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Wireless Transmission of Electromyography (EMG) Signals to operate 3D PrintedMyo-Electric Hand

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----------*ABSTRACT*----------
This paper mainly concern on a new methodology of wireless transmitting Electromyography (EMG) signals to myoelectric prosthetic hand which manufactured from 3D printing technology. A Myoelectric controlled prosthesis is an externally powered artificial limb which can control with the electrical signals generated naturally by muscles. Sometimes in case of particular amputees, fetching EMG signals by sensors is not possible from that destructed muscles but, EMG generated from healthy muscles besides that amputees can be used in the transmission of signals. The objective of this research is to generate the new technique for transmitting EMG signals without wire from any adequate healthy muscles. In this methodology, we used the EMG sensor to detect EMG signals, which perform a pre-processing task and featured extraction on EMG signals by using a microcontroller. That extracted output then applied to universal remote control transmitting circuit as input which sends the signals to the receiver circuit, output signals from that receiver circuit directly applied to servo motor of a myoelectric prosthetic hand. The objective of this research to fetch and carry EMG signals from the healthy muscle and train the victim suffering from amputee in which acquiring adequate EMG signal from very adjacent tissue of damaged area is not possible due to burning and inflammatory issues.

KEYWORDS;-*Wireless Electromyography, Wireless Myo-Electric Hand, 3D Printed Prosthetic Hand, Radio Transmission of EMG Signals, multiple Degree of Freedom in Myoelectric hand, and Pattern Algorithms for multiple DOF.*

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I. INTRODUCTION

Prosthetic hand is artificial substitute or replacement of hand or arm which is designed for functional or cosmetic reasons or both. There are ranges of hand available from mechanical operated prosthetic hand to neurological signal operated prosthetic hand. In the contemporary era, as technological advancing in the field of rehabilitation engineering has given new directions to myoelectric hand which is being controlled by the control signal resulting from discrimination of muscle contraction. Discrimination in the electrical terms due to alterations in muscle contraction are the primary norms to develop hardware to acquire EMG waveforms. Myoelectric Hand has more reliability to provide more accurate DOFs. Similarly, motion of hand can be configured in such a way, victim can utilize prosthetic hand in more natural way as he using his natural hand. More degree of freedom and natural motions are possible in case victim is able to recover his muscle strength by some physiotherapy exercise. For Example: Victim with Wrist disarticulation or wrist amputee can have good amount of healthy muscle which can be used because movement associated with natural muscle contraction can be configured with some trial and error method, but in case of trans-radial amputee victim need to strive hard to learn entire new set of prosthetic control and turning that practice in to cognition to use It naturally.

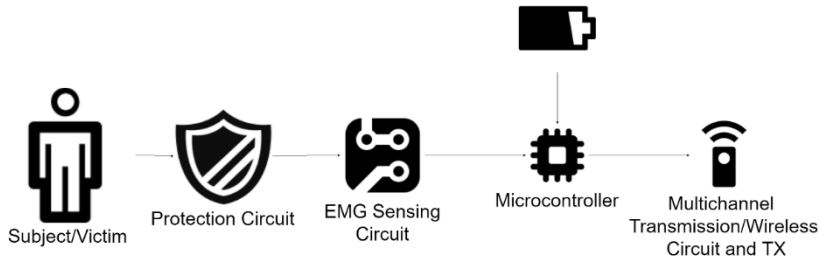
In the year 2005, 1.6 million persons were living with the loss of a limb which is predicted to the double by the end of 2050[1]. Rate of limb amputations, including upper extremity amputations lies in the range of 350,000 to 1,000,000 and 20,000 to 30,000 person per year for patients undergoing amputation[2]. Trauma is found to be the most dominant reason for the injury and upper arm amputation in retrospective study[3]. Some of the efficient study propose implantation of magnetic sensor adjacent to the humeral part of the body, which gives magnetic fluctuation as prompt response to attempting activity by the user who've implanted with it[4]. EMG based Myoelectric Hand are widely popular and commercial in market, they are efficient and powered up with power supply. Common thing is EMG employed electrodes, sensors and motors are powered up from the same power supply. In case of handling load/current of motor more than one, driving current may get reversed owing to hurt patient since electrodes are directly applied on skin and conductive enough.

