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A Low-cost Monitoring and Control of Water Level Using Microcomputer

*Nwohu, Mark N, **Olatomiwa, Lanre J., Adi, T.
Department of Electrical/ Electronics Engineering,
Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria
*mnnwohu@yahoo.com; **jostom05@yahoo.com

***Abstract*-The Computer-Aided Automatic Water Pump Actuator is a system designed to monitor the level of water or any other liquid of resistance under 900kΩ in a reservoir (tank) and operate the pump connected to the reservoir appropriately. This paper highlights the capability of the system to switch ON/OFF any electric device connected to it automatically based on time sharing, thus giving it a wide range of application both in industries and at home. It discusses two major components the system is composed of, viz, the hardware which connects to the microcomputer through the parallel port and the software which is stored in memory of the computer that drives the hardware and gives the system its high level of intelligence and versatility.**

Keywords-Actuator; Microcomputer; Parallel Port; Hardware; Software

I. INTRODUCTION

Water is a basic necessity of life and most of the government organizations strive to provide potable water for their subjects. However, despite concerted effort by the government to make water available to all her citizens, the supply of water to most villages and cities is grossly inadequate. There are usually cases of water being supplied once or twice in a week and at low pressures that can hardly flow onto the first floor in a storey building. Of course, this informs the decision of many homes, hospitals and industries to install pumps and overhead, surface or underground reservoirs (tanks) for water storage.

The installation of pumps in buildings to pump water into an overhead tank for storage and redistribution requires an operator to monitor the water level in the tank which may be tens of meters above the ground level. Besides the difficulty in detecting the exact water level in the overhead tank because of the considerable height at which the tank may stand, the monotony of the work causes boredom and fatigue to the human operator with subsequent deterioration in performance.

Automation describes system in which automatic or programmed devices can operate independently or nearly independently of human control. Such systems are designed to extend the capacity of machine to perform tasks formerly done by human beings and to control sequences of operation without human intervention [1]. Essential of all automatic control mechanism is feedback principle, which enables a designer to endow a machine with the capacity of self-correction. A feedback loop is a mechanical, pneumatic or electronics device that senses or measures a physical quantity, compares it with a pre-established value, and takes whatever pre-programmed action necessary to maintain the measured quantity within the limits of the acceptable standard [1].

Russian Polzunov I. invested the first historical feedback system for water level control in 1765. It consists of a float attached to a lever, which in turn controlled a valve. The system was used in a boiler where the float detects the water level and controls the valve that covers the water inlet in the boiler [1].

Since then, several other approaches to controlling water flow in a container have been developed. One of such is the float switch contact used to operate a motor that pump water into a tank. Float switches are generally designed with two sets of contact: Normally Open (NO) and Normally Closed (NC). When the normally closed contact are used, the pump motor will continue to pump water until the water level rises to a level high enough to cause contacts to open and switch off the pump. The installation of such system are however clumsy [3]. Magnetic control has been used in some places in other to separate the control equipment from the pump motor. Although this approach is more expensive than the float contact switch, it is neater and satisfies certain industrial and commercial installation requirement. Simple electromagnetic device such as solenoids, contactor and magnetic motor starter are used to effect the controlling process.

With the introduction of the first microprocessor by Intel Corporation in 1971 and first personal computer (PC) by IBM in 1981, control systems have been developed as dedicated equipment incorporating a micro-controller or as peripherals interfaced with the PC, where the PC does most of the processing work and issues out control commands as pre-programmed. These systems greatly facilitate the use of feedback loops in control processes.

The whim of use of micro-computer in the monitoring exercise and operation of the water pump to ease human operator of his problem came into prominence. Hence, the design of the alow-cost monitoring and control of water level using microcomputer to monitor the water level in the overhead tank and switch the pump on/off when the level of water reaches predetermined levels in the tank. Eventually, the operator is alerted of possible dangers if there should be failure in the operation of the entire system. Furthermore, having been interfaced with a microcomputer, it utilizes the high processing ability of computer in control of the system and some other electrical devices like security light, room heaters and room coolers on time sharing basis.

