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Design possibilities of illuminator optimization based on escalation of human eye sensitivity in pulsed light*

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Human eye reacts at pulsed lighting in a different way than at constant lighting conditions. In general, more light is seen when the objects observed are illuminated with light pulses than when with a constant light, the energy of light being the same. In this paper the light enhancement phenomenon is analysed in quantitative terms and some practical applications to optical and electronic equipment are suggested.

Light emitting diodes (LED) which are manufactured in a wide selection of types – are applied in optical apparatus for lighting different optical scales. The structural arrangement is usually a copy of traditional design with bulb lamps replaced by LEDs operating with direct current (DC).

Although such a construction is simple and energy-saving it does not utilize all the properties of LEDs. Therefore it is still possible to build with LEDs more economical illuminators of a simple construction. In these newly designed devices not a constant light flux but a series of light pulses are produced, thus they can be called pulsed illuminators.

In a conventional construction LED is DC-operated. Since under such conditions supply current is relatively small, then for all its values the quantum efficiency factor (QEF) of the diode remains nearly the same. In consequence, the emitted light flux changes quasi-linearly with the DC supply current [1]. However, the value of QEF is not constant and it grows considerably when the supply current exceeds about 10 times the rated DC supply current. Due to the limited power dissipation of the junction such a situation is possible only at pulsed operation of LED.

When illuminated with pulsing light the human eye reacts in a way different from that observed at constant lighting. Since seeing processes occur in human eye retina, brain and in nervous system connecting the eyeball and brain (vision is a kind of distributed processing [2]) the sensitivity of eye depends not only on overall quantity of light but also on the way it was introduced into the optical

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system. More light is seen when watching the objects illuminated with series of light pulses than when the same light energy is emitted in a constant way. The phenomenon is particularly due to the eye's retention of high brightness levels. The increase of eye sensitivity is very well observed at low, about 10 Hz, pulse frequency. Then, however, this phenomenon is often accompanied by unwanted by-products, as headaches and optical illusions (one can see non-existing objects in extra-bright, vivid colours) [3]. Because of such effects, working frequency of pulsed illuminator power supply must be higher than the flicker frequency, it can be estimated as $f > 100$ Hz [4].

Figure 1 shows schemes of traditional (a) and pulsed (b) LED illuminator designs. In a traditional construction LED works with DC and light flux is regulated by changing the current which is usually done by a potentiometer. In pulsed illuminator light flux depends on amplitude of current pulse and on the parameters of the duty cycle (frequency, t/T ratio).

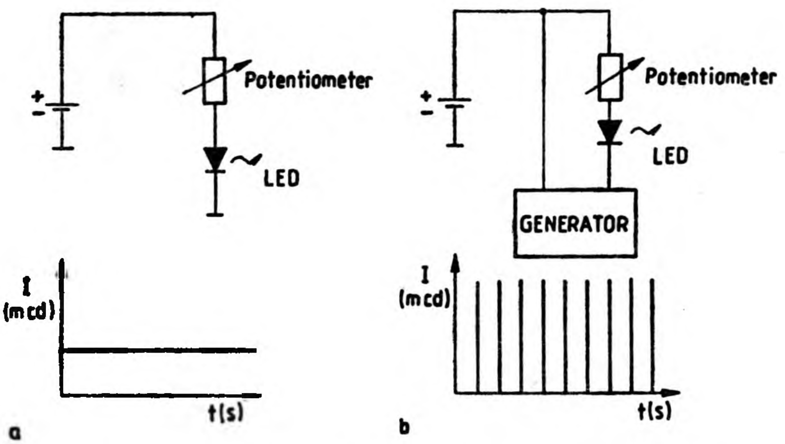

Fig. 1. Schemes of traditional (a) and pulsed (b) LED illuminator

The series of experiments with pulsed light LEDs of different types and conducted with help of many observers have allowed us to define general energetic rules. Scheme of electric circuit is shown in Fig. 2. The observer was requested to set, by using a potentiometer, a specified value of current in DC switch position first and then in AC switch position; the current pulse amplitude was changed as to have the same feeling of brightness in both switch positions. The pulse frequency was always the same, i.e., $f = 200$ Hz. This frequency is sufficiently higher than the flicker frequency, on the one hand, and does not impose on the electronic parts too severe switching-time demands, on the other hand. Voltage V read on resistor R with magneto-electric meter is proportional to the average current value and can be taken for further calculation.

