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LED lighting development for intelligent clothing

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Abstract–LED lighting is applied to clothing. It allows a flexible method to provide illumination of lighting. A family of converter topologies is proposed to give this simply method of power conversion. Analysis for the circuits in terms of output power, efficiency and general operation are provided. Two types of LED lighting clothing are developed. One is using super-bright LED embedded on the cloth. This gives active lighting instead of passive lighting. Another one is using optical fibre with grating to form lighting pattern.

Keywords–Power converter, LED, intelligent clothing.

I. Introduction

LED is now applied for fashionable clothing for its feature of flexibility in shape, colour, dimming control. It can be easy to control the output using switched mode power converter.

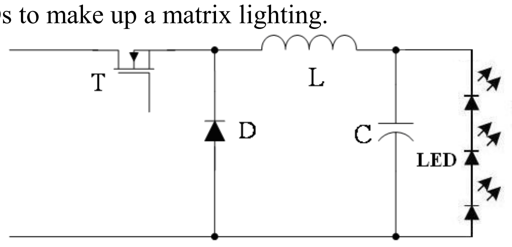
The power levels of LED are now available in 1W to 5W with reasonable price. This is for high brightness illumination. For decoration, the low power with less than 50mW is available. They are placed in various points to provide the required needs for clothing design.

Protective clothing such as reflective clothing have fluorescent reflective tape is not good enough to provide eye-catching purpose during very foggy road condition. There are frequent news of road workers being hit because of the reflection ability is low. A self-illumination clothing is needed. An LED embedded clothing provides stronger light and different colours. It can also be supplied by low voltage battery such as Li-ion rechargeable one. Therefore LED embedded clothing is now getting more popular in today clothing design [1]. The use of LED for clothing is not new [2]. Today we can see numerous examples of embedded electronics in to clothing textile [3-4]

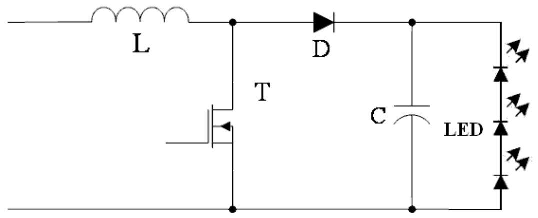
II. Conventional circuit

1. Conventional Circuit

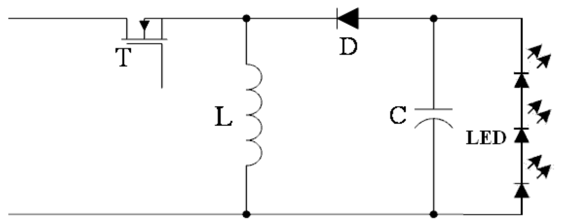
The conventional LED driving circuit is just simple SMPS [5]. Fig 1 revisits the circuits. Only one row of LED is shown. In fact it can be formed by a number of rows of LEDs to make up a matrix lighting.



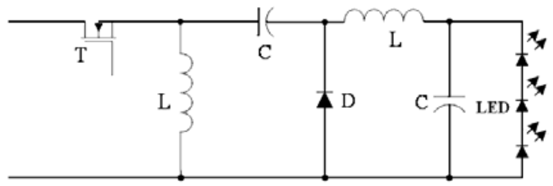
(a) LED Buck converter



(b) LED Boost converter



(c) LED Buck-Boost converter



(d) LED Cuk converter

Fig 1: Conventional method for LED connection

2. Discussion

The circuit should be embedded with current mode control in order to provide good life time. As the LEDs are connected in series, if any one LED is burnt, it may affect the overall current flow, therefore a current mode controller is needed for the work. In some developments, an anti-parallel zener diode is placed. This allows the by-pass of the LED when it is burnt-open.

II. Reduction in LED Circuit

The circuit can be modified easily by removing some components that is not responsible for the power control.

$$nV_{LED} = V_{in}\frac{D}{1-D} \tag{1}$$

where n is the number of LED in the series path, V_{LED} is the voltage drop on LED. V_{in} is the input voltage and D is the duty ratio of the transistor.