II. DESIGN ANALYSIS AND CALCULATIONS

The design approach of Computer-Aided Automatic Water Pump Actuator adopted can be discussed under two major sections, viz, hardware and software.

A. Hardware Design

The hardware comprises the physical components of all units that make up the system such as power supply, water detector, input/output buffers, personal computer, power/cable detection, switching, LED display and alarm units.

1) Power Supply Unit

This unit supplies d.c voltage converted from a.c to all electronic devices required for the operation of the system. It is made of stepping – down transformer which provides physical isolation, though magnetically coupled, between the 220V a.c mains and the rest of the hardware and rectifier converting a.c voltage from the transformer into a pulsating d.c voltage which passes through a capacitive filter that eliminates a.c ripples to produce constant pure d.c voltage. Subsequently, the output voltage of the filter capacitor is stabilized by the regulator (monolithic voltage regulator IC chips) at the varying of the load current or input voltage [2].

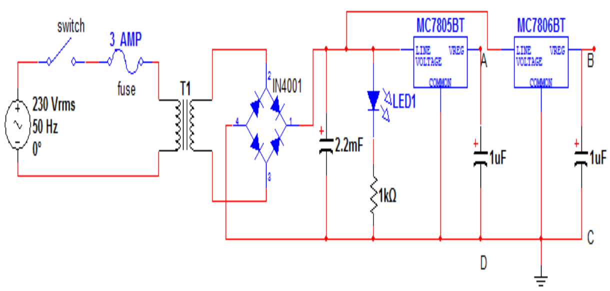

Figure 1. Power supply unit

Thus, the average d.c voltage, V_{dc} across AD or BC is obtained by:

$$V_{dc} = \frac{2V_{2(peak)}}{\pi} = \frac{2\sqrt{2}V_{rms}}{\pi} \quad (1)$$

where $V_{2(peak)}$ and V_{rms} are the peak output and root mean square voltages of the secondary winding of the transformer respectively.

And the discharge time constant, which is the time taken for the capacitor to drop to 33% of the peak value is given as:

$$\tau_d = R_L C \quad (2)$$

where R_L is load resistance which is constant for any given circuit and C is capacitance having smaller ripple voltage as it increases.

TABLE I

TYPICAL CONDUCTIVITY OF SOLUTIONS AT 250 C

Solution	Conductivity (μs/cm)	Solution	Conductivity (μs/cm)
Ultra pure water	0.055	Ground water	20,000
Boiled water	1.0	1.0M KCL	111,342
Tap water	50	10% NaOH	355,000
Sea water	50,000	10% H_2SO_4	432,000

2) Water Detector Unit

The Computer – Aided Automatic Water Pump Actuator uses electrical transducers to convert water level in the tank into electrical signals. These transducers are probes (four in numbers) made of conductors which are lowered into the tank at the desired levels with the common probe at the bottom connected to the circuit ground. The operation of these transducers depends on the conductivity of water which varies with temperature, volume and separation height of the measuring probes.

The probes arrangement is as shown in Figure 2. The LOW probe is suspended at the minimum desired water level in the tank; the HIGH probe is placed at maximum desired water level, while the overflow probe is placed at a level that would indicate the possibility of water spillage from the tank.

