Smart Home Garden Irrigation System Using Raspberry Pi

S.N. Ishak, N.N.N.Abd Malik, N.M. Abdul Latiff, N. Effiyana Ghazali, M. A. Baharudin
Faculty of Electrical Engineering
Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.
noordini@utm.my

Abstract—**Irrigation system is a method of allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through solenoid valve. However, it is found that the market price of the system is expensive for small area coverage. Thus, this paper proposes a design for smart home garden irrigation system that implements ready-to-use, energy-efficient, and cost effective devices. Raspberry Pi, which is implemented in this system is integrated with multi-sensors such as soil moisture sensors, ultrasonic sensors, and light sensors. This proposed system managed to reduce cost, minimize waste water, and reduce physical human interface. In this paper, the relay is utilized to control the switching of solenoid valve. The system also managed to measure moisture of the soil and control the solenoid valve according to human's requirements. It is conducted with Graphical User Interface (GUI) using Android application to activate watering activity. Email notification is also sent to the home user for alert purposes either for normal or critical operations. An experimental setup has been tested and it is proven that the system can intelligently control and monitor the soil moisture levels in the experiment field.**

Keywords—component; Smart Irrigation System; Raspberry Pi; Solenoid Valve; Moisture Sensor; Light Sensor; Ultrasonic Sensor

I. INTRODUCTION

In recent years, the demand of building automation system increases especially in offices and households. Generally, it is because automation helps reducing consumption of electricity, decreases the wastage, uses less manpower, and helps in energy saving [1], [2]. Automation system that is implemented at home is known as home automation. The home automation term is referred to the automation system that can integrate household activities which include sensors to read input condition and centralized the control of electrical appliances. The examples of implementation of automation system at home include home surveillance system, watering plant system, domestic robot, pet feeding system, and other household activities [3].

This paper focuses on greenhouse technology which is known as irrigation system. Nowadays, many researchers have innovated greenhouse technology with home automation system and called it as smart home watering or irrigation system. The purpose of this system is to monitor and control the plant growth in home garden area based on environmental factors, like weather and soil moisture [4], [5]. This technology creates suitable conditions for growing plants such as flowers and vegetables which prevents bad effects that are caused by weather change. This irrigation system also makes efficient use of water and fertilizer.

Most mini gardens in residential area are not covered with house roof and it will be exposed to weather change such as heavy rain or a superhot day. This various environmental conditions may affect the plant growth in the garden. This mini garden should be monitored by home owner frequently to ensure the plants are growing healthily. However, it might be difficult for the home owner who are away for a long time to monitor their plants [6]. One system should be built to monitor and control the system that can irrigate their plant from other places.

Currently, there are a lot of irrigation systems in the market which are operating in automation system. Nevertheless, the equipment used is very expensive and it is not worth to install the system in a mini home garden. The irrigation system that has been developed by many researchers need a complex and highly priced computer to monitor the plant growth [4].

Greenhouse system has been integrated with many technologies due to the specific requirement that can improve its quality in crop productions [5]. The purpose of new technology in greenhouse irrigation system is to monitor plant growth and controlling the system by using wireless sensor network with various platforms [4,5], In [6], Zigbee adhoc network has been implemented by applying Zigbee transceiver in wireless irrigation system for a smart home garden that can be integrated with existing smart home control systems. The system consists of slave nodes and a master station which is equipped with a wireless microcontroller. The authors in [7] have developed a wireless sensor node by integrating a sensor platform from Sensinode Ltd into the irrigation system for greenhouse monitoring environment. Other improvements that have been proposed for irrigation system include controlling via a GSM module [8] and developing a website in greenhouse system to monitor the system. The paper introduces Visual Basic Software Web Server which communicates with other devices such as Android mobile phone using synchronizing software (TEAM VIEWER).

II. SMART HOME GARDEN IRRIGATION SYSTEM

The proposed system design is shown in Fig. 1. It illustrates the block diagram of a whole proposed Smart Home Garden Irrigation System. All sensor nodes are connected to Raspberry Pi and capable to monitor the condition level of each sensor parameter throughout the GUI or Android System. At certain critical condition, user will be notified by email application. User also manage to control the water flow by accessing the system via smartphone. The water will flow out from the solenoid valve that is controlled by relay module which acts as a switch.

