Power Management Business Unit

PWM application note

apply to device family:

AP5724/25/26(SOT26) series

Features

- Inherently Matched LED Current
- High Efficiency: **84%** Typical
- Fast **1.2MHz** Switching Frequency
- Current limit and UVLO protections
- Over Voltage Protect function built-in
- Soft-Start function built-in
- SOT26 and DFN2020C-6: Available in "Green" Molding Compound (No Br, Sb)
- Lead Free Finish/RoHS Compliant (Note 1)

General Description

The AP5724 is a step-up DC/DC converter specifically designed to drive white LEDs with a constant current. The device can drive 2~6 LEDs in series from a Li-Ion cell. Series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminates the need for ballast resistors. The AP5724 switches at 1.2MHz that allows the use of tiny external components. A low 0.1V feedback voltage minimizes power loss in the current setting resistor for better efficiency.

Applications

- Cellular Phones
- PDAs, Hand help Computers
- Digital Cameras
- MP3 Players
- GPS Receivers

Functional Description

Inductor Selection
A 10μH~22μH inductor is recommended for most AP5724 applications. Although small size and high efficiency are major concerns, the inductor should have low core losses at 1.2MHz and low DCR (copper wire resistance).

Capacitor Selection
The small size of ceramic capacitors are ideal for AP5724 applications. X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges than other types such as Y5V or Z5U. A 1μF input capacitor and a 1μF output capacitor are sufficient for most AP5724 applications.

Diode Selection
Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for AP5724 applications. The forward voltage drop of a Schottky diode represents the conduction losses in the diode, while the diode capacitance (C_T or C_D) represents the switching losses. For diode selection, both forward voltage drop and diode capacitance need to be considered. Schottky diodes with higher current ratings usually have lower forward voltage drop and larger diode capacitance, which can cause significant switching losses at the 1.2MHz switching frequency of the AP5724. A Schottky diode rated at 100mA to 200mA is sufficient for most AP5724 applications.

LED Current Control
The LED current is controlled by the feedback resistor (R_{SET} in **Figure 1**). The feedback reference is 0.1V. The LED current is 0.1V/ R_{SET}. In order to have accurate LED current, precision resistors are preferred (1% is recommended). The formula and table for R_{SET} selection are shown below.

AP5724 $R_{SET} = 0.1V/I_{LED}$ (See **Table 1**)

AP5725 $R_{SET} = 0.25V/I_{LED}$
AP5726 $R_{SET} = 0.31V/I_{LED}$

Table 1. R_{SET} Resistor Value Selection

I_{LED} (mA)	AP5724 R_{SET} (Ω)	AP5725 R_{SET} (Ω)	AP5726 R_{SET} (Ω)
5	20	50	62
10	10	25	31
15	6.6	16.6	20.6
20	5	12.5	15.5
30	3.3	8.3	10.3

Open-Circuit Protection

In the cases of output open circuit, when the LEDs are disconnected from the circuit or the LEDs fail, the feedback voltage will be zero. The AP5724 will then switch at a high duty cycle resulting in a high output voltage, which may cause the SW pin voltage to exceed the level of the over voltage protect function. The OVP pin can detect the output voltage and monitor if the output voltage reach to the protect voltage level (**Figure 2**). Once OVP is activated, SW pin stops switching.