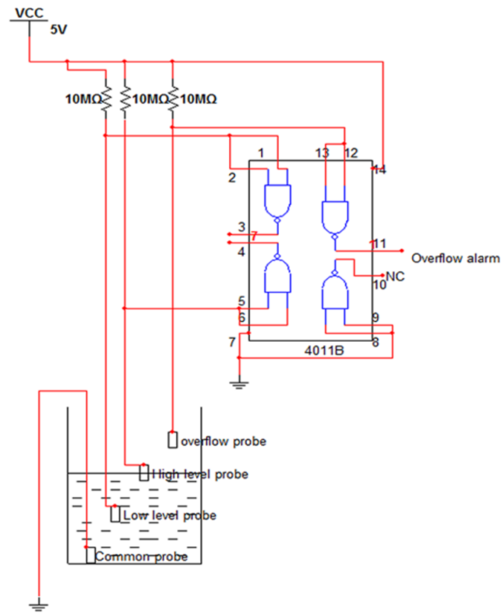

Figure 2: Water Detection Unit

The micro-chip (4011B) in Figure 2 acts as an inverter. If any of the four probes is out of the water, V_{cc} is linked through the 10MΩ resistor to the input of the inverter which the probe is connected, thereby inverting the output to give LOW output. Whenever the water level rises, the input to which the probe is connected is linked through water to the common probe which is at zero potential. The input is thus grounded, and when inverted produces a HIGH output indicating that the probe is inside the water. The voltage at the input pin is given by:

$$V_{IL} = \frac{R_w}{R_w + 10M\Omega} \times V_{cc} \quad (3)$$

where R_w is the resistance of water between the probes. The maximum water resistance (maximum separation height between OVERFLOW and COM), for a given liquid at a given temperature is

$$R_{W(\max)} = \frac{10M\Omega \times V_{IL(\max)}}{V_{cc} - V_{IL(\max)}} \quad (4)$$

$R_{w(max)} = 4.29M\Omega$,

For tap water at 25°C (Table 1), maximum height of the tank in which the system would function optimally would be,

$$\frac{4.29M\Omega}{20k\Omega / cm} = 214.3cm \approx 2m$$

Table 2 presents the truth table of the system, showing all the possible combination of the states of the probes.

TABLE II

TRUTH TABLE OF THE SYSTEM

Overflow	HIGH	LOW	Pump	Alarm
0	0	0	ON	OFF
0	0	1	ON	OFF
0	1	0	X	X
0	1	1	OFF	OFF
1	0	0	X	X
1	0	1	X	X
1	1	0	X	X
1	1	1	OFF	ON

'X' stands for "don't care condition". Under normal operations, such states would never occur. They are therefore used to flag water detection errors.

3) Input/Output Buffers

A buffer is a logic circuit designed to have greater output current and/or voltage capability. They are always used to interface an external device with a microcomputer. Two pieces of 74LS125 buffers are employed in this design; it is a tri-state buffer chip with three possible states (low, high and high impedance)[6]. The water level signals from the water detection unit are connected to the input buffer, while the control signal to enable and disable the input buffer comes from the microcomputer. The signals from the microcomputer to control the switching unit, alarm and LED display are made available through the output buffer.

4) The Microcomputer

The Microcomputer used for the control processes is Pentium 4, Intel architecture 32-bit. Inputs signals from the transducers are interfaced to the control computer via the parallel port. Based on the control algorithm implemented on the software, actuators are instructed. The microcomputer is also capable of detecting power availability in the external devices and proper cable connection [9].

5) The Parallel Port

The standard parallel port is accessible through a 25-pin D-type female connector at the back of the microcomputer. It is used to interface the external devices with the microcomputer. The parallel port is made of 8 to 12 output bits and 5 to 9 or 5-17 input bit for uni-directional and bi-directional ports respectively. Figure 3 shows the structure of the standard parallel port.

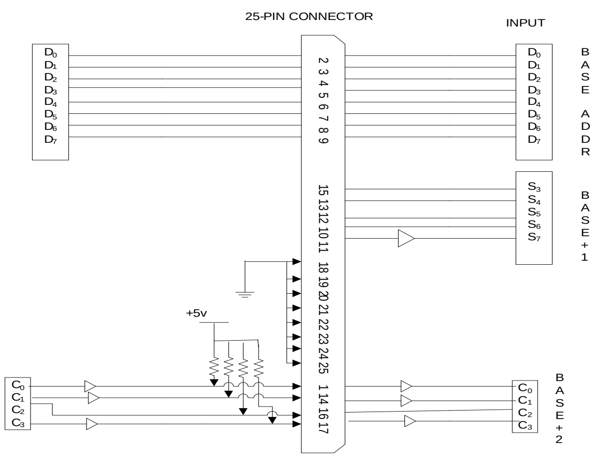

Figure 3. Parallel port hardware

6) Power/Cable Detection Unit

This circuitry is incorporated to enable the microcomputer know whether there is power supply to the external device or not, and also if it is properly connected to the parallel port in order to improve the efficiency and reliability of the entire system. In this design, bit 6 of STATUS port (pin 12) was grounded directly while, bit 7 (pin 11) was grounded through C9013 transistor switch whose base current is supplied by the supply voltage(V_{cc}) through a 1kΩ resistor as shown in Figure 4.

