# A Light Weight Solar Powered Mini Quadcopter for Environmental Monitoring

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***Abstract:** A flying quadcopter equipped with green and environment friendly solar energy is designed and implemented in this study for monitoring purposes. It is capable to operate with light weight small solar panel generated power with designated light weight boost converter integrated in the body of the flying model. A preliminary design of the solar powered quadcopter has been performed by calculating and estimating the maximum lifting weight of flying model, voltage rating of the solar panel, battery voltage rating and its capacity. A charging during operation has been supplemented to the quadcopter to facilitate the operation as well as charging at the same time. In addition, crash protection structure has also been equipped to the design to reduce the impact to the structure during improper landing. With the enhanced ability of providing self-sustaining energy source, the quadcopter is capable to carry out environmental sensing with proper sensor mounted on it.*

***Keywords:** Unmanned Aerial Vehicle; Solar Energy; Quadcopter; Environmental Monitoring; Charge Controller.*

## I. INTRODUCTION

For centuries, people have always been fascinated by the dream of travelling in the space. Unfortunately, the physical limits don't allow us to fly high. Therefore, many of us have tried to create machines such as aircraft or spacecraft. In recent years, there has been rapid development of autonomous unmanned aircraft equipped with autonomous control devices called unmanned aerial vehicles (UAVs) and micro aerial vehicles (MAVs) [1, 4, 5, 8-10]. Unmanned Aerial Vehicle (UAV @drone) has now started to become a popular subject for research & development.

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Many have already come out with state of the art design and the prototypes are remarkable. However, based on current technology, utilizing green energy as power source in such energy consuming drones are still under research. There is design like an airplane-like solar powered UAV but not yet in helicopter shape. Based on current technology on the flying model designs, some has come out with the design of an airplane. Many has come out with the helicopter design, but with 4 rotor blades design for balancing & controlling purposes. After years of research & development, even a mini quadcopter with a size as small as the palm of our hand is already available at consumer end [11, 12]. But the problem with these designs is the considerably large power consumption of aerial vehicles. For instance, a RC helicopter with size as large as a reference book consumes 6 AA heavy duty battery with less than an hour of flight. Such large amount of energy consumption is not environment friendly and of course cost-ineffective. On the other hand, solar powered vehicle has come out with so many innovative designs and can be made as simple as with a small-scale PV cell panel, electric motor, 4 tires with a thin wooden block which is able to move a toy car under a sunny day. On the aerial vehicle side, research has to be done to realise the dream of making something fly with solar energy. There are few researches & studies, which simulate a virtual flight system, or make an airplane-like model to fly it with solar energy [12]. Still there is no recognised research which has been making a hovering aerial vehicle such as helicopter to be powered by solar energy. Since it is possible to make solar powered car, it is also possible to make a solar powered aerial vehicle, more specifically, solar powered heli/quadcopter [13-15]. During design or modification of a drone, there are few things that need to be considered such as electric rechargeable battery, aerodynamics of the drone and so on [6].Generally, a flying robot needs a rechargeable battery to supply power to the system. Currently, Lithium ion and Lithium Polymer rechargeable batteries are commonly used in the market. The battery is normally made to encase by a hard metal to keep the electrodes wound up tight by the separator sheet. This makes the lithium ion battery heavier and limited its possible shapes. The aerodynamics of the drone that is required to consider in the design and modification is the ground effect and dynamic rollover [6]. The ground effect favors the lifting force and thus making the system of flying robot require less power to hover in the air. Dynamic Rollover occurs when the hovering flying robot becomes light on its skids.

This slight movement of the flying robot becomes the pivot point and causing itself leaning towards the ground. Currently, the main UAV applications are defense related and the main investments are driven by future military scenarios [9]. Other than that, many researchers have developed drones for other applications such as agriculture and forestry, firefighting, communications relay, remote sensing, aerial mapping, meteorology and so on. However, the power consumption for operating drones is considerably high and maintenance is very costly for applications like environmental monitoring purposes. So, one of the possible solutions to realize such application is using the green environment friendly energy namely solar energy.

## II. METHODOLOGY

The process flow of designing solar powered mini quadcopter is shown in Figure 1.

