TLD5099EP

Embedded PWM frequency adjustment with RC network

About this document

The TLD5099EP is a flexibly usable DC/DC boost controller with built in diagnosis and protection features especially designed to drive LEDs. It also includes an embedded pulse width modulator to easily implement a dimming function with reduced color shifting.

This document explains how to fine trim the frequency of the embedded PWM engine using an RC network instead of only a capacitor. The content is useful to have smaller granularity on dimming frequency adjustment.

The solution proposed is tailored on characteristics of TLD5099EP, where quite high output current from embedded PMW engine enables usage of RC network.

Scope and purpose

The purpose of this application note is to inform the audience about a possible variant on circuit connected to FPWM pin to trim the frequency of PWM engine.

Intended audience

This application note is intended for hardware designer engineers who want to use the embedded PWM engine to dim the output current.

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1 Introduction

Many light sources are present in the front of a car, each one has its own purpose. The low beam (LB) light source is devoted to illuminate the first 20/30 meters of the road; it has a fairly wide optic and its power is in range of 20 W. High beam (HB) is the light source used to illuminate the far field in front of the car; it has a narrow optic and the power delivered by this light source is in range of 15W. Finally there is a daytime running light (DRL) that is a light without any focusing optics, mainly used to advise other drivers or pedestrian. During night (or when the ambient light is too low and LB has to be turned on), DRL is dimmed down to position light (PL) to avoid glaring of other people.

Simply reducing the current into LED to dim the DRL to PL could produce a color shift of light source that is unwanted by OEM. The shifting is usually reported by LED manufactures using a graph. A way to avoid color shift when the LED is dimmed down to PL is to modulate the current into LED with a pulse width modulation (PWM). In this case, the modulation of the current produces a brightness reduction proportional to the duty cycle applied, while the same peak current into LED in both scenario produces a light with the same point of white.

The frequency of the dimming PWM is usually higher than 100 Hz to avoid any flickering effects, while its maximum is in range of 500-600 Hz. The duty cycle applied during the dimming is usually in the range of 10-20 %.

Common dimming frequency selection on multitopology controllers uses capacitor with only few values available to adjust the PWM frequency. This is a drawback when specific precise frequency has to be chosen to be compatible with other electronics part (e.g. camera module). With quite relative high current on FPWM pin, TLD5099EP offers a way on overcame to this.

2 System overview

To easily switch from DRL to PL TLD5099EP offers an embedded PWM engine to avoid external timers or dedicated peripherals on microcontrollers. The PWM frequency and duty cycle are controlled by two dedicated pins:

Table 1 Pins dedicated to embedded PWM engine

#	Symbol	Direction	Function
3	FPWM	Output	**PWM frequency selector** Connect external capacitor to set PWM frequency
13	EN/PWMI	Input	**Enable or PWM** Apply logic "low" signal to disable device and put it in low current consumption. Apply logic "high" signal to enable device or PWM signal for dimming LED. Apply an analog signal (in a proper range) to enable a PWM engine which works at a defined duty cycle

PWM frequency on TLD5099EP is derived by using internal current sources to charge and discharge the capacitor connected to pin number 3 (FPWM). The simplified schematic of the embedded PWM engine is reported in Figure 1

