DEVELOPMENT OF AN ADJUSTABLE GRIPPER FOR ROBOTIC PICKING AND PLACING OPERATION

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Abstract- Adjustable gripper for robotic system that is capable in identifying shape and size of an object is needed in many applications especially for picking and placing operation. This is due to some of the grippers' design are limited only to one specific shape or size that make picking and placing operation difficult. To hold different size or shape, the user needs to replace gripper which are more time consuming and more expensive. To address this problem, an adjustable gripper for robotic system has been proposed for picking and placing operation. The main objective is to design a robust gripper that can perform easier and faster picking and placing operation for multiple shapes and sizes objects. This adjustable gripper for robotic system can to improve the picking and placing operation in manufacturing field in producing more outputs without the needs to.

Index terms*: Adjustable gripper, picking operation, placing operation, robotic system*

I. INTRODUCTION

Due to high precision in performing different tasks and can perform multitasking work in same time, robot has been widely used in industry, medical and military operations. The robot construction technology has grown exponential every year and some competition is held in selecting the best robot design to perform specific task within period of time.

Pick and place is one of the most famous applications which have been used widely. This pick and place operation is done everywhere and every time because a lot of human movement involves picking and placing objects [1-6]. Pick and place robot can be defined as a simple robot, often with only two or three degree of freedom and little or no trajectory control, which the main function is to transfer items from one place to another. A pick and place robot has been strategically programmed to pick literally any object and to place it wherever required. The pick and place operation is very common in pharmaceutical industry, electronic industry, food industry and consumer goods industry [7-11].

For industrial profitability, manipulators that able to perform such motions in the shortest possible cycle time are required. For this purpose, the gripper should able to perform the task at high speed and high acceleration. In order to fulfill the criteria of an adjustable gripper that able to perform pick and place operation with difference size and shape of object, the robot must have feedback input that can control robot's movement and actuator. The smart device is one of the important electronic equipment need to be considered because the gripper robot involved with adjustable mechanism. This smart device which is conceptually referred as sensor-actuator subsystem with rich sensing and also function as the feedback input to the system for identifying various object with different shape and size[12-14].

Adjustable gripper in pick and place operation that capable to identify shape and size of object is needed as it can be used in many applications. This is because some gripper limited to one shape or size alone. This makes the gripper cannot be used for objects of various sizes or shapes. Beside than that, it may take longer time to replace different gripper for different objects and can cost fortune. To eliminate the limitation of fix size of gripper, adjustable gripper is most needed as it helps to produce more outputs and reduce time to replace gripper for objects with various sizes or shapes. The adjustable gripper needs to be properly designed to make it reliable and able to perform easier and faster pick and place operation.

The paper is organized as follows. In the next section, the specification of the robot gripper is described. Section 3 discusses the details design concept and development of the robot gripper. Section 4 discusses the testing and performance of the adjustable gripper robot based on picking and placing operation. The conclusion of this paper is summarized in the last section.

II. BASIC COMPONENT OF ROBOTIC SYSTEM

Robot has being used widely in industrial as it can perform precisely accurate in difference task, operation, heavy work and dangerous work. This helps industrial company to achieve their product target by replacing some of human task in their production line.

Basic robot system has three main component; the manipulator, the controller, and the power source. The body, arms, and gripper structure called the manipulator while power source for robot can be electrical, hydraulic or pneumatic to operate the manipulator. The controller is the brain of robot which is special-purpose computer that content with central processing unit, memory and input and output devices.

Following are the essential components of a robot:-

1) Sensor, which is an essential limit, is a transducer of some kind whose input is physical phenomena and the output are electronic signal.

2) Actuators, which act as the muscle of the system, produce the motion. The power supply of actuator is electrical, pneumatic or hydraulic.

3) Communication is unit transmitting information and receiving instruction from remote operator.

4) Controller, which integrate the activity of the several microprocessor.

5) End effectors is a gripping device at the end of the manipulator arm and it is used to make intentional contact with an object or to produces the robot final effect on it surrounding.

6) Manipulator is a mechanism consisting of several segment or arms.

7) The energy storage devices, such as battery or AC power supply.

As arms and robot end effectors or gripper play important part in robotic system which it pick and place desired items, it must be built with excellent design. Each robot arm that being build must have their own degree of freedom (DOF) which each joint or movable axis on the arm has their limit of size and movement. Besides that, robot workspace or reachable space is all place

that gripper can reach where the reachable space is dependent on the DOF angle/translation limitations and configuration of robot [15-17].

III.   SPECIFICATION OF THE ROBOT GRIPPER

The arm robot is the crucial part in the pick and place robot. The first stage in the design process is to design the gripper and select the actuator to control it. After that, the arm of robot will be designed to support the gripper without disturbing its operation. The size, length and weight of the gripper will be determined according to the requirement.

Normally, the mechanical design of the gripper is based on average adult human. The mechanical design of robotic gripper needed to address the required interaction between the robot and the environment in order to grasp and hold the object securely when executing the operation. For example, to achieve static equilibrium conditions for hold object with three fingers, the three grasping forces must pass through a single point and the angle spacing between two finger forces must be less than 180˚. There are two basics grasp configurations - cylindrical and spherical as shown in Figure 1. In cylindrical grasp configuration, two finger are placed so as to oppose the third finger where it useful for grasping prismatic objects. Meanwhile for spherical grasp configuration, the three fingers are positioned approximately 120˚ apart where they are suitable to grasping round object [2].
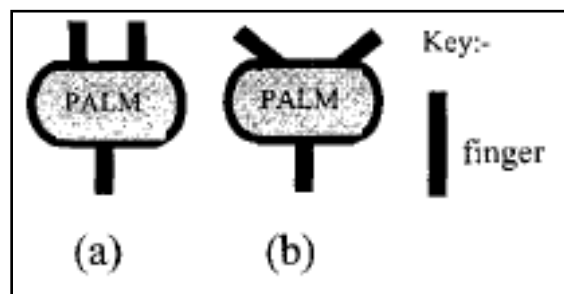

Figure 1. Different of (a) cylindrical and (b) grasp configurations [2]

Some of the industrials using adjustable gripper that using grasp configuration in pick and place operation. By using adjustable gripper, robot is able to grasp object with different sizes and shape without using an additional gripper. The closed-loop mechanism is performed by the finger or

gripper of robot and the object. This kind of application can increase quality of processed products and improve productivity. Basically, the capability of handling objects with difference sizes and shapes depends on the grippers that be used in the operation [6].

