does not have to be high. The sampling rate of 100 samples/sec was chosen because it would satisfy the sampling theorem after encompassing all the frequency present in the signal and also the EMG required this rate. The lowpass filter is set at 9.36Hz thus, the frequencies higher than 9.36 Hz is attenuate. Therefore the highest frequency present is 9.36Hz. Therefore, it is certain that the sampling theorem is satisfied.

The signal is passed to a VI called AI read from the AI start. AI read retrieves data from the buffer and takes it in a loop where further processing takes place. The three channels are separated after the AI start VI; the EMG and the air puff marker channels go to VIs for storage and display while the infrared signal goes for further processing. The airpuff and storage signal are not processed further in the LabVIEW program. The infrared signal is put through a VI where it is multiplied by –1 to invert the signal since the signal is a downward signal. In order to compare it with EMG, which is an upward signal it was necessary to have the consistency between the two signals' directions. Once inverted, the signal is displayed on the front panel and stored. This signal is put through additional VIs to get the maximum, minimum and duration of the signal. These parameters were achieved by placing the signal through a threshold detector, and max/min VI (See Appendix A for the block diagram of the LabVIEW program). These values are also stored for further analyzation.

2.4 Safety Factors

Safety is an important issue when designing any device that deals with medical research. When collecting physiological signals, the subject needs to be connected to the physiological amplifier through an electrode-skin interface. This involves the risk of electric shock since the subject is now part of an electric circuit. This situation can be very dangerous and deadly. To prevent this hazardous condition, an isolation transformer is placed between the electrodes and the physiological amplifier and other electric devices. An isolation transformer isolates the patient from becoming a part of the electric circuit by preventing a path from the electrical system to ground through the patient. When measuring the EMG, it is vital to have a medical isolation transformer since electrodes will be connected to the subject. In the infrared system, there is no direct connection between the subject and the electronics of the system. Therefore, the risk of electric shock is eliminated. The system has emitters and detectors that pick up the signal without direct connections. Hence, the system is safer in terms of electric shock hazards, however infrared radiation can be dangerous to the skin and eye if excessive exposure is presented.

The government has set up safety standards of how much infrared radiation can be shone on the skin and the eye. All medical devices that involve infrared exposure on a human body must abide by these standards. For the exposure duration of the infrared device the government standard suggests to remain below $1.58 mW/cm^2$ [11]. The infrared system for eye blink conditioning also complies with these standards. The infrared radiation involved in this system is much lower than the standards set by the government. The infrared radiation in this system is $0.365 mW/cm^2$ [13], which is significantly lower than the safety standards. Also there is commercially available product by San Diego Instruments, which serves the same purpose as the infrared eyeblink conditioning system[4]. It is also a device to detect eyeblink by shining infrared radiation. It utilizes one pair of emitter and detector placed in front of eye to detect the eyeblinks. This system is extremely position sensitive since the boom must be placed right in front of the eye. The San Diego Instruments device outputs infrared radiation of $0.4 mW/cm^2$, which is higher than the infrared eyeblink conditioning system. Thus, the system not only abides by the government standards but also is safer than the commercially available product in the market.

CHAPTER 3

SYSTEM UTILIZATION

3.1 Protocol

All medical devices need to be reliable and safe. It is part of the design for an engineer to check the performance of the system they build. To check the performance and reliability of the infrared system, a simple experiment was conducted. The experiment involved both the infrared system and the currently used EMG system. Two computers were engaged in the delivery of the stimulus and data collection. The current system was used to deliver the stimulus (air puff) and also to measure the EMG; both EMG and air puff markers were recorded in both the infrared system and the current system.

The experiment was 13 minutes long with 30 trials. Each trial consisted of a stimulus of a puff of air for 50 ms. The airpuff system was used to force the subject to blink in a similar way to the conditioning experiment described in chapter one. The 30 trials had random inter beat interval from 15 to 25 seconds. To see if the system can detect weak blinks compared to the strong blinks the pressure of the puff of air was altered. During the first 10 trials, the pressure of the air was set to 5psi; next ten trials were done at 4psi and the final 10 trials were at 3psi. The system performance and reliability was evaluated at three different pressures.

3.2 Procedure

Six healthy subjects with different head and face sizes were chosen to participate in this experiment. The face and head sizes were evaluated just by visualizing. The subjects were between the ages of 22 to 35 years old. There were two females and four males participating in this experiment. Since the detectors are on the side of the glasses, different depth of the eye would affect the performance of the system. To evaluate the system at different eye depth, the subjects were chosen with various head and face sizes.

The experiment was 13 minutes long and the preparation for the experiment was five minutes long. Two signals were recorded continuously for detection of the eyeblink, the EMG and the infrared signal. The subject was instrumented with both the EMG system and the infrared system. Prior to the instrumentation of the subject, an air puff test was performed by the system to check the intensity of the stimulus. For the measurement of the EMG, there were three electrodes involved. One electrode was placed above the eye and the second electrode was placed on the cheek below the eye. The third, ground electrode was placed on the neck. The skin was cleaned with sterile wipes before placing the EMG electrodes. The electrodes utilized were Ag/AgCl neonatal ECG electrodes. Figure 3.1 shows an example of an eyeblink from a raw EMG signal

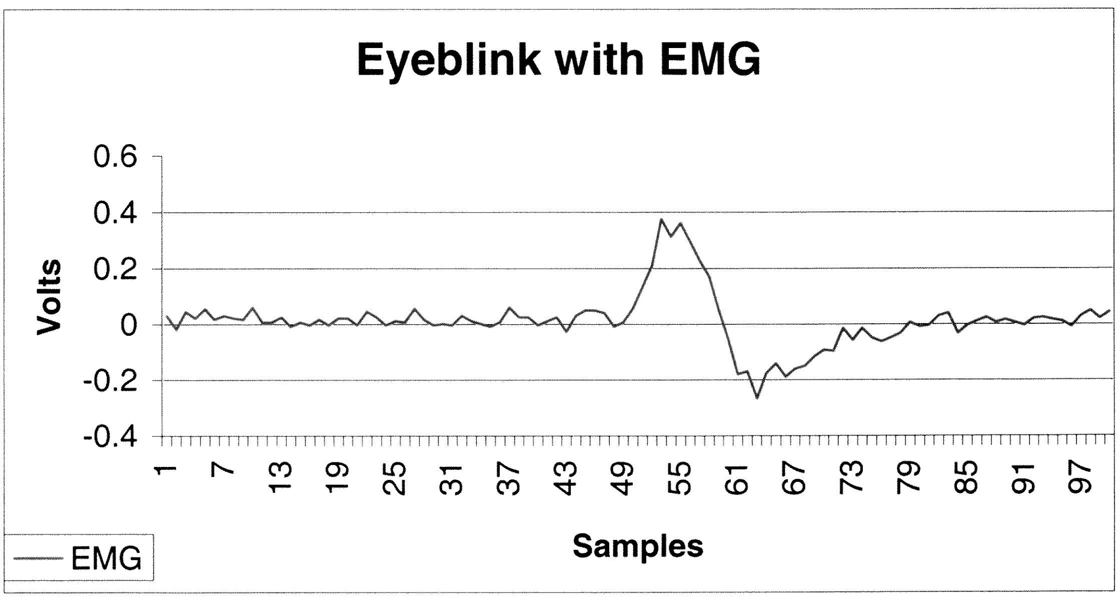


Figure 3.1 Example of an eyeblink from a raw EMG signal

The infrared signal involves a pair of glasses with emitters and detectors on the side to detect the eyeblinks. The subject was asked to wear the glasses and move them around for comfortable position. To provide the air puff stimulus, a set of headphones with a small armature in front of the eye was placed on the subject's head. The armature was adjusted to have it right in front of the eye to have a strong intensity stimulus. The infrared system is sensitive to ambient light. To address this problem, direct sunlight exposure was eliminated by pulling the shades down. The subject was asked to relax and be comfortable. Figure 3.2 illustrates an example of Infrared eyeblink signal.

