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Design of Anti-Collision Light System Using Thick-film Technology

Bhargavi G S , Joshua Daniel Raj
MTECH- Aerospace Engineering (Avionics) IIAEM, Jain University, Bangalore
MTECH- Aerospace Engineering (Avionics) IIAEM, Jain University, Bangalore

***Abstract**: Critical part for pilots to sight airborne vehicle's in both airspace and ground stations during different phases of operations. Tocater for this importance, all aircraft are installed with lights to prevent collision. These warning lights are mounted with the wingtips oron top of vertical-stabilizer. For most of the aircrafts theses lights are strobe type flashing white at daylight and red at night. Types of collision warning lights vary from strobe, oscillating beacon to rotating beacon types, which are located on or underneath the fuselage of an aircraft. The source of the light should adequatelyilluminate in normalflying condition which would be visibleto other aircrafts and prevent collision. Traditionally, red incandescent bulbs (beacons) were used and ended up to their short lifespan and ruggedized design. This paper indicatesuse with,arrays of high-power LEDs as alternative to previous used incandescentbulbs, which has been possible since the development of LEDs of sufficient brightness. Also, helps in longer lifespan, reducing maintenance costs and increasing reliability.This paper establishes the design requirements for flashing type anti-collision light to be installed on Military Variants of fixed wing aircraft. The design and simulationis crucial in order to accommodate military standards and clear various certificationsso that, general aviation pilot can be benefitted from this system in order to perform safe flight. This paper also includes electrical design and simulation of LED based anti-collision light system.*

***Keywords:** Optics design,Driver Module, Mechanical-housing,Hybrid Microcircuit, Thick-Film hybrid technology*

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I. INTRODUCTION

All rotorcraft and fixed-wing aircraft would have approved anti-collision lights for day and nightoperations due to heavy air traffic at various airspace's especially, near to metropolitan cities. It's vital source that pilots need to visualize in and around aircraft with airspace and at ground level. To cater for this event, all aircraft are installed with anti-collision lights to spot one from other at ease. The anti-collision lighting system is designed according to Federal Aviation Regulation (FAR) PART 25.1405(Para (b) to (f)).

Anti-collision lights are used primarily to assist in assuring that, an aircraft is readily visiblewhile, on ground or in air. These lights are generally mounted at the wing tips not far from position lights else, on the top of the Vertical stabilizer. With most airline operated aircraft these lights are white which are strobe type varieties. Another type of anti-collision light is red(flashing, oscillating or rotating beacon type) located on top and/or underneath the fuselage of aircraft. These lights are switched ON for all operations, ground and flight, day and night, below 18,000ft above ground level (AGL). And at night fly time lights are switched on regardless of altitudein airspace. Two places anti-collision lights are located on the fuselage which is, one on upper surface, another at lower surfaceof fixed-wing aircraft are required to provide adequate warning to the distant aircraft. The light should produce sufficient illumination to be seen by the other aircraft in normal contact flying conditions to avoid collision.

Flashing type anti-collision lights are high-intensity lighting devices that are installed at vertical fin,anti-collision strobe light mounted on the vertical fin will meet the minimum requirements on most aircraft. At bottom areas of fuselage mounted anti-collision strobe light system, a minimum of two strobe lights are necessary to get the required vertical visual coverage. This is an approved anti-collision system that serves as collision avoidance method by warning other aircrafts. Such device makes host aircraft more visible to intruder aircraft and is usually used at night, although they may be used during the day as well. These lights need to be of sufficient brightness in order to be visible forother aircrafts. Fuselage mounted units can be either self-contained with the power supply and light -head as one unit, or remote light heads run off with separate power supply. To meet the field of coverage, one must be on top and another at bottom of the fuselage.

