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A Smart Pest Control System Based on Automated Reverse Aerodynamics and Suction Technology

Aniedu A.N[1], Nwokoye C. S[3], Avah S. E[3], Okafor C. S[4]
[1, 2, 3, 4]Electronic and Computer Engineering Department, Nnamdi Azikiwe University, Awka, Anambra State

***Abstract:** Many diseases (including malaria, one of the deadliest diseases especially to those living in developing nations which kills hundreds on daily basis) are transmitted by household insects. Mosquitoes, one of these insects, bites humans and sucks their blood and are pathogens of several diseases (especially malaria) which causes ill health and many times lead to death if it is not well treated. This necessitates the need to smartly eliminate them without chemicals, which may be harmful to human health. This research aims at the design and development of a smart insect trap which attracts and contains household insects and pests automatically. The device incorporates a dual power supply that powers and charges the system, sensors which detects the presence of insects and triggers the vacuum suction mechanism automatically, a charge controller for controlling the charging of the installed battery, an ultraviolet light emitting section that lures the insects to the device, a chamber for containment and dehydration of the insect, and a smart microcontroller based control system. The developed design is smart, environmentally safe, portable and highly cost effective yet very efficient in eliminating household pathogen-transmitting insects and pests*
***Keywords:** reverse aerodynamics, pest control, smart systems, insect trap, vacuum suction, mosquitoes.*

I. INTRODUCTION

Both in hot and cold weather, there are thousands of mosquitos flying on earth and most mosquitoes live in high humid areas. Mosquitoes are small flying insects, the female ones have a long, piercing mouthpiece, with which they use to pierce the skin of their prey to consume blood. Some mosquito bites are harmless, but others carry dangerous diseases, [1] Mosquitoes represent the major arthropod vectors of human disease worldwide transmitting malaria, lymphatic filariasis, and arbo viruses such as dengue virus and Zika virus. It is only female mosquitos that bite and suck blood, the blood serves as a source of protein for their eggs. Generally, mosquito eggs need water to hatch, that is why they appear to be more where there is stagnant or non-moving water. The eggs will hatch into larvae and in less than a week the larvae will grow and develop into pupae and eventually become adult mosquitoes. When the female mosquitoes mature and find their prey, these mosquitoes inject their saliva into the body of the victims. The saliva contains anticoagulants that ensure smoothness of the blood and sometimes contain parasites that can cause diseases. Because this insect is small in size and flies, it becomes sometimes difficult to kill them hence, the need for a smart trap to capture and demobilize them.

II. RELATED WORKS

Several research have been conducted to find a permanent solution to the menace of mosquitoes. For example, the author in [2] developed what he called Bug zapper, formerly called insect electrocuting trap which is an electronic device that kills insects by attracting them to a light source placed behind a high voltage grid which electrocutes them. Bug zapper is usually housed in a protective cage of plastic or grounded metal bars to prevent people from touching the high voltage grid. A light source is placed inside, usually a fluorescent lamp designed to emit both visible and ultraviolet light, the light is surrounded by a pair of interleaved bare wire grids or spirals, a high voltage power supply powered by mains electricity which may be a voltage Tripler circuit or a simple transformer less voltage multiplier circuit made with diodes and capacitors to generate a voltage of about 2000volts or more, high enough to conduct through the body of an insect which bridges the two grids, but not high enough to spark across the air gap. The impedance of the power supply and the arrangement of the grid is such that it cannot drive a dangerous current through the body of a human.

Shiva Rana et al in [3] developed a device that can emit ultrasonic energy of varied frequencies. These frequencies affects the hearing senses of animals and insects like mosquitoes etc. Their circuit was based on 555 Timer IC. This circuit is simple and need few components. The mosquito repellent circuit generates an ultrasonic sound with a high output frequency above 20 KHz that allows spreading mosquitoes within a wide radius. The oscillation frequency was given by the values of the resistor and a capacitor component. The designed electronic mosquito repellent circuit can be supplied from a 9V DC power supply. The hearing distance of this device is around 10 meters.