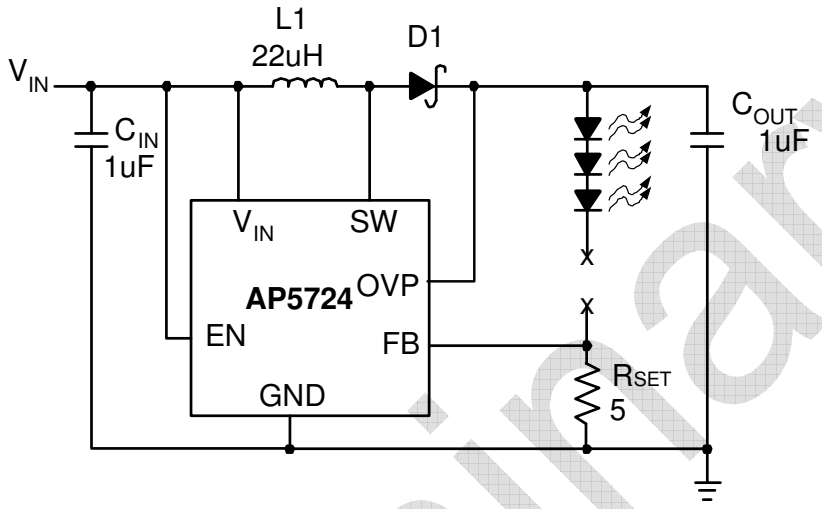


Figure 2. LED Driver with Open-Circuit Protection

Dimming Control

There are four different types of dimming control circuits:

1. Using a PWM Signal to EN Pin

With the PWM signal applied to the EN pin, the AP5724 is turned on or off by the PWM signal. The LEDs operate at either zero or full current. The average LED current increases proportionally with the duty cycle of the PWM signal. A 0% duty cycle will turn off the AP5724 and corresponds to zero LED current. A 100% duty cycle corresponds to full current. The typical frequency range of the PWM signal is below 2kHz.

2. Using a DC Voltage

For some applications, the preferred method of brightness control is a variable DC voltage to adjust the LED current. The dimming control using a DC voltage is shown in **Figure 3**. As the DC voltage increases, the voltage drop on R2 increases and the voltage drop on R_{SET} decreases. Thus, the LED current decreases. The selection of R2 and R3 will make the current from the variable DC source much smaller than the LED current and much larger than the FB pin bias current. For V_{DC} range from 0V to 2V, the selection of resistors in **Figure 3** gives dimming control of LED current from 0mA to 20mA.

3. Using a Filtered PWM Signal

The filtered PWM signal can be considered as an adjustable DC voltage. It can be used to replace the variable DC voltage source in dimming control.

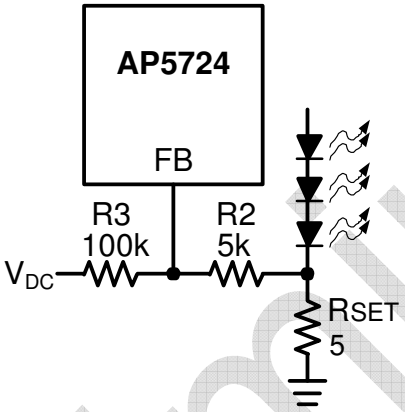


Figure 3. Dimming Control Using a DC Voltage

4. Using a Logic Signal

For applications that need to adjust the LED current in discrete steps, a logic signal can be used as shown in **Figure 4**. R_{SET} sets the minimum LED current (when the NMOS is off). R_{SET} sets how much the LED current increases when the NMOS is turned on.

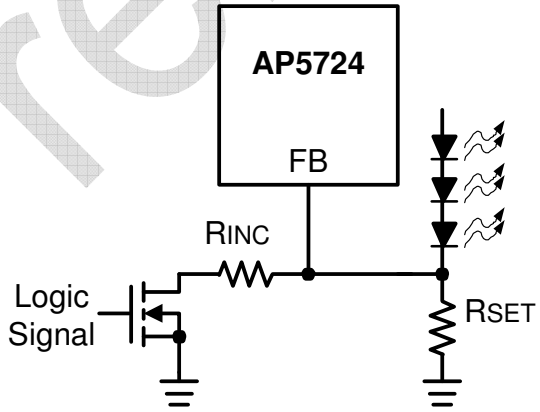
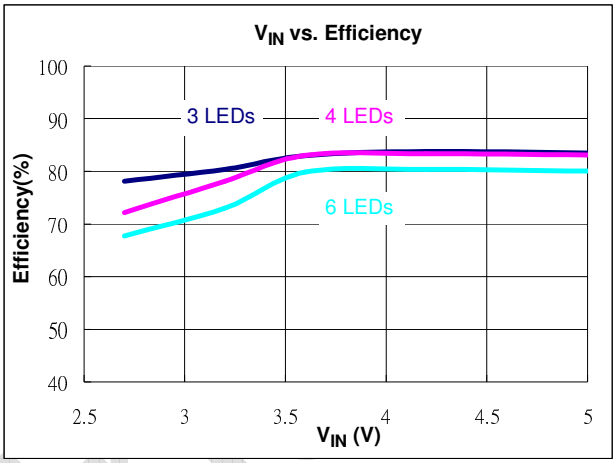


