International Journal of Scientific & Engineering Research, Volume 5, Issue 1, January-2014
ISSN 2229-5518

Analog Haptic Robotic Arm

Jainish S Kothari, Tanay S Vaidya

Abstract— Robotics is an engineering field which has developed since ages and has helped in reduction of human efforts. The invention of robots has increased the precision and repeatability in many fields of operation which would have been difficult using human hands. However, human intervention to control the robot through human actions and gestures extends the domain of its utility. The method adapted to sense human touch and gestures is known as HAPTICS. The robot motion is determined by the haptic feedback received from the user. Haptic feedback refers to the change in the output of a device corresponding to the sense of a human touch. This paper aims at designing and implementation of a haptic robotic arm which can recognize hand gestures of a user. The robotic arm follows the changes in the gestures of the user’s hand. The robotic arm is designed to have three joints consisting of servo motors to provide two degrees of freedom. The human movements are sensed by an electronic component like a potentiometer. The processing of the sensed output will be completely analog in nature which will reduce the effective cost of the robotic arm. Closed loop systems with the help of servo motors have been implemented which drastically reduces the error due to external noise sources.

Keywords— Potentiometers, Robotic Arm, Servo Motors, Voltage Controlled Oscillator

1 Introduction

“If you cannot do it digital, it must be done analog”. There has been a constant approach of creating digital counterparts to the available analog devices since decades. The analog nature of the physical world has signified the need for conversion of analog signals to digital signals for processing and control of electronic devices and digital to analog conversion for communicating with the physical world. The price to be paid for this approach is the increased complexity and cost of the designed system. A pre-eminent approach to this is to use analog circuitry capable of processing analog signals to control complex electronic devices. The analog haptic robotic arm processes the analog signals received from a potentiometer using the Voltage Controlled Oscillator mode of IC 555.

The most versatile part of a human body is the human hand. The 27 degrees of freedom of the human hand facilitates it to perform various gestures and the required grip to hold objects. Haptics can be termed as extension of the human hand versatility to improvise the performance of man-made machines. The analog haptic robotic arm uses potentiometers to detect a specified change in the gesture of the human hand.

2 Design Implementation

2.1 Haptic Sensors

Potentiometers are three terminal variable resistance electronic components capable of generating an adjustable voltage divider network. The voltage obtained between the variable terminal and the grounded terminal of the potentiometer can be determined using the voltage division rule. The application of a potentiometer as a haptic transducer can be achieved by changing the direction of its shaft in accordance to the linear motion of the human hand. In this design, the potentiometer has been fixed to the human hand joint allowing the free movement of the shaft. A plate or a rod intercepted to the shaft is further extended and fixed to the human body. The two point contact of the potentiometer results in movement of its shaft in comparison to the linear motion of the human hand. The change in gesture of the human hand results in the generation of a changing output voltage which can be processed to achieve desired actions.

2.2 Voltage Controlled Oscillator

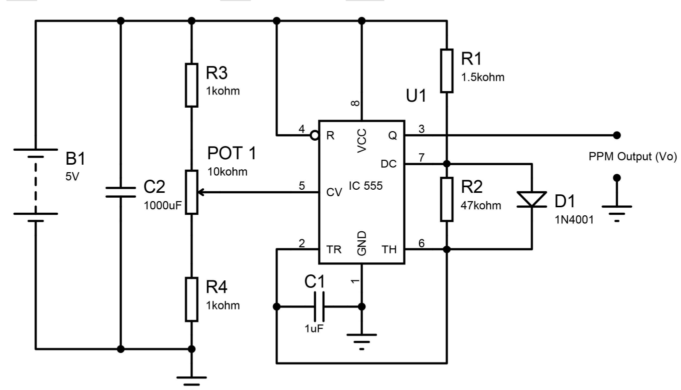

Fig 1. Proteus schematic of voltage controlled oscillator

Monolithic timer Integrated Circuits fulfill the continuous need of astable and monostable operations required on a daily basis in electronics. IC 555 proves its versatility by generating timing signals from microseconds to few seconds range. Fixed duty cycle timing signal can be obtained using the astable mode of IC 555. However, to obtain a variable duty cycle IC 555 is operated in a special mode known as the Voltage Controlled Oscillator (VCO) mode. In VCO mode, the control voltage of the threshold comparator of IC 555 is varied. In this design, this variation in the control voltage of the timer IC is achieved by connecting the potentiometer variable terminal to the control voltage. In this specific astable mode of operation of the timer IC, the reference voltage of the threshold compar-

