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Design and Construction of a Hybrid Hand Wash System, with a Temperature Sensor

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Abstract:

Some contagious diseases like the novel COVID-19 viral disease are contacted through touch and contact with infected patients. The world health organization have guidelines of which one of them is advocating for regular cleaning of hands to help bring to a minimal level, the chances of a person being infected with a disease. Pouring of sanitizers from containers and use of normal wash hand basins would require manual intervention which would in turn help to spread infectious diseases amongst users of such facility. In the present project, we proposed a novel construction of a touchless hand sanitizer, soap dispenser, hand wash, hand drier and temperature sensing system that will help to reduce the risk due to contact. Unlike the conventional manual hand washing and drying machine, the hand washing system in this study is touch-less i.e. no contact is made between the user and the designed machine. The machine comprises of a system with an upper compartment and a lower compartment. The upper compartment is square shaped part that houses the infrared temperature sensor situated in front, hand sanitizer, soap dispenser, a blower for hand drying and the upper tank with a solenoid pump for injecting water into the hand of the user. The lower compartment is made up of a box shaped structure in which the hand washing basin and a lower tank for collection of dirty water is housed. Also the hand drier chamber comprises of air blowing compartment for blowing air through the hand drying compartment. The present work has effectively presented a working and very novel low cost sensor controlled hand wash system that can be comfortably used in our immediate environment.

Keywords: Soap dispenser, temperature sensor, sanitizer machine, Solenoid pump, hand drier.

1.0. INTRODUCTION AND BACKGROUND

One of the major mode of transmission of infectious diseases is through our hand, especially for those in public residences, shopping centers, bank premises, market places e.tc. who live very close to each other. Cases of contamination is very high due to the frequent contacts amongst persons and surfaces. Washing the hands is an important aspect of human health and this is because many infectious diseases can be transmitted through a contaminated hand that is usually as a result of a poor hand hygiene practice. The simplest and cheapest means of maintaining a proper hand hygiene is through hand washing.[1]

There has been an increased availability of sanitizing products in the recent years. Hand sanitizing products are advantageous in the sense that they seem to be more reliable, faster and are much easier to use. In the case of unavailability of water, they provide another reliable means of hand hygiene. For public places like health centers, hospitals, stadiums etc. the use of hand sanitizers is regarded as an effective hand hygiene standard protocol. It is already a common knowledge that the advent of COVID-19 changed our lives in an immense speed. Proper hand hygiene is not just a case for the field of medicine, it is also an important area of focus in the food industry where improper handling of food is an issue for concern. Poor food handling is among the major causes of food borne diseases in the food industry. The outbreak of Infectious gastrointestinal diseases were reported in England and the Wales from 1995 to 1996. About 22% of the outbreak were majorly foodborne while more than half of the infection were as a result of person to person infection.[2]

Hand washing and hand sanitizing machines are generally installed in hospitals, public offices, and toilets. Most of these machines require the users to touch the tap, and even hand sanitizer container. This constant touching of the soap dispenser, hand sanitizer and even the tap of the hand washing machine cause further spread of diseases, especially as the spread of the novel COVID-19 virus continue to spread all over the world.This project therefore wants to bridge the gap by designing an automated hand washing, hand sanitizing and hand drying machine with temperature sensor. This design will be such that the user will have every hand cleaning apparatus plus a temperature sensor in one machine and will not need to make contact or touch any part of the machine.[3]

2.0.DESIGN ANALYSIS AND SPECIFICATIONS OF THE HAND WASHING SYSTEM

2.1.Design Concepts and Considerations

The machine was first designed on proteus and simulated as well after which it was done on bread board for live simulation approach to avoid fatal mistakes during the main implementation on Vero board. The codes were written, compiled and debugged using Arduino IDE before it was copied to the microcontroller using the ATMEL ISP burner. The LCD module was first tested using the capture code and it responded. Other components were tested using the millimeter. Because power is vital part of electronics and every electronic circuit needs power to function the power supply was designed last because the net load of the circuit determines the power system and power rating of every system. The Transformer was selected based on the current and voltage of the system, bridge rectifier was also selected based on the transformer frequency, voltage and current of the system. The pumps and tap were tested to determine the pressure. The smoothing capacitors were used to remove ripples after rectification before voltage regulation. Below are approaches I took to design and implement the project.

