Powered Foot Ankle Prosthesis

Neethu Rajan, Swagatika Mishra, Abhishek Patil & Jyothi Warrier

Abstract— A powered foot ankle prosthesis is a lower body extremity prosthesis, which is an artificial extension that replaces the part missing below the knee. It is part of the field of biomechatronics, the science of fusing mechanical devices with human muscle, skeleton, and nervous systems; to assist or enhance motor control lost by trauma, disease, or defect. This research paper focuses on the transtibial condition and the prosthetic device which acts as an aid to the individuals affected by such conditions. The paper mainly aims at creating a visual record to reeducate an amputee on the normal gait pattern. The main components of the prosthetic device includes the accelerometer sensor, the pic microcontroller and the dc motor. The accelerometer sensor should be placed at the normal foot of the individual and for different standard gait patterns like heel strike, foot flat, heel off and acceleration, the accelerometer measures different values for all the three axes. These values so sensed by the sensor will be read by the microcontroller and the microcontroller will be programmed in such a manner that for specific values, the motor will provide either a clockwise or an anticlockwise motion as per the requirement. Thus both the dorsiflexion and plantar flexion of the prosthetic foot is made possible by the motor whose movement will be controlled by the microcontroller. Thus a co-ordinated working of the sensor, microcontroller and the motor will provide the exact gait pattern for the transtibial prosthetic device and its visual record will help the patient to provide a better understanding of gait which he has to follow while using his prosthetic device.

Index Terms— Accelerometer, Dorsiflexion, Motor, Motor Driver, Plantar Flexion, Stance phase, Swing phase, Transtibial

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1 INTRODUCTION

PROSTHESIS is an artificial extension that replaces a missing body part, which may be lost through trauma, disease, or congenital conditions[1]. Lower extremity prostheses provide replacements at varying levels of amputation. These include hip disarticulation, transfemoral prosthesis, knee disarticulation, transtibial prosthesis, Symes foot, partial foot prosthesis and toe fillers. The two main subcategories of lower extremity prosthetic devices are transtibial (any amputation transecting the tibia bone or a congenital anomaly resulting in a tibial deficiency) and transfemoral (any amputation transecting the femur bone or a congenital anomaly resulting in a femoral deficiency). A transtibial prosthesis is an artificial limb that replaces a leg missing below the knee. Transtibial amputees are usually able to regain normal movement more readily than someone with a transfemoral amputation, due in large part to retaining the knee, which allows for easier movement[1].In the prosthetic industry a transtibial prosthetic leg is often referred to as a "BK" or below the knee prosthesis.

The main objective is to make a powered ankle–foot prosthesis capable of mimicking human ankle dynamics in level-ground walking and to aid in amputee ambulation[2].The project mainly aims at creating a visual record capable of re educating an amputee for gait.

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The analysis on the human gait cycle is an important criteria which helps to study the gait of a normal and a transtibial condition. The standard gait cycle comprises of the stance phase(60% of gait cycle) and swing phase(40% of gait cycle). Out of the different gait patterns, efforts have been made to enact the patterns like heel strike, foot flat and heel off in the stance phase and acceleration in the swing phase.

Consider the diagram given below for the gait pattern of a normal individual :
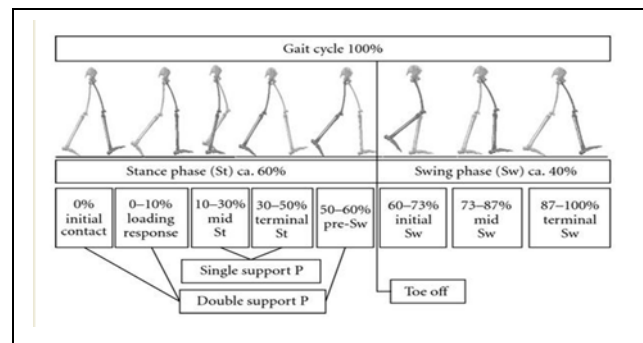

Fig.1 Gait Cycle

2 SYSTEM SUMMARIZATION

2.1 Block Diagram

The block diagram of the Powered foot ankle prosthesis comprises of the following modules mentioned below:

- Power Supply
- Accelerometer Sensor(ADXL335)
- Microcontroller(PIC 16F877A)
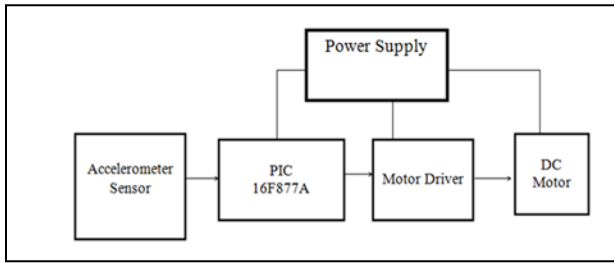- Motor Driver(L293d)
- DC geared motor(12V)

Fig.2 Block Diagram

The sensor used is the tri axial accelerometer sensor which detects its own acceleration and gives the output values. The values so measured by the sensor will be read by the microcontroller. The microcontroller will be programmed in such a manner that for different values of acceleration, the different foot movements like dorsiflexion and plantar flexion will be performed. The different foot positions will be adjusted by the motor whose movement will be controlled by the microcontroller. Thus a co-ordinated working of the sensor, microcontroller and the motor will provide a better gait pattern for the transtibial patient. The prosthetic device should also be able to mimic the two important parameters i.e the standard foot Centre of pressure (COP) and force graph of a normal subject in a transtibial case.