II. PROCEDURES AND METHODOLOGY// RESEARCH METHODOLOGY

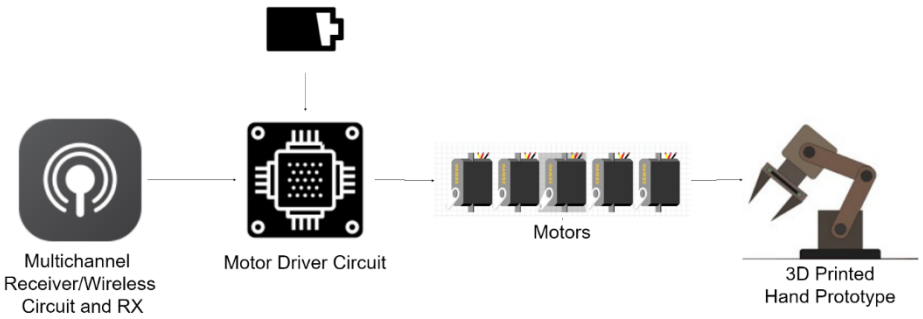
3D printed prosthetic hand control using wireless EMG transmission incorporates various methods and terminology which has described in Block-Diagram. This implementation takes major safety concerns for differently abled person.

A. SUBJECT

Experiment was conducted on 6 healthy-abled body persons, 2 person with wrist disarticulation. Victims suffering with wrist disarticulation was from "ANDHAJAN APANG MANAV MANDAL" which located in Ahmedabad city of Gujarat. Six healthy abled person were members of the project team. All persons were lying under 21-24 age, and right hand was dominantly used for acquiring signals. The subject were provided informed concerns to participate. There was vast difference in the body muscle fat of the subject which has also lead to alterations in the results and graph of the signal.



Block-Diagram (Transmission Terminal of EMG Prosthetics)



Block-Diagram (Receiver Terminal of EMG Prosthetics)

Figure 1. Block Diagram of Wireless EMG Control for Prosthetic Hand

B. Protection Circuit/Safety pre-requisites

In order to acquire EMG signals from either adjacent surface tissues of damage limb, or from any other surface point of the body, electrode need to place on. Electrical circuit employed to remove baseline noise, motion artefacts, and so on to create stable acquisition system. Without proper grounding or Isolation, electrical current flowing through circuit may get obscured and may be drawn/leak towards the human subject which can hurt them by electrical shock or can prove fatal in such case. Isolation Circuit/Protection circuit used here to isolate and separate the power supply is being applied to controller or actuators and a tiny millivolts and current which has applied to EMG sensors in order to became active and sense contraction of muscle.

C. EMG sensing Circuit

EMG is the most indisputable part of the myoelectric based prosthetics. Electromyogram signals are associated with the contraction and relaxation movement of the muscle, EMG can be achieved using MEMS based sensor or can developed using conductive material able to sense contraction of the muscle. Since EMG signals of the body are of very low potential and lies in the range of millivolts of energy, sensing material need to be followed by amplifier circuit and filters to eradicate and remove unnecessary noises encounter during acquisition of the signal [5][6][7][8][9]. In most case, traditional EMG analysis instruments uses needle Electrodes which proves painful in most cases, and it creates painful sensation during insertion in muscle as well placing needle electrodes for long time is not possible which has becomes primary requirement for the portable prosthetics which is used on daily basis. Perhaps, Needle electrode can give better accuracy from analytical

point of view, surface electrode gives comfort and smooth access to EMG signals. EMG signals of the muscle lies in the range of 10Hz to 500Hz, but can be found dominantly in the range of 50Hz to 150Hz [9].

Sometimes, due to such burning issue, allergic issue, and muscle fatigue issue getting adequate EMG signals and potential difference across muscle is not possible, in this kind of situation wireless EMG ideology plays a vital role. For Example: In practical examination, muscle of the subject are not able to generate distinguishable millivolts even after subject/victim suffering with only wrist disarticulation, so placing electrodes on muscles that can generate adequate real time EMG signal and transmitting the same can overcome this issue.

D. Microcontroller

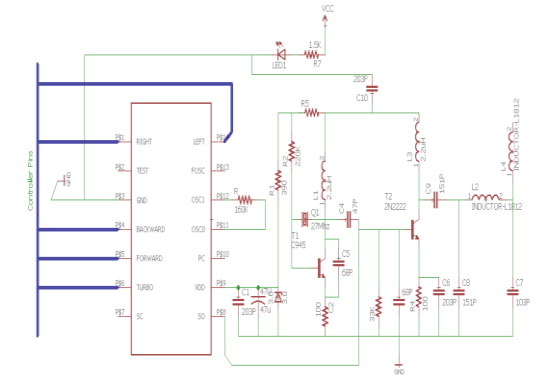
Microcontroller with embedded ADC has been employed here to sample the signal. ADC stands for Analog to Digital Converter and proceed to convert analog signal to digital by sampling them. Analog to digital converter embedded with controller might have limitations regarding to the resolution. Therefore to achieve great accuracy and real time signals ADC should have high resolution, but in the same case to proceed more amount of data and sampling them lead to compromise of reading of real time. So, it is advisable to have calculation of balanced ratio to avoid oversampling and get adequate signal output. We had used here 8 Bit ADC which gives resolution of 256bits which means it can read up to 256 different levels of the signal.