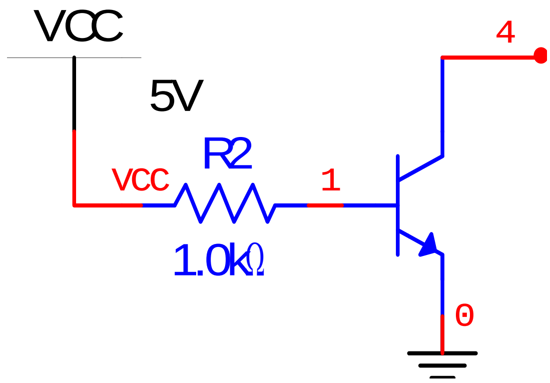

Figure 4. Power detection unit

When the cable is not properly connected, these pins will assume 01 status, and 00 status when the cable is connected but the power is switched off. Finally, they assume 10 status when the cable is connected and the power is on. Hence, the exact problem is detected and the operator is alerted. No further process takes place until the fault is cleared.

7) The Switching Unit

The switching unit performs the major function of switching the pump on/off. It is driven by pin 2 of the parallel port. Transistor switching is used to provide the current necessary to energize the relay coil. Two multipurpose transistors, 2N2222A in the arrangement shown in Figure 5, eliminate the possibility of false triggering due to reverse bias current and improve the switching speed. The relay used in this design is operated by +6V dc to enable the switching on of 220V ac supply that drives the pump.

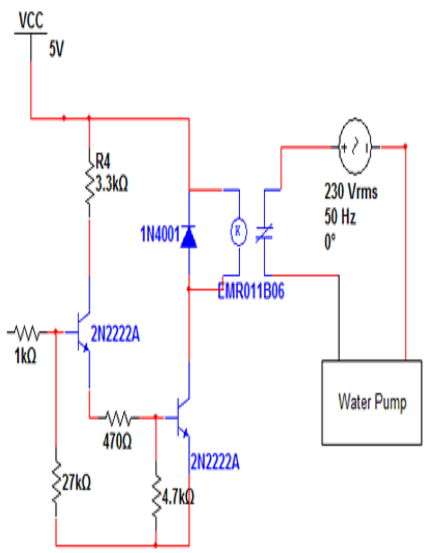

Figure 5: Switching unit

The minimum high output voltage from the output buffer, $V_{OH\,(min)}$ is 3.5 V (as obtained from manufacturer data sheet).

R_1 and R_2 form a voltage divider across the base of transistor Q1 that gives base voltage

$$V_{b1} = \frac{R_2}{R_1 + R_2} \times V_{0H\,(\min)} \quad (5)$$
$$= \frac{27\,k\Omega}{(1+27)k\Omega} \times 3.5 = 3.375\,V$$

The emitter voltage V_{E1} of transistor Q1 is:

$$V_{E1} = V_{b1} - V_{BE} \quad (6)$$
$$V_{E1} = 3.375 - 0.7 = 2.675\ V$$

where $V_{BE} = 0.7$ (Diode voltage drop)

Similarly, R_4 and R_5 constitute voltage divider across the base of transistor Q2, then

$$V_{b2} = \frac{R_5}{R_4 + R_5} \times V_{0H\,(\min)} = 2.43V$$

Hence the base current,

$$I_{B2} = \frac{V_{b2}}{R_4 + R_5} \quad (7)$$
$$= 5.2\,\mu A$$

The collector current,

$$I_{C2} = hfe \times I_{B2} \quad (8)$$

where hfe is the current gain of transistor Q2.