Nahian and co [4] designed a reduced power consumption novel mosquito collection device that sensitively detects the presence of a mosquito via a fibre-optic sensor. **The** overall module of this mosquito trap consists of three major modules (1) power sources (solar) (2) sensor and controller (3) electronic devices. In the prototype, a pushing capture mechanism selectively powers and efficiently captures live mosquitoes without destroying identifying morphological features of the specimens. With appropriate programming, the fans switched ON and OFF based on the triggering of a fibre-optic sensor and detects and counts each mosquito that entered the trap.

This paper [5] proposes a smart low power consumption actuator and selective fan-based trap to capture the *Aedes aegypti* mosquito, main vector of diseases such as Yellow Fever, Dengue Fever, Zika, and Chikungunya. The central purpose of their study was the development of an electronic trap integrated to variable approaches of flying insects' sensors. The electronic circuit of the trap was made up of a microcontroller that operates two DC fans arranged at the ends of an aerodynamic structure, a display, and two DC fans. The structure was built in Medium-Density Fibreboard (MDF), and the walls were aerodynamically designed so that they can direct the airflow out of the trap or into the cage. In this way, the trap can capture female *Aedes aegypti* mosquitoes and eject other flying insects' species.

III.METHODOLOGY

The methodology used in this project is the waterfall methodology. This is because it has a well-defined phase which follows a sequential method. Hence each phase determines the outcome of the other successive phases.

A. System Architecture

Fig 1 is the block diagram showing the different units of the electronic mosquito trap. This work was designed in such a way that it will have dual power supply, one from Mains and the other from a solar panel, the system has a unit for switching from Mains power supply to solar power whenever there is a power failure and back to Mains when the Mains power is back. The selected power is then fed to the smart charge controller for charging of the lithium-ion battery.

The power supply unit powers up the system and charges the battery, the vacuum sucker deployed in this work is a 5 volts DC electric fan; the electric fan and motor are positioned in such a way that the upper part sucks in air and the lower part blows air. The electric motor is placed directly under the attractant so that when a mosquito is attracted to the ultraviolent LED, the vacuum sucker sucks it into the containment chamber. The attractant used for this work is the ultraviolet light emitting diode which emits ultraviolet light of wavelength 405nm (the mosquito has a photoreceptor which detects ultraviolet light, thus they are attracted to ultraviolet LED). This design also incorporates a display unit that consists of the LCD which displays the manual and automatic modes and vcdv the detection Unit consisting of two chambers, the upper chamber and the lower chamber, both consisting of photodiodes and phototransistors as sensors.

