International Journal of Research in Engineering, Science and Management
Volume-2, Issue-5, May-2019
www.ijresm.com | ISSN (Online): 2581-5792

Multipurpose Ultrasonic Dishwasher

Jimmichan Joseph[1], Justin V. Jose[2], Joseph Joseph[3], Melbin Joseph[4], Jiss Paul[5]
[1,2,3,4]*B.Tech. Student, Dept. of Electronics and Communication, MA College of Engg., Kothamangalam, India*
[2]*Professor, Dept. of Electronics and Communication, MA College of Engg., Kothamangalam, India*

***Abstract*: A high tech ultrasonic cleaner works as a result of sound waves being introduced into a cleaning liquid by means of a series of transducers mounted onto the cleaning tank. The sound travels throughout the ultrasonic cleaner's tank creating waves of compression and expansion in the liquid. In the compression wave, the molecules of the cleaning liquid are compressed together tightly. Conversely, in the expansion wave, the molecules are rapidly pulled apart. The expansion is so dramatic that molecules are ripped apart, creating microscopic bubbles. The bubbles are unable to be seen by the naked eye because they are so small and exist for only a split second of time. The bubbles contain a partial vacuum while they exist. As the pressure around the bubbles becomes greater, the fluid around the bubble rushes in, collapsing the bubble very rapidly. We are taking advantage of the associated phenomena to deliver ultra-precise cleaning capabilities. When the bubbles collapse, a jet of liquid is created that travels at an extremely high rate. An associated rise in temperature as high as 5000°C occurs; this is roughly the temperature of the surface of the sun. This extreme temperature, combined with the liquid jet's velocity provides a very intense cleaning action in a very concentrated area that ultrasonic manufacturers can use. Because of the very short duration of the bubble expansion and collapse cycle, the liquid surrounding the bubble quickly absorbs the heat and the area cools rapidly. As a result, the tank and liquid only becomes warm and does not heat excessively due to the introduction of parts in the ultrasonic washing equipment.**

***Keywords*: Transducer, Solenoid valve, Ultrasound, PIC controller, Relay driver.**

1. Introduction

Ultrasonic cleaning is a process that uses ultrasound (usually from 20–40 kHz) to agitate a fluid. The ultrasound can be used with just water, but use of a solvent appropriate for the item to be cleaned and the type of soiling present enhances the effect. Cleaning normally lasts between three and six minutes, but can also exceed 20 minutes, depending on the object to be cleaned [1].

Ultrasonic cleaners are used to clean many different types of objects, including jewelry, lenses and other optical parts, watches, dental and surgical instruments, tools, coins, fountain pens, golf clubs, fishing reels, window blinds, firearms, car fuel injectors, musical instruments, gramophone records, industrial parts and electronic equipment. They are used in many jewelry workshops, watchmakers' establishments, and electronic repair workshops.

Here we explore the possibilities of integrating Ultrasound into our day to day using machine like a dishwaher.

Ultrasonic cleaning uses cavitation bubbles induced by high frequency pressure (sound) waves to agitate a liquid. The agitation produces high forces on contaminants adhering to substrates like metals, plastics, glass, rubber, and ceramics. This action also penetrates blind holes, cracks, and recesses. The intention is to thoroughly remove all traces of contamination tightly adhering or embedded onto solid surfaces. Water or solvents can be used, depending on the type of contamination and the workpiece. Contaminants can include dust, dirt, oil, pigments, rust, grease, algae, fungus, bacteria, lime scale, polishing compounds, flux agents, fingerprints, soot wax and mold release agents, biological soil like blood, and so on. Ultrasonic cleaning can be used for a wide range of workpiece shapes, sizes and materials, and may not require the part to be disassembled prior to cleaning [5].

Objects must not be allowed to rest on the bottom of the device during the cleaning process, because that will prevent cavitation from taking place on the part of the object not in contact with solvent

A dishwasher is a machine for cleaning dishware and cutlery automatically. Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water, typically between 45 and 75 °C (110 and 170 °F), at the dishes, with lower temperatures used for delicate items.