Force requirement in the gripper application is one of important criteria need to consider when choose the type of gripper. The style of robot jaws that is used plays major roll to determine the force requirement in gripper application. There are two types of jaws: friction or encompassing. Figure 2 shows the different of friction grip and encompassing grip where friction grip jaws rely totally on the force of the gripper to hold the part meanwhile encompassing jaws add stability and power by cradling the part. In other hand, friction grip pick up the desired item with "hand" completely flat like paddles meanwhile encompassing grip use "fingers" spreads and wrapped around the items. This shows that encompassing jaws provide advantage of 4 to 1 ratio, in force required because the jaws must be driven open apart to be dropped from encompassing grips [10].
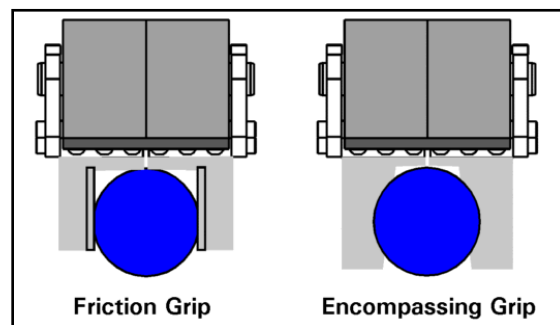
Figure 2. The different between friction grips and encompassing grip [10]

The arm of robot is important for pick and place robot as it will hold and manipulated the gripper. The selection for type and design of arm robot that suitable according to applications are crucial as it will determine the performance in terms of speed and accuracy. Some of applications require robot arm to rotate around it station, move left to right in straight line or move upward or downward to make the gripper pick and place the desire object. Figure 3 shown four basic operations of robotic arms for picking and placing task. The interaction between human and robot in this operation can be defined as force guided motions meanwhile in free movement, robotic arms perform pick and place operation by its own. As fine motions require the robotic arms to

place object according it specific location meanwhile gross motion require robotic arms to move in straight line and move upward or downward to place the desired object [1].
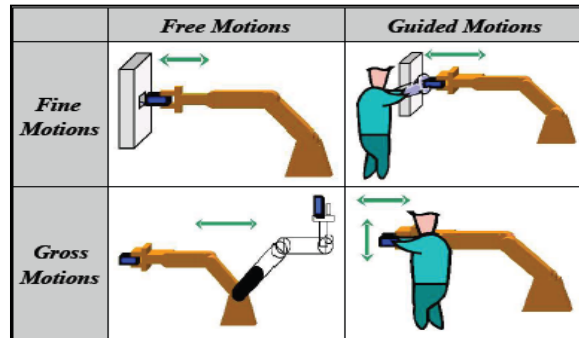

Figure 3. Classification of robot arms operation modes [1]

IV.   DESIGN CONCEPT AND DEVELOPMENT OF GRIPPER ROBOT

Each part of this robot is essential as it plays major role in building suitable robot to perform the pick and place operation. Mechanical part is the structure of the robot meanwhile electronic part acts as the interface or connection between PIC and equipment for the robot to perform its task such as motor or sensor. Programming is the commands or codes that send certain signal to activate specific motor to perform pick and place operation. The overall process is shown in flowchart in Figure 4.

In this project, DC motors that being used for lifting purpose must have high torque and have strong braking system which can support the weight for entire robot arms and gripper. For gripper, selection DC motor must be made which much have enough torque where it must be able to pick and hold the object during lifting process. As for input, selection photoelectric sensor are suitable due of object that need to be pick up is in bright color and within it measurement limit.
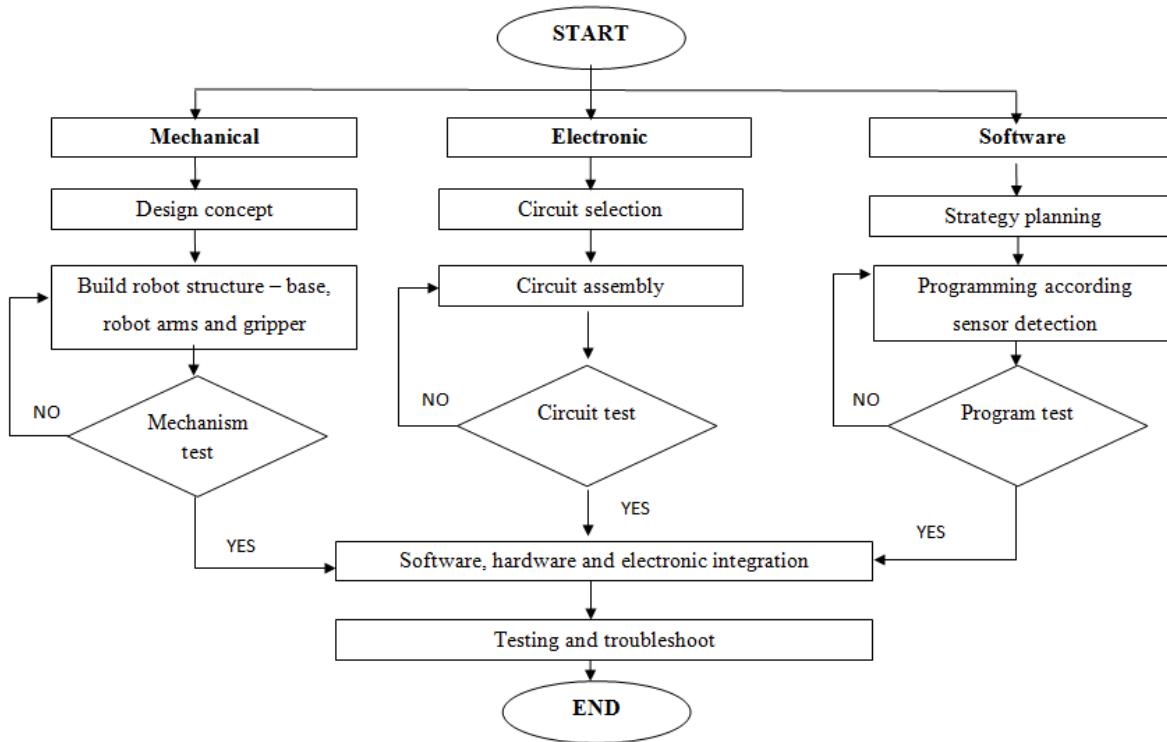
Figure 4. Flowchart for the development of gripper robot

a. Part I: Mechanical Structure

The structure of the robot is constructed using aluminums which is lightweight, no corrosion and strong. There are two main parts for this robot; the main base which holding main pillar which holding robot arm; and robot arm which holding the adjustable gripper. The dimension of main base is 38 cm width and 36 lengths. The height include main pillar is 70 cm but there are stopper where 13 cm from ground that being made for safety if robot arm suddenly drop and to protect DC motor, circuit and battery which being place below it.

