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# Preliminary Investigation of Driving Circuits for White Light Emitting Diode Lamps

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## 1. Introduction

White LEDs are useful for very small power systems (eg. 200W, fig. 1) because it uses very little power compared to other light sources. This means that a village of 100 one houses can be lit by two 1W white LED lamps per house (eg. figure 1). Although impressive, the LEDs need to be current controlled. This inherently produces losses. When the power involved is very small (eg. 1W), it is difficult to control the current without reducing the efficiency significantly. This paper presents some control methods for the WLED and compares them.

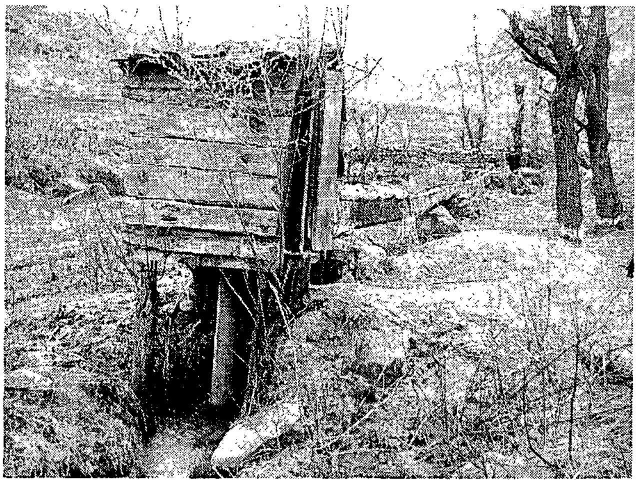

Fig. 1. 200W picohydro generator used for village lighting with white LEDs.

## 2. Characteristics of WLEDs

The interest in white LEDs comes from their high light output per Watt compared to many other light sources. Their output is typically 24lumems/Watt [10], which compares well to incandescent and halogen lamps (12-15lm/W). However, fluorescent lamps and red LEDs have light outputs of the order of 60lm/W.

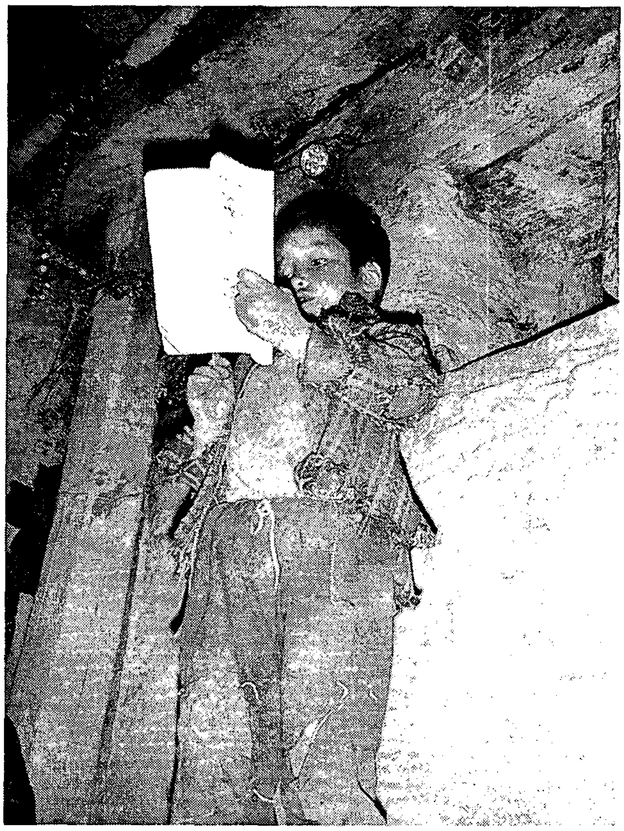

Fig. 2 White LED lighting used in a remote village in Nepal (Photo: Alex Zahnd)

Table 1 Lumens/Watt of Various Light Types [10]

| Incandescent | Halogen | White LED | Red LED, Tube fluorescent |
|---|---|---|---|
| 12 | 15 | 24 | 60 |

Data from the data sheet of a typical WLED is given in table 2. Typically the forward voltage is of 3.5V at a current of 20mA, but there is considerable variation in light output due to manufacturing difficulties. The operating temperature range is large, which suits cold areas well.

