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Research Article

Driving Circuits for DC Motor Control using 8051 Microcontroller Suitable for Applications Related to Prosthetic Legs

Ashmi. M[a*] S. Jayaraj[b] and K.S. Sivanandan[a]

[a]Electrical Engineering Department, [b]Mechanical Engineering Department, National Institute of Technology, Calicut-673601, India

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Abstract

The human locomotion with two legs is a periodic physical activity occurring by driving of the bones by muscles, which are stimulated by electrical signals transferred by neurons from the brain. Artificial limb is a mechanism for supporting the physically disabled by understanding the percentage of their disability and helps amputee get back to their normal functioning to a certain degree. This paper focuses on developing a control system drive to actuate the motorized assistive device. The driving circuit for the supervisory control of DC motors to lock and unlock the knee and hips for both limbs is designed and it should be synchronized such that the locomotion of both the hip and the knee is executed simultaneously. Here, 8051 microcontroller is used to control the 12V DC series motors for the desired position. The entire operation can be made closed loop with the help of feedback circuitry.

Keywords: *DC Motors; Speed and Position control; Prosthetic Legs*

1. Introduction

According to the present living conditions, people with lower limb weakness are increasing day by day. Leg amputees need artificial legs for mobility and arm amputees use prosthetic arms to help with many daily activities. It is expected that 10% of people in total population of India having the age sixty five years old and over in 2015. As the people age increases their physical functions degrade. Normal walking requires muscular strength, joint mobility and coordination of the central nervous system and the absence of any of these capabilities can challenge a person's ability to walk.

Human gait is the way locomotion is achieved using human limbs. Human locomotion involves the dynamics of two legs which includes the locking of first leg knee joint called stance phase, unlocking of the knee of the second leg called swing phase and dynamics of both legs during their unlock condition. The forces which have the most significant influence during gait analysis are due to gravity, muscular contraction, and inertia and floor reaction. The gait cycle begins when one foot contacts the ground and ends when that foot contacts the ground again. Stance phase accounts for approximately 60% and swing phase for approximately 40 % of a single gait cycle (Kaiyu Tong *et al*,1999). People with partial or complete paralysis of the lower extremity may require orthotic intervention for stability during stance phase.

In the 20th century a great deal of emphasis has been placed on developing artificial limbs that look and move more like actual human limbs. With the improvement of new technologies like CAD prosthetic limbs are getting better and unfortunately more expensive. Newer systems are looking at integrating the limb directly into the bone for a purer movement and less pain for the amputee. An embedded electronic system for sensory data acquisition and motor control was proposed in (Marcio V *et al*,2009) wherein the movements of the joints of the orthosis are controlled by DC motors equipped with mechanical reductions, whose purpose is to reduce rotational speed and increase the torque, thus generating smooth movements. A biologically inspired motor control scheme based on sensory-motor interaction within the central nervous system was developed for the application to control the single joint limb segment actuated by pneumatic muscles (Eskiizmirililer.S *et al*,2001).

A SmartLeg model was developed (Dedic.R *et al*,2011) to prove a real possibility that a person with an above or below knee amputation can perform different types of motions which require power in knee and ankle joints, like climbing stairs, with hydraulic units whose weight and overall dimensions would not interfere with the comfort of the prosthesis user. An upper limb below elbow prosthetic was designed which can be used by both amputees and paralyzed patients to bring simple hand movements to the fingers like flexion, extension and grabbing of objects (Debika Khanra *et al*,2011). Electrodes were attached

*Corresponding author: **Ashmi. M** is a Research Scholar; **S. Jayaraj** and **K.S. Sivanandan** are working as Professors.

between the patient limb and the microprocessor, which analyses nerve signals to be processed and a 360 degree rotational arm was developed by appropriately selecting the motor and impulse sequence (Aravinthan.P,*et al*,2010). An on/off switch is provided on the waist harness to control the start and stop of the hand movement and is connected to the 8051 micro-controller to control the motor movement. The micro-controller is programmed to control the 12V DC motor movement. The Control System extracts the mechanical or electrical signals from the amputee to perform signal processing and then combine them to take decisions and supervise the system function.

