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Design and Implementation of an Eye Blink Controlled Human Computer Interface

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Design and Implementation of an Eye Blink Controlled Human Computer Interface

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This is to certify that the thesis prepared by Poonam Chandru Gwalani entitled 'Design and Implementation of Eye Blink Controlled Human Computer Interface' has been approved by her committee as satisfactory completion of the thesis requirement for the degree of Master of Science in Biomedical Engineering.

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DESIGN AND IMPLEMENTATION OF EYE BLINK CONTROLLED HUMAN COMPUTER INTERFACE

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science at Virginia Commonwealth University.

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ABSTRACT

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A Thesis submitted in partial fulfillment of the requirements for the degree of Masters of Science at Virginia Commonwealth University.

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Advances in Human Computer Interface (HCI) have made this area of research important for improving the standard of living for people with disabilities. An eye blink system is presented to allow people with disabilities to control a standard computer mouse. This system is designed for people who are paralytic with no control over their arms, speech, and anyone who is restricted to only the control of eye and head movements. This system is based on infrared reflectivity to capture and analyze real time eye blink signal of the user. It uses simple economical hardware electronics to emulate the functionality of computer mouse click based on user eye blinks. Informal tests show that the system can successfully distinguish between voluntary and involuntary eye blinks and can emulate

user mouse clicks. This interface offers an economical, non-invasive, hands-free, plug and play device that provides the disabled with flexibility to improve their quality of life.

1 Introduction

1.1 Background

Human computer interaction is present in nearly every aspect of daily life: whether buying groceries, withdrawing cash from an ATM, or using a calculator, all involve interactions with a computer. Advances in HCI have provided the general population greater access to internet and email. Additionally computer peripherals designed for the general population have been constantly updated. However, approximately 12% of the United States population suffers from severe disabilities which prevent them from using traditional computer interfaces[1].

Traditional computer interfaces are comprised of a physical input device or peripheral, and a graphical display. There are two basic computer peripherals: the keyboard is used to enter words and symbols; and the mouse moves the cursor to select different fields. The graphic user interface (GUI) is responsible for displaying graphics on the computer screen i.e. it serves as visual feedback; whereas, computer peripherals are used for receiving input instructions from the user.

Since traditional human computer interfaces demand good manual dexterity and refined motor control, not all people are able to use these devices[2]. Disabilities can occur due to spinal cord injuries, traumatic brain injuries or from neurological diseases. People with such disabilities have difficulty conveying their intentions and communicating with other people in daily life[3]. By customizing the design of computer peripherals to accommodate for an individual's disability, researchers can improve their standard of living. In designing computer peripherals for people with disabilities, this project took into account people with severe disabilities such as amyotrophic lateral sclerosis (ALS), brainstem stroke, brain or spinal cord injury, cerebral palsy, muscular dystrophies, multiple sclerosis and myopathy. The majority of the target population has poor motor control and/or vocal impairments which prohibits them from using a mouse or speech recognition software, respectively. Because of these deficits, this design proposes the use of eye blinks in order to control and interact with computer.

One of the most frequent interactions of humans with a computer is using a mouse. It has been observed that the left click is executed 95 percent of the time while the right click function is used only 2.3 percent of time[4]. The left click is further distinguished into double click which is used approximately 17.3 percent of time.

Research has been conducted on eye-gazing techniques, eye movement tracking, head tracking, and techniques using facial expressions to help physically and vocally disabled individuals attain some measure of independent communication and control to allow interaction with a computer.

1.2 Eye tracking

Eye tracking is a technique that measures eye movements to determine where the individual is looking at any given instance and the sequence in which their eyes are shifting from one location to another[5]. Tracking eye movements allows researchers to understand an individual's visual information processing and provide insight on how to improve the usability of a system[6]. The measurement device most often used for measuring eye movements is known as an eye tracker. There are two types of eye movement monitoring techniques: those that measure the position of the eye relative to the head, and those that measure eye position orientated in space, or the "point of regard"[7]. The latter measurement is typically used when the concern is the identification of elements in a visual scene, e.g., in (graphical) interactive applications. The most widely used apparatus for measurement of point of regard is the video-based corneal reflection eye tracker.

1.3 Eye Blink

An eye blink is defined as the rapid closing and opening of the eye lids[8]. Blinks occur under three response conditions (a) spontaneously, such as in the case of normal periodic closing for eye lubrication; (b) reflexively, such as in response to an air puff or an object moving towards the eye and (c) voluntarily[9]. The blink is composed of three distinct phases: the down (closing) phase, on closure phase and the up (opening) phase. The down phase of the blink is the most rapid part of the blink compared to the up phase while the duration of the closure phase depends on the type of the blink [10].

Blink duration is defined as the time between the start of the lid closure to the moment of the highest velocity of the lid reopening. Involuntary blinks are usually less than 200ms in duration. Spontaneous eye blinks and reflexive eye blinks are generally within 150ms in duration while the duration of involuntary blinks can increase up to 50ms with drowsiness[11].In contrast, voluntary blinks are longer in duration than involuntary blinks and can vary from as short as 225ms to as much as 500 to 800ms.The duration of blinks is highly subjective with respect to an individual and can be affected by disability. For example, individual suffering from progressive supranuclear palsy (PSP) tend to have longer blink duration and are generally greater than 478ms[12]. The main reason for this is that the opening and closing phases of the eyes during voluntary blink is longer than healthy people.

Blink rate can be defined as the number of times per minute that an eyelid closes. Humans blink anywhere from five to thirty times per minute in intervals from 1 to 10 seconds and average sixteen blinks per minute. Blink rate can also depend on the task performed by a user[13]. Blink rate increases progressively at rest and during conversation, and can decrease to 3 to 4 blinks/minute during reading and computer use[8]. Blink rate decreases resulting in dry eye. Blink rate also changes with respect to diseases. On an average, blink rate decreases in patients with Parkinson's disease (11 ± 7.5 blinks/min), nondyskinesia (3 blinks/min), and myotonic dystrophy (7.6 ± 4.9/min)[12]. However, blink rate increases in patients with facio-scapulo-humeral dystrophy (FSH) (17.5 ± 4.3/min) and schizophrenia (31 blinks/min) [14].

1.4 Physiology of Eye blink

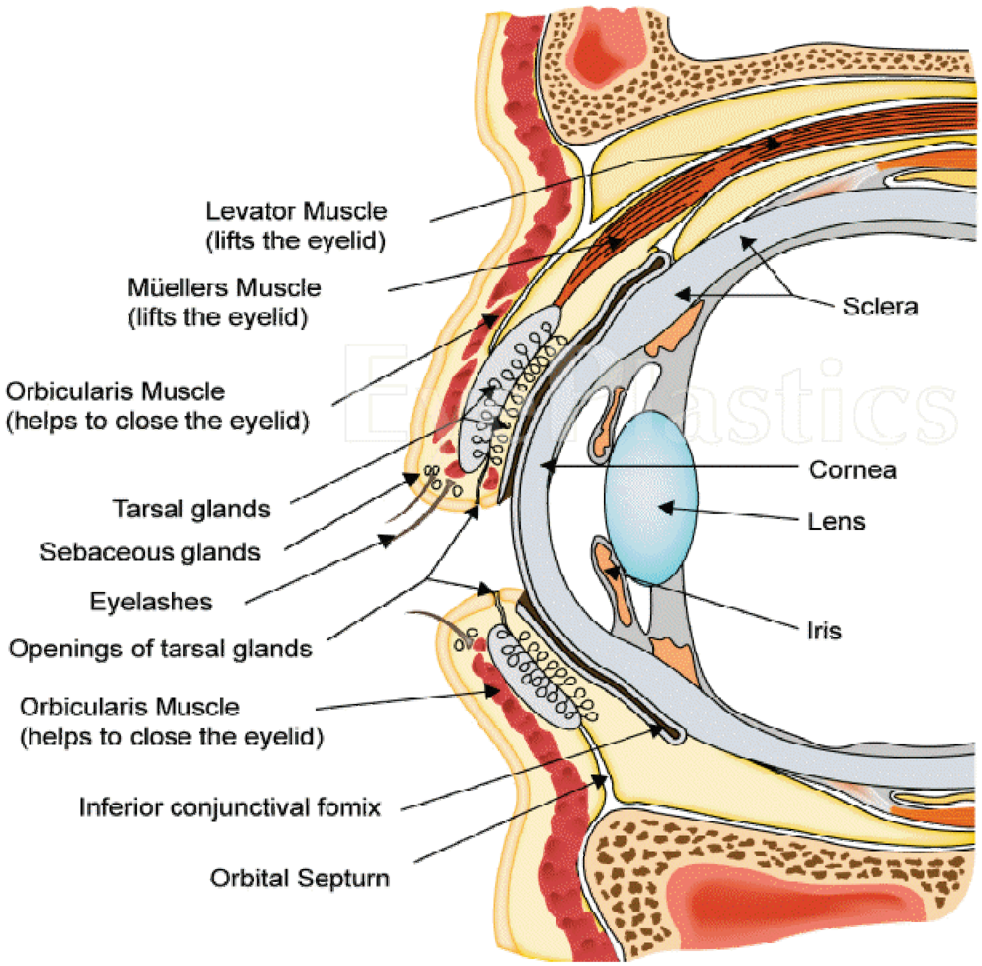

Figure 1. Anatomy of the eyelid. (from, "Cosmetic and Reconstructive Surgery of the eyelids, orbits, and tear ducts.")[15]