2. Literature Survey

Worapol Tangsopha, Jatuporn Thongsri et.al [1] presents a new study which shows that increasing power of piezoelectric transducers can lead to increasing the power of acoustic pressure; however, it cannot lead0 to the change of acoustic pressure distribution. To change the acoustic pressure distribution, the difference of frequencies is required. For such typical ultrasonic cleaning tank, the position of the highest cleaning efficiency is at the middle of the tank. Finally, the result can lead to the optimization between the power and frequency of ultrasonic to reach the maximum cleaning efficiency.

Chankit Buasri and Anuwat Jangwanitlert et.al [2] presents the comparison of Control Signal Patterns in ultrasonic cleaner by using the microcontroller for generating Pulse-Width Modulation (PWM), Phase-Shift PWM control (PS-PWM) and Pulse Density Modulation (PDM) patterns. These control patterns are fed in the full-bridge inverter to drive the ultrasonic transducers. The resonant frequency of 50 kHz is tested in order to find the efficiency of ultrasonic cleaner which one should be the best. Ultrasonic transducer can generate ultrasonic wave to transfer electrical energy to mechanical energy. Cavitation and implosion are occurred in liquid when ultrasonic wave travels through liquid medium in the process of cleaning.

J R M Van Dam and B L J Gysen et. al [3] focus on incorporating the eddy current effect in the models and their effect on performance, as well as control methods to improve the performance and minimize energy consumption. The performance of a classical reluctance actuator is compared to a PM-biased topology which reduces the energy consumption. Modeling is performed using transient, axisymmetric, nonlinear finite element (FE) simulations, coupled to Matlab-Simulink. Actuator topology and constraints Two single-coil reluctance actuators are shown in Fig. 1. One is a classical reluctance actuator with a stationary coil and a moving plunger (CLA). A second actuator includes a permanent magnet atop the core (PMB) to allow zero-power latching by means of a passive attraction force. In addition, the actuator height and diameter are 16 and 13.

3. Experimental Setup

A. Methodology

The experimental setup contains the microcontroller which is the heart of the system, managing the overall operation of the system. It provides an attractive user interface to interact with external world. The Program is written to help the user use the system effectively directing them to use the system without any problem.

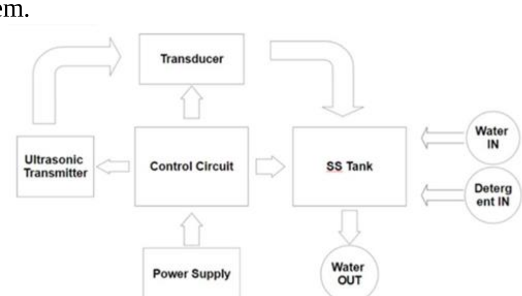

Fig. 1. Block diagram

After the dishes are made input the control circuit board is turned on. Now the soap inlet valve which outputs the required amount of soap is turned on. After the required amount of soap is flown inside the pipe the water inlet valve is turned on. The water is continuously flown into the tank through the tap attached to the pipe, along with the liquid soap. when the water level reaches the required height the water level sensor senses it and turns off the water inlet valve. The experimental setup contains the microcontroller which is the heart of the system, managing the overall operation of the system. It provides an attractive user interface to interact with external world. The Program is written to help the user use the system effectively directing them to use the system without any problem.

B. Control Board

The circuit consists of a microcontroller Pic16f877A, a relay driver ULN2003,4 6v relays, a 16 Mhz crystal, 2 22pf capacitors,3 100uf 25v capacitors,4 pushbuttons,4 10k resistors, an LED,1 330 resistor, a buzzer. The 1,2,3 and 4 pins of the relay driver are respectively connected to the 19,20,21 and 22 pins of the microcontroller. The output of the relay driver is taken through the 16,15,14 and 13 pins of the relay driver which is respectively connected to the 4 relays. The 4 relays are connected with 4 connectors at normally open pin and a 12 v connector at the common pin except the relay 3 as the common pin of relay 3 is connected with a 230v AC supply. Relay 1 is connected with a water inlet solenoid valve at normally open and respectively relay 2 with soap inlet solenoid valve, relay 3 with ultrasonic transducer and relay 4 with water outlet solenoid valve.