II. EASE OF USE

A. OBJECTIVE

This paper establishesdesign requirements for flashing type anti-collision light to be installed on Military Variants of fixed wing aircraft, which is capable of flying by airfoil shaped wings that generate lift caused byvehicle's forward airspeed through constant relative velocity.The anti-collision system is recommended to be in good visibility, where only strobes and beacon are required to indicate or signal ground-crew. For example, just before pushback from decking position, the pilot must keep the beacon lights on, to indicate ground-staff that, engines are about to turn-on and stays on for entire duration of flight. At taxiing,taxi lights are on. While moving towards runway field, the taxi lights are off and the landing lights along with strobes are on. Whenaircraft climbs 10,000ft AGL, the landing lights are no longer requiredand pilot can elect to turn-off. This cycle repeats in reverse order before landing phase. Similarly, when pilot at cruise phase i.e., altitude constant flightwill encounter with other aircrafts flying in variant airspace,so in order to make host aircraft visible to pilot of intruder aircrafts; he must switch-on his flashing type anti-collision light. This helps both the pilots to maintain their flight route and avoid collision. Civilian commercial airliners also have to compulsorily install anti-collision light to avoid collision in case of failure of collision avoidance system or in absence of Terrain Collision Avoidance System (TCAS).In order to help pilot operate safely; an anti-collision light is designed for the particular aircraft and this paper explains each design parameters necessary to fabricate an entire Anti-collision light assembly.

B.PROBLEM FORMATION

In India, anti-collision light for rotary wing aircraft is availablebut until now no known sources have designed and developedanti-collision light for fixed-wing aircraft. So,anti-collisionlight for fixed-wing aircraftis designed and developedconsidering the following parameters:

(a) WeightConstraints

For all aircraft, weight aspect is the crucial parameter to be considered,weight of the existing anti-collision light is more due the optical design. To meetdesired output, a greater number of LEDs has been utilized, which in-turn have placed much more drivers, all this led to weight constraints.This has made it incompatible to be used in aircraft. To overcome this,new design optical configuration is optimized so as to have reducedweight which yields in decreasing aerodynamic drag. Light module is fabricated in a sophisticated manner so as to make it look elegant without compromising on the robustness.

(b) Vibration

The blade rotates at higher rotations per motor (RPM), causes vibration of the light module. To avoid routine services of the damages to the light module the mechanical structure is made more rugged which in turn increasesweight of the light module. This new design is unique, by modulating intensities it can be used for either rotary wing or fixed-wing aircrafts. Design standards are followed while developing this light module such as:

(1)FAR Part 25: This regulation covers the insights on color oflight,field of coverage, flash-rate, effective intensity, etc.
(2) MIL-STD 810E/F: Military Standard brief details of environmental tests that light module should be subjected in order to be used on aircrafts.
(3) MIL-STD461/462: This standard describes the surge protectionsthe light must provide. Specifically, test requirements i.e., Electromagnetic Interference and Compatibility (EMI/EMC).

III. DESIGN SYSTEM REQUIREMENTS

(a)Field of Coverage:

The system mustilluminate sufficient amount of light around vitalregions of the aircraft considering the physical configuration andcharacteristics representing the flight. The field of coverage must extend in each direction, at least 30 degrees above andbelowhorizontal plane of aircraft, except for a solid angle or angles of obstructed visibility totaling not exceeding 0.03 steradians (SI unit of solid angle) is allowable within a solid angle equal to 0.15 steradians centered about the longitudinal axis in the rear-ward direction.

(b) Color Specifications:

This should comply with FAR Part 25.1401, which implies that white LED is used foranti-collision light and should have the applicableInternational Commission on Illumination chromaticity coordinates (CIE) as follows:

Red Scatter Color—
y is not greater than 0.335; andz is not greater than 0.002
Green Scatter Color—

x is not greater than 0.440-0.320y;x is not greater than y - 0.170; y is not less than 0.390-0.170x;

White Scatter Color—
x is not less than 0.300 and not greater than 0.540;
y is not less than x−0.040; or y_0−0.010, whichever is the smaller; andy is not greater than x + 0.020 nor 0.636−0.400x;

Where y_0 is the y coordinate of the Planckian radiator for the value of x considered.

(c) Flash Rate:
The number of lightarrangement sources, beam-width, speed of rotation, etc., must emit an effective flash frequency that should not cross 40or more than 100 reputations per minute. The effective flash frequency, at which the airplane's complete anti-collision light system is observed from a distance, and applies to each sector of light including any overlaps that exist when the system consists of more than one light source.With overlapsflash frequencies may exceed 100, but not 180 reputations per minute. The designed flash rate is 42 flashes per minutes which means for every 1.43seconds one flash is emitted for providing the assembly continuous flashing.

(d) Light Intensity:
The minimum light intensities in all vertical planes, measured with the red filter (ifused) and expressed in terms of "Effective Intensities",should be minimum of 400 candles (cd).