2.2 Module Description

Accelerometer Sensor: The accelerometer sensor used in the project is ADXL335. The ADXL335 is a complete 3-axis acceleration measurement system. It has a measurement range of ± 3 g minimum. It can measure the static acceleration of gravity in tilt-sensing applications as well as dynamic acceleration resulting from motion, shock, or vibration. The ADXL335 uses a single structure for sensing the X, Y, and Z axes. The accelerometer sensor has to be attached to the normal foot of the individual and it gives the output values for all three axes for different foot gait patterns which are then fed to the controller.

Fig.3 Accelerometer Sensor ADXL335

Microcontroller: PIC is referred to Peripheral Interface Controller. The controller used is PIC16f877A which is a 40pin IC. It accepts the ADC values from the accelerometer sensor and it enables the motor to perform the required motions as per the set values. The PIC microcontroller has certain special microcontroller features like inbuilt ADC, High-Performance RISC CPU and CMOS technology which make it more preferable over other controllers.
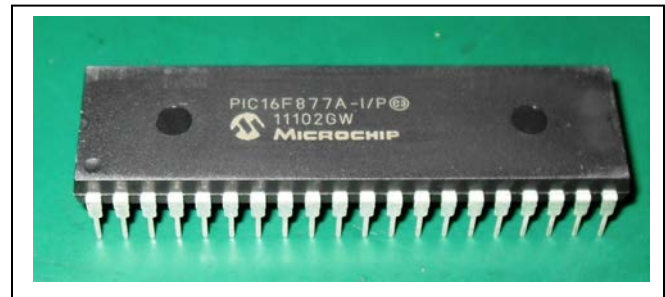

Fig.4 PIC16F877A Microcontroller

Motor Driver L293D: The motor driver used is L293D. L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16-pin IC which can control a DC motor in any direction. The L293D is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads (such as relays solenoides, DC and stepping motors) and switching power transistors.
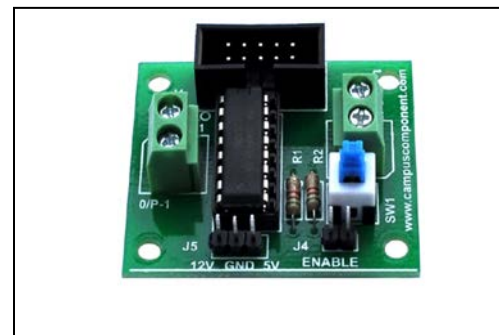

Fig.5 Motor Driver L293D

DC Motor: A DC motor is a device that converts direct current (electrical energy) into mechanical energy. A 12V dc gear motor having 3.5rpm is used .The motor provides both clockwise and anticlockwise motions in response to the set values programmed by the controller. 3.5RPM 12V DC geared motors are mostly used in robotics applications. 3.5 RPM 12V DC Geared Motor is high quality low cost DC geared motor. It has steel gears and pinions to ensure longer life and better wear and tear properties.
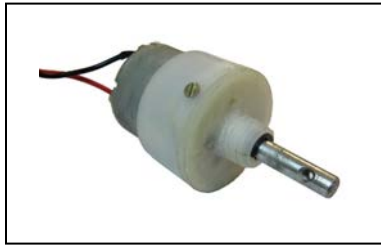
Fig.6 DC gear motor

3 RESULTS

TABLE 1
ACCELEROMETER ADC READING OUTPUT

Accelerometer X-axis value	Accelerometer Y-axis value	Accelerometer Z-axis value	Standard Gait Pattern
ADC1 > 105	ADC2 > 90	ADC3 > 80	Heel Strike
ADC1 > 103	ADC2>85	ADC3>93	Foot Flat
ADC1 > 95	ADC2 > 90	ADC3 > 100	Heel off
ADC1 > 76	ADC1 > 85	ADC1 > 117	Acceleration

- Initially, the accelerometer sensor should be placed on the anterior tibial shin, at a distance of 4" from the Mid-Patella Tendon on the normal foot and the amputee should be allowed to visualize the gait pattern followed by the prosthetic foot, with the changing sensor positions.
- This enables the amputee to learn the gait pattern that he should make possible, when the prosthetic limb is attached to his body.
- After educating the patient likewise, in the later stages, the accelerometer sensor should be placed in the prosthetic device itself and the patient should try to carry out the motions which he had learned in the visual training.
- Thus, the patient will enact the same type of gait pattern he has seen in the visual record and it will help him in attaining the standard gait patterns with the aid of the coordinated working of all the electronic mechanisms built in the prosthetic device.

4 CONCLUSION

It can be concluded that better transtibial gait patterns can be acquired by considering the visual record, which will educate the transtibial patients to get a clear image of the gait pattern their prosthetic device should carry out. The prosthetic device provides the standard gait patterns like heel strike, foot flat and heel off for corresponding values sensed by the accelerometer sensor. Thus, the basic idea of providing the movements of dorsiflexion and plantar flexion which is normally absent in a transtibial subject has been successfully carried out by the active coordination between the sensor, microcontroller and the motor.

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