Kinkajou γ Prototype Development Report 15-29 March 2004

LED

The LED we've been using is the Luxeon Star LXHL-LW6C, called a "Portable V, Lambertian white" manufactured by LumiLEDs. It can safely draw 700 mA at 6.07 V, consuming 4.34 watts. Its light output is 120 lumens. (The reference in the design journal that reads: "The Kinkajou Microfilm Projector currently uses a LumiLEDs Luxeon Star V LED (5-watt Lambertian White, Part Number LXHL-MW1D) rated at 25 lumens." needs to be modified.) This LED has 4, 1.5mm □ chips wired in series-parallel.

Driver circuits

We have 2 driver circuits:

The LUTW (Light Up The World) circuit, as modified by us, delivers 550 to 600 mA at 6.0V, but powers down automatically to 350 mA when disturbed, e.g. by clipping in a voltmeter. It draws 360mA from a nominal 12V battery. Its efficiency is thus ~80%.

The WPI (Worcester Polytechnic Institute) circuit delivers 640 mA at the operating voltage, between 6.0 and 6.5 V. It draws 470mA from a nominal 12V battery. Efficiency ~70%.

A third method of powering the tests is to use a bench power supply, generally at 700 mA, current regulated.

Temperature control

Whether we use LEDs or incandescent bulbs, >95% of the input power must be removed as heat (assuming 1 lumen = .00147 watt at 550nm.) In the case of LEDs, the vast majority of this heat is conducted into a heatsink at a low temperature (~40C). The heatsink can be located on the exterior of the projector. The incandescent bulb, however, emits its heat into the optical path by convection and radiation at high temperature. I performed some experiments to quantify the heat problem:

1. LXHL-LW6C mounted with thermal compound to a pin-fin heatsink 5cm square having pins 3.5cm long (the standard Kinkajou-beta heatsink). Fan cooling. Placing a thermocouple in contact with the metal core pcb of the LED, and driving it with the WPI supply at 630 mA, (6.46 V) the temperature stabilized at 2C above ambient within 1 minute.
2. Same, fan removed. The temperature rose to 17C above ambient in 22 minutes, and was continuing to rise at .3C per minute.
3. Same, a chimney 30 cm long was added. The temperature dropped to 13C above ambient and stabilized within 9 minutes.
4. Same, chimney length cut to 18 cm. Temperature stabilized at 15C above ambient.
5. Same, except current increased to 700 mA by use of bench power supply, current regulated. Chimney removed, and heatsink bolted to an aluminum bar 0.6 cm thick, 5 cm wide and 24 cm long. Temperature stabilized at 13C above ambient.

6. The lamphouse of an inexpensive toy projector using a krypton flashlight bulb (Fisher-Price Viewmaster) was operated with the thermocouple mounted to the outside of the black plastic lamphouse moulding. The temperature stabilized at 24C above ambient after 12 minutes, but there appeared to be signs that melting might have taken place adjacent to the bulb. Power was 6V*800 mA=4.8 watts.

Thus, for the LED, an extended heatsink area has an equivalent effect to the long chimney. This suggests that an aluminum housing thermally bonded to the chip might cool adequately without fan or chimney. At 13C above ambient, we would expect (from the LumiLEDs literature) a 5% loss of light output. Lumileds gives data for light output loss with time at 85C case temperature, showing <5% loss at 1000 hours. Since the ambient temperature in Mali wouldn't exceed 50C, at least in the evening when the Kinkajou would operate, we could expect an LED case temperature of 63C, worst case. We could expect a 15% loss in light output at this temperature, but no life-shortening effects. An incandescent bulb might require ventilation within the optical path to prevent overheating of components, even though the bulb itself would tolerate heating effects. In the dusty environment of Mali, this would need to be done without introducing outside air.

Illumination intensity

To compare the light output of the Kinkajou with that of the Viewmaster, a simple test was performed, using a photographic light meter. The resolution of this meter was quite limited, and a laboratory meter has been ordered. The Viewmaster was brighter than the Kinkajou by a factor of 2, more or less, but the Kinkajou was running at 550 mA, rather than the 700 mA possible. It thus was using only 3.4 watts. Better illumination data await the lab light meter.

Condenser lenses

The Kinkajou β prototype uses an expensive ($90) 3-element condenser lens, of short focal length. This lens allows close (~6mm) placement of the LED, to capture a large solid angle of illumination. By comparison, the 2-element condenser in the toy projector has a longer focal length, requiring the LED to be placed ~17mm away in order that the image of the light source isn't magnified outside the projector lens aperture. For this reason, we won't want to use the toy lens as it is.

LED life test.
On 27 March a life test was initiated, to accumulate 500 hours of operation at a current of 700 mA and an operating temperature of 33C, without fan cooling. At time of writing, 40 hours of stable operation have been observed.

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