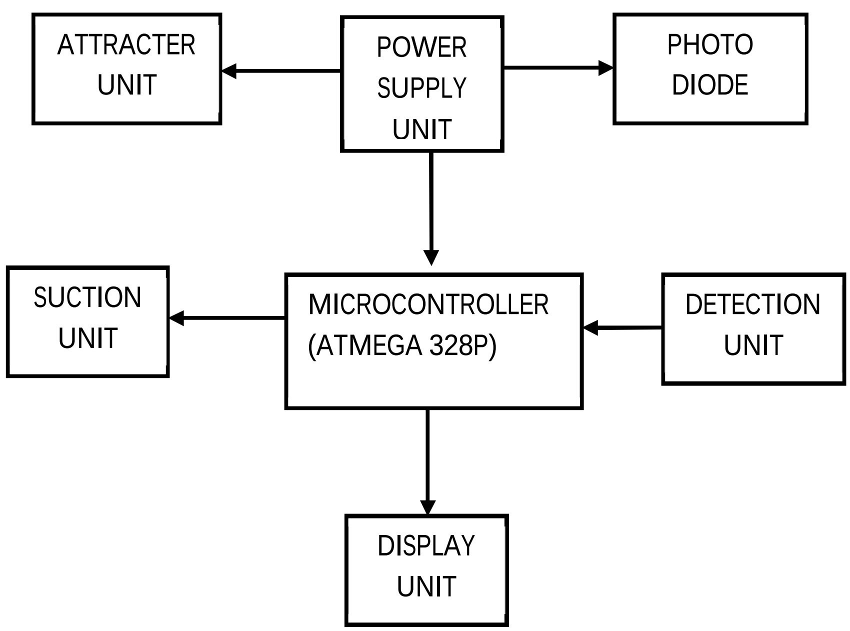

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Figure 1: Block diagram of the Smart Insect Trap

IV. SYSTEM DESIGN

A. Hardware Design

The hardware design consist of a power supply unit which consist of a switching unit that switches between two power sources (i.e. solar and the mains power supply) and a battery protection that monitors the charging of the lithium ion battery, a containment chamber (mesh box) for mosquito collection, a microcontroller based circuit for monitoring and controlling the device, a DC fan interfaced to the Atmega 328P, a display unit (LCD) used to display manual and automatic mode. Mathematically, some empirical equations were used to determine the values of electronic components which will give the optimum output for the device. These are shown from equation 1 – 31 below.

Transformer design for the Mosquito trap

Parameters needed for the design:
Input voltage nominal $V_{in(nom)}$ = 220 VAC
Input voltage minimum $V_{in(min)}$ = 85 VAC
Input voltage maximum $V_{in(max)}$ = 240 VAC
Output voltage, V_o = 18 VDC
Output current, I_o = 2 amps
Auxiliary voltage V_A = 12volts
Window utilization, K_u = 0.29
Efficiency η = 0.8
Frequency, f = 100 kHz
Converter efficiency, = 80%
Maximum duty cycle D_{max} = 0.5
Dwell time duty ratio D_w =0.1
Regulation α = 1.0%
Operating flux density B_m = 0.25 tesla
Diode voltage V_D = 0.7 volt

$$V_{BULK(max)} = \sqrt{2} \times V_{i(\max)} = \sqrt{2} \times 240 = 339.4VDC \quad (1)$$

$$V_{BULK(min)} = \sqrt{2} \times V_{i(min)} = \sqrt{2} \times 85 = 120.21VDC \quad (2)$$

$$V_{REFLECTED} = 0.8 \times (V_{DS} - 1.3 \times V_{BULK(max)}) \quad (3)$$

A 650V rated MOSFET IRFB9N65A was selected for this 18V 2-amp switch mode power supply circuit i.e. V_{DS} = 650V.

$$V_{REFLECTED} = 0.8 \times (V_{DS} - 1.3 \times V_{BULK(max)})$$

$$V_{REFLECTED} = 0.8 \times (650 - 1.3 \times 339.4) = 167.02V$$

$$\frac{N_p}{N_s} = N_{ps} = \frac{V_{REFLECTED}}{V_o^*} = \frac{167.02}{18.7} = 8.93 \quad (4)$$

$$N_{PA} = N_{ps} \times \frac{V_o^*}{V_{BIAS}} \quad (5)$$

For ease of design, we chose a turn ratio of 9:1
Where,
V_o^* = output voltage taking the diode voltage into account ($V_o + V_D$) = 18 + 0.7 = 18.7V
$\frac{N_p}{N_s} = N_{ps}$= turn ratio of primary and secondary winding
$V_{BULK(\min)}$ = minimum input DC voltage
From equation (3) (4) and (5)

$$\text{Skin depth } \mathcal{E} = \frac{6.62}{\sqrt{f}} = \frac{6.62}{\sqrt{100000}} = 0.0209\ cm \quad (6)$$

$$\text{Wire diameter} = 2 \times \mathcal{E} = 2 \times 0.0209 = 0.0418\ cm \quad (7)$$

$$\text{Bare wire Area } A_w = \frac{\pi D^2}{4} = \frac{\pi(0.0418)^2}{4} = 0.00137\ cm \quad (8)$$

Table 1
Wire Gauge Table

Wire AWG	Bare Area	Area Ins.	Bare/Ins.	$\mu\Omega/cm$
#26	0.001280	00.1603	0.798	1845
#27	0.001021	0.001313	0.778	1687
#28	0.0008046	0.0010515	0.765	2142

From Table 1, it can be seen that #26 wire gauge has the closest bare area to the one we calculated, thus our wire gauge will be #26 AWG.

