R.V. COLLEGE OF ENGINEERING, BANGALORE 560059

(Autonomous Institution Affiliated to VTU, Belgaum)

AUTOMATIC PAGE TURNER WITH EYE TRACKING

PROJECT REPORT

Submitted by

REMO GEORGE JOSEPH	**1RV09EE041**
SHIV SURYA	**1RV09EE048**
SNEHA CHHABRIA	**1RV09EE051**
TUSHAR PRAKASH	**1RV09EE064**

Under the Guidance of
Dr. M N DINESH,
Associate Professor, Department of Electrical & Electronics Engineering,

R. V. College of Engineering.

in partial fulfilment for the award of degree

Of

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IN

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R.V. COLLEGE OF ENGINEERING, BANGALORE - 560059

(Autonomous Institution Affiliated to VTU, Belgaum)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CERTIFICATE

Certified that the project work titled **Automatic Page Turner with Eye Tracking** is carried out by **Remo George Joseph (1RV09EE041), Shiv Surya (1RV09EE048), Sneha Chhabria (1RV09EE051), Tushar Prakash (1RV09EE064),** who are bonafide students of R.V College of Engineering, Bangalore, in partial fulfilment for the award of degree of **Bachelor of Engineering** in **Electrical and Electronics** of the Visvesvaraya Technological University, Belgaum during the year **2012-2013**. It is certified that all corrections/suggestions indicated for the internal Assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed by the institution for the said degree.

Signature of	**Signature of**	**Signature of**
Dr. M.N.Dinesh	**Dr. R.Jayapal**	**Dr.B.S.Sathyanarayana**
Guide	**Head of Department**	**Principal**

External Viva

Name of Examiners **Signature with date**

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DECLARATION

We, **Remo Gorge Joseph (1RV09EE041), Shiv Surya (1RV09EE048), Sneha Chhabria (1RV09EE051), Tushar Prakash (1RV09EE064),** the students of eighth semester B.E., Electrical and Electronics**,** hereby declare that the project titled **“Automatic Page Turner with Eye Tracking”** has been carried out by us and submitted in partial fulfilment for the award of degree of Bachelor of Engineering in **Electrical and Electronics.** We declare that this work is not carried out by any other students for the award of degree in any other branch.

Place: Bangalore **Signature**

Date:

1. Remo George Joseph

2. Shiv Surya

3. Sneha Chhabria

4. Tushar Prakash

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We sincerely thank our Project co-ordinator **K.V. Bannithaya** and the Head of our Department, **Dr. R. Jayapal** for giving us an opportunity to test our skills and come up with ingenious solutions. Also, the transparent schedule of mini project ensured that we students were extremely comfortable and confident in tackling this task.

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Finally, we would like to show our immense gratitude to other members of the faculty, friends and family for their continued support and encouragement to make this effort a successful one.

ABSTRACT

Out of 7 billion people who inhabit the world, a staggering 53 million people suffer from paralysis. India alone has more than 9 million victims of paralysis. This means that one in 50 people in U.S. are living with this condition and are deprived of an acceptable standard of life. Quadriplegics are people paralyzed neck down. They have no control over any muscle below their neck region due to which they are constantly dependant on others to perform simple tasks. This project attempts to cater to victims of paralysis keeping in mind the aforementioned constraints, thus providing them with a greater degree of independence and a better quality of life.

Several Page turner devices have been designed for musicians and by major corporations like Sharp, Canvas for their photocopiers. However these page turners mostly use a simple push button as an input for actuation, making it inaccessible to the quadriplegic population.

This project implements a page turner using eye tracking as an actuating input, thus improving its accessibility to the disabled population. Electro-Oculography is used as an eye tracking method for user input. In Electro-Oculography, Silver-Silver Chloride EOG electrodes placed at the outer-canthi of the eye are used as the primary sensors to convert eye gaze into a proportional voltage signal. This signal is conditioned before being processed by a microcontroller serving as the input to a page turning mechanism. The page turning mechanism involves the use of two DC motors to drive the arm and contact wheel, and a DC servo motor driving the wiper which flips the page.

This prototype is capable of turning the pages of an ordinary book regardless of the number of pages in either direction. The page turner is capable of continuous operation, thus, making it reliable. It has a simple and robust structural design. Furthermore, electro-oculography, which is used as user input, is non-invasive and less hardware intensive, making the page turner cost effective.

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LIST OF SYMBOLS, ACRONYMS AND NOMENCLATURE

Sl. No	Abbreviation	Expansion/ Meaning
1.	Vcc	Positive Power Supply
2.	GND	Supply Ground/ Common
3.	EOG	Electro Oculagraphy/ Electro Oculogram
4.	ECG	Electro Cardiograph/ Electro Cardiogram
5.	EEG	Electro Encephalography/ Encephalogram
6.	V	Volts
7.	mV	Milli Volts
8.	Hz	Hertz
9.	R	Resistance
10.	C	Capacitor
11.	G	Gain
12.	Ag	Silver
13.	AgCl	Silver Chloride
14.	A	Amperes
15.	mA	Milli Amperes
16.	DIP	Dual In-Line Package
17.	PWM	Pulse Width Modulation

CHAPTER 1

INTRODUCTION

1.1 Paralysis - statistics and details

The Reeve Foundation is a charitable organization dedicated to curing spinal cord injury by improving the quality of life for people with paralysis through grants, information and advocacy. In a study [1] conducted by the Christopher and Dana Reeve Foundation, it was found that paralysis was the result of a number of causes ranging from Spinal Cord Injury (SCI) and traumatic brain injury to birth defects, multiple sclerosis and amyotrophic lateral sclerosis, the major contributor being stroke. This can be better understood through Fig. 1.1.

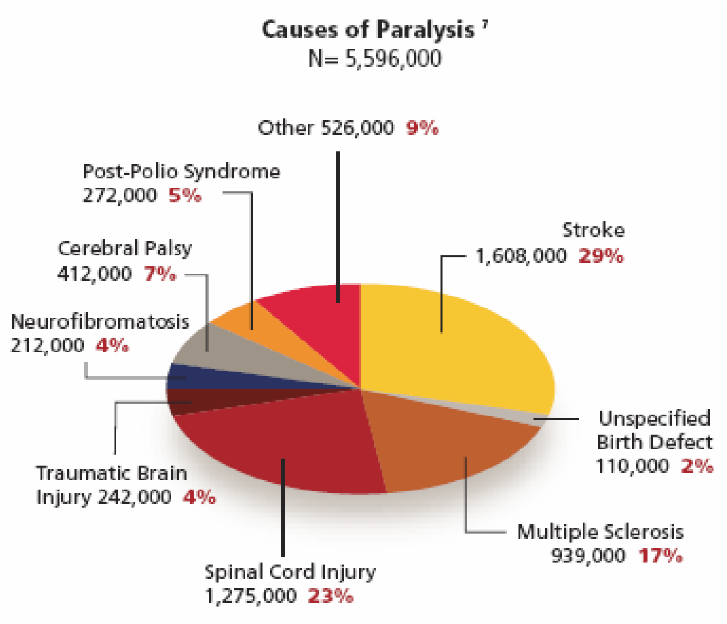


Fig. 1.1: Pie chart showing the cause of Paralysis

Considerable amount of effort has been made to make the lives of the paralyzed better, but the cost of implementing them is still an inconvenience.

1.2 Quadriplegia

Damage caused to the spinal cord could lead to a condition called quadriplegia. People suffering from quadriplegia no longer have control over their arms and legs. Usual reasons for SCI are rough contact sports, vehicle accidents and Progressive Motor Neuron Diseases (PMND). People afflicted with PMNDs tend to lose motor control starting from lower extremities, progressing upwards. By medical evidence and reason of logic, it can be discerned that ocular control is one of the last affected functionalities. Living with quadriplegia is not only tough for the victim but becomes strenuous for family members and friends. Such people are inherently robbed off their ability to perform even simple tasks such as holding up and reading a book on their own. Since their muscle movement is severely limited or sometimes, completely non-existent, they are constantly dependent on others for their basic needs.

1.3 Page Turner

Professor Ernesto Blanco from MIT was the first to design a page-turner, which was capable of automatically turning the pages of a book without the reader lifting a finger. The device was created at the request of musicians, who don't always have a free hand for turning the pages of their music while they're playing. The device utilizes a mechanical arm with a small spool of sticky tape that lifts each page and turns it. The musician or reader can operate it with the push of a button, or set a timer.

But it could also prove useful for people with multiple sclerosis, Parkinson's disease or other medical conditions. This project aims at using simple eye movements to facilitate page turning.

1.4 Eye Tracking Methods

In order to create a device which works hands free, a suitable user input method by which the user could initiate the page turning mechanism at will is to be designed. The essential criterion that we considered while evaluating the user input method was

- Accessibility to population with disability

  This prototype is intended for use by differently abled: multiple amputees, quadriplegics and bed-ridden patients and the user input method has to be user-friendly and require minimal training before use.

- Accuracy of user input method

  The input user method should be accurate and not produce erroneous actuations and recognize multiple user input commands/patterns intelligently with minimal error

- Cost and availability of parts

  The parts required should have minimal auxiliary interface requirements and ideally be nominally priced

- Compatibility with existing input methods

  The value of the user input method, its operability, and scope for future development are greatly enhanced if the user input method is already used in existing systems.

We shortlisted eye tracking as it met all the above requirements. We found seven major methods for eye/gaze tracking which are currently in use:

1. *Video oculography* – pupil and corneal reflection
2. *Video oculography* – pupil only
3. *Video oculography* – dual Purkinje image corneal reflection
4. *Video oculography* – limbus, iris-sclera boundary
5. *Electro oculography* – electro-potential about the eye
6. *Electromagnetic* – scleral coil in the eye
7. *Contact lens* – contact lens in the eye

The electromagnetic method is invasive as a coil needs to be inserted in the retina. Contact lens, although offers a high degree of accuracy, is again invasive. Hence these methods were not considered, as the invasive nature of these techniques pose considerable danger to the user due to the presence of foreign object in the eye. Video oculography of the limbus, iris-sclera boundary has very little available literature and has not been extensively developed. Table 1.1 shows a brief summary of all eye tracking methods.

Table1.1: Eye Tracking Methods

Technology	Method of Tracking	Used as an eye mouse system?	Invasive?	Ease of set up	Accuracy	Sampling Rate
Pupil and Corneal reflection	Video tracking of light reflection from the cornea and dark pupil (Video-Oculography)	Yes	No	Medium	High	Medium
Electro-potential	Measurement of electro-potentials around eye (Electro-oculography)	Yes	No	Medium	Medium	High
Pupil	Video Tracking of dark pupil (Video-Oculography)	Yes	No	High	Medium	Medium
Scleral Coil	Electromagnetic tracking of coil inserted in eye	None Known	Yes	Low	Medium	High
Dual Purkinje image	Video tracking of light reflections from the cornea and lens boundary	None Known	No	Low	Medium	High
Limbus	Video tracking of iris-sclera boundary	None Known	No	Medium	Low	High
Contact lens	Tracking of light reflected from contact lens inserted in eye	None Known	Yes	Low	High	High

The other three methods were evaluated as follows:

i. Video oculography with pupil and corneal reflection: The method of video oculography with pupil and corneal reflection determines gaze direction by comparing the pupil position with a reflection of incident light reflected from the cornea of the eye [2] (Duchowski, 2000; [3] Young et al, 1975; [4] Glenstrup et al 1995). Typically, the gaze-tracking system consists of a single eye tracker box with an infrared light source to illuminate the eye, an infrared camera to capture video of the eye, and automated camera focus and field of vision lens and steering mirrors to track head movements. The method determines gaze by calculating the changing relationship between the moving dark pupil of the eye and the essentially static reflection of the infrared light source back from the cornea. This approach relies on shining infrared light (to avoid the tracked subject squinting) at an angle onto the cornea of the eye, with the cornea producing a reflection of the illumination source (Fig. 1.2). The corneal reflection tends to remain stationary during eye movements of the pupil; this property typically is used to give a reference point in space for both the pupil and any head movements that might occur.