Besides that, there was a stand that being used to place the object that needs to be picked and placed. The dimension of the stand is 32 cm width, 32 cm length and 18 cm height. The stand was build slightly higher than the stopper to prevent the robot arm to fall down. The length for robot arm is 75 cm which support of gripper. Figure 5 shows the overall views of robot for pick and place operation.
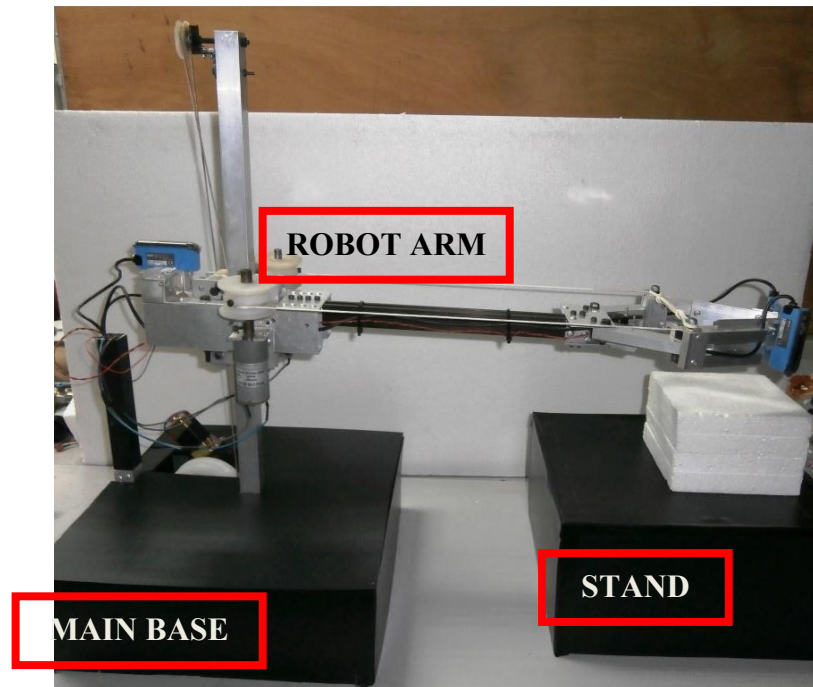
Figure 5. Mechanical structure for gripper robot

b. Part II: Electronic System

The electronic part of this design robot involve with sensor circuit, onboard microcontroller development and motor and driver to power up the system. The electronic system for pick and place operation is shown in Figure 6. The input of this operation is photoelectric sensor also known as color sensor and the main controller is microcontroller PIC 18F4550.

Basically, the microcontroller will receive feedback from the photoelectric sensor and give signal in term of voltage to motor driver before the motor driver converts signal in term of voltage to pulse width modular (PWM) to DC motor. Each part plays important task as photoelectric sensor will determine the size of the object that needs to be picked by the adjustable gripper. Microcontroller will control the robot action during pick and place operation based on the feedback that being received by the photoelectric sensor. To control the movement of adjustable gripper and robot arms, DC motor required the signal from the motor driver that convert voltage signal that being received from the microcontroller to PWM that control the speed of the DC motor.
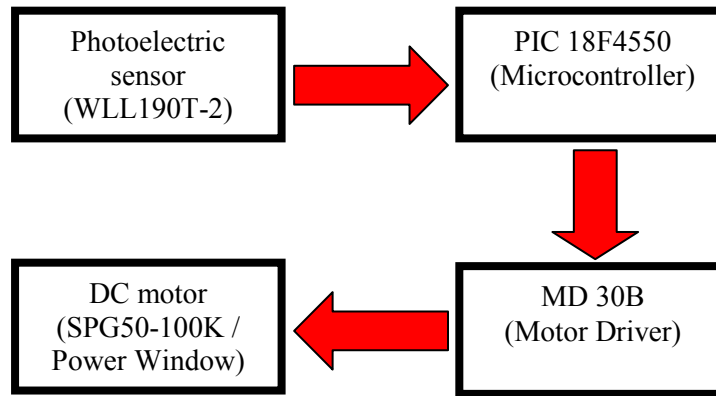
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┌─────────────────┐        ┌─────────────────┐
│  Photoelectric  │        │  PIC 18F4550    │
│     sensor      │ ====>  │ (Microcontroller)│
│   (WLL190T-2)   │        │                 │
└─────────────────┘        └─────────────────┘
                                    ‖
                                    V
┌─────────────────┐        ┌─────────────────┐
│    DC motor     │        │    MD 30B       │
│ (SPG50-100K /   │ <====  │ (Motor Driver)  │
│  Power Window)  │        │                 │
└─────────────────┘        └─────────────────┘
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Figure 6.The block diagram of the electronic system for the gripper robot

b.i Photoelectric sensor circuit design

Sensor is a transducer that converts physical parameter such as motion, humidity, light and sound into electric parameter such as voltage. A photoelectric sensor is a device used to detect the distance, absence or presence of an object by using a light transmitter which often infrared and photoelectric receiver.

Sensor is essential as it is more consistent and eliminates damaging an object as it only detects the present of object and not in contact with the object. This can produces more accurate and protect the quality of an object during pick and place operation.

For this robot where adjustable gripper automatically open and close according to the size of an object, photoelectric sensor was used as an input where it detects the presence of object when it is lifted. This allows robot to indicate the size of the object that need to be pick and place. Photoelectric sensor was chose as it has the longest ranges, fast switching frequency, precise, stable switching point, user friendly and have several operation mode. Figure 7 shows the design of photoelectric sensor circuit to perform the pick and place operation.

As shown in the figure, input for this pick and place operation is a photoelectric switch or color sensor and push button that being used to start the pick and place operation. For this robot, three photoelectric sensors being used where one is use for lifting purpose where it gives certain signals when assured height of main structure being achieved. Each gripper has its own photoelectric switch where it being used for opens and closes the adjustable gripper. Basically, photoelectric switch at adjustable gripper act like indicator for sizing object that need to be lift.
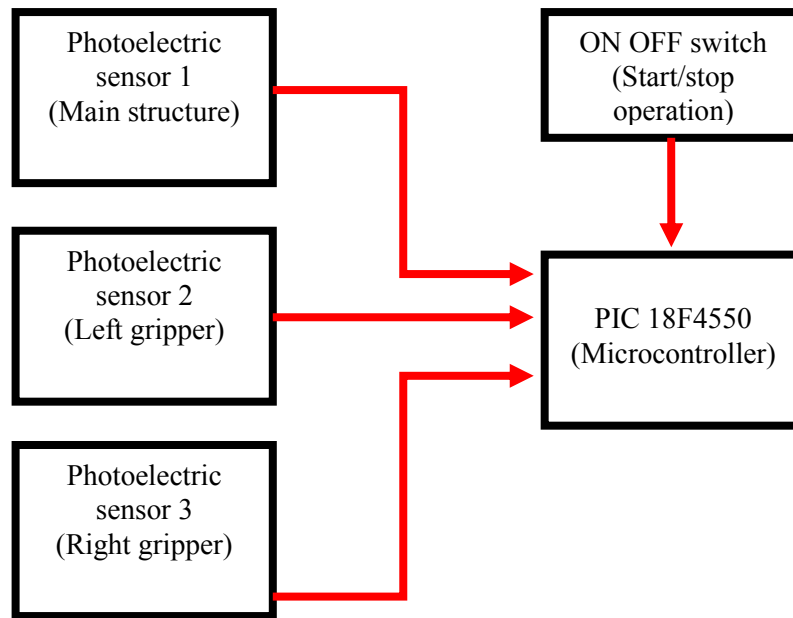
Figure 7. The block diagram of photoelectric sensor circuit

As been mentioned above, three photoelectric sensors being used which two are used for open and close gripper meanwhile another one being used for lifting upward and downward. Figure 8 shows the locations for all three sensors. Basically, each sensor has its own function as sensor 1 is to control open or close for right gripper, sensor 2 is to control for left gripper meanwhile sensor 3 is to indicate the position of the robot arm at the main pillar. All three sensors will react as input for robot during pick and place operations. Fundamentally, this sensor is the main component that controls adjustable gripper to operate according to the size of the object that needs to be picked.