E. Motor Driver Circuit

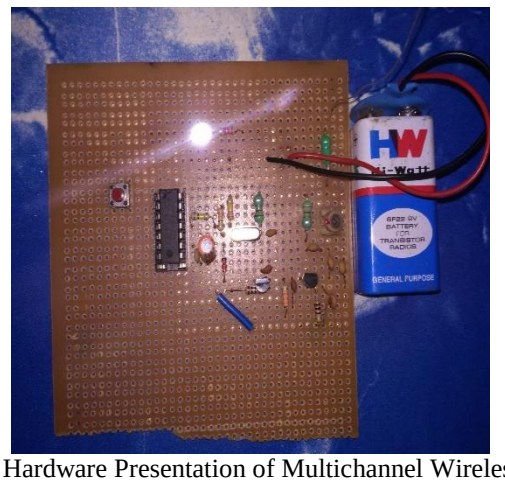
At the end the receiver Motor Driver Circuit need to employ. Motor Driver circuit controls amount of voltages and current that need to be supplied to the motor in order to drive it at high performance. Since motor requires high current to bear large load. As well every motor should be get enough voltage while giving isolation kind of protection to other part of circuitry.

F. Multichannel Wireless TX

There are many modules and terminology that are available in market like Bluetooth and Wi-Fi connectivity. But the most significant concern undertaken by our study that all modules requires basic power consumption and first time pairing and in such case that doesn't proved to be most useful due to some connectivity issue. Therefore, developing RF Based Wireless unit opted by our team. Since we had utilize almost 5 servo motors, we need to develop multichannel wireless TX that can control up to 5 different appliance or motor. Wireless TX concept is based on transmitting our low frequency signal from one end to another by modulating with pre-decided carrier frequency which has high frequency which can transmit signal at a large range, even prosthetics don't require such a high range. We had used 27MHz of frequency to modulate our low energy signal which is encoded to certain signal by IC TX-2B.



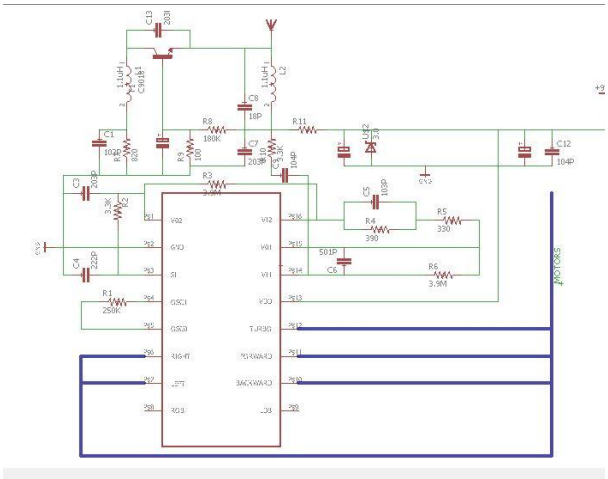
2. Schematic of Multichannel Wireless Tx.



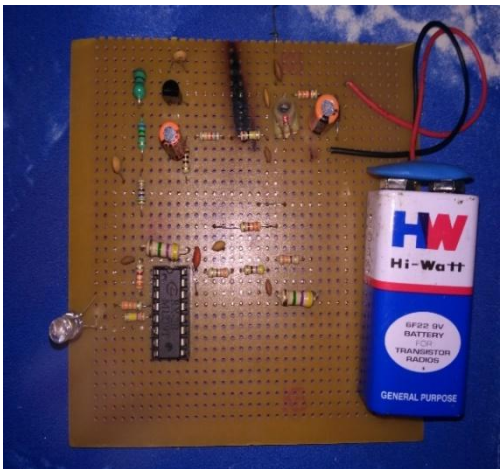
3. Hardware Presentation of Multichannel Wireless Tx.