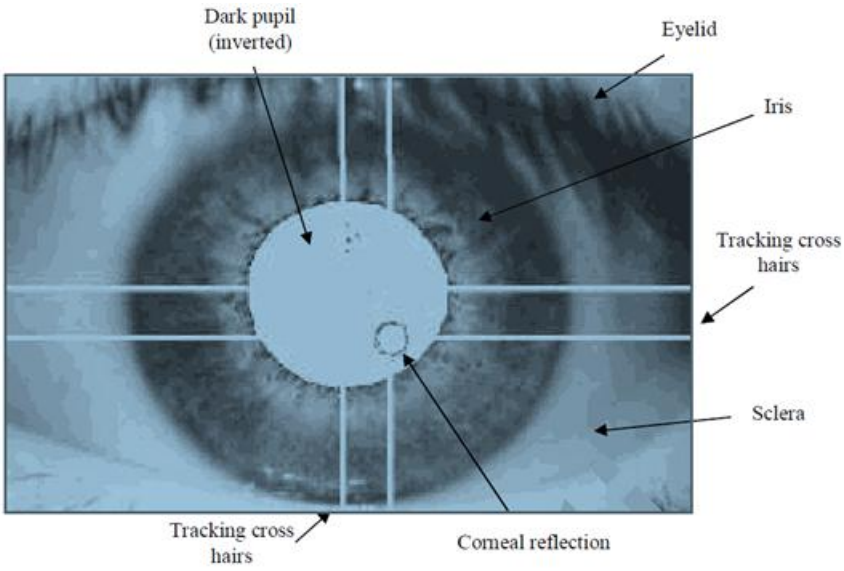


Fig. 1.2: Reflections in pupil and cornea

ii. Video oculography with pupil only: Pupil-only video oculography is similar to pupil and corneal reflection video oculography, except that only the position of the pupil is tracked. This tends to make the system sensitive to head movements causing gaze direction measurement inaccuracies. Typically, this is overcome by wearing the system on the head. Communication using this system is achieved by placing a small screen with dedicated on-screen keyboard within the head worn system, with the user communicating using typing on the on-screen keyboard [5] (Kahn et al., 1999). A second approach to pupil only oculography is the use of cameras to capture a complete image of the face [6] (Hansen et al., 2002). This is a simpler variant of pupil and corneal reflection video oculography and uses an inexpensive camera such as a web or

USB camera in conjunction with advanced video processing software to track the gaze direction of the pupil along with the position of the eye, thus compensating for any head movements Fig. 1.3.

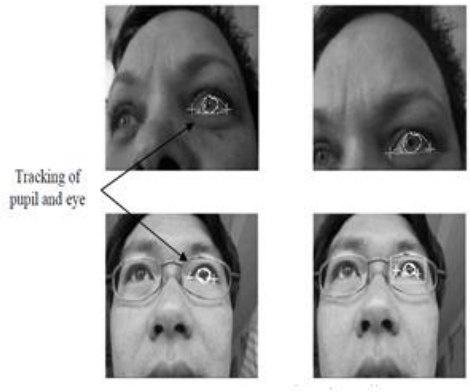


Fig. 1.3: Pupil and Eye Tracking

iii. Electro-potential oculography: Electro-potential oculography gaze tracking is based on electrical measurement of the potential difference between the cornea and the retina. This potential creates an electrical field in the front of the head that changes orientation in sympathy with gaze direction and can be detected by electrodes placed around, but not in, the eyes ([2]Duchowski, 2000; [3]Young et al., 1975; [7]Gips et al., 1993;[8] Gips et al., 1996;[4] Glenstrup et al, 1995). Typically, systems consist of an eye-tracking box with sensitive instrumentation amplifiers, adjustment controls and a small computer to convert the detected eye position to a digital signal. A system is illustrated in Fig. 1.4.

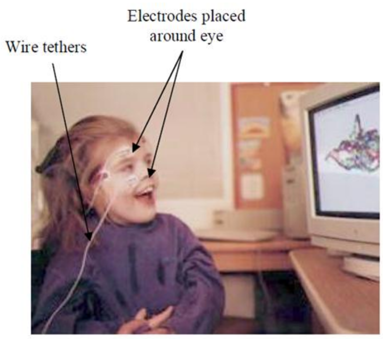


Fig. 1.4: EOG Tracking

We shortlisted Electro-oculography because of its low cost, ease of implementation and compatibility with Eagle eyes system [9].

1.5 Motivation

Several methods as described in section 1.4 exist to detect eye-gestures. Amongst these, the video processing method, which detects eye movements from real time images of the eyeball, has inherent problems such as slow reaction time and cumbersome processing algorithms which make the system poorly characterized in terms of real-time response. The video processing based approach also becomes expensive owing to the need for costly equipment (video camera, DSP kit) required for acquisition and processing of the signal. The head mounted camera based eye-gaze solution presents large camera sizes, unstructured luminance conditions, and complicated image recognition efforts. Another method for eye movement detection is using infrared reflectance of the cornea, which is difficult to use over a long period because the eyes tend to become dry and fatigued. The sclera reflection method detects eye movements using the differential reflectivity of eyes, but its accuracy is not sufficient for practical application. In these methods, vision is hindered by these devices themselves. Electroencephalogram (EEG), Electromyogram (EMG) and Electro-oculogram (EOG) are of prime interest in Human-Machine Interface applications. The electroencephalography based Brain Controlled Interface (BCI)[14][15][16] approach is not easy to implement due to weak signal strength, complicated signal distributions, heavy computation efforts, possible wrong recognitions, and inconvenient surface electrode installations. Compared with EEG and EMG signals, the physiologies of EOG are better understood. Moreover, it is simpler to complete the acquisition, feature extraction and analysis of EOG signals. Therefore, EOG based approach is more suited for this application in terms of dependability, accuracy and cost. Section 1.6 gives an insight into the applications of electro-oculography as an eye tracking method.

1.6 Electro-oculography

Kenji Yamagashi et al., 2006 [10] proposed a communication support interface controlled by eye movements and voluntary eye blink developed for disabled individuals with motor paralysis. Horizontal and vertical electro-oculograms were measured using two electrodes attached above and beside the dominant eye, referring to an earlobe electrode. The signals were amplified with AC-coupling in order to reduce unnecessary drift. The authors were successful in controlling the movement of a mouse cursor using the signal of electro-oculogram. The experiment conducted by the authors involved a virtual screen keyboard that examined the use of Electrooculography. The algorithm developed eliminated the baseline drift and increased the accuracy thereby yielding the desired result. Using the electro-oculogram signals eight directional movements were realized.

An eye-control method based on electro-oculography (EOG) to develop a system for assisted mobility is described in Rafael Barea et al.,2002 [11] according to which one of most important features is its modularity is, making it adaptable to the particular needs of each user depending the type and degree of handicap involved. An eye model based on electrooculographic signal is proposed and its validity is studied. Different strategies of electrooculographic guidance have been commented (direct access, automatic or semiautomatic scanning, and eye commands), describing their main characteristics of electro-oculography: acquisition and processing of the EOG signal and its applications in assistive systems for the disabled.

Min Lin et al.,2010[12] the authors propose a wireless EOG based Human Computer Interface (HCI). They employ an ARM controller for signal processing and the technique of Electro-oculography. For wireless communication between the HCI and the device, a Zigbee module is used. Bio-potentials such as Electroencephalogram, Electromyogram and Electro-oculogram are used as inputs of this HCI system. The HCI or the Human Computer Interface constructs a direct communication or control way between the human body and the computers or any other electrical device.

EagleEyes, a new technology that allows a person to control the computer simply by moving his or her eyes or head as described by the James Gips et al.,1996 [9]. The technology is based on the measurement of the EOG, or electro-oculographic potential, through electrodes placed on the head. The authors have worked with people with severe disabilities to try out the system and to teach them how to use the system to control the computer. The system runs on a Macintosh and allows us to run both custom-developed software and most commercial software. Through EagleEyes, people can run educational and entertainment software, spell out messages, and navigate through the internet just by moving their eyes.

Rafael Barea et al.,2002 [13] involves a new method to control and guide mobile robots. In this case, to send different commands is used electro-oculography techniques (EOG), so that, control is made by means of the ocular position (eye displacement into its orbit). Eye movements require minimal effort and allow direct selection techniques, this increase the response time and the rate of information flow. This control technique can be useful in multiple applications, but in this work is used to guide an autonomous robot (wheelchair) as system to help to people with severe disabilities. The system consists of a standard electric wheelchair with an on board computer, sensors and graphical user interface running on a computer. There are a lot of applications can be developed using EOG because this technique allows to users a free degree in the environment. If the eye gaze is known, it is possible to development different user interfaces to control different task.

1.7 Objectives

The objective of our project is the development of a robotic page turner system which meets the following criteria:

- The page turner should reliably turn a single page on user input in both directions.
- The page turner's ability to turn pages should be invariant to the book's dimensions and page thickness.
- The resting position of the robotic page turner must not reduce the readability of the page in any manner.
- Test the page turning system for consistency.

- Implement a suitable signal conditioning circuit to acquire the Electro-Oculography signal used for eye tracking and render it suitable for acquisition.
- Test the conditioned signal against the user input for coherence.
- Integrate the page turning system with the eye tracking input.
- Test the integrated system for consistency, bugs and address issues.

1.8 Methodology

1.8.1 System Architecture

The system architecture as shown in Fig. 1.5 can be broadly categorized into four major parts:

(A) EOG signal acquisition: The signal from the eye is of low magnitude and is acquired through low impedance electrodes which minimises signal attenuation.

(B) Signal conditioning: When dealing with real time analog signals such as those obtained from the eye, it is necessary to implement suitable signal processing techniques to successfully acquire the signal and make it usable for digital control.

(C) Microcontroller: The microcontroller processes the sampled signal from the conditioning module and provides a suitable actuation signal to the drive.

(D) Page Turning Mechanism: This module involves D.C and servo drives which carries out the page turning operation.

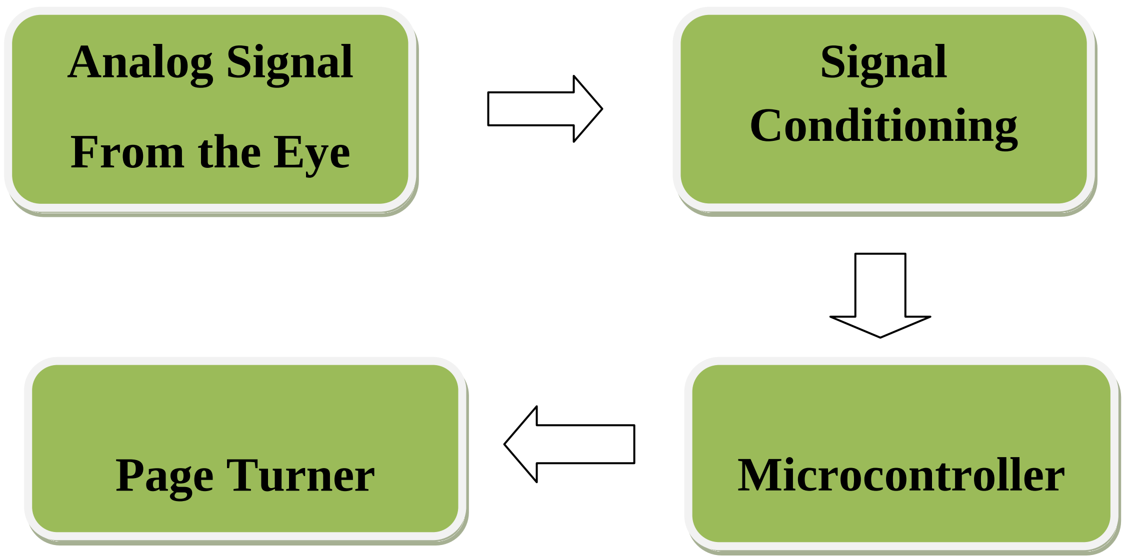


Fig. 1.5: Block Diagram of System Architecture

1.9 Organization of the report

This section will cover the different aspects of the project from the fundamentals involved, the implementation of our design and concludes with our inference.

Chapter 1: Introduces the project. It goes on to point out the drawbacks of the current system and gives an insight to our implementation as well as our project objectives.

Chapter 2: It deals with the fundamentals of various modules of the page turner including Electro-oculography, nature of the signal from the eye and signal conditioning requirements to render it feasible as an actuation input. Also, it discusses the motors used to drive the page turner and their control.

Chapter 3: We have presented our design of the signal acquisition and conditioning circuit and structure of the page turner mechanism.

Chapter 4: This chapter discusses the output of the signal acquisition circuitry to acquire the EOG signal and the application software required to process it and actuate page turning.