2.2.Selection of the Microcontroller Board

The microcontroller board consists of the microcontroller, crystal oscillator circuit, the reset resistors, pull up and pull down resistors also attached to the microcontroller is the IR transmitter and receiver, LCD and the Keypad module. The microcontroller was used to implement the project is ATMEGA328P. This microcontroller was used because it bears the whole features needed for the project which include: Serial port, digital I/O, up to2234B of RAM, 32KB of ROM, 1B of EEPROM and Speed of up to 16MHZ. The above listed features made the microcontroller worthy of the design. Below is the circuit diagram of the microcontroller board. The best way to summarize this process is a block diagram.

2.2.1. Block Diagram

The diagram below is categorized into the basic blocks of the system to give a clearer explanation of the working principle of the system.

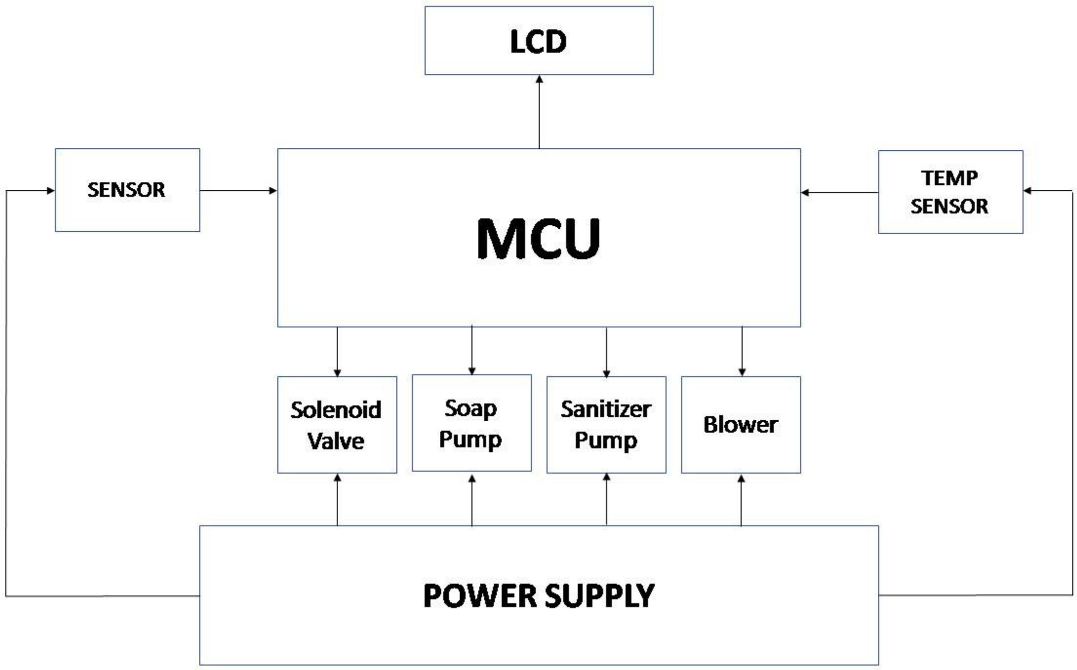

Fig. 2.1. Block Diagram

2.2.2. Block Description

Sensors: Ultrasonic sensors which detect obstacle (palm) using ultrasound principle. The sensors have two data pins each; TX and RX which stands for transmitter and receiver. The sensor sends ultrasound using the trigger protocol, and receives the ultrasonic ray using the echo protocol.

LCD: The LCD is the liquid crystal display which displays the temperature status.

