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Internet of Things-Based Water Level Management System

Oke A. O., Ajala F.A., Baale A. A.

Abstract: Water is one of the most important basic needs for all living things. It is a limited resource and is very important for all and sundry. Unfortunately, a huge amount of water is being wasted by uncontrolled use. This problem is quietly related to poor water allocation, inefficient use, and lack of adequate and integrated water management. Therefore, the need for an intelligent expert system for home or office water management arises which is the problem this project aims to solve. At the end of the research, an intelligent internet of things based water level management system which was capable of detecting water level and preventing water overflow was designed and implemented.

Keywords: Internet of Things (IOT), Water, Intelligent, Expert system, WIFI Module.

I. INTRODUCTION

Water is a very essential resource in our lives today. All plants and animals live more on water to survive. If there is no water, there would be no life on earth. Apart from drinking water, there are many other uses for water in cooking, washing, keeping communities clean and recreation. Water is also essential for the healthy growth of farm crops and live stocks. It is commonly used in agriculture, industry, commercial and domestic consumption (Matiur *et al*, 2014). Water is stored in storage tanks that hold liquids, compressed gas or mediums for short and long-time duration. However, these tanks are generally spread across a large area and use a manual detection measurement method. This makes it more laborious and time consuming to monitor the tank levels. Remote monitoring and data collection systems are necessary to collect information from these tanks and to monitor them. Therefore, it is necessary to build a system which is fast, accurate in measurement and also simple to install and handle, but has an intelligence which takes decisions in real-time, alerts and communicate when necessary. The Internet of Things (IOT) Liquid Level Monitoring System is an innovative system which will inform the user of the level of the liquid contents in the container (tank) and thus prevent it from overflowing. Liquid level monitoring plays an important role in today's automotive oil, water, pressure and gas industries to name a few. For example, pumping oil into a storage tank requires liquid-level monitoring to prevent spillage (Oke *et al*, 2015). In the last few decades, several monitoring system integrated with water level detection have become accepted. Measuring water level is an essential task for government and residential perspective.

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Oke A. O., Department of Computer Science and Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria. E-mail: aooke@lautech.edu.ng
Ajala F.A, Department of Computer Science and Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria. E-mail: faajala@lautech.edu.ng,
Baale A. A, Department of Computer Science and Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria. E-mail: aaadigun@lautech.edu.ng

In this way, it would be possible to track the actual implementation of such initiatives with integration of various controlling activities. Therefore, water controlling system implementation makes potential significance in home applications and would help in reducing water consumption and as well as water overflow.

II. RELATED WORKS

In an attempt to know the level of liquid in containers and reduce or totally avoid its wastage, some research works have been done by various persons all over the world and obviously they all have the intention of providing efficient water level monitoring systems. Though, the aim behind the development of all water level monitoring systems has been the same. However, better systems are being developed continually for better water level monitoring. Zachos *et al*, (2008) implemented remote measuring station in present of wireless system for monitoring of water level. An ultrasonic distance measuring system was achieved. In this the remote stations are considered as simple measuring units with a communication interface so that he may be operating under the control of base station. The advantages of this research are no mechanical parts required, remarkable accuracy and resolution. Zulhani *et al*, (2009) elaborated the ZigBee network for water irrigation control monitoring system.

They had used a various sensor node to detect the water level in the reservoir and it is based on the signal from the sensors, and a simple electronic circuit can either open or close the gate controlling the flow of water. In their paper it is important to mentioned here, the circuit present in their project is on a conceptual scale and not yet in the form than can be directly applied to the available water irrigation controlling gate. Brito *et al*, (2009) implemented control of water level in two tanks without interaction. They had performed in a remote collaborative method. In this paper the system includes two tanks made in acrylic, a pump to circulate the water from the lower part of tank to the upper tank, two ultrasonic sensors was used for measuring both tank levels, and electronic valve to stop the flow of water between the upper level tank and the lower level tank and a manual valve for security purposes. Zhang, (2011) elaborated the control and monitoring of water level in nuclear power plant.