- Jainish Kothari is currently UG student pursuing degree program in electronics engineering in Fr. CRCE, Bandra,University of Mumbai, India, PH-+91 8898846272. E-mail: jaiin987@gmail.com
- Tanay Vaidya is currently UG student pursuing degree program in electronics engineering in Fr. CRCE, Bandra, University of Mumbai, India, PH-+91 9819774249. E-mail: tanay.vaidya1@gmail.com

International Journal of Scientific & Engineering Research, Volume 5, Issue 1, January-2014
ISSN 2229-5518

ator (V_{TH}) depends upon the voltage across potentiometer keeping the reference voltage of the trigger comparator (V_{TL}) constant. Thus, the on time (T_{ON}) of the output depends upon the input to the control voltage keeping the off time (T_{OFF}) always constant which is known as Pulse Position Modulation (PPM). The selected values of R_1, R_2 and C_1 are responsible to generate T_{ON} varying from 1milliseconds to 2milliseconds when the corresponding control voltage is varying between 3V to 4V. This generated timing signal is used to provide the required control signal to the servo motors.

2.3 Servo Motors

In this design, DC servo motors were used to achieve the different movements of the robotic arm. DC servo motors are DC motors possessing an internal feedback mechanism for achieving controlled rotations. The DC servo motors used were capable of rotating from 0 degrees to 180 degrees. Power and control signals are required to achieve controlled rotation using DC servo motors. A +5V power was supplied to the power signals of all the servo motors using an external power source. The control signal should be a digital signal of ON time varying from 1 miliseconds to 2 milliseconds and the corresponding duty cycle less than 10% to achieve full rotation. The control signals to individual motors were provided through individual voltage controlled oscillator sections of IC 555. The direction of movement of the motor shaft was observed to be a function of the control voltage of IC 555.

2.4 Robotic Arm

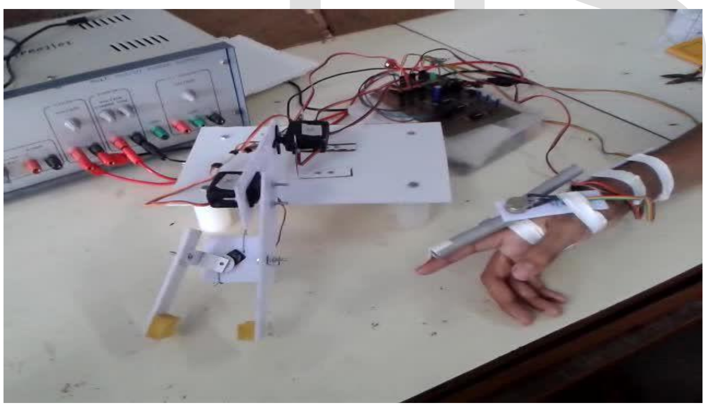

Fig 2. Physical Implementation of the analog haptic robotic arm

The designed robotic arm has two axes facilitating the arm to pick up objects in the required plane. Construction of the robotic arm gives it the flexibility to perform movements in pitch and yaw rotations. Servo motors 1 and 2 provide rotational motion to the robotic arm in pitch direction to achieve the required distance and depth. Servo motor 3 provides rotational motion in the yaw direction to control the opening and closing of the claw. The body of the robotic arm is constructed from a 20 gauge acrylic sheet to give the arm a rigid structure. The motor and plate assemblies are connected by standard 3mm nuts and bolts. Servo motor 1 is fixed to the base by standard 50mm I-clamps. The entire robotic arm assembly is supported by a 24 gauge mild steel plate of 15cm x 10cm dimension. The mild steel plate stands on 4 acrylic bases at a height of 80mm.

3 Analysis and Calculations

3.1 PPM Calculations

3.1.1 Servo motor at 0 degree angle:

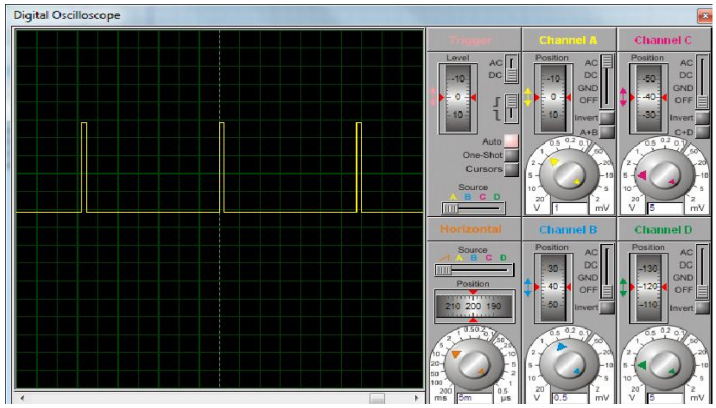

Fig 3. Proteus PPM waveform for 3V control voltage

T_{ON} $= R_1 \times C_1 \times \ln((V_{B1}-V_{TL})/(V_{B1}-V_{TH}))$
$= 1.5k \times 1u \times \ln((5-1.5)/(5-3))$
$= 0.84$ milliseconds