Microcontroller (MCU): The microcontroller is the brain box of the system. The MCU accepts information from the transducers and sends commands to the modules.

Power Supply: The power supply is a hybrid system which consist of the battery, solar system and transformer for charging from the AC.

3.1. Clock Circuit

The clock signal is a periodic sequence of pulses. The ATMEGA328P can generate its own internal clock signal. In order to generate clock for the microcontroller, the output of the clock circuit must be connected to the XTAL and EXTAL on pin. A crystal and 2capacitors 30pF are require for the connection as shown in Figure The internal clock frequency is one-fourth of that supplied to the crystal pins. In this project, to design a clock frequency 16 MHz crystal was used.

Hence, the clock speed (frequency) is 4 MHz and often referred as E clock. The E clock can be measured on ATMEGA328P by using an oscilloscope or any frequency measurement devices.

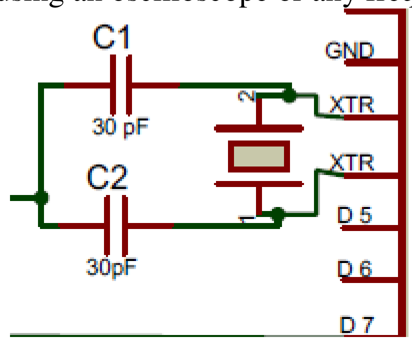

Fig.3.1. Clock Circuit

3.2. The Obstacle Sensor

The voltage sensor is a voltage divider. Two resistors were connected across the VCC and GND to achieve a voltage division configuration while the output was fed to the ADC of the MCU.

$$Vout = \frac{\text{Vs X R2}}{(\text{R1+R2})} \quad (3.1)$$

Vs = 220V

R1 = 100K

R2=1K

$$Vout = \frac{220 \text{ X } 1000}{(100{,}000 + 1000)} \quad (3.2)$$

Vout = 2.17V

This handles the activation of the relay. Because the microcontroller has low current too little to activate the relay hence a resistor is needed for amplification. The motor used in the system is a CCW geared DC motor with 5.8 current consumption at 15V.

The BC337 transistor which is an NPN transistor and TIP42C PNP was used here because the microcontroller pin goes high whenever the buzzer is needed to be activated.

Using the transistor values from the datasheet of BC337where:

β = 200,

Ic = 133mA

and Ib = 20uA,

Vbe = 0.9

(from the datasheet)

Calculating for the base resistor we apply the Krichoff's law to find the value of the Base resistor (Rb) required to switch the load fully "ON" when the input terminal voltage exceeds 2.5v.

From Kirchhoff's voltage law: +Vin – I B RB – VBE = 0

$$Rb = \frac{\text{Vin}-\text{Vbe}}{\text{Ib}} \quad (3.3)$$

Where $Ib=\frac{\text{Ic}}{\text{hfe}}$

From the datasheet hfe= 20-100

Designing for the Worst Case:

Since the gain of the transistor ranges from 20 – 100 a gain of 30 can be assumed.

VBE, SAT=0.95VBE, SAT=0.95 # datasheet, nearest match is 50mA. Maximum value, practical value is probably much lower (0.65V)

Now to calculate the base series resistance. This is equal to the voltage across the resistor, divided by the current through it. The current through the resistor is the same as the base current. The voltage across it is the rail voltage (5V) decreased by the base-to-emitter voltage of the transistor V (CE,sat).

$$RB = \frac{\text{URb}}{\text{Ib}} = RB = \frac{\text{Vcc}-\text{VBE}}{\text{Ib}} \quad (3.4)$$

But $Ib=\frac{133\text{mA}}{30}$ =4.43mA

Therefore:

$$Rb = \frac{5-0.9}{0.00443}$$

RB=925.5Ω

RB=1k being the nearest available value

3.3 Power Requirement of the Hand Washing Machine

The power supply comprises of the transformer, rectification circuit and the smoothing stage which makes up the power supply.