Sensor 3 which located at the main pillar has three desired position which is high, low and initial position. The high position is stated as position 3, initial position as position 2 and low position as position 1. These states are made to indicate and let the PIC to know which location that robot arms should be during pick and place operation. The height of lower position is 18 cm above stopper (31 cm from ground), initial position is 36 cm above stopper (54 cm from ground) and top position is 48 cm above stopper (61 cm from ground). Figure 9 shows the desired position of top, initial and lower position at main pillar of robot.
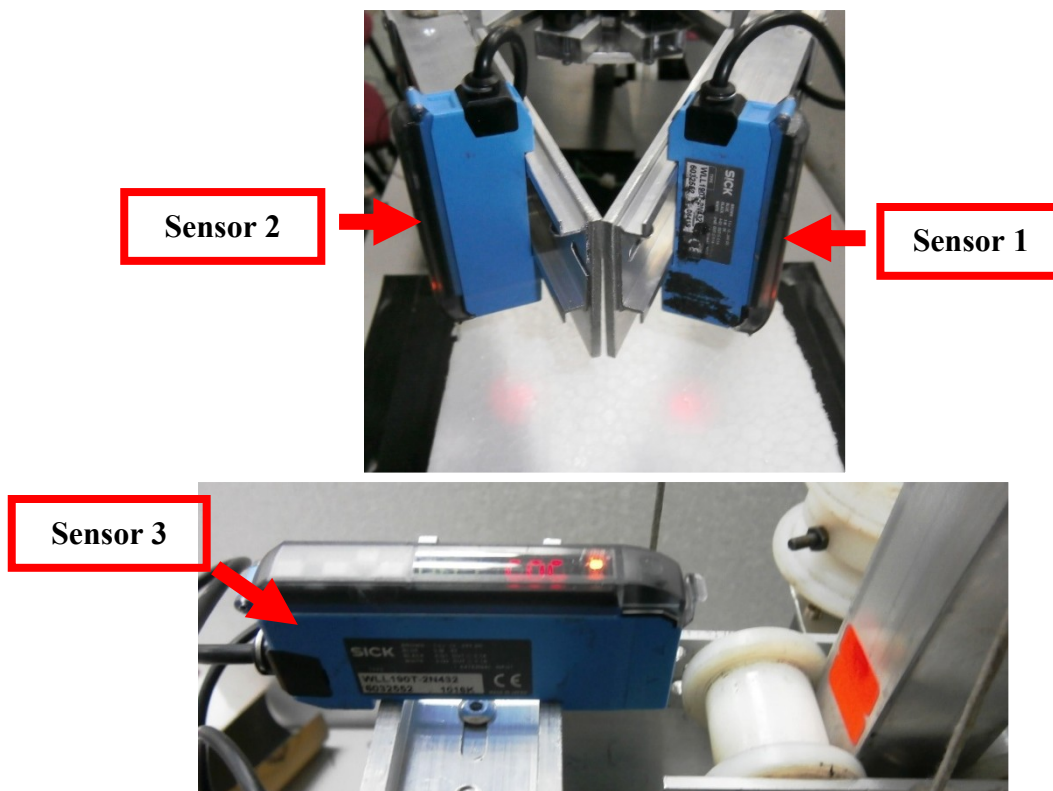
Figure 8. Photoelectric sensor 1 and 2 being place at left and right gripper (top) and sensor 3 at main pillar (below)
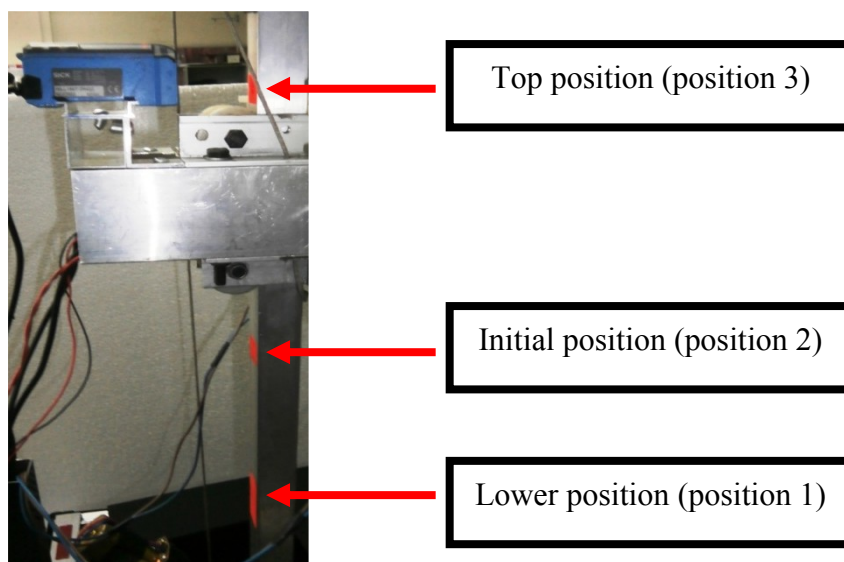

Figure 9. The desired position of top, initial and lower position of robot arm

b.ii Development of onboard microcontroller

There are many types of microcontroller widely used as a brain for a robust gripper robot. The microcontroller will process all data from sensors, apply algorithms to the data and generate commands for the actuator and motors. Basically, microcontroller become main component for autonomous robot as it control for robot movement or robot action according feedback from the sensor or according program that being install inside it.