A bio mechatronic knee with maximum knee flexion of 150° or more is proposed in (Bharathi Y.E, *et al*,2012) which include the stance- phase, swing-phase with maximum angular movement. In normal level walking the human knee rotates through a range of approximately 70° going from a position of full extension and mid-stance to 70° of flexion shortly after toe off. A wearable robotic device for the patients with knee problem was designed for reducing the load at the knee (Low K.H, *et al*,2006). In order to detect the knee motion and to provide appropriate actuating signals to the motor, the sensor has to be programmed to recognize the direction and magnitude of the knee movement from the encoder. This signal will be passed to the motor to actuate the structure correspondingly. The rotary encoder works by using two photo detectors placed at multiples of at least 90° out of phase away from each other. A knee-ankle-foot orthosis (KAFO) has been designed which locks the knee during stance and allows free-knee motion during the swing phase of gait (Kenton R. Kaufman *et al*,1996). KAFO provided complete stability in stance phase and unrestricted knee movements in swing phase. The electronic control system is composed of digital logic-integrated circuits and a combination logic network monitors input data and produces electrical output commands based on the input states. The inputs to the control circuitry are signals generated by strategically located foot contact sensors. The gait efficiency when walking with locked as well as unlocked knee joints are then compared with that of normal gait. With the advanced technology biomechanics has made great strides in analyzing more complex body movements and because of the considerable interactions between adjacent muscles it is becoming necessary to identify motor synergies (David A. Winter *et al*,1990).

2. System Description

The system envisaged can be represented by the block diagram shown in Fig.1. A photograph of the hardware setup fabricated in the laboratory is given in Fig.2. The wired diagram representing the interfacing of driver circuit with motors is given in Fig.3. The input from the power supply unit is 12V which is provided to 8051 microcontroller which in turn generates pulses to drive the DC motors using the driver circuit L293D as per the requirement.

8051 Microcontroller is a Harvard architecture, single chip microcontroller (µC) series which was developed by Intel in 1980 for use in embedded systems. Intel's original versions were popular in the 1980s and early 1990s. While Intel no longer manufactures the MCS-51, several companies also offer MCS-51 derivatives as IP cores for use in FPGAs or ASICs designs. One particularly useful feature of the 8051 core is the inclusion of a Boolean

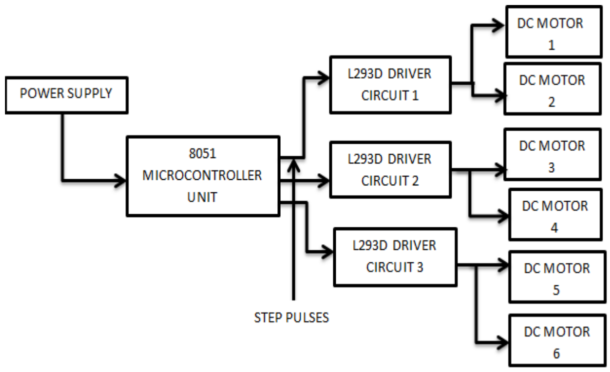

Fig.1 Block diagram of the entire system

processing engine which allows bit-level Boolean logic operations to be carried out directly and efficiently on select internal registers and select RAM locations. This advantageous feature helped in 8051's popularity in industrial control applications because it reduced code size by as much as 30%. Another valued feature is the inclusion of four bank selectable working register sets which greatly reduce the amount of time required to complete an interrupt service routine. With a single instruction the 8051 can switch register banks as opposed to the time consuming task of transferring the critical registers to the stack or designated RAM locations. These registers also allow 8051 to quickly perform a context switch which is essential for time sensitive real-time applications.

