Development of Controlling Method of a Five-Degree of Freedom Robotic Arm

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تطوير طريقة التحكم بذراع روبوتية ذو خمسة درجات حرية

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الخلاصة

تعتمد الحياة المعاصرة بصورة متزايدة على استخدام الروبوتات لتسهيل انجاز المهمات اليومية وكذلك في زيادة إنتاجية التطبيقات الصناعية وفي انجاز العمليات الخطرة والمتكررة. ولهذا، تلعب طريقة السيطرة على الاذرع الروبوتية دورا مهما جدا في توجيه محركات الروبوت وبالتالي تلعب دورا مهما أيضا في تنفيذ وظائف ومهام الروبوت. تصف هذه الورقة البحثية عملية تطوير طريقة التحكم الخاصة بالذراع الروبوتية من طراز OWI-535 وهو ذراع روبوتية ذو خمس درجات حرية يستخدم في رفع ووضع الاجسام الخفيفة بصورة متكررة. عملية تطوير طريقة التحكم الخاصة بالذراع الروبوتية تم إنجازها بتصميم وتنفيذ دائرة متحكم رقمية السلكية مصممة ومنفذه باستخدام المتحكم الدقيق من نوع ATmega 328P-PU وتقنية البلوتوث وهاتف أندرويد ذكي وذلك لزيادة مدى التحكم بالذراع الروبوتية وللاستغناء أيضا عن الطريقة القديمة في التحكم والمتمثلة باستخدام المتحكم اليدوي الموصل سلكيا بالذراع بصورة نهائية. إضافة إلى ذلك، قد تم تطوير طريقة السيطرة على عملية تزويد قطبية الفولتية للمحركات النظامية والمحتواة ضمن الذراع الروبوتية الى الأسلوب الالي وذلك باستخدام المتحكم AA51880 بدلا عن استخدام طريقة المفاتيح الكهربائية التي تعمل بالحركة الميكانيكية. عملية تطوير الذراع الروبوتية تم اخضاعها لعدة فحوصات مختبرية ولعمليات التحقق من أداء الذراع بعد التطوير، حيث أظهرت النتائج المختبرية ان عملية تطوير طريقة التحكم اللاسلكية الخاصة بالذراع الروبوتية من طراز OWI-535 قد تم تحقيقها بنجاح ومن الممكن استخدامها بدلا عن طريقة التحكم اليدوية اللاسلكية السابقة، حيث اصبحت الذراع الروبوتية تنفذ لاسلكيا مهام الرفع والوضع كما يرغب مشغل الذراع الروبوتية.

الكلمات المفتاحية

الروبوتات، ذراع روبوتية OWI-535، ATmega 328P-PU، المتحكم AA51880، تقنية البلوتوث، هاتف أندرويد ذكي.

Abstract

Contemporary life depends increasingly on the use of robots to facilitate the achievement of daily activities, increasing the productivity of the industrial applications and accomplishing the hazardous and repeatable processes. Therefore, the controlling method of the robotic arms plays an important role in coordinating the robot actuators and hence in executing the robot functions and tasks. This paper describes the development process of the controlling method of OWI-535 robotic arm which is five-degree of freedom robotic arm used for lifting and placing of light objects repetitively. The robotic arm controlling method development is achieved by replacing the manual wire controller by a digital wireless controller that is designed and implemented by using ATmega 328P-PU microcontroller, Bluetooth technology, and an android smart phone. Furthermore, the control technique of the voltage polarity supplement for regular motors contained in the robotic arm is developed to an automated technique by utilizing AA51880 controller instead of the used mechanical manner. The development of the robotic arm was under experimental tests and the validation of the robotic arm performance, the experimental results indicate that the development process of wireless controlling method of OWI-535 robotic arm is realized successfully instead of using manual wire controller and the robotic arm executes wirelessly the lifting and placing tasks as desired by the robotic arm operator.