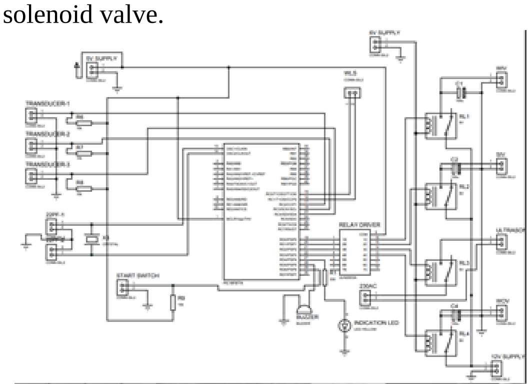

Fig. 2. Schematic of Control Board

The LED is connected at 27th pin of microcontroller with a 330 resistor at negative terminal of led. The buzzer is connected at the 28th pin of the microcontroller. The start push button is connected at the 29th pin of the microcontroller. The water level switch is connected at the 15 and 16 pins of the microcontroller. The 3 push buttons which set the timing of the ultrasonic transducer is connected at the 17, 18 and 23 of the microcontroller. The crystal is connected at the 13 and 14 pins of microcontroller with 2 22pf capacitors at each end of the crystal which are grounded. The 11 and 32 pins of the microcontroller is connected to the 5v supply along with the pin 1 which is the reset pin. The 12 and 31 pin are the ground.

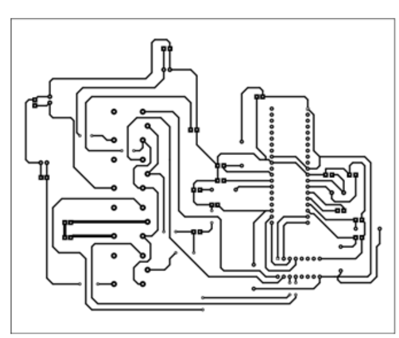

Fig. 3. PCB Layout

International Journal of Research in Engineering, Science and Management
Volume-2, Issue-5, May-2019
www.ijresm.com | ISSN (Online): 2581-5792

The PIC microcontroller PIC16f877a is one of the most renowned microcontrollers in the industry. This microcontroller is very convenient to use, the coding or programming of this controller is also easier. One of the main advantages is that it can be write-erase as many times as possible because it use FLASH memory technology. It has a total number of 40 pins and there are 33 pins for input and output. PIC16F877A is used in many pic microcontroller projects. PIC16F877A also have many applications in digital electronics circuits.

PIC16f877a finds its applications in a huge number of devices. It is used in remote sensors, security and safety devices, home automation and in many industrial instruments. An EEPROM is also featured in it which makes it possible to store some of the information permanently like transmitter codes and receiver frequencies and some other related data. The cost of this controller is low and its handling is also easy. Its flexible and can be used in areas where microcontrollers have never been used before as in coprocessor applications and timer functions etc.

There are 40 pins of this microcontroller IC. It consists of two 8 bit and one 16-bit timer. Capture and compare modules, serial ports, parallel ports and five input/output ports are also present in it.

The ULN2003 is an array of seven NPN Darlington transistors capable of 500 mA, 50 V output. It features common-cathode flyback diodes for switching inductive loads. It can come in PDIP, SOIC, SOP or TSSOP packaging. In the same family are ULN2002A, ULN2004A, as well as ULQ2003A and ULQ2004A, designed for different logic input levels. A Darlington transistor (also known as Darlington pair) achieves very high current amplification by connecting two bipolar transistors in direct DC coupling so the current amplified by the first transistor is amplified further by the second one.

ULN2003 IC is one of the most commonly used Motor driver IC. This IC comes in handy when we need to drive high current loads using digital logic circuits like Op-maps, Timers, Gates, Arduino, PIC, ARM etc. For example, a motor that requires 9V and 300mA to run cannot be powered by an Arduino I / O hence we use this IC to source enough current and voltage for the load. This IC is commonly used to drive Relay modules, Motors, high current LEDs and even Stepper Motors.

2-Channel 5V Relay Module is a relay interface board, it can be controlled directly by a wide range of microcontrollers such as Arduino, AVR, PIC, ARM and so on. It uses a low level triggered control signal to control the relay. Triggering the relay operates the normally open or normally closed contacts. It is frequently used in an automatic control circuit. To put it simply, it is an automatic switch to control a high-current circuit with a low-current signal.

