Aerodynamic stability on piezoelectric multi Rotor UAV with numerical case learning

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Abstract : The purpose of this scheme is to design and manufacture a quadcopter that can work without interrupting the power supply. One of the main problems regarding UAVs is endurance, and various researches are under way to improve the endurance parameter. One of these is the use of electric generators from Piezo, which generate vibration power. In the quadcopter, the Piezo electric generators are used and power is increased and its durability increases. The reach of the scheme is Improved endurance, uninterrupted power supply Long range missions

Key word: UAV, aerodynamic stability, piezoelectric

1. INTRODUCTION

Piezoelectric concept:

Mechanical energy may typically be converted into electric energy by means of converters or generally known dynamo type of alternator. Nevertheless, other physical phenomena such as piezoelectropower can turn mechanical movements into electricity.

In two fields there are piezoelectric effects. One is a direct piezoelectric effect describing the ability of the material to transform machine strain into electric charge, while the other is a reverse effect which can convert the electrical potential applied into mechanical strain energy. the second form. figure 1.

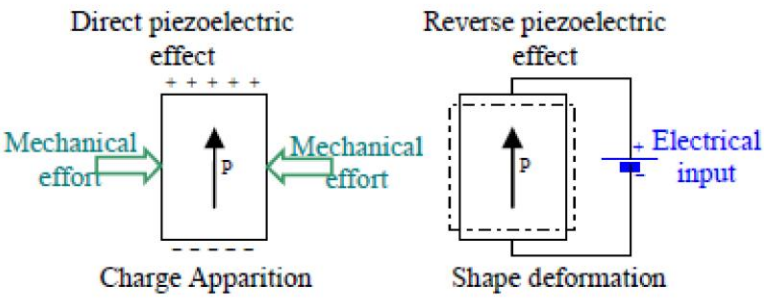


Fig.1 Electromechanical transfer by piezoelectricity

The same piezoelectric effect means that the material is able to act like a sensor and that its ability to act as an actuator is the reverse piezoelectric effect. When a material is capable of converting electric energy into mechanical stress as well as mechanical pressure energy, this is also called piezoelectric. Non-interesting electricity-producing piezoelectric materials that grow naturally as quartz, whereas artificial piezoelectric materials such as zirconat titanate (ZZT) are advantageous. Piezoelectric materials are part of a wider variety of so-called ferroelectric materials.

One of the defining characteristics of a ferroelectric substance is that the molecular structures are arranged to ensure that the material has a division of local charges, known as an electric dipole. Although the dipoles are distributed uniformly across the artificial piezoelectric material system, electric dipols are proportionally re-oriented to the electric field when a strong electrical field is applied and this step is called a poling phase. After the electric field is disappeared and the material is then called board. The dipoles follow their course. After the poling process is completed, the substance will feel the piezoelectric effect. The mechanical and electrical behavior of a piezoelectric material are described by two linearized constituent equations.

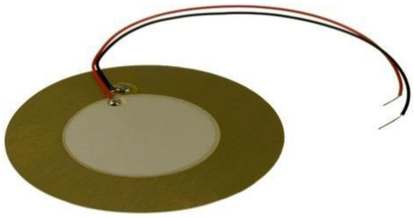


Fig.2 Piezoelectric crystal

2. ENERGY CONSERVATION FOR A PIEZOELECTRIC POWER HARVESTING SYSTEM

This paper studies a rectified piezoelectric power harvester's energy conversion efficiency. An empirical model is proposed and under steady-state activity an expression of output is derived. However, it clearly establishes the relationship between conversion efficiency, electrically induced damping, and ac–dc power output. It is shown that the optimization parameters vary depending on the coupling's relative strength. For the soft electromechanical coupling unit, the maximum power transfer is achieved when the output and induced damping surpass their peak values. Methodology involves - Concept development, Literature review, Weight estimation, Cost estimation, Design , Fabrication, Testing

Design of vehicle

Primary weight calculation

$W_{TO} = W_C + W_{PL} + W_F + W_E$

W_{TO} - Overall weight of the aircraft
W_C - Crew weight
W_{PL} - Payload weight
W_F - Fuel Weight
W_E - Empty weight

For the RC model we don't have any passenger weight. So W_{PL} is considered to be zero and the payloads include the electrical components weight, which is of 70 grams in approx.