Keywords
Robotics, OWI-535 robotic arm, ATmega 328P-PU, AA51880 controller, Bluetooth technology, Android smart phone.

1. Introduction

Robotics is a branch of engineering sciences that relates to the study, design, operation, and use of robotic systems [1]. It is an interdisciplinary field of researches that deals with electrical and electronic engineering, mechanical engineering, and computer sciences. With the development of the manufacturing industrial activities, a robotic arm systems are invented to assist various industries to implement a given task instead of using human power. For instance, they are generally used to perform unsafe, hazardous, highly repetitive, and unpleasant tasks [2-6]. Furthermore, they have many different purposes and functions such as material handling, resistance welding, arc welding, machine tool load functions, spraying, painting, etc. Therefore, the robotic systems can be classified in two mainly distinct classes of systems: The service robotic systems and the industrial robotic systems. Service robots are run and managed semi or fully autonomously to carry out services useful to the welfare of humans being and instruments except for manufacturing processes [7]. Moreover, industrial robot is defined officially by the International Organization for Standardization (ISO) as a multipurpose manipulator which can be reprogrammable in three or more axes, controlled automatically, and it can be either movable or fixed in place for the use in industrial automation applications [8].

Many research works are carried out to design robotic systems for reducing the cost factor and manufacturing time of a product [9], medical care purposes for disabled people treatment [10-12], for industrial applications [13], for space inspection and satellites deployment processes, and for enhancing the features of the robotic arm [14]. A robotic arm is widely utilized in the high-precision assembling operations or packing line by lifting the small things and materials with repetitive motion that human couldn't afford to do for a long period of time [15]. The light object lifting task can be achieved by the robotic arm systems efficiently and in a time-saving manner because it is not limited by exhaustion, fatigue and health risks which the human worker might experience. Therefore, this paper describes the steps of developing the control technique of OWI-535 robotic arm which is utilized for lifting the small things and materials by using a smart phone, Bluetooth technology, ATmega 328P-PU microcontroller that is contained in Arduino Uno electronic board and AA51880 controllers as shown in Figure (1).

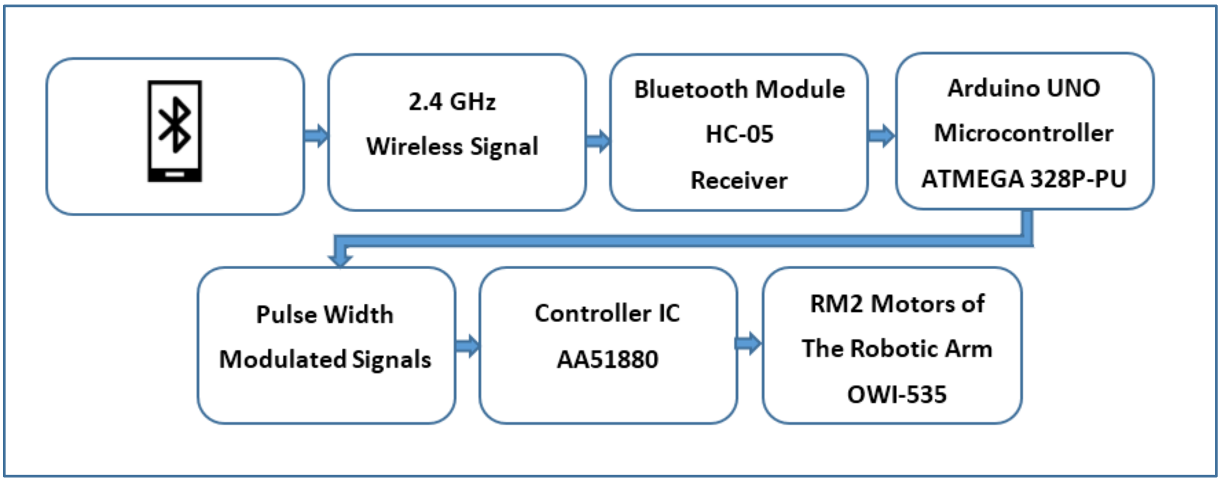


Figure (1): The Block Diagram of the Developed Controlling System of OWI 535 Robotic Arm.