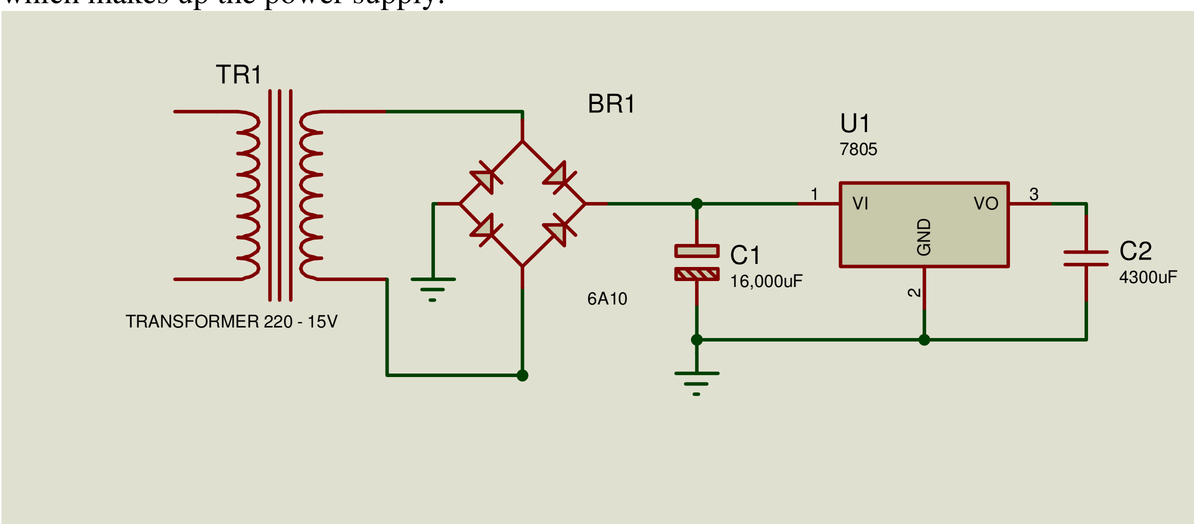

Fig 3.2. Power Supply

Table 3.1. The total power demand of the microcontroller board is stated in the table below:

QTY	DEVICE	VOLTAGE	CURRENT(A)	POWER(W)
3	Relay	12V	0.03	0.09
3	LCD	5V	0.4	1.2
1	Solenoid valve	12	0.02	0.24
1	ATMEGA 328P	5V	0.016	0.048
4	Ultrasonic sensors	5V	0.14	0.7

2	Water pump	12V	6.6	80
	Total			82.278

Since the net load of the system is 89.5W our power supply must be not less than 89.5W. This led to selecting a transformer of 15V 100W/ 7A

The diode is 6A10 diode which can withstand up to 1000v at 6A.

The ripple was trimmed by applying the ripple calculation.

Q = C * V, C = capacitance in farads,

Q = charge in coulombs, V = voltage potential

Q = I * T, I = current flow in amps,

Q = charge in coulombs,

T = time in seconds

F = 1 /T, F = frequency in hZ, T = period in seconds

Therefore,

I * T = C * V, or C = (I * T) /V

The delta "Δ" symbol indicates a change, such as a change in voltage or a change in time

*C = I * ΔT / ΔV*

In this case, ΔT = 1 /F e.g. the time period of a 50hZ waveform = 1 /50hZ = 0.02seconds

Therefore,

C = I / (ΔV * F)

Now including the 70% factor we get the final relationship: C = 0.7 * I /(ΔV * F)

C = capacitance in farads, I = current in amps, ΔV = peak-to-peak ripple voltage, F = ripple freq in hZ

Note that ripple frequency in a full-wave rectifier is double line frequency. For half-wave rectification, the ripple frequency is the line frequency.

Solving for ΔV

*ΔV = 0.7 * I /(C * F)*

The 70% factor

This is an assumption—in cases where the capacitor is oversize, it will be perhaps 80%, but this is close enough for government work and not very critical.