The proposed system design consists of three major steps:

(i) Development of the system hardware by using Raspberry Pi.

(ii) Development of the monitoring system by using Android application as GUI in order to monitor and control the parameter of sensors remotely.

(iii) Development of a notification system by sending email.

Therefore, this smart home garden irrigation system replaces the computer with Raspberry Pi board which can act as a computer [1]. This board is much cheaper compared to a computer in market. On the other hand, there are no such system yet that has communication link between user and the irrigation system available in the market. Thus, Wi-pi adapter will be connected with Raspberry Pi to build an email configuration as a communication link between user and the system via internet. Additionally, the proposed irrigation control system in this paper has also been developed with an Android application by using smartphone. This paper contributes not only a smart system but also cost-effective home garden automation system which is user-friendly.

Sensor nodes which include moisture sensor, light sensor, and ultrasonic water level sensor are used to measure and monitor environment parameters such as soil moisture, light and water level in tank, respectively. Raspberry Pi acts as a microcontroller to control all the sensors' conditions. Relay is also connected to the Raspberry Pi GPIO pins to control the solenoid valve that is supplied by 12VDC for allowing water to flow out. In this proposed system, user can remotely control the irrigation system from smartphone and access it via internet connection. Furthermore, they will also get notifications from the system through email.

Raspberry Pi uses Python programming in this development. For Android system development, Android Developer's tool is used in Android Studio, while the programming code is developed in JAVA language. Email notification is also adopted in this system to notify user for critical conditions. SMTP command library that configures email application is being installed in Raspberry Pi. After the development of hardware and software are integrated, the irrigation system is analyzed and verified.

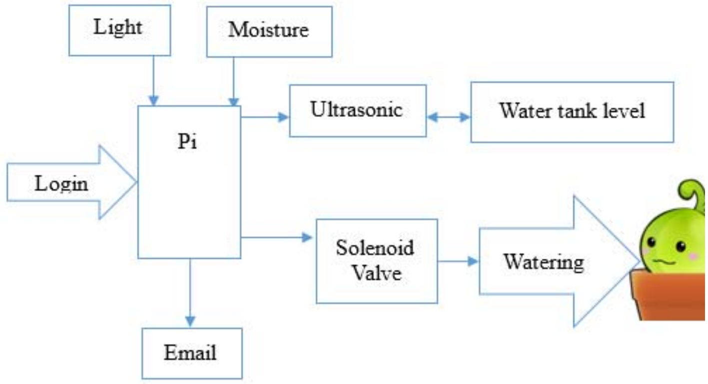

Fig. 1. Proposed System Design Block Diagram

III. HARDWARE AND SOFTWARE IMPLEMENTATION

The components of the system are installed with Raspberry Pi for hardware development. The installation work is carried out step by step. The schematic diagram for the proposed system is shown in Fig. 2. The components that are involved are as follows:

Raspberry pi B+: This board is popular nowadays that is used in mini project development [1]. It is chosen because of its low cost and the optimum credit card-size. Raspberry Pi can act like a computer, which connects with a monitor, mouse and keyboard, and it operates in Linux.

Soil moisture sensor: Known as hygrometer sensor and it detects moisture level of soil. This sensor detects the resistance of soil to get its moisture level. The soil with much water has less resistance while dry soil has more resistance.

Light sensor: Light sensor module function in this work is to detect day and night. This sensor is capable to detect the brightness of environment because there is a Light-dependent Resistor (LDR) provided in the module.

HC-SR04 Ultrasonic sensor: This sensor uses sonar and capable to determine the distance of object, which is not easily affected by sunlight. It is also packaged with a transmitter and a receiver.

Wi-Pi Adapter: It is a WLAN USB dongle. The function of this adapter is to connect Raspberry Pi with Wide Local Area Network (WLAN).

Solenoid Valve: The valve function is applied to allow water flow from the tank to the plant pot. The valve was manufactured for low pressure environment.