The relay module is an electrically operated switch that allows you to turn on or off a circuit using voltage and/or current much higher than a microcontroller could handle. There is no connection between the low voltage circuit operated by the microcontroller and the high power circuit. The relay protects each circuit from each other.

Each channel in the module has three connections named NC, COM, and NO. Depending on the input signal trigger mode, the jumper cap can be placed at high level effective mode which ‘closes’ the normally open (NO) switch at high level input and at low level effective mode which operates the same but at low level input.

C. Mechanical Structure

Stainless steels are most notable for their corrosion resistance, which increases with increasing chromium content. Additions of molybdenum increase corrosion resistance in reducing acids and against pitting attack in chloride solutions. Thus, there are numerous grades of stainless steel with varying chromium and molybdenum contents to suit the environment the alloy must endure. Stainless steel's resistance to corrosion and staining, low maintenance, and familiar luster make it an ideal material for many applications where both the strength of steel and corrosion

Fig. 4. Stainless Steel Tank

Stainless steels are rolled into sheets, plates, bars, wire, and tubing to be used in: cookware, cutlery, surgical instruments, major appliances; construction material in large buildings, such as the Chrysler Building; industrial equipment (for example, in paper mills, chemical plants, water treatment); and storage tanks and tankers for chemicals and food products (for example, chemical tankers and road tankers). Stainless steel’s corrosion resistance, the ease with which it can be steam cleaned and sterilized, and no need for surface coatings has also influenced its use in commercial kitchens and food processing plants. Stainless steel is commonly used in kitchens and commercial applications because it represents a good trade-off between cost, usability, durability, and ease of cleaning. Most stainless steel sinks are made by drawing a sheet of stainless steel over a die. Some very deep sinks are fabricated by welding. Stainless steel sinks will not be damaged by hot or cold objects and resist damage from impacts. One disadvantage of stainless steel is that, being made of thin metal, they tend to be noisier than most other sink materials, although better sinks apply a heavy coating of vibration-damping material to the underside of the sink.

Metal rods are metals and alloys designed in the pattern of round bars or rod, rectangular or flat bars, square bars, hexagons, and other patterns of bar stock. These shapes also come in billet form and generally include a cross-section based on the shape of rod or bar stock. Reinforcing bars are also a type of metal rods that are used to give strength or internally sustain the concrete and masonry structures. Some other forms of metal rods include coil stock and hollow tube stock.

Rods made of ferrous metals and alloys are iron based. Some common ferrous metals and alloys used to make rods are carbon steel, stainless steel, alloy steel, cast iron, tool steel, and cast steel. Plain carbon steels are based on iron, carbon, and other alloying elements in small varying amounts. Alloy steel is used in a variety of industrial applications and can be fabricated easily by machining, forming, casting, and welding.

An alloy of carbon and iron, tool steel is known for its high levels of hardening and property alloying elements. The alloy exhibits superior wear resistance, however it is difficult to fabricate in its hardened form. Cast iron is another ferrous metal, which is used in metal rods. An iron alloy, carbon alloy contains high amount of carbon. Cast steel is an alloy, which is produced by pouring molten iron into a mold.

Fig. 5. Square Pipe

D. *Water and Soap Inlet/Outlet System*

Water and soap inlet/outlet system consists of solenoid valves, water level switch and buzzer system. If control board is the heart of Ultrasonic Dishwasher, inlet/outlet system is the valves.

Water and soap inlet/outlet setup consists of complex network of pipes and connectors. Each inlet ie, water and soap is governed by our control board using solenoid valves. Outlet system is also governed by control board using solenoid valve. Control board controls which valve turns on at a time and the amount of time the valve turns on. We are achieving this by using PIC16F877A microcontroller.

Soap inlet valve is turned on at first. We are using a funnel like structure before the solenoid valve so that the soap or detergent is stored there. When system is turned on the solenoid valve turns on soap is introduced into the inlets system. The amount of time soap inlet turns on is set to 5sec. The flow of soap or detergent depends on the viscosity of the soap or detergent.