IV. NUMERICAL CALCULATIONS

Considering loss of glass and reflector:
Effective intensity with losses (I_e) = 400/(0.90*0.90) i.e., 493.8cd and flashes per minute that can give maximum intensity is considered to be 42 flashes.
Therefore,42 flashes = 60 seconds
1 flash = 60/42
1 flash = 1.42 sec
So, 60flashes occurrence timeper seconds are: (1.43, 2.86, 4.29, 5.72, 7.15, 8.58, 10.01,…...60) sec, between flash time interval(t_1 and t_2)t_1= 1.43 and t_2 =2.86
(1) Effective Intensity (I_e),

$$I_e = \frac{\int_{t_1}^{t_2} I(t)\, dt}{0.2 + (t_2 - t_1)}$$

Where,I(t) = Instantaneous Intensity asfunction of time.
I(e) =Effective Intensity = 400(Designed goal/required)
$t_1$and t_2 are flash time interval in seconds.
From above formula,we can calculate instantaneous intensity as, I(t) =455.94 cd
(2) Power Calculation
Number of LEDs per phase = 3
Number of phases = 10
Total LEDs number = 30
Voltage (V) = 2.90 V
Current (I) = 0.70 mA
So,
Power (P) per LED = Voltage (V) * Current (I)
P = (2.90* 0.70)
P = 2.03 Watt per LED
And,
Power for entire light Assembly (P_{total}) = (2.03* 30)
P_{total}= 60.9 Watt
Minimum effective Intensities for an anti-collision light system, effective intensity must be equal or exceed the applicable value in the following table:

TABLE 1

Angle above or below Mounting plane of light	Minimum Effective Intensities	
	Designed Goals	Required
Degree	Candle (Cd)	Candle (Cd)

0 to 5 5 to 10 10 to 20 20 to 30	400 400 240 240	400 240 80 40

Table 1: Represents mounting plane of flight (deg) to required (cd)effective intensities

V. LED MODULE

LUXEON Rebel ES High power LED from Philips is selected for this project with a typical angle of 120 degrees and ideally forward voltage of 2.90 V. The LEDs are assumed to work at DC forward current of 700 milliamps with color temperature of Cool White 5650K atoperating temperature ranging from -40 degree Celsius to +135 degree Celsius. Based on the size and nature of LEDs; a metal core PCB is designed using AutoCAD and figure 1 illustrates the metal core PBC below.

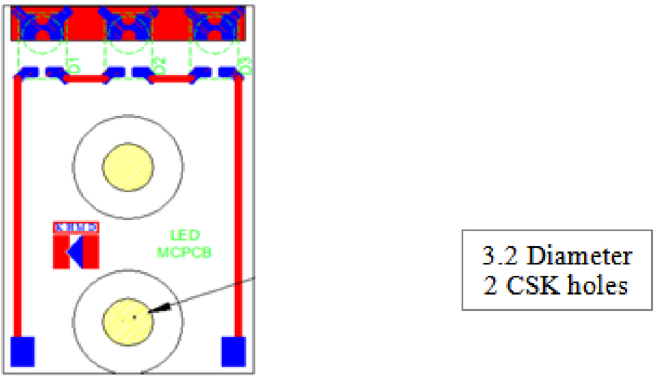

Figure 1: Metal Core PCB

VI. ELECTRICAL DESIGN

All connections as per the standards MIL-DTL-38999 series III orequivalent standards to the unit. The connector to the light shall be of polarized type.Mating connectors along with back shellsbe supplied by vendor for the prototype units for flight-testing on the airborne vehicle. Electrical bonding shall be either through, ground lug connectors or connector pin, vendorindicate the type of bonding available with schematic details.

The driver is specifically designed to suit the military standards. Hence a sophisticated technology is being used to achieve the driver parameters accurately with the design. This technology is called Thick-Film hybrid technology, whereinsizeparameters of driver is miniaturized without compromising on the space constraints. Hybrid Microcircuit is used and attempt to introduceintegratedmicrocircuits using screen printed thick-film for required designto approach this technology.

1)Benefits of hybrid microcircuits over PCB as follows:-

a. High performance
b. Miniaturization
c. High reliability
d. More precision
e. Extreme environment handling capabilities
f. Low signal interference
g. Weight Reduction
h. High Accuracy
i. Better Heat Management
j. Reduced failure rate
k. Better Inventory Management

2)Design Process

a. Printing
b. Drying
c. Firing
d. Trimming of resistors

3) Assembly Process

a. Dieattach
b. Wire bonding

c. Soldering of chips
d. Substrate attachand leads attach
e.Testing and Packaging
f. Final testing (Electrical and Environmental)

Figure 2, displayed a driver design using DUREZ coated with hybrid microcircuit layer.