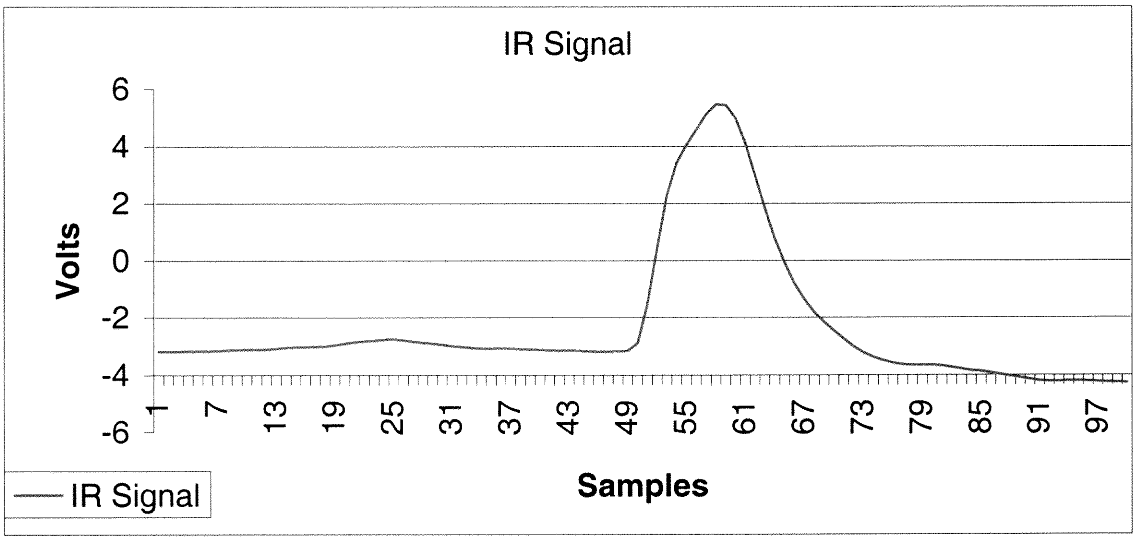


Figure 3.2 Example of eyeblink from a raw infrared signal

3.3 Data Collection and Processing

The signals were collected and stored via the software program for further processing. They were digitized at a sampling rate of 100 samples/second for both EMG and infrared signals. The marker channel of the air puff stimulus was also collected at the same sampling rate. The marker channels and EMG were collected through the EMG system and the infrared system. The data was stored in ASCII format. For further processing to provide a good comparison between EMG and infrared, the data was transferred to Microsoft Excel. In order to do further analysis in LabVIEW, the program would have to be expanded to do the analysis. Microsoft Excel provided a simple way of analyzing the data for the signal. Thus, Microsoft Excel was utilized to do further analysis.

The data files were matrices and were opened in the Microsoft Excel. The data processing began with the air marker data. Each row was plotted to identify the onset of the air puff. The airpuff is a signal that is 50ms long and has an amplitude of 5volts. Thus when the signal goes above 1volt in amplitude; the onset is identified. The onset of the air puff informs that an eyeblink should be occurring following the stimulus. Once all the onset rows are recorded, the infrared data files were opened next. The rows with the air puff markers were checked in the infrared data to see if there was an eyeblink following the air puff. Also, to obtain further information about the eyeblink, the x-y coordinates of the onset, offset and the peak of the infrared signal were documented. The onset, offset and the peak are shown in figure 3.3 for the infrared signal.

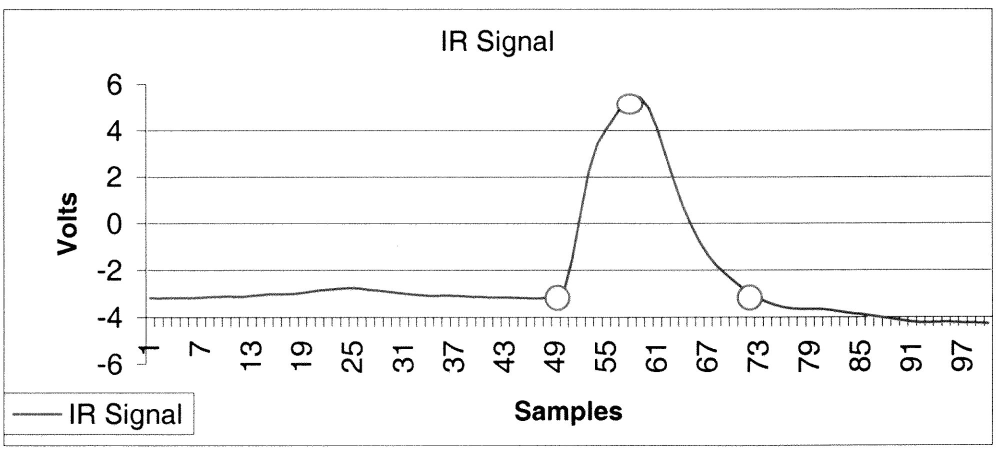


Figure 3.3 An example of onset, offset and peak of the infrared signal

The amplitude range of the noise present in the signal was also recorded to attain signal to noise ratio (SNR). The SNR is the ratio of the amplitude range of the signal to the amplitude range of the noise present in the signal. This was calculated by acquiring the amplitude range of the signal and the average amplitude range of the noise present just before the signal. The ratio of this two provided the signal to noise ratio.

The same steps were followed with the EMG signal. Each row with the air puff marker was checked to see if the signal was present from the eye blink. The x-y coordinates of the onset, offset and the peak of the EMG signal were also documented. The onset, offset and the peak of the EMG signal are shown in figure 3.4.

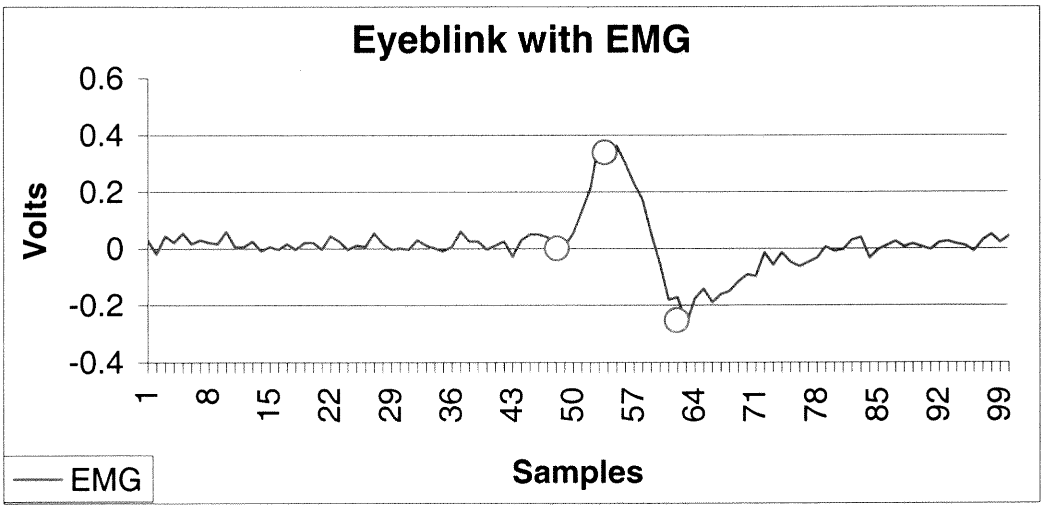


Figure 3.4 An example of onset, offset and peak of the EMG signal

Once all these data points were obtained, there was a spreadsheet generated in Excel to do further processing. There were three measurements of interest accomplished from these data points. Duration of the signal, latency, and signal to noise ratio were the measures attained from the data points. The duration and latency values were calculated to validate the signal of infrared. This would be discussed in details in the later chapters. The duration was obtained by subtracting the x coordinates of onset from the x coordinates of the offset of the signal. The latency was obtained by subtracting the x coordinate of onset of the signal from the x coordinate onset of the air puff. The signal to noise ratio was calculated by dividing the amplitude range of the signal by the amplitude range of the noise. The amplitude range of the signal was calculated by subtracting the y coordinates of the onset of the signal from the y coordinate of the peak of the signal. The range of noise was acquired by getting the average maximum and minimum of the noise just before the onset of the signal. By dividing the amplitude range of the signal and amplitude range of the noise, the signal to noise ratio was acquired. To compare the EMG and the infrared signal, the same measure of each signal was plotted on the same graph to see the differences present (The graphs are present in the next chapter). Also, the mean and standard error of the latency, duration and signal to noise ratio is calculated and graphed for further comparison.

CHAPTER 4

RESULTS AND CONCLUSION

4.1 Results

The comparison between the infrared and the EMG system was done in terms of validity, reliability and the quality of the signals. Three parameters were compared to fulfill this objective. The reliability of the signal was confirmed by observing the blinks that were missed by the either system. It was concluded that if both systems do not detect any signal for an eyeblink, the subject did not blink. If one of the systems detected an eyeblink while the other system did not then the system is said to have failed in the detection process. This affects the reliability of the system. The following table (Table 4.1) summarizes the performance of both systems in terms of reliability measures. The table combined all the trials from all the subjects. Therefore, six subjects with 30 trials each resulted in a total of 180 trials that are used for assessment. This table shows that the infrared system missed one blink while the EMG system missed five blinks. This parameter will be discussed further in the conclusion section of the paper.