As shown in Figure 1, the upper eyelid is separated into anterior, medial, and posterior lamella. The anterior lamella consists of the skin and the orbicularis oculi muscle, the medial lamella is the septum and fat, and the posterior lamella comprises the tarsus and conjunctiva[16]. The main muscles in the upper eyelid, that control the opening and closing are the orbicularis oculi and the levator palpebrae superioris muscle. The closing of the eye is controlled by the orbicularis muscle. The orbicularis muscle which acts as a sphincter for the palpebral fissure. The orbicularis muscle is also divided into the orbital and tarsal segments by the supratarsal fold which is formed by the insertion of the levator aponeurosis and the orbital septum on the deep surface of the orbicularis. The opening of the eyelid is controlled by the levator palpebrae muscle. The levator muscle is approximately 45 mm long and is under the control of the oculomotorius nerve. It originates within the orbital cavity and inserts on the levator aponeurosis. The levator aponeurosis extends 12 mm superior to the supratarsal fold between the levator muscle and Muller's muscle. Müller’s muscle, or the superior tarsal muscle, in the upper eyelid and the inferior palpebral muscle in the lower eyelid are responsible for widening the eyes. In addition, the inferior palpebral muscle is coordinated with the inferior rectus to pull down the lower lid when the eye rotates downwards.

The upper eyelids are supplied by the sensory nerve supply from the infratrochlear, supratrochlear, supraorbital and the lacrimal nerves from the ophthalmic branch of the trigeminal nerve[17]. The skin of the lower eyelid is supplied by branches of the infratrochlear at the medial angle while the rest is supplied by branches of the infraorbital nerve of the maxillary branch of the trigeminal nerve. In addition, most of the muscles of the orbit are innervated by the superior division of the oculomotor nerve (Cranial Nerve III).

1.5 Eye-Blink detection

In the past, researchers have used various different methods to detect eye blinks and track eye movements. There are three broad categories for such methodologies: Electro-oculography, camera based eye blink detection and Photo-Oculography (POG) or Video-Oculography (VOG).

Electro-oculography as shown in Figure 2 is the most widely used low cost method for eye movement recording for the past forty years[22]. It involves the measurement of the electric potential between surface electrodes placed around the orbicularis oculi muscle of the eye[18]. In this method, the eye acts as an electrical dipole that is cornea is more positive with respect to retina resulting in the corneal-fundal potential (CFP). The peaks observed in EOG waveform are considered blinks. These recorded potentials are in the range 15 to 200µV/deg of eye movement[18]. But, this technique contains various artifacts such as motion and muscle artifacts including drift[19]. The major disadvantage of this technique is that it requires the application of surface electrodes applied to the locations as shown in Figure 2 which is not well-suited for everyday use by disabled users.

Figure 2. Placement of EOG surface electrodes around the eye. (from, "Metrovision: instruments for measuring eye movements")[20]

Researchers have also attempted to create more portable, non-invasive and low cost systems. Several designs have used off the shelf cameras and image processing techniques[[23243]] One approach required complex software to locate the eyes by applying an image mask to the user's face and then detected eye blinks by template matching and motion analysis techniques[25]. However, the system was ineffective particularly if glare occurred on the glasses lenses. Another approach used variance mapping to track only the user's face, instead of trying to focus to the eyes. This method suffered from accuracy issues, due to head movements creating situations where only one eye might be visible[26]. In addition to the restrictions and inaccuracies associated with the software computation, this method is highly limited to the frame rate and resolution of the camera.

Photo-OculoGraphy (POG or IR-OG) or Video-OculoGraphy (VOG) involves the measurement of distinguishable features of the eyes under rotation / translation, e.g., the shape of the pupil, the position of the limbus, and corneal reflections[27]. Most of times in POG, the signal is recorded using hardware components such as infrared LED emitters, phototransistors/diodes, analog to digital converters, and microcontrollers. The signal is then processed by software algorithms designed to detect eye blinks and track eye gaze position. One study used IR-OG to detect eye blinks to alert the driver in case of fatigue[28]. This system required serial cable connection to send data to the PC and did not allow the head to move freely. Another approach used VOG comprised of infrared cameras and real time image processing algorithms to track the eyes and evaluate eye blinks[29]. There are two ways in which software is used to detect eye blinks: 1) by detecting the disappearance of the iris; 2) by detecting the disappearance of the pupil. In order to detect the iris the software applied masking techniques on the user's face. The eyelid closure was defined as the disappearance of the iris. This technique was affected by user variability, which resulted in inaccuracies in predicting eye movements and eye blinks. Another drawback to this technique is that measurement of ocular features may require visual inspection of recorded eye movements. Manual visual inspection (e.g. stepping through a video frame by frame), can be extremely tedious and prone to error. In addition, these systems are limited to the temporal sampling rate of the video device and are expensive.

Figure 3. Pupil Cornea Eye tracking system. (from, "Eye Movement Monitoring of Memory") [30]

Software determines the position of the corneal reflection measured relative to the location of the pupil center [30]. Eye blink was defined as the disappearance of the pupil. Locating the Purkinje image allows free head movements of the user and is fairly accurate. However, it becomes fairly complex and expensive since it involves the use of a camera, hardware components and image processing software. This method requires a high resolution camera which causes the system to be very expensive and requires a high sampling frequency which can be computationally expensive and requires a large amount of data storage.

Many eyes tracking techniques reviewed are expensive, making them inaccessible to the much of the disabled population. In order to address this need, a cost effective, non-invasive and user-friendly human computer interface must be developed for people with limited motor abilities. This project is an extension of previous research conducted by Robert Filler and Dr. Wetzel.

1.6 Objective

The objective of this study is to develop a low cost, non invasive and user friendly device that would emulate the functionality of a computer mouse. The device should use eye blinks to offer the user the functionality of the mouse buttons. The design should consider the needs of people with limited or no control over their arms, poor speech, and retain normal control of eye movements. The system is designed to avoid obstruction the user's field of view or endanger their eyesight. The device should be usable by a variety of people and requires simple adjustments to adapt the interface. This low cost device would not only enable disabled people to interact with their surroundings but also improve their quality of life.

2 Methods

2.1 Design Criteria

It is essential to outline the most important design criteria to solve the problem as described in the objective section. The device should identify different kinds of blinks in order to emulate the left, right and double clicks of a standard mouse. In addition, the device should have the capability to support the addition of head or eye control for cursor movement. The proposed design must meet the following criteria:

- Totally hardware based without the need for software
- Relative low cost
- Low noise and minimal delay
- Non-invasive, non-obstructive to user's field of vision
- Windows compatible
- Easy to use
- Requires minimal training
- Low power
- Electrical and optical safety
- High level of accuracy

2.2 Approach and Proposed Design

The proposed design utilizes an infrared reflectivity method for detection of blink. Additional circuitry will then be developed to analyze the duration of the blink and then emulate the left, right and double click actions of mouse standard. The hardware consists of infrared sensors mounted to safety glasses, circuitry for detecting eye blinks and a standard computer mouse. The system requires no additional software. This system will be designed to accept at a future time, signals from either a head or eye tracker to control cursor positioning. The overall block diagram of the system as shown in Figure 4.

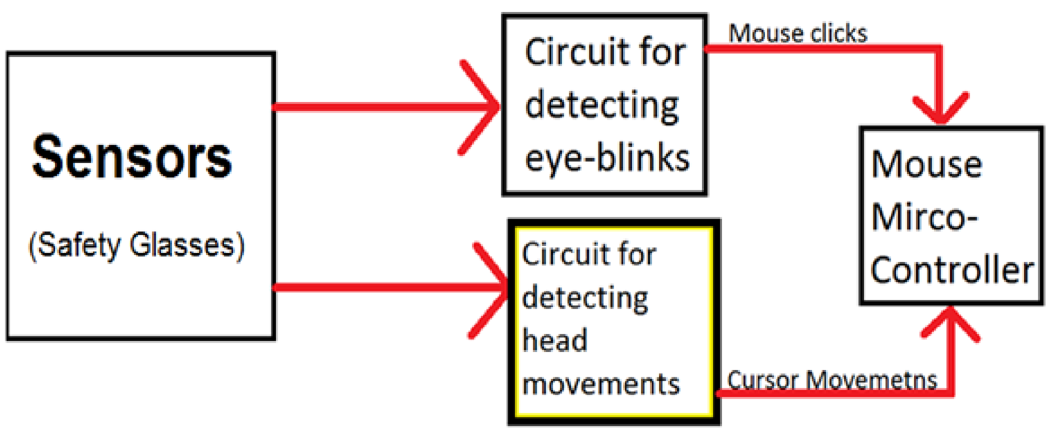

Figure 4. Block diagram of system.