PIC18F4450 is a mid-range processor with built in memory and have 33 pin within 5 port for input output process. Beside than that, it is more suitable and required small space and very lightweight. In order to make it fully function, crystal oscillator in to be connect to the OSC1 and OSC2 pin for clock purpose, and two VDD pin in port A need to supply with 5VDC. As make sure to have emergency button, the master reset button being create as 5VDC being supply to pin 1 at port A for low reset button. After getting the input from the photoelectric sensor, PIC18F4550 microcontroller will process the signal from the input. Then, microcontroller will transfer the signal to driver motor MD 30B to move the motor according the input. Three motors being used in this autonomous robot, therefore three driver motors are required to operate it. Figure 10 below shows the connection from the microcontroller to the driver motor that will control each motor.
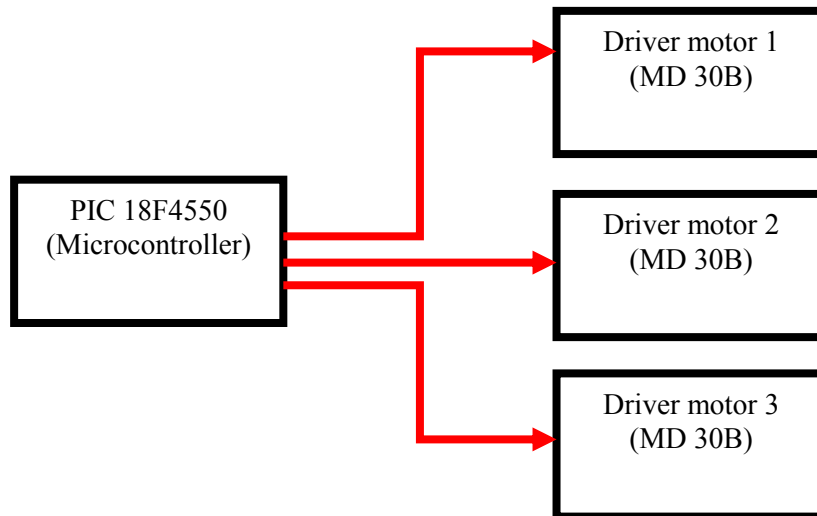

Figure10. Connection between microcontroller and motor drive

Driver motor being used to control DC motor as it became interface between PIC microcontrollers to DC motor. It converts signal from the PIC and convert it as PWM that readable for the DC motor. The drivers were selected according to the type and value of the current that flow to the DC motor. In each driver motor, it contains H-bridge which may contain with variety of power electronics such as BJT, MOSFET or even H-bridge embedded chip.

MD30B is a driver motor for bush motor that capable of driving up to 30 Ampere peak motor current. It offers low cost and easy to use and also user friendly and reliable. Basically, it is a full bridge motor deriver intended for wide range automotive application. It has several features which have bi-directional control for one motor, can support PWM speed control up to 10 KHz, heat sink with fan for fast thermal release, linear current limiter and using 5 volt logic level input which suitable with PIC18F4550 output. Figure 11 show the actual picture of MD30B driver motor for DC brush motor. After MD30B driver motors get the signal from PIC18F4550 microcontroller, it will change the signal into pulse width modulation (PWM) that control the speed and direction of DC motor that being used. For this autonomous robot, three DC brush motor being used as one of it is for lifting arm robot upward and downward purpose. Meanwhile other two motor is for open and close the gripper. Figure 12 show the connection between driver motor to each specific DC brush motor.

Figure 11. MD 30B driver motor for DC brush motor

For this project, DC Brush motor being used to control movement of robot arm and gripper. DC brush motor being select because it is cheap and have simple connection for operation. To control DC brush motor, driver motor use pulse width modulation (PWM). PWM control the motor by switching the power supplied to motor for turn on or off in rapidly and by adjusting the duty

cycle of the signal or modulating the width of the pulse for motor run, the average power can be varied and speed of motor also can be control. Rotation speed of mechanical component being measure of full rotations completed in one minute for motor called revolutions per minutes or RPM.

Selecting a suitable DC motor is also important as each DC motor has different rate of speed, torque, input voltage, power and dimension. DC motor requires either high torque or high speed where high torque equal to slow speed but strong when stopping or holding meanwhile high speed is faster but not strong when stopping. Normally, DC motor that high torque being used for heavy task such lifting, starting movement for heavy robot and holding item where DC motor with high speed being use for task that need quick and easy task such as pick small and light weight item.
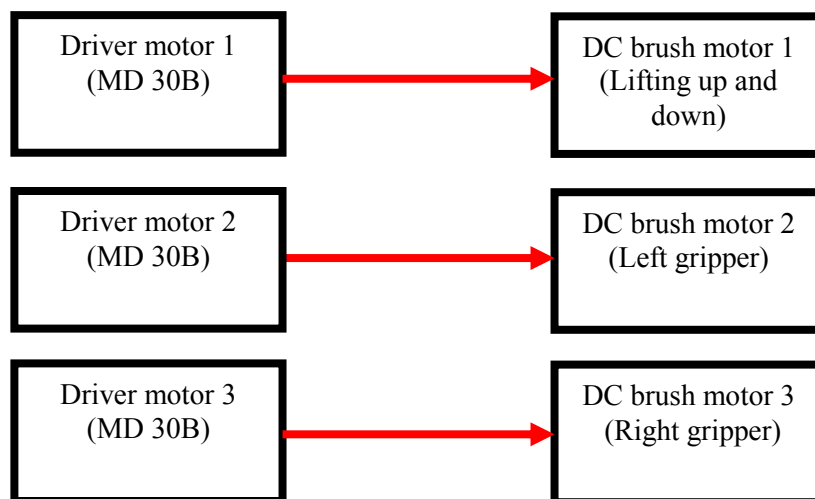
Figure 12. The connection between motor drive and DC brush motor

c. Part III: Software Development

For performing pick and place operation smoothly, planning must be made before creating suitable program. First, all possible route for movement of robot and major movement probability of robot arm and gripper for lifting, gripping and release must be determined. Then, the program being made using the short subroutine that perform the task quickly and smoothly. Several program subroutine being made as for strategy purpose which each program subroutine will perform different technique or method for pick and place operation. Lastly, all the strategy subroutines are combining in main program which being install in PIC18F4450.