The steam generator was used for water level control system which was the most important components of the nuclear power plant. He developed the performance assessment method for a class of SG level of water control systems, two PI controller systems. A major contribution of this paper was to take the performance assessment technology into an industrial area, SG water level control in NPPs,

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where not much work has been done before. Komeswarakul *et al*, (2011) proposed automatic water monitoring system using microcontroller for dam. The Remote terminal unit (RTU) based on DSPIC30F4011 microcontroller was mainly designed to precisely measure, store and send instruments output to the computer server including real-time communication for dam behaviour monitoring system. This system also provides the real-time information via reliable fibre-optic communication. The sensors installed into structure of dam and in reservoir to measure physical quantities of interests such as water level, deformation, pressure and temperature parameters. The aim of this research presents the RTU that operates in the dam monitor system. Rahman *et al*, (2014) implemented automatic system to control tap water. It involves the procedure of water level sensing system to control the misuse of water in tap. It consists of automatic system of a solenoid valve, relay, float level controller and electrodes. This research was implemented and tested with bucket water and tap, it shows that a float water level switch connected with a solenoid valve via relay, where the solenoid valve converts the electrical energy into motion, and which start and stop the water flow. It has three sensors,1st was upper level sensor,2nd lower level sensor, and 3rd one was a common sensor, these sensors was made up of copper wire which act like electrodes and helps in conducting path. The advantage is that it has low power consumption, and the disadvantage is that it is not used for the Wireless sensor network (WSN).

III. METHODOLOGY

The water level monitoring system using internet of things was built around a microcontroller programmed to detect water level in two tanks through the use of ultrasonic distance sensor. A WIFI (ESP8266) module used provides a means to connect to the internet using WIFI connection. The WIFI module links the hardware to a small internet server designed to send commands to the hardware to obtain the current water level in the tanks. The microcontroller, embedded in the hardware, on receiving the message interprets it and carries out the instructions. This design also features the use of a solenoid valve which provides a means to close the inlets into the tanks electronically. The parts that make up the design are shown in Figure 1.

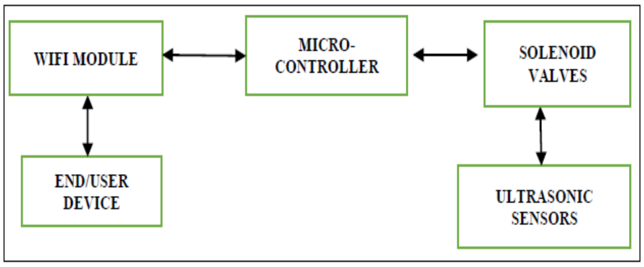

Figure 1 Block Diagram of The Design.

3.1. Data Acquisition

The data acquisition is done by the sensors used to sense the changes in the liquid level of the tank and is stored in the system's memory. A server collects the information sent from the on-board microcontroller through a wireless modem in the tank; saves it to a database and displays it on a website graphically. Such intelligent monitoring systems help in effective management of tanks, by assessing the status of the tanks periodically allowing optimized logistical supply of product and minimized inventory holding. Efficient utilization of the low power modes of the microcontroller reduces power consumption and extends the longevity and reliability of the system with less maintenance cost.

3.2. Measuring Water Level

To ensure a non-contact water level measurement, an ultrasonic distance sensor is used. The sensor, the HC-SR04 (as shown in Figure 2) ultrasonic distance sensor is able to provide a precise measurement of distances ranging from 2 centimeters to 3 meters (0.79 inch to 9.84 feet). It works by emitting a short ultrasonic burst and then measuring the time it takes the burst to bounce back when it hits an object. By timing this process, it is able to calculate the exact distance between the sensor and the object (water level).

Figure 2: THE HC-SR04 Sensor

The HC-SR04 sensor has a four-pin connector: GND, TRIGGER, ECHO and VCC. The signal line returns the distance measured in pulses. The HC-SR04 sensor runs at 5V (TTL) and uses pulse-trigger and pulse-width to trigger. A microcontroller, ATMega328P, is connected to the sensor to generate and also to measure the pulse. To activate the HC-SR04 sensor, a low-high-low pulse is sent to trigger it. After it is triggered, it waits for about 200 microseconds before it sends out an ultrasonic burst. In the meantime, there is a wait for the burst to bounce back; this entire pulse duration (which starts when the burst is sent) represents the round-trip distance from the sensor to the object being detected. In the microcontroller, a pulse is defined to be 2µs (two microseconds). Hence, to convert the pulse to time, the number of pulses is multiplied by 2. This gives the time in µs. Because the measured pulse is for the trip to and fro, it is divided by 2 to get the time from the sensor to the detected object. As sound travels through air at 1,130 feet per second (at sea level), this works out to be 1 inch in 73.746 µs (or 1 cm in 29.034 µs). Converting the time in µs to a distance in centimeters, the time is multiplied by 29.034 (or 30 for simplicity). This gives the distance in centimeters.