2.3 Hardware Design

2.3.1 Infrared Sensors

Infrared reflectivity was measured from each eye using an infrared LED emitter and infrared phototransistor. When a blink occurs the eye lid increases the amount of reflected. IR returning to the detector resulting in a positive voltage increase as shown in Figure 5.

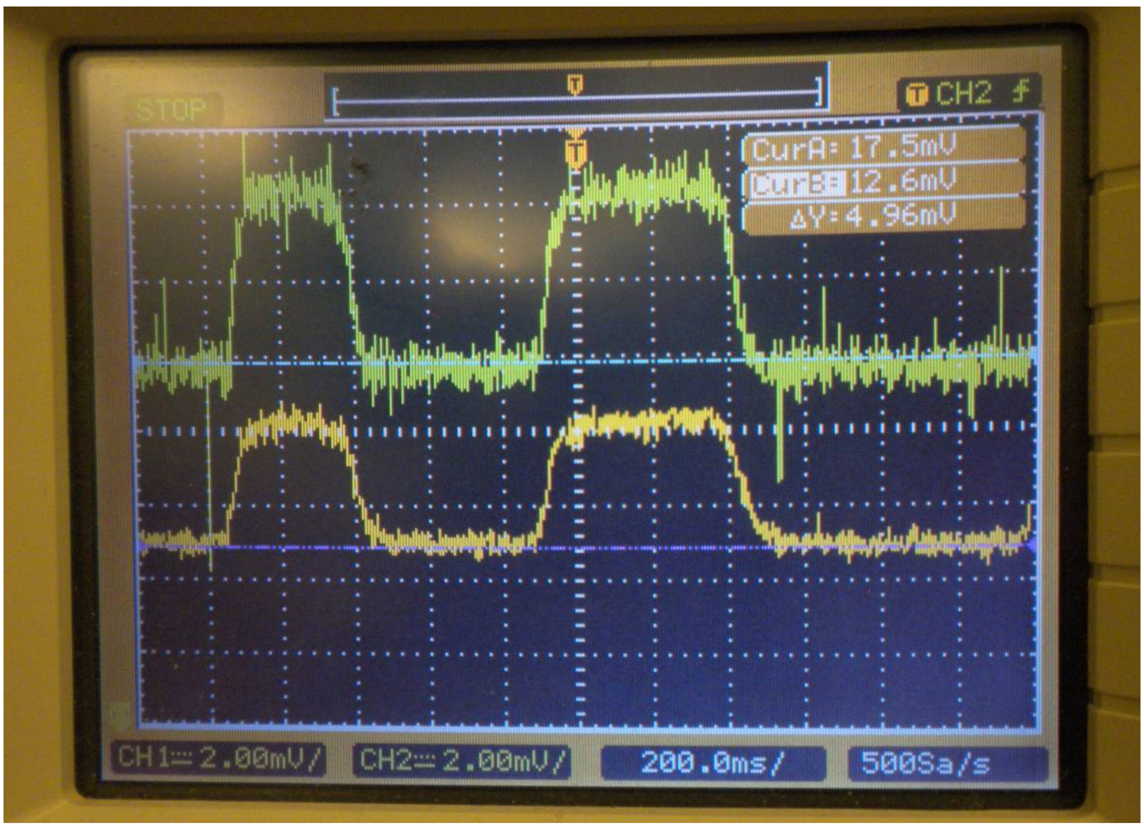

Figure 5. Eye blink signals captured from left eye (top graph); and from right eye (bottom graph). Baseline voltage represents eye open state, positive voltage potential represents eye closed states.

Two types of sensors were considered in this design: a) QRD1113/14 b) infrared LED emitter and phototransistor. The QRD1113/14 reflective object sensor (Fairchild Semiconductor: California, USA) consists of an infrared emitting diode and a NPN silicon phototransistor mounted in a plastic housing. The QRD1113/14 offered a peak wavelength emission of 940nm. This was within the near infrared zone which is invisible to the human eye. This allows for illumination without obstructing the user's field of view. However, QRD1113/14 responded optimally at a distance of 50-300mils (1.27 to 7.62mm). This would require the sensor to be placed very close to the eye and was deemed uncomfortable for the user. Thus, 950nm matched pair of infrared LED emitter and phototransistor were selected. For both sensor systems, the output voltage decreased with distance from the user's eye. However, the matched pair performed better compared to the QRD1113/14 sensor. From a distance of 5cm from the user's eye, the matched pair produced an output voltage of 5-6mV (Figure 6); whereas the QRD1113/14 produced an output voltage of 0 mV (according to the manufacturer's datasheet). This characteristic of the matched pair allowed substantial room for customizing the distance from the user's eye. This would be useful for users who wear glasses. Characteristic plots for the matched pair of infrared LED photodiode and phototransistor were not available and were determined experimentally (see Appendix).

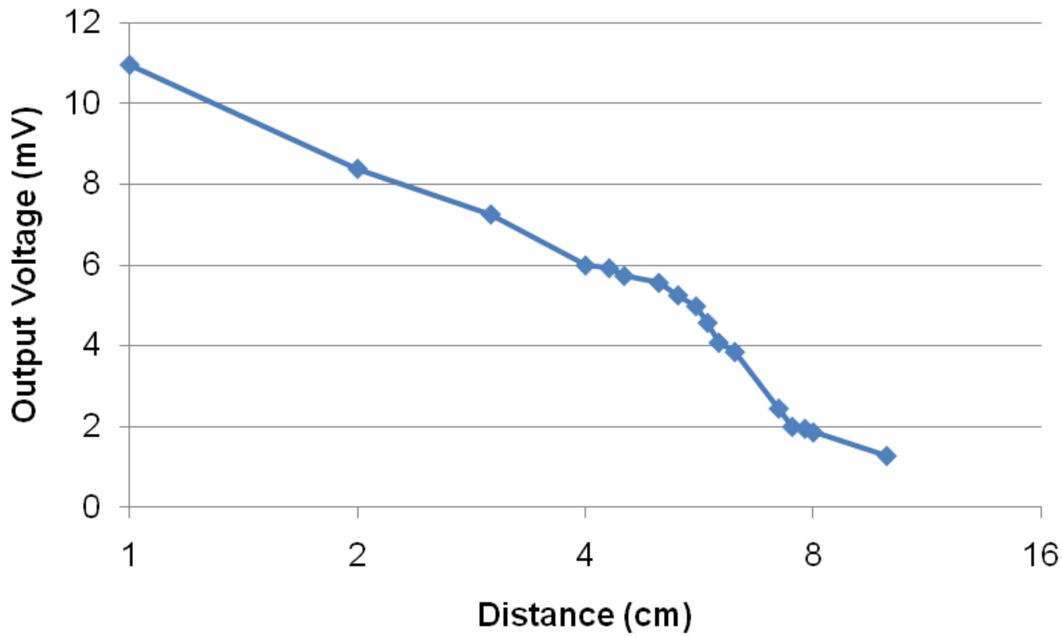

Figure 6. The relationship between distance on sensor distance and output volatge.

2.3.2 Blink Detection Circuit

The blink detection circuit was required to generate a pulse waveform in response to a voluntary eye blink. Two designs were considered to discriminate between voluntary and involuntary blinks. The first design was a RC component circuit, which measured the charge accumulated across a capacitor to measure time. The second more accurate design used digital counters to measure time. The RC component design requires a comparator and variable resistor to set the threshold voltage. The digital logic method required a clock circuit to generate reference waveform, counter chips and a frequency to voltage converter circuit to measure the eye blink duration. The major disadvantage of the digital timer method is the number of Integrated Circuits (IC) required to measure blink duration. The performance of the RC method could be improved by the use of high precision capacitors and an electronically controlled resistor. The RC component design offers the most compact and economical system. For these reasons the RC component design was selected for the final design. Once the blink detection circuit identifies a voluntary blink the next step is to interpret different types of mouse clicks.