W_{PL} = Passenger weight + payloads = 0 + 1 = 1 Kg

$W_C = 0$

$$W_{TO} = \frac{W_C + W_{PL}}{1 - \left(\frac{W_F}{W_{TO}}\right) - \left(\frac{W_E}{W_{TO}}\right)}$$

Since for RC model there won't be change in weight due to loss of fuel. Here the fuel is considered as battery, so due to discharge there is no change in weight.

Where K =1, A= -0.00296 and b=0.87 for RC model. So,

$$\frac{W_E}{W_{TO}} = -0.00296(W_{TO})^{0.87} * 1$$

Therefore, $$W_{TO} = \frac{1}{1+0.00296{W_{TO}}^{0.87}}$$

By iteration method the above condition is solved.

Iteration	Guess W_{TO} (Kg)	Actual W_{TO} (Kg)
1	1.2	0.996543
2	0.996543	0.997058
3	0.997058	0.997056
4	0.997056	0.997056

So, the approximate weight for the model is considered as 0.997 Kg or 1 Kg.

Thrust estimation

Overall weight of the model is W_{TO} = 1 Kg

T / W_{TO} for RC model aircraft are 1 for average flying aircraft and for some acrobatic flight it's given as 2. In here we use it for surveillance, so it's assumed to be 1. Thus,

T = 1 *1 =1 Kg = 9.81 N

So the total thrust for the model is considered to be 9.81 N.

Motor Selection

We need to know the engine and their specifications in order to select the engine first. The choice of the motor is based solely on the iterative process. The propeller must also be chosen for the design in relation to the diameter of the motor shaft. We selected a motor and propeller with the following specifications by approximation.

Power = 250 W
Motor efficiency = 0.7
Propeller Diameter = 0.254 m (10 inch)

Based on these parameters the thrust produced by the motor is calculated by the formula:

Where

T – Thrust in Newton
P – Power = Voltage*current*Motor efficiency
r – Propeller radius in meters
η – Prop hover efficiency (Ranges from 0.7 - 0.85)
ρ – Density of air (1.225 Kg/m^3)

The thrust obtained by a single motor is 9.57 N. In here we use four motors, so the total thrust produced by the motor will be

T = 9.57*4 =38.28 N = 38 N or 3.9 Kg

The above mentioned thrust will be produced when it's operating under full power condition. When the battery drains the power will also starts to decrease.

3. FABRICATION OF QUAD COPTER

Two micro-air and mini-air aircraft are known as Quad Copters. The category depends primarily on the quadcopter's size and weight. In creating thrust, torque and direction, each rotor has its own importance. The propellers that provide an impulse to the Quad copter are separate from two of them, clockwise, and two other propellers are counter-clockwise. As a result,' Zero' is the result of the torque. Aero Space engineers usually define three dynamic parameters, angles of delay, pitch and roll as shown in figure 1, to determine the orientation (or attitude) of an plane around the center of its mass. By varying speed of the engines the quad's direction differs as shown in figure 3 and 4 .