Total period $T = \frac{1}{f} = \frac{1}{100000} = 10\,\mu sec$ (9)

MOSFET ON time $t_{on} = TD_{max} = 10 \times 10^{-6} \times 0.5 = 5\,\mu sec$ (10)

Secondary load power $P_{o(max)} = I_o \times V_o^* = 2 \times (18 + 0.7) = 37.4\,watts$ (11)

Table 2
Core Geometries and Typical Transformable Power

Core geometry	Transformable power (W)		
	Fly back converter	Forward converter	Push-Pull Converter
ER 11/5	8.5	10	14
ER14.5/6	20	23	32
EFD15	26	30	42
EFD20	50	57	80
EE12.6	17	20	28
EE16	41	48	67
EE20	73	85	118
EE25	135	155	218

From Table 2, we choose our core to be EFD 20 as this is capable of transforming up to 50 watts.

EFD 20 has the following parameters:
Core Area $A_c = 0.31cm^2$
Window Area $W_a = 0.501\ cm^2$
Mean length turn, MLT = 3.80 cm
Area Product, A_p = 0.155 cm4
Core geometry, K_g = 0.00506 cm5
Magnetic path length, MPL = 4.7 cm
Core weight, W_{tfe} = 7.0 grams
Copper weight, W_{tcu} = 6.8 grams.

Maximum input current $I_{in(max)} = \frac{P_{o(max)}}{V_{in(min)} \times \eta} = \frac{37.4}{85 \times 0.8} = 0.55\,A$ (12)

Primary peak current $I_{prim(pk)} = \frac{2P_{o(max)}T}{V_{in(min)} \times \eta \times t_{on}} = \frac{2 \times 37.4 \times 10 \times 10^{-6}}{85 \times 0.8 \times 5 \times 10^{-6}} = 2.2\,A$ (13)

Primary RMS current $I_{prim(RMS)} = I_{prim(pk)}\sqrt{\frac{t_{on}}{3T}} = 2.2\sqrt{\frac{5 \times 10^{-6}}{3 \times 10 \times 10^{-6}}} = 0.90\ A$ (14)

Maximum input power $P_{in(max)} = \frac{P_{0(max)}}{\eta} = \frac{37.4}{0.8} = 46.75\ watts$ (15)

Equivalent input resistance $R_{in(equiv)} = \frac{V_{in(min)}{}^2}{P_{in(max)}} = \frac{(85)^2}{46.75} = 154.55\ \Omega$ (16)

Primary inductance $L = \frac{R_{in(equiv)} \times T \times D_{max}{}^2}{2} = \frac{154.55 \times 10 \times 10^{-6} \times (0.5)^2}{2} = 193\ \mu H$ (17)

Energy handling capability $E = \frac{L \times I_{prim(pk)}{}^2}{2} = \frac{193 \times 10^{-6} \times (2.2)^2}{2} = 0.000467$ w-s (18)

Electrical condition $K_e = 0.145 \times P_o \times B_m{}^2 \times 10^{-4} = 0.145 \times 37.4 \times (0.25)^2 \times 10^{-4}$ (19)

$K_e = 0.000389$

Current density $J = \frac{2 \times Energy \times 10^4}{B_m \times A_p \times K_u} = \frac{2 \times 0.000467 \times 10^4}{0.25 \times 0.155 \times 0.29} = 831\ amp/\ cm^2$ (20)

Primary wire Area $A_{pw(B)} = \frac{I_{prim(RMS)}}{J} = \frac{0.90}{831} = 0.00108\ cm^2$ (21)

Required number of primary strands $S_{np} = \frac{A_{pw(B)}}{Wire\ Area} = \frac{0.00108}{0.00128} = 0.84$ (22)

This approximately equal to 1, therefore we use a single strand

Window Area of primary is half the window Area of the core.