2.3.3 User Input

This goal of this project was to emulate the left click, right click and double click of a standard mouse through the detection and measurement of eye blinks. Instinctively, one might expect that the left eye blink could be associated with the left mouse click, right eye blink with the right mouse click and corresponds double left blink with the double click. From previous work, left mouse click is used more often that right and double click[1]. For the proposed system this would require the user to perform left eye blink for 95 percent of the time which would lead to potential fatigue. Additionally, closing just one eye may be difficult for some users. For the final design, user input to the mouse was determined as shown in Figure 7:

- Left click: both eyes blink simultaneously
- Right click: either eye blinks while the other remains open (either left or right)
- Double click: both eyes blink twice in rapid succession

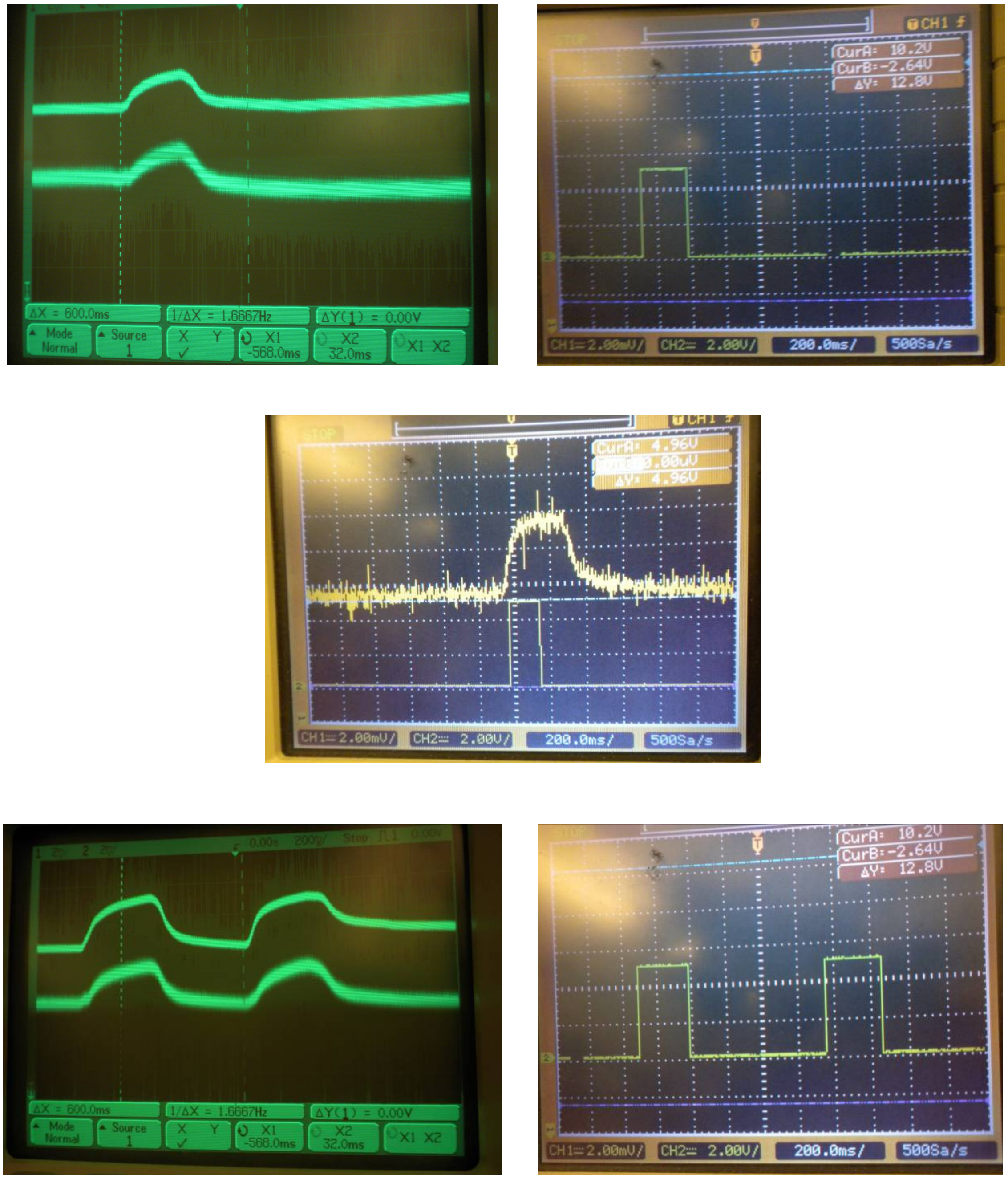

Figure 7. Mouse clicks in response to eye blinks. Left click (a) left and right eye blink of the user (b) left mouse click corresponding to user's eye blink; right click (c) right eye blink with either one eye blink; and double click (d) left and right eye double blink, (e) output pulses corresponding to double click of the mouse.

2.3.4 Mouse Microcontroller

A mouse microcontroller HT82M98A (Holtek, USA) was used as an interface between the blink circuitry and the PC. An additional advantage is that the mouse controller is recognized as a Windows compatible “Plug and Play” device without the need for additional software. The mouse microcontroller is compatible with either standard PS/2 or USB connections further; the device allows support of an additional mouse. That is, two mice can be connected to the computer at once.

3 Final Design

The eye blink system consists of separate but identical infrared emitter and matched photodetectors for each eye. IR sensors, hardware components to detect and analyze voluntary eye blinks and a USB port to send mouse data to the computer. For the purpose of testing, a chin rest was used to stabilize the user's head as shown in the setup in Figure 8. Sensors were placed on a mechanical stand. The final product would include sensors mounted on frames to allow free head movements.

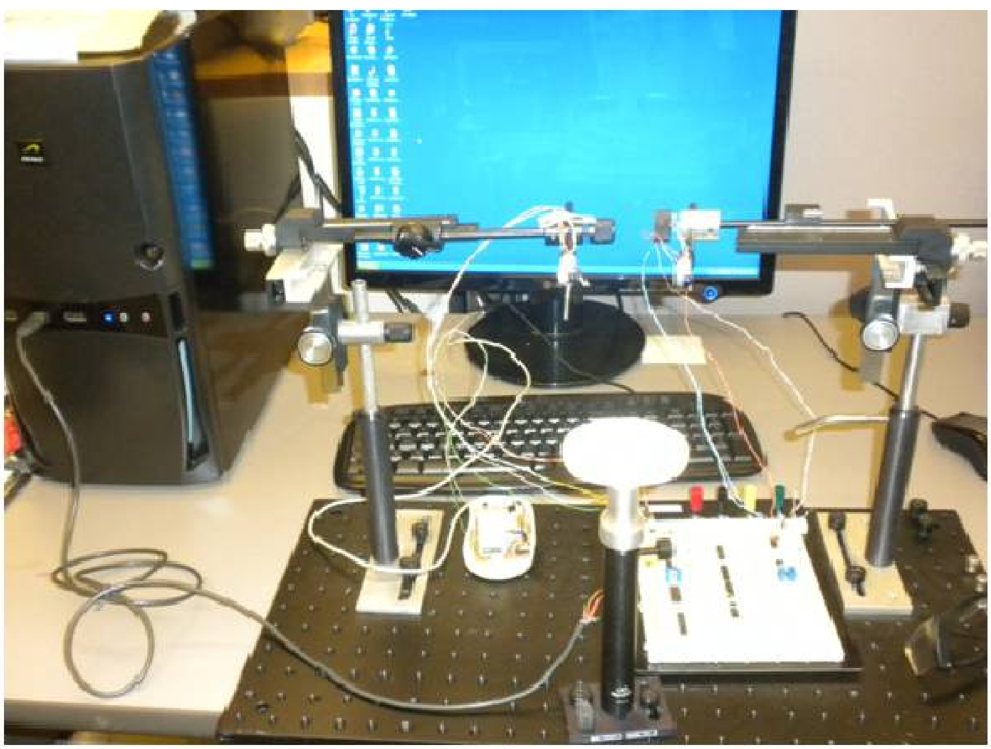

Figure 8. Entire experimental set up.

The final design of the eye blink detection system is shown in the block diagram depicted in Figure 9. The IR emitter was powered by a constant 5V source obtained from the USB connector. The IR emitter provides illumination of eye with infrared light which is detected by the phototransistor.

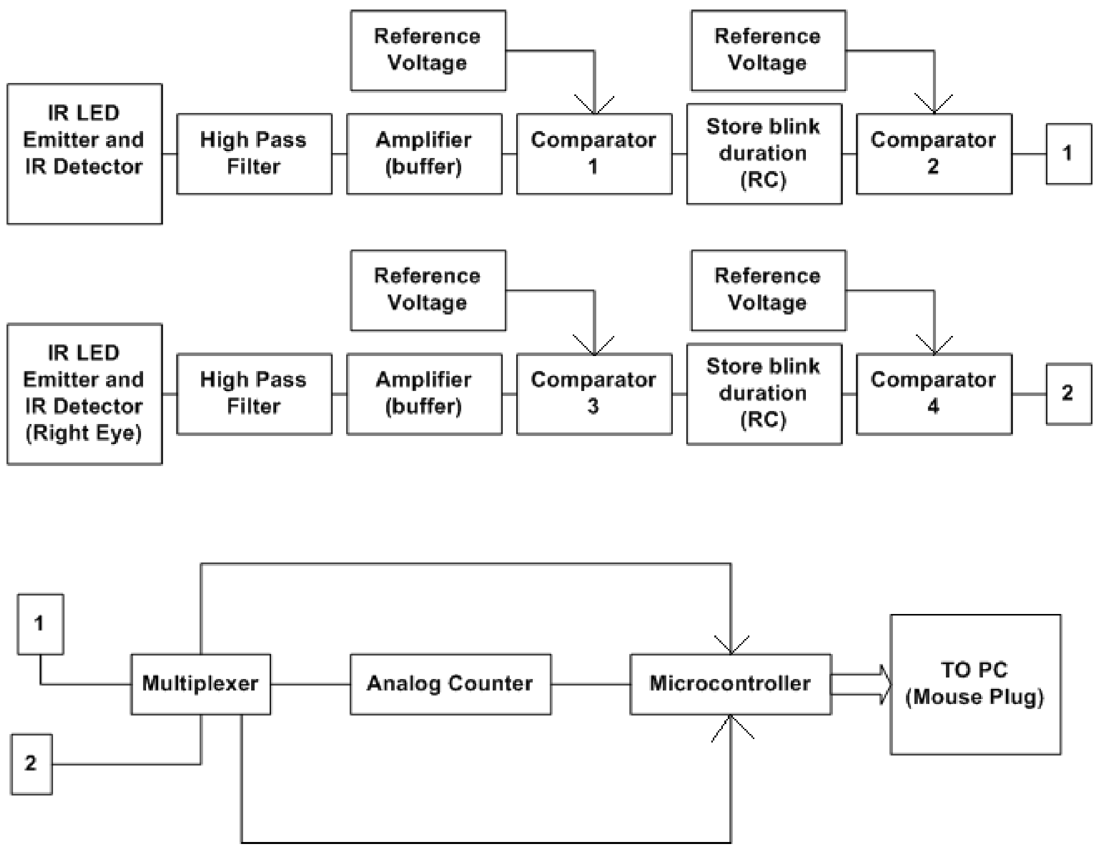

Figure 9. Block diagram of eye blink detection system.