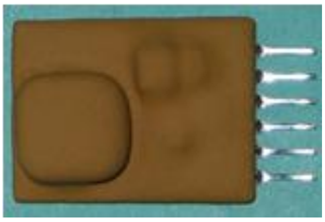

Figure 2: DUREZ coated hybrid microcircuit Driver

VII. SIMULATION

This regulator device is qualified for automotive applications. All passives and components selected in this design arequalified to automotive applications. The user is required to verify that all components in the design meet the qualification and safety requirements for their specific application with the help of WEBENCH SOFTWARE that helps to yield:

1) Electrical Simulation Report:
WEBENCH simulation tools attempt to recreate the performance of a substantially equivalent physical implementation of the design. Simulations are created using Texas Instruments' published specifications as well as the published specifications of other device manufacturers.

2) Thermal Simulation Report:
The driver is simulated at different operating temperatures i.e. at -40, 25, 55 and 71 degree Celsius in order to verify the robustness of the driver at all environmental conditions. The simulation is done using WEBENCH software and the same is attached below in order to show the condition of parts being used in the driver at same operating condition (i.e. Vin 16 V to 32 V and Iout 0.7 A), Different ambient temperature (i.e. -40, 25, 55 and 71 degree Celsius), convection air flow and insulated edge temperature.

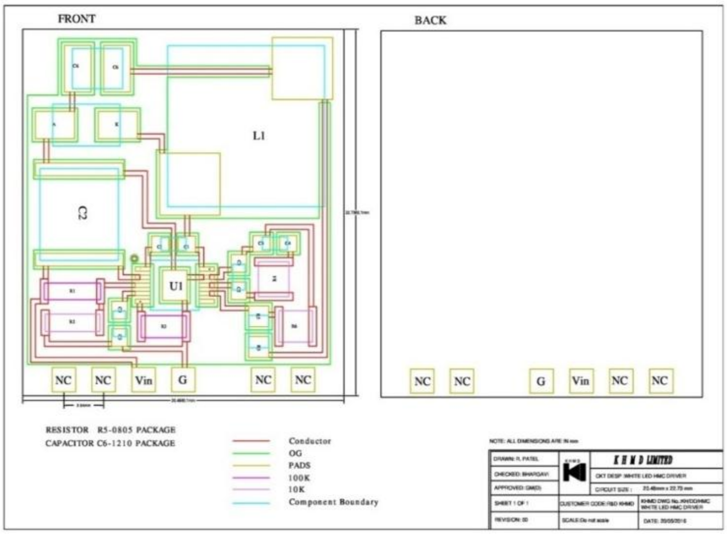

Figure 3:Hybrid Microcircuit Driver using software

NOTE: To realizeform factor, performanceand reliability goals in product development, design process should perform thermal simulationin the development cycle. So, thermal simulation enables engineers to design smaller, more economical products that perform better and endures longer. Thermal simulation offers added benefit of being able toiterate the design rapidly, trying multiple options in thermal management and ultimately in cutting timetomanufacturer.

VIII.MECHANICAL DESIGN

The mechanical module is designed by using Aluminum 6082 material with exterior hard coat anodized finish and silicon gaskets are used for sealing the assembly to prevent from water, humidity, dew and air resistance. Assembly of parts is done by fastener and heli-coilinserts which helps in multipleassemblies also in making its structure stronger and rugged.The mainobjective is to design light weight housing compromisedof requirements mentioned as follows-

a. Dimensions

The light source will havedimensions requiredto be installed on the aircraft within overall dimensions such as,

Diameter = 150mm ± 0.5mm

Height = 90mm ± 0.5mm

b. Installation

Suitable locking mechanism will be provided for properadaptabilityof the light assembly in the installed condition. Metricthreads and interfaces will be required for customization of design.

c. Total weight

The weight of design unit will be approximately 750g,including the visible flashing unit with integrated power supply. The weight can be optimized in consultation with the vendor in necessary conditions.