Chapter 5: We display the results that we have obtained after extensive testing of the project.

Chapter 6: Concludes with the outcomes that we obtained from our project. The future scope of our design is also explained in this section.

The report for our project concludes with a list of references we have used and the appendix.

CHAPTER 2

PRINCIPLES OF ELECTRO-OCULOGRAPHY AND PAGE TURNER DRIVES

This chapter deals with the fundamentals of various modules of the page turner mentioned in 1.8. Sections 2.1-2.3 deals with Electro-oculography, nature of the signal from the eye and signal conditioning requirements to render it feasible as an actuation input. Section 2.4 discusses the motors used to drive the page turner and their control.

2.1 EOG Signal

The eye is known to have a resting potential and acts as a dipole in which the anterior pole (cornea) is positive and the posterior pole (retina) is negative. The magnitude of this cornea-retinal potential is in the range 0.4-1.0 mV. This difference in potential can be explained by the metabolic activities in the eye. Electro-Oculography (EOG) ([17] Jakka Malmivuo et al., 1995) is a technique for measuring this resting potential. The resulting signal is called the "Electro-oculogram". This can be better understood through Fig. 2.1.

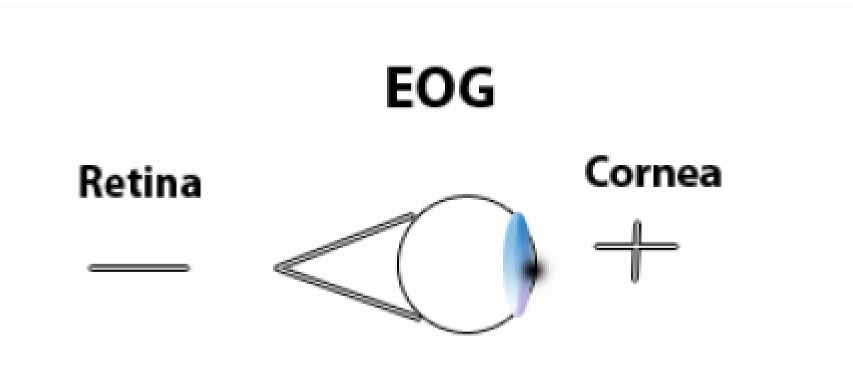


Fig.2.1: Polarity of the Eye

The movement of each eyeball in its orbit is caused by the individual contractions of six small voluntary muscles attached to the surface of the eyeball. Four of the six muscles run straight from origin to insertion, and thus are termed recti muscles (rectus, straight): the superior rectus, the inferior rectus, the medial rectus, and the lateral rectus.

Muscle	Eye Direction
Inferior Rectus	Downward
Superior Rectus	Upward
Lateral Rectus	Laterally
Medial Rectus	Medially
Superior Oblique	Downward and Laterally
Inferior Oblique	Upward and Laterally

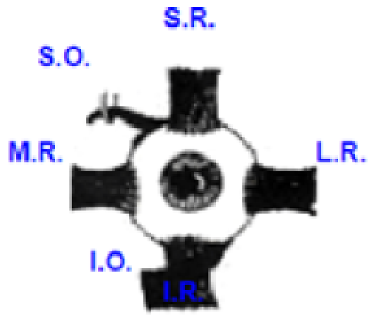


Fig. 2.2: Muscles related to Eye Motion

The remaining two muscles are obliquely attached to the eyeball surface and are called the superior oblique and the inferior oblique. Collectively, the four recti muscles and the two oblique muscles are called extrinsic eye muscles. This is shown in Fig. 2.2.

Nine cardinal directions of gaze in concerted eye movement and the extra-ocular muscles moving the eyes to the gaze position are shown in Table 2.1. When a person maintains visually focused on a moving object without moving the head, such as in watching the swinging pendulum of a clock, each eye must move precisely and in concert with the other for the brain to receive the sensory information required to produce a clear, single image of the moving object.

Table 2.1: Muscles corresponding to eye motion

Position	**Right Gaze**		**Straight Ahead**	**Left Gaze**	
	Right Eye	**Left Eye**	**Both Eyes**	**Right Eye**	**Left Eye**
Upward	Superior Rectus	Inferior Rectus	Superior Rectus Inferior Rectus	Inferior Oblique	Superior Rectus
Centered	Lateral Rectus	Medial Rectus	Central Gaze	Medial Rectus	Lateral Rectus
Downward	Inferior Rectus	Superior Oblique	Inferior Rectus Superior Oblique	Superior Oblique	Inferior Rectus

Coordinated voluntary eye movements are initiated and controlled in the motor cortex of the frontal lobes. Cortical activity associated with motor control of the extraocular muscles can be detected and recorded using conventional electroencephalographic techniques. Electro-oculography (EOG) is the measurement and interpretation of electro-oculograms, which are the electroencephalographic tracings obtained while the subject, without moving the head, moves their eyes from one fixation point to another within the visual field.

2.2.1 Silver/Silver Chloride (Ag/AgCl) Electrodes

The signal from the lateral canthi of the eyes is converted into voltage by electrodes. A typical surface electrode used for EOG recording is made of Sliver- Silver Chloride (Ag/AgCl). These electrodes are attached to the patients‟ skin and can be easily removed. For this project, Electro-Encephalogram (EEG) Electrodes are used as they are commercially available and are permanent. EEG electrodes exhibit similar characteristics as EOG electrodes. The main design feature of these electrodes which help in reducing the possibility of artifacts, drift and baseline wandering is the provision of a high-absorbing buffer layer with isotonic electrolyte.

2.3 Signal Conditioning

The EOG signal is a low voltage range bio-potential signal which can be easily corrupted by noise in the ambiance. It therefore is passed through a signal conditioning module to extract the horizontal and vertical gaze direction.

2.3.1 AD620 Instrumentation Amplifier

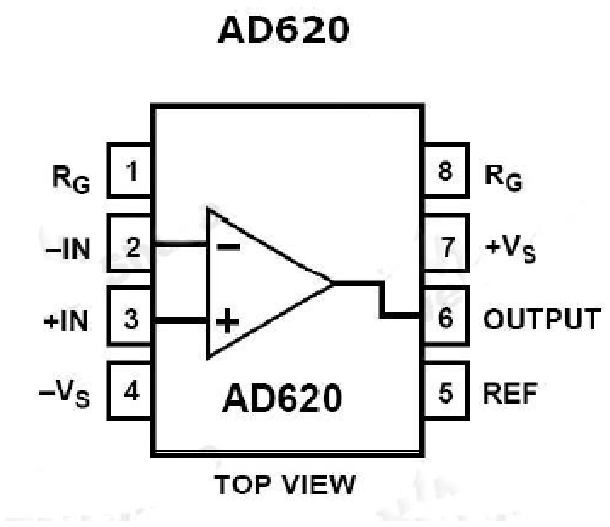


Fig. 2.3: Pin configuration of AD620

Fig. 2.4: AD620 DIP IC

The first stage in the signal conditioning module is amplification. Since biomedical signals are used, care must be taken to provide the right type of amplification else there would be a great danger of losing the signal all together. For such an application an instrumentation amplifier AD620 is used. The pin configuration is as shown in Fig. 2.3.

AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC (Small Outline Integrated Circuit) and DIP (Dual In-line Package) packaging that is smaller than discrete designs and offers lower power (only 1.3mA max supply current). Fig. 2.4 shows an image of AD620 in dual in-line package.

Since this project uses standard EOG electrodes to receive the signal, the AD620 is ideal because of its low noise, low input bias current and low power consumption. The AD620 works well as a preamplifier due to its low input voltage noise of 9nV/√Hz at 1 kHz, 0.28μV p-p in the 0.1 Hz to 10 Hz band, and 0.1pA/√Hz input current noise.

2.3.2 Filtering

A filter is a device or process that removes from a signal some unwanted component or feature. Filtering is a class of signal processing, the defining feature of filters being the complete or partial suppression of some aspect of the signal. Most often, this means removing some frequencies and not others in order to suppress interfering signals and reduce background noise. A low-pass filter passes low-frequency signals but attenuates (reduces the amplitude of) signals with frequencies higher than the cutoff frequency. The actual amount of attenuation for each frequency depends on the order of the filter. High pass filter passes the high frequency signals above the cutoff frequency and attenuates the low-frequency signals.

The filter implementation of the EOG signal acquisition circuit uses the Sallen-Key topology which provides for easier selection of circuit components, and at unity gain, it has no gain sensitivity to component variations. A Butterworth filter ([18] Ron Mancini et al.,2009) was found most suitable as it offered the best all-around filter response. It has maximum flatness in the pass-band which is particularly important to us as EOG signals are very sensitive to ripples in the pass band. Also, the Butterworth filter exhibits moderate rolloff past cutoff, and shows only slight overshoot in response to a pulse input.

A high pass Butterworth filter, with a very low cut-off frequency of 0.1Hz is used ([19] B. R. Greene et al., 2004). Therefore the output of the filter removes signals corresponding to sweat and other artifacts present in the skin which cause the DC drift. The low pass filter is designed to cut off noise from the 50Hz power source and radio frequency noise. Since humans can act as antennas, they can pick up signals from nearby wireless equipment such as cell phones. Therefore, a low pass filter with a cut-off frequency of 30Hz is designed to remove these signals.

2.3.3 UA741 Op-Amp

The UA741 as shown in Fig. 2.5 is a high performance monolithic operational amplifier constructed on a single silicon chip. It is intended for a wide range of analog applications.

- Summing amplifier
- Voltage follower
- Integrator
- Active filter
- Function generator

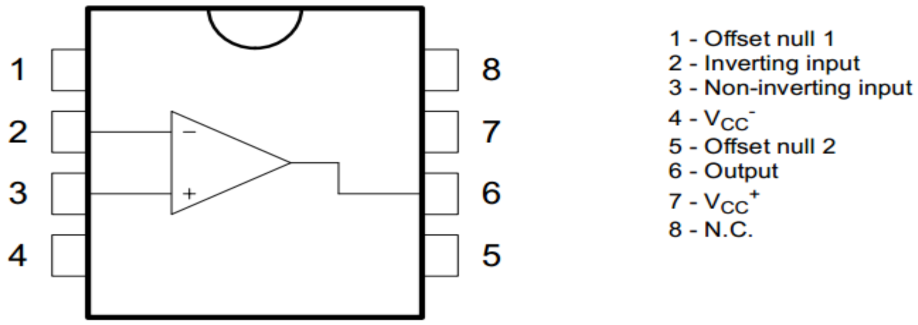


Fig. 2.5: Pin Diagram of UA741

The high gain and wide range of operating voltages provide superior performances in integrator, summing amplifier and general feedback applications. The internal compensation network (6dB/octave) insures stability in closed loop circuits.

2.3.4 AVR ATmega328 Microcontroller

The AVR is a modified Harvard architecture 8-bit RISC single chip microcontroller which was developed by Atmel. The AVR was one of the first microcontroller families to use on-chip flash memory for program storage, as opposed to one-time programmable ROM, EPROM, or EEPROM used by other microcontrollers at the time. Program instructions are stored in non-volatile flash memory. Although the MCUs are 8-bit, each instruction takes one or two 16-bit words. The size of the program memory is usually indicated in the naming of the device itself (e.g., the ATmega64x line has 64kB of flash while the ATmega32x line has 32 kB).There is no provision for off-chip program memory; all code executed by the AVR core must reside in the on-chip flash.

This particular microcontroller was chosen owing to the following reasons:

- It has a 5 volt linear regulator and a 16 MHz crystal oscillator.
- The high-performance Atmel 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities.
- The microcontroller is also pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory.
- It has 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs.

Fig. 2.6 has the pin configuration of ATmega328.

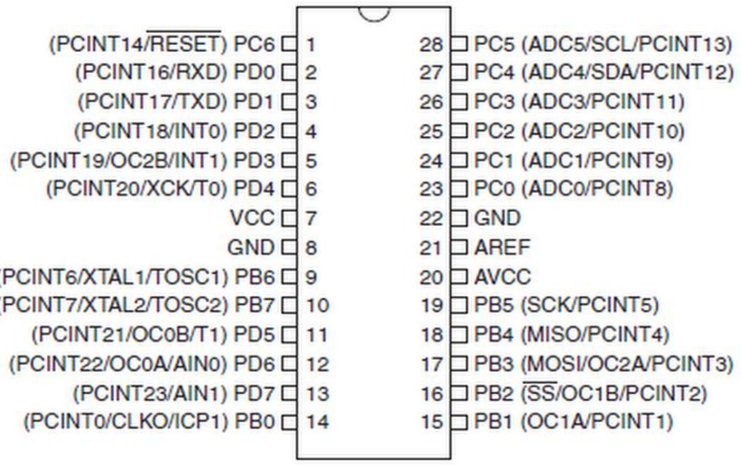


Fig. 2.6: Pin Configuration of ATmega328 IC

The AVR microcontroller is used along with a “development board” called Arduino. Arduino is a single-board microcontroller designed to make the process of using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open source hardware board designed around an 8-bit Atmel AVR microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. The Arduino Uno board used in our application is shown in Fig. 2.7.