When the lid is closed, the lid reflects infrared light back to the phototransistor. This signal is then amplified (AD820AN) to a level of 0.9 to 1.5 volts as shown in schematic in Figure 11. The amplified signal was then compared to determine the eye-closed or an eye open state. To distinguish between voluntary and involuntary eye-blinks, the threshold of the voltage comparator was adjusted to a level corresponding to 150ms. Blink durations less than 150ms are considered involuntary while durations greater than 150ms are considered voluntary. An example of the output to these voluntary blinks is shown in Figure 10.

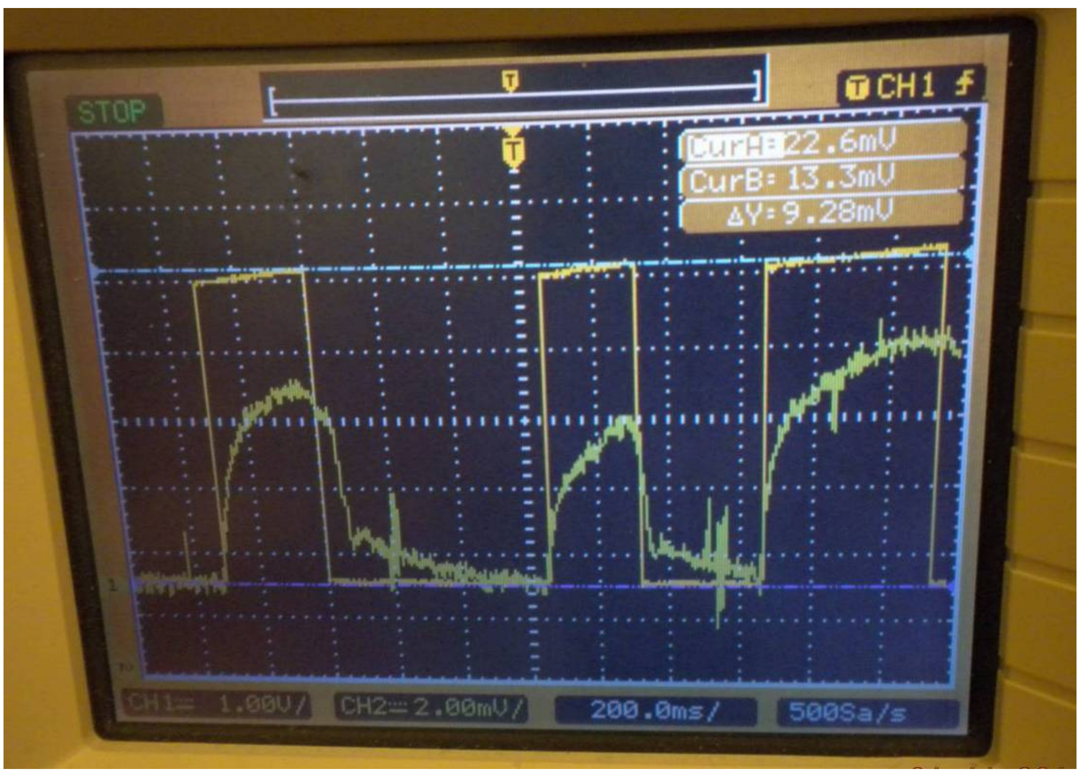

Figure 10. Eye blinks with different time duration

The logic high signal from the comparator is used to charge a capacitor to filter out involuntary blinks. A second comparator was then used to measure blink duration, using the capacitor voltage as an input. The output from both the parts of these stages was controlled by a multiplexer to provide the appropriate signal to the mouse microcontroller. Finally, a switched capacitor discharge circuit was activated during eye open state to prevent false involuntary blink recognition resulting from the voluntary blink.

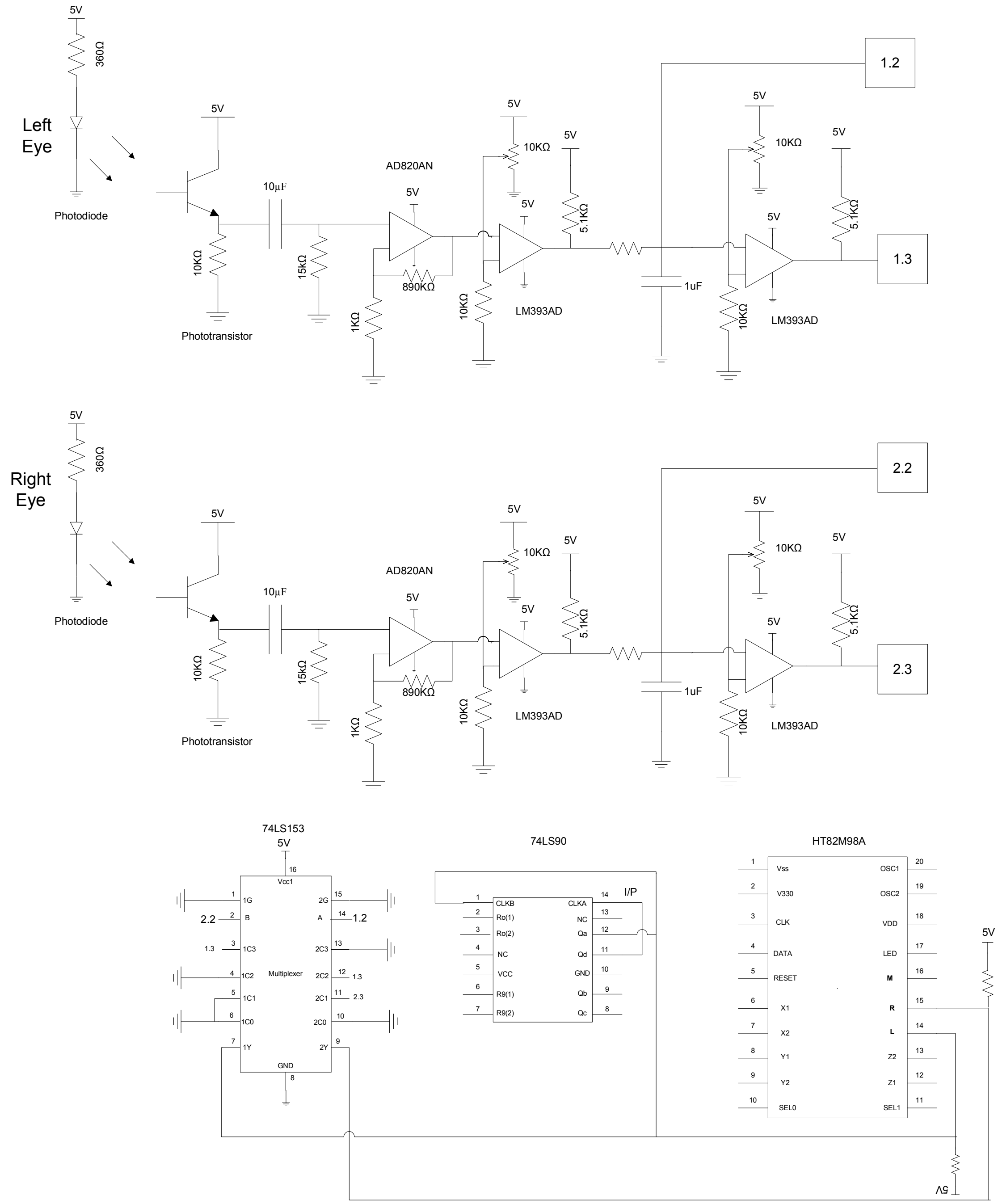

Figure 11. Circuit diagram of eye blink detection system.