Table 4.1 Reliability measures

	EMG SYSTEM	INFRARED SYSTEM
# OF TRIALS PRESENTED	180	180
# OF TRIALS DETECTED	170	174
# OF TRIALS MISSED BY ONLY ONE OF THE SYSTEM	5	1
#OF TRIALS MISSED BY BOTH SYSTEMS	5	5

The validity of the signal was verified by the duration and latency of the signals. It was expected that the electrical signal of the muscle activity occurs before the actual mechanical movement of the eyelids. Thus one would expect to observe the EMG onset before the onset of the infrared. This can be confirmed by the latency measurement. The latencies observed of the EMG signals were less than the latencies in the infrared signals (see figure 4.1 to 4.6). The figures verify our hypothesis and endorse the validity of the signal. The mean of the latency for infrared is higher than for EMG and the standard error is similar which adds to the advantages of infrared (See Figure 4.7). The validity of the signal assists in the determination of the performance and reliability of the infrared system.

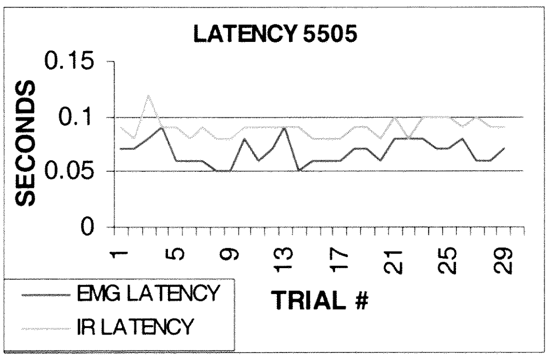


Figure 4.1 Latency of EMG and Infrared Signal of subject 5505

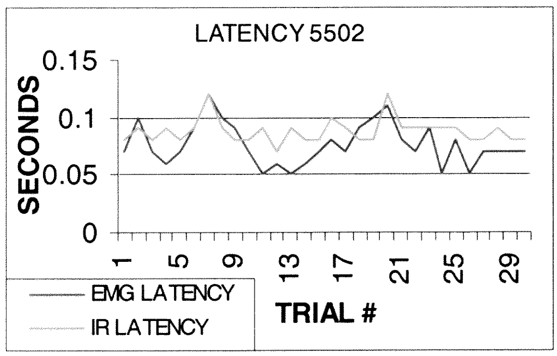


Figure 4.2 Latency of EMG and Infrared Signal of subject 5502

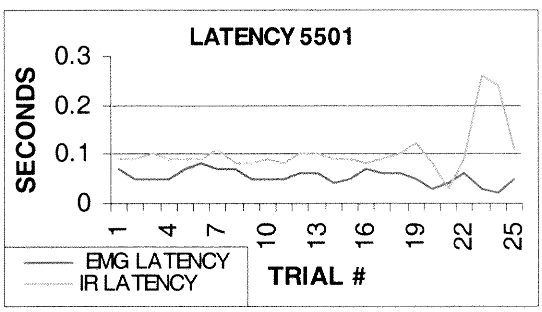


Figure 4.3 Latency of EMG and Infrared Signal of subject 5501

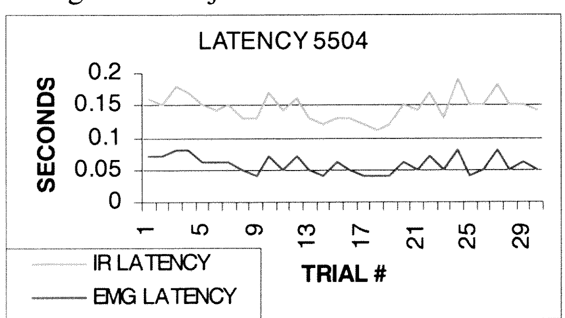


Figure 4.4 Latency of EMG and Infrared Signal of subject 5504

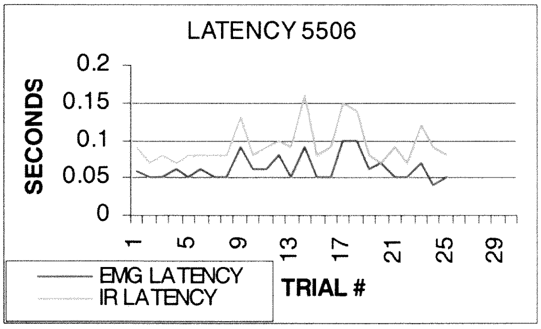


Figure 4.5 Latency of EMG and Infrared Signal of subject 5506

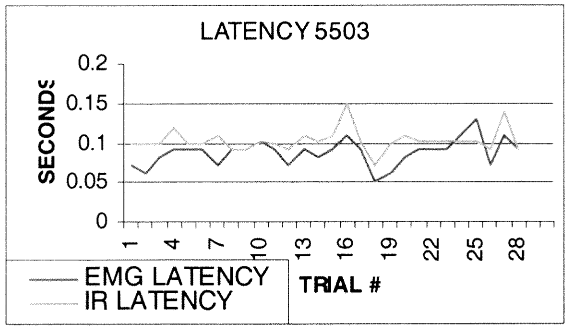


Figure 4.6 Latency of EMG and Infrared Signal of subject 5503

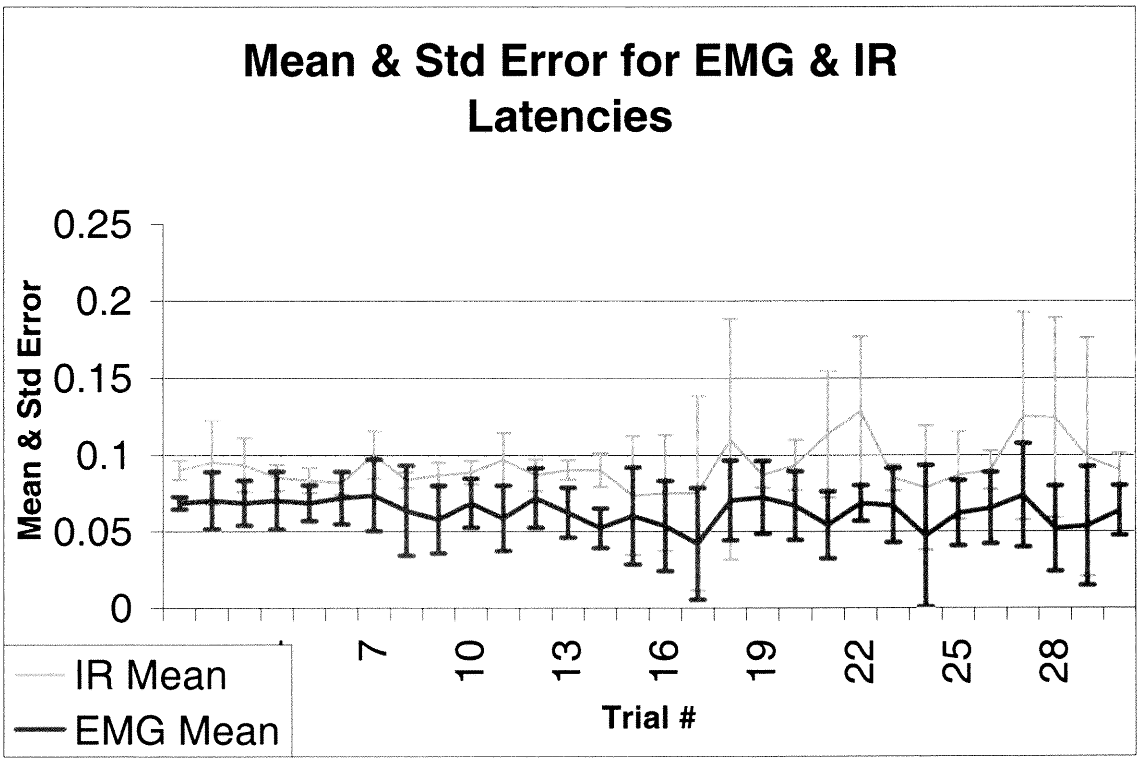


Figure 4.7 Mean and Standard Error of EMG and Infrared for Latency

A t-test was performed on the latency measure. This test took all the 180 trials and gotten a mean and standard error for them. The graph below will show the difference in the mean and standard error of the EMG and the infrared signal. The p-value for this is p<0.001; thus, the confidence interval is 99.9%. This shows that there is statistically significant difference between the EMG latency and the infrared latency.

