

The Influence of the PWM frequency and duty cycle of a RGB LED driver on the optical spectrum of the emitted light

Abstract. The concept of digital 3-channels RGB LED driver is presented in the article. The proposed driver allows for independent control of PWM frequency and duty cycle to achieve the light intensity and color regulation. The results of laboratory investigations are presented in the paper. The influence of the control signal frequency and duty cycle on the optical spectrum of the emitted light is discussed.

Streszczenie. W artykule przedstawiono koncepcję trójkanałowego cyfrowego sterownika diod LED RGB. Układ pozwala na niezależną regulację częstotliwości i współczynnika wypełnienia sygnału PWM w każdym kanale do regulacji jasności świecenia oraz barwy diody. Proponowany układ został przebadany w laboratorium. Przeanalizowano wpływ częstotliwości oraz wypełnienia na charakterystyki widmowe emitowanego światła. (Wpływ częstotliwości i współczynnika wypełnienia impulsów sterujących LED RGB na charakterystyki widmowe emitowanego światła).

Keywords: LED driver, RGB, PWM, optical spectrum.

Słowa kluczowe: sterownik LED, RGB, PWM, charakterystyki widmowe.

Introduction

The tremendous interest concerning the use of LED lighting, causes increasing attention of specialists paid on LED power supply circuits and the optical spectrum of the emitted light control. The concept of digital 3-channels RGB LED driver presented in the article is such an example.

The proposed driver allows for independent control of PWM frequency and duty cycle to achieve the light intensity and color regulation. The results of laboratory investigations of the LED driver are presented and discussed.

Concept of RGB LED Driver

The block diagram of the RGB LED driver is presented in the Fig.1. The logical control of the proposed driver named PWM_VF (Fig. 1) consists of the composition of three main functional blocks: the control, regulated monostable generators and variable frequency generators.

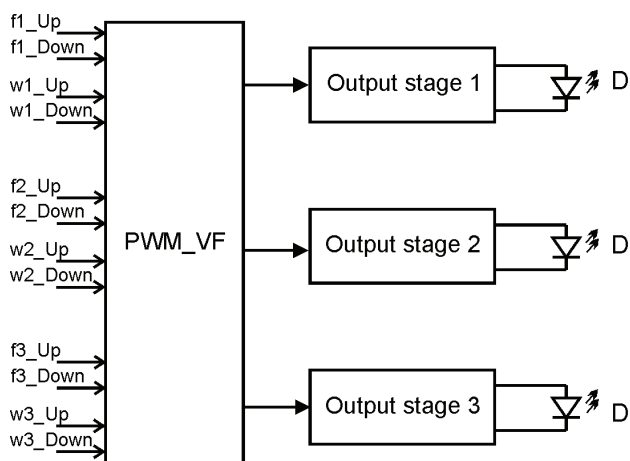


Fig.1. Block diagram of RGB LED driver

It allows for independent regulation of PWM and frequency in each of the three output channels. It is showed in the Fig. 2.

Each channel is equipped with output stage which amplifies the output currents to the level required in power LED lighting applications.

The whole PWM_VF block is implemented in the Altera FPGA device Cyclone II EP2C20 [1] using Quartus II Web Edition design software [2].

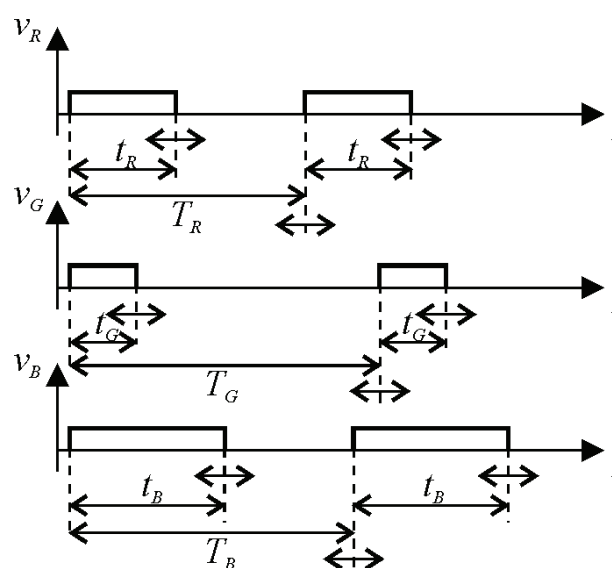


Fig.2. RGB LED control waveforms

The programmable mono-stable generator named Ch1_vw, which is showed in the Fig. 3, consists of the control circuit, standard monostable generator (one standard lpm_counter and one D flip-flop) and programmable Width1_set block (Fig. 3) allowing setting of the pulse width [3].