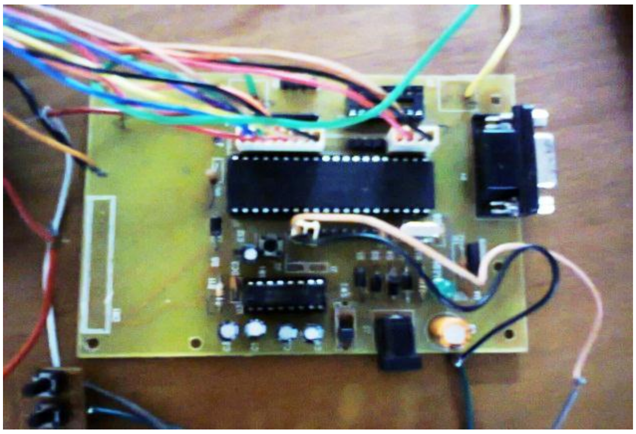

Fig.2 Hardware setup of 8051

To control the direction of the DC motor L293D IC, which is an H bridge converter is used. An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards. The great ability of an H-bridge circuit is that the motor can be driven forward or backward at any speed, optionally using a completely independent power source. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V.

The L293D is a quadruple push-pull 4 channel driver capable of delivering 600 mA (1.2 A peak surge) per channel. The L293D is ideal for controlling the forward/reverse/brake motions of small DC motors controlled by a microcontroller such as a PIC or BASIC stamp.

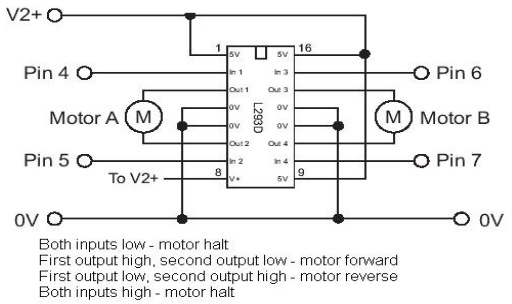

Fig.3 L293D interfacing with DC series motor

The L293D is a high voltage, high current four channel driver designed to accept standard TTL logic levels and drive inductive loads (such as relays solenoids, DC and stepping motors) and switching power transistors. The L293D is suitable for use in switching applications at frequencies up to 5 KHz.

DC motors are a good choice whenever controlled movement is required due to simplicity, low cost, high reliability, high torque at low speeds, and high accuracy of motion in applications where you need to control rotation angle, speed, position and synchronism. This application presents a driver with capable of controlling acceleration as well as position and speed. DC motors are mechanically commutated electric motor powered from direct current. They have a rotating armature winding (winding in which a voltage is induced) but non-rotating armature magnetic field and a static field winding (winding that produce the main magnetic flux) or permanent magnet. Different connections of the field and armature winding provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems called DC drives.

The switch which acts as an input to the 8051 microcontroller holds the key to convert the circuit into open loop or closed loop. A binary switch is used in case of the open loop system and a bell type push button is used for the closed loop. The switch is the input to the 8051 microcontroller which gives the binary outputs for the ON and OFF of the DC motor respectively. The switch delivers the pulse to the micro controller and outputs an on-off signal depending on if there is force being applied to it.

A rotary encoder also called a shaft encoder is an electro-mechanical device that converts the angular position or motion of a shaft or axle to an analog or digital code and it is fixed to the shaft of the DC motor which has number of transparent slots within its design (ie.30 slots in this work). As the disc rotates with the speed of the shaft, each slot passes by the sensor in turn producing an output pulse representing logic "1" or logic "0" level. These pulses are sent to a register or counter which can be used to keep track of the rotation. When the wheel rotates, each state transition will cause the counter to either increment or decrement depending on direction and finally these pulses are sent to an output display to show the speed or revolutions of the shaft. By increasing the number of slots within the disc more output pulses can be produced for each revolution of the shaft.

The advantage of using wheel encoders is that motor revolution can be sensed with greater resolution and accuracy and even fractions of a revolution can be detected. Then this type of sensor arrangement could also be used for positional control with one of the discs slots representing a reference position. Here we have used MOC 7811 infrared based optical sensor which contains an IR emitter and receiver pair mounted facing each other. It can be used with wheel encoders to detect speed, angle, etc.