G. Multichannel Wireless RX

Multichannel Wireless RX comprises of receiving antenna and enameled magnetic wire which has wrapped



4. Schematic of Multichannel Wireless Rx.

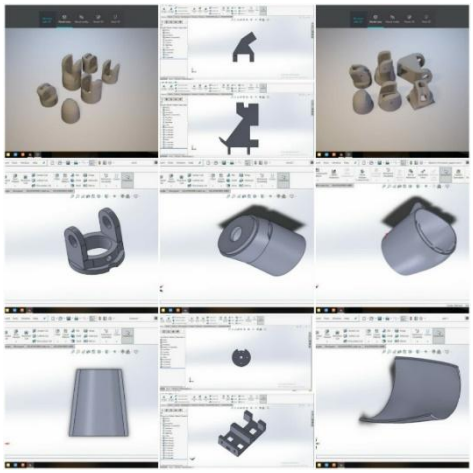


5. Hardware Presentation of Multichannel Wireless Rx.

around ferrite core. Turns of wire around ferrite core and size of antenna judges the range of area under which it can be used. 5 Channel decoder chip RX-2B has used here which decodes signal encoded by the Transmitting end. Single channel used here for single servo motor and supports two functions of opening and closing movement of the finger. As portrayed in picture, Motors can be used instead of led by cascading it with motor driver. Standalone supply from controller can be enough to support functionality of wireless.

III. DESIGN IDEOLOGY

Design of 3D Printed Myoelectric Hand gives a range of flexibility to achieve subjective results. Either it can be by printing material selection or selecting high printing speed by reducing in filling ratio of the printing. It gives opportunity to rapid prototyping for testing all prosthetic parts. Since entire object need to print by combining all tiny parts, if any single part get manufacture wrong, only same parts need to re-manufacture. Therefore it gives immense opportunity to design accurate parts even with software calibrations as well trial and error method of the printer.

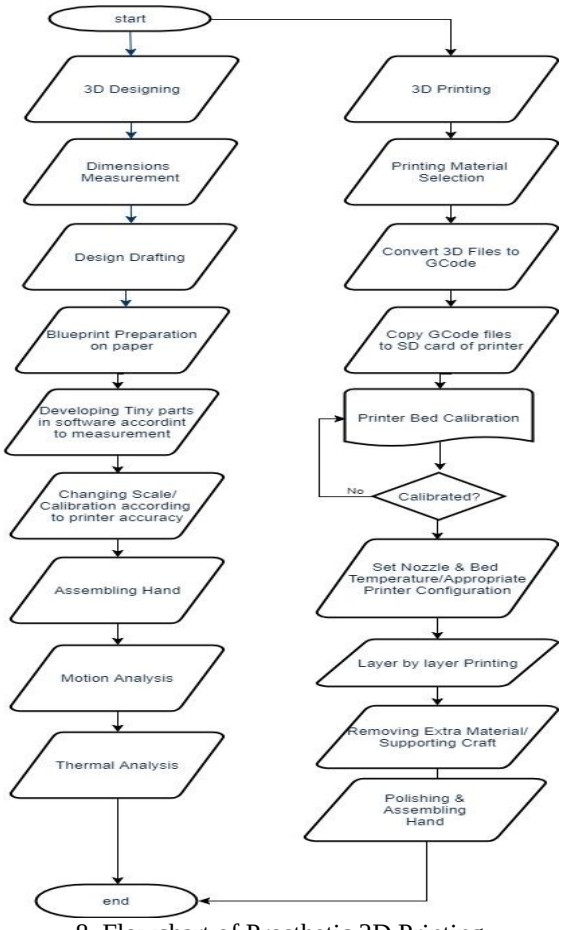


6. STL File Views of the Prosthetic hand

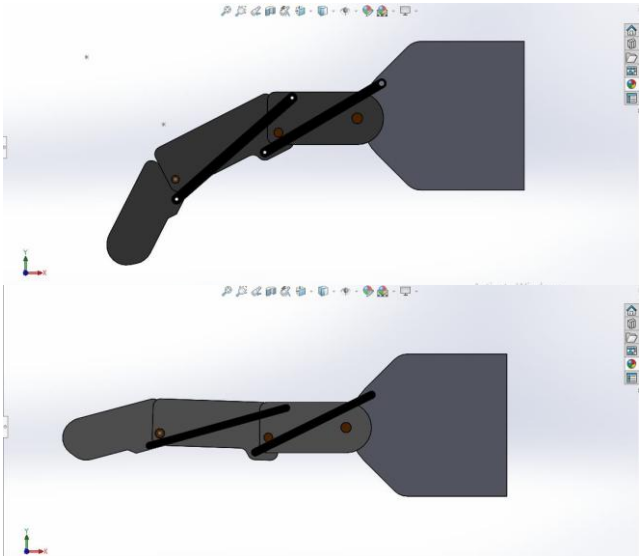
7. Aesthetic and Ergonomic appearance of Assembled Prosthetic Hand