3.4Ripple Factor of Bridge Rectifier

The pulsating output of a rectifier can be considered to contain a dc component and ac component called the ripples. The ripple current is undesirable and its value should be the smallest possible in order to make the rectifier effective.

The ripple voltage or current is measured in turn of the ripple factor which is defined as the ratio of the effective value of the ac components of voltage (or current) present in the output from the rectified to the direct or average value of the output voltage (or current)

At this point we need a capacitor to eliminate the ripple in the power supply

Here we solve for the filter capacitor by applying the formula:

$$dv = I * \frac{dt}{C} \quad (3.5)$$

$$C = I\ Rms\,\frac{\mathrm{dt}}{\mathrm{dv}}$$

Where :

Rms = 0.7 (ripple factor)
I = 2.278A
dt=2(1/50) = 0.04 (which is time period in full bridge rectification)
dV = 15 (peak to peak voltage of stepped down AC supply)
$C = 2.278\frac{0.04}{15}$C= 0.0157 F = 6,074 Farad
Therefore C = 6800uF nearest available value.

Solving for the capacitor at the voltage regulator
Applying the formula

$$C = I * \frac{\Delta T}{\Delta V} \quad (3.6)$$

Where *I = 0.53 (current of devices connected to voltage regulator)*
ΔT =2(1/50) = 0.04 (which is time period in full bridge rectification)
ΔV = 15 – 5 = 10V
$C = 0.53\ \frac{0.04}{5}$= 0.0042= 0.0042Farad
Therefore C = 4300uF closest available value

3.5. Selection of Dispensing Pump

This is a low cost, small size Submersible Pump Motor which can be operated from a 6 ~ 12V power supply. It can take up to 120 liters per hour with very low current consumption of 220mA. Just connect tube pipe to the motor outlet, submerge it in water and power it. Make sure that the water level is always higher than the motor. Dry run may damage the motor due to heating and it will also produce noise. Since one litter of water is enough to wash hand this pump can discharge 2 liters per minute.

3.6. Testing

Components	**Test Type**	**Results**
Resistors	Resistance	Read approximately expected values
Transistors	Continuity test	Values between 420 to 630 was observed
Capacitors	LC test	Read approximately expected values
LED test	Continuity test	Emitted light on correct polarity
Diode test	Continuity test	Only read on forward bias
Battery test	Voltage test	Read approximately expected values
Microcontroller	Firmware	Uploading of a sketch file was successful
Ultrasonic sensor	Distance sensing	Responded to serial monitor when tested with example code

3.7.Developmental Procedure/Description of the Hand Washing Machine

The image in figure 4.2 below shows the major components of the fabricated hand washing system. It includes hand washing, soap dispensing, hand sanitizing, hand blower and temperature sensor units.