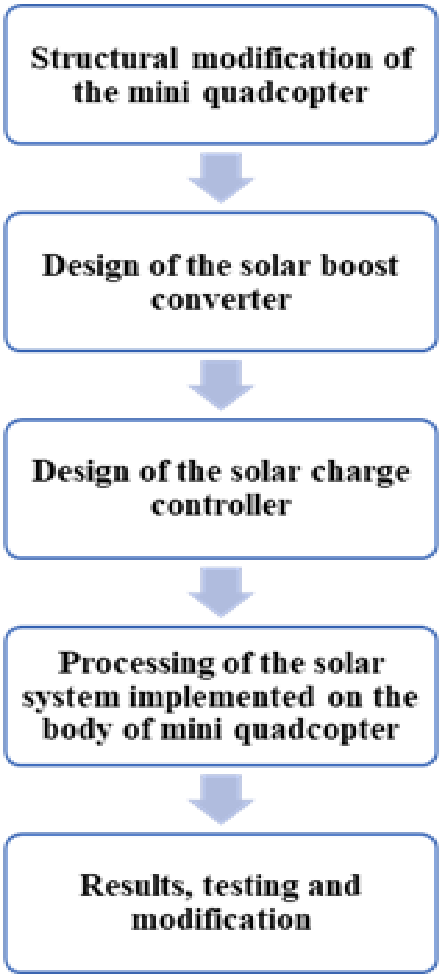


**Fig. 1 Flow chart of the design methodology**

At the very first step, a quadcopter model Hubsan X4 H107d FPV was chosen for the design & development of solar power system. The Hubsan x4 h107d FPV was chosen because of several good reasons. Firstly, it is small and light weight which fulfil the requirement of this project to develop a solar powered mini drone. Secondly, it is built-in with first-person-view camera which favours the environmental monitoring tasks as one of the possible future applications. In this step, the position of the solar panel was determined. The modified structure was first drawn using Autocad and the realisation of the designed structure was carried then. Next, the design of the circuitry of solar boost converter and charge controller was carried out. All sources from the website and electronic societies were taken as reference. Simulation software such as TINA was used to run the simulation test for the circuitry designed to make sure the circuitry was fully functional before going to the practical stage. Then, the designed solar system was ready in this step and implemented on the body of the mini drone which was then tested in the final stage. Adjustment and modification were done in the final stage to make solar power system fully functional enabling the mini drone to perform flight operation.

### A. Structural modification of mini quadcopter

The design and modification of the structure of mini quadcopter is shown in Figure 2. The black shape on top represented the solar panel. The placement of the solar panel was located at the best position in body to get most radiation energy from the sunlight without affecting the aerodynamics of the quadcopter since it was located at the center of the body. The blue frame which covers around each motor was the typical frame work provided by mini drone in the market for outdoor protection.

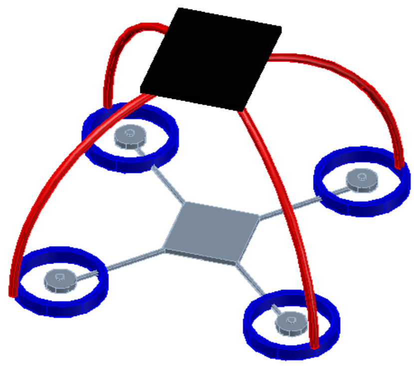

**Fig. 2 CAD design of structural modification of the mini quadcopter**

When designing the structure of the flying model, firstly light weight possible structure was considered. This provided an idea to make the added structure as a frame. The wire frame has the advantages of not only light weight, but also bendable which makes modifying process a lot easier.

### B. Design of the solar boost converter circuit

A solar boost converter boosts low input voltage to higher output voltage. The current will surely be stepped down in the process of stepping up the voltage input. To design the solar boost converter for mini quadcopter, the circuit must be as simple as possible so that the circuit board is light weight and can be easily installed to the body of the mini quadcopter. The solar boost converter needs to be designed and added into the whole system so that the potential difference produced by the solar panel can be boosted to a higher voltage. The solar panel used in this development has a size of (5.5cm X 4.5cm) with a voltage rating of 1.5V.

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However, the voltage it provided was insufficient to charge a battery with a voltage rating of 3.7V. A boost converter was designed so that the voltage produced by the solar panel could be stepped up to around 5V or slightly higher. The circuit design of the solar boost converter is shown in Figure 3. Voltage supply to the converter was 1.5V. Once the power supply was switched on, R1 resistor witnessed the decreasing current and the current went through T1 transistor base. Both T1 & T2 transistors were in inductance stage. Firstly, the T2 transistor collected them in zero voltage and increased current went to transistor's collector. The current was increasing until the transistor reached its saturation stage. This increased the voltage in the transistor's collector. As a result, T1 & T2 transistors were turned off. As the current throughout the T2's collector increased, T2' collector showed high voltage which charges the C1 condenser when going through the Schottky diode. The zener diode (Z1) restrained the charge voltage on C1. As the magnetic field and the inductance stopped, the voltage of T2'collector decreased to the supply voltage. Both transistors returned to the conductance stage and the increasing current went to the inductor again. The frequency of the process was about 10 Hz [2].

