ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 10(24), DOI: 10.17485/ijst/2017/v10i24/111848, June 2017*

A Novel Approach to Power Optimization for Projection Systems

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Abstract

Objectives: To use ambient light and distance as parameters to optimize power consumption of a projector system without deteriorating visual experience. **Methods/Statistical Analysis**: In this work, an efficient approach to optimize power consumption of a projector module is proposed using a light sensor and a distance sensor. Depending on the ambient light condition and distance between projector module and screen, backlight of the projector is adjusted, which affects the power consumed by the module. We have taken different ambient light condition ranging from LUX value of 1 to LUX value of approximately 150, as other conditions are not of practical use. **Findings:** The experience of a viewer depends on surrounding environment specifically ambient light. As the value of ambient light increases, to have a better visibility backlight of the display system/projector need to be increased and vice versa is also true. Again distance between the screen and source/projector also plays an important role in determining output visibility at a given power consumption. Both of these parameters are combined and used in this work to have an adaptive projector system. Experimental results show that around 30% powers saving can be achieved by implementing our proposed power optimization technique without compromising on the quality of the output. **Application/Improvements:** The outcomes of the work discussed in this paper can be used in most of the display system. The proposed method has taken care of both ambient light and distance between the screen and source by taking care on light that falls on per square unit area.

Keywords: Ambient Light, DLP Technology, LED PWM, LUX, Power Optimization

1. Introduction

Advancement in technology has increased the proliferation of various electronic devices in our day to day life. On one hand, the computational capacity of these devices are increasing at a very rapid speed, on the other hand, reduction in power consumption of these devices is one of the major challenges in front of the researchers. Power is one of the most critical parameter in most of the devices towards smooth and successful acceptance of the devices in the mass scale. Power optimization, starting from enhanced power profile of silicon chip, operating system or application software and hence power optimizing the whole system is a significant research hot spot for both industry as well as academia in the recent times.

Systems having display as a module, power optimization in case of display units is of paramount importance, as display module consumes a considerable power in any system. According to several studies[1,2], the display is one of the components with the highest percentage of total energy consumption and hence an appropriate candidate for improvement. Display units especially in case of projectors, power profile mainly depends on the backlight. For example lamp based projector provides maximum backlight and hence is used for large audience. However for day to day office use and other small gatherings, this kind of projector is not an efficient option and there comes the concept of Pico projector. A Pico projectors are small portable projectors. Depending on the source of backlight projectors there are currently three major com-

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peting imager technologies for Pico projector DLP, LCD and LBS.

1.1 DLP

DLP technology was invented by Texas Instruments in 1987[3]. It uses optical semiconductor also called tinny scanning mirrors on a chip that directs the light. It controls the amount of light that each pixel on the target picture gets. These mirrors refresh itself many times in a second and percentage of the time it is on is equivalent to percentage of brightness. It also uses a color wheel between the light source and mirrors which split the light in three components, namely red, blue and green. DLP technology is capable of generating large and bright projections with very high contrast ratios on screens with up to an order of 35 trillion colors.

1.2 LCD

LCoS projector uses Liquid Crystal Display (LCD). LCD controls the amount of light that each pixel gets. For getting color it uses Color Filter (CF)-LCoS and Field Sequential Color (FSC). CF-LCoS have three sub-pixels, each with its own color among RGB. FSC uses a faster LCD with a color filter which split the image for the three main colors i.e. RGB sequentially. These LCD are refreshed three times (once for each color). There are two types of LCD: Tran missive and reflexive. Both need artificial light source to illuminate the display[4]. The power consumption by the light source plays a major role in total power consumption.

1.3 LBS

LBS projector uses a directed laser beam to create the image one pixel at a time. Three different lasers of different color (RGB), each at its required brightness, are combined using an optics and guided using one or two mirror depending on the designs.

2. Basic Principle Behind Working of a Projector

A projector is based on uses basic principle of optical physics. A projector consists of a light source, concave mirror, condensing lenses, Projection lens and a slide as shown in Figure 1. The slide is placed behind the projector lens in such a way that the slide is beyond the focal length of projection lens. This slide is illuminated by a small but very powerful source of light. Condenser lenses or mirror are used to increase the amount of light going from source to transparent slide.