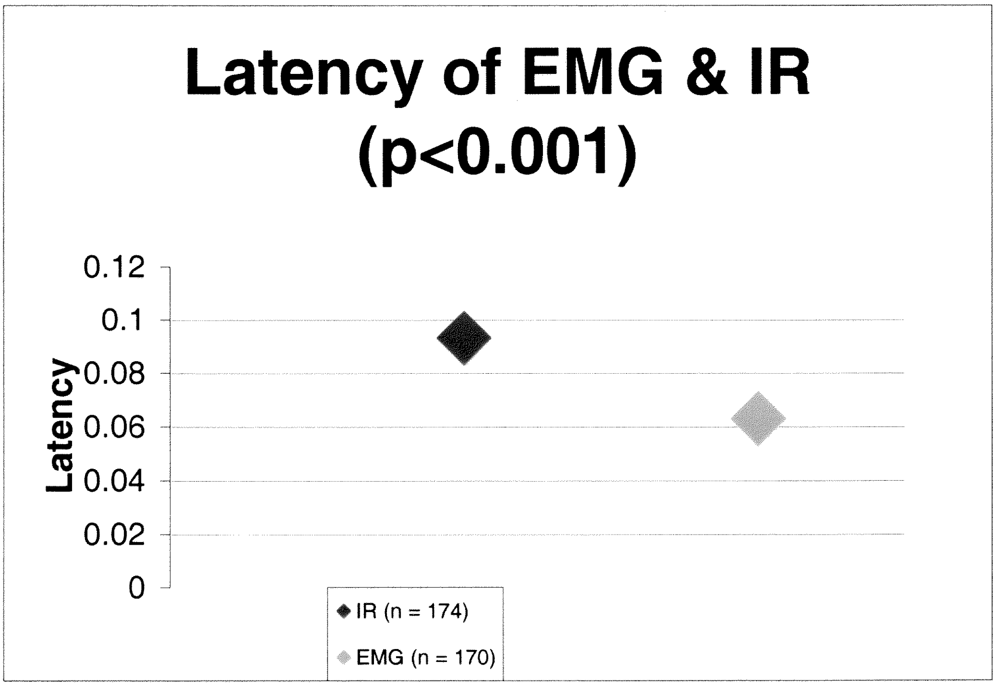


Figure 4.8 T-test for the EMG and infrared signal latencies

The duration of the signal is defined as the length of the eyeblink in the infrared signal and the length of electrical activity in the muscle in the EMG. It is understood that the length of the electrical activity would be shorter than the actual mechanical movement of the eyelids. Therefore, it was expected that the duration for the infrared signal would be longer than the EMG signal duration. This is verified by the figures below (see figure 4.9 to 4.14). The figures for duration further validate the infrared system.

below (see figure 4.9 to 4.14). The figures for duration further validate the infrared system.

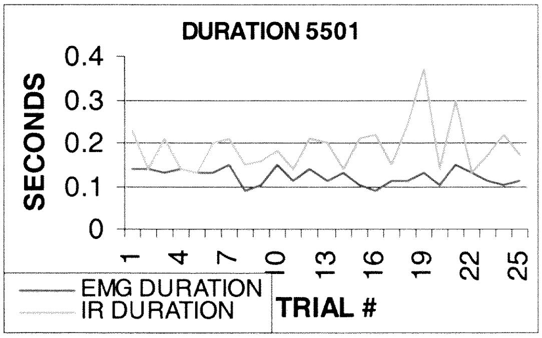


Figure 4.9 Duration of EMG and Infrared Signal for subject 5501

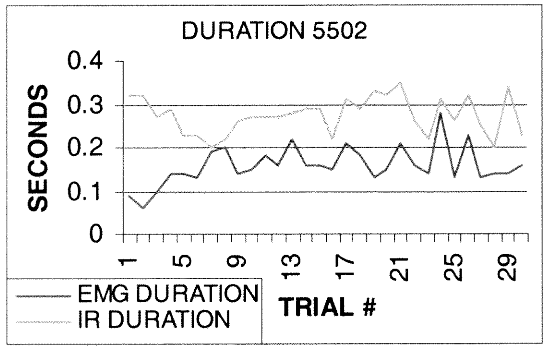


Figure 4.10 Duration of EMG and Infrared Signal for subject 5502

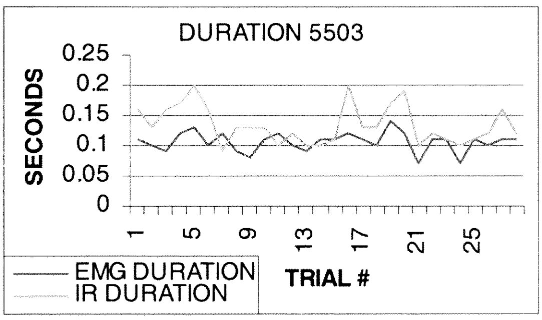


Figure 4.11 Duration of EMG and Infrared Signal for subject 5503

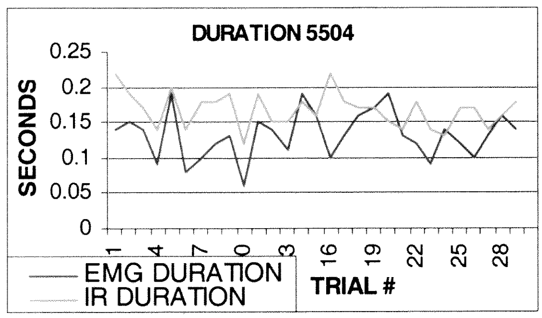


Figure 4.12 Duration of EMG and Infrared Signal for subject 5504

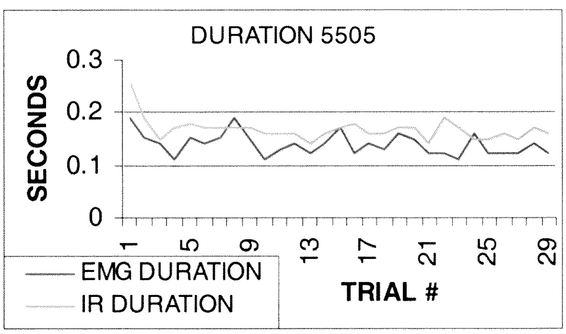


Figure 4.13 Duration of EMG and Infrared Signal for subject 5505

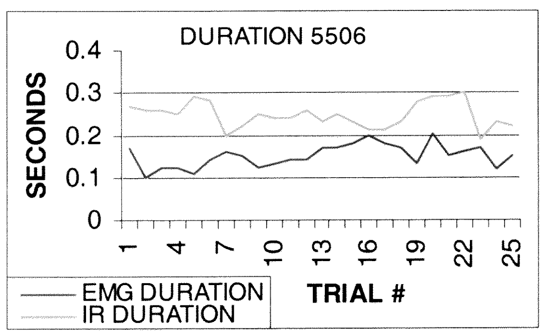


Figure 4.14 Duration of EMG and Infrared Signal for subject 5506

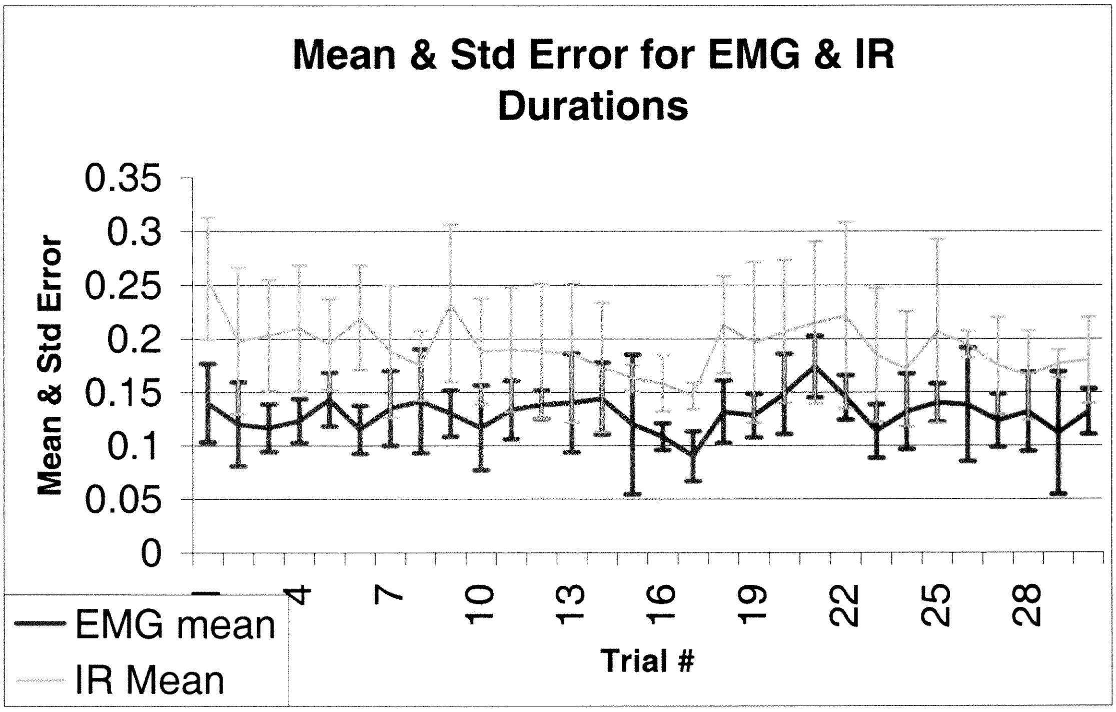


Figure 4.15 Mean and Standard Error of EMG and Infrared for Duration

The mean and the standard error provide a good measure of comparison (See figure 4.15). The mean of the infrared is higher than the EMG, however the standard error is little higher too, which is a small drawback of the system. A t-test was also performed for the measure of duration. This was to provide further evidence that the duration of the EMG is shorter than the duration of the infrared signal. The p-value for the test is P<0.001, which states that the confidence interval is 99.9%. The graph below states that there is statistically significant difference between the duration of the EMG and the duration of the infrared signal (See Figure 4.16).