Water inlet valve is turned on next. Water inlet controlling solenoid valve is connected to a water source using a hose. Water inlet valve is turned on and water is introduced to the inlet system. Water inlet system is placed before the soap inlet valve, so that water can be mixed with the soap or detergent and no wastage of soap or detergent is occurring. Water inlet valve is kept open until water level switch is triggered.

Water outlet valve is opened after the cycle of ultrasound. Water outlet valve is placed under the tank, so that we can use the advantage of gravity to our cause. Water outlet is turned kept open for a particular amount of time which is sufficient enough to drain all the water inside the tank.

A solenoid valve is an electromechanical device in which the solenoid uses an electric current to generate a magnetic field and thereby operate a mechanism which regulates the opening of fluid flow in a valve.

Solenoid valves differ in the characteristics of the electric current they use, the strength of the magnetic field they generate, the mechanism they use to regulate the fluid, and the type and characteristics of fluid they control. The mechanism varies from linear action, plunger-type actuators to pivoted-armature actuators and rocker actuators. The valve can use a two-port design to regulate a flow or use a three or more port design to switch flows between ports. Multiple solenoid valves can be placed together on a manifold.

Fig. 6. Solenoid Valve

There are many valve design variations. Ordinary valves can have many ports and fluid paths. A 2-way valve, for example, has 2 ports; if the valve is open, then the two ports are connected and fluid may flow between the ports; if the valve is closed, then ports are isolated. If the valve is open when the solenoid is not energized, then the valve is termed normally open (N.O.). Similarly, if the valve is closed when the solenoid is not energized, then the valve is termed normally closed

The core or plunger is the magnetic component that moves when the solenoid is energized. The core is coaxial with the solenoid. The core's movement will make or break the seals that control the movement of the fluid. When the coil is not energized, springs will hold the core in its normal position.

The core tube contains and guides the core. It also retains the plugnut and may seal the fluid. To optimize the movement of the core, the core tube needs to be nonmagnetic. If the core tube were magnetic, then it would offer a shunt path for the field lines [10]. In some designs, the core tube is an enclosed metal shell produced by deep drawing. Such a design simplifies the sealing problems because the fluid cannot escape from the enclosure, but the design also increases the magnetic path resistance because the magnetic path must traverse the thickness of the core tube twice: once near the plugnut and once near the core. In some other designs, the core tube is not closed but rather an open tube that slips over one end of the plugnut.

To retain the plugnut, the tube might be crimped to the plugnut. An O-ring seal between the tube and the plugnut will prevent the fluid from escaping.

A float switch is a device used to sense the level of liquid within a tank the switch may actuate a pump, an indicator, an alarm, or other device it can be easily converted from normally open to normally close by inverting the float note: Because the current that the switch can carry is much little(05a), you must use a relay or connector when it is connected by a load.

Fig. 7. Water Level Switch

E. *Ultrasonic Transducer Unit*

Ultrasonic transducers convert AC into ultrasound, as well as the reverse. Ultrasonics, typically refers to piezoelectric transducers or capacitive transducers. Piezoelectric crystals change size and shape when a voltage is applied; AC voltage makes them oscillate at the same frequency and produce ultrasonic sound. Capacitive transducers use electrostatic fields between a conductive diaphragm and a backing plate.

The beam pattern of a transducer can be determined by the active transducer area and shape, the ultrasound wavelength, and the sound velocity of the propagation medium. The diagrams show the sound fields of an unfocused and a focusing ultrasonic transducer in water, plainly at differing energy levels.

Fig. 8. Transducer Unit

Since piezoelectric materials generate a voltage when force is applied to them, they can also work as ultrasonic detectors. Some systems use separate transmitters and receivers, while others combine both functions into a single piezoelectric transceiver.

Ultrasound transmitters can also use non-piezoelectric principles. such as magnetostriction. Materials with this property change size slightly when exposed to a magnetic field, and make practical transducers.

A capacitor ("condenser") microphone has a thin diaphragm that responds to ultrasound waves. Changes in the electric field between the diaphragm and a closely spaced backing plate convert sound signals to electric currents, which can be amplified.