From the basic principal of optical physics that states: When an object is placed at between the focal length of the lens and twice of the same, the image formed will be real and magnified. Refer Figure 1. The distance at which image will be formed depends on the object distance from lens and also on the focal length of the lens. Refer Equation (1) and (2) for mathematical expression of magnification and image distance from lens.

- Parameters Related to Image Formation by a Lens:

Object distance from Lens = O mm.
Image Distance = Throw Distance = I mm.
Focal length of the lens = F.
Magnification = M.
Image Height = Hi.
Object Height= Oi.

- Relation Between Different Parameters:

$$\frac{1}{F} = \frac{1}{I} + \frac{1}{O} \dots\dots\dots\dots\dots\dots (1)$$

$$M = \frac{I}{O} = \frac{Hi}{Oi} \dots\dots\dots\dots\dots (2)$$

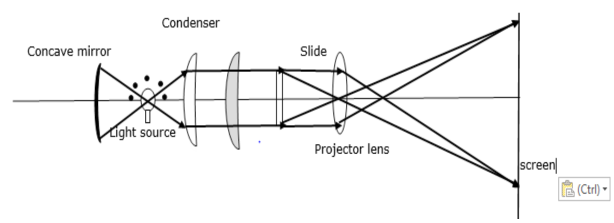

Figure 1. Basic principle behind working of a projector.

3. Methods for Power Optimization

Power consumption of a system mainly depends on the following parameters: Processor, Display unit, DDR design and design of power section[5]. An Intel study[6] on "Optimizing Mobile Power Delivery" shows that display backlights is responsible for 33% of the total battery drain in notebook computers. Almost similar is the case with the display of Pico projectors. Again the quality of display depends on the content, surrounding environment (ambient light) in which it is working.

The power consumption of a display device can be tailored using various methods. For example by developing application which turn off the display panel if it is ideal for a long time. Study shows it can save up to 23 percent of processor power consumption. Again display can be enabled using some external event such as touch. Dynamically dimming the backlight is considered as one of the effective method to save energy[7]. Some other ways to optimize power is by optimizing display resolution, refresh rate, brightness and contrast of the display unit etc.

4. Proposed Method of Power Optimization

The Power Optimization in Projector is done by controlling mainly two parameters:

- Ambient Light[8].
- Distance between the system and the projected wall.

4.1 Power Optimization using Ambient Light

There are mainly three parameters that we are controlling for good visibility with less power consumption in all light condition.

4.1.1 LED PWM

In non-emissive family of display technology, backlight is necessary for its full operation and hence for calculation of power consumption. (Which directly affects the power consumption): It is a measure of current driven by the LED Source or Optics.

4.1.2 Brightness

It is the level of light intensity perceived by the viewer. Brightness refers to the overall lightness or darkness of the image. It doesn't have any direct effect on Power consumption, but with increased brightness better visibility can be achieved even with less backlight that is less LED PWM. Power consumption of an LED based display is directly proportional to its LED PWM.

4.1.3 Contrast

The "contrast" is a measure of the brightest to the darkest area of the image. Thus it is defined as the ratio (CR) between the luminance of the brightness and the darkest color that the display is capable of producing. (No direct effect on Power consumption, but with proper setting of brightness and contrast, better visibility can be achieved even with lower Power Consumption).

In our research work, we have four different modes with different visibility choices.

- Intelligent mode.
- Movie mode.
- Standard mode.
- Vivid mode.

Intelligent mode: In this mode PWM varies according to ambient light condition. For dark rooms (LUX very small value) and power consumption is also less and it is considered as most efficient mode in terms of power consumption. As ambient light increases, power consumption also increases and at some extreme condition this mode can be the most power consuming mode. In this mode PWM varies according to the mathematical equation discussed below[8].