These experiments allowed us to estimate the numerical value of light enhancement factor (LEF). LEF can be defined by the following ratio:

$$\mathrm{LEF} = \frac{I_{\mathrm{DC}}}{I_{\mathrm{AC}}} = \frac{U_{\mathrm{DC}}/R}{U_{\mathrm{AC}}/R} = \frac{U_{\mathrm{DC}}}{U_{\mathrm{AC}}}$$

where I_{DC} is DC supply current to produce brigthness B, I_{AC} – average LED pulsed current to produce brightness B, U_{DC}, U_{AC}, are the respective voltages read on the resistor (R) with a voltmeter, according to Fig. 2.

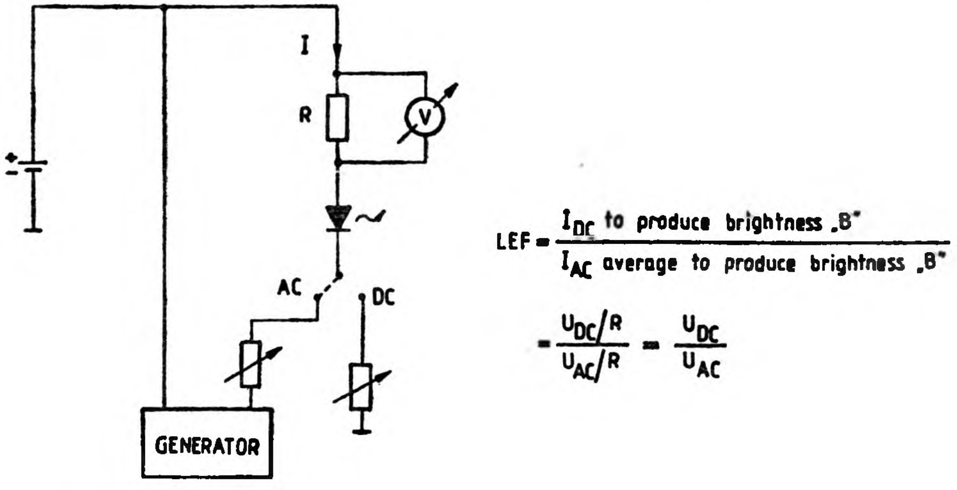

Fig. 2. Experimental setup

LEF values as a function of duty cycle for different DC currents being a parameter are shown in Fig. 3. Each diagram is made at constant I_{DC}, i.e., light intensity of steady-state operation is also constant. From these curves the following conclusions can be drawn:

1. For low supply currents ($I_{\mathrm{DC}} = 5$ mA) the maximum LEF is for 0.4%–1% duty cycle, numerical value of LEF is about 2.6 within these limits.

2. For medium supply currents ($I_{\mathrm{DC}} = 10$ mA) maximum LEF is for 1%–4%, numerical value of LEF is about 1.2.

3. For relatively high currents ($I_{\mathrm{DC}} = 20$–30 mA) maximum LEF is for 2%–6% duty cycle, numerical value of LEF is about 1.7.

The characteristics obtained for different types of diodes were similar, however, the value of LEF can be changed by 20% of the given average value for different diodes of the same type. The position of the maximum LEF value for each single diode can be also different. The change is especially well observed at high currents where the maximum can be placed between 2%–6% duty cycle. The compromise, i.e., 4% duty cycle, seems to be a well balanced value. Pulse frequency shift ranging within 100 Hz–10 kHz has no influence on LEF – only the duty cycle is of importance.

Decay of LEF values for low duty cycle stays in opposition to QEF which in these conditions increases as LED is not optically saturated yet. This shows the influence of psychology and physiology on the processes of seeing, while shift of the maximum LEF value towards higher duty cycle with the increasing current seems to be due to the diode parameters.