2. The Elements of the Proposed Controlling System

The design of the proposed system aims to replace and to develop the controlling method of the OWI-535 robotic arm, for more clarity, to be wirelessly controlled using Bluetooth technology and ATmega 328P-PU microcontroller instead of the manually control method that is achieved by a wire-connected controller panel. Moreover, the implementation of the wireless controlling system depends mainly on the technical features and the operational characteristics of ATmega 328P-PU microcontroller, Bluetooth module, AA51880 controller and the OWI-535 robotic arm. The most important technical feature of this robotic arm is the type of five DC motors (Regular Motor - RM2) that are performed to actuate the joints of the arm clockwise and anticlockwise. The selection of the rotation direction of this type of motors is achieved by changing the states of mechanical switches manually to provide the (RM2) DC motors with appropriate polarities of the supply voltage. Therefore, this type of DC motors cannot be controlled directly by the digital output instructions of ATmega 328P-PU microcontroller, that are produced as PWM waveforms with different widths of pulses to specify the direction of motors rotation. Therefore, this previously mentioned technical feature introduces a necessity to use an electronic circuit of AA51880 controller to convert the PWM digital signals to suitable voltage polarities to each motor of the five DC motors of OWI-535 robotic arm. The designed electronic circuit of the developed robotic arm wireless controller is plotted by using Fritzing program and it is illustrated in Figure (2).