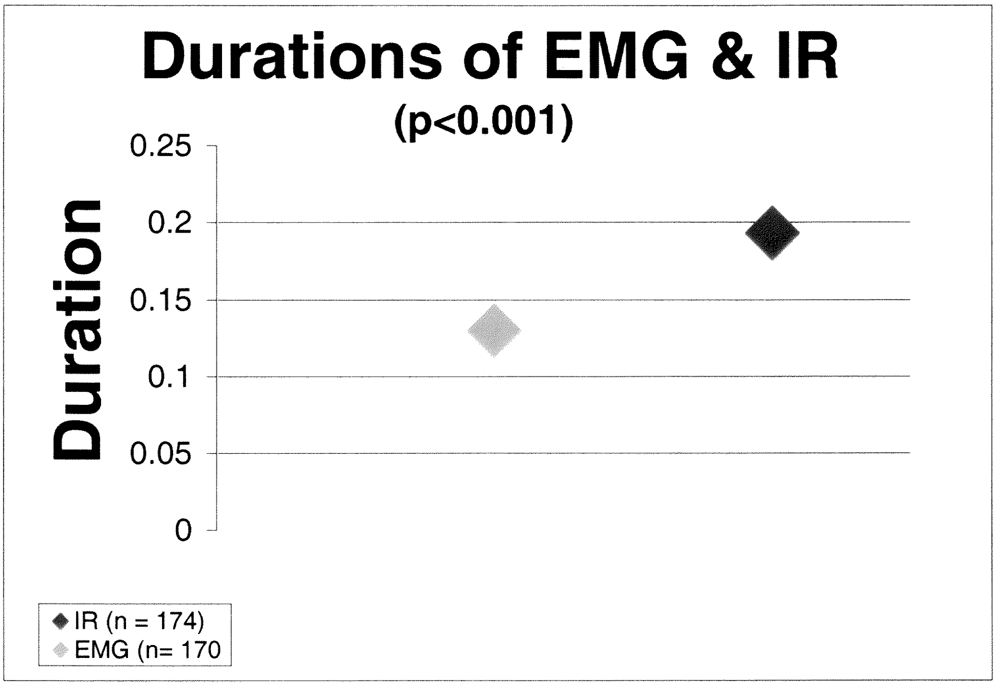


Figure 4.16 The T-test for the EMG and the infrared signal durations

The signal to noise ratio was used to determine the quality of the signal. A signal can have a large amount of reliability and validity but if the signal is of low quality, it is hard to process and analyze that signal. The signal to noise ratio provides a measure of the quality since noise can be a big problem for signal processing. The signal to noise ratio gives an indication of the noise present in the signal. A high signal to noise ratio would indicate a significant difference between the signal amplitude range and the amplitude range of the noise. Thus it is easier to process and analyze this signal. The following graphs indicate the difference between the signals to noise ratios of the two signals (see figure 4.17 to 4.22). They indicate that there is a large difference in the signal to noise ratio of the two signals. In every subject, these results indicate that the infrared system has a higher signal to noise ratio compared to the EMG system.