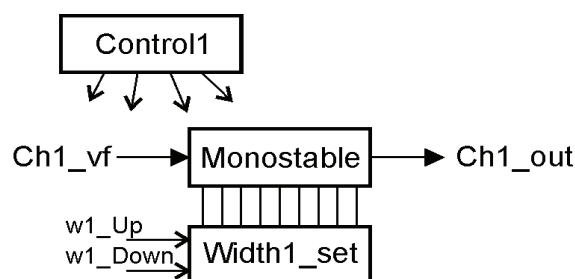


Fig.3. Block diagram of programmable mono-stable generator (Ch1_vw)

The variable frequency generator Ch1_vf (Fig. 4) consists of the digital comparator, counter, programmable setting frequency block Freq1_set and RS flip-flop.

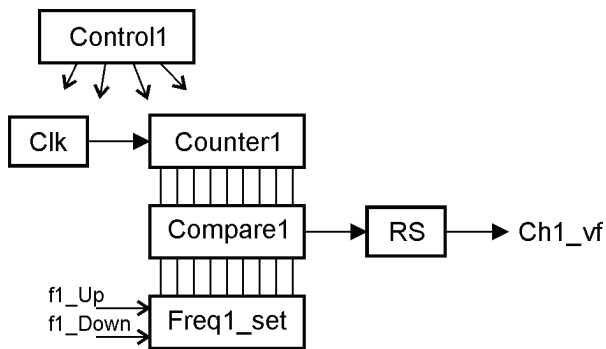


Fig.4. Block diagram of variable frequency generator (Ch1_vf)

The block diagram of the whole logical control named PWM_VF is presented in the Fig. 5. It consists of three independent programmable channels and allows to the signal regulations showed in the Fig. 2. Every input named with extension _Up allows for increasing regulated frequency or pulse width value while every input with extension _Down allows for decreasing.

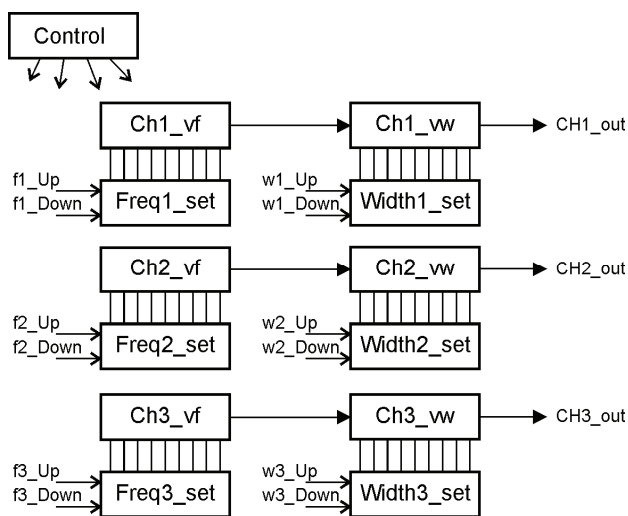


Fig.5. Block diagram of the three channel logical control PWM_VF

Experimental results

The experimental breadboard was built to prove the concept and to evaluate the proposed LED driver. Additional laboratory equipment used during the experiment: Hamamatsu Mini-Spectrometer TM-CCD C10082CAH, four channel Tektronix digital oscilloscope TDS2024B, portable PC with installed professional software for acquired data recording and for FPGA software design purpose.

Experimental investigations were aimed to evaluate the influence of the PWM frequency and duty cycle of the RGB LED driver on the optical spectrum of the emitted light. As a light source was used LED OSTA56A1A-C.

The set of the measurement conditions that was used during the investigations is presented in the Table 1.

Table 1. Set of measurement conditions during experiment

Measurement Conditions	Frequency, Hz			Duty, %		
	R	G	B	R	G	B
Case A	200	200	200	50	50	50
Case B	400	400	400	50	50	50
Case C	300	100	200	50	50	50
Case D	200	200	200	55	50	15
Case E	400	400	400	55	50	15
Case F	300	100	200	55	50	15
Case G	200	200	200	50	10	50
Case H	200	200	200	90	95	15

The figures 6, 7 and 8 show the screens from Hamamatsu software controlling spectrophotometer. They present the influence of the pulse duty cycle at the constant frequency (200Hz) on the optical spectrum of the emitted light. The change of the pulse duty ratio is an easy way of changing color of the emitted light which is widely used in the lighting applications.