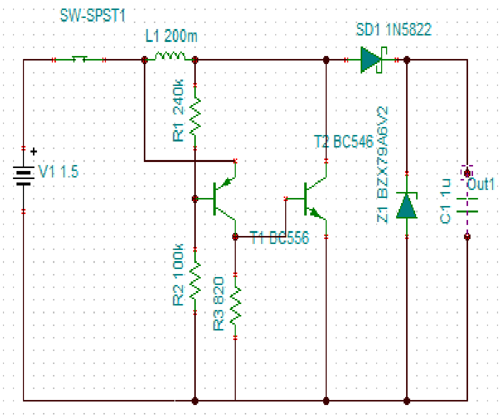


**Fig. 3 The circuit design of the solar boost converter**

### C. Design of the solar charge controller circuit

The circuit design of the solar charge controller is presented in Figure 4. The generation voltage of the solar panel used in this work was 1.50V-1.70V. The battery of 3.7V was used here to extract and boost up the voltage from the source to the required level. To transmit and distribute the generated voltage as well as boost voltage to the whole circuit, a charge controller was designed. A charge controller is a voltage or current controller that controls the power that supply into or draw from the battery storage. It helps to protect the battery and prevents it from overcharging, overvoltage that will later influence the performance of the battery, reduce its life span or even giving the risk of damaging the battery at the same time pose a potential threat to health and safety. The ultimate goal of a charge controller in standalone PV systems is to maintain the highest possible state-of-charge while preventing battery over-charge during high solar insolation and avoid over-discharging during low insolation and excessive loading [7]. A 555 timer was used as a switching device that can control the connections between the solar panel and the battery [3]. This timer circuit helped to set the threshold voltage levels of the solar as well as the battery to automatically switch back and forth between charging mode and cut off mode [3]. The timer used a relay to switch the modes. The low voltage cut of the circuit was 3.1V indicating the battery will start charging at 3.1V level. The high voltage cut of the circuit was 4.2V. It signified that the battery charging will be automatically stopped when the boost voltage crossed the 4.2V level. Two resistors (R1 and R2) made a voltage divider circuit, where the voltage drop of R1 was the solar panel output voltage, Vout= 1.667V. The voltage drop of R2 was the voltage after boosting the generated or output voltage of the solar at 3.333V from the transistor T1. In this state, the battery will be started to charge, so this voltage through the R2 resistor also worked as the input voltage (Vin) of the battery. By solving the voltage divider equations, the resistor value of R1 and R2 were determined. In order to make any adjustment possible, preset resistors were used to set up R1 & R2.

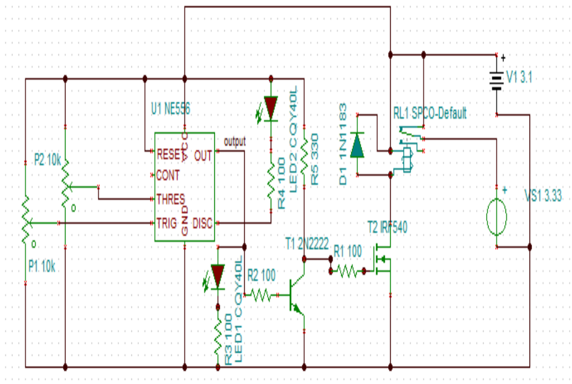


**Fig. 4 The circuit design of solar charge controller**

From Figure 4, the voltage regulator was not used in the charge controller. This was because the voltage produced by the solar panel was small enough to assume. It was harmless to the system. With the voltage regulator circuitry removed from the charge controller, it could reduce the weight of the circuit board making it possible to be mounted on the mini drone structure.

## III. RESULTS & SIMULATIONS

### A. Structural modification of the mini quadcopter

The structure of mini drone Hubsan X4 H107d FPV is modified so that the solar panel can be put on top and center of the quadcopter with the help of self-made wire frame. The wire frame gives advantages in terms of light weight. It is also an extra protection to the mini drone which helps to reduce the impact towards the ground or even protects the rotor blade during improper landing. The designed circuitry will be put on the bottom of the solar panel which ease the connection between the solar charging system and the battery. The modified mini quadcopter is illustrated in Figure 5.

**Fig. 5 The modified mini quadcopter**

### B. Circuit design simulation of solar boost converter

Figure 6 shows simulation results of boost converter. From the graph it is observed that the voltage is being boosted by the circuit from initial 1.5V to above 5V and stable at around 6V.