Sensor digital output = D

PWM to be added for intelligent mode = PWM_i

Final PWM value = PWM_f

Intensity of light = LUX

RANGE_K = 4000 (Range of the LUX for our experiment)

$$LUX = \frac{D * \left(RANGE_{(\_K)}\right)}{65535} \tag{3}$$

$$PWMi = (75 - 9.932 * \log(LUX)) \quad \text{if } LUX = +ve\ value$$
$$= 0 \quad \text{if } LUX = 0 \tag{4}$$

$$PWMf = X + PWMi \tag{5}$$

The value of X varies depending on the LUX, it is set manually.

The above mathematical equations represent the relationship between the backlight brightness and the environment brightness. We use this equation for the computation of the best backlight brightness value under any given ambient brightness. The standard equation y = 9.932Ln(x) + 27.05 shows nonlinear characteristics of the brightness[8]. To derive mathematical expression that suits our requirement the same standard curve is customized and adapted by changing the value of the constants in given equation.

4.2 Power Optimization using Distance Sensor

As the distance between LED light source of projector and projection wall changes, the size of the image changes and hence lumens in any fixed area such as a square foot (an area equal to 1 foot by 1 foot) also changes. The brightness of the image is directly proportional to per unit area lumens. In other words the lower the light in a unit area, the less bright the image becomes. This theory is utilized for power optimization depending upon distance.

5. Experimental Setup

In the proposed method of power optimization two sensors, light sensor for sensing the ambient light of the environment and Distance sensor for sensing distance between the projector and projection wall is used as shown in Figure 2 and Figure 3. Both the sensors are I2C compliant and communicate to the host board using I2C protocol. Host board acts as master and sensors act as slave. The data received by the host from the sensors is used for calculating the adjustment required in backlight, brightness and contrast level. The calculated data is sent to the board driving current for optics and accordingly current is withdrawn. This current consumed by the optics is directly related to the backlight and hence power consumption of the system. To measure and compare the power consumption the light and distance sensor function is enabled and disabled in the host board. When function is disabled, adjustment is zero and we can note down the power consumption of the system without any optimization. Again to check the value of power consumption when function is enabled we adjust the environment brightness to several no. of light conditions in order to separate them during the course of the whole experiment. These environment conditions are mainly categorized into different bands of LUX value. Table 1 shows the LUX values against the brightness conditions.

Table 1. LUX values against the brightness conditions

LUX Value	Condition
1 - 4	Very dark
10 - 50	Normal office room in day time with all lights off
100 - 250	All lights of the office room in ON condition
>500	Room with windows in Day light
>5000	Outdoors in day time

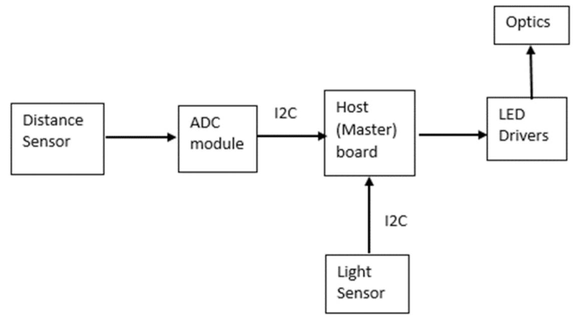

Figure 2. Experimental setup for power optimization.

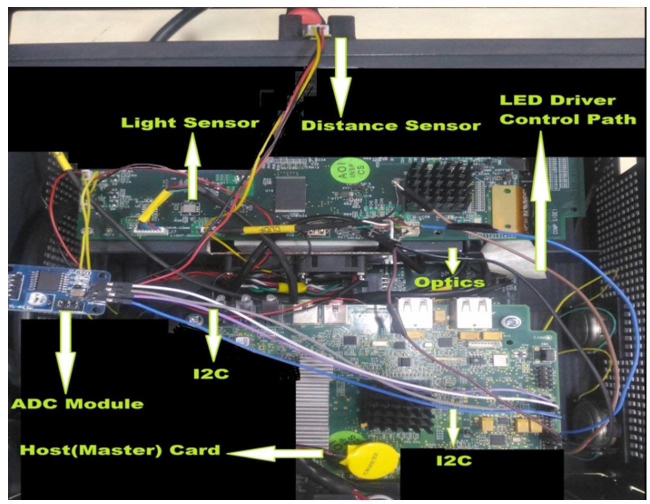

Figure 3. Actual experimental setup.

