# Chapter 8

# Smart Prosthetic Thumb controlled by EMG Signals: Design and Build

**A.Josephin Arockia Dhivya[a*], Vinoth N [b], Danush R[b], Jaya Rubi [a]**

[a] *Assistant Professor, Department of Biomedical Engineering, Vels Institute of Science Technology and Advanced Studies, Chennai 600117.*

[b] *III Year ,Department of Biomedical Engineering, Vels Institute of Science Technology and Advanced Studies, Chennai 600117.*

** Corresponding Author: a.dhivya.se@vistas.ac.in*

**Abstract**: This research work presents the design and construction of thumb amputation or dysfunction a natural and functional replacement. The proposed design incorporates a sophisticated control mechanism that interprets the EMG signals and translates them into corresponding thumb movements. A combination of 3D printing and bioengineered materials is employed to fabricate the prosthetic, ensuring a lightweight and customizable solution. Preliminary tests with amputee subjects demonstrate promising results, indicating improved dexterity and usability. The artificial thumb prosthesis offers a novel approach to enhance the quality of life for individuals with thumb-related impairments advancement in prosthetic technology is led to the development.

***Keywords:*** *EMG sensor, servo motor, prosthetic thumb, micro controller, sensor module kit*

## INTRODUCTION

In recent years, the intersection of biomedical engineering and robotics has led to remarkable advancements in the field of

ISBN 978-819871346-9

prosthetics. The loss or impairment of a thumb can significantly impact a person's ability to perform everyday tasks, leading to challenges in independence, productivity, and quality of life. In response to this problem, the present project aims to design and construct an artificial thumb prosthetic that can be controlled by the EMG signals. This innovative solution seeks to restore hand functionality and empower individuals who have experienced thumb loss due to injury, amputation, or congenital conditions.

The artificial thumb prosthetic will be a technologically advanced device that mimics the movement and functionality of a natural thumb. This biofeedback-based approach ensures a more intuitive and natural control over the prosthetic, making it an extension of the user's hand. Beyond the technical aspects, the project aims to prioritize user comfort, safety, and adaptability. The prosthetic will be designed with the user's needs in mind, providing customization options to fit individual hand sizes and functional requirements. Additionally, safety features will be incorporated to prevent any unintended movements or harm to the user. An innovative artificial thumb prosthesis that utilizes the EMG signals  for control. The prosthesis aims to provide individuals with

An EMG-based prosthetic bio-thumb represents a remarkable fusion of advanced technology and biomedical science, offering the potential to revolutionize the field of prosthetics. This cutting-edge innovation integrates real time EMG sensor module kit with 3D printing technology to create a highly functional and adaptive solution for individuals with limb loss. In this introduction, we will explore the key components, benefits, and implications of an EMG-based prosthetic bio-thumb

**Restoration of Functionality**: The thumb plays a crucial role in hand dexterity and is essential for performing numerous everyday tasks, such as grasping objects, writing, and manipulating tools. By creating an artificial thumb, individuals with thumb loss or impairment can regain a level of functionality and independence that may have been otherwise difficult or impossible to achieve.

**Improved Quality of Life:** Losing a thumb can be emotionally and psychologically challenging. It affects a person's ability to participate in activities they previously enjoyed, impacting their self-esteem and mental well-being. Providing a functional and aesthetically pleasing prosthetic can greatly improve their quality of life and overall happiness.

Education and employment opportunities can also be affected by the absence of thumbs. The traditional educational and work environments may not always be accessible to individuals with this condition. However, advancements in assistive technology and the growing awareness of diversity and inclusion have improved access to education and employment for people with disabilities. Many individuals without thumbs have successfully pursued careers in various fields, proving that determination and adaptability can overcome physical limitations. Additionally, personal relationships and social interactions can be impacted. People may be curious, well-intentioned, or unintentionally insensitive when interacting with someone without thumbs. It's crucial for both the individual and society to foster understanding, respect, and empathy to create a more inclusive and accepting environment.