The aim for this project is to make the arm robot to move upward and downward using sensor at left and right gripper. The planning of the behavior is starts by configuring the size of object that need to be picked up using sensor at the gripper. Then, the sensor at the main structure indicates the movement of arm robot in term of height. After that, object will be picked and be held before arm robot being raised upward until certain height as indicated by the sensor at the main structure. Finally, the arm robot will place the object back in it position after being held few seconds and arm robot will be back to its initial position. The flowchart of main program is shown in Figure 13.
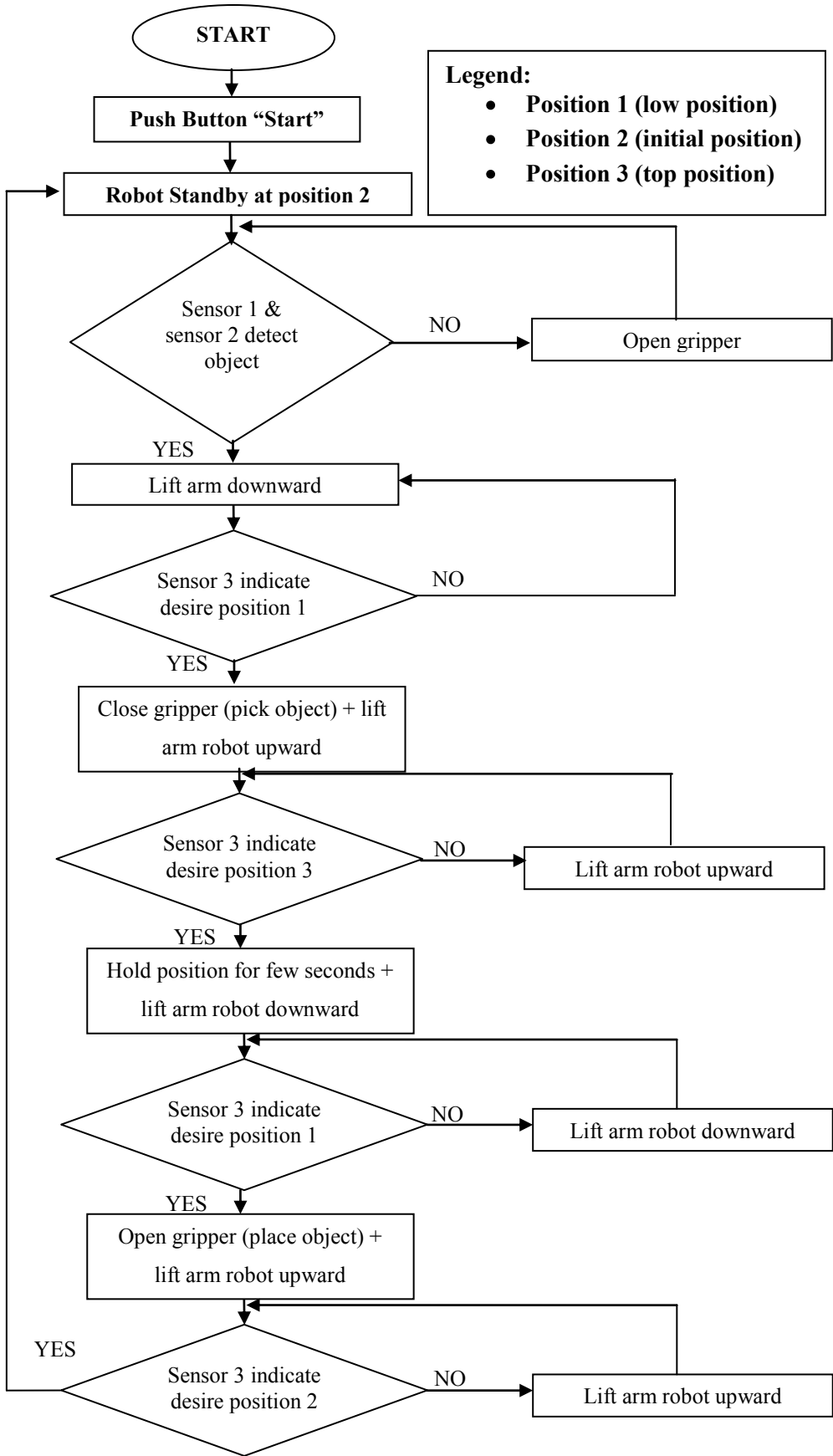
Figure 13. Flowchart of C programming for adjustable pick and place operation

V.   TESTING AND PERFORMANCE ADJUSTABLE GRIPPER ROBOT

For testing the operation of pick and place, several objects has been made as each object has different length and width. This is due to test the capability of adjustable gripper to grip different size of desired object. Besides that, different size of object will give different result during pick and place due of different character and weight. Table 1 show the dimension and weight of each object for pick and place operation. Due of maximum opening of adjustable gripper is only 28 cm wide, the object being made slightly small of it to make sure gripper be able to pick it.

Table 1: Dimension and weight of each object for pick and place operation

Type of Object	Height (cm)	Length (cm)	Width (cm)	Weight (gram)
Object 1	10	15	10	25
Object 2	10	15	15	30
Object 3	10	15	18	35
Object 4	10	15	20	40

Basically, objects that been used in this project are made by polystyrene which are soft, fragile, lightweight and it can represent object that have similar category and form. Besides that, polystyrene being pick as desire object due of it have compact density and can be used frequently without need to change. Furthermore, it has bright color which is visible and easy to see if any damage being happens to it.

Photoelectric sensor will give signal to PIC microcontroller using voltage which if it have not detect object within it range, it will give 5V while if still detect object within it range, it will give 0V. When the gripper is open, it will trigger limit switch which being connect as normal close which when it open, it will give signal to PIC for indicate that gripper are opening from its initial position. Table 2 shows the reaction of the motor and the robot during opening the gripper meanwhile Table 3 show the reaction during closing the gripper.

Table 2: Motor and robot action (open gripper)

Sensor	Voltage	Motor action	Robot action
Sensor 1	0V	Right motor (counter clockwise)	Detect object, open right gripper, open right limit switch
Sensor 2	0V	Left motor (counter clockwise)	Detect object, open left gripper, open left limit switch
Sensor 1	5V	Right motor (Stop)	No detect object, stop right gripper, and hold position.
Sensor 2	5V	Left motor (Stop)	No detect object, stop left gripper, and hold position.

Table 3: Motor and robot action (close gripper)

Sensor	Voltage	Motor action	Robot action
Sensor 1	5V	Right motor (clockwise)	Close right gripper
Sensor 2	5V	Left motor (clockwise)	Close left gripper
Sensor 1	0V	Right motor (Stop)	Close right gripper until reach right limit switch
Sensor 2	0V	Left motor (Stop)	Close left gripper until reach left limit switch

As shown in Figure 14, waveform that being generated during sensor gives signal 0V or 5V to the PIC. During sensor detecting the object, suppose it gives 0V but the plot indicates that voltage that being transferred to the PIC is 352mV. This value is too small and can be ignored due of harmonic signal or other interrupt that may happen because of human error during wiring process.
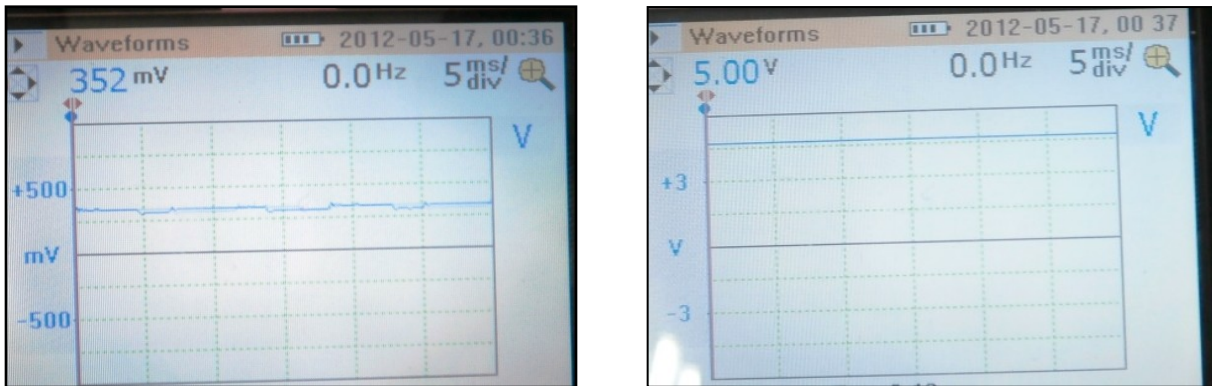
Figure 14. Waveform of sensor during detect (top) and no detect (below)

Due of several sensors being attached to the robot, it gives a lot of feedback to the robot which make it capable to perform the task as been programmed. Sensor 3 that being attached to main pillar react as an indicator where should robot arm must be during certain operation meanwhile sensor 1 and sensor 2 will control the operation of opening and closing the gripper. Table 4 shows the time that have been taken for the robot to complete the operation of pick and place for each object. From the average results, it shows that for bigger object size, longer time is taken for completing the pick and place operation.