The whole process of measuring the distance can be mathematically represented as:

$$distance = speed \times time \qquad (1)$$

And since actual distance to obstacle is only half of the distance travelled by sound

$$distance\ to\ obstacle = \frac{(speed \times time)}{2} \qquad (2)$$

Speed of sound in air is:

$$34359\ cm/sec = 0.03459cm/uS$$

Substituting this value in equation 2 gives

$$distance\ to\ obstacle = (0.034359 \times time)/2 \qquad (3)$$

Or

$$distance\ to\ obstacle = (0.01718 \times time)$$

3.3. The WIFI Module Setup

Figure 3 shows the ESP8266 module which is a TTL "Serial to Wireless Internet" device which can be used with microcontrollers that have the ability to communicate with a TTL serial device. The ESP8266 module is a 3V device, and has a current consumption between 10uA and 170mA. When transmitting at full power, it can consume up to170mA but when in a deep sleep, it only needs about 10uA. To set up the module in this work, the module was directly connected to the PC using a TTL Serial to USB adapter. A terminal program was used to program the unit and configure to a wireless network. The default baud rate settings are 115200, N, 8, 1(Baud rate = 115200, No parity, data bits = 8, and one stop bit).

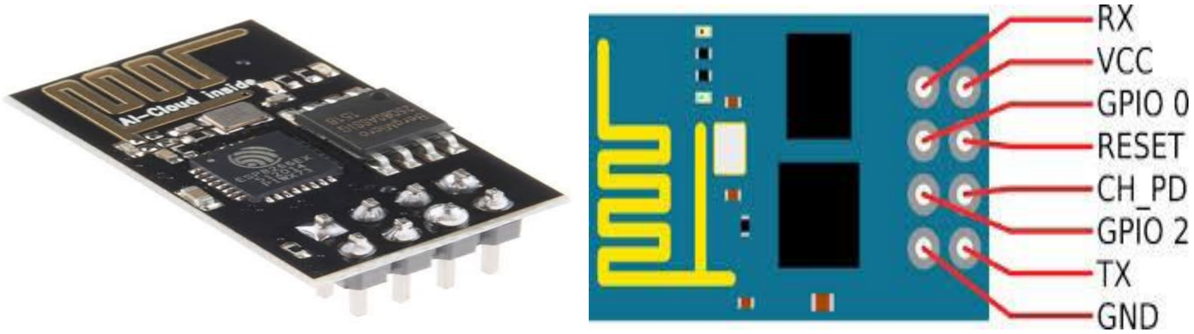

Figure 3. Picture of the ESP8266 WIFI Module and Its Pin Assignment.

3.4. The Microcontroller Specifications

Various factors were considered in the choice of microcontroller to use for a particular purpose. These include:

- The number of digital inputs, analogue inputs the system concerned requires; a factor which helps to determine the minimum number of inputs and outputs (I/O) that the chosen microcontroller must have and the extent of need of an internal analogue to digital converter module.
- The size of program memory storage required
- The magnitude of clock frequency; a factor which determines the execution rate of tasks by the microcontroller
- The number of interrupts and timer circuits required.

In a situation where the communication between the controller and WIFI module is largely dependent on the amount of memory available, a microcontroller with a large memory sufficient input/output ports and analogue/digital channels such as the ATMega328P is quite acceptable for use.

The major parts of the AVR MCU (Microcontroller Unit) are the program memory, data memory which is also called file register, the working register, and finally the EEPROM memory section.

- Program Memory: 32kB flash
- File Register Memory (Data Memory): 2272 bytes SRAM
- EEPROM Memory: 1kBytes EEPROM
- Working Register: Byte wide used in most instructions

3.5. Power Supply Stage

All stages in the work use +5V except the relay circuit that uses +12V and the WIFI module that uses 3V. The power supply stage is a linear power supply type and involves step down transformer, filter capacitor, and voltage regulators, to give the various voltage levels. The power supply circuit diagram is shown in Figure 4.