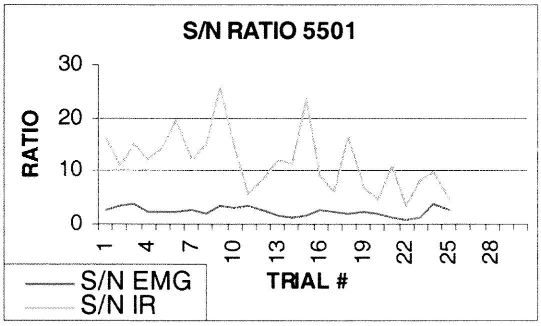


Figure 4.17 S/N Ratio of EMG and Infrared Signal for the subject 5501

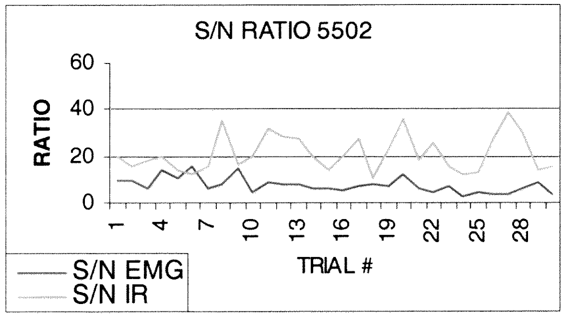


Figure 4.18 S/N Ratio of EMG and Infrared Signal for the subject 5502

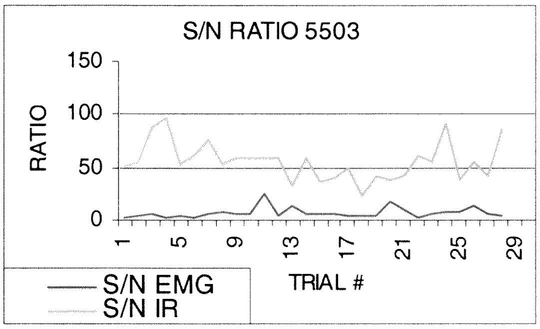


Figure 4.19 S/N Ratio of EMG and Infrared Signal of subject 5503

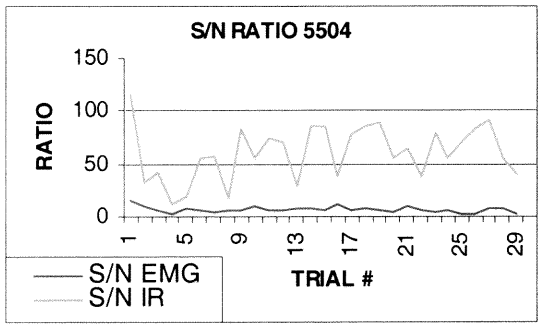


Figure **4.20** S/N Ratio of EMG and Infrared Signal of subject 5504

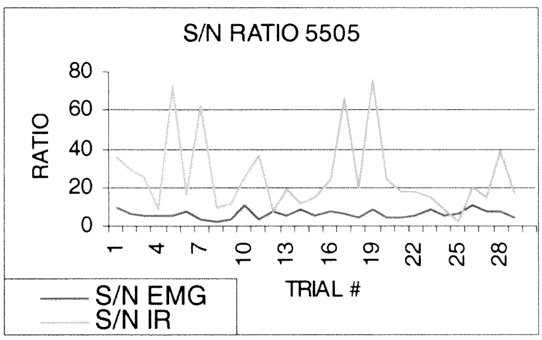


Figure 4.21 S/N Ratio of EMG and Infrared Signal of subject 5505

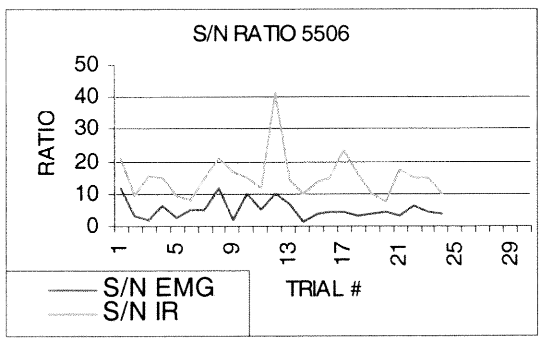


Figure 4.22 S/N Ratio of EMG and Infrared Signal of subject 5506

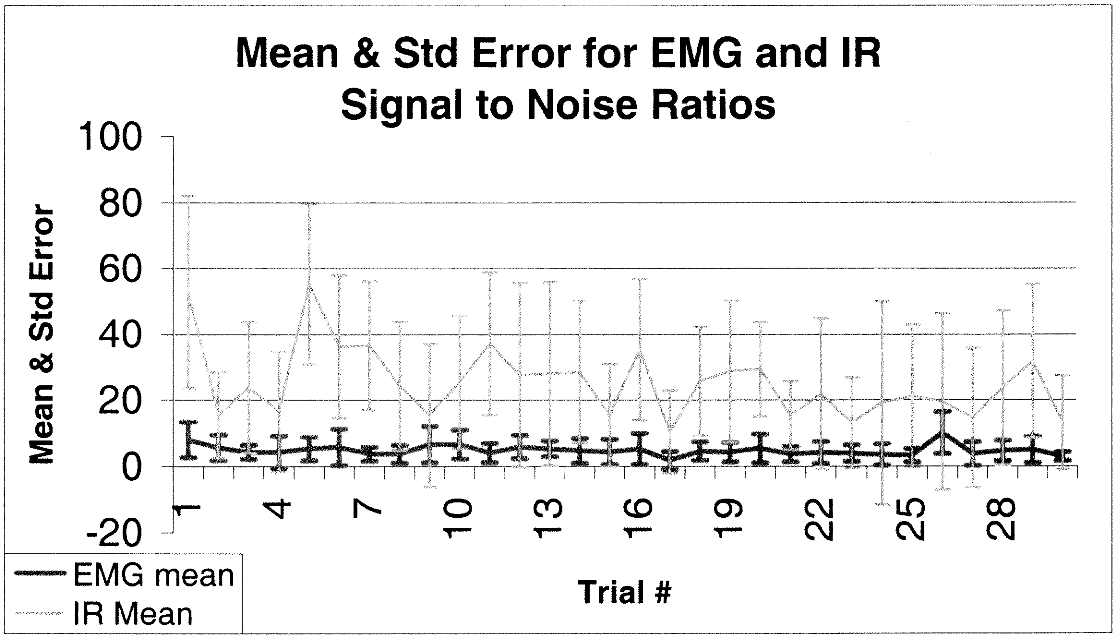


Figure 4.23 Mean and Standard Error of EMG and Infrared for S/N Ratio

The mean for S/N ratio for infrared is greater than the EMG but the standard error is also higher. The EMG has lower mean but also has lower standard error. The higher error rate is due to the variability in the signal intensity. Nonetheless, the infrared signal has much higher signal to noise ratio thereby improving signal processing abilities. This is further evident in the graph below of the t-test. The t-test averaged all the 180 trials and calculated the mean and standard error. The p-value is $P<0.001$, which shows that there is a statistically significant difference between the signal to noise ratio of EMG and the infrared signal (See Figure 4.24).

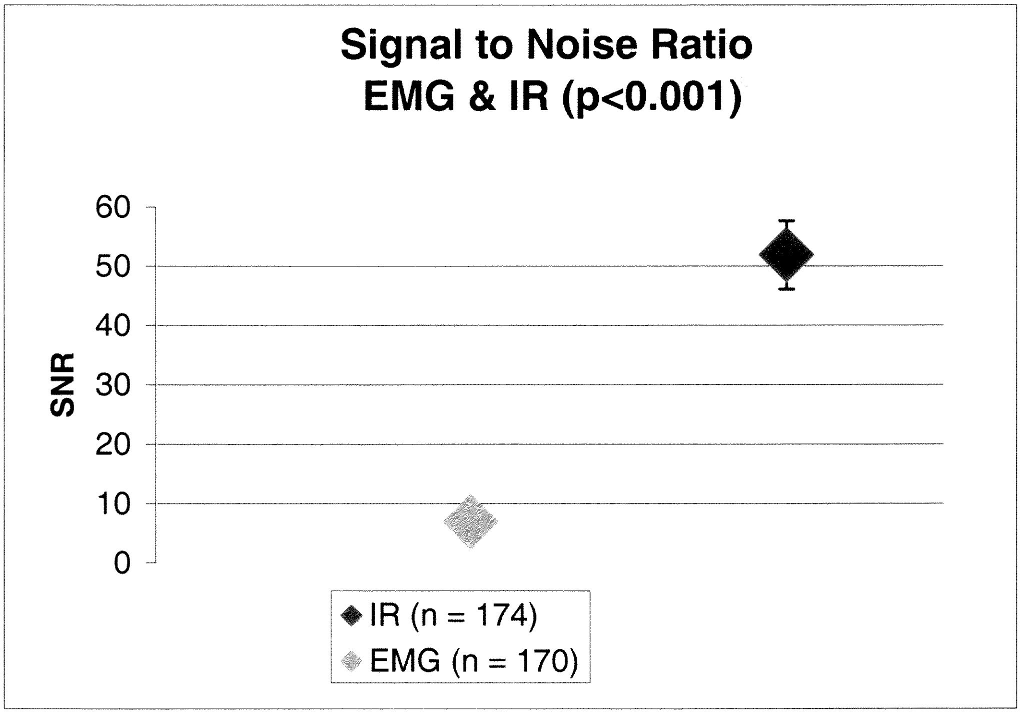


Figure 4.24 T-test for the signal to noise ratio of the EMG and the infrared signal

4.2 Conclusions

The Infrared System has many advantages when compared with the EMG and the currently available commercial device from San Diego Instruments. As confirmed by the results, the infrared signal has both reliability and validity. The Infrared system proves to be more reliable than the EMG system, which increases the advantages to the infrared system. The infrared system did not record one eyeblink compared to the EMG system, which did not record five eyeblinks (see Table 4.1). The five that were missed by both systems are neglected since it is assumed that the subject did not blink. Thus the error of detection of the infrared is only 0.57% while the error of detection of EMG is 2.85%.

The duration and the latency parameters validate the signal. The assumption that the electrical activity of the muscle occurs before the actual mechanical movement of the eyelids is corroborated by these measures. Since the data supports the assumption, it is believed that the Infrared system is valid technique to record the eyeblinks.

The quality in terms of noise present in the signal is very important because a noisy signal is very hard to analyze. It requires lots of filtering and processing to analyze and make judgments out of a noisy signal. To get a legitimate indication of this quality of the signals, the signal to noise ratio was derived and compared. The signal to noise ratio of both signals was compared and it was concluded that the infrared signal has a much higher signal to noise ratio than the EMG signal. The EMG signal contained noise that would make the analyzing difficult. Also the EMG noise depends on the skin preparation and electrode placement. If the skin preparation is not done properly and the electrode placement is not correct location the EMG signal will have poor signal to noise ratio. Thus, one must administer care in subject preparation. With the Infrared system, it is not vital to have a good preparation. The preparation for the Infrared system is easier and shorter; it only requires wearing a pair of glasses. The photo collecting detectors are on the side of a pair of glasses, so as long as the subject has glasses on the signal will be collected and it will be a good quality signal. The Infrared system has multiple detectors, which allows it to disregard the differences arising from the preparation of the experiment. Also the multiple detectors permit the system to not be affected by the different depth of the eyes or the facial characteristics.

The EMG system requires the subject to be connected to a physiological amplifier through an electrode interface. This involves the risk of electrical shock since the subject is now part of an electrical circuit. To protect the subject from the hazard of electrical shock, medical isolation is required. The Infrared system has no direct connection to the subject, which eliminates the risk of electrical shock. However, the Infrared system must meet other requirements of safety to protect the subject. The Infrared system engages in shining the Infrared rays on the skin and towards the eye; if infrared radiation exposure is excessive, it involves the risk of skin and eye damage. Therefore, the Infrared system must meet the requirements of the government safety limit standards to protect the subjects. The Infrared system is well below the safety limits, which ensures the safety of the subjects. Thus, the Infrared system is safer in terms of the electrical shock hazard than the EMG system.

The EMG system is very costly to use since it involves the electrodes, an expensive physiological amplifier and medical isolation for patient safety. The electrodes can be costly since they are disposed after use thus subject requires new electrodes. Also, a physiological amplifier and medical isolation can be expensive. The Infrared system is very economical compared to the EMG system. The hardware of the Infrared system is inexpensive which reduces the cost of the experiment. As a result, the Infrared system is a more economical way of human testing.

Patient comfort can be a vital issue when an experiment is done over a long period of time. The eyeblink conditioning experiment is about one hour long. It is difficult for a patient to endure through a long experiment if they are not comfortable. Also it is difficult to sit for an hour without any movement. The EMG system is not very tolerant to the patient movement. If a patient moves significantly, the signal can be embedded in lot of noise. For example, if the patient scratches the head it will move the electrode wires; this will cause significant noise in the signal. The Infrared system is more tolerant to patient movement. The patient can scratch the head and move the glasses a bit, but the signal would still be recorded for eyeblinks.