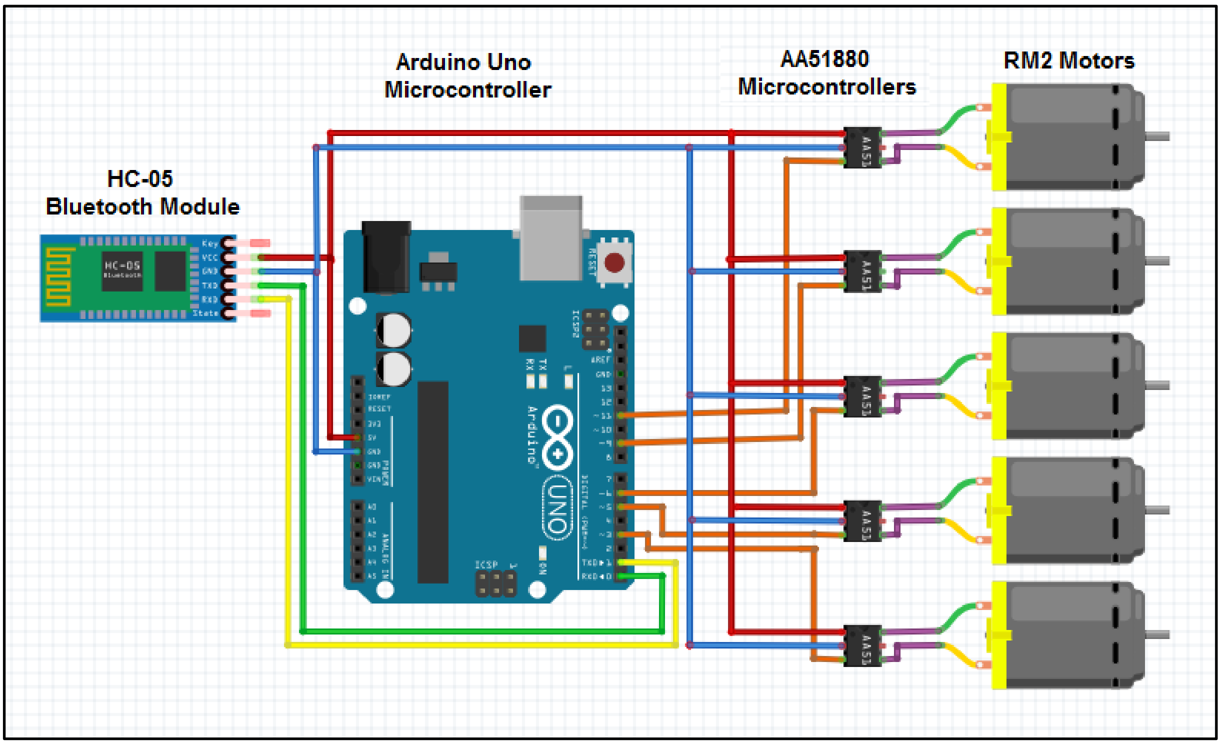


Figure (2): The Electronic Circuit of the Developed Controlling System of OWI-535 Robotic Arm.

The elements of the proposed controlling system are as follows: -

2.1 HC-05 Bluetooth Module

The robot user can communicate with the robotic arm through HC-05 class 2 Bluetooth module that installed with the developed controlling circuit of the robotic arm. This type of module is an easy to use, Serial Port Protocol (SPP) Bluetooth module that is designed for clear wireless serial connection setup. The HC-05 serial port Bluetooth module is a complete 2.4 GHz radio transceiver and baseband with fully qualified 3 Mbps Enhanced Data Rate (EDR) Bluetooth Modulation. It is based on the Cambridge Silicon Radio (CSR) Blue core External single chip V4.0 Bluetooth system implemented by complementary metal oxide semiconductor (CMOS) technology with Adaptive Frequency Hopping (AFH) feature.

2.2 Arduino Microcontroller

The electronic circuit that is utilized to control the robot wirelessly is constructed basically on the performing of HC-06 Bluetooth module and Arduino microcontroller. The Arduino Uno microcontroller board is based on the use of ATmega 328P-PU microcontroller IC. It contains 14 digital Input/ Output pins (6 pins of them are dedicated to deal with PWM signals), a 16 MHz Clock speed, 6 analog inputs, and operating voltage of the Arduino micro controller is 5V. Furthermore, it contains a 32 KB of flash memory that is very adequate to store the data of the controller program.

2.3 AA51880 Controller

The AA51880 controller is a Bipolar Junction Transistor (BJT) integrated circuit utilized for servo motor control applications. The controller which is shown in Figure (3) contains a built-in voltage regulator that provides the AA51880 IC with extremely stable output voltage. Furthermore, the controller also incorporates a linear one-shot function and pulse-width demodulator to improve the positional accuracy. One of the most important features of this controller is the very small outline package of the controller (5.8×4.8) mm as compared to L293D IC size (20.0×7.1). This feature reduces the required area of implementing the robot controller circuit and it provides the ability to insert the AA51880 circuit within the structure of the OWI-535 robotic arm neatly.

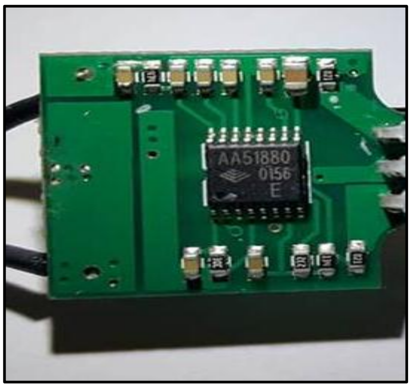


Figure (3): The AA51880 Controller.

2.4 RM2 Regular Motor

It is an ordinary brushed DC motor that is used to actuate the joints of the OWI-535 robotic arm. It is operated by supplying its terminals with DC voltage with a range of 3 – 9 V.