Therefore, Window Area of primary $W_{ap} = \frac{W_a}{2} = \frac{0.501}{2} = 0.250\ cm^2$ (23)

Primary turns $N_p = \frac{K_u \times W_{ap}}{S_{np} \times Wire\ Area} = \frac{0.29 \times 0.250}{1 \times 0.00128} = 56.64 \approx 57\ turns$ (24)

Secondary turns $N_s = \frac{N_p \times V_o^* \times (1 - D_{max} - D_W)}{V_{in(min)} \times D_{max}} = \frac{57 \times 18.7 \times (1 - 0.5 - 0.1)}{85 \times 0.5} = 10.032 \approx 10\ turns$ (25)

Secondary peak current $I_{sec(pk)} = \frac{2 \times I_o}{(1 - D_{max} - D_W)} = \frac{2 \times 2}{(1 - 0.5 - 0.1)} = 10\ A$ (26)

Secondary RMS current $I_{sec(RMS)} = I_{sec(pk)}\sqrt{\frac{(1 - D_{max} - D_W)}{3}} = 10\sqrt{\frac{(1 - 0.5 - 0.1)}{3}} = 3.65\ A$ (27)

Secondary wire Area $A_{sw(B)} = \frac{I_{sec(RMS)}}{J} = \frac{3.65}{831} = 0.00439\ cm^2$ (28)

Required number of strands $S_{ns} = \frac{A_{sw(B)}}{wire\ Area} = \frac{0.00439}{0.00128} = 3.4 \approx 3\ strands$ (29)

$\frac{V_{in(nom)}}{V_A} = \frac{N_p}{N_A}$ (30)

From equation (30)

$N_A = \frac{N_p \times V_A}{V_{in(nom)}} = \frac{57 \times 12}{85} = 8.05 \approx 8\ turns$ (31)

The calculated values were then used to design the entire schematic of the project using Proteus Professional (Proteus ISIS) software and is shown in figure 2.