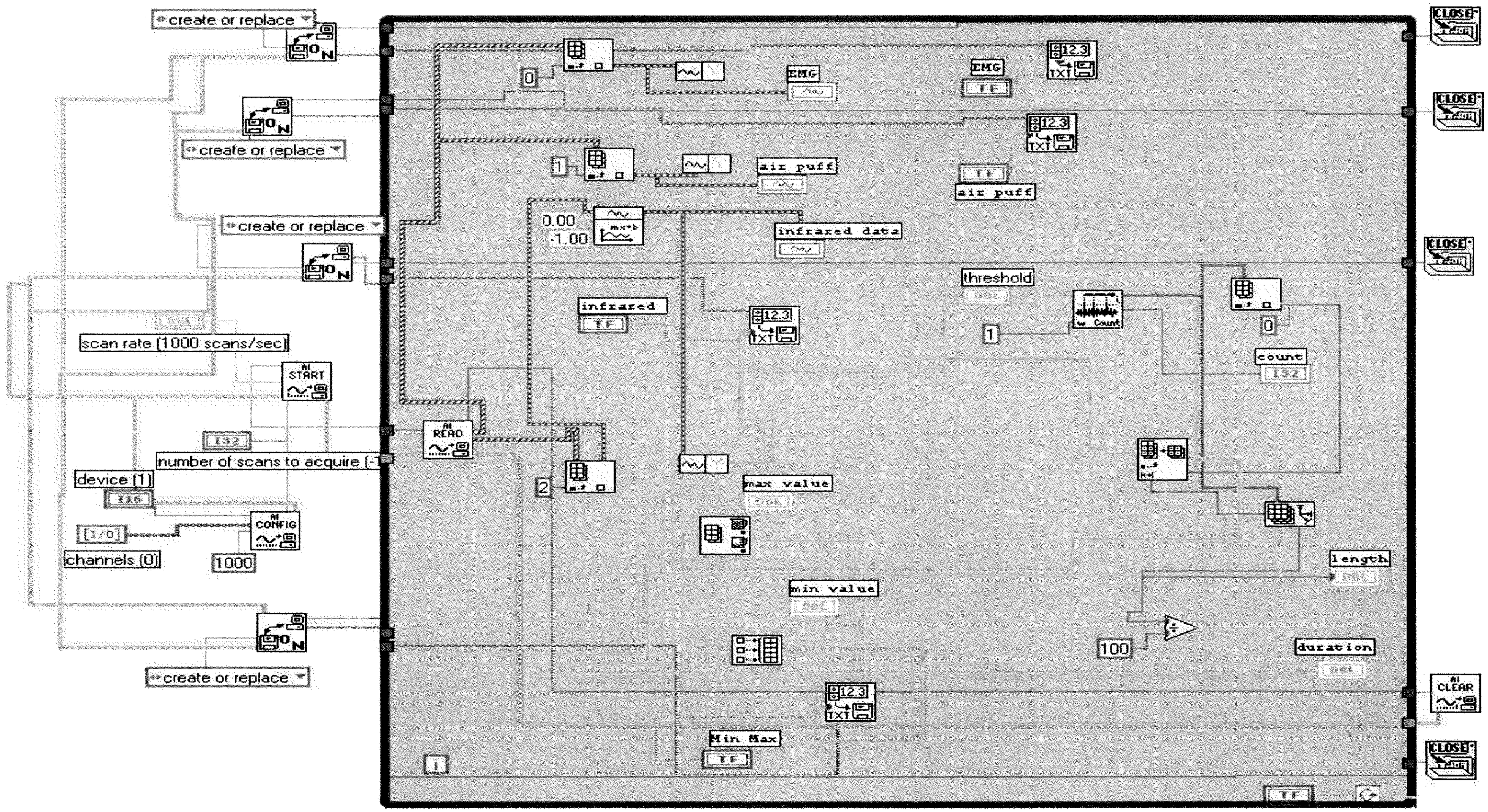
Another comparison carried out is to the commercially available device from San Diego Instruments. This device performs the same function as the Infrared device. It has a single pair of emitter-detector, which is placed in front of the eye to detect the eyeblink. The emitter-detector pair is connected to a piece of wire that is flexible and can be adjusted for different people. However, this wire is very flexible and can get displaced while running the experiment; now it will then not detect the eyeblinks. This problem is eliminated in the Infrared device by mounting multiple emitters and detectors on the side of the glasses. Since the detectors are multiple and they are on the side of the glasses, they are tolerant to movement of the subject and the glasses to some extent. Also, the intensity of the Infrared radiation used by the Honeywell device is higher than the Infrared device, which makes the Infrared device safer.

One concern came up while running the pilot study. The Infrared system is sensitive to ambient light and picks up the 60 Hz noise in the signal, which can make processing difficult. It was discovered that if there is no direct exposure of the light on the detectors, this noise is very minimal. To solve this, a visor or a hat can be used to eliminate the direct exposure of the light on the detectors. Thus, this problem is solved and the signal collected contains minimal amount of noise. All these measures of the signal quality, reliability, and validity prove the performance of the Infrared system to be better than the EMG system. The increase of comfort to subject and decrease in cost justifies to use the infrared system compared to the EMG system to detect eyeblinks.

APPENDIX A

BLOCK DIAGRAM OF INFRARED PROGRAM – LABVIEW

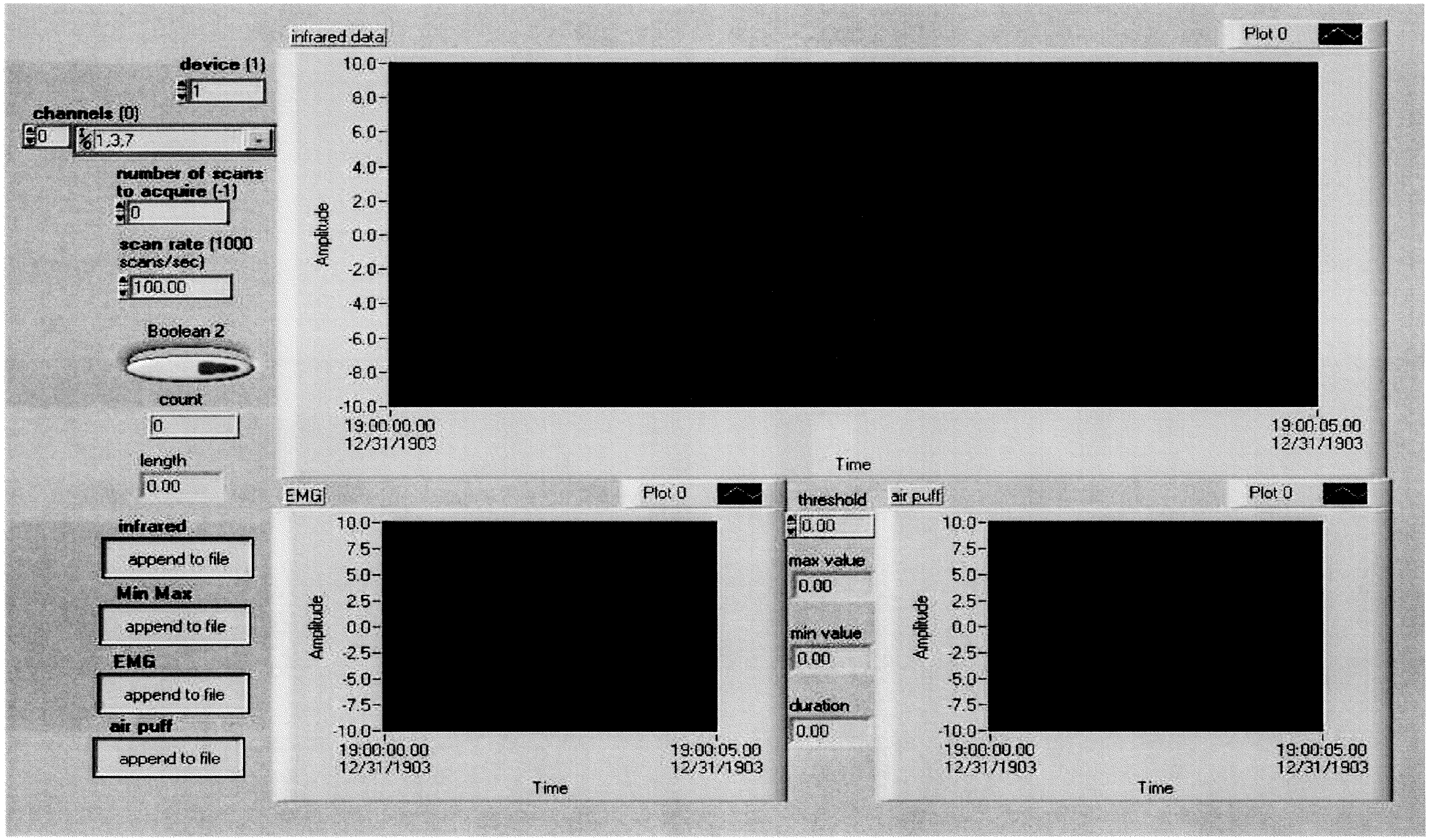
Block diagram shows all the VIs wired together to perform a function