3. Tests of the Developed Controlling Circuit

The developed controlling circuit of the robotic arm is implemented by using an Android smart phone, HC-05 Bluetooth module, ATmega328P-PU microcontroller, and AA51880 controller as mentioned previously. The Android smart phone is uploaded with Blue Core application which is an open source application used to generate and to send the control instructions to ATmega 328P-PU microcontroller. The control instructions are sent in the form of ASCII code wirelessly through the connection that is established between the built-in Bluetooth module of the smart phones and the HC-05 module. The ATmega 328P-PU microcontroller is programmed by utilizing the open source application Arduino IDE 1.8.5 that is used to write the codes of Arduino C programing program and then to upload the written program to Arduino microcontroller board. The program of ATmega 328P-PU microcontroller is intended to convert the received control instructions to a suitable width of PWM signals,

these PWM signals are output from the digital ports of Arduino microcontroller and then are measured by AA51880 controller to produce the required voltage polarities, the produced voltage polarities are used to rotate a specified RM2 motor or motors of the robotic arm toward a desired direction. Moreover, after the completion of the connection of the developed controlling circuit that is illustrated in Figure (2), many testes are carried out to examine the performance of HC-05 module, ATmega 328P-PU microcontroller, and the AA51880 controller.

3.1 The Test of HC-05 Bluetooth Module

The test of HC-05 module is achieved by using GWINSTEK GSP-830 spectrum analyzer to determine the frequency of the wireless signal that is radiated by HC-05 module; and also to measure the signal power far from the robotic arm in order to determine the maximum usable range of coverage of the HC-05 Class 2 Bluetooth module. The frequency of the detected wireless signal is 2412.399 MHz with a signal power of -34.1 dBm as shown in Figure (4). The test is done at a maximum usable range of 12 meter far from HC-05 module.

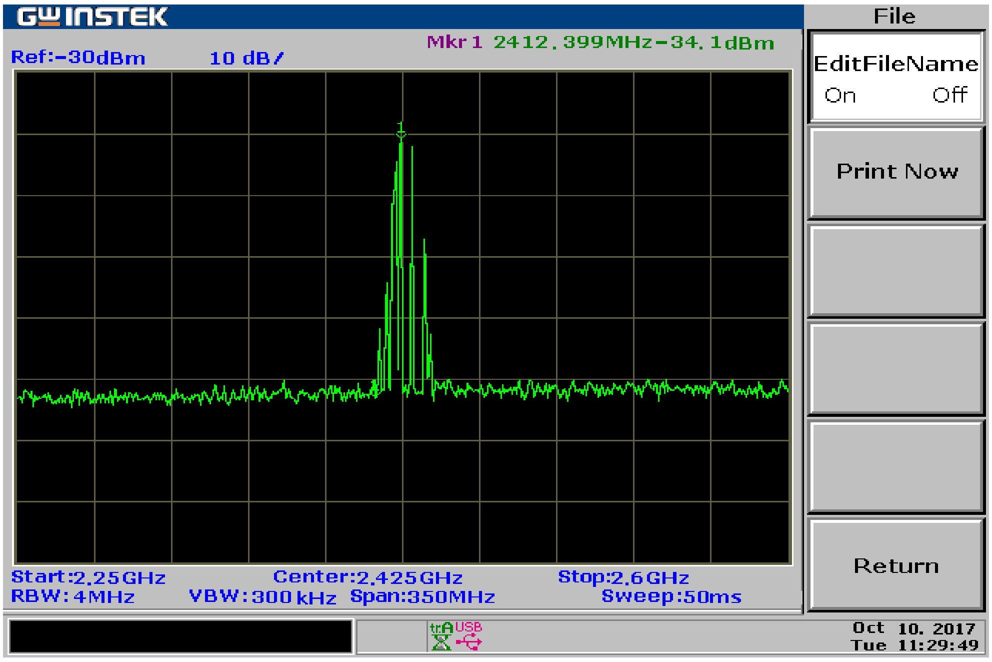
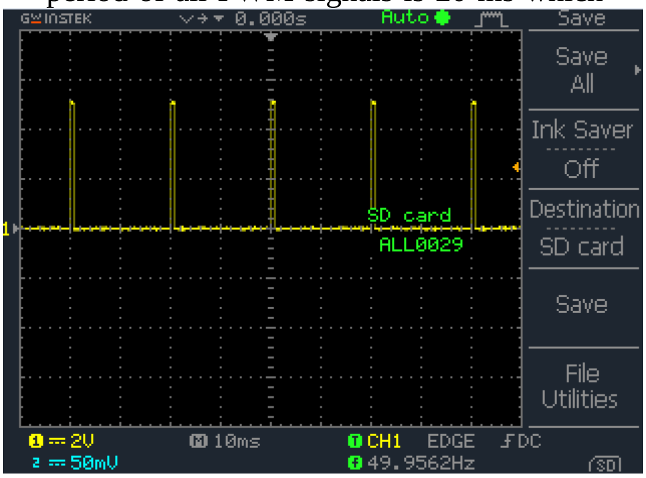
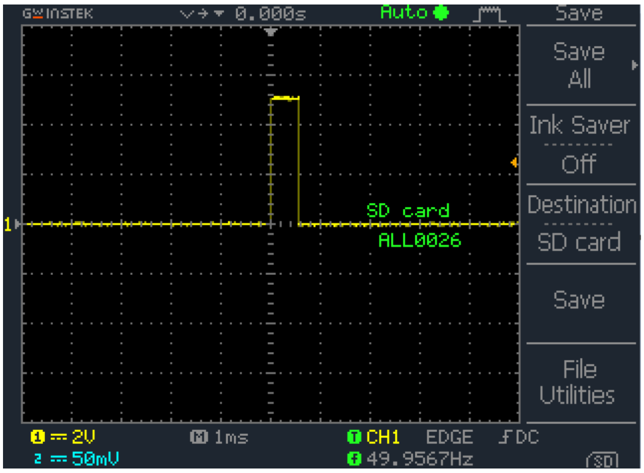


