DESIGN & DEVELOPMENT OF POWER & COST EFFICIENT LED PROJECTOR

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ABSTRACT

A video projector is an image projector *that receives a* video signal *and projects the corresponding image on a* projection screen *using a* lens *system. Video projectors are widely used for many applications such as,* home theatre*, conference room presentations, classroom training and other educational settings. This paper illustrates a design and testing of a low cost yet energy efficient video projector with a high power custom made LED as the light source giving it a long life completely different from the conventional projectors that employ Metal Halide Lamps. The high power LED is cooled using a liquid cooling system and thermo switch is also installed preventing LED to reach high temperatures.*

Keywords: Led, Liquid Cooling System, Projector, Thermo-Switch, Temperature Controller

I INTRODUCTION

There are basically two types of video projector technologies. First type is the 3LCD technology [1] projector using Liquid Crystal Display (LCD) light gates. This is the simplest system, making it one of the most common for home theaters, business and educational use. Second type is Digital Light Processing (DLP) projector using DLP technology [2]. This technology uses one, two, or three micro-fabricated light valves that are called Digital Micromirror Devices (DMDs). The single- and double-DMD versions use rotating color wheels in time with the mirror refreshes to modulate color.The common part in these projector types is there projector lamp. Both these technologies employ Metal Halide (MH) lamps as the main light source. The Projector Lamp, otherwise known as the projector bulb, is a replaceable part of the projector that needs to be maintained according to the lamp life of the projector, which averages between 1,000 and 2,000 hours only [3]. A commercial projector with basic features and Super Video Graphic Array (SVGA) resolution is generally priced at an amount of Rs 25,000 or above. The lamp life of the basic projector is typically not more than 3000 hours. Plus what adds to its cost is the replacement of lamp in a short time period which cost more than half of projector price itself. Since the lamp is based on Metal Halide technology it does not achieve full light output immediately after starting. Rather, they require a time period of 1 to 15 minutes to reach 90% of their full light output. This period is called the Warm-up (or run-up) time. After a lamp has been switched on for a period of time and then extinguished, it cannot be immediately turned back on. Before the lamp can be turned back on, the arc tube must have a chance to cool down or the lamp will not restart. This period of time is called the Restrike time. That is the reason commercial projectors with MH lamp technology do not start up instantly and once turned off require a gap of certain time to cool down before tuning on again. Also frequent turning on and off of a commercial projector affects the life of the lamp [4]. In keeping with technological developments, customer requirements on projectors have become even more sophisticated, requiring more hours on projector lamp life and less power consumption in order to run these projectors continuously in educational setting like schools and various institutions which utilise Digital Content in Smart Classes for learning purposes. In the same way, low cost projection systems are now requested that can offer increased functionality for a given cost. This arises a need for efficient video projection system which has greater lamp life and inexpensive initial cost and maintenance. Hence, this paper is proposed to design a video projector which posses given properties:

- Low power consumption
- Continuous long run without any issue
- More hours of lamp life.
- No warm-up time
- Cost efficient
- Low maintenance

There are projector designs presented before which works on basic rules of optics but they poses significantly large size, weight, high on power consumption and still are very expensive[5]. The projector proposed here gives a perfect solution to discussed problems. The basic idea starts from a strong light source which is employed that shines through a LCD and is then focused onto a screen some distance away from the projector. Light is generated by the lamp in rays that extend perpendicularly from the filament within the bulb. If these rays were to shine through an LCD the light entering the edges of the display would be entering at a severe angle. This would cause the light to pass through more than one pixel which would blend the colors and prevent a sharp image from being obtained. To prevent this, a lens is used to refract the rays so that they run parallel to one another. This is referred to as collimating the light and is done using a collimator lens. The collimated light then passes through an LCD. The pixels within the display are what provide color to the final image. This LCD is hooked up to a controller card which is used to project the image from a computer or other media device. The light then passes through another lens called the concentrator lens.