APPENDIX B

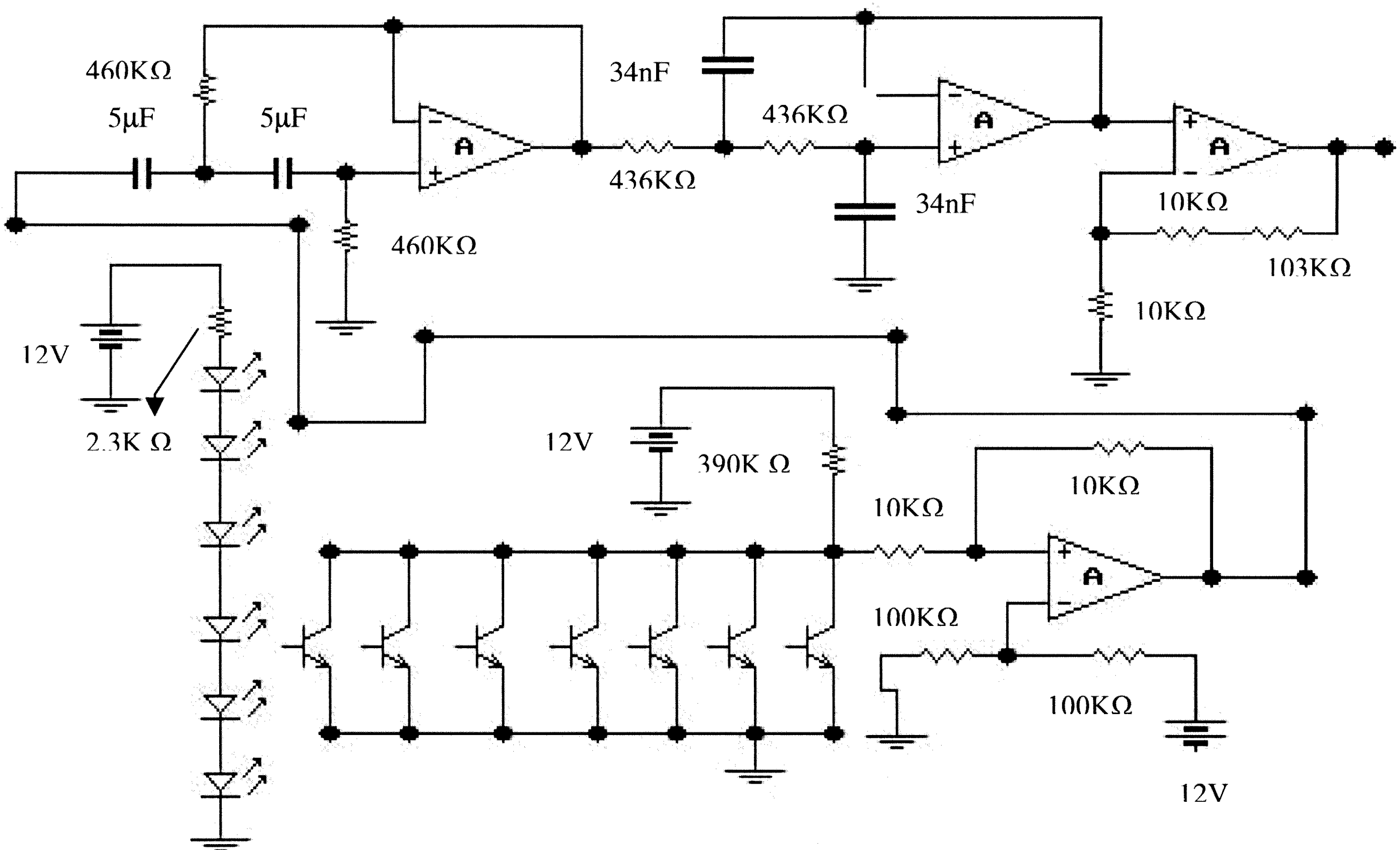
FRONT PANEL OR USER INTERFACE OF THE INFRARED PROGRAM

The user interface of the program where the user can alter the necessary parameters.



APPENDIX C
CIRCUIT DIAGRAM OF THE SYSTEM

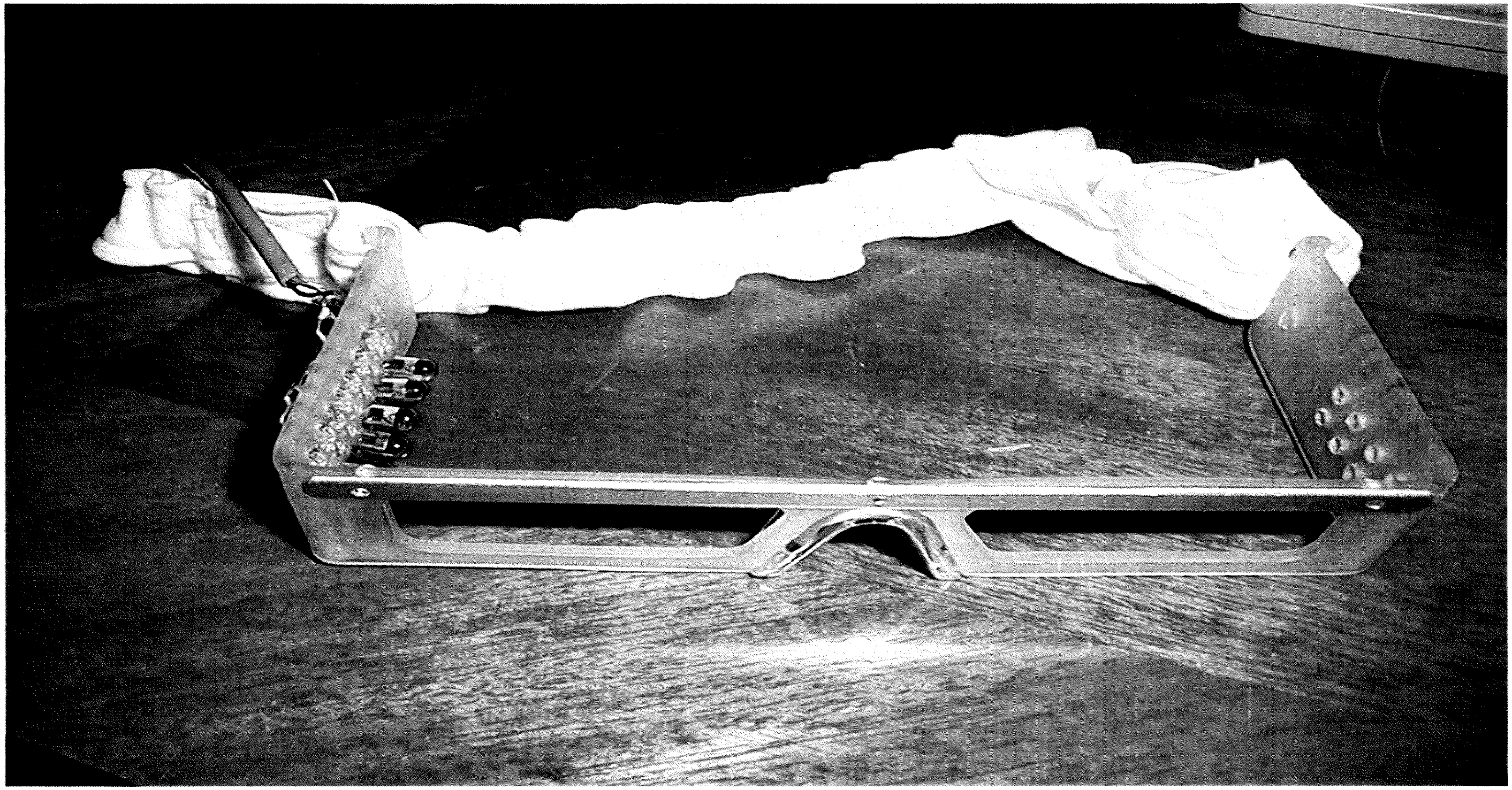
The circuit diagram of the infrared system which tells the information about electronics involved and the values of these.



APPENDIX D

AN ILLUSTRATION OF THE GLASSES OF THE INFRARED

The glasses show the array of emitters and detectors on the side of the glasses. These enhance the design of the system.



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