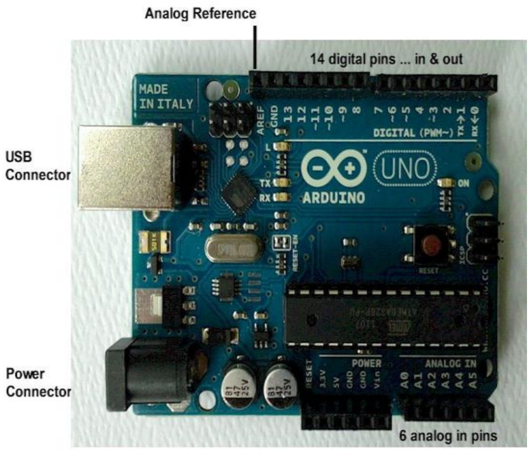


Fig. 2.7: Arduino Uno Development Board

2.4 Page Turner Mechatronics

2.4.1 Servo Motor

Fig. 2.8: Servo motor

Servo refers to an error sensing feedback control which is used to correct the performance of a system. Servo Motors as shown in Fig. 2.8 are DC/AC motors equipped with a servo mechanism for precise control of angular position. A 0-180 DC servo motors is attached to the base and drives the wiper enabling the page turner to flick a page. The technical specifications of the VS-1 servo motors used in the project are shown in Table 2.2.

Table 2.2: Technical Specifications

Control System	PWM, 1500 μs neutral
Operating Voltage	4.8V-6V DC
STD Direction	Counter Clockwise
Operating Speed	0.18s/60degrees at 6V
Stalling Torque	4.0 kg.cm at 6V
Running Torque	0.35 A
Stall Current	1.2A
Output Angle	>=120 degrees
Dead Bandwidth	5 μs
Motor Type	3 Pole Metal Brush
Bearing	Resin Bush

The servo motors receive the PWM signal from the Microcontroller and then rotate, in our case a full 180 degrees to turn the page and then return back to 0 degree position.

2.4.2 Permanent Magnet DC Motor

Two Permanent Magnet DC motors (shown in Fig. 2.9) are used, one to drive the arm which supports the contact wheel and another driving the contact wheel itself. The DC motor has following specifications:

Fig. 2.9: Geared PMDC motor

- 10RPM 12V DC motors with Metal Gearbox and Metal Gears
- 18000 RPM base motor
- 6mm Diameter shaft with M3 thread hole
- Gearbox diameter 37 mm.
- Motor Diameter 28.5 mm
- Length 63 mm without shaft
- Shaft length 15mm
- 180gm weight
- 12kgcm torque

The DC motors have a gearbox which reduces the speed from a base motor speed of about 18000 RPM to 10 RPM delivering a high torque of 12 kg-cm at load. The High torque requirement of the motor driving the contact wheel to overcome friction between wheel and page is met easily by this motor. Also use of a PMDC geared motor to drive the movement of the supporting arm enables use of a robust metal structure for contact wheel support and easy direction control of the central motor for changing page turning direction.

2.4.3 H-bridge based direction control

A D.C. Motor requires a voltage difference between its terminals to rotate. The direction in which a motor rotates in determined by which side of the motor is connected to the positive and negative terminals. Swapping the positive and negative terminals will cause the motor to rotate in the opposite direction. An H-Bridge ([20] Al Williams, 2002) is used to control the direction of the motor and to also provide enough current for the motor to run.

To force a motor to switch in two directions, one requires a minimum of 4 switching elements. We will use 4 MOSFET to control the direction of the motor as shown in Fig. 2.11.

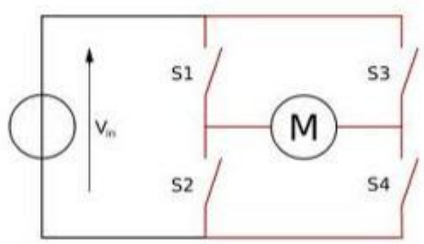


Fig. 2.10: H-Bridge Configuration

Initially, all switches are open. There is no potential difference across the ends of the motor. It will therefore, not rotate in any direction. If only switches 1 and 4 are ON (Q-Drive), there will be a voltage drop across the motor and it will run. This also occurs when only switches 2 and 3 are ON (Inverted QDrive), however the motor runs in the opposite direction. If only S1 and S3 are ON, or if only S2 and S4 are on, there will be no voltage drop across the motor and it will brake.

Instead of Individual MOSFETs, we use the L293D H-bridge dual IC driver which has the following specifications:

- Wide Supply-Voltage Range: 4.5 V to 36 V
- Separate Input-Logic Supply
- Internal ESD Protection
- Thermal Shutdown
- High-Noise-Immunity Inputs
- Output Current 600mA per channel
- Peak Output Current 1.2 A
- Output Clamp Diodes for Inductive
- Transient Suppression

CHAPTER 3

DESIGN OF SIGNAL CONDITIONING CIRCUIT AND PAGE TURNER

3.1 Electro-Oculagraphy Signal

Specially designed electrodes for EOG are place on the corners (lateral canthi) of both the eyes. When the eyes look left the positive end of the dipole (the eye) comes closer to the electrode on the left canthus and the negative end to the right canthus ([17] Jaakka Malmivuo et al., 1995). The vice versa is observed for the eyes looking towards right. Ideally the difference in potential should be proportional to the sine of the angle the eye produces with respect to the central axis.
Fig. 3.1 shows the relation between eye movements and the corresponding voltage produced graphically.

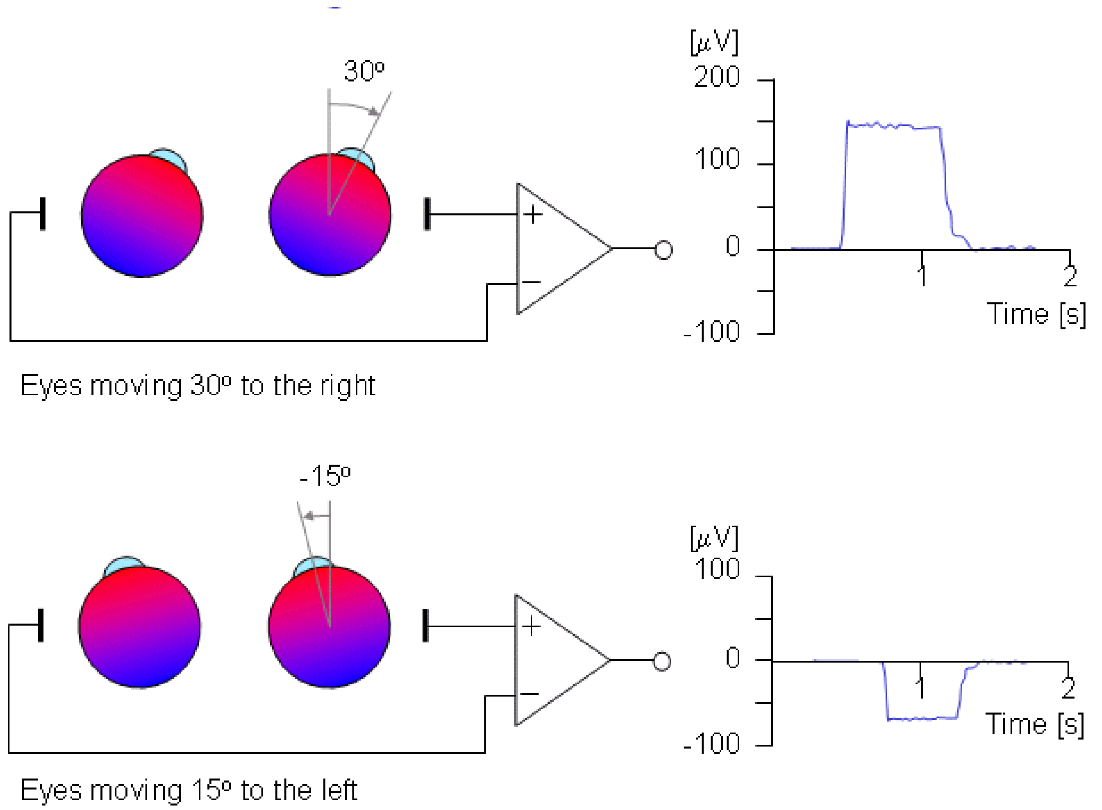


Fig. 3.1: Graphs of electrode output

This change in dipole proximity produces slight voltage variation which is the source signal for Page Turner. This layer absorbs the effects of movement of the electrode in relationship to the skin, and attempts to maintain the polarization associated with half-cell potential constant. Due to conditions such as sweat, oil, on the skin, the conductivity changes constantly. Therefore, noise tends to be added in the signal. Also, the EOG signal exhibits a constant DC drift of 0.5 Hz.

3.1.1 Ag-Agcl Electrodes:

The electrical characteristics of Ag-AgCl electrodes are:

Output frequency	: 1Hz to 30Hz
Output Voltage	: 100μV to 10000μV
DC Drift	: 0.5Hz

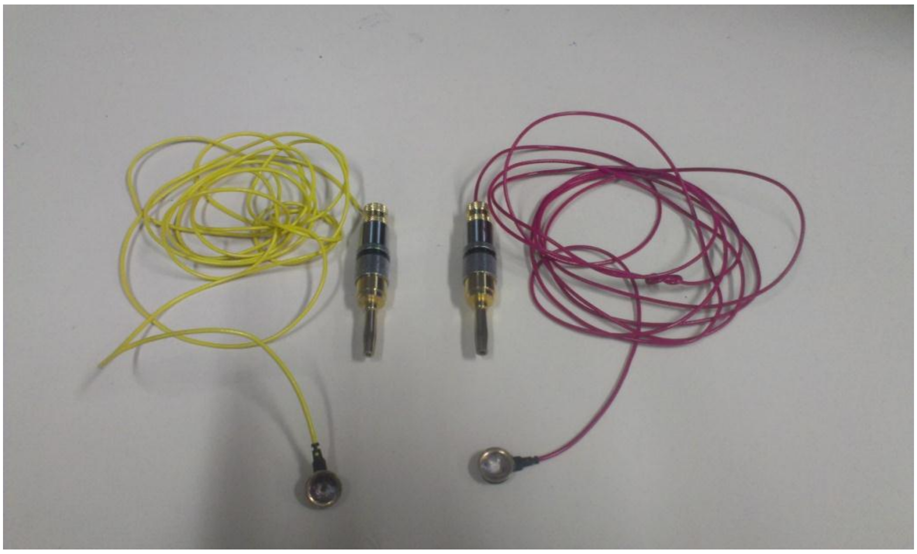


Fig 3.2: Ag/AgCl Electrodes

3.1.2 Electrode Placement

The electrodes are placed on the skin ([13] Rafael Barea et al., 1999) as shown in Fig.3.3

Fig. 3.3: Placement of Electrodes

3.2 Signal Conditioning

3.2.1 Initial Design

The 2mV to 20mV signal generated from the electrodes needs to be amplified and filtered to feed it to the ADC. A 0.5 Hz drift exists in the EOG signal due to power line surges and noise. Hence suitable methods have to be adopted to filter and amplify the signal removing the drift greatly reducing inconvenience in signal acquisition.

a) Amplification: For the first and fourth stage amplification of 10 and 100 respectively, the calculation is as follows:

$$Gain\ (G) = 1 + \frac{49.4k}{R}$$

Therefore, resistor value is

$$\mathrm{R} = \frac{49.4k}{G-1}$$

For a gain of 10, hence the resistor value obtained was 5.5kΩ. While for a gain of 100, the calculated value of resistance is 50Ω.