This lens directs the light into a projection lens. The projection lens is used to focus the projected image onto a screen. This projection lens is usually referred to as a triplet because it often contains 3 glass elements. The size of the projection depends on the optical configuration of the projector, the size of the LCD that is used, and the distance from the projector to the projection surface. The distance required for a given projection size is referred to as the throw of the projector. This arrangement is shown in Fig.1.

II. COMPONENTS

2.1 Optics

The lenses in a projector are one of the most important parts of the build. They are also the most difficult to place. The reason for this is that the optics in this projector is based on the size of the LCD that is being used. To achieve a high resolution at a low cost, this typically involves a relatively large LCD screen. Both the collimator and field lenses need to be larger than the LCD that is used. If traditional lenses were used a single lens could be very expensive. To avoid these costs, Fresnel lenses are used.

A Fresnel lens is usually made out of plastic and contains a series of concentric rings which mimic the effect of a traditional lens. These Fresnel lenses are relatively inexpensive and come in large sizes which make them ideal for use in a projector. Fresnel lenses are described using focal length (FL), distance between grooves (groove pitch) and sheet dimensions. The focal length of a lens is the location at which parallel light rays entering a lens are focused on; this is common between all lens types. The groove pitch is only used to describe Fresnel lenses and less distortion is present from lenses with a lower pitch. The physical sheet dimensions represent the thickness, width, and height of a lens.

2.1.1 Fresnel Lens Collimator - Normally a Fresnel lens is cut according to an aspheric surface profile in order to minimize the imaging optical aberrations. The lens can therefore do an excellent job of collimating an idealized point source. In real life, no source is a true point; however solid state emitters such as LEDs can be quite small, so with enough distance between the lens and the LED, it may be approximated as a point source. A Fresnel lens can therefore be used to collimate the LED output.

2.1.2 Fresnel Lens Concentrator - An optical system in which the goal is to converge light from a relatively large regional area to a significantly smaller aperture can be labelled as a condenser or concentrator. For a concentrator system a Fresnel lens design will be thinner and lighter weight than an equivalent continuous surface optic. Here concentrator Fresnel is used to converge colour light from LCD to Projection Lens or triplet lens. Fresnel lenses are discussed in detail in reference [6].

2.1.3 The triplet is a series of 3 lenses within a single enclosure. The triplet is used to focus the image on the projection screen. Without this lens, the image would be blurry, making it impossible to watch. Focus is achieved by mounting the triplet in such a way that small adjustments can be made to its position.

3D diagram showing the path followed by light rays from lamp to collimator Fresnel lens to stripped LCD and then to field Fresnel lens shining according to the LCD pixels which are then projected on a screen via projection lens is given in Fig.2.

2.2 Light Source

The light output of the light source determines how bright the final projection will be. The color temperature of the light source influences how accurate the color of an image is projected. If the light source has a specific color the whites of the projected image will contain that same hue. It is important that the chosen light source has a high light output and color as close to white as possible. The ideal color temperature is around 6500 degrees Kelvin. The power of a light source is often used to describe how bright the bulb is (100 watts, 200 watts, etc), however this is only applicable when comparing light sources of the same type. There are a variety of light sources that can be used when building a projector which include Metal halide, halogen, xenon, LED, and plasma. From these LED is used in our projector as it is the most efficient light source.

An LED is a semiconductor diode with a p-n junction, in which electrons and holes are able to recombine due to a supplied electrical current. Upon recombining, electrons jump from the conduction energy band to the valence band, and by crossing the Fermi level may emit light. The chromaticity of the light output is directly related to the emitted light's wavelength, which depends on the energy band gap that is dictated by the p-n junction materials and the junction temperature. Thus, the color of LED lighting is tunable without the usage of filters. The high power Light Emitting Diodes (LED) belongs to the group of electronics with increasing volume heat flux. The high power LEDs is becoming popular in the lighting industries, where it is considered as the "green" replacement of discharge light bulbs. The automotive industry has adopted the high power LEDs for front and rear light on cars and in near future this expands to include the forward head light. High power LEDs has problems with low efficiency, and together with a high current this leads to a heating problem. The heating problem is related to packaging design and this challenge is handled by the solid state lighting manufactures [7].For a projector to be projecting sharp images, a point source light is ideal but in reality there is not any availability of point source light which can offer high luminosity (measurement of brightness). The LED chip used in this projector is a 8X8 array chip design producing total light of 15500 lumens output. The dimension of the glowing area in LED is 15X15mm. The High Power LED used is shown in Fig.3.