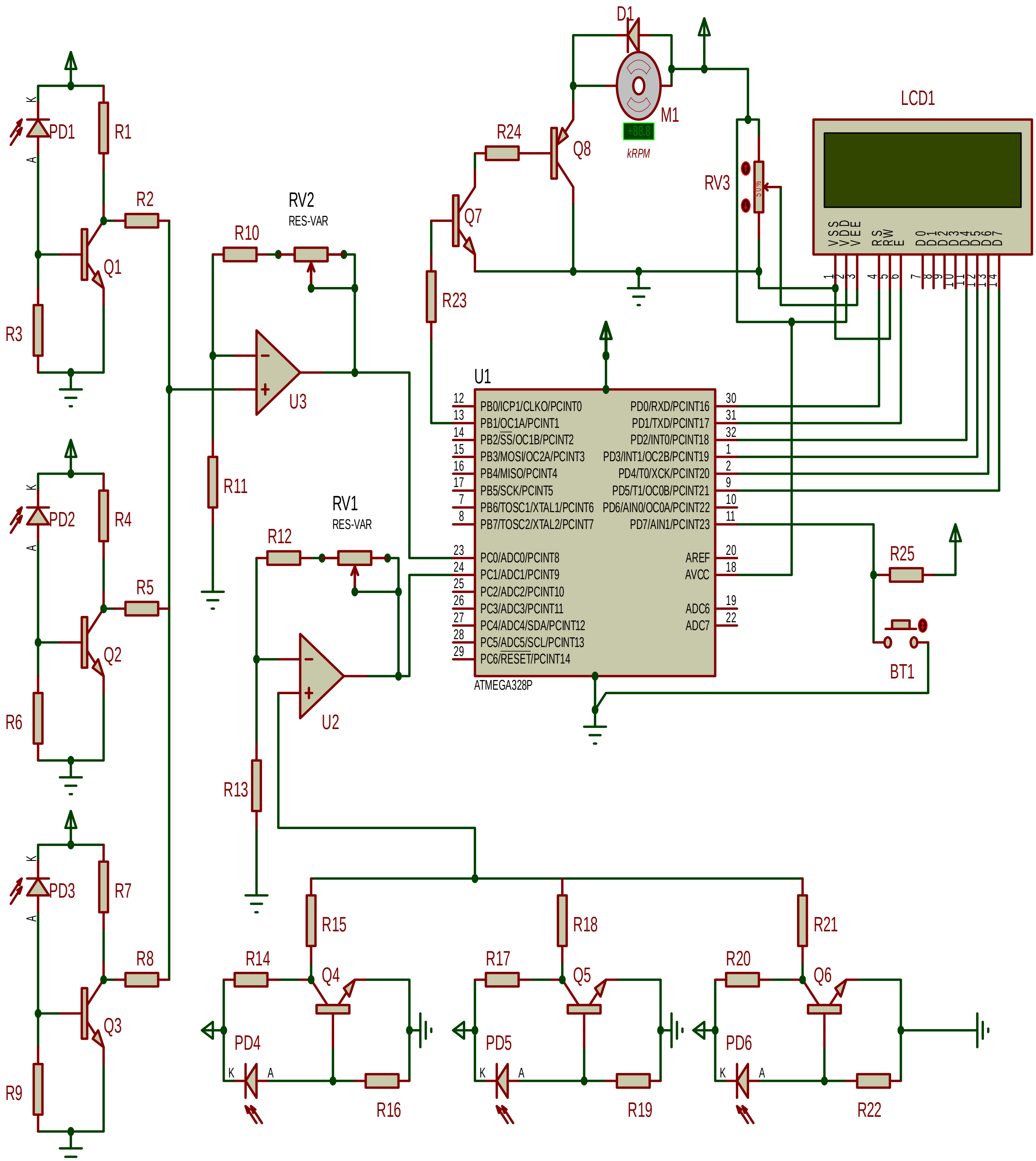

Figure 2: The Schematics of the Smart Insect Trap

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B. Software Design

The software design of the project consists of writing computer program for the microcontroller to implement the desired smart insect trap. This includes the program codes to implement and interface the various sub-unit of the system with the microcontroller. Basically the programs was developed using Arduino IDE and implemented on the microcontroller. Figure 3 shows a flowchart of the software program powering the device.