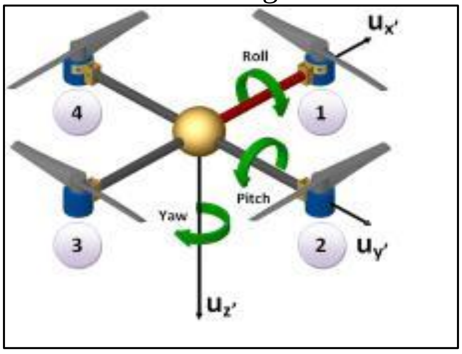


Fig.3 Common degrees of freedom of quadcopter

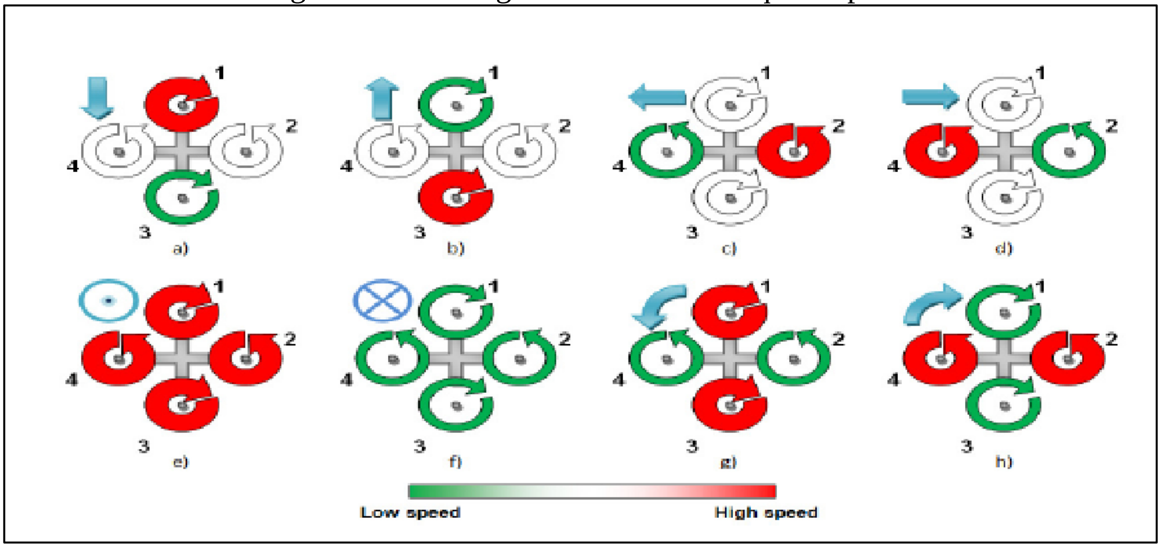


Fig.4 various movements of quadcopter

4. FRAME CONSTRUCTION

Frame is a key component in the manufacture of quadcopter. The frame holds the model's maximum load. The frame must thus be sufficiently rigid to handle the load. The frame and the flight control board are combined in order to reduce weight and be reliable. The flight control panel is essentially a Printed Circuit Panel (PCB) with certain other components of electricity and electronics. The PCB contains all the mechanism for operation and monitoring of the quad copter, in electrical and electronics systems. The PCB is thus made similar to the motor-mounted frame. The frame should include components for running the quadcopter, such as MEMS gyro, MCU, transformers, resistors and antenna. Selection and specification of the components is provided below.

For almost all sensing modalities such as temperature, sound, inertial forces, chemical compounds, magnetic field, radiation, etc., MEMS researchers and engineers have shown a huge number of micro sensors over the past decades. Remarkably, many of these micro-machine sensors surpassed their macro-scale counterparts ' efficiency. In other terms, for example, a pressure transducer's micro-machined model typically beats a pressure sensor produced using the most sensitive methods of macro-level processing.

Description of L3GD20

The L3GD20 is an angular rate sensor with 3 axis of low power. This includes a sensor and an IC interface providing the external world with a digital interface (I2C / SPI) for the measured angular value.The sensing component is created using an inertial sensor and actuator on silicon wafers built with STMicroelectronics. In order to match up the features of sensing component, the CMOS interface is developed and designed for a higher degree of integration, thus enabling the development of the required circuit for the same. This is a full-scale L3GD20 with ±250/±500/±2000 dps and is able to use user-selective bandwidth for measuring rates. The L3GD20 can be operated within the temperatures-40 ° C to+ 85 ° C in a plastic land grid array (LGA) package.