The printer we had used here is MakerBot and printing material we had examined and tested are PLA and ABS. We had use almost 90 to 100% of in filling during printing of the parts, and normal speed to ensure that all parts are getting well printed. Printer creates extra base support during printing which need to remove carefully at the end of print. In addition, polishing material gives smooth appearance and extravagance aesthetic design since material used in filament doesn't create any chemical reaction when comes in contact with skin. Entire Design Ideology has mentioned here with description.

Collage Picture express the pictures of tiny parts of the prosthetic hand which need to assemble in order to complete entire Hand. It includes metacarpal fingers, and its enclosure, wrist and ring of the wrist. Standard below elbow part with its enclosure, pulley and link structure that utilize to push and pull the fingers.



8. Flowchart of Prosthetic 3D Printing



9. Motor Moving Mechanism of the Prosthetic finger

Each finger is a typical 6 bar planar mechanism which consists one fixed (LINK-1) and 3(LINK-4, LINK-5, LINK-6) movable binary links, two (LINK-2, LINK-3) ternary links. In the entire mechanism, both the ternary links are in different length. Long ternary (LINK-2) connected with the fixed binary link and remain one short ternary link (LINK-2) connected with the long ternary link. Binary link (LINK-4) connected to short binary link in such a way that all 3 links connect in the sequence of longest to shortest. Remain two movable binary links (LINK-5, LINK-6 connected as the shown in FBD. DOF, As per kinematics synthesis (Kutzbach–Grübler's equation)

$F = 3\,(n-1) - 2\,f$
Total links- 6
Total no. of joints- 7
F=1 (Angular Motion)

IV. EXPERIMENTAL RESULTS

Experiments was taken on 6 healthy abled person and 2 differently abled person who were suffering with below elbow amputee. Muscle sensors are need to employed on the damaged part of the limb. Before employing electrodes, EMG Spectrum analysis of the victim need to done, in order to identify ability of the victim to generate EMG signal according to various task that has provided to him. This test can help out and reveal the information about the muscle that are able to generate the EMG signal most dominantly. Inconsistencies in signal can be avoided using this method.

As portrayed in picture this person having amputee from last four years due to accidental occurrence during labor work. During EMG spectrum analysis, enough though he is suffering with wrist disarticulation, Standard lower elbow part was not able to generate EMG signal sufficiently regards to his attempt of performing activity. This inability may be due to muscle destruction, lack of physiotherapy exercise or deposition of extra fat on the muscle. Then after Standard above elbow muscle did employed to gain EMG signal which was not demolish and quite efficient toward generating EMG signal corresponding to attempts of movement.

10. Placement of EMG module on Standard upper elbow due to lack of healthy muscle at the stump which can generate adequate EMG

V. DISCUSSION

Wireless EMG Based Prosthetic Hand can be consider meaningful for both condition either person suffering with wrist disarticulation or standard above elbow. The main ideology behind wireless terminology is allowing victim to gather EMG signals from healthy muscle in case tissue of damaged stump is not able to generate adequate threshold of the muscle potential which can be distinguish to operate hand. As portrayed in figure, cons can be easily identify. Prosthetic with wire connection are sensitive for routine use. It may hurt victim due to any uncertain occurrences of reverse current through skin. Wireless method completely isolates the sensor and actuator portion because they get communicate by radio frequency network only which drives by low power.

Figure 11. Comparison of Wireless vs. Wired Prosthetic Hand

Here, portrayed victim has slim posture, as he having low fat deposited on his muscle, it is easy to acquire EMG signals. Other victim that have posture with high or moderate amount of fat, they face a critical problems of signal identification through sensor. Therefore, placing electrode at place of low fat can help for better accuracy.

VI. CONCLUSION

This paper portraits all the aspects of wireless transmission of Electromyography signal to control the prosthetic hand from mechanical and electrical point of views. We had perform this experiment on subject with oral consent and gathered result that are satisfactory for use in prosthetics. Overall, we had taken observation that it is novel technology to transfer EMG signal from healthy muscles rather than amputate hand to the sensor to operate prosthetic hand.

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