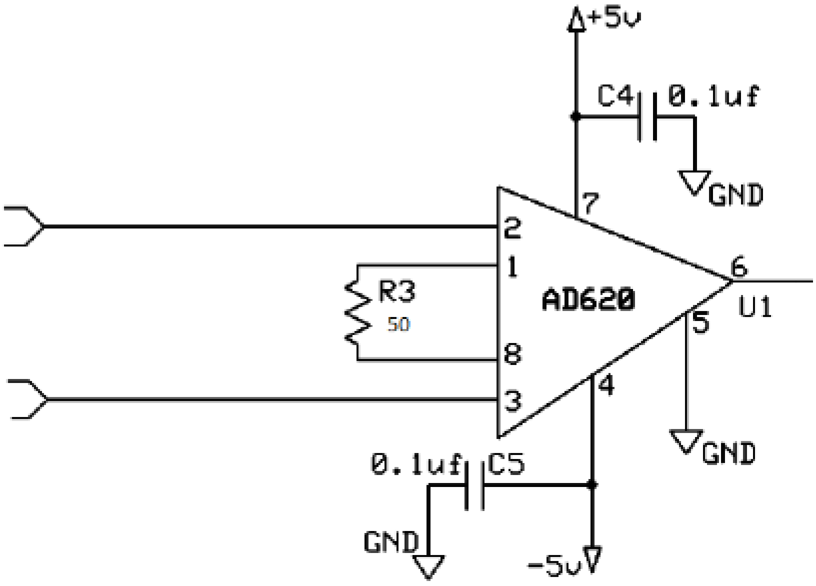


Fig. 3.4: AD620 Circuit Design

b) Filter Design: Cut-off frequency of a passive 1st order low pass filter is given by:

$$Fc = \frac{1}{2\pi RC}$$

A cut-off of 30Hz was desired and hence for a standard capacitance of 0.1μF resistor value of 53kΩ is obtained.

For the third stage a high pass filter with a cut-off of 0.2Hz is designed using the above mentioned formula. Using a standard capacitance of 1μF a resistance value of 795k**Ω** is obtained.

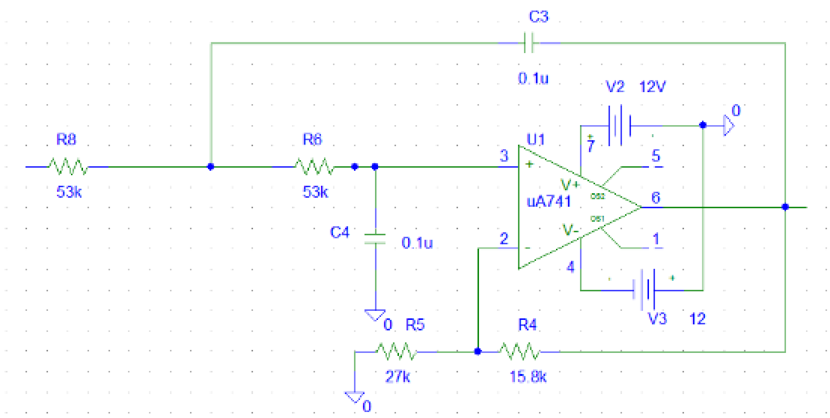


Fig. 3.5: Low Pass Filter Design

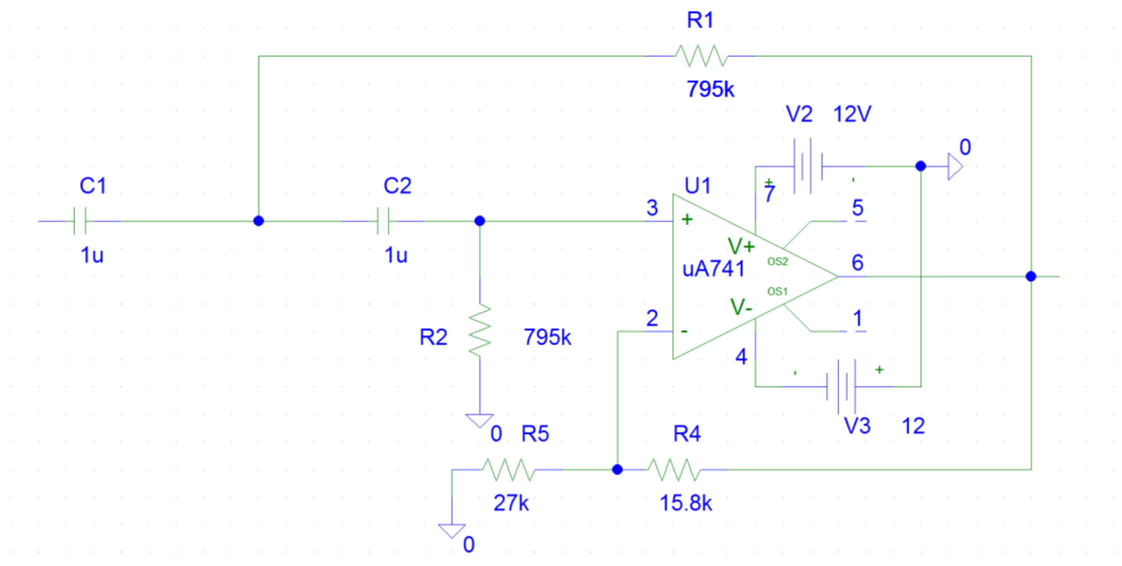


Fig. 3.6: High Pass Filter Design

3.2.2 Drawbacks of Initial Design

The above circuit was simulated on Pspice platform and the simulated frequency response concurred with the design. The hardware implementation of the circuit worked adequately when a frequency sweep was performed with a sinusoidal wave input from a signal generator. However, with an EOG input, the output showed a substantial ripple and did not agree with the expected waveform.

The problem with this circuit, seen in Fig. 3.5 and 3.6 was that it did not address the issue of EOG drift due to which our signals did not remain at the new level when the user makes an extreme eye movement. The issues of sweat and other artifacts on the user's face were also not resolved.

3.2.3 Final Circuit Design

a) Amplification: An AD620 instrumentation amplifier with a gain of 100 was designed using the same principle and concept as used in our initial circuit design. The amplifier design is shown in Fig. 3.7.

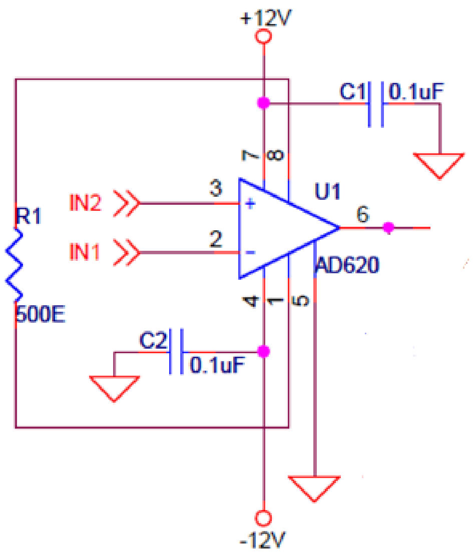


Fig. 3.7 AD620 Amplifier Design

b) Filtering: The current design does not cancel baseline drift, instead limits the effect of baseline drift by accounting for it while processing the sampled signal. This is done by sampling two temporally spaced signals and evaluating the sign of their difference, which is an indicator of the direction of eye movement. A sixth order Butterworth low-pass filter with a frequency cut off of about 30 Hz was used. The Butterworth filter is implemented using standard 741 op amps. The values of resistors and capacitors are designed in such a way that the cut-off frequency of the filter is about 30Hz as indicated in figure 3.8. Butterworth filter's ripple-less characteristics are useful as the EOG electrodes output are extremely unstable. Using a filter with prominent ripples (Chebyshev, Elliptical filters) in its characteristics is not desirable.

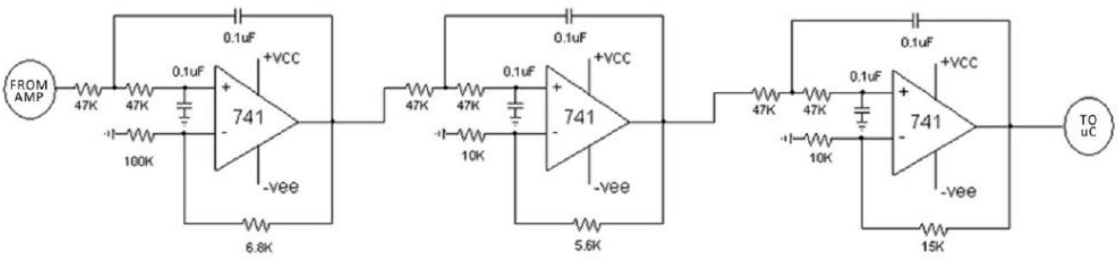


Fig. 3.8: 6^{th} order low pass Butterworth Filter

3.2.4 Final Signal Conditioning Schematic

The final schematic of the signal conditioning board is given in Fig. 3.9. A PCB layout was made and given for fabrication to a professional organisation.

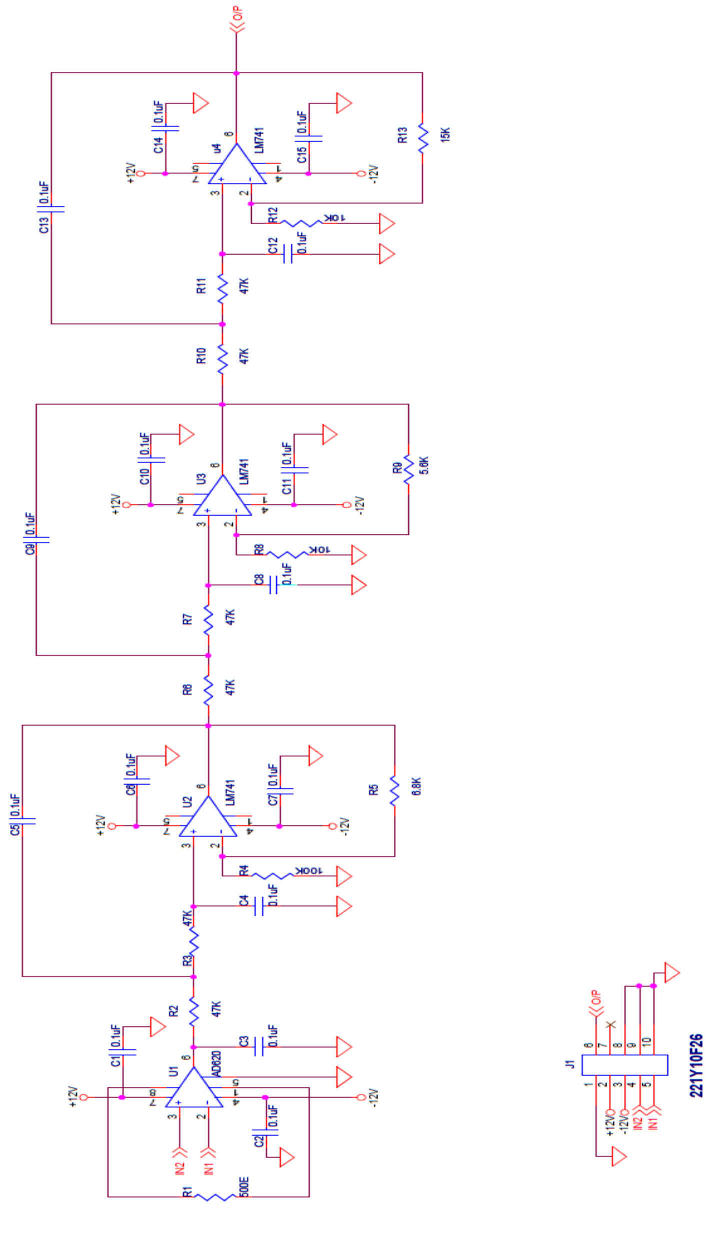


Fig. 3.9: Final schematic of Signal Conditioning

3.3 Page Turner Design

3.3.1 Structure

Fig. 3.10 shows the final structural design of the page turning mechanism consisting of the two DC motors, the servomotor, strut and the wiper.