The figure schematically depicts an oscillator circuit for driving a piezoelectric transducer to excite vibrations in a mechanical structure. The circuit was designed and built to satisfy application-specific requirements to drive a selected one of 16 such transducers at a regulated amplitude and frequency chosen to optimize the amount of work performed by the transducer and to compensate for both (1) temporal variations of the resonance frequency and damping time of each transducer and (2) initially unknown differences among the resonance frequencies and damping times of different transducers.

The diaphragm (or membrane) principle is also used in the relatively new micro-machined ultrasonic transducers (MUTs). These devices are fabricated using silicon micro-machining technology (MEMS technology), which is particularly useful for the fabrication of transducer arrays. The vibration of the diaphragm may be measured or induced electronically using the capacitance between the diaphragm and a closely spaced backing plate (CMUT), or by adding a thin layer of piezo-electric material on diaphragm (PMUT). Alternatively, recent research showed that the vibration of the diaphragm may be measured by a tiny optical ring resonator integrated inside the diaphragm (OMUS).

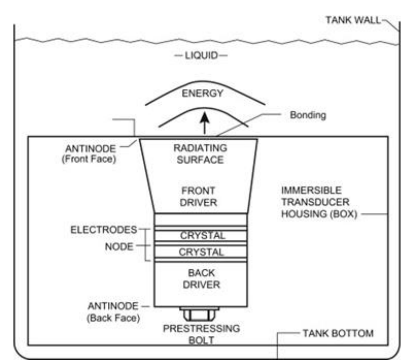

Fig. 9. Schematic Transducer

Systems typically use a transducer which generates sound waves in the ultrasonic range, above 18 kHz, by turning electrical energy into sound, then upon receiving the echo turn the sound waves into electrical energy which can be measured and displayed.

In other words, the circuit is designed to adjust itself to optimize the performance of whichever transducer is selected at any given time. The basic design concept may be adaptable to other applications that involve the use of piezoelectric transducers in ultrasonic cleaners and other apparatuses in which high-frequency mechanical drives are utilized.

4. Results

After thorough testing of our Multipurpose Ultrasonic Dishwasher, we obtained the results we expected. We were successfully able to clean the test dishes we placed in the dishwasher. The test dishes where cleaned thoroughly and clearly. With our prior studies we came to understand that, a normal dishwasher uses upto 6 to 7 liters of water in for a cleaning cycle. With our Ultrasonic Dishwasher we were able to reduce the water used to 4 to 5 liters. Also we found that water from the second cleaning cycle of our dishwasher can be reused upto some extant. Thereby increasing water efficiency drastically.

Since we are making advantage of agitation of water, we are able to obtain the same results of a normal dishwasher with using lesser amount of dishwasher detergent. Thereby increasing the eco friendliness of our product.

5. Conclusion

Ultrasonic cleaning is a process that uses ultrasound to agitate a fluid cleaning normally lasts between 3 and 6 minutes, but can also exceed 20 minutes, depending on the input. We have successfully created a control circuit which includes a PIC16F877A, ULN2003, and successfully tested the circuit. The circuit was incorporated with solenoid valves and ultrasonic transducer. We are using ultrasonic transducer with 40Khz and 50W. We were able to incorporate the solenoid valve, ultrasonic transducers along with control circuit to the main stainless steel tank. A test phase was conducted and the results were promising. It is recommended to avoid using flammable cleaning solutions because ultrasonic cleaners increase temperature even when not equipped with a heater. When the unit is running, inserting your hand into the solution could cause burning due to the temperature; discomfort and skin irritation can also occur.

References

[1] Azar J. U. Duncombe, “Infrared navigation—Part I: An assessment of feasibility,” *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959.
[2] Williams, Douglas, “Guide to Cleaner Technologies: Cleaning and Degreasing Process Changes. Washington DC: United States Environmental Protection Agency, 1994.
[3] How to Simulate PIC Microcontroller in Proteus Design Suite 8 - Circuits Gallery".
[4] PIC micro Family Tree", PIC16F Seminar Presentation "Archived copy"
[5] C. Buasri and A. Jangwanitlert, "Comparison of Switching Strategies for an Ultrasonic Cleaner," *2008 5th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology*, Krabi, 2008, pp. 1005-1008.