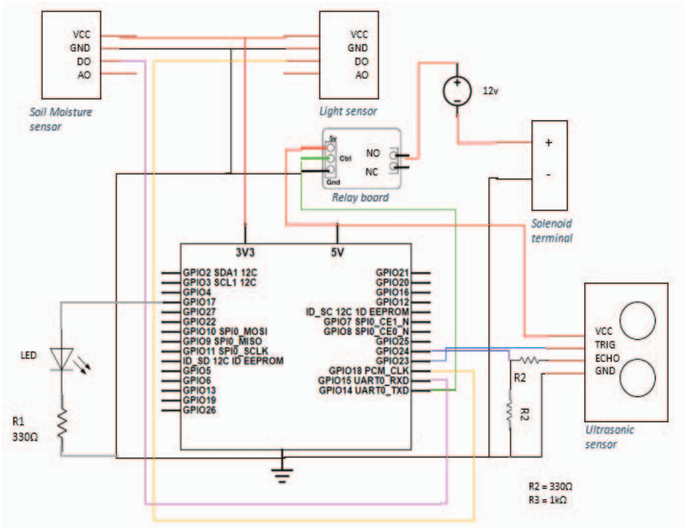

Fig. 2. Schematic Diagram for Hardware Development

The software development is divided into 2 parts, i.e. python and PHP programming for Raspberry Pi and Java programming in Android Studio. User needs to log in into the system in Raspberry Pi through their smartphone, i.e. Android application to start the system. After the system has been activated, LED will turn ON and the system starts to monitor the condition of each sensor. At critical condition level for each sensor, the system will notify user by sending an email. Then, user will send back the notification to the system to activate the watering system. The system will loop back to monitor the parameter that involves light, soil, and water level tank. Fig. 3 illustrates the flow chart of this system.

The software that are used for this work are as follows:
Python: The language used for programming Raspberry Pi is Python language.
PHP program: PHP file based on C program is created to make a connection between Android application and Raspberry Pi. Raspberry Pi can be accessed by typing its IP address or local hostname in internet server.
Android software: In previous works, many researchers have developed the android application for Raspberry Pi with Eclipse tools. However, Android Developer Tools has been depreciated from Eclipse at the end of year 2015. The benefit of using Android Studio directly is it provides the latest tools for building application on every type of Android API and gives the best quality application. Java code program is used to run the Android Studio.

After the hardware and software have been developed and implemented, both parts are integrated. The system is then tested and verified.