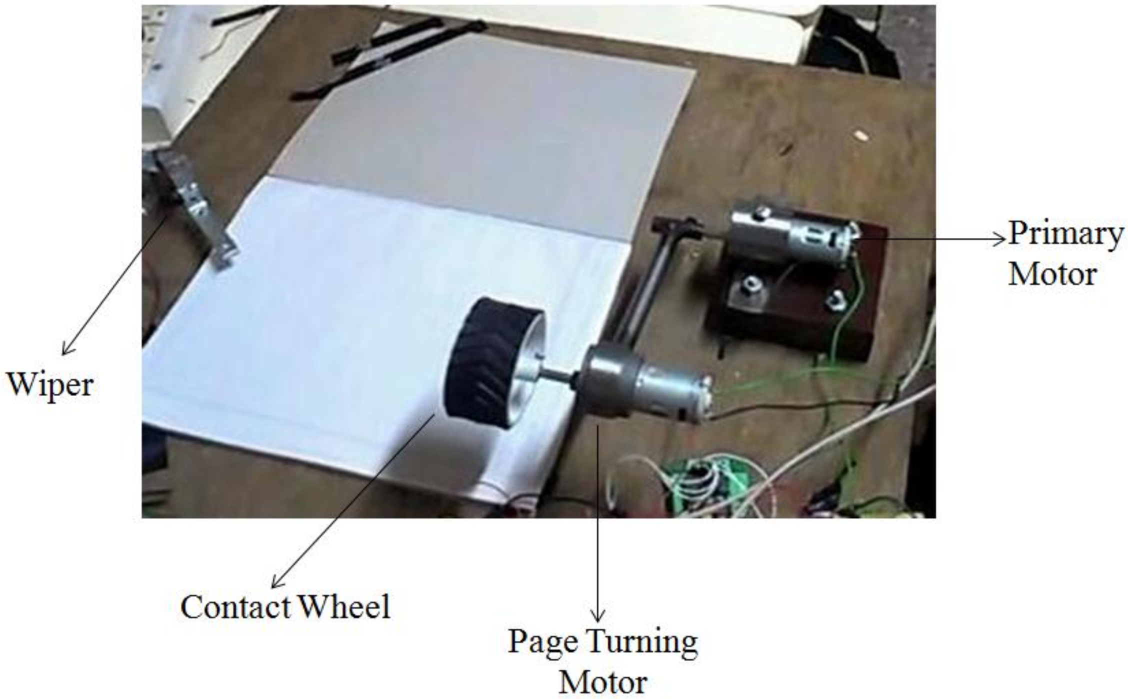


Fig. 3.10: Page Turner Structure

The primary dc motor pivots an arm on to provide access to either side of an open book. Mounted at the end of the arm is a contact wheel which is driven by another DC motor. The Wheel is driven when in contact with a page to create a fold in the page. The viper then driven by a 0-180 DC servo motor, swipes into the fold and across the breadth of the book to turn a page successfully.

CHAPTER 4

TESTING OF SIGNAL ACQUISITION CIRCUIT AND SOFTWARE APPLICATION DEVELOPMENT

This chapter discusses the output of the signal acquisition circuitry to acquire the EOG signal and the application software required to process it and actuate page turning.

4.1 EOG Signal

Tables 4.1 and 4.2 illustrate the voltage output from the electrodes placed on two subjects, when looking in three different directions namely straight, left and right. All readings were taken using the same reference as straight or centre.

Table 4.1: Electrode Output of Subject 1

Sl.no	Left (mV)	Straight (mV)	Right (mV)
1	5.2	6.1	7.3
2	5.4	6.0	7.1
3	5.1	6.3	7.0
4	5.3	6.4	7.5
5	5.0	6.1	7.0
6	5.5	6.4	6.9
7	5.1	5.7	7.2
8	5.3	6.2	7.0
9	5.4	6.0	7.1
10	5.2	6.3	7.2

Table 4.2: Electrode output of subject 2

Sl.no	Left (mV)	Straight (mV)	Right (mV)
1	4.1	5.2	6.1
2	4.3	5.4	6.2
3	4.0	5.1	6.3
4	4.4.	5.3	6.0

5	4.6	5.5	6.3
6	4.4	5.4	6.5
7	4.3	5.4	6.4
8	4.2	5.1	6.2
9	4.4	5.5	6.4
10	4.3	5.2	6.1

From the tables 4.1 and 4.2 it can be inferred that output of the electrodes is not constant. It is heavily dependent on skin texture, size of eyes and ambient conditions as well. Sweat increases conductivity whereas oil decreases it. Therefore, for the same people in different conditions, different outputs would be read.

4.2 Signal Conditioning

4.2.1 Amplification

The EOG signal acquired from the electrodes are passed through an amplifier and a series of filters in order to eliminate unnecessary noise and obtain only the useful signal.

Table 4.3 shows the voltage levels of the acquired signal for one subject after the initial amplification.

Table 4.3: Acquired Signal after Amplification for Subject 1

Sl.No	Left (V)	Straight (V)	Right (V)
1	0.52	0.63	0.72
2	0.51	0.65	0.70
3	0.54	0.62	0.73
4	0.53	0.65	0.71
5	0.51	0.61	0.74
6	0.50	0.65	0.73

4.2.2 Final Signal Conditioning Output

The readings shown in table 4.3 are susceptible to several noise sources and fluctuate drastically.

The voltage levels after filtering and another stage of amplification (Gain= 2.8) is shown for two subjects in table 4.4 and 4.5. The additional amplifier was necessary to make the signal suitable for the ADC.

Table 4.4: Final Voltage Level after Signal Conditioning for Subject 1

Sl.No	Left (V)	Straight (V)	Right (V)
1	0.82	1.1	1.35
2	0.77	1.02	1.3
3	0.75	1.0	1.26
4	0.76	1.3	1.55
5	0.76	1.03	1.32

Table 4.5: Final Voltage Level after Signal Conditioning for Subject 2

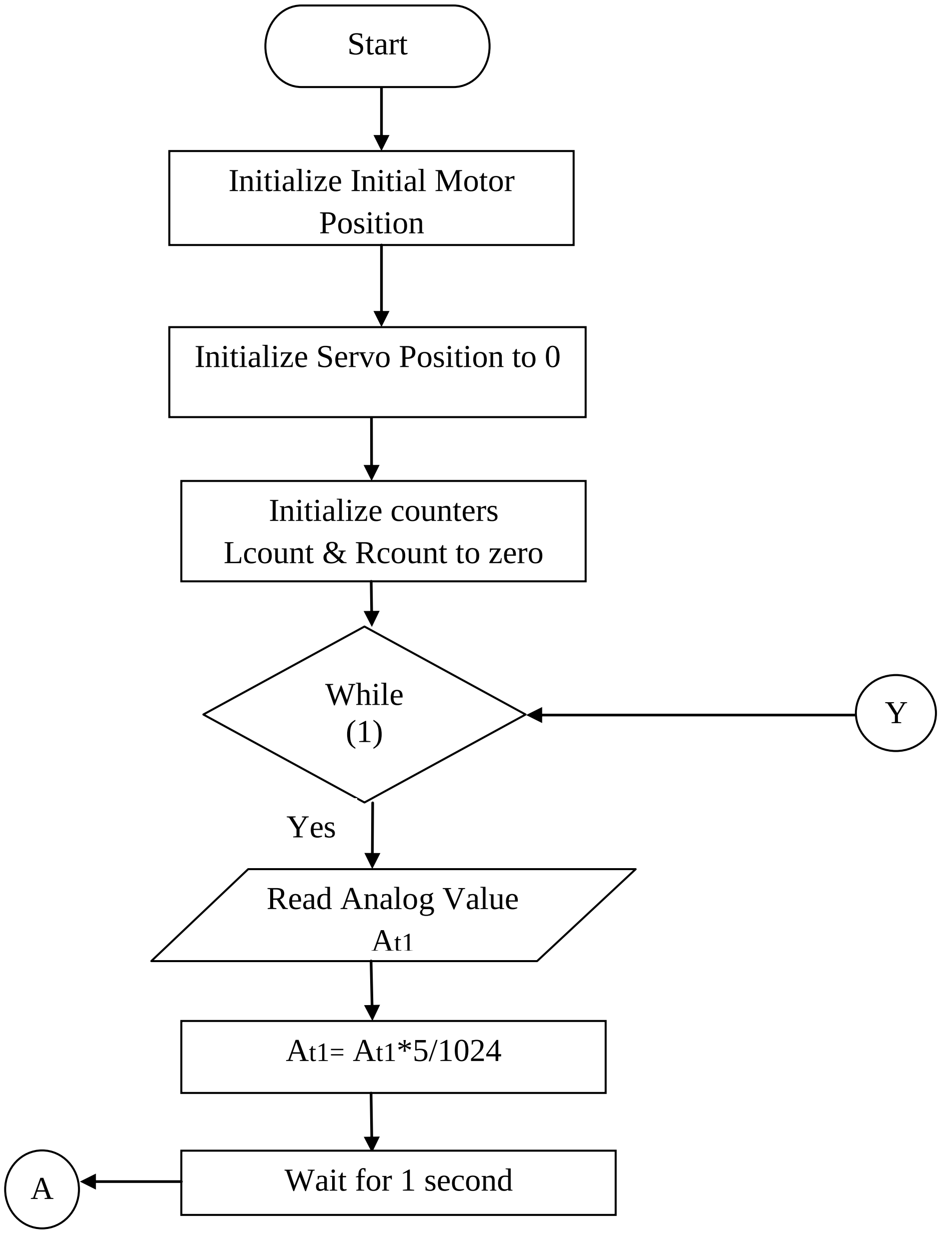
Sl.No	Left (V)	Straight (V)	Right (V)
1	2.93	3.2	3.48
2	2.72	3.0	3.27
3	2.76	3.1	3.38
4	2.78	3.2	3.47
5	2.77	3.3	3.52

The voltage levels shown in tables 4.4 and 4.5 are suitable enough to be read by a microcontroller. When the subject looks in either direction the voltage change remains predominantly uniform, however, the absolute value of the voltages can vary depending on the subject, time of testing and other environmental conditions.

4.3 Software

4.3.1 Flow Diagram for Page Turner

In the generic flow diagram, Fig. 4.1 At1 and At2 are two temporally spaced EOG signals sampled by the ADC in the microcontroller. At1 and At2 are then compared to a threshold and status of user input i.e. whether it is a command to turn page to the right or left is determined by the sign of the difference between At1 and At2. Fig. 4.2 shows the corresponding rotate functions i.e. rotate_left() or rotate_right() is called which actuates the page turner mechatronics.