The main cause of LED failures is improper thermal management. Many performance characteristics of LED components are influenced by the operating temperature, so LED system designers need a basic understanding of thermal design and performance. Some performance characteristics experience a recoverable change, such as light output, color and voltage, while others, such as lifetime, can experience a non-recoverable degradation due to high operating temperatures. However, exceeding the maximum operating temperature specification, which is 54'C at the base of LED that is used, can cause improper color, low output and if further increased can also result in permanent and/or catastrophic damage to LEDs, so care must be taken while operating LEDs below this limit.

This LED is custom designed for the source light to be made such that it can be made as small as possible. Due to this reason chips are closely packed to each other resulting in more heat formation at the junction which in turn is conducted to the base of the LED. As the temperature increases to higher degrees the chips burn and get permanently damaged as shown in Fig.4.

2.3. Closed Loop Liquid Cooling System

The thermal management of the LED is carried out using closed loop liquid cooling system that is also used in high performance computers for cooling processors [8]. The liquid cooling system has three basic elements: a very efficient integrated pump and cold plate unit; a heat exchanger (radiator) and finally, connecting tubes to transport the liquid. The specialized heat exchanger or radiator is mounted behind the rear chassis with fans with the tubes connecting the pump and heat exchanger together. The cold plate transfers heat from the LED base into the cooling liquid. The integrated pump assembly pushes warm liquid to the heat exchanger and draws cool liquid back to the cold plate. A closed loop liquid cooling system is shown in Fig.5 showing a radiator attached with a fan. The cold plate unit integrated with pump is connected to the radiator by hose through which transfer of liquid occurs. Generally, water is used in the liquid cooling systems. The advantages of using water cooling include water's higher specific heat capacity and thermal conductivity. This allows water to transmit heat over greater distances with much less volumetric flow and reduced temperature difference.

2.4. Thermal Switch

A bimetallic strip is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different metals which expand at different rates as they are heated, usually steel and copper, or in some cases steel and brass. The strips are joined together throughout their length by riveting, brazing or welding. The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its initial temperature. The metal with the higher coefficient of thermal expansion is on the outer side of the curve when the strip is heated and on the inner side when cooled. For further prevention of LED from reaching higher temperatures, LED is equipped with a bimetallic strip based thermal switch [9] which cut off the power supply to the LED when base temperature reaches 50'c. A bimetallic thermal-switch is shown in Fig.6.

2.5. LCD

LCD can be found from a variety of sources. LCD technology is used in both TV's and computer monitors. In these applications a backlight is placed behind the LCD panel as a light source. This backlight is not nearly strong enough to project an image. An LCD for projector is obtained by either purchasing the LCD panel without a backlight, or separating a LCD panel from LCD display (requires removing the backlight). The LCD panel itself is extremely fragile, so one should be very careful when handling them. There are a variety of terms used to describe LCDs; most notably: resolution, size, aspect ratio, response time and contrast ratio.

The resolution of a screen identifies the number of pixels that make up the width and height of the display. As such, it is described with a pair of numbers such as 1280 X 800. The number of horizontal lines of the display is often used by itself as an indicator of the quality of the display.

Aspect ratio and size both describe the physical dimensions of the display. The size of a display is measured from corner to corner, usually in inches. The aspect ratio describes the shape of the display. It is the ratio between the width and the height of the display. Traditional monitors use a 4:3 ratio while widescreen monitors often use a 16:9 ratio.

The response time of a screen describes how fast the screen updates to changing inputs. This is often extremely important to gamers who want to acquire every advantage. Typical response times ranges from 8 to 16 millisecond. Too high response time can result in blurriness when watching video or playing video games.