4 Results

4.1 Testing Parameters

The prototype of the proposed design was tested at each stage of the circuit. The sensor characteristics were tested under a variety of different lighting conditions. The sensor performed satisfactorily under overhead florescent lighting, dim incandescent light and in darkness. (See Appendix)

The important functions of the mouse buttons were tested and found to perform satisfactorily. These functions included single click, double click, and click then hold for dragging and selecting. It was observed that the click cannot be held indefinitely because of the input high pass filter at the beginning of the circuit. The accuracy of the device was evaluated by holding the mouse over a desktop icon on the computer screen and recording the percentage of eye blinks correctly registered as mouse clicks. Accuracy was also tested by providing a series of left click, right click and double click selections while monitoring the number of unregistered single clicks.

4.2 Preliminary Test Data

Design accuracy was informally tested on five healthy individuals with different skin tones and different eye features. The individuals required minimal training which consisted of verbal explanation of how to execute the left, right and double click functions of a mouse. The duration of voluntary eye blinks were all greater than 150ms, indicating a voluntary blink. For blinks greater than 575ms, the threshold values may need an additional adjustment. Skin color appeared to have no effect on performance.

It was observed that when an attempt is made to close just one eye the other eyelid tends to partially close. This result could affect the ability to accurately distinguish an intended right mouse from an unintended left mouse click. (Figure 12)

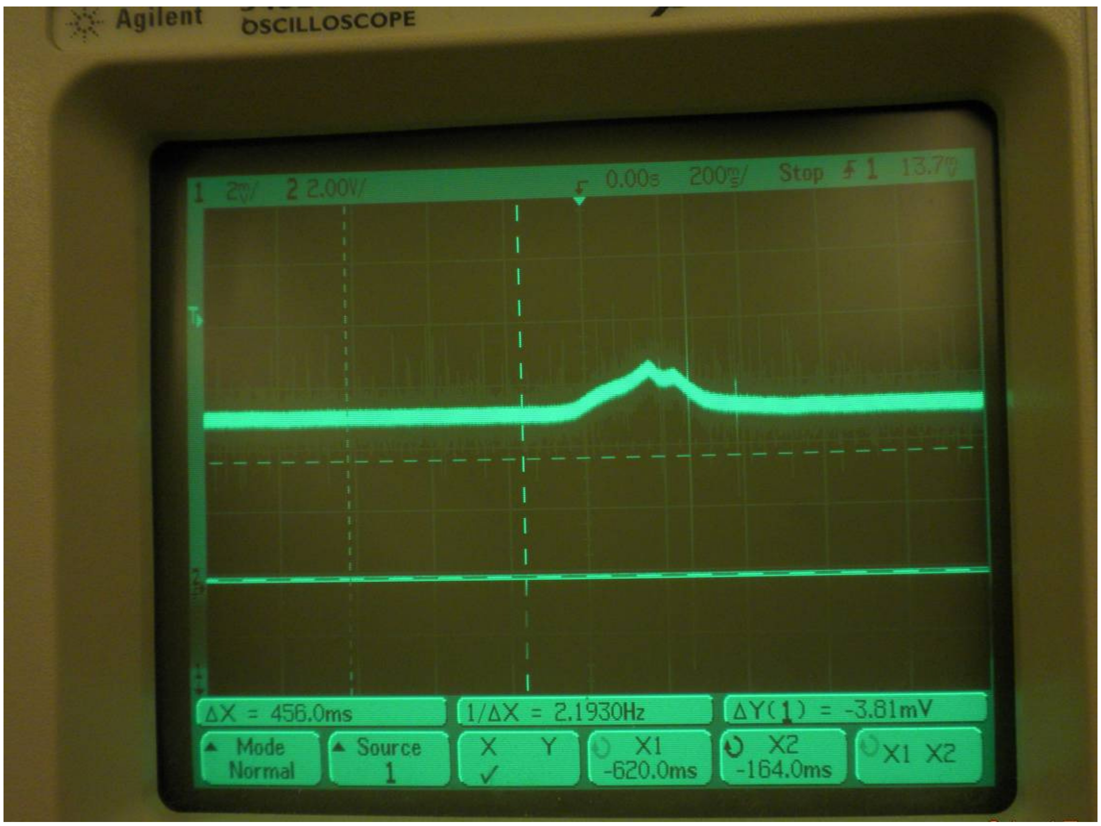

Figure 12. Partial eye-blink recorded using the IR LED transmitter (top graph). A logic high is suppressed (bottom graph), demonstrating that partial eye-blink is correctly interpreted as eye-open state.

Accuracy was defined as the percentage of true clicks divided by the total number of eye blinks. The system had an overall accuracy greater than 90% across all mouse click types. Inaccuracy was attributed to a low blink duration threshold, which could be adjusted to accommodate the low state of the multiplexer. The position of the sensor also affected accuracy. However, once the sensors are mounted on safety goggles in the final design, the position of the sensor would be fixed and would not require any calibration.

The eye-blink signal detected from both eyes is shown in the Figure 13. The baseline waveform shows the eye-open state and the voltage peaks are due to the positive increase in infrared reflectivity, which represents the voluntary closure of the eye during a blink and peaks occur when the eye lids are close.

4.3 Electrical Characteristics

The electrical performance of the system was measured by the multi-meter and oscilloscope. Table 1 shows the electrical characteristic of the system.

Table 2 Electrical characteristics of the eye blink system

Parameter	Value
Operating voltage	4.5-5.00V
Max current	50mA
High Pass Input Filter	.00107 Hz
Input gain	100x
Threshold 1 Voltage	1.017V
Threshold 1 Resistance	1.67kΩ
Threshold 2 Voltage	3.508V

Threshold 2 Resistance	2.083kΩ
Maximum capacitor discharge	<1mA
Time constant (RC)	150ms
blink duration threshold as tested	200ms

5 Discussion

A human computer interface was designed to control left, right and double click actions of a computer mouse in response to eye blinks. The design and implementation met the following requirements as described below:

- Totally hardware, no software for processing: The system is currently hardware based and requires no software.
- Low cost (less than $200).
- Near real-time performance: The delay between the blink detection and the logic high output is less than 50 ms. This delay is required to accurately discriminate between voluntary and involuntary eye blinks.
- Non-invasive, non-obstructive to user's field of vision: The system does not interfere with vision. Future work will include mounting the sensors on safety glasses, which will allow for free head movements and further improve the comfort level of the user.
- Windows compatible: The final design is compatible with other computer applications and follows standard PS/2 and USB protocols.
- Easy to use: Because the final design was USB compatible, this offered an easy-to-use device. Some considerations may have to be made for disabled users to ensure that they are easily able to plug in the USB device. This design can also be used in conjunction with a standard computer mouse, which allows a nondisabled

person (e.g. a disable user's family member) to operate the computer at the same time. This allows multiple users to operate the same computer without needing to plug and unplug the eye blink detection system. Additionally, if the disabled user requires help operating the computer, it allows for a fast transition between users.

- Requires minimal training: Informal tests showed that healthy individuals can use the system in under 5 minutes. The speed with which users became acclimated to the system can be attributed to the choice of user input. Voluntary closure of both eyes at the same time for left mouse click reduces the user's effort to perform left click. Voluntary closure of either left or right eye for right mouse click provides the user with the flexibility to blink the eye that they are comfortable with. Thus, dominant eye tendency of the user is considered in the system design.
- Low power: The final device draws power from the computer via the USB port and does not require any additional power supply.

The above mentioned advantages and features of this device make it favorable for users with the following conditions: spinal cord injuries, multiple sclerosis, myopathy, brainstem stroke, cerebral palsy, Parkinson's disease, including those in the initial stages of Amyotrophic lateral sclerosis (ALS) and quadriplegia. This system can easily adapt to many types of users through simple adjustment of the voltage threshold which distinguishes between involuntary and voluntary blinks.

The final design may not be appropriate for users with the following disabilities involving: diseases related to infraction of eye muscles or possessing disabilities like blepharitis, chalazion (eyelid cyst), age – related macular degeneration, and the late-stages of ALS. Nondisabled users may also find the system a convenient alternative to a traditional computer mouse. For example, technicians or mechanics that need to switch from a manual task to using a computer may prefer using an eye blink system to be able to perform both tasks simultaneously.

The present design achieved a similar level of blink detection accuracy compared to other techniques. Compared to camera based systems, this design achieves the same accuracy at a fraction of the cost and complexity. The implemented eye blink detection system uses simpler hardware components that do not require software processing of the detected signal. The blink detection circuit required no additional software in order to analyze signals in near real-time. While this device is not optimal for users with specific disabilities, it offers a high level of repeatable accuracy that is competitive with other devices at a fraction of the cost. This makes the implemented eye blink detection system a viable product for the rehabilitation market.

6 Future Work

A design to emulate the functionality of standard computer mouse buttons is complete and works in real time on a low cost hardware platform. The design could be further improved by integrating the system with the cursor movements of the mouse based on head movements of the user involving three degree of motion i.e. roll, pitch and yaw.

Experiments should be performed to determine the utility of a blink controlled mouse for individuals with disabilities. Additional work needs to be completed combining eye blink mouse clicks with head controlled cursor movement.