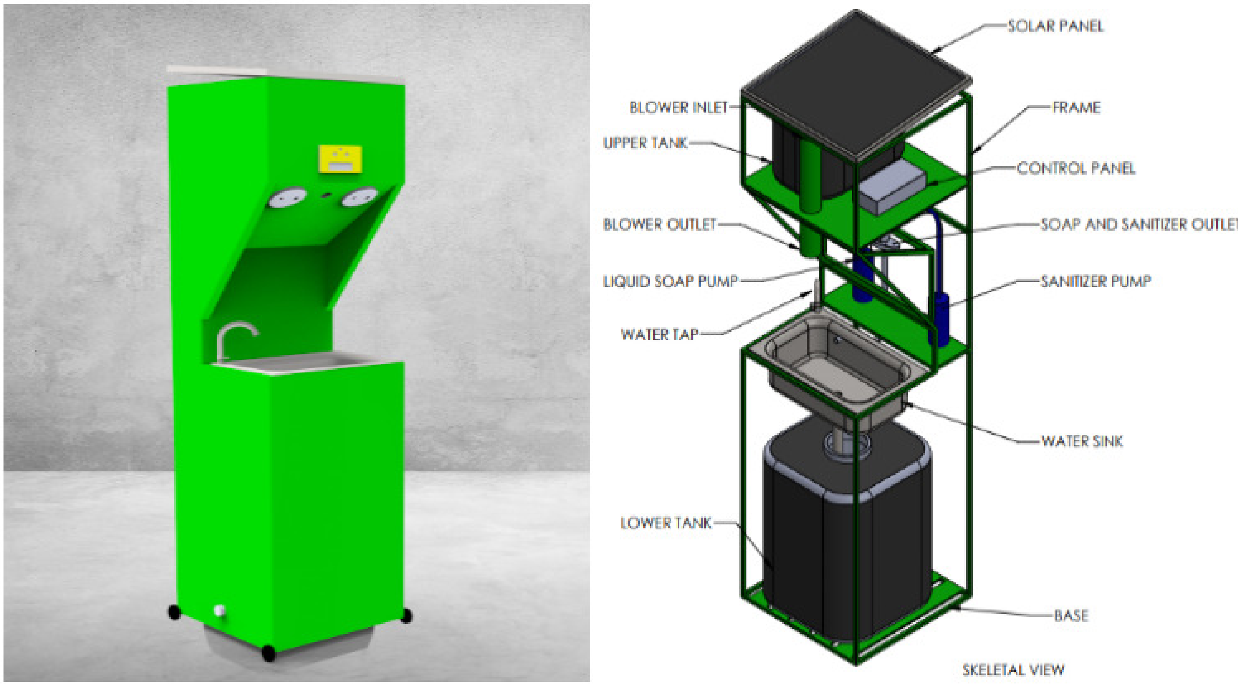

Figure 3.3. The hand washing system.

The components of the machine were assembled on a structural frame made from a steel bar. The system contains wash hand basin which is for hand washing. There is an upper tank which serves as the source of clean water used for hand washing. There is also a lower tank where the dirty water from the sink collects for drainage. The hand washing sink has a water tap which is controlled by an ultrasonic sensor. The soap dispensing unit has another ultrasonic sensor connected to it which controls the dispensing of liquid soap to users when they stretch out their hands. The third sensor functions to regulate the dispensing of hand sanitizer, while the fourth one is for the reading of temperature of the users. The system also contain an LCD device in the front of the upper tank which displays information gotten from the temperature reading. The hand blower unit contains a blower that is capable of drying up the wet hand after washing. It is alsocontrolled by a sensor. Above the upper tank is the solar panel which is part of the hybrid power system of the machine. The whole system is controlled by the Arduiuno microcontroller which is located inside the box for the control panel.

4.0 RESULTS AND DISCUSSION

4.1 Implementation procedure:

The circuit was first designed on proteus after which it was implemented on the bread board for proper testing. Component test was carried out with the multi-meter. For the resistors and transistors I used the continuity test while for the battery and regulators I used the voltage test. The modules where tested by following the troubleshooting instruction in the datasheet. The main implementation was done on a Vero board. I used soldering iron and lead to assemble the component on the Vero board after which I did the final packaging.