Table 4: Time for each object complete the operation of pick and place

Object	Test 1 (sec)	Test 2 (sec)	Test 3 (sec)	Average (sec)
Object 1	18.21	18.45	18.38	18.35
Object 2	19.52	19.40	19.55	19.49
Object 3	20.28	20.34	20.51	20.38
Object 4	22.45	22.19	22.32	22.32

For this project, switch case subroutine being used as it is more suitable and give better output that if else subroutine. Switch case subroutine allow robot to determined robot action from feedback that being received from sensor. To control adjustable gripper to perform pick and place smoothly, all three sensor will give feedback to PIC18F4550 microcontroller that will determined the robot action. Figure 15 show the block diagram of program for this project.
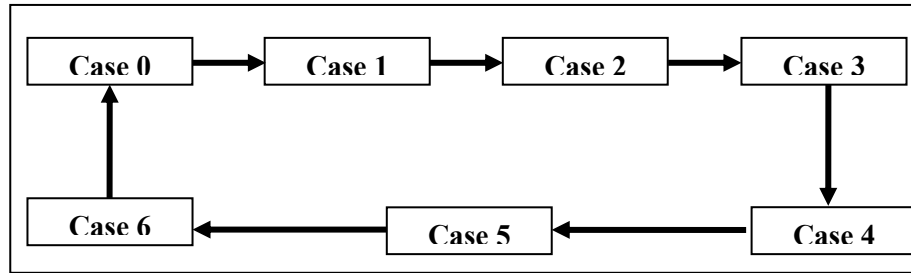
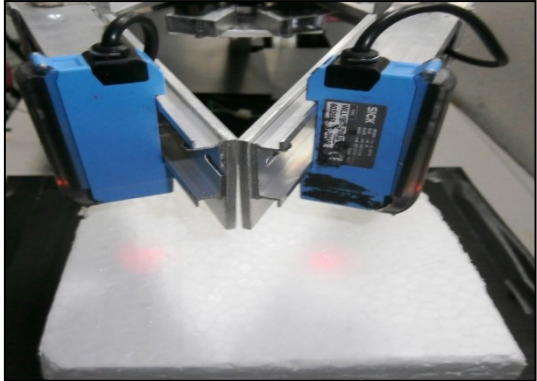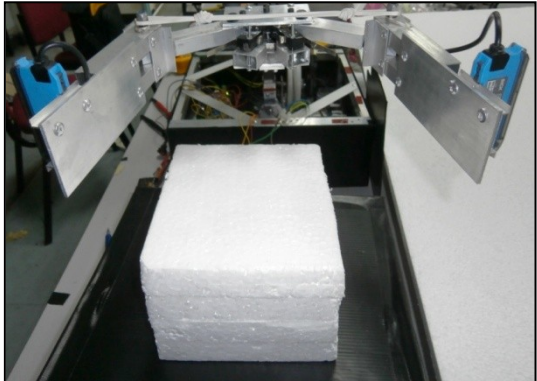Figure 15. Block diagram of program for pick and place operation

Table 5 show the robot action for each case that being program in PIC18F4550 microcontroller. Basically, all three photoelectric sensors give feedback that allow robot arm to lift upward or downward to position that it supposed to be during pick and place operation. Beside than that, adjustable gripper can perform it task from the feedback signal that come from sensor 1 and sensor 2 according each case that being successfully program in PIC18F4550 microcontroller.
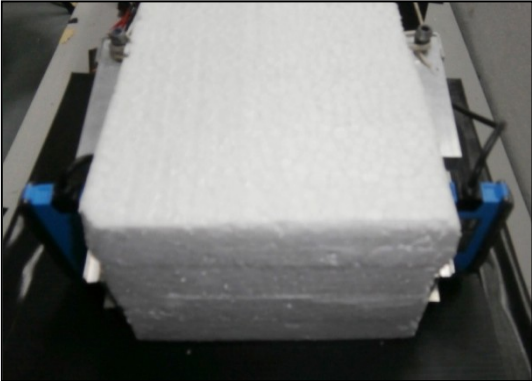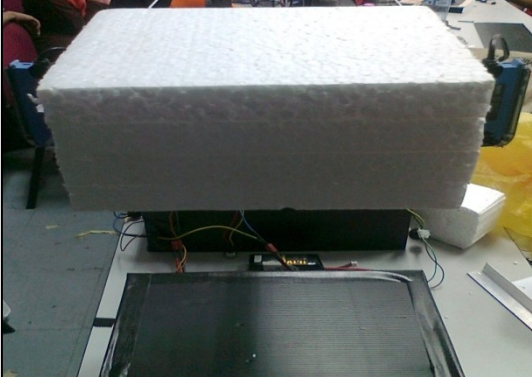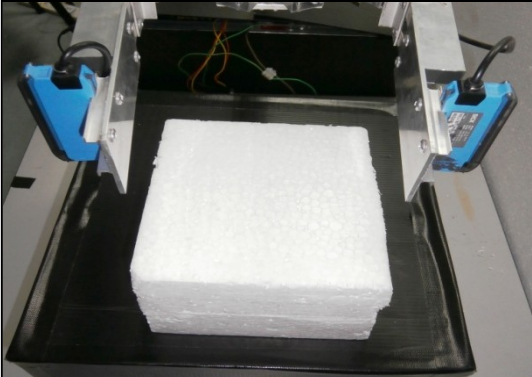
Table 5. Robot action for each case that being program in microcontroller

| Case	Robot Actions
0	Both left and right gripper is close; sensor 1 and sensor 2 ready for pick and place operation; sensor 3 at initial position.
1	Both left and right gripper is open; sensor 1 and sensor 2 will detect size of object; sensor 3 at initial position ready to bring gripper downward to lower position.
2	Both left and right gripper is open; sensor 1 and sensor 2 will give signal to close gripper; sensor 3 at lower position.
3	Both left and right gripper is close; sensor 1 and sensor 2 maintain position for make gripper close; sensor 3 at lower position then lift robot arm upward to top position.
4	Both left and right gripper is close; sensor 1 and sensor 2 maintain position; sensor 3 at top position will bring robot arm lift downward to lower position. When reach lower position, both gripper will open.
5	Both left and right gripper is open; sensor 1 and sensor 2 ready to close gripper; sensor 3 at lower position bring robot arm lift upward to initial position.
6	Both left and right gripper is close; sensor 1 and sensor 2 ready for pick and place operation; sensor 3 at initial position where it will bring the program back to Case 1 situation.