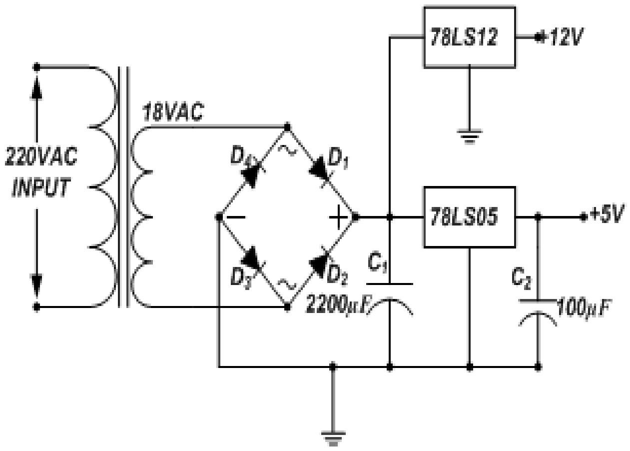

Figure 4: Power Supply Stage

3.6. Transistor Switching Stage

The output of the microcontroller controls the switching of the relays via the transistor switching stages, which switches power to the solenoid valve. The power of the load to be activated depends on the relay contact rating; hence the choice of relay is critical. The transistor as a switch operates in class A mode and is shown in Figure 5. The relay is switched on when the microcontroller gives a HIGH output. A base resistor is required to ensure perfect switching of the transistor in saturation. The diode protects the transistor from back EMF that might be generated since the relay coil presents an inductive load. In this case R, which is the collector resistance, is the resistance of the relay coil, which is 400Ω for the relay type used in this work.

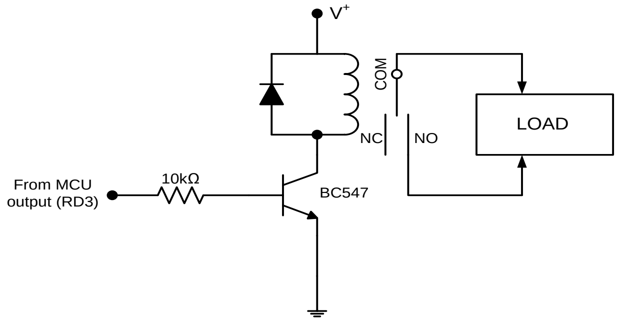

Figure 5: Switching Transistor Stage

Hence, given that Rc = 400Ω (Relay coil resistance), V^+ = 5V (regulated voltage from the power supply stage.), Vbe = 0.6V (silicon), Vce = 0V (when transistor is switched), Vin = 4.0V (from microcontroller), Hfe = 300 (from data sheet for BC337) Since,

$$V^+ = I_C R_C + V_{CE} \text{ and } V_{in} = I_B R_B + V_{BE}$$

$$5 = I_C R_C + V_{CE}$$

$$5 = I_C(400\Omega) + 0$$

$$I_C = 12.5mA$$

Where, I_C = collector current, I_B = base current, V_{in} = input voltage, V_t = supply voltage

V_{CE} = collector-emitter voltage, H_{fe} = current gain,

$$I_B = \frac{12.5mA}{300} = 0.417\mu A$$

$$5 = 0.417\mu A \, R_B + 0.6$$

$$R_B = \frac{4.4V}{0.417\mu A} = 10{,}000\Omega$$

3.7. Circuit Diagram

The circuit diagram in Figure 6 entails all components that make up the whole system. This includes the pins, diodes, capacitors, resistors and switches. Also, Figure 7 shows the visual studio interface used to build the webpage while Figure 8 shows the arduino interface used to program the microcontroller.