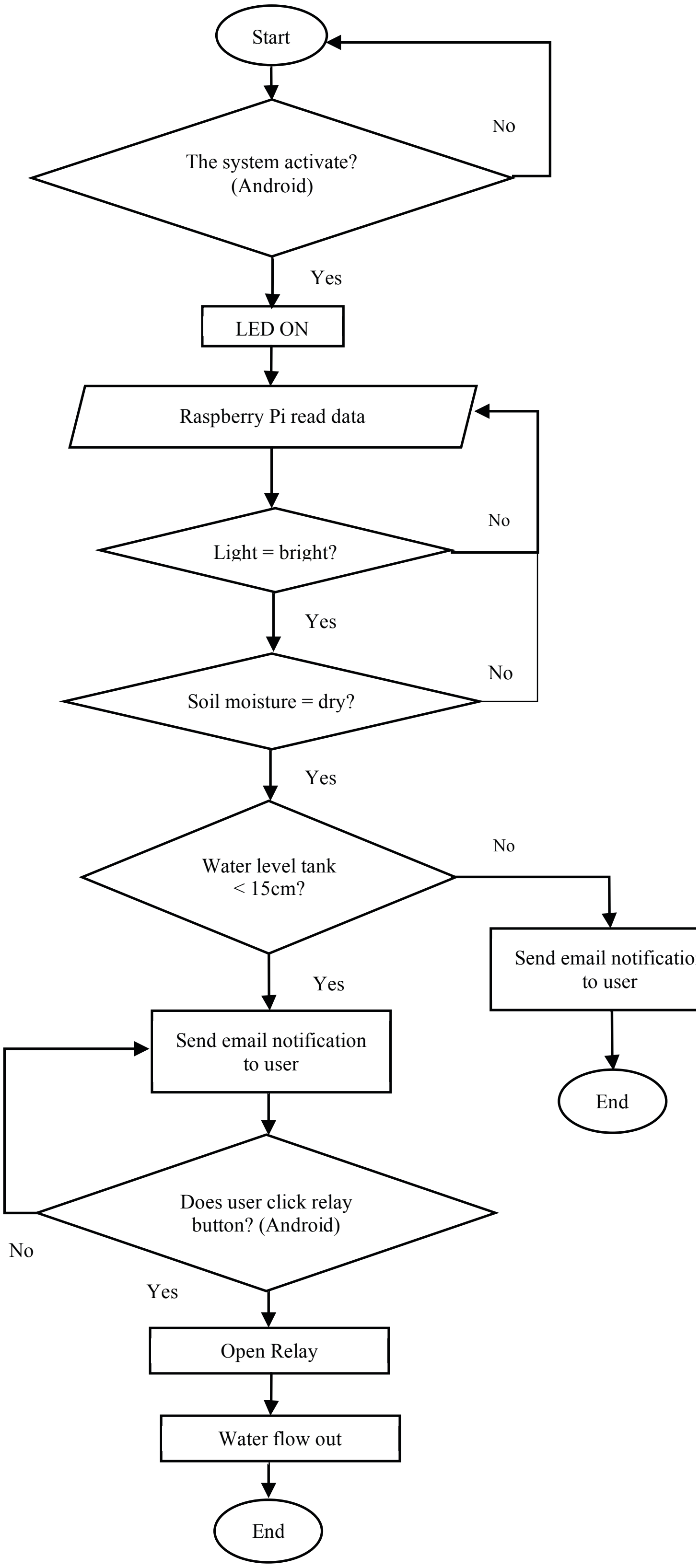

Fig. 3. Proposed System Flow chart

IV. Results And Analysis

Fig. 4 shows the completed hardware setup for Smart Home Garden Irrigation System which has been integrated with Raspberry Pi. All sensor modules are connected with Raspberry Pi GPIO pins as shown in the Fig. 4 for monitoring purposes. Sensor modules involved in this work are light sensor for detecting the present of light, soil moisture sensor for detecting the moisture of soil, and ultrasonic sensor that are located at the top part of the water tank to detect water level. The ultrasonic sensor function has been developed in Python as shown in Fig. 5. While for the controlling part, the single relay module is working as switch to control the solenoid valve. Furthermore, LED represents the symbol of activation system and it will turn ON after the user activates the system through their smartphones. For email configuration, Wi-Pi adapter is connected with USB port of Raspberry Pi board to allow the internet connection from router.

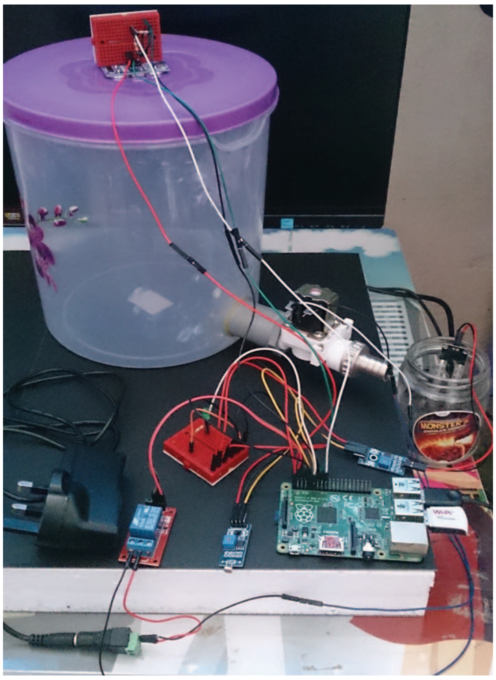

Fig. 4. Smart Home Garden Irrigation System Hardware Setup

```
#measure distance level function
def measure():
        GPIO.output(TRIGGER, True)
        time.sleep(0.00001)
        GPIO.output(TRIGGER, False)
        start = time.time()
        while GPIO.input(ECHO)==0:
                start = time.time()
        while GPIO.input(ECHO)==1:
                stop = time.time()
                duration = stop-start
                distance = (duration * 34300)/2
                return distance

def measure_average():
        distance1 = measure()
        time.sleep(0.1)
        distance2 = measure()
        time.sleep(0.1)
        distance3 = measure()
        time.sleep(0.1)
        distance = (distance1 + distance2 + distance3)/3
        return distance
```

Fig. 5. Ultrasonic Sensor Function in Python

Android Apps had been developed and configured using Java program code. There are three layouts that have been designed as shown in Fig. 6 for this GUI layouts. The first layout shows the user login for the system. The user has to key in their information in database through the second layout before logging in into the system. After the Sign Up and the Login steps completed, user can access the last layout and control the system by clicking the button as displayed.

