PMP15037 Test Results

System Description

Figure 1 is a basic LED driver circuit where the LED is connected between the Vout pin and the FB pin of the converter. The LED current is determined by V_{FB} and R_S. So the higher the FB pin voltage, the higher the loss across the R_S. Therefore, if we can make V_{FB} both contributes by the output voltage and the LED current, then the conversion efficiency can be greatly improved.

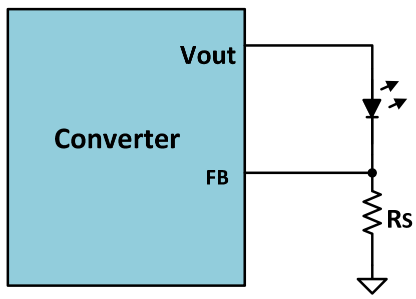

Figure 1. Basic LED driver circuit

TPS61021A is a high efficiency synchronous boost converter. It isolates the output from the input side when shutdown. So it can help to reduce the battery loss when the LED is turned off.

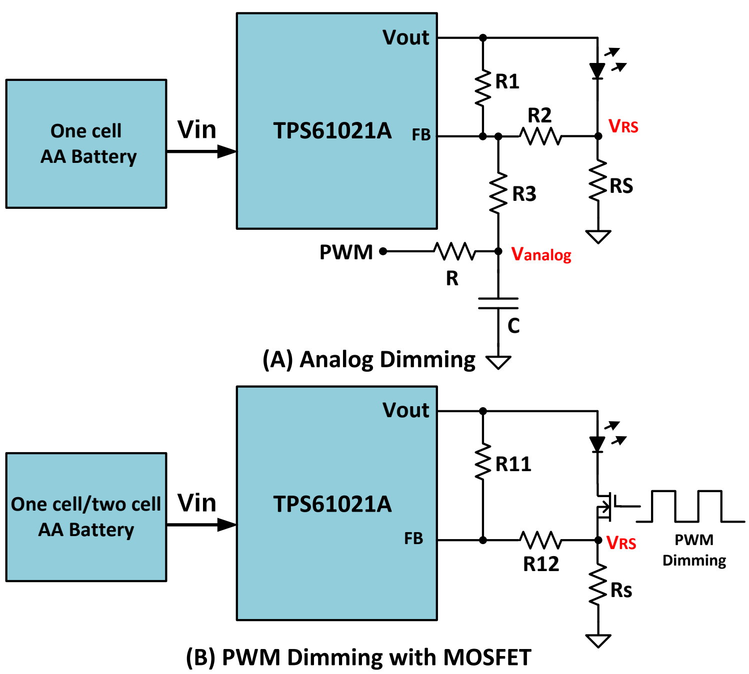

Figure 2. Block Diagram of the PMP15037

The block diagram of reference design PMP15037 is shown in Figure 2. This reference design delivers a high efficiency LED driver circuit with dimming function with the boost converter TPS61021A. The PWM dimming method (Figure 1. (A)) can be used in the one cell or two cell AA battery input application. The analog dimming method (Figure 1. (B)) can be used in the one cell AA battery input application. The TI design PMP15037 is very simple, it realizes the dimming function by just adding several resistors and one MOSFET into the circuit. So this is a low cost and high efficiency solution for the LED driver application.

Table 1 gives out the performance specification of the TI design PMP15037 under PWM dimming. It has 0.5A output current capability at one cell AA battery input application and has 1A output current capability at two cell AA battery input applications.

Table 1 Performance Specification under the PWM Dimming

Input Voltage Range(V)	Maximum LED Current(A)	Dimming Frequency(HZ)
One cell AA Battery	0.5 (R1=383k)	200-1k
Two cell AA Battery	1 (R1=523k)	200-1k

Table 2 gives out the performance specification of the TI design PMP15037 under analog dimming. It has 0.5A output current capability at one cell AA battery input application. It has no limit on the dimming frequency since the dimming depth is only determined by the analog voltage level V_{ANALOG} added to the FB pin. Two cell AA battery input is not supported under the analog dimming method.

Table 2 Performance Specification under the Analog Dimming

Input Voltage Range(V)	Maximum LED Current(A)	Dimming Frequency(HZ)
One cell AA Battery	0.5	Not limited

Design Theory

Figure 2.1 shows the schematic of the TI design PMP15037 under analog dimming. R5 and C6 forms a RC filter, it converts the PWM signal PWM1 to the analog signal V_{ANALOG}. The voltage level of V_{ANALOG} changes in accordance with the duty cycle of PWM1. The high voltage level of PWM1 set at 3V, the low voltage level of PWM1 set at GND in this TI design.