Therefore, $I_{C2} = 239 \times 5.2\,\mu A = 1.2\,mA$

$$I_{C2(sat)} = V_{cc} / R_c \quad (9)$$

where, R_c is the coli resistance (100Ω) . Hence, $I_{c2(sat)} = 0.6mA$

8) LED Display and Alarm Units

This unit shows the relative level of water in the tank. It consists of three light emitting diodes (LEDs), orange, green and red. The orange LED is switched on when the water level is below the LOW probe, green LED is on when the water level is between the LOW and HIGH probes, while the red LED light when the water level is above the HIGH probe. All the three LEDs are switched on when the water level reaches the OVERFLOW probe.

Alarm unit is designed to give an audible tone upon the occurrence of a serious problem in the system, e.g. possibility of water spillage from the tank or pump failure. Once the alarm is triggered, it remains on until the user acknowledges the accompanied command (click OK or press ENTER). The alarm unit is designed using a 555-timer chip and configured to operate as an astablemultivibrator.

B. Software Design

Software is a program, stored in the memory of a microcomputer which directs the microcomputer on what to do at any given point in time. In every real-time control system, the ingenuity in the software design determines the intelligence of the system. The microcomputer based water pump actuator driving software was written in object oriented programming language, C++ [4,5]. The design can be divided into three sections, viz, the graphical user interface (GUI), the input/output (I/O) routine and the Mouse/Keyboard routine.

1) The Graphical User Interface (GUI)

The GUI is a graphical display on the monitor to ensure easy and effective communication between the computer (software) and the user. The user interacts with the computer through GUI to effect efficient operation of the system. The graphic display is designed using the rich graphic command in Borland Graphic Interface (BGI) incorporated in the Borland C++ compiler.

(a) The Welcome Window: This is the first screen display when the program is started. It contains a welcome massage, the title of the software and the name of the designer. There are three buttons, viz, o the “EXIT” to terminate the program, “MENU” to jump to the menu screen and “CONTINUE” to move to the next screen which is the introduction

(b) The Introduction: This window contains an introduction to the system design and how it operates.

(c) The Menu Window: This displays the menu function for the user to select a mode of operation of choose to quit the program. There are two mode of operation of the system viz, the automatic water pump control and the automatic devices control mode.

(d) The Automatic Water-Pump Control Mode: This screen displays a tank with water running to depict the kind of operation. There is a pump status display on the screen to show that the pump is ON/OFF. There is also a “RESET” button to clear the over-riding effect of ON and OFF button, and to return control to automatic operation [10].

(e) The Automatic Device Control Mode: In this mode, the system can be used to switch ON/OFF any electrical device connected to it automatically based on time sharing. The screen display provide window for entering the ON/OFF period and DELAY time. It also display the date and time of initiation of the operation.

(f) Error Message Boxes: The program is designed to trap errors and inform the user of such error. Serious error like, possible overflow from the tank and pump failure are accompanied with an alarm while, less serious errors are simply displayed on the screen with the aid of a dialogue box carrying the error message. Error trapped by the software includes, mouse error (not detected), no power supply to the external device, improper cable connection, water –overflow, pump failure and water detection error.

2) Input/ Output Routine

Input and output routine involves the communication between the microprocessor and the external device via the parallel port. It includes the acquisition of probes status from the input buffers through the status port and sending out of control signals via the DATA port to switch on/off the pump/electrical device, alarm and the LEDs. The parallel port is accessed using the *inportb (Address)*and *outportb (Address, value)* C++ commands. The LOW probe is connected to bit 3, High probe to bit 4, OVERFLOW probe to bit 5, while the power detection transistor is connected to bit 7 of the STATUS port.