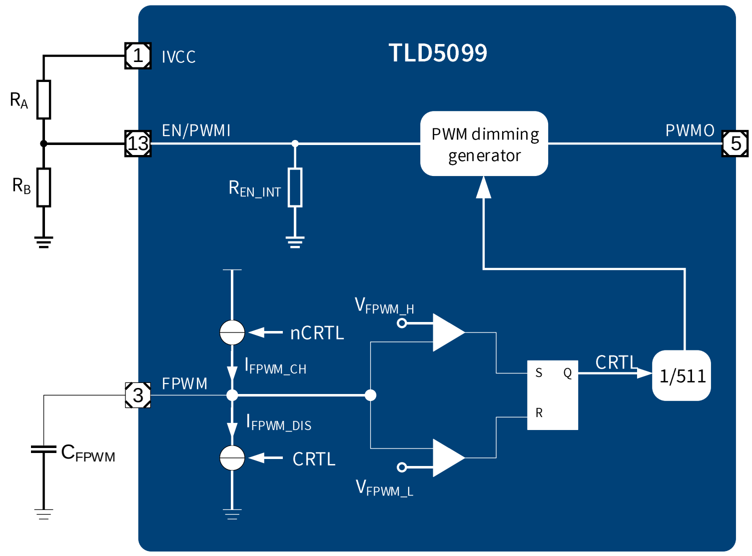

Figure 1 Simplified schematic of PWM engine

Starting with the voltage on FPWM pin lower than V_{FPWM_H}, the capacitor C_{FPWM} is charging with I_{FPWM_CH} current source until the V_{FPWM_H} threshold is reached. Then, the signal CTRL goes high and nCRTL goes to low level. With this configuration, the capacitor C_{FPWM} is discharged by I_{FPWM_DIS} current source. The capacitor is discharged until the voltage on FPWM pin reaches V_{FPWM_L}. At that time, the output of RS latch toggles again to low and the sequence is repeated.

A timing diagram of the voltage on FPWM is shown on Figure 2. C_{FPWM} affects the slope of the voltage on pin FPWM and then the frequency of PWM engine.

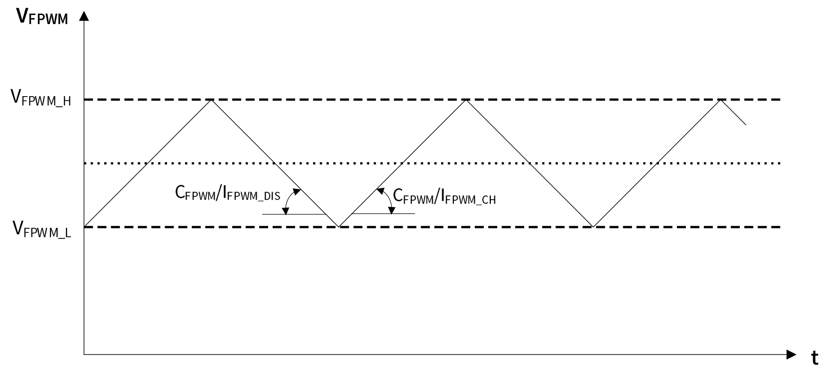

Figure 2 Timing diagram of voltage on FPWM pin

The formula to calculate the PWM frequency as a function of C_{FPWM} is:

$$f_{PWMO} = \frac{1}{511 \cdot C_{FPWM} \cdot (V_{FPWM\_H} - V_{FPWM\_L}) \cdot \left(\frac{1}{|I_{FPWM\_CH}|} + \frac{1}{|I_{FPWM\_DIS}|}\right)}$$

Using E12 series capacitor, the variation of f_{PWMO} as a function of C_{FPWM} is reported in the Table 2

Table 2 Relation between f_{PWMO} and C_{FPWM}

C_{FPWM} [pF]	f_{FPWMO} [Hz]
390	502
470	416
560	349
680	288
820	239
1000	196

3 Proposed solution

The solution illustrated in the Section 2 is a common solution adopted by many boost controller on the market. It suffers of low granularity on the frequency adjustment. Indeed, common capacitors on the market follow E12 series. Especially in case of selection of high frequency dimming, the change from a value to the next produces a big variation on PWM frequency. Just as an example, 390 pF capacitor generates a frequency of PWM engine equal to 502 Hz, while 470 pF produces a frequency of 416 Hz with a gap of 86 Hz. Possible solution is to play with multiple capacitors in parallel and/or in series.

Using TLD5099EP, a solution to improve the granularity of the PWM dimming frequency is to use an RC network instead of a simple capacitor. The solution is depicted in Figure 3.

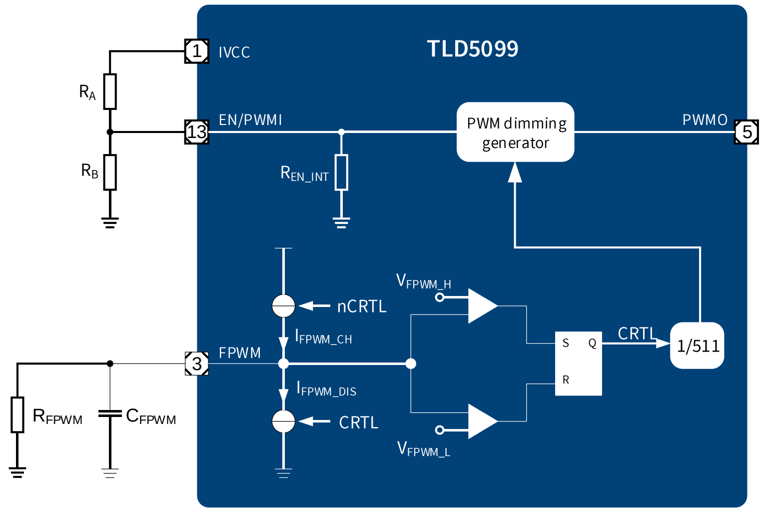

Figure 3 Simplified schematic of PWM engine with RC network on FPWM pin

Basic idea is to apply an RC filter on FPWM pin. In this way, the triangular shape showed on Figure 2 is changed with an exponential charge and discharge of the RC network.