When the duty cycle of PWM1 is 0%, V_{ANALOG} is 0 V. The LED is always on. The current flowing through the LED is a DC current, which is set at 0.5A in this TI design. The FB pin voltage is determined by the output voltage V_{OUT1} and the voltage V_{RS} across the sense resistor.

$$V_{OUT1} \times \frac{R_{p1}}{R_{p1} + R1} + V_{RS} \times \frac{R_{p2}}{R_{p2} + R2} = V_{FB} \qquad (1)$$

Where

- V_{OUT1} is the TPS61021's output voltage when LED current is 0.5A, V_{OUT1}=3.2V.
- V_{FB} is the TPS61021's feedback regulation voltage (V_{FB}=0.795V).

- $R_{p1} = \frac{R2 \times R3}{R2 + R3}$, $R_{p2} = \frac{R1 \times R3}{R1 + R3}$
- $V_{RS} = I_{LED} \times R_S = 0.5 \times 0.3 = 0.15V$

When the duty cycle of PWM1 is 100%, V_{ANALOG} is 3V. The LED is off. The FB pin voltage is contributed by the output voltage V_{OUT2} and V_{ANALOG} at this time.

$$V_{OUT2} \times \frac{R_{p1}}{R_{p1} + R1} + V_{ANALOG} \times \frac{R_{p3}}{R_{p3} + R3} = V_{FB} \tag{2}$$

Where

- V_{OUT2} is the TPS61021's output voltage when LED off, V_{OUT2}=2.7V.
- $R_{p3} = \frac{R1 \times R2}{R1 + R2}$

From equation (1) and (2), equation (3) and equation (4) can be deduced:

$$V_{OUT1} \times \frac{R_{p1}}{R_{p1} + R1} + V_{RS} \times \frac{R_{p2}}{R_{p2} + R2} = V_{OUT2} \times \frac{R_{p1}}{R_{p1} + R1} + V_{ANALOG} \times \frac{R_{p3}}{R_{p3} + R3} \tag{3}$$

$$(V_{OUT1} - V_{OUT2}) \times \frac{R_{p1}}{R_{p1} + R1} + V_{RS} \times \frac{R_{p2}}{R_{p2} + R2} = V_{ANALOG} \times \frac{R_{p3}}{R_{p3} + R3} \tag{4}$$

In equation (4), set R2=200k, R3=2M, thus Rp1=181.8k. So only R1 is an unknown number. We can get equation (5) and (6):

$$(V_{OUT1} - V_{OUT2}) \times \frac{181.8}{181.8 + R1} + V_{RS} \times \frac{\frac{R1 \times 2000}{R1 + 2000}}{\frac{R1 \times 2000}{R1 + 2000} + 200} = V_{ANALOG} \times \frac{\frac{R1 \times 200}{R1 + 200}}{\frac{R1 \times 200}{R1 + 200} + 2000} \tag{5}$$

$$0.5 \times \frac{181.8}{181.8 + R1} + 0.15 \times \frac{\frac{R1 \times 2000}{R1 + 2000}}{\frac{R1 \times 2000}{R1 + 2000} + 200} = 3 \times \frac{\frac{R1 \times 200}{R1 + 200}}{\frac{R1 \times 200}{R1 + 200} + 2000} \tag{6}$$

Solving equation (6), we can get R1≈ 665k ohm.

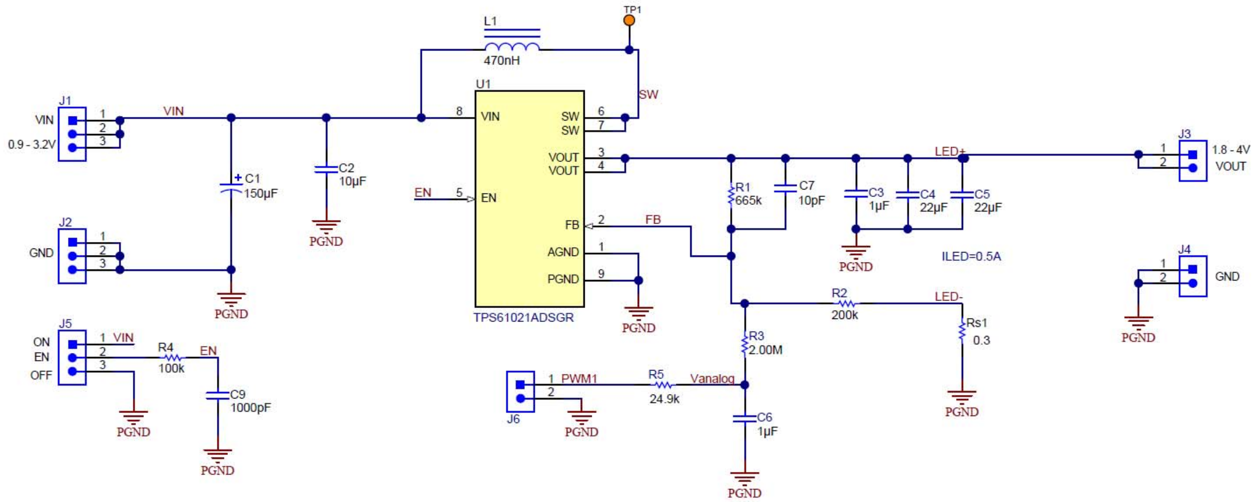

Figure 2.1 Schematic of the PMP15037 (Analog Dimming)