Figure (4): The Test of the Wireless Signal of HC-05 Bluetooth Module.

3.2 The Test of the ATmega 328P-PU Microcontroller Output

The tests of ATmega 328P-PU microcontroller outputs are accomplished to verify the width of the logic 1 and the frequency of PWM waveforms that should be produced by ATmega 328P-PU in according to the received control instructions. The test is done by using GWINSTEK GDS-1062 oscilloscope. The results of the test showed that the total period of all PWM signals is 20 ms which is equal to frequency of 50 Hz as shown in Figures (5-7,A) , the width of logic 1 for left direction of rotation instruction is 0.6 ms as illustrated in Figure (5 - B), the width of logic 1 for no rotation instruction is 1.42 ms as illustrated in Figure (6 - B), and the width of logic 1 for right direction of rotation instruction is 2.4 ms as illustrated in Figure (7-B), then, these signals are fed to the input of AA51880 controllers in order to control the movement of the motors.

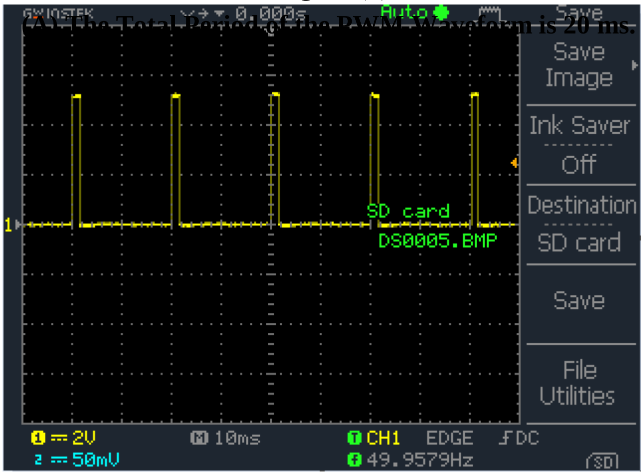


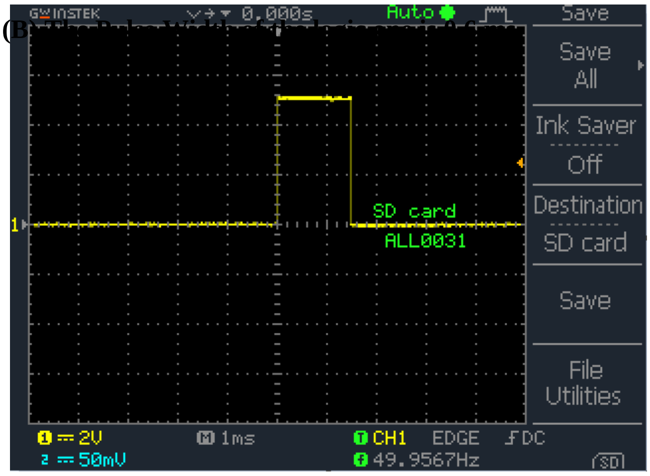


(A) (B)

Figure (5): The PWM Waveform for the Left Rotation Direction

(A) The Total Period of the PWM Waveform is 20 ms. (B)

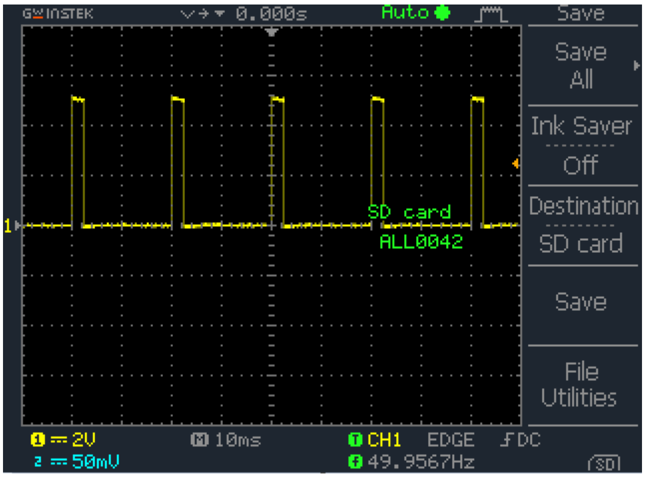


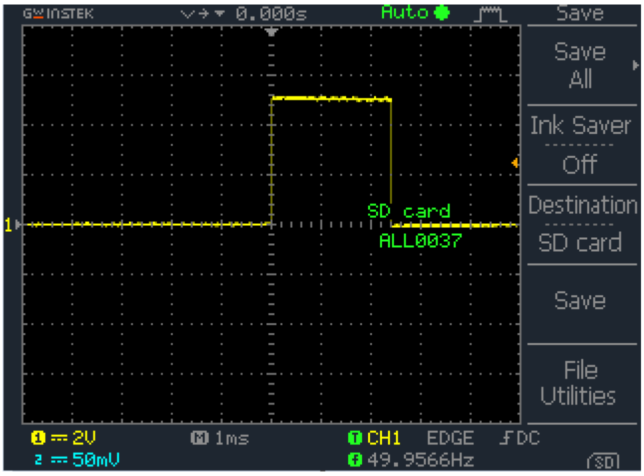


(A) (B)

Figure (6): The PWM Waveform for No Rotation State

(A) The Total Period of the PWM Waveform is 20 ms. (B) The Pulse Width of the logic one is 1.42 ms.





(A) (B)

Figure (7): The PWM Waveform for the Right Rotation Direction

(A) The Total Period of the PWM Waveform is 20 ms. (B) The Pulse Width of the logic one is 2.4 ms.

3.3 The Test of AA51880 Controller

The tests of the performance of each of AA51880 controller is done to verify the polarities of the voltage that operate the RM2 regular motor. The test is achieved by using MASTECH MS8264 digital multimeter, the results of the tests are listed in Table (1) as follows:

Table (1): The Results of Output Tests of AA51880 Controller.