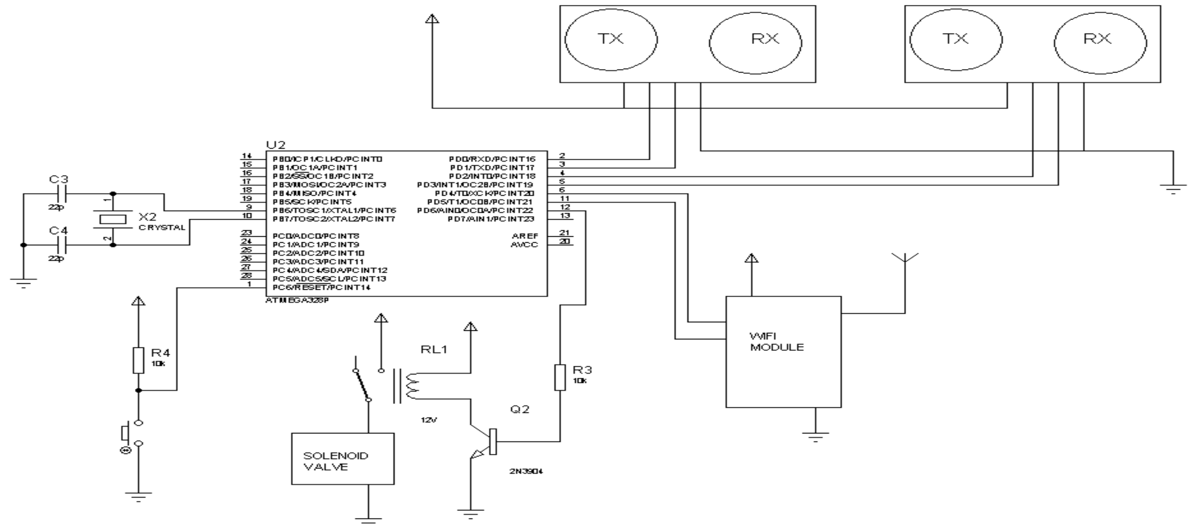

Figure 6: Circuit Diagram for the Water Level Detector.

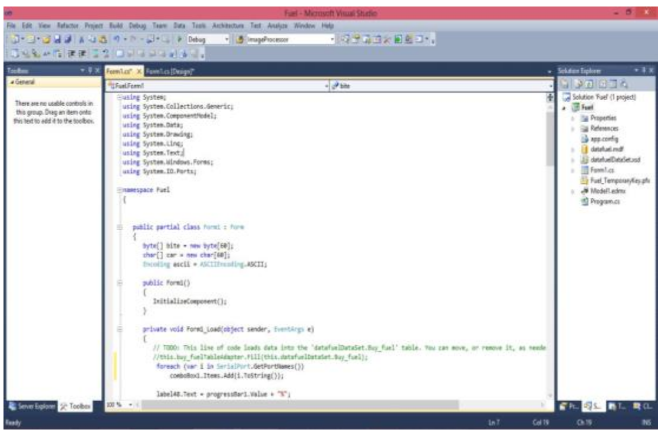

Figure 7: Visual Studio Interface

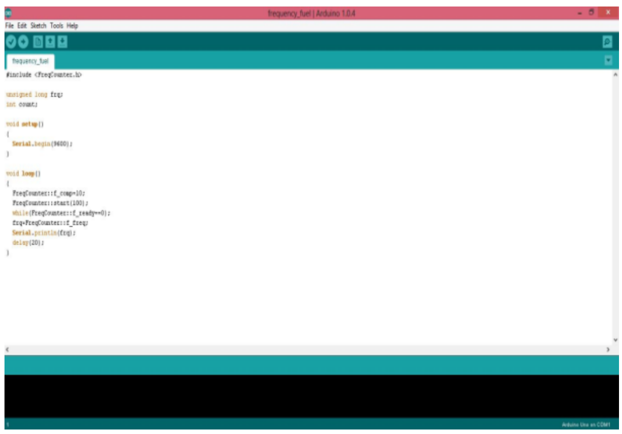

Figure 8: Arduino Interface

IV. RESULT

The IOT water level monitoring system was tested and implemented. The graphical results were obtained from the URL (waterlevel.western-fund.com) with the use of a mobile phone and computer system and it was physically confirmed by checking the water level in the tanks A and B. Figures 9 and 10 show the results of the water level in tanks A and B with the use of a mobile phone and laptop respectively.