The contrast ratio is measured by comparing the luminance of pure white to pure black. That is, comparing the brightest the display can go to the darkest it can go.

The LCD Used in our projector is N070ICG LD1. This LCD is manufactured under Chimei Innolux which also manufactures touch panels for IPAD mini tablets [10]. The input to the LCD is given using a universal LCD controller through which it can be connected to various graphic interfaces including HDMI, VGA, Ypbpr, Composite Video, S-video, TV Tuner and even with an USB.

2.6. Power Supply

To power the LED, LCD and the cooling system of the projector, Switch Mode Power Supply (SMPS) has been used. SMPS are an extraordinary array of high frequency alternative. These are the switching regulators of high efficiency that can step up, down and invert the input voltage. Controlled DC supply can also be obtained from phase controlled rectifiers. But an AC to DC rectifier operates at supply frequency of 50 Hz (or 60 Hz). In order to obtain almost negligible ripple in the DC output voltage, physical size of the filter circuits required is quite large. This makes the DC power supply inefficient bulky and weighty. On the other hand SMPS works like DC chopper. By operating the on/off switch very rapidly, AC ripple frequency rises which can be easily filtered by L and C filters circuits which are small in size and less weighty. It may therefore be inferred that it is the requirement of small physical size and weight that has led to the wide spread use of SMPS [11].

III. BUILDING OF PROJECTOR

The projector enclosure is the most time consuming portion of the build. The basic layouts are straight, folded, and vertical folded. The straight design introduced involves placing each of the elements in a row such that the light source is in line with the projection triplet. It is important that each of the projector components is aligned with each other in order to prevent distortion of the projected image. The light source is located at the focal length of the collimator Fresnel, while the focal length of the projection triplet dictates its distance from the concentrator where LCD rests between both Fresnel Lenses. The triplet is mounted in such a way that it can be moved slightly forward or backwards to focus the projected image.

Air flow is another important factor in keeping a projector cool. Case fans, such as the ones found in desktop computers, are used to exchange the air within the projector. One common setup uses a single case fan to blow air out of the projector enclosure. Slots to allow air to enter the enclosure are made beside the LCD. This keeps the LCD extremely cool and cycles the air within the lamp chamber keeping the entire unit cool adding advantage to the projector for long continuous use.

The enclosure and frames of the projector is made out of 5mm thick plywood. First, the frames for Fresnel lenses and LCD are made so that collimator lens, LCD and concentrator lens could be fixed in it. Similarly the high power LED is also fixed in a wooden base fixture with hot side of LED in contact with the cold plate of liquid cooling system. The fixture for Projection lens is made such that is can be moved freely for focusing of image. Fig.7. shows a 3D view of the setting up of all the components in the enclosure. Fig.8. shows research based developed working model of the projector.

IV. FEATURES OF DESIGNED PROJECTOR

The name given to our projector is '*Ilumina64*' where the word '*Ilumina*' is taken from the word Illumination and 64 represents the no. of chips glowing in LED. Ilumina64 has following features -

- High Definition WXGA Resolution (1280x800).
- Low Power Consumption of 150W max .
- Long Duration Continues Run.
- Lamp Life 40,000+ Hours
- Instant Light Up
- Full Function Remote Control