7 Conclusions

A robust human computer interface has been developed to emulate the functionality of mouse clicks in response to eye blinks based on hardware analysis of blink duration. The system requires no additional software to operate, can be plugged directly into any Windows based computer and is low cost. Informal testing have shown that the duration and pattern of eye blinks can be used to accurately identify the left, right and double mouse click. This device provides a high level of repeatable accuracy at a fraction of the cost compared to other eye blink detection systems. This makes the implemented eye blink detection system low cost but highly beneficial device for the disabled user.

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9 Appendix

9.1 Bill of materials

Part	**Manufacturer**	**Quantity**	**Cost Each**	**Cost**
IR Sensors	RadioShack	2	$3.50	$7.00
Op Amp	Analog devices	2	$1.20	$2.40
Dual Comparator	National Semiconductor	2	$0.55	$1.10
Hex Inverter	Digikey	1	$0.40	$0.40
Capacitors	DigiKey	4	$0.10	$0.40
Resistors	Digikey	22	$0.05	$1.10
Potentiometers	Digikey	4	$0.40	$1.20
Multiplexer	Texas Instruments	1	$0.95	$0.95
Microcontroller	Holtek	1	$4.00	$4.00
			Total:	**$18.55**

9.2 Datasheet for Photodiode and Phototransistor Matched Pairs

Electrical characteristics of photodiode

Parameter	**Value**
Reverse Voltage	5V
Continuous Forward Current	150mA
Forward Voltage	1.3V typical, 1.7V max
Radiant Power output	13-15mW
Wavelength at peak emission	950nm

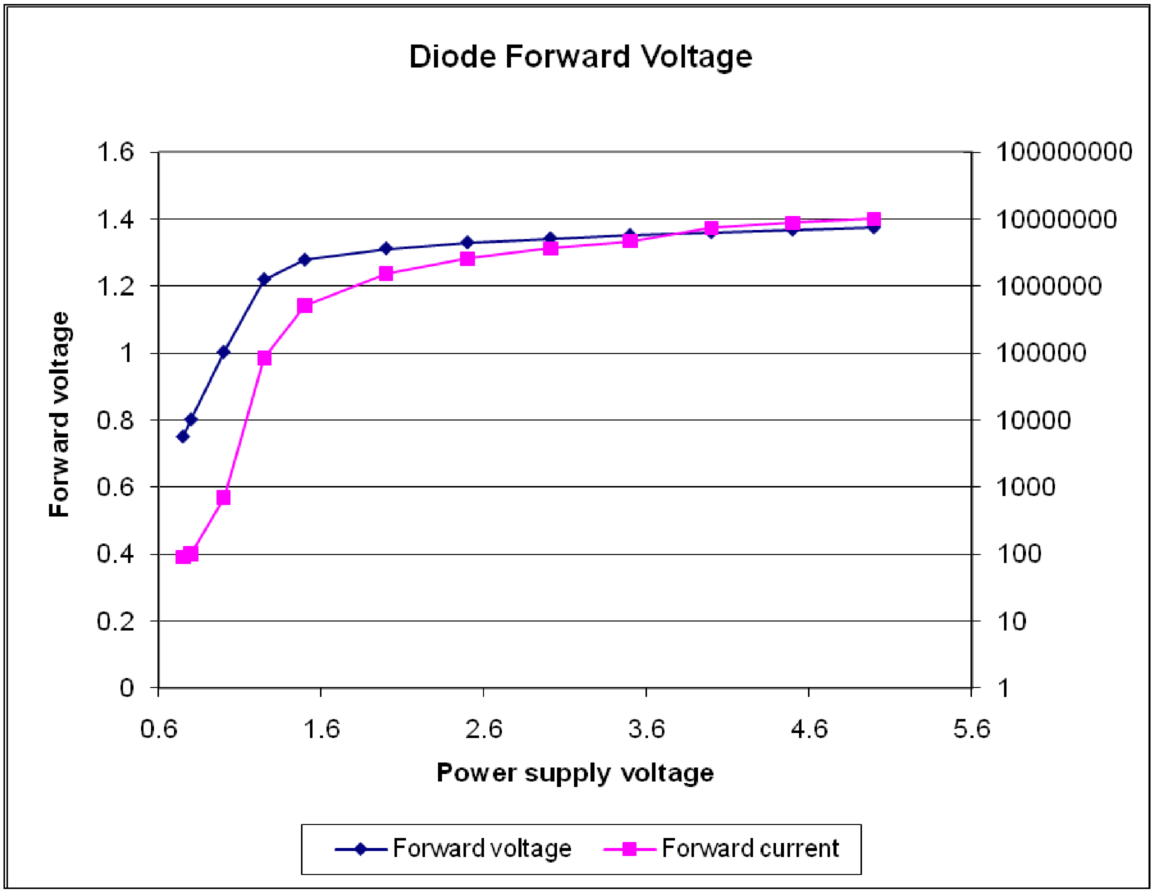
Electrical characteristics of phototransistor

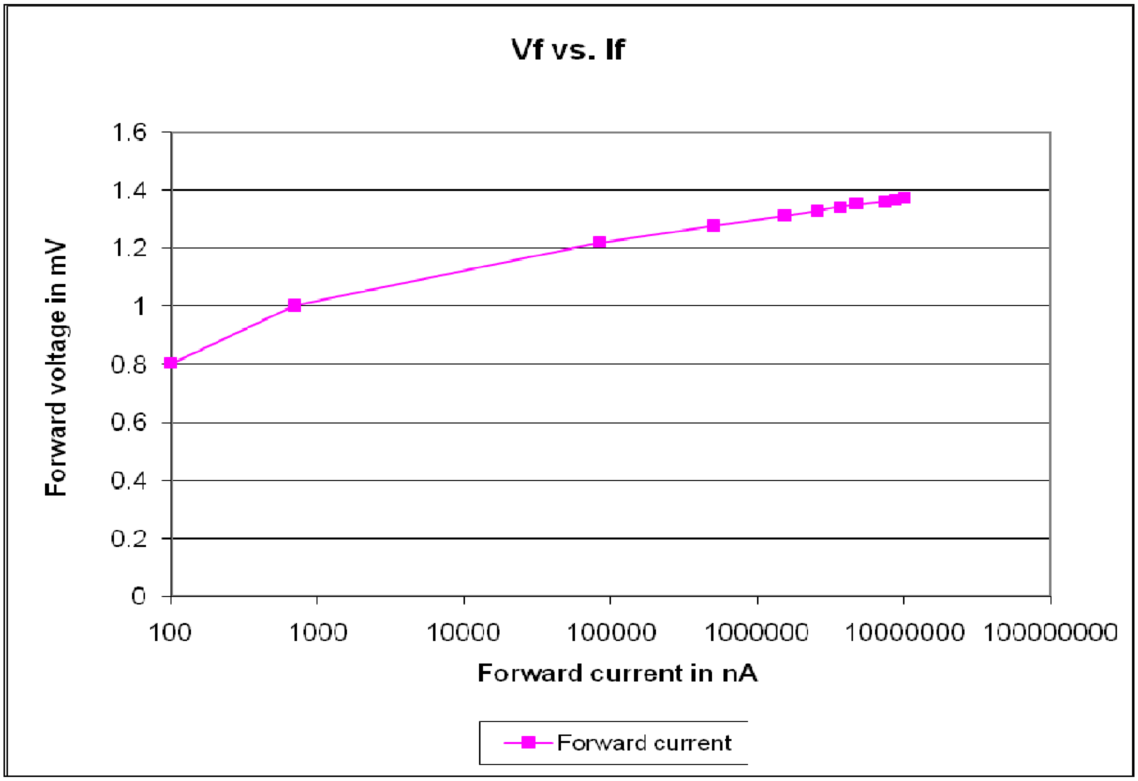
Parameter	**Value**
V_{CEO} Collector to emitter	70V
V_{ECO} Emitter to collector	5V
I_C Collector Current	50mA
Total power dissipation	150mW