Table 6 shows the robot behavior for pick and place operation that being installed inside the PIC18F4550 microcontroller. Basically, it show the real picture for each case that being program in microcontroller. The relationship of input that comes from photoelectric sensor with PIC18F4550 microcontroller can be seen in Table 6 where each action has its own behavior. It shows the capability of the adjustable gripper in performing pick and place where it use sensor to determine the size of the object before proceed to another action.

Table 6: Robot behavior for pick and place operation using PIC18F4550

Robot Action	Description
Case 0 = initial position (sensor 3 = position 2)	
Case 1 = open gripper (sensor 3 = position 2)	

Case 2 = lifting downward + close gripper (sensor 3 = position 1)	
Case 3 = lifting upward to top position + close gripper (sensor 3 = position 3)	
Case 4 = lifting downward + open gripper (sensor 3 = position 1)	
Case 5 = lifting upward to initial position + open gripper (sensor 3 = position 2)	

Case 6 = close gripper (sensor 3 = position 2)	
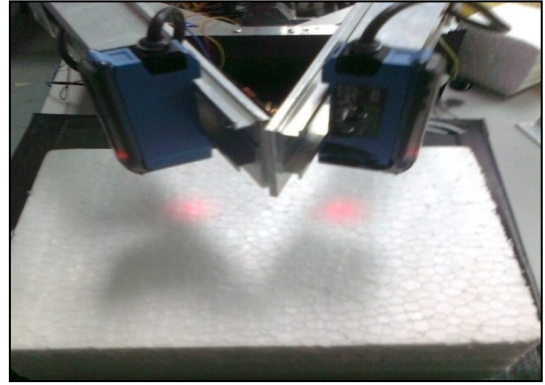
From the results, it shows that the operation of the pick and place robot depends from sensor input. Photoelectric sensor is suitable sensor for this project since the object that needs to pick is bright and it is easy to install. Selection of DC brush motor gives good result as it is easy to make connection and it have enough torque to perform pick and place smoothly. The overall movement of the robot using adjustable gripper can be seen in Table 6 and each action being controlled by microcontroller with signal from the photoelectric sensor.

V. CONCLUSIONS

Overall, an autonomous robot with adjustable gripper that perform pick and place operation has been successfully built. The robot has been able to pick the object and place it effectively. The robot is also able to perform lifting upward and downward smoothly. By using PIC microcontroller, the robot have performed it task perfectly according program that being made. Beside than that, the adjustable gripper with sensors is able to open its grip according to the size of the object. Due to this advantage, the robot can pick object that within the gripper limitation.

REFERENCES

[1]   Y.C. Lee, S.J Lim, S.W. Hwang and C.S. Han, "Development of the robot gripper for a home service robot", Proceeding of ICROS-SICE International Joint Conference, August 18-21, 2009, Fukuoka, Japan, pp. 1551-1556.

[2] T. Gecks and D. Henrich, "Human-robot cooperation: safe pick and place operation", Proceeding of IEEE International Workshop on Robot and Human Interactive Communication, August 13-15, 2005, Nashville, USA, pp. 549-554.

[3] Z.B. Li, Y.J Lou, Z.X. Li, G.L. Yang and J. Gao, "T2:a novel two degree of freedom translational parallel robot for pick and place operation", Proceeding of 2010 8th IEEE International Conference on Control and Automation, June 9-11, 2010,Xiamen, China, pp. 725-730.

[4] Aliasgar, O. K Sastry, S.B Hampapur, S.S Kamat, V.K Vyshak, "Automated pick and place system", Proceeding of 2010 International Conference on Mechanical and Electrical Technology (ICMET), September 10-12, 2010, Singapore, pp. 682-686.

[5] H. Ali, H.H Low, and C.S Tei, "Design and development of smart gripper with vision sensor for industrial application", Proceeding of 3rd International Conference on Computational Intelligence, Modeling & Simulation, September 20-22, 2011, Langkawi, Malaysia, pp.175-180.

[6] M. Riedel, M. Husing, M. Nefzi and B. Corvers, "An adjustable gripper as a reconfigurable robot with a parallel structure", Proceeding of 2nd International Workshop on Fundamental Issue and Future Research Directions for Parallel Mechanisms and Manipulator, September 21-22, 2008, Montpellier, France.

[7] A.R. Mannaa, M. Akyurt and A.K. El-Kalay, "Six-link gripper for cylindrical objects", Journal of Islamic Academy of Sciences, Vol. 3, No. 1, pp. 6−10, 1990.

[8] G. Lundström, "Industrial robot grippers", Industrial Robot: An International Journal, Vol. 1 No. 2, pp.72 − 82, 1974.

[9] P.S.Ramaiah, M.Venkateswara Rao and G.V.Satyanarayana, "A microcontroller based four fingered robotic hand", International Journal of Artificial Intelligence & Applications (IJAIA), Vol.2, No.2, pp. 90-102, April 2011.

[10] Konukseven E. İ., Kaftanoğlu B. and Balkan T., "Multisensor controlled robotic tracking and automatic pick and place", Proceeding of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'97), September 8-12, 1997,Grenoble, France, pp. 1356-1361.

[11] M.Mehdian and H.Rahnejat, "A sensor gripper using tactile sensors for object recognition, orientation control, and stable manipulation", IEEE Transactions on Systems, Man, and Cybernetics, Vol. 9, pp 1250 – 1261, 1989.

[12] N.Hoshikawa, M. Ohka and H. Yussof," Bottom-up approach for behavior acquisition of agents equipped with multi-sensors", International Journal on Smart Sensing and Intelligent Systems ,Vol. 4, No. 4, pp. 583-606,December 2011.

[13] H. Yussof, J. Wada and M. Ohka, "Analysis of tactile slippage control algorithm for robotic hand performing grasp-move-twist motions", International Journal on Smart Sensing and Intelligent Systems, Vol. 3, No. 3, pp. 359-375,September 2010.

[14] K.Qian, X.Ma, X. Z. Dai and F. Fang," Spatial-temporal collaborative sequential Monte Carlo for mobile robot localization in distributed intelligent environments", International Journal on Smart Sensing and Intelligent Systems, Vol. 5, No. 2, pp. 295- 314,June 2012.

[15] C.M. Seguna and M.A. Saliba, "The mechanical and control system design of a dexterous robotic gripper", Proceeding of International IEEE Conference on Electronics, Circuits, and Systems, September 2-5, 2001, Malta, pp. 1195 – 1201.

[16] M. A. Saliba and M. Axiak, "Design of a compact, dexterous robot hand with remotely located actuators and sensors", Proceeding of the 15th Mediterranean Conference on Control and Automation, July 27-29, 2007, Athens, Greece.

[17] S. Costo, G. Altamura, L.E. Bruzzone, R.M. Molfino and M.Zoppi, "Design of a re-configurable gripper for the fast robotic picking and handling of limb sheets", Proceeding of the 33rd International Symposium on Robotics, October 7-11, 2002, Stockholm, Sweden.