V. FIGURES AND TABLE

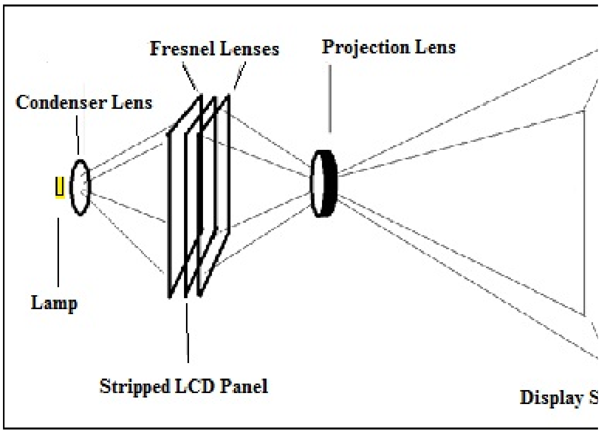

Figure.1. Ray diagram followed in the projector

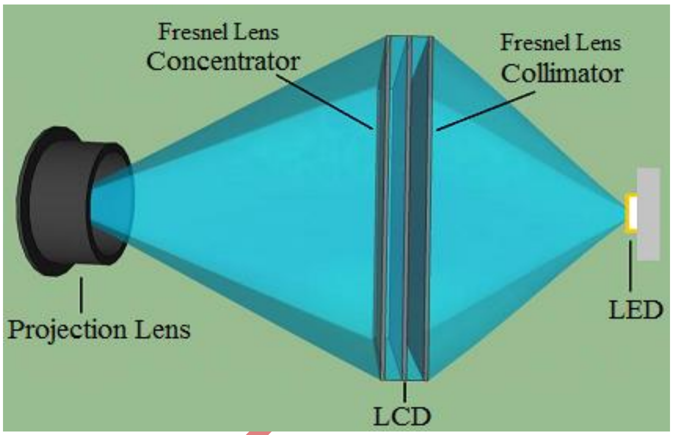

Figure.2. 3D diagram showing the path followed by light rays through optics and LCD

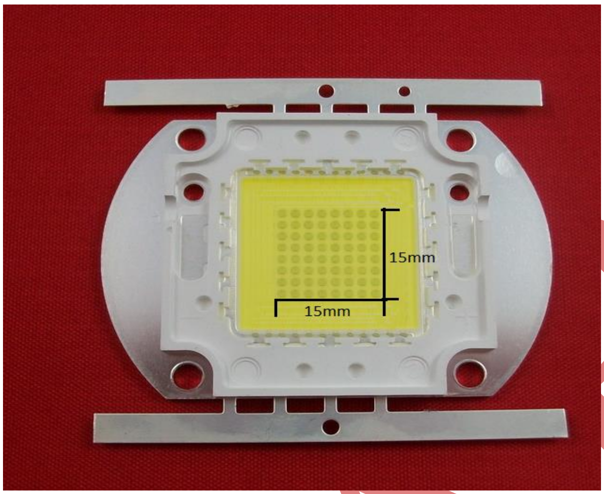

Figure.3. LED having 8x8 array chip design used in the designed projector

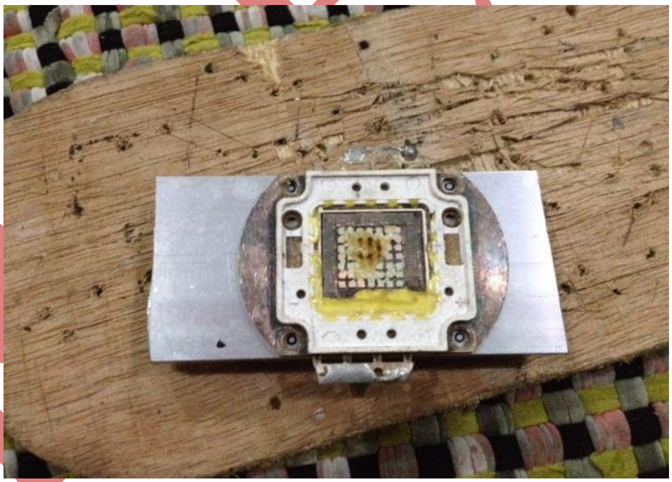

Figure.4. Permanent damage to LED when operated without proper thermal management during the research work