ISBN 978-819871346-9

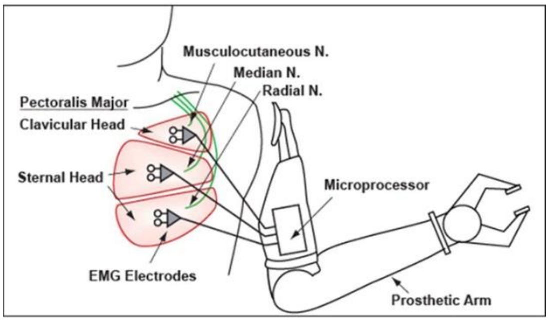



**Figure 1.1** Person with EMG Sensor and Prosthetic Bio Arm

Furthermore, individuals without thumbs may encounter challenges related to healthcare and medical expenses. Prosthetic limbs, rehabilitation, and other specialized treatments can be expensive, and access to quality healthcare can vary based on geographical location and economic factors. This highlights the importance of healthcare accessibility and support systems for individuals with disabilities. Despite the numerous challenges, people without thumbs often demonstrate remarkable resilience and adaptability. They learn to use their feet, mouths, or other body parts for tasks that would typically require thumbs. They engage in sports and hobbies, and they pursue their passions with determination. Many have become advocates for disability rights, promoting inclusivity and raising awareness about the capabilities of individuals with disabilities. In conclusion, individuals without thumbs face a wide range of physical, emotional, and societal challenges. However, with determination, adaptability, and support from society, they can overcome these challenges and lead fulfilling lives. It is essential for us as a society to promote inclusivity, accessibility, and understanding to ensure that individuals without thumbs, and those with other disabilities, can participate fully in all aspects of life.

## II. Methodology

### A. EMG Signal Acquisition

The first step in the proposed work is to develop a robust EMG signal acquisition system. This system will consist of surface electrodes that adhere to the skin above the residual muscles of the user's limb. The electrodes will capture EMG signals generated during muscle contractions and transmit this data to a microcontroller or a computer for processing.

Prosthetic Thumb Prototype

A functional prosthetic thumb prototype will be developed, integrating the Arduino and microcontroller for EMG signal decoding. The prosthetic thumb will be designed to replicate the natural movements of a human thumb, offering a wide range of motion, including wrist rotation, elbow flexion/extension, and finger dexterity. The prototype will be lightweight, durable, and customizable to fit the user's

User Trials and Refinement: A critical phase of the project involves user trials. Amputee volunteers will be recruited to test the EMG-controlled prosthetic thumb in real-world scenarios. These trials will allow us to collect feedback on the system's performance, comfort, and usability. Any issues or limitations identified during the trials will be addressed in the refinement phase.

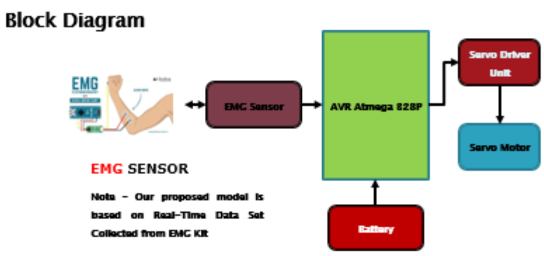



Figure 1.2

ISBN 978-819871346-9

## 1.2. Block diagram

**COMPONENTS REQUIRED**

1. ELECTRODE PADS

2. EMG MUSCLE SENSOR

3. ARDUINO

4. SERVOMOTOR

**III. EMG Signal Acquisition**

The acquisition of EMG signals from the muscles involves standards and protocols for electrode placement, signal processing, and data transmission. The most commonly used standards for electrode placement are those outlined by the International Society of

Electrophysiology and Kinesiology (ISEK). Signal processing methods can follow standard practices for filtering, amplification, and digitization

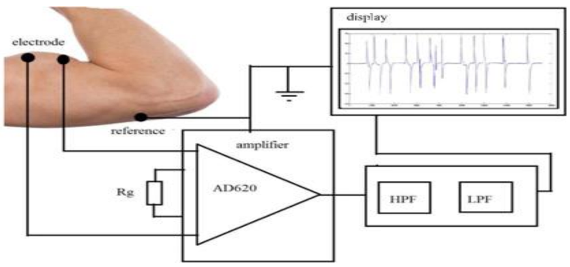



Figure 1.3 EMG signal acquisition

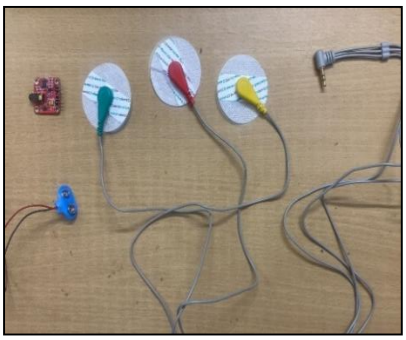


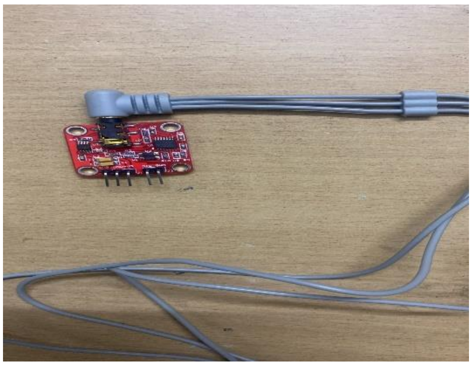
Figure 1.4

### Electrode Pads

Gel electrodes are used with muscle sensor v3 to capture data. The electrode is replaced when to record for another subjects, to get the higher quality EMG signal, maintain cleanliness, and prevent the spreading of infectious diseases. This electrode has three colors, red, green and yellow —the red electrode is (ground), the yellow electrode (reference) and the green color electrode is (the EMG signal )