Table 2 WLED Characteristics [7]

Absolute Maximum Rating (Ta = 25°C)

| PARAMETER | MAXIMUM RATING | UNITS |
|---|---|---|
| DC Forward Current | 30 | mA |
| Peak Pulse Forward Current | 100 | mA |
| Avg. Forward Current (Pulse Operation) | 30 | mA |
| Operating Temperature | -30 to +80 | °C |
| Storage Temperature | -40 to +100 | °C |

COLOR : INTENSITY BIN

| Bin Code | Min. | Max. |
|---|---|---|
| Intensity Bin Code | | |
| 1 | 900 | 1,300 |
| 2 | 1,300 | 1,800 |
| 3 | 1,800 | 2,600 |

## 3. WLED Driving Methods

Since LEDs are current regulated, it is necessary to control the current. Various methods have been used for this, including resistors, transistor current limiters, switch mode current controllers and switched capacitive circuits. Whereas all these circuits have their advantages in relation to cost or performance, for use in lighting applications, the aspects of efficiency, cost and lifetime need to be considered.

### 3.1 Current Regulation with a Series Resistor

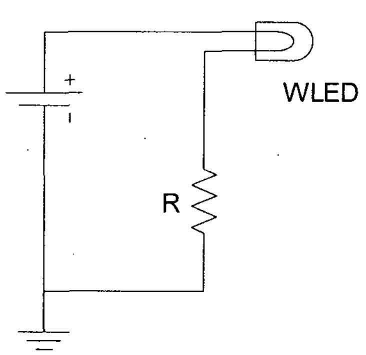


Fig. 2 Current regulation with a series resistor

Current regulation with a series resistor is the simplest and lowest cost way to limit the current. However, it has two disadvantages. These are that it is intrinsically inefficient and that if the supply voltage is close to the forward voltage drop across the WLED, the current flowing is very sensitive to the LED forward voltage drop.

### 3.2 Analog current control

Better current control can be arranged by using transistors in an analogue circuit (fig. 3). Although the current control will be less sensitive to voltage changes due to the current feedback, the basic function is resistive and hence there is considerable loss of efficiency.

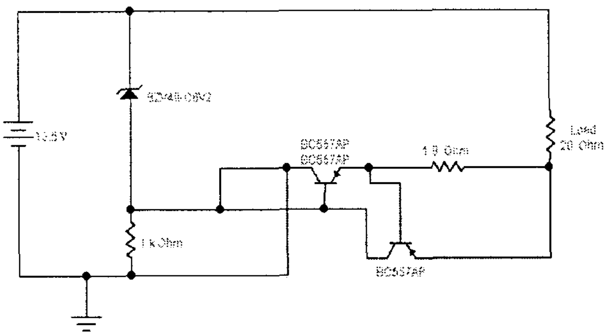


Fig. 3 Current Limiting with BJTs. Adapted from [8]

Under usual circumstances, the current flows through the 1.8Ohm resistor and through the series connected PNP transistor. As the current increases, the voltage across the 1.8Ohm resistor becomes large enough to turn on the other transistor and hence the main transistor is partially turned off. A simple circuit like this is not accurate and does not limit the current completely, but illustrates the principle of analogue current limiting and its limitation in being inefficient.

### 3.3 PWM(Pulse width modulation) current control

Pulse width modulation is a very important method of power control as it can, in principle, be very efficient. The concept is well known in that a switch is turned on fully briefly and then fully off, so that the only losses with the switch are associated with it being on in the saturated state (which has a low loss). Two popular PWM topologies are shown in figure 4.

The losses are usually considered to be the switching losses (transistor and diode) and the magnetic losses. However, given that the white LED uses so little power, the controller for the switch must also be considered in terms of its energy consumption. Any current control usually uses a sense resistor and hence losses are also produced.