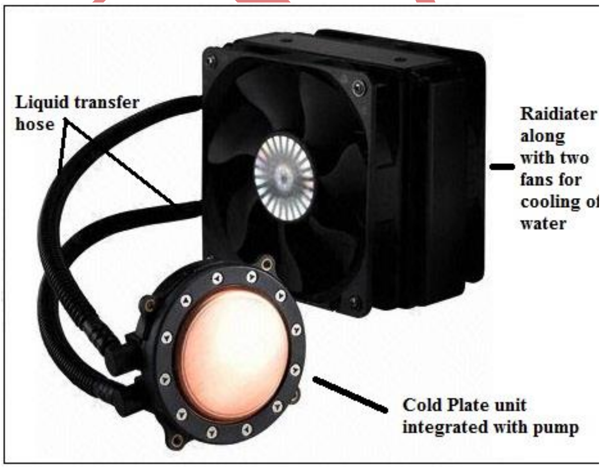

Figure.5. Closed Loop Liquid Cooling System

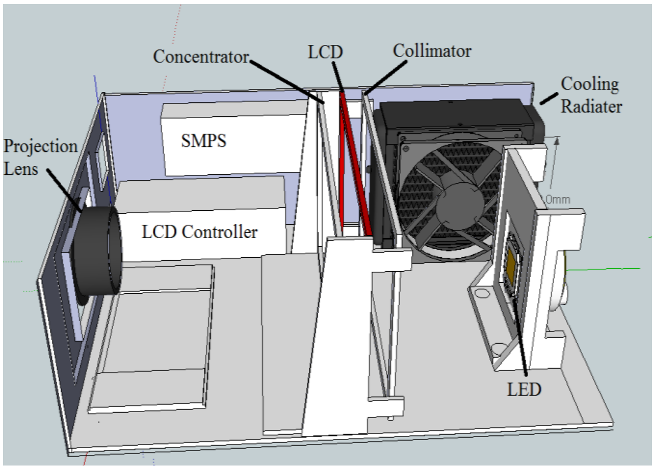

Figure.7. 3D view of all components fixed together in the projector

Figure.6. Bimetallic thermal switch

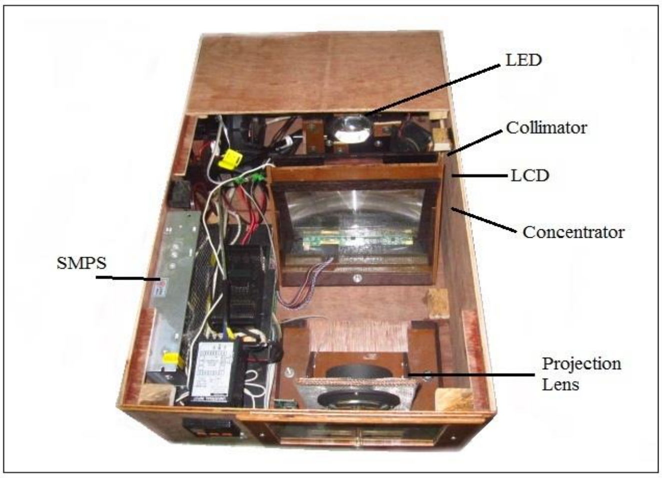

Figure.8. Real working model of the projector

Table.1. Comparison of Designed Projector with Commercial Projectors

Parameters	(Designed)Ilumina64	Benq MS502P	Sony ES4	LG BS275
Resolution	1280x800	800x600	1280x 1024	800x600
Lamp Type	LED	MH	MH	MH
Power Consumption	150W	275W	253W	255W
Lamp Life (Hrs)	40,000+	6000	3000	3500
Price (Rs)	16,750	24,899	30,500	35,000

VI. FUTURE SCOPE

This project is based on optics and display technology to form projection using an efficient light source in a very cost & power efficient way. Thus giving it a bright future scope. It can be used in various workplaces like school, institutions, conference, business and home theatre settings where low cost yet efficient projectors are required.

VII. CONCLUSION

The Projectors in these days are very common in use. Ilumina64 can be used in schools, institutions, and conferences to make learning effective. Also these can be used for entrainment purpose for example in home theatre systems for projecting on big screens. Employment of LED as a light source in the projector facilitates instant functioning as any warm-up time is not required. Ilumina64 has long life and can also be used for longer durations continuously spending fewer amounts in owning and also consuming half of the power as consumed by present commercial projectors.

VIII. ACKNOWLEDGMENT

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