In last two environment conditions experiment is not done since usability is very less.

Similarly for measuring power consumption at different distances between projector and projection wall, we have taken 4 bands of values.

Distance (0 cm-30 cm) (Very near usability is less)

Distance (30 cm-60 cm)

Distance (60 cm-90 cm)

Distance (>90 cm)

6. Results of the Experiment

6.1 For light sensor:

For LUX <10, X = 105, Brightness is set to 0 and contrast to 100.

Table 2. Power consumptions

Mode	LUX	Function disable			Function enable			Gain
		Brightness	Contrast	Power	Brightness	Contrast	Power	
Movie		0	100	18.5 W	40	90	15 W	3.5 W
Standard		0	100	24 W	40	90	18.5 W	5.5 W
Vivid		0	100	29.5 W	40	90	23 W	6.5 W
Intelligent	3	0	100	16 W	40	90	15 W	1 W
	5	0	100	17 W	40	90	15 W	2 W
	14	0	100	18 W	40	90	15 W	3 W
	24	0	100	19 W	40	90	15 W	4 W
	37	0	100	19.5 W	40	90	16 W	3.5 W
	55	0	100	20.5 W	40	90	17 W	3.5 W
	83	0	100	21.5 W	40	90	18 W	3.5 W
	120	0	100	22.5 W	40	90	18.6 W	4 W

For 10 < LUX < 50 X = 135, Brightness is set to 40 and contrast to 90.

For LUX < 240 X = 125, Brightness is set to 40 and contrast to 90.

Table 2 gives the power consumptions under different conditions and configurations.

Table 3. Distance sensor

Distance factor	PWM added
<30 cm	+55
30 – 60 cm	+25
60 -90 cm	+10
>90 cm	+00

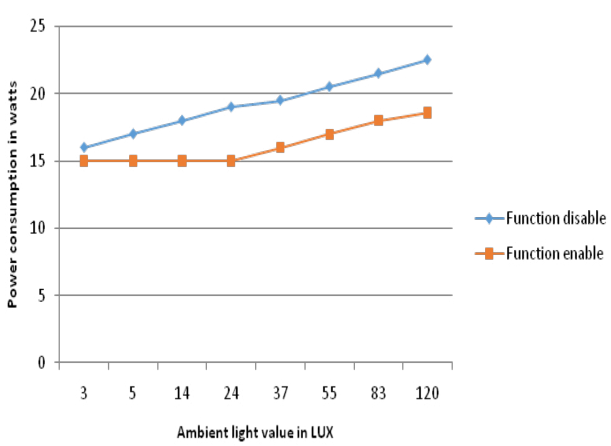

Figure 4. Graph for power consumption with function enable and disable.

6.2 Movie mode

Brightness is set to 40 and contrast to 90 irrespective of ambient light condition. PWM in movie mode is 180, corresponding power consumption = 15 W.

6.3 Standard mode

Brightness is set to 40 and contrast to 90 irrespective of ambient light condition. PWM in standard mode is 150, corresponding power consumption = 18.5 W.

6.4 Vivid mode

Brightness is set to 40 and contrast to 90 irrespective of ambient light condition. PWM in standard mode is 120, corresponding power consumption = 23 W.

6.5 For distance sensor

Note: The above readings as given in Table 3 are in the condition when power optimization based on adjustment of brightness and contrast is not enabled.

7. Conclusion

In this paper we adjust brightness and contrast of the display unit to achieve better visibility. Our experiment results shows that, using this approach more than 6 Watt of power can be saved without sacrificing video quality considerably as shown in Figure 4. To reduce the power consumption more, distance sensor method is also described. Distance sensor method is useful when screen size requirement is small. In other words distance between projector and screen is less and viewers are supposed to be within a close space from screen.

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