### MUSCLE SENSOR

The Muscle Sensor that is used to record electrical potentials produced by contracting muscles. This sensor process the raw signal when records because its sequence is constructed of an instrumentation amplifier, rectifier, analog filter circuits, and an end amplifier circuit. After recording the signal, the sensor amplifies and processes the complex electrical activity of a muscle before converting it to a simple analog signal that is easily read by a microcontroller Arduino) to convert it into a digital signal.



## 1.5 Components and hardware prototype

### Arduino UNO

Arduino UNO with ATmega328P-based microcontroller board. It contains 14 input/output digital pins (of which six can be used as PWM outputs). Arduino UNO is used to convert analog to digital

ISBN 978-819871346-9

output due to the signal produced by muscle sensor v3. Muscle sensor output was interfaced with an Arduino UNO microcontroller to record the signal on a laptop operating in battery mode for signal processing and classification .


Figure 1.6

**SERVO MOTOR**

A servo, short for servomechanism, is a type of device used for precision control of angular or linear position, velocity, and acceleration. It usually consists of a motor coupled to a sensor for position feedback, which is then controlled by a servo controller. The servo system is a closed-loop control system where the controller uses the feedback signal to accurately control the position or speed of the motor. This is accomplished by comparing the desired position or speed (the command signal) with the actual position or speed (the feedback signal), and then adjusting the motor's operation to reduce the difference (the error signal).

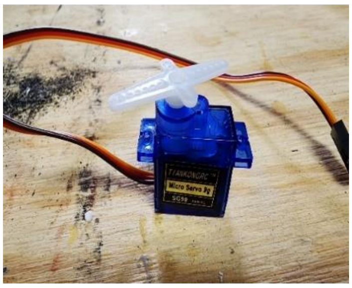


Figure 1.7

## IV. RESULT AND CONCLUSION:

It’s worth noting that prosthetic technology continues to advance, leading to increasingly sophisticated and functional prosthetic thumbs. These advancements aim to improve the overall quality of life for individuals who have lost their natural thumb and provide them with opportunities to participate in various aspects of life more fully. Our proposed model will surely bring a novel changed for the people who suffer to continue their routine ADLs activity

The foundation of EMG-based prosthetic thumb lies in the acquisition and processing of electromyographic signals. These signals are recorded from the residual muscles of the amputated thumb and are used to decode the user’s intended movements. Current signal processing techniques have become increasingly sophisticated, allowing for accurate and real-time signal decoding.

EMG-based prosthetic thumb, augmented by Arduino and microcontroller, have come a long way in improving the lives of individuals with thumb loss. They offer greater control, enhanced functionality, and a more natural user experience. However, there are still challenges to overcome, such as cost, sensory feedback, and ease of use. The future scope of EMG-based prosthetic thumb is promising, with advancements in signal processing, biomechanical integration, sensory feedback, and cost reduction. These developments have the potential to make prosthetic thumb more accessible and user-friendly, ultimately providing a better quality of life for those who rely on them. As technology continues to advance, the prospects for EMG-based prosthetic thumb will only become more exciting, with the ultimate goal of restoring as much function and autonomy as possible to individuals with loss of thumb.

ISBN 978-819871346-9
9 788198 713469

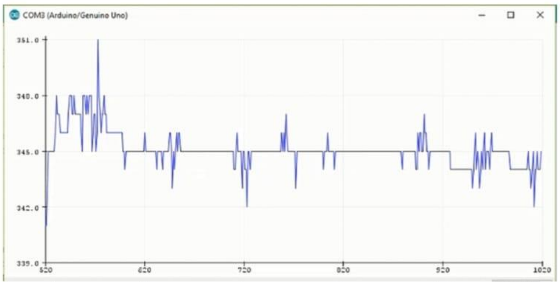



Figure 1.8

The frequency range involved in controlling a prosthetic thumb using an electromyography (EMG) module typically falls within the range of 20 Hz to 500 Hz. These contractions generate electrical signals that can be detected and used to control a prosthetic device. Read the analog signal from the EMG sensor using our controller board via analog pins.