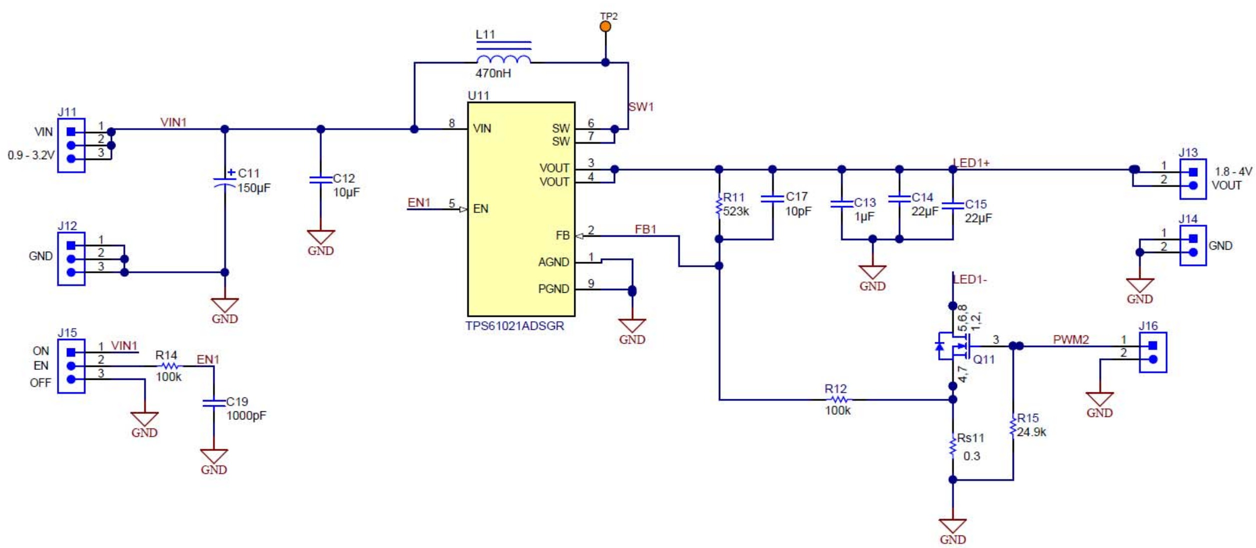

Figure 2.2 Schematic of the PMP15037 (PWM Dimming)

Figure 2.2 shows the schematic of the TI design PMP15037 under PWM dimming. When MOSFET Q11 is fully on, the FB pin voltage is contributed by the output voltage VOUT and the voltage V_{RS} across the sense resistor.

$$V_{OUT} \times \frac{R12}{R11+R12} + V_{RS} \times \frac{R11}{R11+R12} = V_{FB} \tag{7}$$

Where

- V_{OUT} is the TPS61021's output voltage when LED current is 1A, V_{OUT}=3.4V.
- $V_{RS} = I_{LED} \times R_{S11} = 1 \times 0.3 = 0.3V$

Set R12=100k ohm. Then R11 is the only unknown value in the above equation.

$$R11 = \frac{(V_{OUT} - V_{FB}) \times R12}{(V_{FB} - V_{RS})} \tag{8}$$

Solving equation (8), we can get R11≈523k ohm in this TI design.

Test Result

Figure 3 shows the LED current versus the PWM duty cycle under analog dimming. The LED current changes in accordance with the PWM duty cycle, which is the voltage level of V_{ANALOG} under analog dimming.