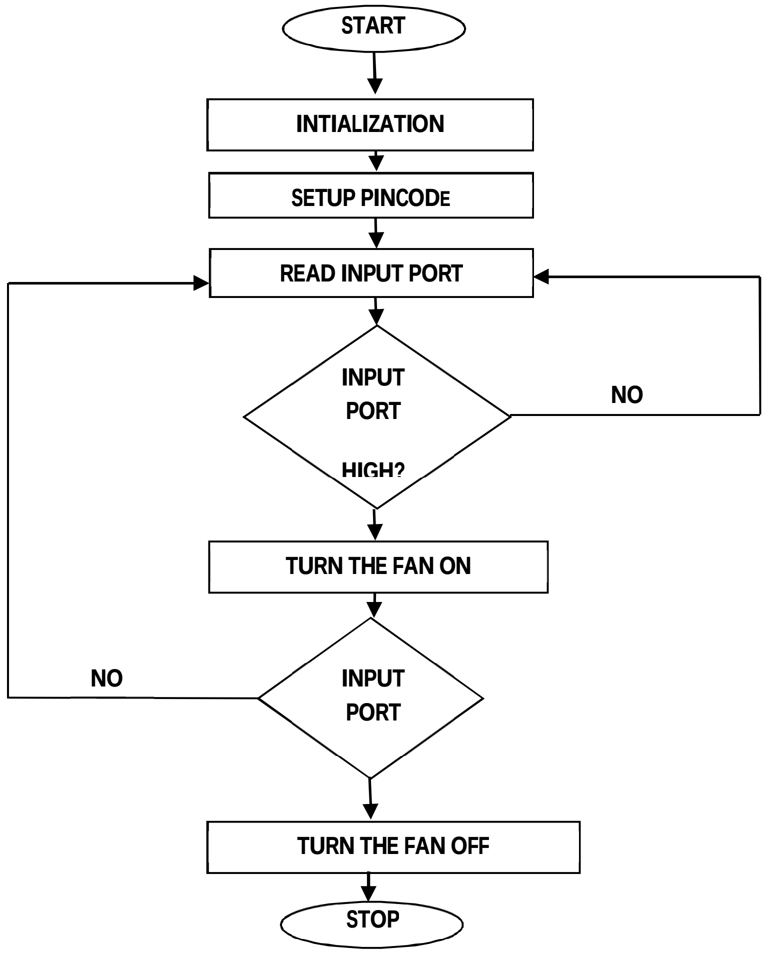

Fig 3: Program Flowchart

After the integration of the various sub-units of the system the complete prototype of the smart insect trap was developed as shown in figures 4, showing various angles of the models when powered with different power supply mode**.**

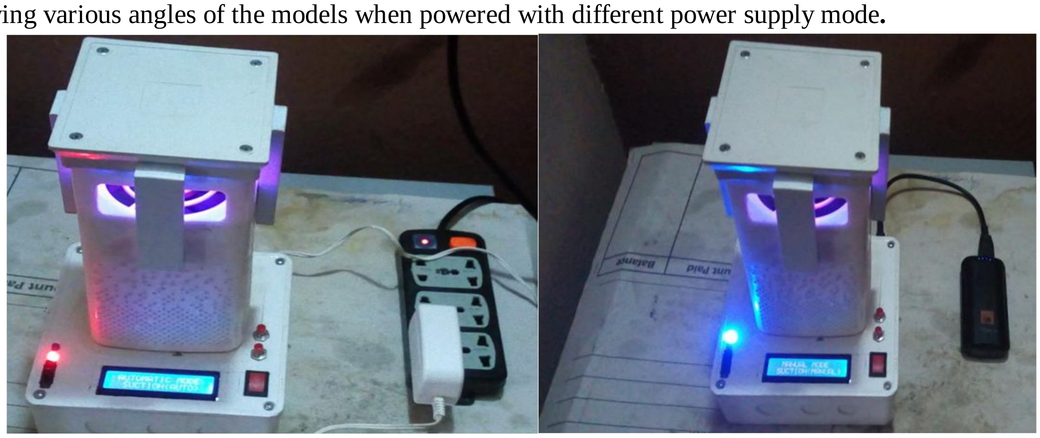

Figure 4: The Main, Power Bank (Solar) Manual and Auto Mode

V. CONCLUSIONS

The automatic pest control device described in this paper was designed with the capability to detect mosquitoes and other household insects which it then lures and captures automatically using reverse aerodynamics technique and vacuum suction technology. These insects are attracted to the trap via the ultraviolet light, and the suction device pulls them into the containment chamber. In other to avoid inefficiency in power supply utilization, the device was designed to be powered by both AC from mains and solar power. However it also incorporates energy saving mechanism, hence will go into sleep mode when idle and wakes up when an insect is in close proximity. The system is very beneficial for people who wish to safeguard their health against malaria and other insect transmitted diseases. This system is very affordable (incorporating mostly locally sourced materials) and easy to operate, making it a useful, handy, safe and cost-effective alternative for insect control.