C. Keyboard and Mouse Routines

This routine is incorporated in order to detect all keyboard command including the non-ASCII keys. Besides clicking, buttons can be activated by pressing ALT+ underlined letter of interest, as found in windows programs. This feature allows the user to use the program without the mouse. The mouse routine ware is incorporated using a mouse library shareware. The program was compiled into a stand-alone executable module; this allows the program to be run on any computer with or without C++ compiler installed

III. LABORATORY PERFORMANCE

The power system cable, parallel port cable and the water sensing probes were connected to their respective connecting points at the back of the device. The device was switched on and the program was launched. In the automatic water pump control mode, when no probe was inserted in the tank, the pump and the orange LEDs came on. When the LOW probe was dipped into the water tank, the orange LED went off and the green came on. The HIGH probe was then lowered into the tank, the green LED switched to RED and the pump stop pumping. When the OVERFLOW probe was inserted, the pump remain off, while all the three LEDs and the alarm came on, consequently, an error message was displayed on the screen, prompting the user to click OK button. The probes were then removed in turn and the processes reversed, the pump remains off until the LOW probe was removed from the water tank. The complete circuit diagram of the system is shown in figure 12.

IV. CONCLUSION

From the results obtained, we can conclude that the microcomputer based water –pump actuator performed its intended function satisfactorily and has higher efficiency than other existing ones in the market. The components used in this design were cheap and readily available, and with wide spread use of computer together with an easy-to-use program, the device will be useful in homes, industries, hospitals and schools to provide water at reduced cost and minimum energy input.The device has also the capability of controlling liquids other than water, which can conduct electricity and whose conductivityiswithin an acceptable range. This finds a useful a pplication in chemical/petrochemical industries.

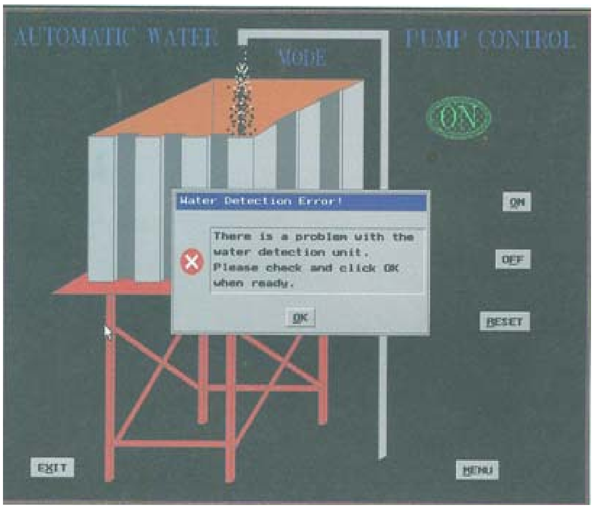

Figure 7. Snapshot of user interface Automatic Water Pump Control Mode

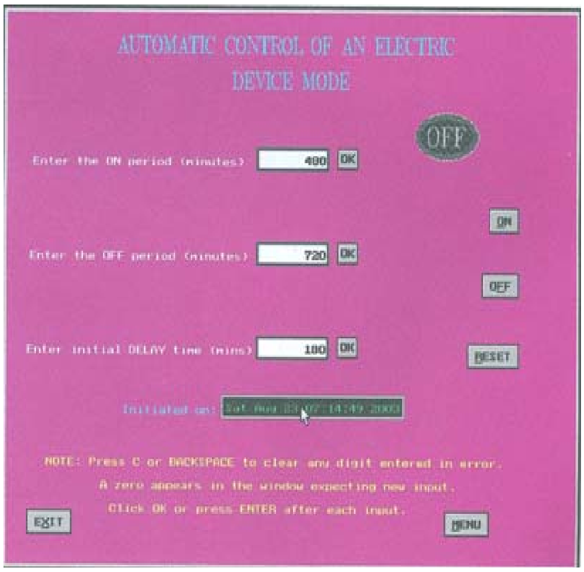

Figure 8. Snapshot of user interface: Automatic Control of an Electric Device Mode