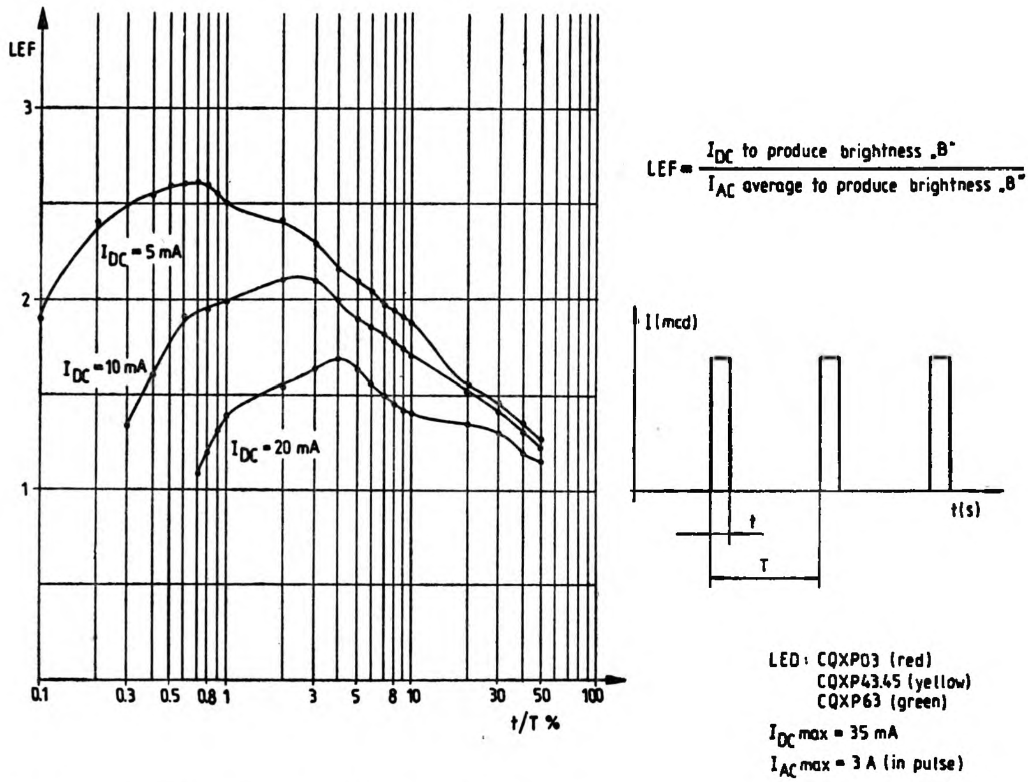

Fig. 3. LEF value as a function of duty cycle

Pulsed illuminators should be used in every optical system where low supply current is required, especially in battery-powered field application. Energy-saving factor and prolongation of battery life are nearly the same as LEF value. A small difference is caused by pulsed power supply power consumption, however, energy-saving of 40% (compared with conventional LED design) can be easily achieved. Selection of LED using QEF value as the selecting criterion can make pulsed illuminators more effective. An idea of pulsed illuminator with very low power consumption (about 1 mA/5 V DC) by power supply is shown in Fig. 4.

According to the experiments it is possible to optimize alfa-numerical LED displays in electronic apparatus. As yet LED displays are usually supplied with about 10% duty cycle current pulses. Such working conditions are due to electro-

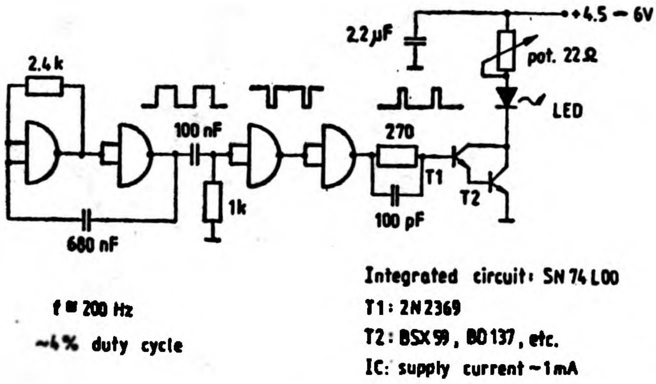

Fig. 4. Design of a pulsed illuminator

nic design. Since the display often takes most of the power, the change to 4% duty cycle would improve the parameters of the equipment.

As yet there is no information about negative influence of bright and short light pulses on human vision. The case has not been medically tested, however, no undesired effects have been observed in dozens of persons who participated in the experiments.

References

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