Features of L3GD20

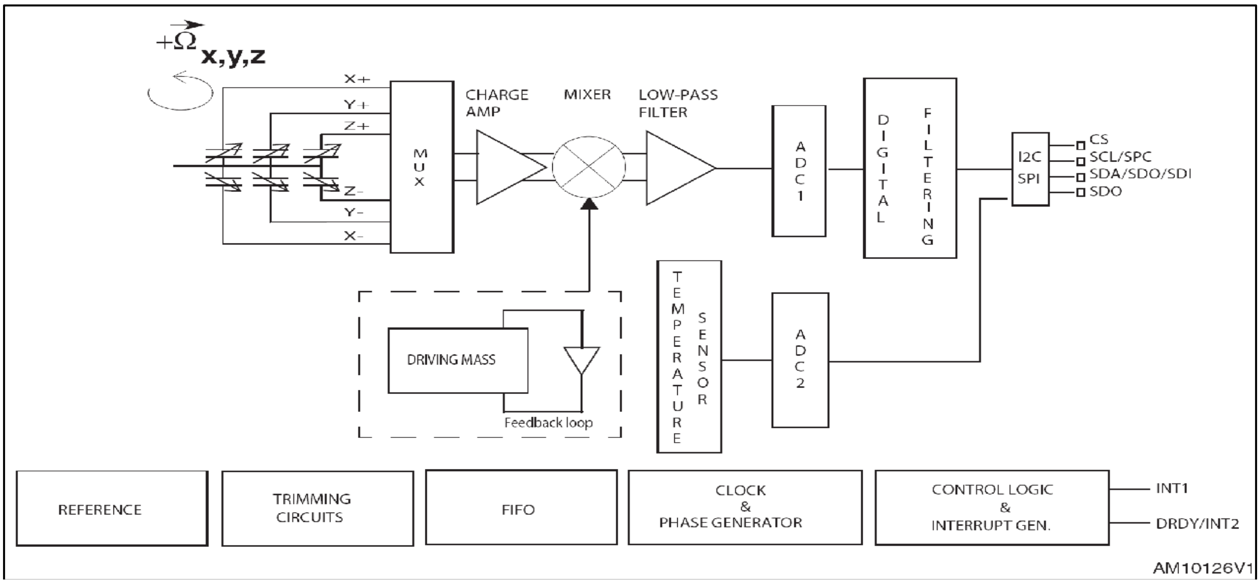


Fig.5 Block diagram of L3GD20

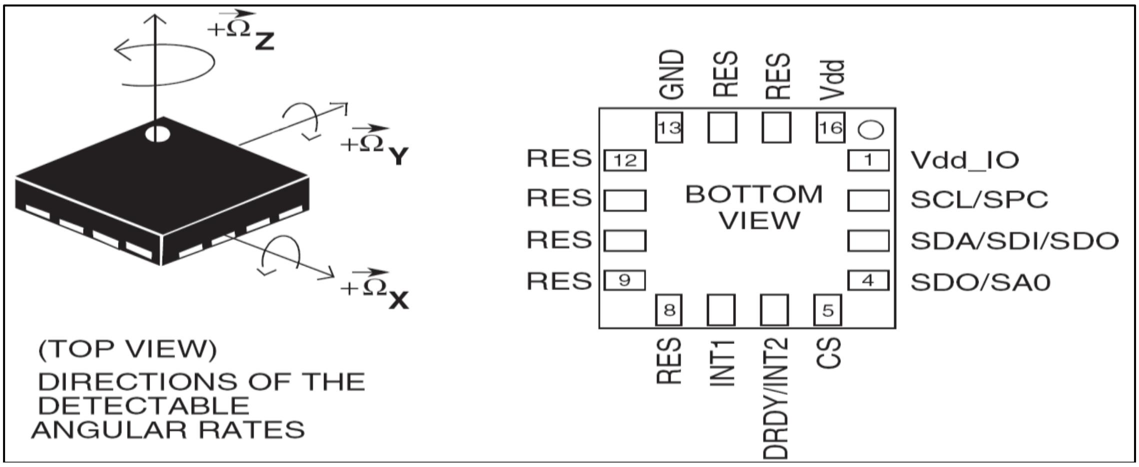


Fig.6 Pin connection of L3GD20

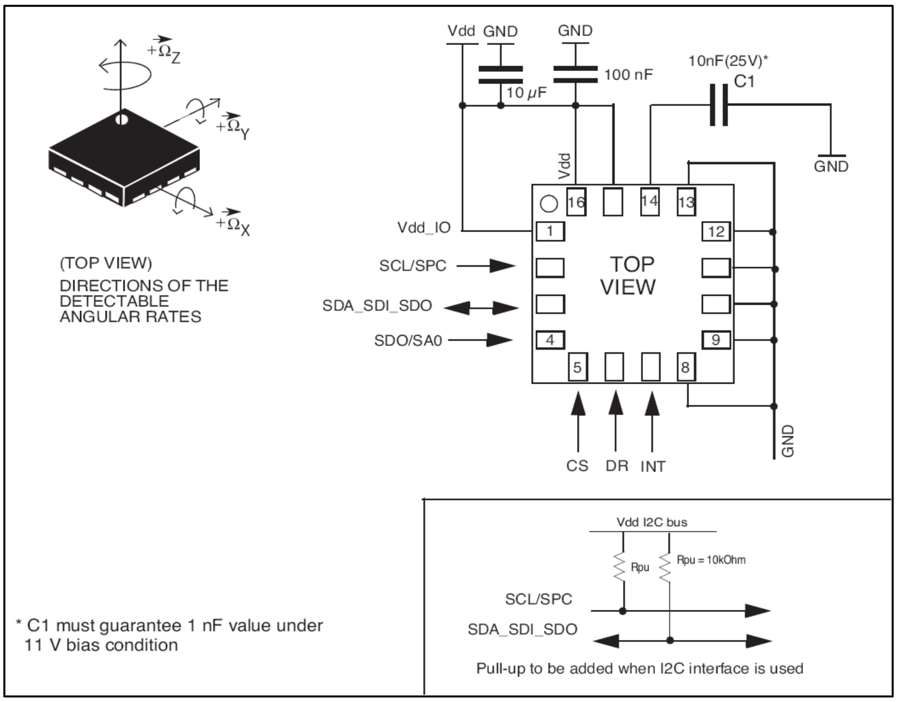


Fig.7 L3GD20 electrical connections and external components

5. MCU

Of automatic control articles and facilities, automated control systems, implant medical devices, remote controls, office computers, electronic appliances, cars, toys and other embedded system are all used. Its use is restricted by definition. Compared with systems which have a single microprocessor, memory and input / output sensors, microcontrollers allow cost-effective remote monitoring of several devices and processes. Microcontrollers with mixed signal are common and have analog components needed for electronic non-digital systems control. Different devices and processes may be remotely operated via microcontrollers, compared to a system that uses a single microprocessor, memory, and input / output sensors. Microcontrollers with mixed signal are common and have analog components required for control of non-digital electronic systems.

The frame for the quadcopter is built on the basis of the components. The quadcopter's frame length is 450 * 540 mm. The quadcopter's last version is shown in below fig. 8.

Fig.8 Frame and board for quadcopter

Motor

An electric motor is a mechanical energy-transforming system. The reverse is the conversion of mechanical energy into electricity by an electrical generator.

Table.1 Major Categories of motors