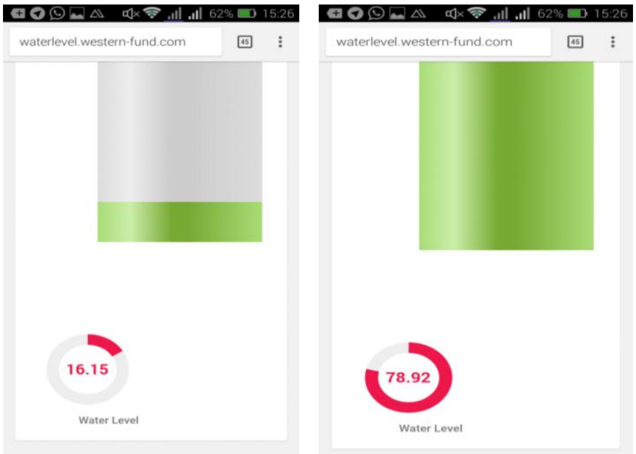

Figure 9: User Interface (Output) on a Mobile Phone with Tank A at 16.15% and Tank B at 78.92%

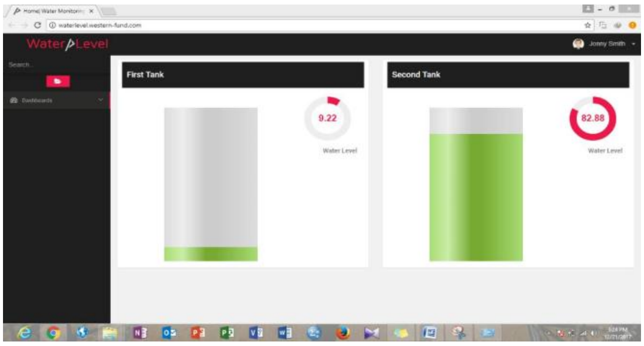

Figure 10: User Interface (Output) on a Laptop with tank A at 9.22% and tank B at 82.88%

4.1. Discussion of Result and Working Principle

From the Figures 9 and 10, the water level in both tanks is different. This is due to the pressure from the reservoir which is determined by rate of water flow into the tanks A and B simultaneously. Hence, when the amount of water in the reservoir is low or reducing, the flow of water into the tanks reduces. Also, if the amount of water in the reservoir is high, the pressure speeds up the water flow rate into the tanks. . To demonstrate this system, 2 containers were used. The system uses ultrasonic sensors placed over the containers to detect the liquid level and compare it with the container's depth. The system makes use of AVR family microcontroller, LCD screen, WIFI modem for sending data and a buzzer. The system is powered by a 12V transformer. The LCD screen is used to display the status of the level of liquid in the containers. Here, a web page is built to show the status to the user monitoring it. The webpage gives a graphical view of the containers and highlights the liquid level in color in order to show the level of liquid. The LCD screen shows the status of the liquid level. The system puts on the indicator when the level of liquid collected crosses the set limit. Thus this system helps to prevent the wastage of water by informing about the liquid levels of the containers and providing graphical image of the containers via a web page and also providing the level of liquid in each tank to the user.

After the system is completely setup and plugged to a stable electricity supply, the system connects to the internet. The connection to the internet is known with the LED indicators on the casing of the microcontroller, on the casing there are: the Red LED that indicates power, the Orange LED which indicates the system is connected to the internet and the Green LED that tells that the solenoid valves open and water pumps into the two tanks simultaneously. After the two tanks are filled up, the solenoid valves close automatically and water stops pumping. The result is sent to the web page which can be obtained anywhere (any location) with a device. Figure 11 shows the complete setup of the system while Figure 12 shows the casing with the different LED indicators.

Figure 11: Complete Setup of the IOT

Figure 12: Casing with the LED Indicators Water Level Monitoring System

V. CONCLUSION

The design and construction of an IOT based water level detector was designed considering some factors such as economic application, design economy, availability of components and research materials, efficiency, compatibility and portability and also durability. The performance of the work after test met design specifications.

Also the operation is dependent on how well the soldering is done, and the positioning of the components on the printed circuit board. If poor soldering lead is used the circuit might form dry joint early and may cause malfunctioning of the system. Also if logic elements are soldered near components that radiate heat, overheating might occur and affect the performance of the entire system. Other factors that might affect performance include transportation, packaging, ventilation, quality of components, handling and usage. The construction was done in such a way that it makes maintenance and repairs an easy task and affordable for the user should there be any system breakdown.

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