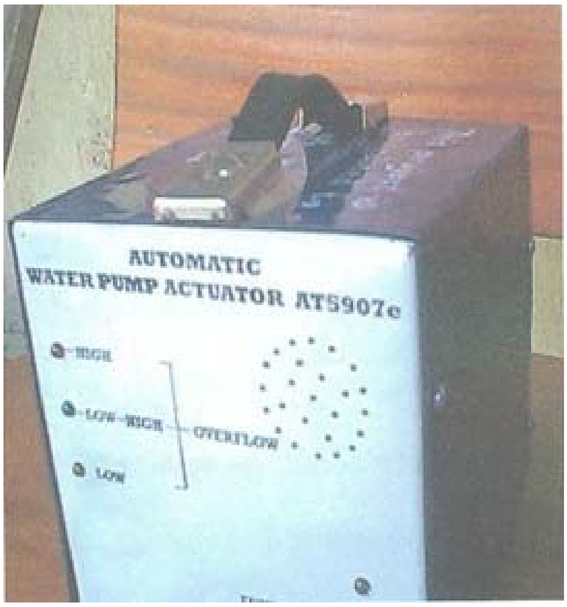

Figure 9. The constructed work

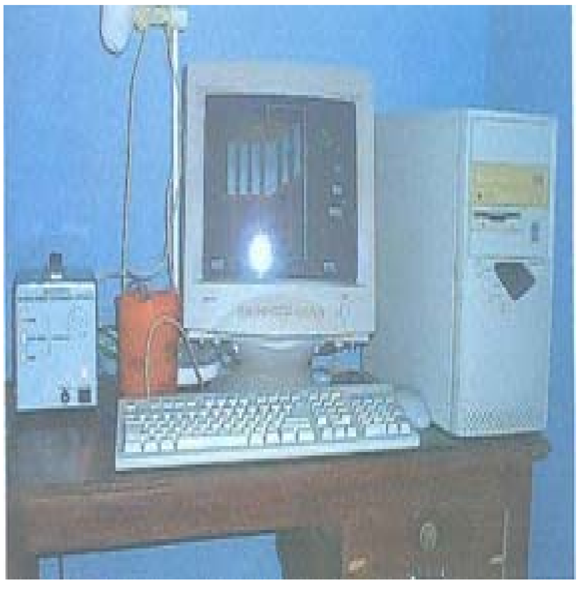

Figure 10. The Microcomputer and the Actuator

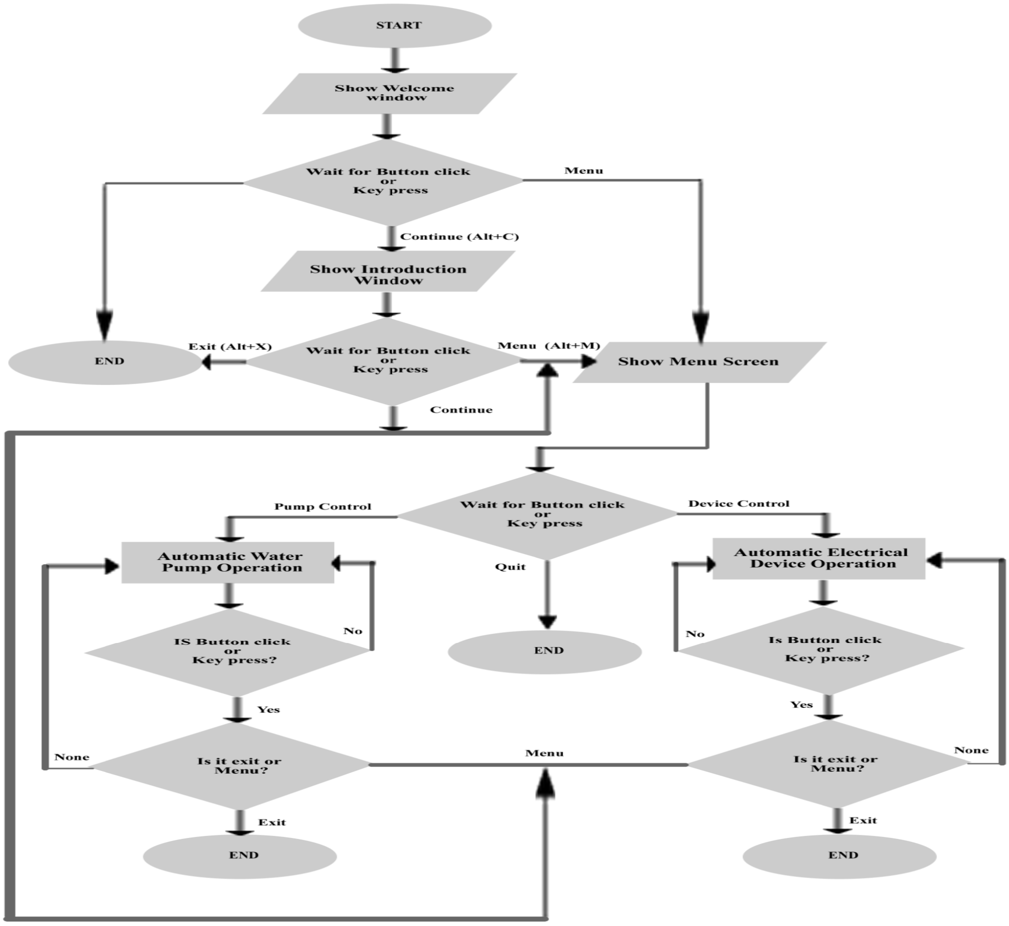