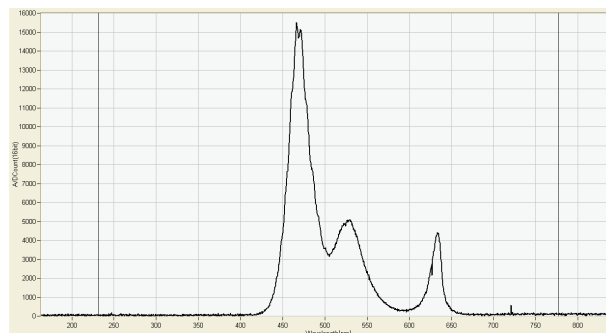


Fig.6. Optical spectrum of the emitted light: Case A (output of the 16 bit ADC versus wavelength)

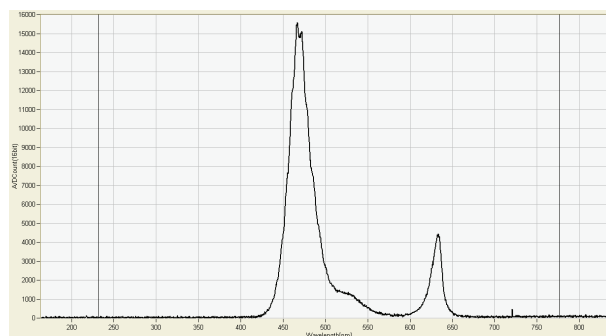


Fig.7. Optical spectrum of the emitted light: Case G

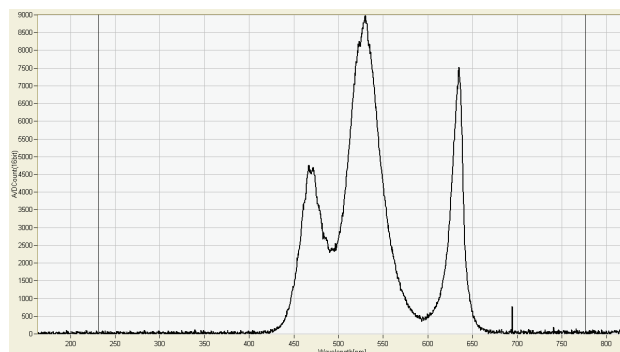


Fig.8. Optical spectrum of the emitted light: Case H

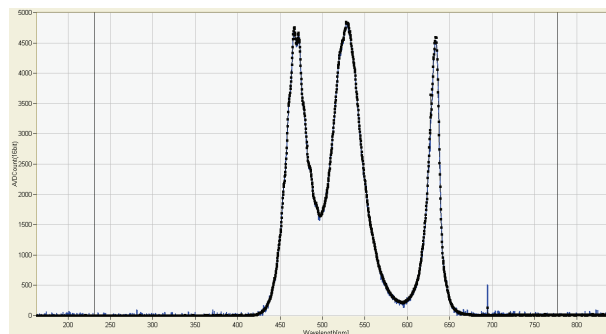


Fig.9. Comparison of the optical spectrum: Case D (solid line) and Case F (dot line)

The influence of the control frequency on the emitted light optical spectrum was evaluated as well. The first three cases A, B and C were considered to check the influence of the control frequency on the emitted light at the constant duty ratio 50% on every channel while the next three cases D, E and F were evaluated to check the influence of the control frequency on the emitted light at different duty cycles (channel R - 55%, channel G - 50%, channel B - 15%). Using the reference mode in spectrometer software it was possible to compare optical spectrum. All the acquired results show no influence of the control frequency on the emitted light. The experimental results for cases D and F are presented in the Fig. 9.

Conclusion

The experimental results show that under considered range there is no influence of the control frequency on the optical spectrum of the emitted light of the investigated RGB LED. In lighting practice there is a lot of implementations where it is important to control LED with higher frequency than commonly used 50-100 Hz [4]. Especially it should be taken into account when the impact on the human eye is considered. The emitted spectrum will not change, but for the eye it will be more similar to the constant current LED light. The most important conclusion is that PWM frequency can be increased in lighting applications demanding high quality of the light.

The color of the emitted light may be regulated using the pulse duty cycle at any chosen control frequency from the considered range.

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Autorzy: dr. inż. Wojciech Wojtkowski, Politechnika Białostocka, Wydział Elektryczny, Katedra Automatyki i Elektroniki, ul. Wiejska 45D, 15-351 Białystok, E-mail: w.wojtkowski@pb.edu.pl;
dr inż. Andrzej Karpiuk, Politechnika Białostocka, Wydział Elektryczny, Katedra Automatyki i Elektroniki, ul. Wiejska 45D, 15-351 Białystok, E-mail: andrzej.karpiuk@pb.edu.pl