MOC7811 is a slotted Opto-isolator module, with an IR transmitter and a photodiode mounted on it. This is normally used as positional sensor switch (limit switch) or as Position Encoder sensors used to find position of the wheel. It consists of IR LED and Photodiode mounted facing each other enclosed in plastic body. When light emitted by the IR LED is blocked because of alternating slots of the encoder disc logic level of the photo transistor changes. This change in the logic level can be sensed by the microcontroller or by discrete hardware. This sensor is used to give position feedback to the robot or as limit switches. A photograph of the entire setup of control system drive setup is shown in Fig.4.

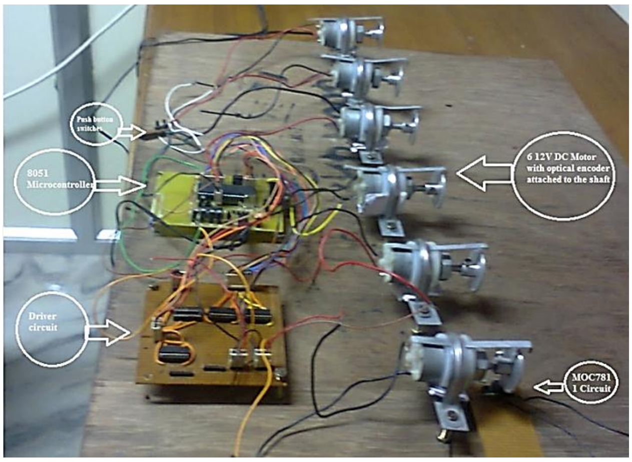

Fig.4 Entire setup of control system drive

3. Simulation Circuit

The system was simulated using Keil µVision and Proteus software as shown in Fig.5. The µVision IDE from Keil combines project management, make facilities for source code editing, program debugging, and complete simulation in one powerful environment. For the purpose of coding the software package used is Keil µVision 2. The µVision editor and debugger are integrated in a single application that provides a seamless embedded project development environment. The Embedded C code was written on Keil µVision and the hex file was generated and then loaded on the AT89C51(8051) micro-controller. Proteus is the software for microprocessor simulation, schematic capture, and printed circuit board (PCB) design.

The logic of the software is detailed below.

(i) The direction of rotation of motors can be varied by changing the inputs to the corresponding L293D driver. An input Combination of 1, 0 or 0, 1 results in the motor rotating clockwise or anti-clockwise direction whereas an input combination of 0, 0 or 1, 1 will result in stopping of the motor.
(ii) The locking motors of the legs are connected to the ports P2 (4, 5) and P3 (4, 5). To lock one leg give an input of 1, 0 and to unlock the other give an input of 0, 1 respectively and then stop running the motors.
(iii) The knee motors and hip motors are connected to the ports P2 (0,1), P3 (0,1) and P2 (2,3), P3 (2,3) respectively. To move the unlocked leg rotate the knee in the forward direction by giving an input of 1, 0 and rotate the hip in the anti-clockwise direction by giving an output of 0, 1 and then stop the motors after a delay.
(iv)Above steps are repeated continuously in order to achieve the continuous walking movement.

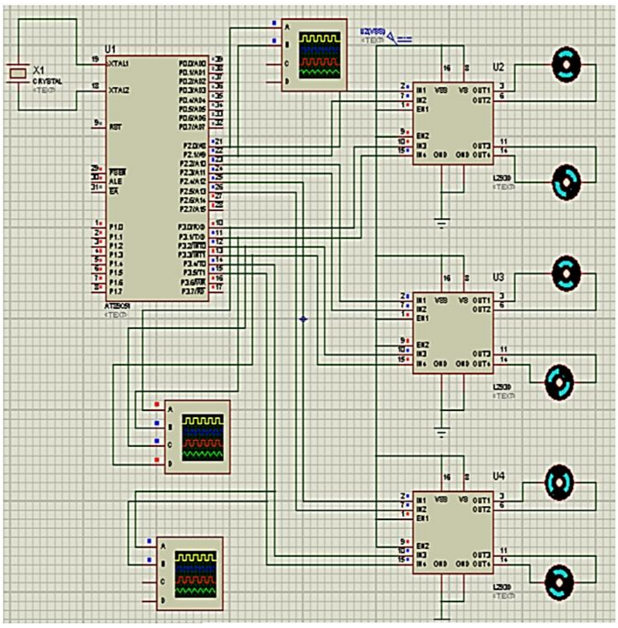

Fig.5 Simulation circuit of the proposed System

4. Results

In medical terminology the walking of a human leg is coordinated as follows:

1) When one leg moves forward, the knees of that leg rotate in clockwise direction whereas the hips rotate in the anti-clockwise direction and the motor in knee gets locked.
2) When one leg is moving the other leg locks itself.