Major Categories by Type of Motor Commutation				
Self-Commutated			Externally Commutated	
Mechanical-Commutator Motors		Electronic-Commutator (EC) Motors	Asynchronous Machines	Synchronous Machines
AC	DC	AC	AC	
* Universal motor (AC commutator series motor or AC/DC motor) * Repulsion motor	Electrically excited DC motor: * Separately excited * Series * Shunt * Compound PM DC motor	With PM rotor: * BLDC motor With ferromagnetic rotor: * SRM	Three-phase motors: * SCIM * WRIM AC motors: * Capacitor * Resistance * Split * Shaded-pole	Three-phase motors: * WRSM * PMSM or BLAC motor - IPMSM - SPMSM * Hybrid AC motors: * Permanent-split capacitor * Hysteresis * Stepper * SyRM * SyRM-PM hybrid
Simple electronics	Rectifier, linear transistor(s) or DC chopper	More elaborate electronics	Most elaborate electronics (VFD), when provided	

Motor selection

Based on the design calculation the motor with the following specification is selected for the quadcopter model.

RPM per Volt = 850 kV
Maximum power of 250 W
272 mΩ
Ampere ratings = 0.6 A
Total number of Wire wounding is 14

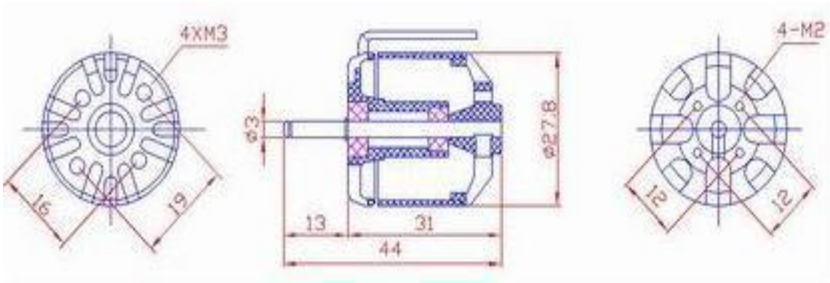


Fig 9 Motor dimension

RF module

A RF module for transmission and/or receiving of radio signals from two devices is a small electronic network. Wireless contact with another device in an embedded system is often helpful. This wireless communication can be rendered through radio frequency (RF) or optical contact. The medium of choice is RF in many applications because it doesn't require a display board. RF communications include a receiver or a transmitter [8].