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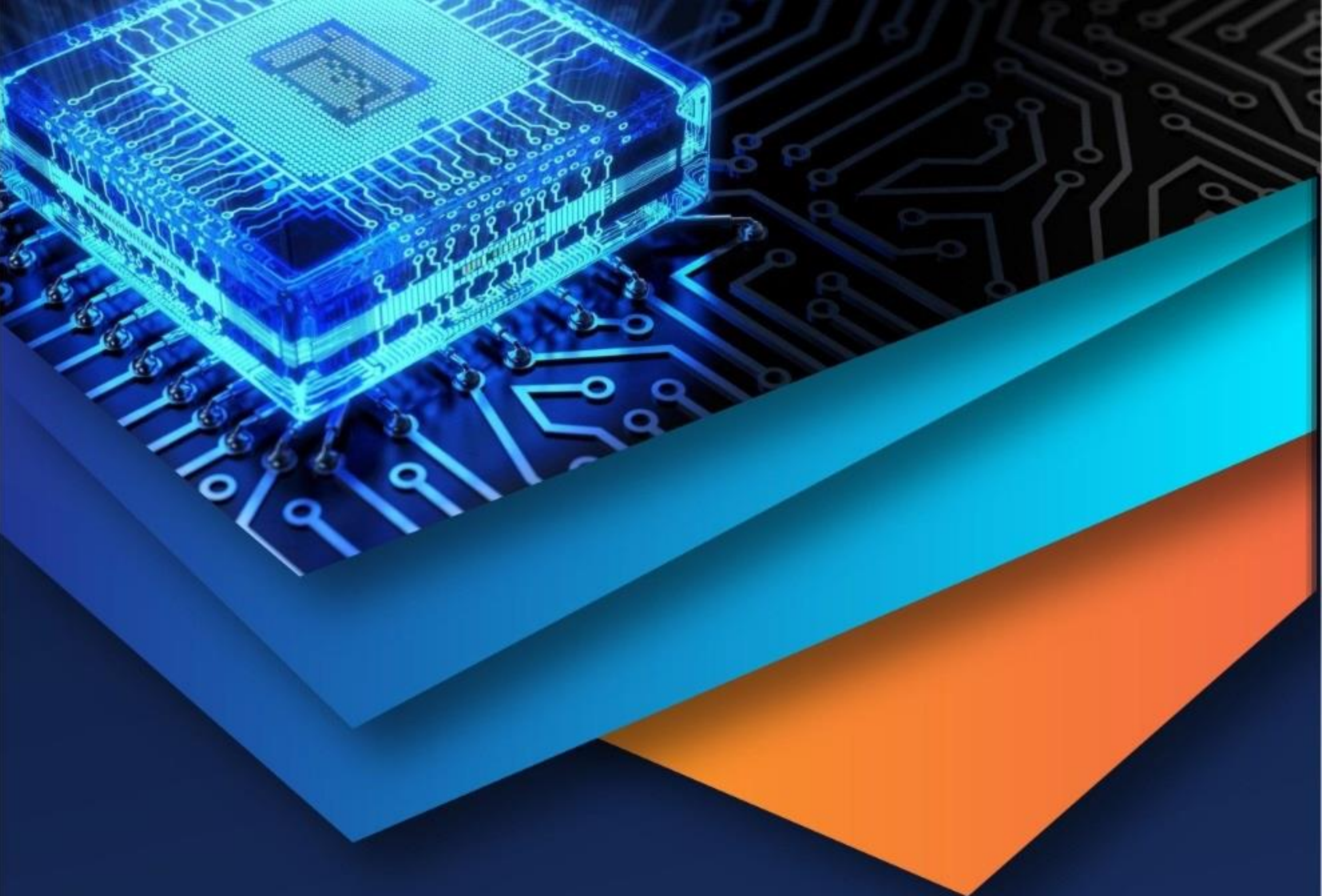

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