This movement can be achieved by using 6 DC motors mimicking the various movements of the knees, hips and the locking of the legs. The output pulses of six DC motors in clockwise and anticlockwise directions are shown respectively in Figures 6(a) –6(f).

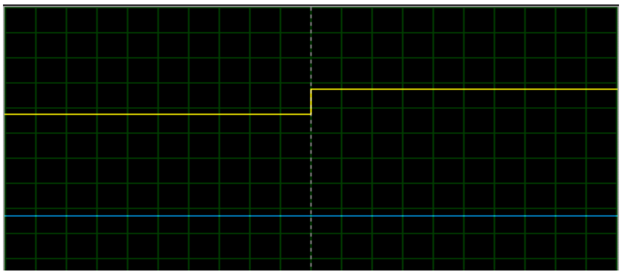

Fig. 6(a) Right leg locking motor signal

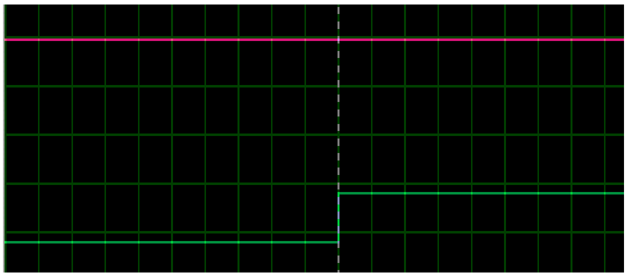

Fig. 6(b) Left leg locking motor signal

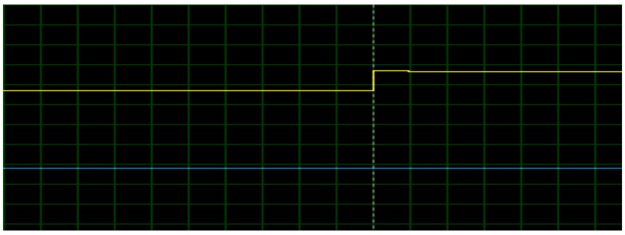

Fig. 6(c) Right knee motor signal

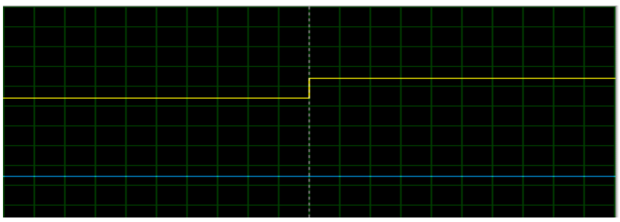

Fig. 6(d) Left knee motor signal

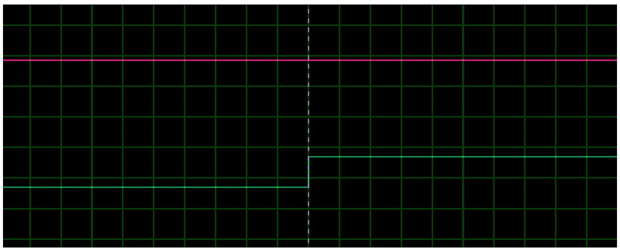

Fig. 6(e) Left hip motor signal

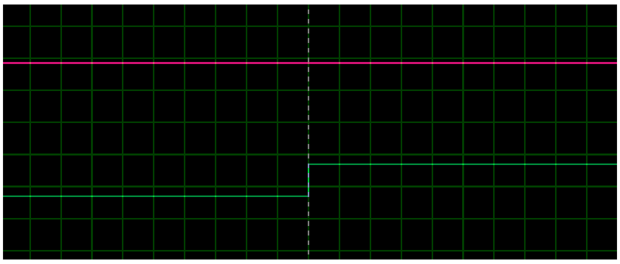

Fig. 6(f) Right hip motor signal

5. Conclusion

The objective of this work is to develop a control system drive (software as well as hardware based) for the assistive limb by considering modification of existing control theory. The driving circuit for the supervisory control of two DC series motors to lock and unlock the knee helps to oscillate knee flexion and knee extension whenever required during stance phase and swing phase of gait was designed. Furthermore the proper locomotion of the hips is also developed by again using the help of two DC series motors to conduct the motion and dynamic analysis for variable speeds. These two drives need to be synchronized such that the locomotion of both the hip and the knee is executed. The microcontroller used is Intel MCS-51, commonly known as the 8051 microcontroller to control the DC series motors for the desired position. Proper software for the smooth synchronization of human locomotion is to be developed, and this must be burned into the microcontroller for driving the respective motors properly. The proposed mechanism is an open loop control and checked with the hardware developed and results seem to be satisfactory. Future works include making the control system drive closed loop with the help of feedback circuitry which includes optical encoders.

The closed loop operation for the above circuit can be done by replacing the switch with a pressure sensor. When the user is in stance phase i.e. foot resting on the ground firmly, then the signal is send to the driving circuit to lock the knee. If the leg is at the starting of swing phase the foot is lifted up and the push button switch is released sending signal to unlock the knee. Whenever there is any pressure