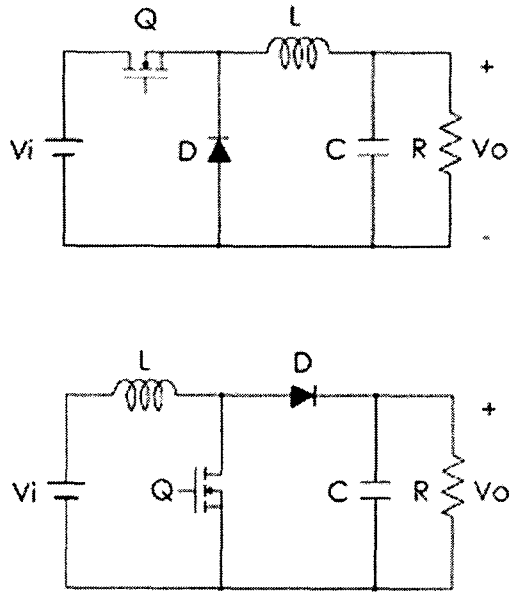


Fig. 4 Top: Step Down(Buck),
Down: Step Up(Boost) Converter [11]

### 3.4 Switched capacitor converter

A switched capacitor (SC) converter also uses a PWM technique, usually for voltage change rather for current control. It differs from conventional PWM techniques, in that it uses a capacitor instead of an inductor. Hence there are no magnetic losses. This may be offset by the losses from the high currents in the switches as one capacitor is connected to another. The principle of operation can be seen from figure 5 below. It takes the form of charging capacitors and then repositioning them with respect to the ground so that a different voltage can be obtained. With a suitable current feedback control loop, the switched capacitor converter can be current regulating.

## 4. Currently Available Commercial Controller Technology

A number of companies manufacture white LED controller integrated circuits, such as MAXIM, Linear Technologies, SEIKO and NPC etc. They fall under 3 main categories:

1. dc-dc step up converters with current control
2. linear current control
3. charge pumps, with current control

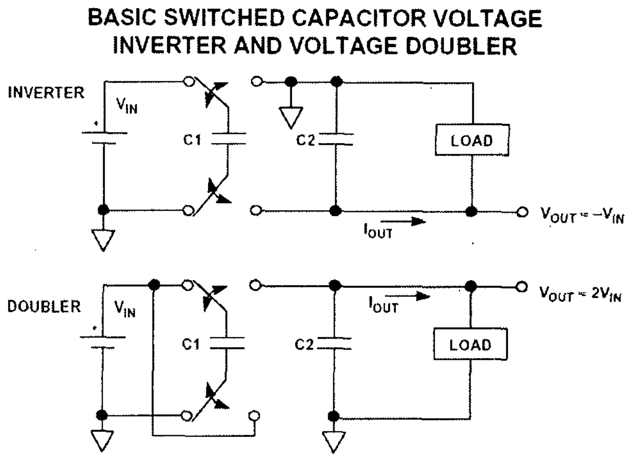


Fig. 5 Switched Capacitor Voltage converter [6]

M ost of the integrated circuits do need external components to operate, and in particular, the current controllers mostly use a resistor to sense the current. The step up dc-dc converters need an external inductor and most of them require also an external diode. The switching MOSFET is internal to the IC. A recent integrated circuit from MAXIM has an inbuilt synchronous rectifier [5], which will have less losses than using a diode.

The linear controller is an interesting concept in which a reference current is formed and then the current through the LEDs is controlled to be a multiple of this reference current.

The efficiencies of the integrated circuits are claimed to be high, but this does not include the losses of the external components. With switching frequencies of usually 1-2MHz, losses in any external magnetic and diode components need to be considered.

## 5. Conclusion and Discussion

The two main aspects of white LED controllers are that it should be efficient and should have a similar lifetime to that of the white LEDs. Whereas many of the controller ICs claim to be nearly 90% efficient, the current sensing resistor will reduce the efficiency further and so will any external components. It is considered unlikely that any of the presently available controllers will have the same lifetime as the WLEDs themselves, and hence to gain reliability, the simple series resistor is likely to be the best. In remote and poverty struck areas, this may be the only acceptable solution presently.

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