T_{OFF} $= R_2 \times C_1 \times \ln(V_{TH}/V_{TL})$
$= 47k \times 1u \times \ln(3/1.5)$
$= 32.57$ milliseconds

Duty Cycle (%) $= (T_{ON} / (T_{ON}+T_{OFF})) \times 100$
$= 2.51\%$

3.1.2 Servo motor at 180 degree angle:

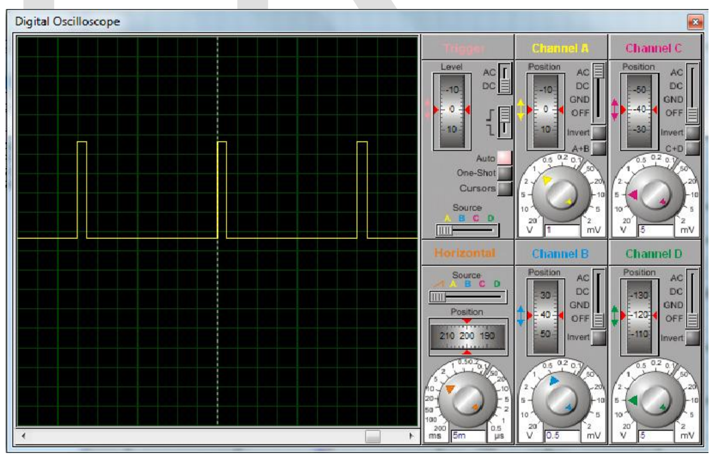

Fig 4. Proteus PPM waveform for 4V control voltage

T_{ON} $= R_1 \times C_1 \times \ln((V_{B1}-V_{TL})/(V_{B1}-V_{TH}))$
$= 1.5k \times 1u \times \ln((5-2)/(5-4))$
$= 1.64$ milliseconds

T_{OFF} $= R_2 \times C_1 \times \ln(V_{TH}/V_{TL})$
$= 47k \times 1u \times \ln(4/2)$
$= 32.57$ milliseconds

Duty Cycle (%) $= (T_{ON} / (T_{ON}+T_{OFF})) \times 100$
$= 4.79\%$

3.2 Torque Calculations for the robotic arm

The terms Effective Length and Effective Mass correspond to the maximum length and the maximum weight the specified

International Journal of Scientific & Engineering Research, Volume 5, Issue 1, January-2014
ISSN 2229-5518

motor has to encounter while controlling the robotic arm. Both the parameters are responsible for determining the torque of the servo motors.

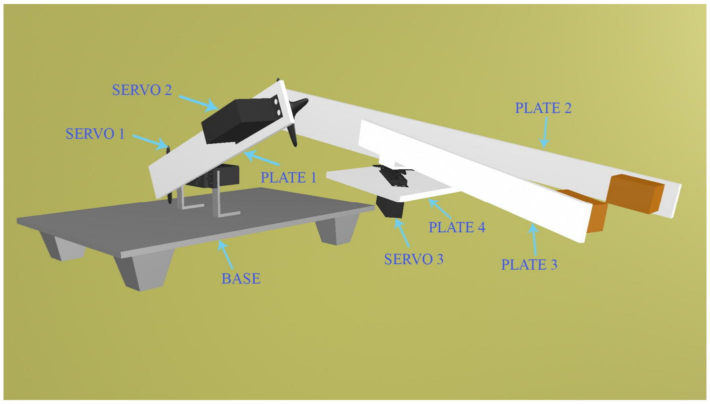

Fig 5. 3D model of the robotic arm

TABLE 1
Parameters for torque calculations of servo motors

Servo Motor	Effective Parameter	Value
Servo 1	Effective Length (L_1)	29 cm
	Effective Mass (M_1)	150 g
Servo 2	Effective Length (L_2)	16 cm
	Effective Mass (M_2)	65 g
Servo 3	Effective Length (L_3)	10.5 cm
	Effective Mass (M_3)	15 g

Torque required for Servo 1 = L_1 x M_1
= 29cm x 150g
= 4350g-cm
= 4.35kg-cm
Torque of selected Servo 1 = 5.0kg-cm
Torque required for Servo 2 = L_2 x M_2
= 16cm x 65g
= 1040g-cm
= 1.04kg-cm
Torque of selected Servo 2 = 3.0kg-cm
Torque required for Servo 3 = L_3 x M_3
= 10.5cm x 15g
= 157.5g-cm
= 0.157kg-cm
Torque of selected Servo 3 = 1.0kg-cm