Figure 11. Flowchart of the entire processes

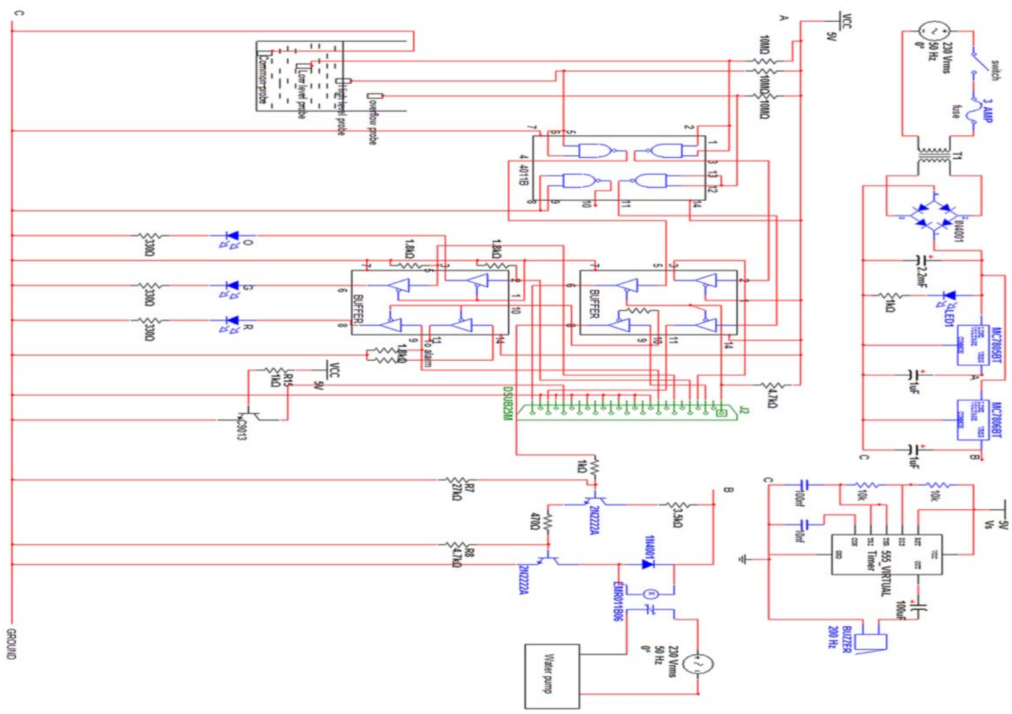

Figure 12. The complete circuit diagram of the water pump actuator

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