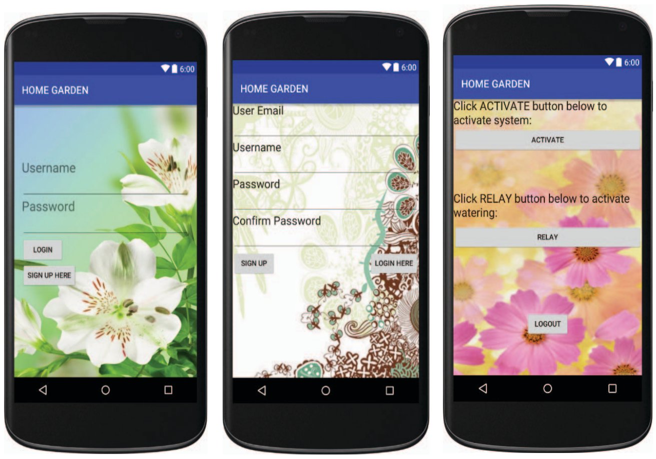

Fig. 6. Android Apps Development

An experimental setup was carried out in two different cases, i.e. normal operation and critical operation. Normal operation is to monitor the light and moisture of the sand, while critical operation occurs when there is an alert in water tank level.

Both operations are developed in one program code in Python. To begin the operation, the filename, i.e. *project.py* must be written in terminal window. After the project name file has been called, the system starts reading the data from Android Apps when the button ‘Activate’ has been clicked in the smartphone application. The LED will turn ON if the user has clicked the button in Android Apps. The system then starts reading the data from all sensors (light sensor, soil moisture sensor, and ultrasonic sensor). For normal operation, the system will run smoothly if the water level is less than 15 cm. The system will email and notify the user as shown in Fig. 7 to activate the relay button in Android Apps for allowing the water flow out from the solenoid valve. The status of successful of watering system will be displayed on terminal window as illustrated in Fig. 8.