We need to filter, amplify, or preprocess the EMG signal to extract meaningful information, like muscle activity levels or patterns.


Figure 1.9

**Real-time Feedback:** The Arduino Uno can provide real-time feedback to the user, which is essential for refining motor skills and ensuring safety during everyday tasks. Users can receive sensory input through vibrations, sounds, or other feedback mechanisms, enhancing their control over the prosthetic. With this setup, individuals can regain fine motor control and dexterity, enabling them to perform a wide range of once-challenging tasks. The AVR microcontroller processes the EMG signals and translates them into commands to actuate the prosthetic thumb's movements, allowing for natural and intuitive control

*Position of servomotor at 90°*

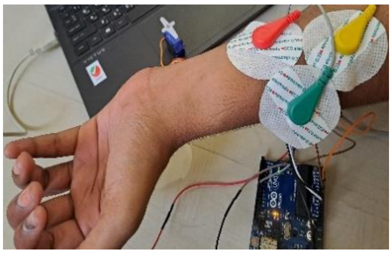


Figure 1.10

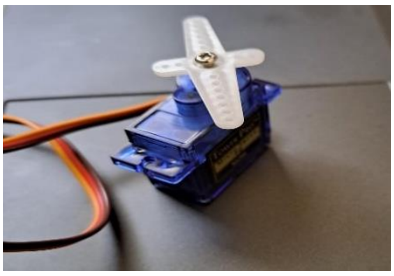


Figure 1.11

Implement feedback mechanisms to ensure the servo responds correctly to muscle activity. We may need to calibrate the system to adapt to different users or varying signal strengths.

***Position of servomotor at 180°***

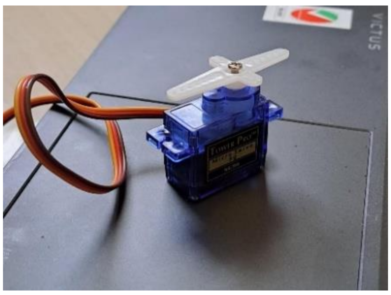


Figure 1.12

ISBN 978-819871346-9

## REFERENCES


[1] R.F. Weir, “Design of artificial arms and thumbs for prosthetic applications,” in Standard Thumbbook of Biomedical Engineering and Design, M. Kutz, Ed. New York (NY): McGraw-Hill, 2003, pp. 32.1–32.59.

[2] S.M. Engdahl, B.P. Christie, B. Kelly, A. Davis, C.A. Chestek, D.H. Gates, “Surveying the interest of individuals with upper limb loss in novel prosthetic control techniques,” Journal of Neuro Engineering and Rehabilitation, 12(1), pp. 53(11 pages), 2015.

[3] J.T. Belter, J.L. Segil, A.M. Dollar, and R.F. Weir, “Mechanical design and performance specifications of anthropomorphic prosthetic thumbs: A review,” J. Rehabil. Res. Develop., 50, pp. 599–618, 2013.

[4] C. Cipriani, M. Controzzi, M.C. Carrozza, “Objectives, criteria and methods for the design of the SmartThumb transradial prosthesis,” Robotica, 28(6), pp. 919–927, 2010.

[5] D.A. Bennett, S.A. Dalley, D. Truex, M. Goldfarb, “A multigrasp thumb prosthesis for providing precision and conformal grasps.” IEEE Trans. Mechatronics, 20(4), pp. 1697–1704, 2015.

[6] C.-H. Xiong, W.-R. Chen, B.-Y. Sun, M.-J. Liu, S.-G. Yue, W.-B. Chen, “Design and Implementation of an Anthropomorphic Thumb for Replicating Human Grasping Functions,” IEEE Transactions on Robotics, 32(3), pp. 652–671, 2016.

[7] M. Controzzi, F. Clemente, D. Barone, A. Ghionzoli, C. Cipriani, “The SSSA-MyThumb: A dexterous lightweight myoelectric thumb prosthesis,” IEEE Transactions on Neural Systems and Rehabilitation Engineering, 25(5), pp. 459–468, 2017.

[8] M. Owen, C. Au, A. Fowke, “Development of a Dexterous Prosthetic Thumb,” Journal of Computing and Information Science in Engineering, 18(1), pp. 010801, 2018.

[9] J. ten Kate, G. Smit, P. Breedveld, “3D-printed upper limb prostheses: a review,” Disability and Rehabilitation: Assistive Technology, 12(3), pp. 300–314, 2017.