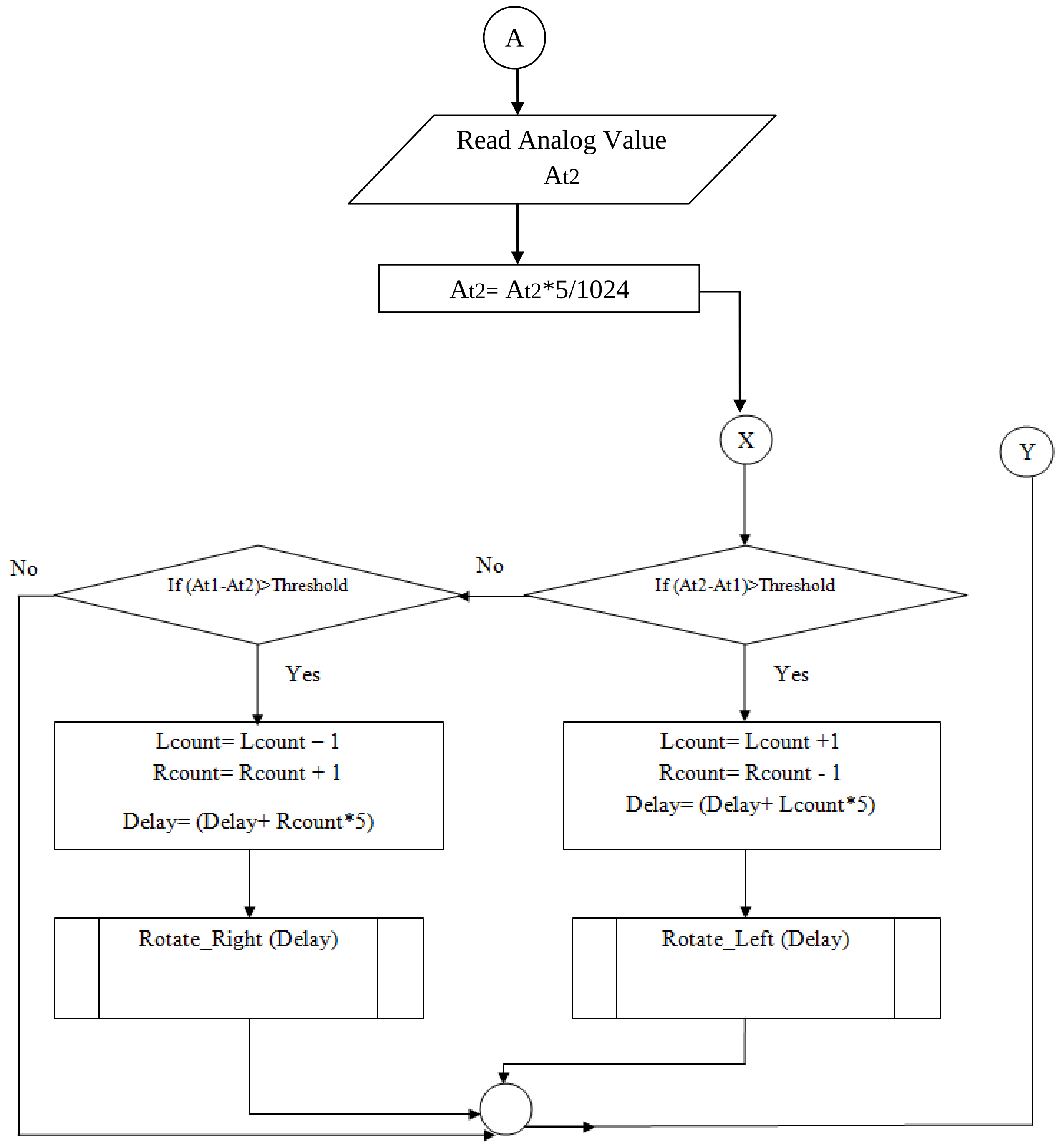


Fig. 4.1: Generic Flow Diagram

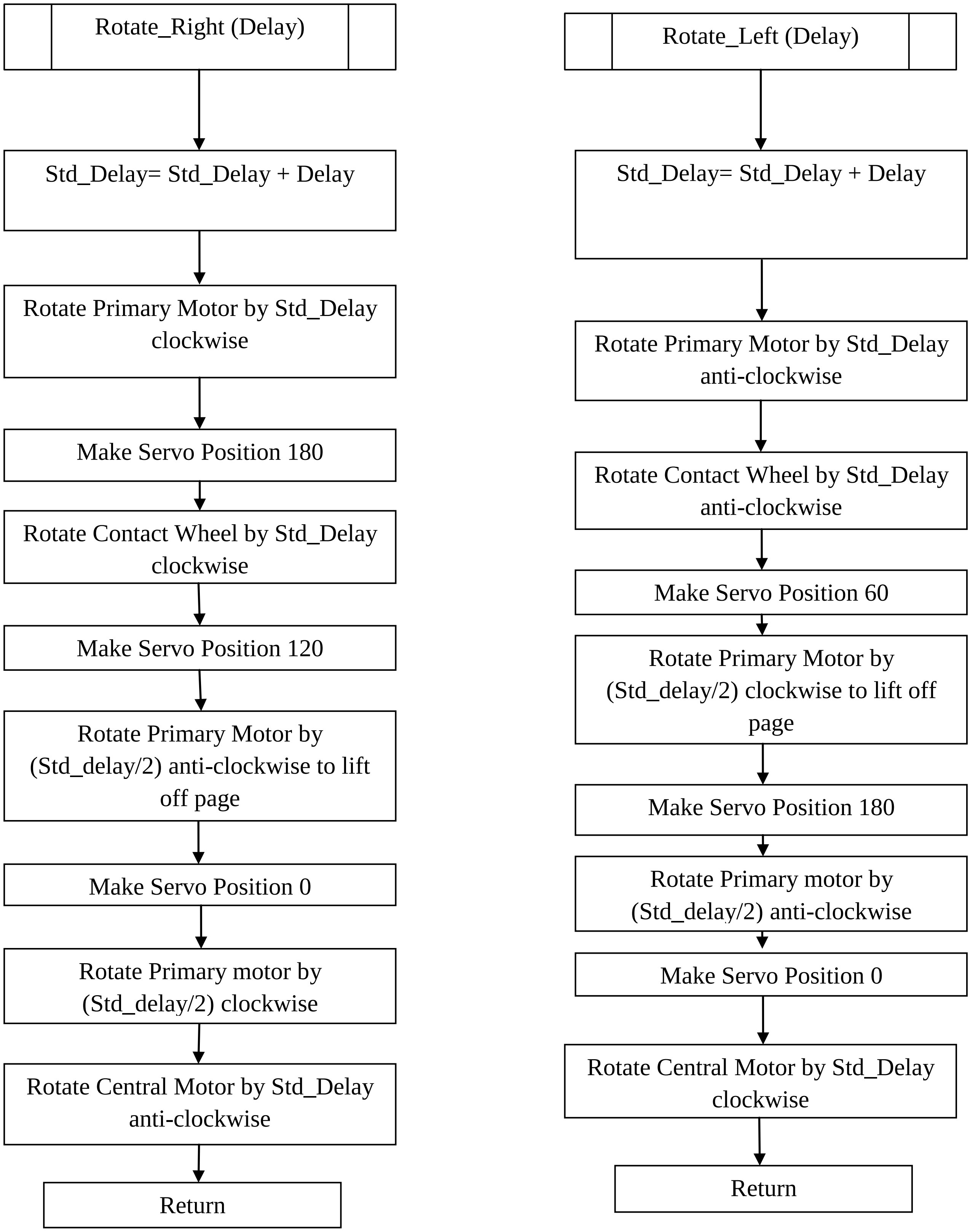


Fig. 4.2: Rotate Functions

4.3.2 Code

This embedded application drives the page turner. The application consists of:

(1) setup() - which initializes the mode of digital ports, initial position of page turner ,servo parameters including pin to which it is attached and initial position of the servo. The function takes no parameters and returns none.

(2) loop() -This function is non-parameterized and executes infinitely. It measures the EOG signal from the analog input pin and compares it to a threshold to determine the status of the user input from the eye tracker to the page turner. Based on this decision , it determines the time(variable delay) by which the constant speed central motor must be driven so that the contact wheel of the page turner touches the page surface and calls either of the two functions- rotate_right(delay) or rotate_left(delay).

```
#include <Servo.h>

 Servo myservo;  // create servo object myservo of class Servo to control a servo
motor

//Assign microcontroller pins to variables
int motorPin1 = 10;
int motorPin2 = 11;
int motorPin3 = 12;
int motorPin4 = 13;
int motorPin5 = 5;
int motorPin6 = 6;
int motorPin7 = 8;
int motorPin8 = 9;
#define thresh  0.13



//initialize flags and counters
int f=1;
int lcount=0;
int rcount=0;
int delay=0;

void setup()
{
myservo.attach(6);  // attaches the servo on pin 6 to the servo object myservo

myservo.write(0); //initialize servo position to 0 degrees
```

```
  //switch off indicator led’s
  digitalWrite(motorPin7, LOW);
  digitalWrite(motorPin8, LOW);

  // conFig. pin status for microcontroller pins
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(motorPin3, OUTPUT);
  pinMode(motorPin4, OUTPUT);
  pinMode(motorPin5, OUTPUT);
  pinMode(motorPin6, OUTPUT);
  pinMode(motorPin7, OUTPUT);
  pinMode(motorPin8, OUTPUT);
  digitalWrite(motorPin5, HIGH);
  digitalWrite(motorPin6, HIGH);

  //Initialize primary motor position
  digitalWrite(motorPin1, LOW);
  digitalWrite(motorPin2, HIGH);
  delay(1000);

   digitalWrite(motorPin2,LOW);
   digitalWrite(motorPin1, LOW);
   delay(2000);

}

void loop()
{

  f=1;

  while(f==1)
  {
    // sample first EOG output
    int sensorValue1 = analogRead(A5);

    float voltage1 = sensorValue1 * (5.0 / 1023.0);

    //wait for 1 second
    delay(1000);

    // sample second EOG output
    int sensorValue2 = analogRead(A5);
    float voltage2 = sensorValue2 * (5.0 / 1023.0);

    delay=0;

    if((voltage2-voltage1)>thresh)
```

```
        {
            f=0;
            lcount=lcount-1;
            rcount=rcount+1;
            delay=delay+(rcount*5);
            rotate_right(delay);

        }

     else if((voltage1-voltage2)>thresh)
       {
           f=0;
           lcount=lcount+1;
           rcount=rcount-1;
           delay=delay+(lcount*5);
           rotate_left(delay);

        }
     }
  delay(1000);
  digitalWrite(motorPin7, LOW);
  digitalWrite(motorPin8, LOW);

}

void rotate_left(delay)
  {
      digitalWrite(motorPin7, HIGH);

      //Rotate primary motor counter-clockwise
      digitalWrite(motorPin1,LOW);
      digitalWrite(motorPin2,HIGH);
      delay(1000+delay);

      //Stop primary motor rotation
      digitalWrite(motorPin2,LOW);
      digitalWrite(motorPin1, LOW);
      delay(3000);

       // Rotate wheel counter-clockwise
       digitalWrite(motorPin3,LOW);
       digitalWrite(motorPin4, HIGH);
       delay(1300);

       // Stop wheel
       digitalWrite(motorPin3,LOW);
       digitalWrite(motorPin4, LOW);
       delay(2000);

      // Set servo to 60 degree to hold folded page
```

```
    myserve.write(60);
    delay(1000);
   //lift wheel off page
   digitalWrite(motorPin1,HIGH);
   digitalWrite(motorPin2,LOW);
   delay(500);
  // Set servo to 180 degree to flip the page
   myservo.write(180);
   delay(1000);
  //return wheel to page surface
  digitalWrite(motorPin1,LOW);
  digitalWrite(motorPin2,HIGH);
  delay(500);
 // Set servo to 0 degree (original position)
 myservo.write(0);
 delay(1000);

  //Bring arm to rest position
  digitalWrite(motorPin2,LOW);
  digitalWrite(motorPin1,HIGH);
  delay(1000+delay);


}



void rotate_right(delay)
 {

  digitalWrite(motorPin8, HIGH);

  //Rotate primary motor clockwise
  digitalWrite(motorPin1,HIGH);
  digitalWrite(motorPin2, LOW);
  delay(3700+delay);

  //Stop Primary motor
  digitalWrite(motorPin2,LOW);
  digitalWrite(motorPin1, LOW);
  delay(2000);
```

```
// Set servo to 180 degree
myservo.write(180);
delay(1000);

// Rotate wheel clockwise
digitalWrite(motorPin3,HIGH);
digitalWrite(motorPin4, LOW);
delay(1300);

// Stop wheel
digitalWrite(motorPin3,LOW);
digitalWrite(motorPin4, LOW);
delay(2000);

// Set servo to 120 degree to hold folded page
myservo.write(120);
delay(1000);

//lift wheel off page
digitalWrite(motorPin1,LOW);
digitalWrite(motorPin2,HIGH);
delay(500);

// Set servo to 0 degree to flip the page
myservo.write(0);
delay(1000);

//return wheel to page surface
digitalWrite(motorPin1,LOW);
digitalWrite(motorPin2,HIGH);
delay(500);


//Rotate primary motor counter-clockwise
digitalWrite(motorPin2,HIGH);
digitalWrite(motorPin1, LOW);
delay(3700);

//Stop primary motor
digitalWrite(motorPin2,LOW);
digitalWrite(motorPin1, LOW);
delay(2000);

}
```

CHAPTER 5

RESULTS AND DISCUSSIONS

Through this project we successfully designed a page turning mechanism actuated by eye movement. The final iteration of the prototype has been discussed in this chapter.