sensed by the sensor, the sensor will give the input to the 8051 microcontroller which in turn rotates the DC series motor clockwise or anti-clockwise direction as per the requirement. For the laboratory purpose, the sensor is been replaced with a push button. The bell type push button gives the signal when the pressure is applied and when the pressure is removed, the motor rotates in the opposite direction. The feedback signal from the foot is given to the driving circuit which actuates the DC motor connected to the assistive device. The DC motors operation can be used for the locking and unlocking of the knee in assistive device.

References

Kaiyu Tong, Malcolm H. Granat (1999), A practical gait analysis system using gyroscopes, *Elsevier- Medical Engineering & Physics*, pp 87–94.

Marcio V. Araujo, Pablo J. Alsina (2009), Development of an active orthosis prototype for lower Limbs, *Proceedings of COBEM.*

Eskiizmirililer.S, Tondu.B (2001), Motor Control of a limb segment actuated bty artificial muscles, Engineering in Medicine and Biology Soceity- *Proceedings of the 23rd Annual International Conference of IEEE*, pp 865-868.

Dedic.R, Matice Hrvatske (2011), SmartLeg: An intelligent active robotic prosthesis for lower-limb amputees, *Information, Communication and Automation Technologies* (ICAT), pp1-7.

Debika Khanra, Sudesh.S (2011), Below Elbow Upper Limb Prosthetic for Amputees and Paralyzed Patients, *International Journal of Computer Applications*, Vol. 16– No.5, pp 35-39.

Aravinthan.P, GopalaKrishnan.N (2010), Design, Development and Implementation of Neurologically Controlled Prosthetic Limb Capable of performing rotational movement, *Emerging Trends in Robotics and Communication Technologies (INTERACT)*- IEEE , pp 241-244.

Bharathi Y.E, Mareshamani.M, Nada Thasneem (2012), Design of Biomechanical Lower Limb to Assist the Amputees, *International Conference On Advances In Engineering, Science And Management* , pp 434-438.

Low K.H, Yuehong Yin (2006), Providing Assistance To Knee In The Design Of A Portable Active Orthotic Device, *IEEE-International Conference on Automation Science and Engineering*, pp 188-193.

Kenton R. Kaufman, Irby S.E(1996), Energy-Efficient Knee-Ankle Foot Orthosis: A Case Study, *American Academy of Orthotists and Prosthetists-JPO*, Volume-8, pp 79-85.

David A. Winter (1990), Biomechanics and Motor Control of Human Movement, 2 edn, *Wiley-Interscience.*