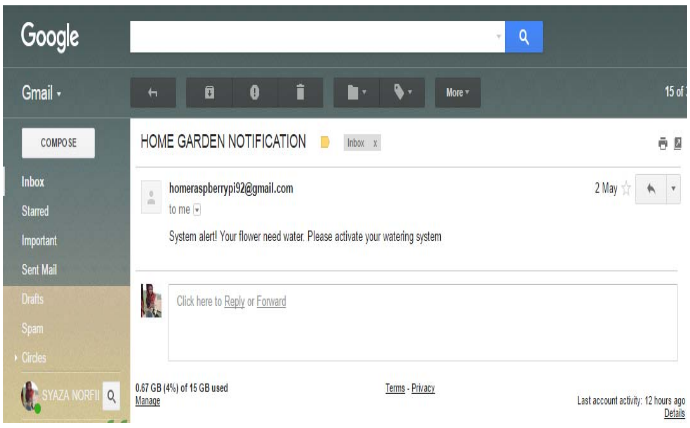

Fig. 7. Email Configuration for Normal Operation

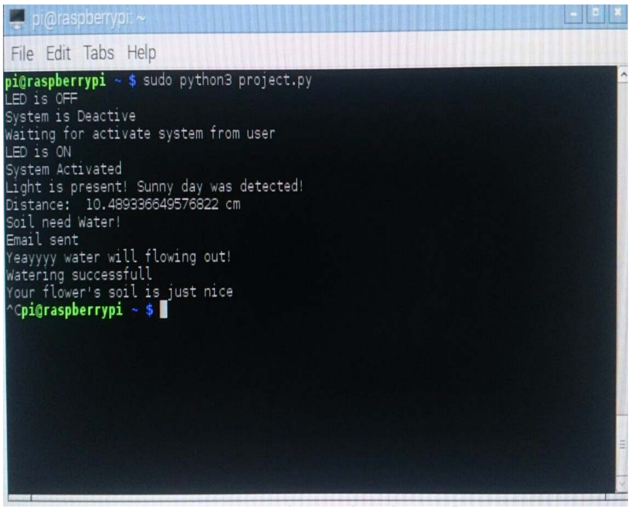

Fig. 8. Raspberry Pi terminal for Normal Operation

The system is detected as in a critical condition if the reading of water level in tank or ultrasonic measurement is more than 15 cm. Fig. 9 shows Raspberry Pi terminal for Critical Operation. An email as shown in Fig. 10 will be received by the user to inform that the water level that has run out. The system will be automatically stopped if the user did not refill the water tank.

It is proved that the system can successfully monitor the soil moisture levels and light of the test field wirelessly by keeping the moisture levels of the home garden. The plants can be watered automatically with the considerations of user requirements. Solenoid valves and relay board which control and monitor the water flow can be controlled remotely by the user. The system also proved that it can be accessed anywhere, anytime by using android apps in smartphones and email.

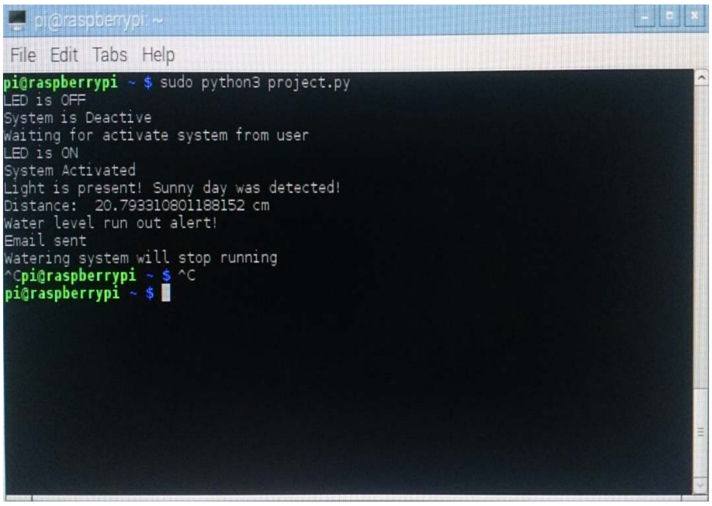

Fig. 9. Raspberry Pi terminal for Critical Operation

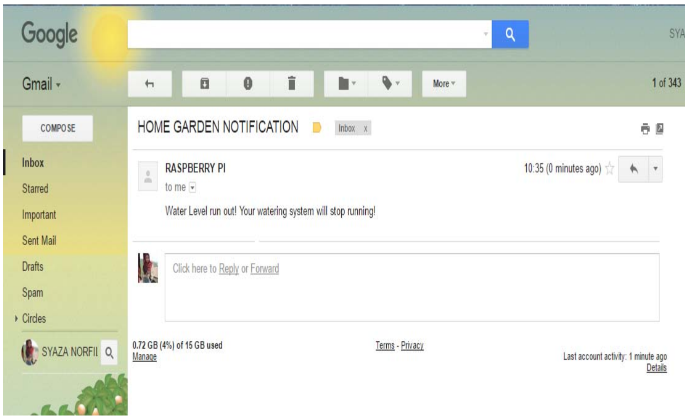

Fig. 10. Email Configuration for Critical Operation

V. CONCLUSION

Smart Home Garden Irrigation System has been successfully developed with Raspberry Pi by connecting it with light sensor, soil moisture sensor, ultrasonic sensor and a single relay module. All sensors have provided good measurement of parameters when carrying out the experimental cases. Raspberry Pi controls on and off of the relay. It is also proved that the relay manages to control the solenoid valve. The system is feasible and cost effective for optimizing water resources in any small scale agricultural sectors. By implementing Android interface apps in mobile, a user can manage to control the irrigation system remotely. Additionally, email is also sent to the user to give information about the system. Therefore, the intervention of human is much reduced using this smart irrigation system. It saves time and also water consumption.

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