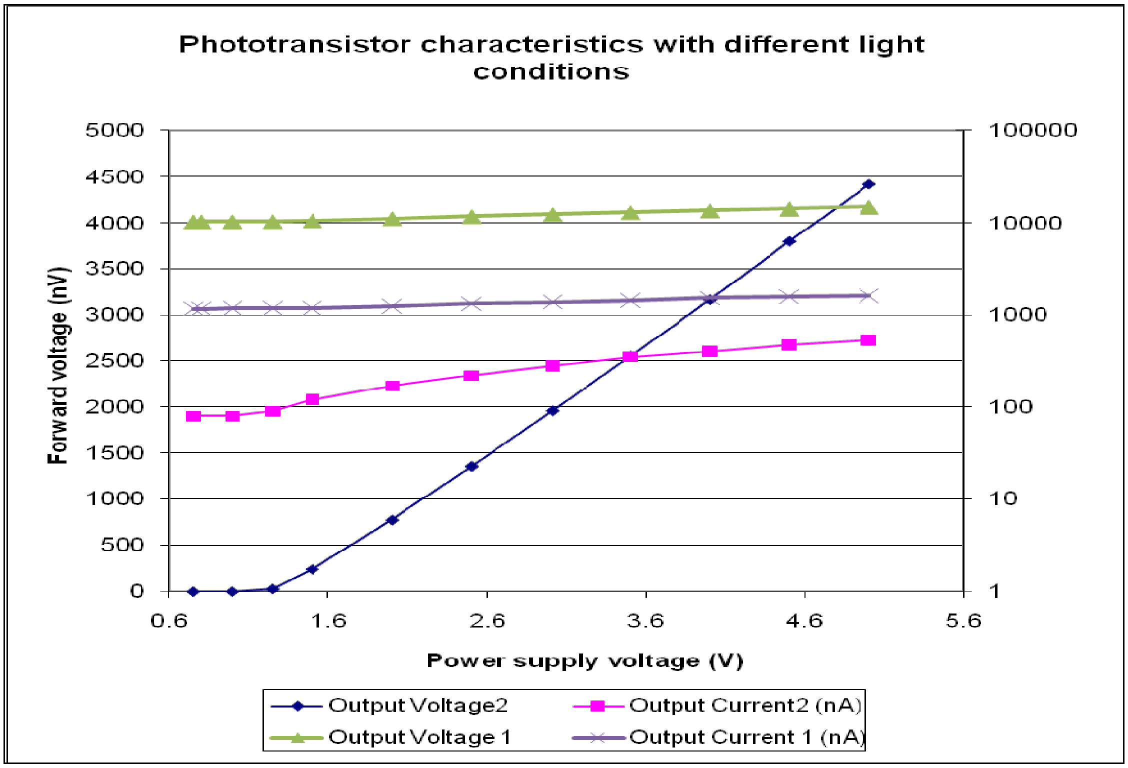
Spectral bandwidth range 620-980nm

Angle of half sensitivity ±20º

Characteristic Plots:

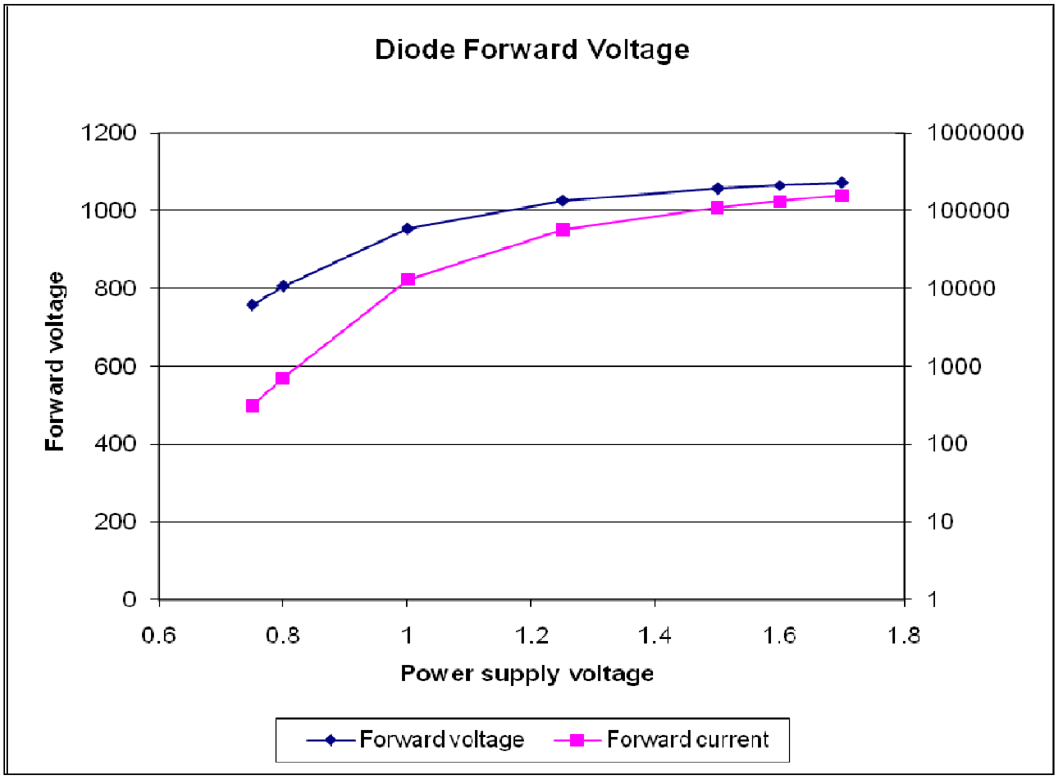


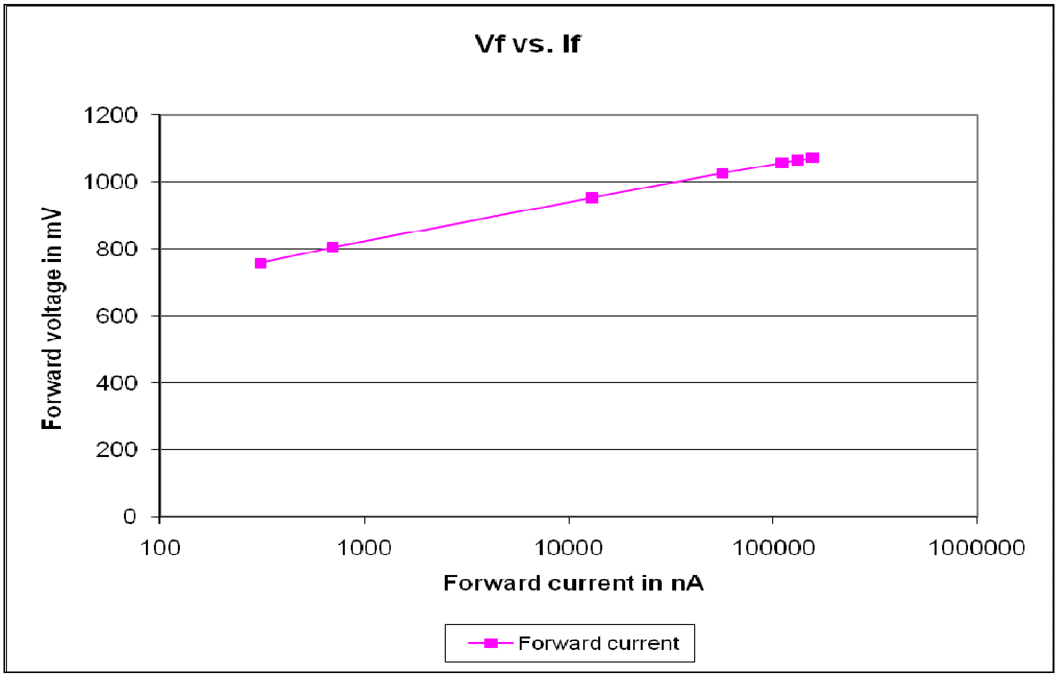

Vf vs. If
Forward voltage in mV
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
100
1000
10000
100000
1000000
10000000
100000000
Forward current in nA
Forward current



Phototransistor characteristics with different light conditions
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
100000
10000
1000
100
10
1
0.6
1.6
2.6
3.6
4.6
5.6
Forward voltage (nV)
Power supply voltage (V)
Output Voltage2
Output Current2 (nA)
Output Voltage 1
Output Current 1 (nA)

9.3 Modified datasheet for QRD113/14





9.4 Parameters for Cursor Control

Preliminary testing was conducted to determine the signal for the cursor movements of the mouse. Since, to design a circuit for cursor movements of the mouse it is extremely important to determine the specifications of the signal for the cursor movements of the mouse. The operational test for signal for the cursor movements was conducted on Intellimouse 1.2A. In addition, pulses required for cursor movement were measured using the Oscilloscope and Heathkit counter.

Procedure for measuring pulses:

Position the mouse cursor at top of the screen and move the cursor to the bottom of the screen. Measure the distance and the pulses required to move cursor from one side to the other. Position mouse cursor at extreme left side of the screen and move the cursor to the extreme right side of the screen. Measure the distance and the pulses required to move cursor from one side to the other.

Results and Specification of the signal

The signal observed for the cursor movement of the mouse is square pulses with voltage approximately equal to 5 V (4.68V).

Distance measured from top to bottom of the screen: 5cm

Number of pulses required to move cursor from top to bottom: 180 pulses

Distance measured from left to right of the screen: 7cm

Number of pulses required to move cursor from top to bottom: 252 pulses

Number of pulses per cm: 36

Time taken for slow cursor movement from left to right: 30 seconds.

Time taken for fast cursor movement from left to right: 0.25 seconds.

From top to bottom: 180 pulses/5cm and 4.27pixels/pulse

From Left to right: 252 pulses/7cm and 4.06pixels/cm

Slow movement left to right: 252 pulses/30 sec = 8.4 Hz

Fast movements left to right: 252 pulses/0.25 sec = 1,008 Hz

Scroll speed: “medium”, 6/11 notches no acceleration

Screen Resolution: 1024x768