5.1 Final Design

Fig. 5.1 shows the Final Circuitry consisting of the Signal Conditioning Model and Motor Driver

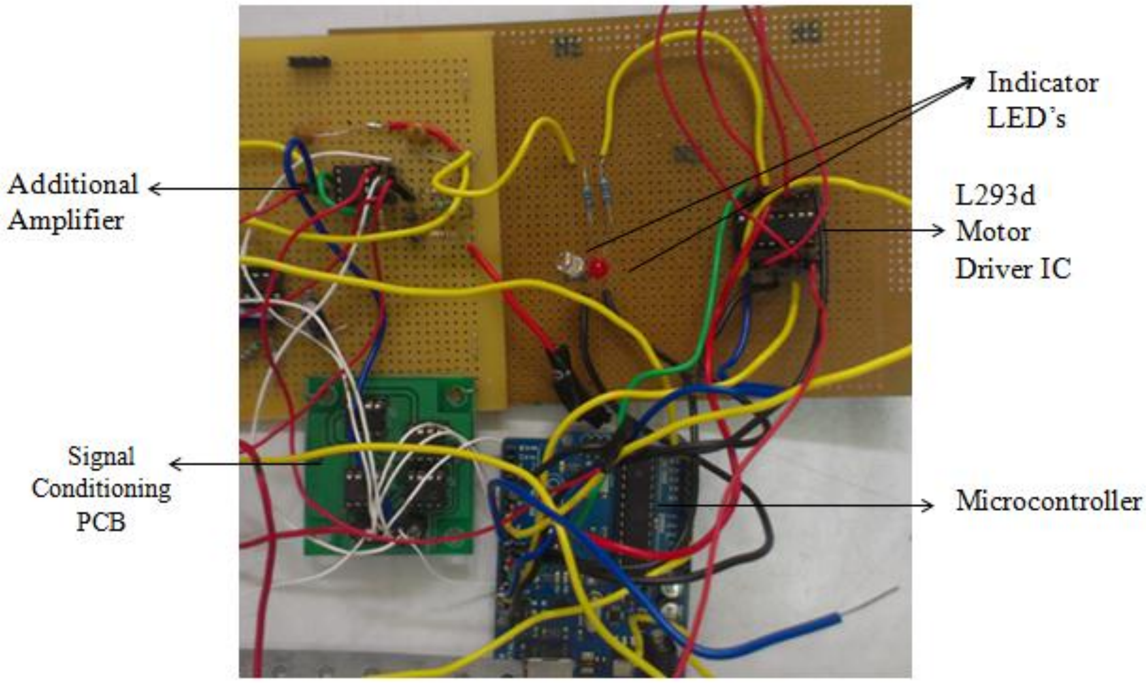


Fig. 5.1: Signal Conditioning Circuit

5.2 Initial Results

From the initial results the following problems have been eliminated:

- Baseline drift due to sweat and other artifacts
- No need for repeated calibration
- Speed Control using eye gestures
- Power line surges
- Dependence on page number and thickness

5.3 Result Tables

From tables 5.1 and 5.2, the changes in voltage levels after each stage can be studied. An initial gain of 100 is provided since a typical EOG signal has a very small value. The signal is passed through a Butterworth filter (refer Section 3.2) to eliminate noise. However, it was found that an additional amplifier was necessary to make the signal suitable as input to the microcontroller. An Op-amp based amplifier with a gain of 2.8 was designed for this purpose.

The final output obtained is shown in the last column of the tables above. The final output as shown in Table 5.1 shows the swing in voltage of about 0.2V from straight to either extremity. This difference in voltage is used as a trigger for actuating the page turning mechanism. The sign of the difference indicates the direction of page turning i.e. left or right. The microcontroller provides the control signals to the H-Bridge to drive the motor in the desired sequence.

Table 5.1: Signal Conditioning output for subject 1

Eye Motion	EOG Signal (mV)	AD620 (V)	Filter (V)	Final Output (V)
Straight	6.1	0.65	0.63	1.68
Straight to Left	5.3	0.54	0.52	1.51
Straight to Right	7.2	0.73	0.71	2.04

Table 5.2: Signal Conditioning output for Subject 2

Eye Motion	EOG Signal (mV)	AD620 (V)	Filter (V)	Final Output (V)
Straight	5.1	0.50	0.53	1.48
Straight to Left	4.3	0.44	0.42	1.34
Straight to Right	6.2	0.63	0.61	1.71

CHAPTER 6

CONCLUSION

6.1 Conclusion

Through *Automatic Page Turner with Eye Tracking*, the conceptual idea of trying to turn the pages of a book using eye movement was made a reality.

EOG was chosen as the input method as it is non-invasive and less hardware intensive when compared to the other eye tracking methods, making the project cost effective, thus, increasing its commercial viability.

The ultimate objective of science and technology is to alleviate problems faced by humans, millions of paralyzed victims might benefit from the idea presented through this project.

6.2 Future Scope

An intelligent algorithm for improved signal acquisition with its essence in Neural Networks and Artificial Intelligence can be coupled with flexible hardware and feedback to make future Page turner designs more robust.

Bluetooth or other RF communication modules can be incorporated in future iterations to interface the electrodes to signal acquisition modules enhancing the page turner’s aesthetic appeal and enhance user comfort.

Also a more complete solutions package can be developed by integrating the current module with an e-book reader

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APPENDIX

1. AD620 Instrumentation Amplifier Datasheet:

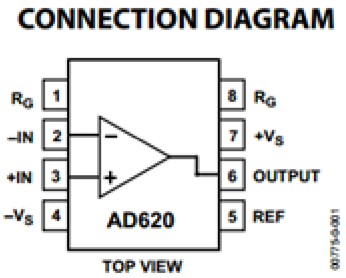

Fig. 6.1: AD620 PIN DIAGRAM

Features

- Easy to use
- Gain set with one external resistor
- (Gain range 1 to 10,000)
- Wide power supply range (±2.3 V to ±18 V)
- Higher performance than 3 op amp IA designs
- Available in 8-lead DIP and SOIC packaging
- Low power, 1.3 mA max supply current
- Excellent dc performance (B grade)
- 50 µV max, input offset voltage
- 0.6 µV/°C max, input offset drift
- 100 dB min common-mode rejection ratio (G = 10)
- Low noise
- 9 nV/√Hz @ 1 kHz, input voltage noise
- 0.28 µV p-p noise (0.1 Hz to 10 Hz)
- Excellent ac specifications
- 120 kHz bandwidth (G = 100)
- 15 µs settling time to 0.01%

Applications

Weigh scales

ECG and medical instrumentation

Transducer interface

Data acquisition systems

Industrial process controls

Battery-powered and portable equipment

2. L293d Motor Driver Datasheet:

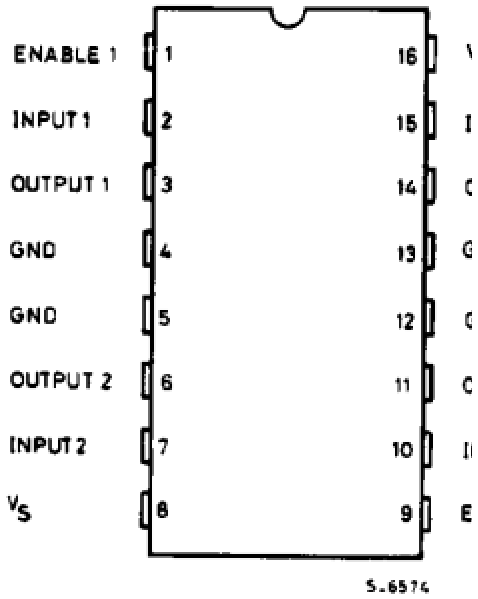

Fig. 6.2: L293D PIN DIAGRAM

Features:

- 600mA output current capability per channel
- 1.2a peak output current (non repetitive) per channel
- Enable facility
- Overtemperature protection
- Logical ”0” input voltage up to 1.5 v
- High noise immunity
- Internal clamp diodes

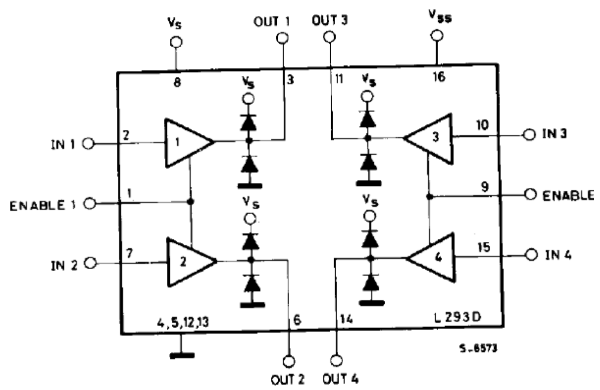

Fig. 6.3: L293D BLOCK DIAGRAM

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V_S	Supply Voltage	36	V
V_{SS}	Logic Supply voltage	36	V
V_i	Input voltage	7	V
V_{en}	Enable voltage	7	V
I_o	Peak output current (100µs non repetitive)	1.2	A
P_{tot}	Total power dissipation at $T_{ground\text{-}pins}$ = 80°C	5	W
T_{stg}, Tj	Storage and junction temperature	-40 to 150	°C

3. Atmel Atmega 328 Datasheet:

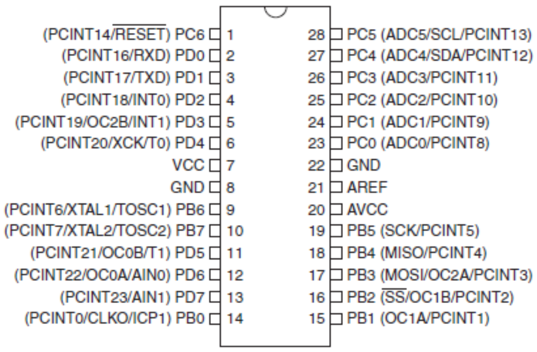

Fig. 6.4: ATMEGA 328 MICROCONTROLLER PIN DIAGRAM

Features

• High Performance, Low Power AVR® 8-Bit Microcontroller

• Advanced RISC Architecture

– 131 Powerful Instructions

– 32 x 8 General Purpose Working Registers

– Up to 20 MIPS Throughput at 20 MHz

– On-chip 2-cycle Multiplier

• High Endurance Non-volatile Memory Segments

– 4/8/16/32K Bytes of In-System Self-Programmable Flash progam memory

– 256/512/512/1K Bytes EEPROM

– 512/1K/1K/2K Bytes Internal SRAM – Write/Erase Cycles: 10,000 Flash/100,000 EEPROM

– Data retention: 20 years at 85°C/100 years at 25°C

• Peripheral Features

– Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode

– One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode

– Real Time Counter with Separate Oscillator

– Six PWM Channels

– 8-channel 10-bit ADC in TQFP Temperature Measurement

– 6-channel 10-bit ADC in PDIP Package

Temperature Measurement

– Programmable Serial USART

– Master/Slave SPI Serial Interface

– Byte-oriented 2-wire Serial Interface (Philips I2C compatible)

– Programmable Watchdog Timer with Separate On-chip Oscillator

– On-chip Analog Comparator

– Interrupt and Wake-up on Pin Change

4. UA741 Operational Amplifier Datasheet:

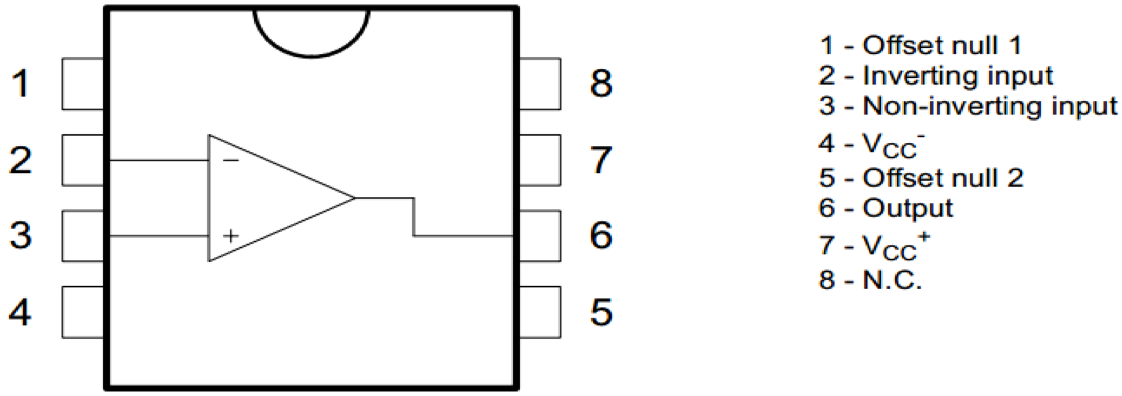

Fig. 6.5: UA741 PIN DIAGRAM

Features:

- Large input voltage range
- No latch-up
- High gain
- Short-circuit protection
- No frequency compensation required
- Same pin configuration as the ua709

Description:

The UA741 is a high performance monolithic operational amplifier constructed on a single silicon chip. It is intended for a wide range of analog applications.

- Summing amplifier
- Voltage follower
- Integrator
- Active filter
- Function generator

The high gain and wide range of operating voltages provide superior performances in integrator, summing amplifier and general feedback applications. The internal compensation network (6dB/octave) insures stability in closed loop circuits.