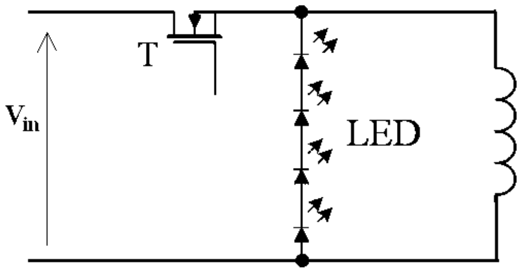


Fig 2: Simplified LED Buck converter

Fig 3 shows the Simplified LED Boost converter. The voltage conversion ratio is:

$$nV_{LED} = \frac{V_{in}}{1-D} \tag{2}$$

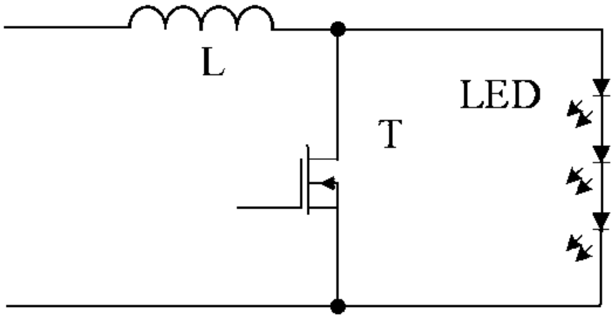


Fig 3: Simplified LED Boost converter

Fig 4 shows the Simplified LED Buck-Boost converter. The voltage conversion ratio is:

$$nV_{LED} = \frac{V_{in}}{1-D} \tag{3}$$

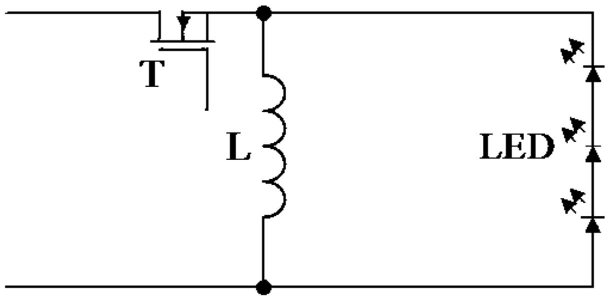


Fig 4: Simplified LED Buck-Boost converter

Fig 5 shows the Simplified Cuk converter. The voltage conversion for the Cuk converter is:

$$nV_{LED} = \frac{V_{in}}{(1-D)^2} D \tag{4}$$

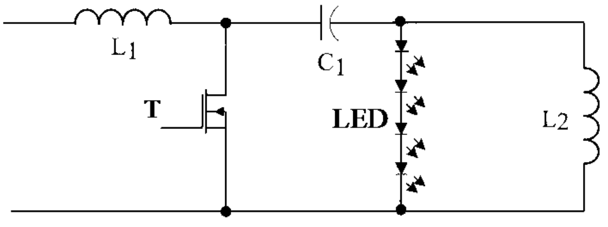


Fig 5: Simplified LED Cuk converter

III. LEDs IN TRANSISTOR PATH

1. Transistor path for Buck converter

There are other topologies for LED connection. The LED array can be put in series with the transistor. Fig 6 shows the connection of the LED in the transistor path. When the transistor is turned on, the LED is turned on as well.

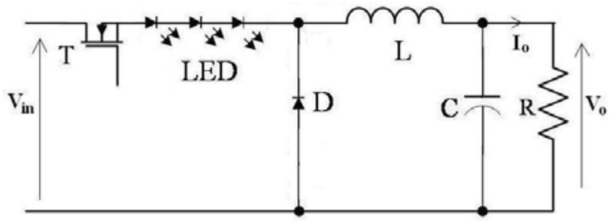


Fig 6: Transistor path LED converter

In the present circuit, the on-state voltage of LED cannot be ignored, the revised voltage conversion is:

$$V_o = V_{in} D - nV_{LED} D \tag{5}$$

The peak voltage across the LED is

$$V_{D\_p} = V_{in} - V_o \tag{6}$$

The average current of LED is:

$$I_{LED} = \int_0^{DT_s} i_T dt = I_o D \tag{7}$$

The power level of LED is

$$P_{LED} = \int_{0_s}^{DT_s} i_{LED} v_{LED} dt = nV_{LED} I_o D \tag{8}$$

$$= \frac{nV_{LED} D^2 (V_{in} - nV_{LED})}{R}$$

The efficiency of the LED circuit is reduced to:

$$\eta = \frac{P_{LED}}{P_{LED} + P_R} = \frac{nV_{LED}}{V_{in}} \tag{9}$$

B. Other converters

The efficiency and voltage conversion can be derived using the standard power equation. They are derived in a similar method and is listed in Table 1 below:

Table 1 : Output and power of LED in transistor path

	Output voltage, Vo	Power of LED, P_{LED}
Boost	$\frac{V_{in} - nV_{LED} D}{1-D}$	$\frac{nV_{LED} D (V_{in} - nV_{LED} D)}{(1-D)^2 R}$
Buck-Boost	$\frac{(V_{in} - nV_{LED}) D}{1-D}$	$\frac{nV_{LED} D^2 (V_{in} - nV_{LED})}{(1-D)^2 R}$
Cuk	$\frac{(V_{in} - nV_{LED}) D}{1-D}$	$\frac{nV_{LED} D^2 (V_{in} - nV_{LED})}{(1-D)^2 R}$

IV. THE CLOTHING

There are a lot of concerns in the road safety. This is especially for roads worker because the passive lighting is not effectively to provide reflection when road users are working with darkness environment. The protective clothing should meet the EN417 and ANSI471standards.

The standard although can endorse many clothings for road users, but the active illumination depends on the road condition, the weather, and the eye-sight of the users. An active lighting is needed for the protective clothing. Fig 7 shows the sample of the active lighting protective clothing. It is based on 3W super-bright LED embedded on the clothing. Three LEDs are used and is powered by a rechargeable battery. The LED power is regulated so that its power consumption or light output can be controlled.

Table 2 shows the reflection obtained through passive clothing. The result is not tested directly according to the standard but is under a controlled environment. The results shows that under strong illumination of 300Lux at 3 meter from the clothing injected to the clothing, the reflection is little. The test was conducted with different angles of incidence and the reflection light is measured with Lux meter. The results clearly show that the clothing has a wide range of reflection feature.

Table 2: The measurement of the reflection of protective clothing

Type of protective clothing	Maximum reflection (Lux)	Minimum reflection (Lux)
Ambulance officer	12	8
Road worker	30	25
Yellow and grey belt	24	20
Road cleaner	23	18
Orange and yellow belt	23	18

Fig 7: Active protective clothing excited by LED

Another clothes is developed that is based on optical fibre which is excited by LED light. The LED lighting is based on RGB types which can produce a mixed colour. The light transmitted through the fiber is originally confined within the fibre and now escapes to through the grating. Grating has been used in fibre optics for communication and sensors for a long history [7-8]. Some breaking point is created by a cut in the fibre that can create the pattern on the clothes as shown in Fig 8.

Fig 9 shows the zoom in diagram of the grating. The colour light is emitted from the fibre to form a pattern as we needed.

Fig 8: The LED embedded for a cloth.

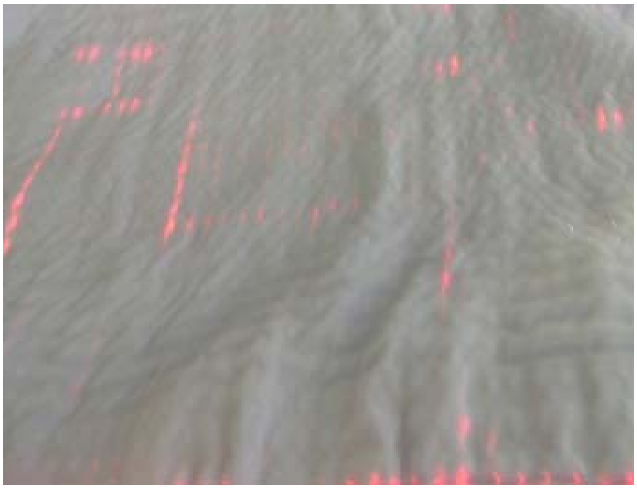


Fig 9: The optical fibre grating to provide the light pattern.

IV. CONCLUSION

This paper has proposed a new method of LED active clothing. It is based on LED light that produces the active light as we want. The conventional belt type reflector is weak and is passive. It cannot produce sufficient illumination for road users. Another method of clothing is produced by optical fibre. Suitable grating is placed in the fibre to form a pattern for illumination. The fibre is excited by LED as well. LED is powered by a switched mode power converter that is able to provide dimmable lighting. The LED can also be modulated to provide communication to other road users. It is expected that the future LED lighting will be used extensively not only for illumination, but also for communication with other road users.

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