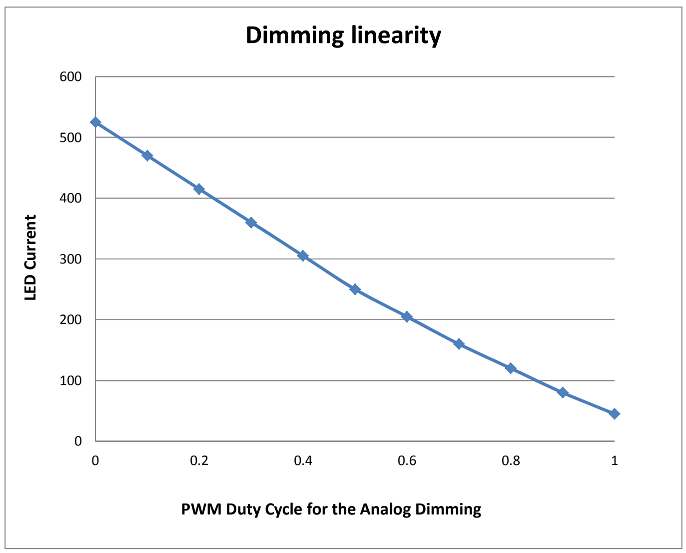

Figure 3. LED Current VS. PWM Duty Cycle under Analog Dimming

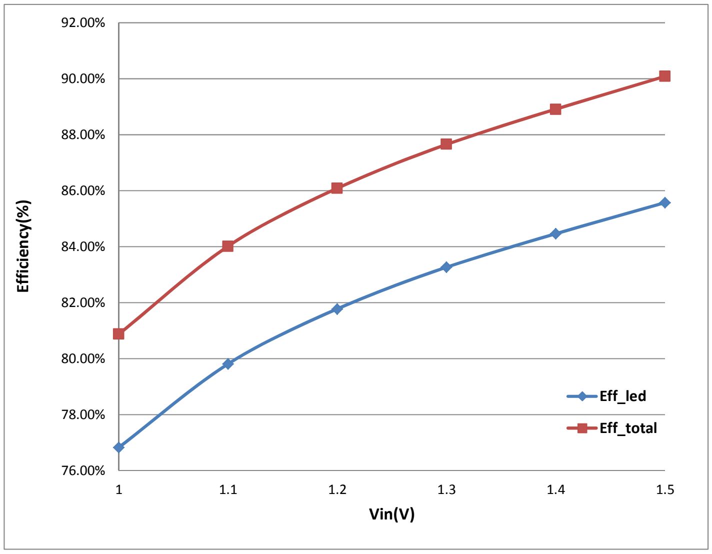

Figure 4. Conversion Efficiency under Analog Dimming (Io=0.5A)

Figure 4 shows the conversion efficiency under analog dimming when the sense resistor is 0.3 ohm. Reducing the sense resistor from 0.3 ohm to 0.15 ohm can increase the conversion efficiency by 2%.

Figure 5 shows the conversion efficiency under PWM dimming at different dimming frequency. When MOSFET Q11 is fully on, the LED current is 1A. So the average current flowing through the LED is 0.5A at 50% duty cycle and 0.95A at 95% duty cycle.

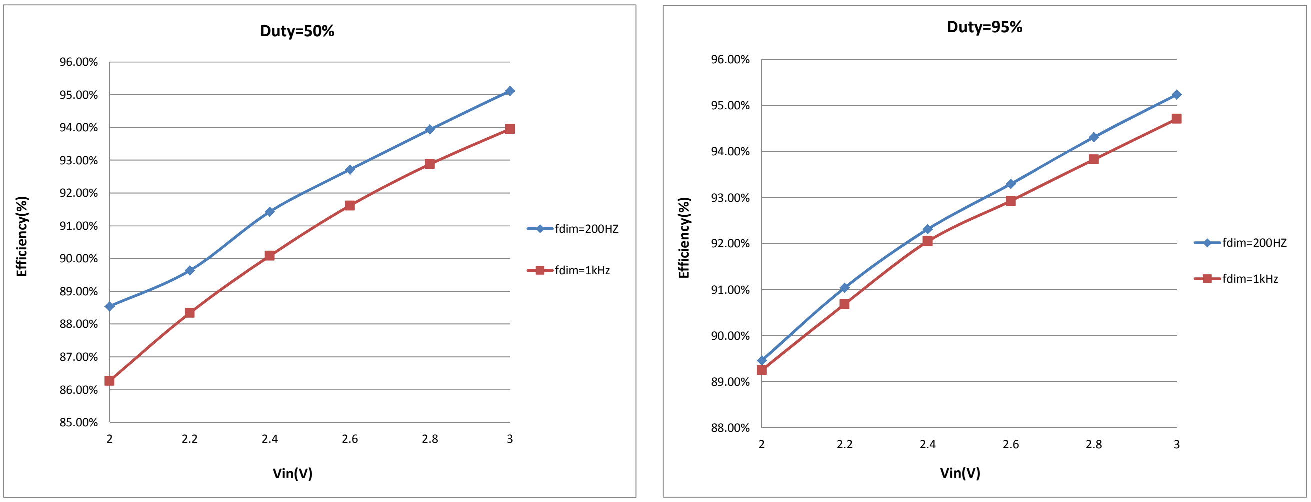

Figure 5. Conversion Efficiency under PWM Dimming