3.3 Voltage across Potentiometer v/s Servo Angle

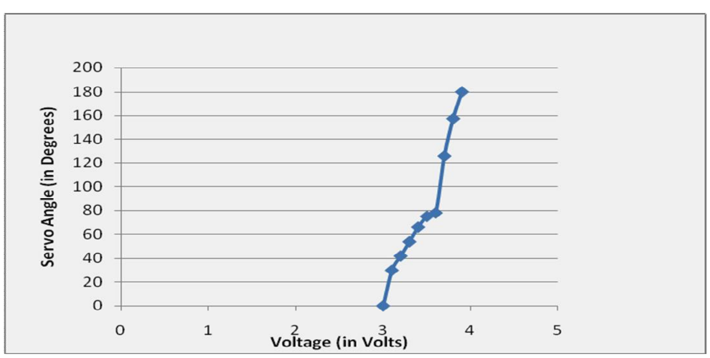

Fig 6. Potentiometer voltage v / s servo angle graph

A linear increase is observed in the angle of the servo motors with increase in the voltage drop across the potentiometer. Thus, the user has the flexibility to select the direction of rotation of the robotic arm by selecting the start and stop angle of the corresponding servo motor.

4 Advantages of Analog Haptic Robotic Arm over Conventional Haptic Robotic Arms

The term 'conventional' here refers to the various designs of small scale robotic arms available in the market. The designed analog haptic robotic arm proves to be more advantageous than the conventional haptic robotic arms in many aspects. The analog electronics involved in the control of the arm reduces the effective cost of the design drastically. The use of analog electronics eliminates the use of expensive microcontrollers which are used in conventional arms. The manufacturing of this robotic arm design becomes cheaper due to the reduced fabrication of the materials used and absence of processes like welding and brazing. Another advantage of this design is the less cost and easy availability of the haptic sensors. The process of calibration of these haptic sensors is easy compared to the sensors like accelerometer used in conventional robotic arms. Thus, the analog haptic robotic arm finds its utility in variety of small scale applications like pick and place, assembly operations, etc.

5 Future Scope

5.1 Analog PID implementation

The optimum way of eliminating the effect of external interferences on electronic circuits is the implementation of the Proportional, Integral and Derivative (PID) control. The errors caused due to changes in the environmental factors like temperature on potentiometers can be eliminated by implementation of an analog PID circuit. An operational amplifier PID circuit involves addition of outputs of an inverting amplifier, a differentiator and an integrator by a summing amplifier followed by an inverting amplifier. Higher level of precision in the movement of the robotic arm can be obtained by use of operational amplifier PID circuit.

5.2 Wireless haptic arm

Wireless communication can be established between the user and the robotic arm using a suitable transreceiver and an encoder decoder pair. Encoder decoder pair like HT12A and HT12D can be used along with suitable data processing techniques to make the system wireless.

5.3 Increased degree of freedom

The conventional robotic arms manifest their limited efficiency by increase in complexity of the design because of the demand to increase the specified degrees of freedom. The design of the analog haptic robotic arm involves simple motor and plate assemblies facilitating the user to increase the degrees of freedom of the robotic arm involving least possible complexities.

International Journal of Scientific & Engineering Research, Volume 5, Issue 1, January-2014
ISSN 2229-5518

5.4 Multi-arm technology

Master slave configuration comprising of multiple slave robotic arms controlled by the same analog circuit can be designed. A single IC 555 VCO section can control the same joints of similar constructed multiple arms for repetitive operations.

6 Conclusion

An analog haptic robotic arm was successfully designed and implemented. Lifitng of an object weighing upto 250 grams was achieved successfully. A high level of precision was observed in the movement of the robotic arm due to generation of accurate control signals for the servo motors.

Acknowledgment

The authors wish to thank Dr. Deepak V. Bhoir, Mrs. Swapnali Makade, Mr. Anasta Rumao for their guidance and technical support. This work was supported in part by a grant from Fr. Conceicao Rodrigues College of Engineering.

References

[1] Sergio Franco,"Design with Operational Amplifiers and Analog Integrated Circuits"
[2] Robert F. Coughlin, Frederick F. Driscoll,"Operational Amplifiers and Linear Integrated Circuits"
[3] R.K Mittal, I.J Nagrath,"Robotics and Control"
[4] Riazollah Firoozian,"Servo Motors and Industrial Control Thory"
[5] Nisha Sharma, Swati Uppal, Sorabh Gupta,"Technology Based On Touch: Haptics Technology",IEEE,2011
[6] Dzmitry Tsetserukou, Naoki Kawakami, Susumu,"Humanoid Robot Arm for Intelligent Haptic Interaction with the Environment",ASME Paper,2009