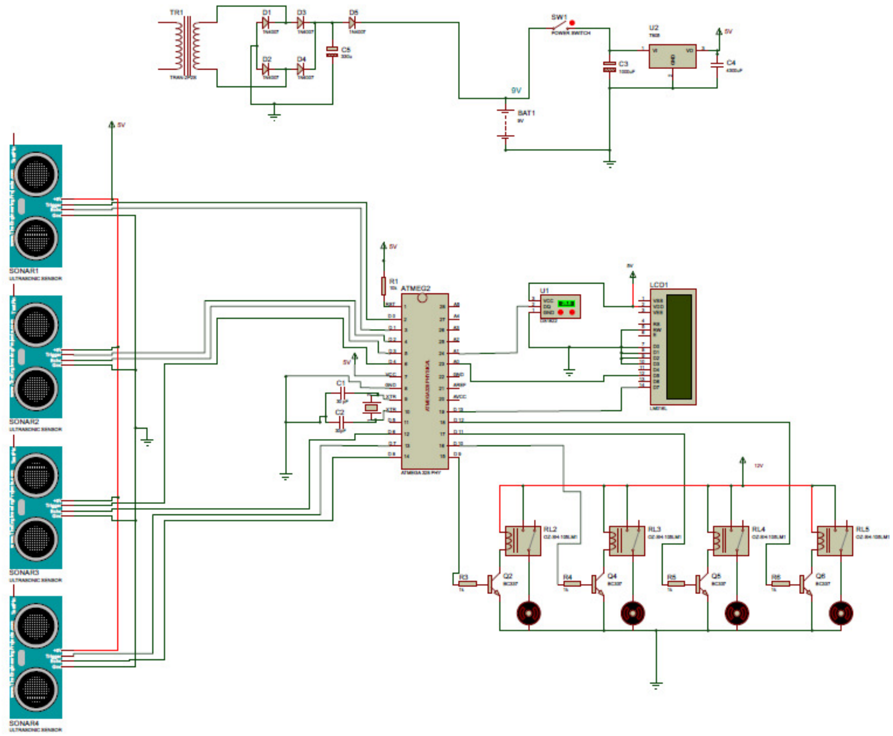

Fig.4.1. The Complete Circuit Diagram

Using the proteus simulation software I placed a voltmeter between the output of the 7805 regulator and it read 5 Volts showing that the regulator was able to regulate the voltage from the battery from 12V to 5V.

4.2 Parameter Calculations

4.2.1. Power Requirements of the Centrifugal Fan Motor

The power of the motor of the centrifugal fan was obtained considering the power required for the pressure drop from the inlet of the centrifugal fan casing across the heating chamber.

Given that;

Density of air = ρA = 1.72kg/m^3

Operating temperature T_2 = 40°C = 40 + 273k = 313K

Specific heat capacity of air at constant pressure (Cp) = 1.005J/kg°K

Knowing that,

The speed of the fan N_f = 300rpm

Diameter of the fan D_f = 120mm

The velocity of air stream is given by: $V_f = (18852 \text{ x}10^{-3})$m/s = 18.85m/s

Coefficient of entry (Ce) = 0.97m/s

Area of heating chamber = $(0.2\text{x}0.2)m^2 = 0.04m^2$ using the relation

$$W = FA.\phi.CP \qquad (4.1)$$

But $\phi = A1.Vf\ Ce.$ (4.2)

Where A_1 = area of the inlet section

$$A1 = \frac{\pi d2}{4} \qquad (4.3)$$

Substituting in equation (iii)

$A_1 = 3.142(0.12)^2/4 = 0.189m^2$

Then $\phi = (0.189m^2 \times 19.85 \times 0.97)m/s = 3.45m^3/s$

Substituting in equation (i)

$W = 1.172 \times 3.45 \times 313 \times 1.005 = 1272.9$ W

4.2.2. Time for Drying

The power required drying/producing the warm air that will dry the hand is the combination of the power of the heater and the power of the fan.

Illustration

$$PR = PH\ X + PF \qquad (4.4)$$

Where P_R = power required, P_H = power of heater, P_F = power of fan

P_R = 5600W + 1271.9W = 6871.9W

And

$$PR = PA \times Qx\ cp \times \Delta T \qquad (4.5)$$

$$PR = PA \times V \times cp \times \frac{\Delta T}{T} \qquad (4.6)$$

Where,

PA = 1. 172 $\Delta T = 40 - 37 = 3^0C$ Volume (V) = $165\text{x}10^3$litres = $165m^3$

Cp = 1.005 kJ/kg/°k

Now the time (t) required for drying is given by

$t = P_A \times Vxcp \times \Delta T / P_R$ = 1.172×165×1.005×3/6.872 = 44. 84sec

Time required for drying is, say, 45 seconds.