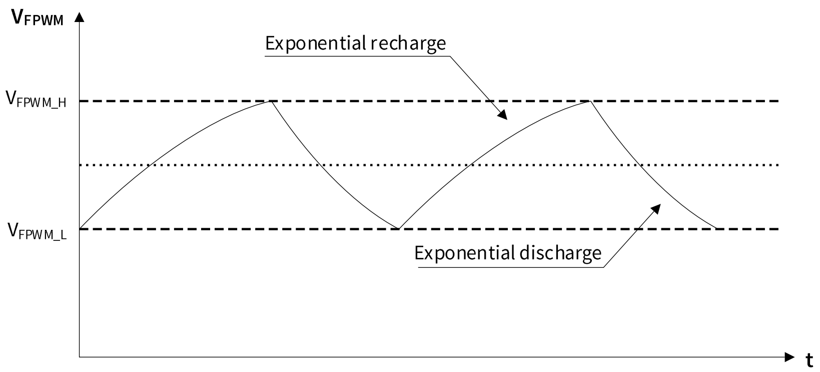

Figure 4 Timing diagram of voltage on FPWM pin when RC network is used instead only C

The dimming frequency can be calculated with the following formula that take into consideration also the effect of the resistor R_{FPWM}:

$$f_{PWM} = \frac{1}{511 \cdot R_{FPWM} \cdot C_{FPWM} \cdot \ln\left[\frac{I_{FPWM\_CH} \cdot R_{FPWM} - V_{FPWM\_L}}{I_{FPWM\_CH} \cdot R_{FPWM} - V_{FPWM\_H}} \cdot \frac{I_{FPWM\_DIS} \cdot R_{FPWM} + V_{FPWM\_H}}{I_{FPWM\_DIS} \cdot R_{FPWM} + V_{FPWM\_L}}\right]}$$

The improvement on the granularity can be checked in Table 3.Values f_{PWMO} are reported as a function of R_{FPWM}; the capacitor C_{FPWM} has been set to 390 pF.

As shown, the maximum gap is now 24 Hz if an E12 series resistor is used. This result is more than three time better than what achievable with only C_{FPWM}. Better result can be achieved with higher precision resistors.

Table 3 Relation among f_{PWMO}, R_{FPWM} and C_{FPWM}

C_{FPWM} [pF]	R_{FPWM} [kΩ]	f_{FPWMO} [Hz]
390	open	502
	100	499
	82	497
	68	495
	56	492
	47	488
	39	482
	33	474
	27	461
	22	440
470	open	416

Just a reminder: FPWM voltage has to reach the upper threshold to swap the status of current sources. This means the minimum resistor times the minimum charging current has to be higher than the maximum threshold. This leads to the following constraint related to minimum R_{FPWM} usable in this application.

$$R_{FPWM,min} > \frac{V_{FPWM\_H,max}}{I_{FPWM\_CH,min}} = \frac{2.1\ V}{150\ \mu A} = 14\ k\Omega$$

4 Conclusion

Dimming the daytime running light (DRL) to position light (PL) usually requires either an external timer or dedicated peripherals on microcontrollers. TLD5099EP offers an embedded PWM engine to help designer to easily implement the swap between light functions. This feature also reduce the overall cost of the front light.

The dimming PWM has to be generated with a certain duty cycle and precise frequency to avoid interference with other systems (e.g. camera module). Off the shelf capacitors from E12 series does not satisfied the granularity requirements on frequency adjustment.

In this application note, a cost effective solution is proposed for fine adjustment on PWM frequency. It is based on RC network connected to FPWM pin instead of a simple capacitor. This solution improves of factor three the resolution of dimming frequency achievable with TLD5099EP.

Revision history

Document version	Date of release	Description of changes
1.00	2020-02-21	First release

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