Most carrier frequencies, like automotive, scientific and medical radio (ISM) frequencies such as 432.92 MHz, 915 MHz and 2400 MHz, are commonly used in consumer RF modules accessible. Due to national and international laws on radio communication, these frequencies are used. Short range phones may also use 315 MHz and 868 MHz unlicensed frequencies [9].

Piezo electric Generator:

Piezoelectricity is an electrical charging mechanism in response to mechanical stress for certain solids, including crystals, ceramics or biological materials such as bone and DNA.

The piezoelectric effect is seen as the continual electromechanical relation between mechanical and electrical conditions in crystalline materials without symmetry of inversions. The piezoelectric effect is a reversible mechanism in which immediate piezoelectric effects (the internal production of electrical charge arising from the mechanical force applied) are observed. There is also the reverse piezoelectric effect (inner mechanical pressure generations arising from the applied electrical field). Blei zirconatetitanate crystals for instance generate measurable pieza power when they deform about 0.1 percent of the original dimension of their static structure [10].

In comparison, in the external electrical field applied to the material the same crystals change about 0.1% of their static dimensions. Ultrasonic Sound Waves from the opposite piezolelectric effect are generated. Piezoelectricity is used for useful applications including sound production and detection, high voltage production, electronic frequency production, micro balances, ultrasonic nozzle operation and ultrafine optical assembly. It also supports a number of research instruments, microscopy sampling instruments, including STM and AFM, MTA and SNOM and daily applications, including the inflammation of cigarette flame, propane push-start barbecues and quartz watches. By using the following circuit, the power generation can be achieved. Fig. 12 depicts the block diagram for the piezoelectric generator.

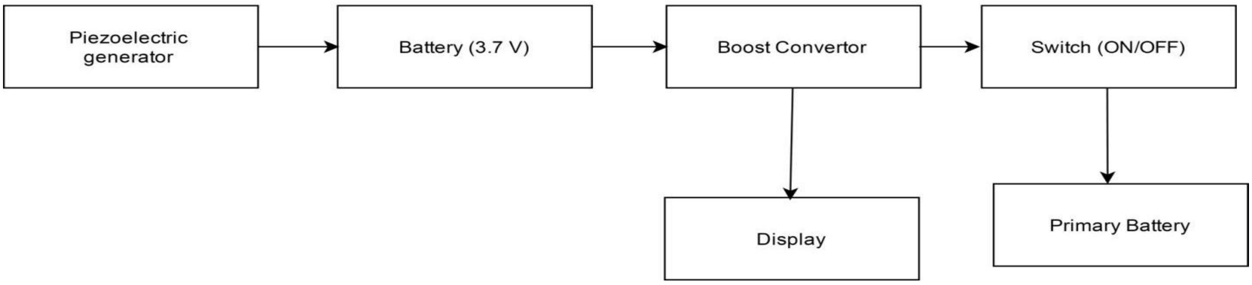
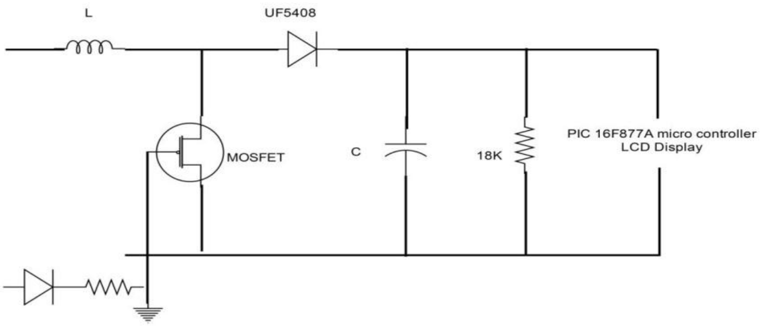


Fig.10 Block diagram for Piezoelectric generator

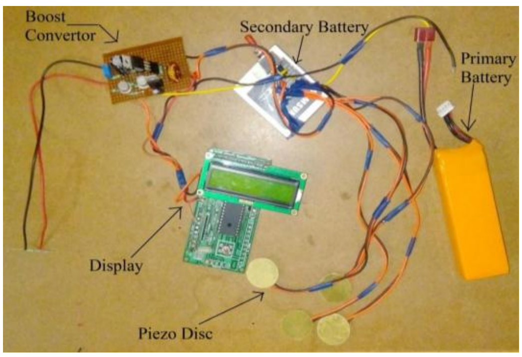
Boost Convertor

A boost converter is a converter that switches the voltage from the input (supply) to output (load) while lowering the current. A minimum of two semi-conductors (one diode and one transistor) and at least one energy storage component, one condenser and one or two inducers are present. In addition to the output (cargo-side filter) and input (supply-side filters), a condenser filter is usually added to the voltage riple (sometimes coupled with an induction system).