The module is designed using CATIA V6 and the actual design is presented in figure 4. with labelled components layer

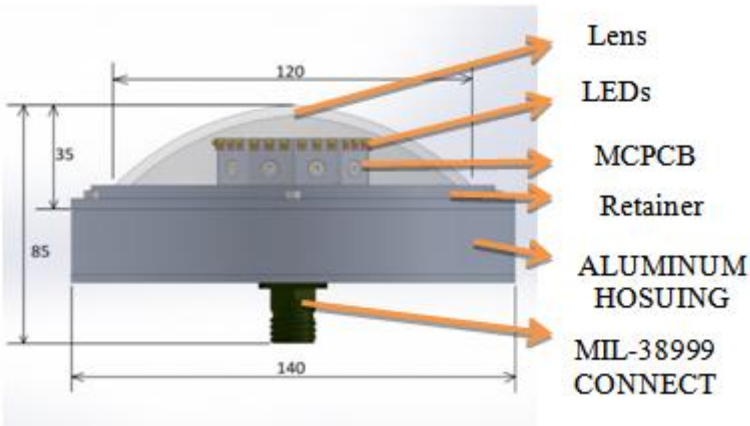

Figure 4: Anti-Collision Light Module

IX. WORKING OF ANTI-COILLSIONLITHING SYSTEM

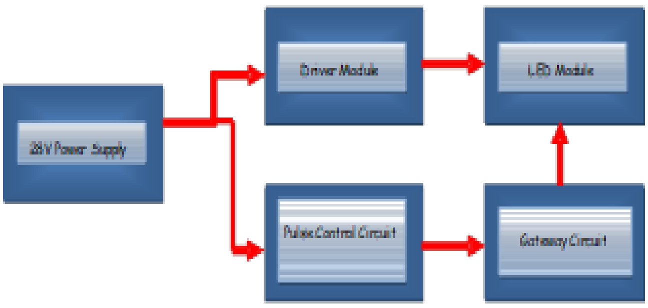

Figure 5: Block Diagram of Anti-Collision LightSystem

From above figure 5, operation for each block are mentioned below:

a) Power Supply Unit

sources power to both driver module and frequency generator module. Power to turn on the driver is 28V and for the frequency generator is 3.3 V

b) Driver Module
This has a device (IC) to drive the LED at constant voltage. This driver is designed using the hybrid technology.

c) Pulse Control Circuit
This generates pulses of required frequency with internal regulator which down converts 28V from power supply to 3.3V.

d) Gateway Circuit
Acts as barrier between Pulse controller and LED module. It is a transistor switch that turns at a regular time period in order to flash the LED.

e) LED Module
This consists of the high-power LEDs that are determined to flash at a constant rate. The LEDs are mounted a metal core PCB for it to avoid dissipating heat and in turn increase its efficiency and life span.

X. CONCLUSION

This study proves thatAnti-Collision light design is compact, and rugged, this proves to be the apt solution for military or any airborne application. The advantage of reducing the number of LEDs has become prominent in reducing the number of drivers, therebyreduction in weight and overall cost of the light module. White LEDs have twice the intensity of Red LEDs and hence lesser number of LEDs has been used to get the required effective intensity.Redesigned approach of the drivers has made a great impact on the performance of drivers to drive the LEDs which led to reduction in space consumed by the drivers, as two drivers per phase in the old module is replaced with a single driver per phase in the illustrated new design and performance of the module has been enhanced togreater extent. In addition, to assembly of driver are made less susceptible to vibration by 50%. Redesigning the mechanical module to reduceheight and increase diameter at the LED mounting part has helped to achieve maximum optical illumination with sleek design view. Hence provision for additional payloads is made available. The height reduction also helps in decreasing dragforce of the aircraft, also reducing the consumption of fuel by aircraft.

XI. FUTURE SCOPE

The advanced light module could include the usage of single chips on Board (COB) LED with reduced components. The driver can be attached behind COB that can also act as a heat sink for the LED light.Hence, we can eliminateother external heat sinks and better light distribution can be obtained.The existing LEDs which are mounted vertically can be mounted horizontally which can drive the LEDs with low currents and thereby,improving on thermal protection for the LEDs. The entire LEDs can be mounted on a single MCPCB but10 of those MCPCS are required for the ten phases as of now.Advantages of new designed LED system includes weight reduction, power saving, longer lifetime, higher reliability and significantly minimised maintenance effort in comparison to previous anti-collision light system. Further based on the intensity required for various type of aircraft andoperation orientated; the anti-collision light system can be designed and fabricated with different drivers and LEDs to suit particular aircrafts. It can also be made dual mode anti-collision light system including infrared (IR) mode for Night Vision Goggles (NVG) compatible in order to experience safe flight during hazards weathermeteorology conditions.We can design the light module body and structures with composite materials instead of aluminium material in order to reduce theirweight further.

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