4.2.3. The Efficiency of the Blower

$$n = \frac{power\ input}{Power\ output} \quad (4.7)$$

P_{in} = IV = 220V x 37A = 814W

P_{out} = 6872W

n=6982/8140 × 100/1 = 84%

4.2.4. Efficiency of the Pumps

Power output of the pump, $P_{out} = \rho gQH$ = 1000 x 9.81 x 0.591 x 1= 5800W

Where, ρ = 1000kg/m^3, g = 9.81m/s^2, Q =0.591m^3/s, H = 1m

Efficiency, *n = Power input/Power output* =5800/100 = 71%

4.2.5. Rate of Flow ϕ

We know that $\phi = A_2 V_2 = \pi/4 \times 0.02^2 \times 0.181$ = 0.00005m^3/s

4.2.6. The Power Delivered To the Water by the Pump

$$hf = \frac{flv2}{D} \times 2g \quad (4.8)$$

Where hf = head loss due to friction F = 0.03 (Darcy – Weisbach friction)
L = 50m (length of the pipe) D = 10mm = 0.01m (Pipe diameter)

hf= 0.03 × 50× 0.181/0.01 × 2× 9.81= 0.2715/0.1962 = 1.38 *m*

$P = w\phi h\ Wf = 9.81 \times 0.000057 \times 1.38 = 7.7 \times 10^{-4}\ W = 0.77$

Table 4.1: Performance Result Obtained from each Stage

Stages	**Performance Results**
Solar Power Unit:	36.3V was read from the solar panel while still under direct sunlight. This shows that the solar panel is active and functioning optimally. Voltage was deliberately reversed, solar

	connection was reversed, thus; there was no current flowing under this condition. This shows that the protection diode is functioning well. The voltage regulators,LM312T and 7812, supplied 30V and 12V respectively as prescribed when performance test was carried out on them.
The Hand-dryer Unit:	Each time the transmitted signal from the transmitter to the receiver was deliberately interrupted by placing an obstacle between the transmitter and the receiver thereby disrupting the line of sight (LOS) during the performance test, the receiver was triggered, thus activating the transistor-relay switch combination (a part of the receiver) which switched 'ON' two LEDs connected as loads simultaneously. This simply shows that the transmitter performance is excellent. The triggering of the receiver and the resulting activation of the transistor-relay switch combination (a part of the receiver) which switched 'ON' two LEDs connected as loads simultaneously shows that the receiver is active. The two LEDs connected as load remained 'ON' for 25seconds each time there was triggering; thus confirming that the delay stage is performing in consonance with design objective. This stage performed optimally as heat and air were simultaneously produced whenever the heater and fan were simultaneously activated by the transistor-relay switch combination whenever there was triggering

Hand Sanitizer and Soap Dispenser Unit:	The ultrasonic sensors controlling both the hand sanitizer and soap dispenser performed optimally when tested against an obstacle (the human hand). Both sensors were set to detect an obstacle at a distance of 0.06 metres.
Hand Wash Unit:	In the hand wash unit, the sensor obstacle detection function was set at 0.38 metres. The distance between the hand washing sink and the position of the sensor was considered.
Temperature Sensing Unit:	The infrared sensor in the temperature sensing unit during testing performed optimal when the distance between the obstacle and the infrared sensor was set at 0.04 metres.

5.0 CONCLUSION AND RECOMMENDATION

This research work has successfully presented a functional and highly efficient low cost sensor-controlled hand washing, sanitizing and drying machine which is usable in different places within our geographical environment and settings such as hotels, homes, hospitals, executive offices, restaurants, schools etc. as way of adopting a good hand washing and drying process or procedure hence improving hygienic condition of individuals; and this eliminates the transfer of diseases like COVID19. Adoption of this machine is recommended to facilitate mass production of hand washing system and also its possible exportation.

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