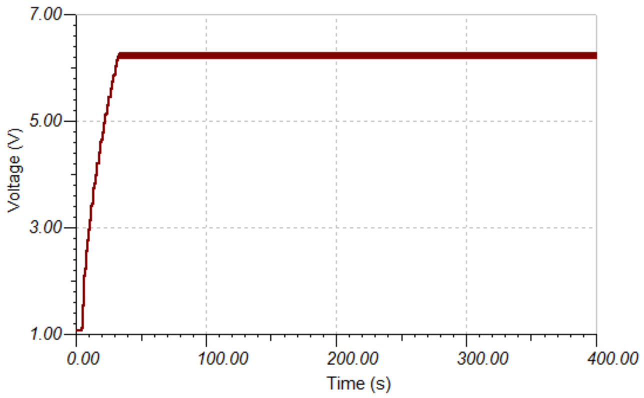


**Fig. 6 The simulation graph of output voltage of solar boost converter**

Figure 7 represents the second simulation result by using input voltage of less than 1.2V. It clearly signifies that the voltage is not boosted and becomes stable at certain level which is slightly below 1V. It also implies that the minimum operating threshold of the boost converter circuit is not less than 1.2V.

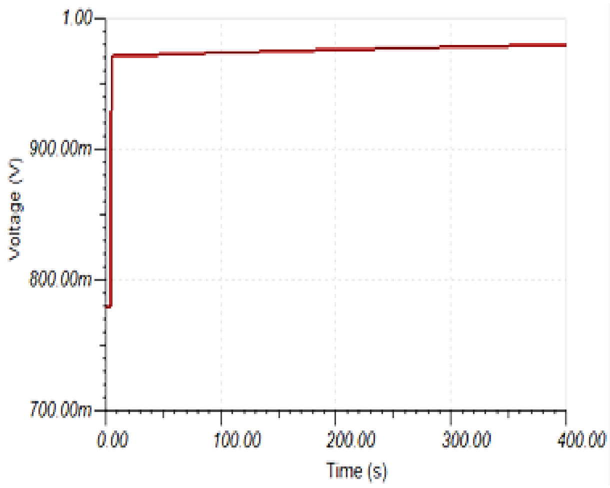


**Fig. 7 Simulation graph of output voltage with input voltage of 1V**

Figure 8 shows the PCB board which is designed so that the circuitry mounted on the body of the mini quadcopter is light weight and gives less burden to the quadcopter during flight operation.

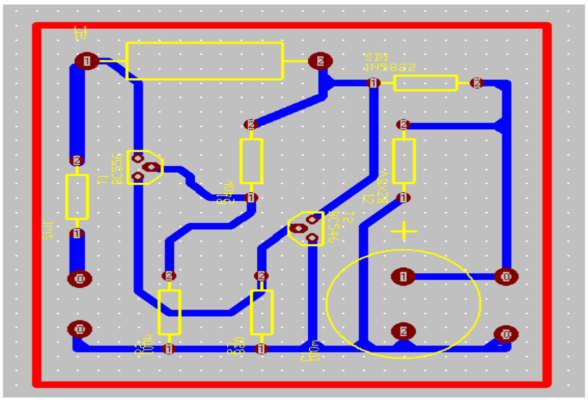

**Fig. 8 The PCB design of solar boost converter**

### C. Circuit design simulation of solar charge controller

From the simulation result of the charge controller, it can be observed in Figure 9 that the charging indicator LED is lighten up when the input voltage is supplied to the circuit. The 555 timer will allow the charging process going on until the battery reaches 4.2V. Till then, the charging process will be stopped by the timer and the dumping indicator LED will be lighten up.

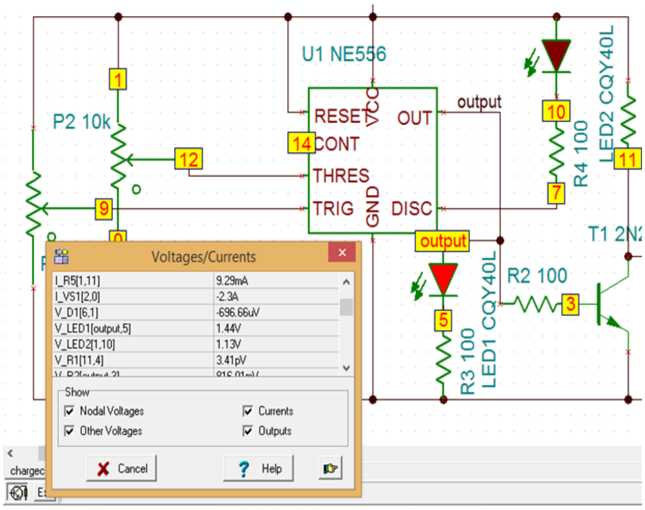


**Fig. 9 Simulation results of solar charge controller**

## IV. CONCLUSION

A light weight solar powered flying quadcopter has been developed for environmental monitoring purpose. The structural construction of the flying model is accomplished in such way that the solar panel gets the best position to gain optimum solar energy together with additional crash protection frame structure. The designed circuitry of solar charge controller and boost converter focuses on light weight aspect to make flying possible with added weight for various environmental sensors mounted for constant monitoring purposes.

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