Logic (1) Pulse width (ms)	Voltage of Motor's Feed Wire 1 (V)	Voltage of Motor's Feed Wire 2 (V)	Rotation Direction of RM2 Motor
0.6	GND	5	Left
1.42	GND	GND	No Rotation
2.4	5	GND	Right

The developed OWI-535 robotic arm is shown in Figure (8).

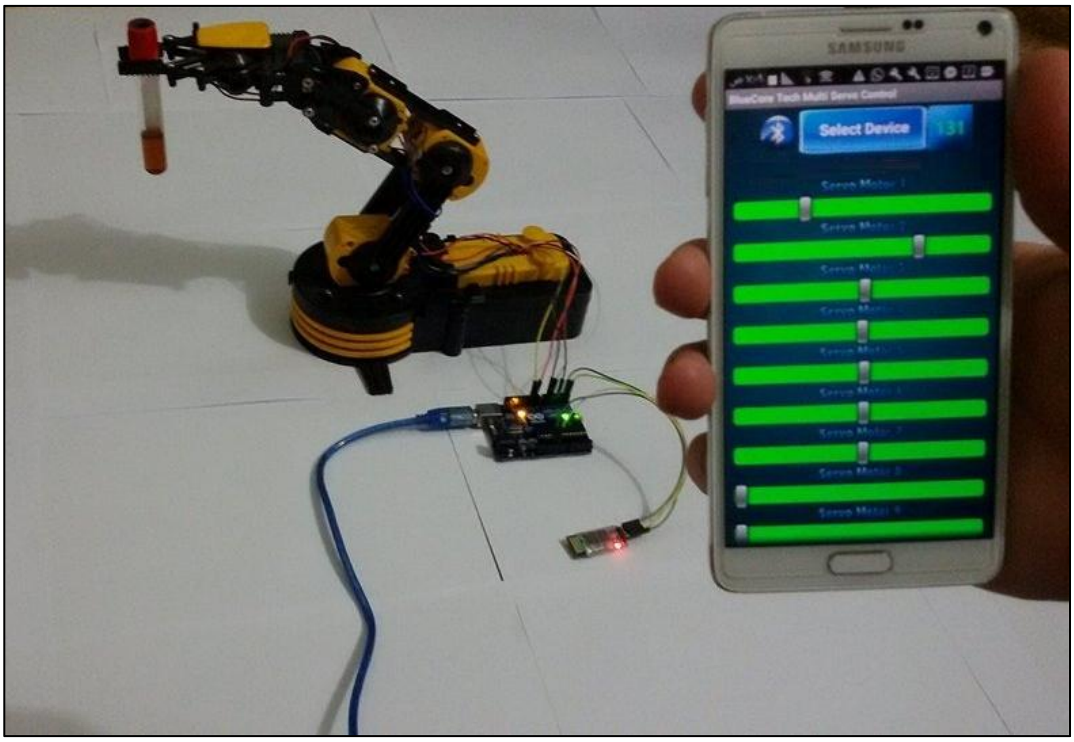


Figure (8): The Developed OWI-535 Robotic Arm.

4. Conclusions and Future Work

According to the results of the validation tests of the developed controlling circuit performance of OWI-535 robotic arm, it is concluded that design and the implementation of the digital controlling circuit is realized successfully. The developed control range is attained up to 12 meter by using wireless signals of Bluetooth technology, through utilizing android smart phone and HC-05 module instead of 1 meter control range of a wired manual controller, furthermore, the RM2 regular motors of the robotic arm are developed successfully by using AA51880 controllers, and they are controlled by 328P-PU microcontroller instead of the mechanical switches of the manual controller. The OWI-535 robotic arm can be further developed in future by adding a wireless digital camera, changing the end effector type of the robot arm, and by controlling the OWI-535 robotic arm wirelessly through the Wi-Fi and internet networks.

5. References

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