Designated CD sources, including batteries, solar panels, rectifiers and power generators, produce the converter energy boost. DC to DC conversion is a switching method for a DC to another DC voltage. A boost converter is the DC-to-DC converter with a voltage greater than the source voltage [11]. Often a booster converter is called a Step-up converter when the input voltage "steps up." The current output is less than the current source, because it should be handled under (P = V x I). The boost converter circuit for the generator is shown below.



The Boost convertor system for the above block diagram is as shown in figure 26 and the final block of Piezo electric generator is as shown in below figure 15.



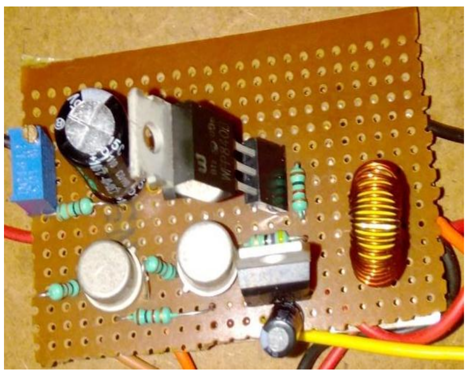


Fig.12 Boost convertor

Fig.13 Piezoelectric generator

Final Assembly

Thus by the use of all these components micro quad model has been fabricated. The Completed model of quadcopter with piezoelectric generator is shown in figure.16

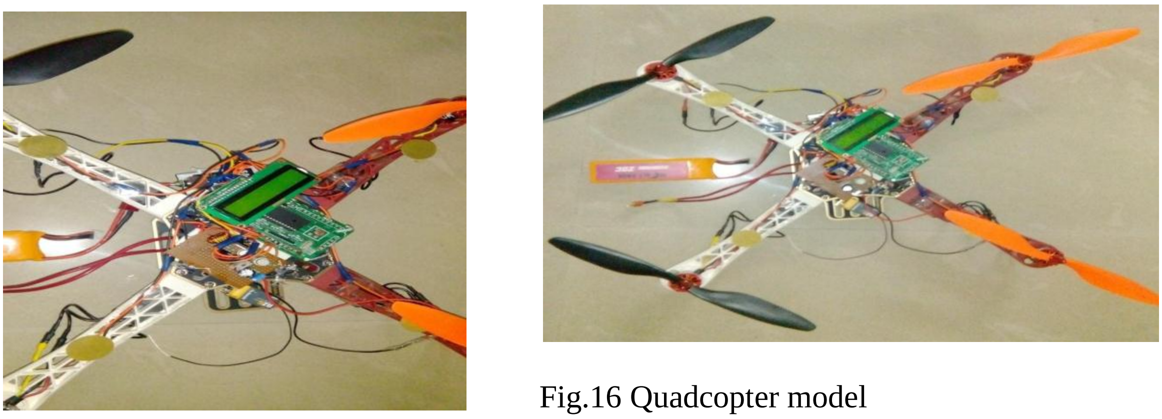


Fig.16 Quadcopter model

6. CONCLUSION

The location estimator functions very well in the calculation of the quad copter's position in the fixed navigation frame. It is robust and for the quad copter it tests any possible rotation. For the phi and theta tilt angles, a drift correction is also implemented. For the yaw drift correction is applied to make the quad copter stable. The other sensors also work extremely well in addition to the inertial measurement unit. The engine rpm is monitored continuously and almost no noise is present. Voltage and current sensors also work well and are an essential component of the controller board that requires a voltage to operate. The engines and propellers provide enough strength to lift the payload. The high engine power can also be used to stabilize rapidly and control the quad copter heavily. The quad copter can communicate with a base station via a Wi-Fi connection. The radio link allowed the control unit to be adjusted to the quad copter without the need for wires. Stabilization on one axis has been checked before free flight. This has been done in a quad copter test rig. We have therefore achieved our design goals successfully and demonstrated autonomous flight which, as mentioned earlier, could be used for any application.

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