Figure 4. Dimming Control Using a Logic Signal

Evaluation Board



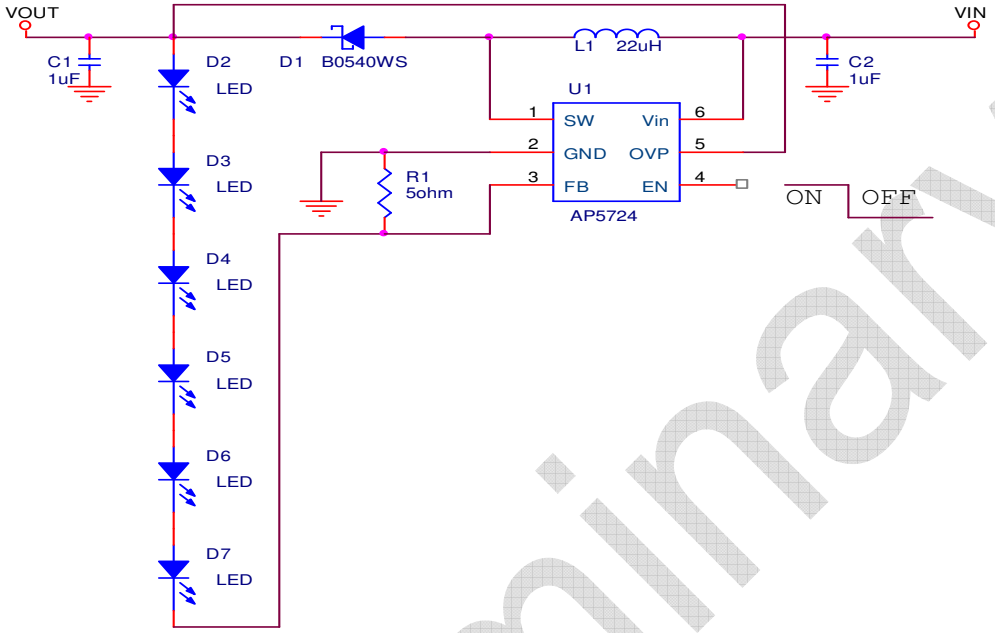
Specification

Symbol	Parameter	Conditions	Min	Typ.	Max	Unit
System Supply Input						
V_{IN}	Operating Input Voltage		2.7	-	5.5	V
UVLO	Under Voltage Lockout		-	2.2	2.4	V
	Under Voltage Lockout Hysteretic		-	85	-	mV
I_Q	Quiescent Current	FB=0.2V, No Switching	-	500	-	μA
I_{SD}	Shutdown Current	V_{EN} < 0.4V	-	0.1	1	μA
Oscillator						
F_{OSC}	Operation Frequency		1	1.2	1.4	MHz
Dmax	Maximum Duty Cycle		86	90	-	%
Reference Voltage						
V_{FB}	Feedback Voltage		0.09	0.1	0.11	V
I_{FB}	FB Pin Bias Current		10	45	100	nA
MOSFET						
Rds(on)	On Resistance of MOSFET		0.5	0.75	1.0	Ω
I_{OCP}	Switching Current Limit	Normal Operation	-	750	-	mA
Control and Protection						
EN	Voltage High	ON	1.5	-	-	V
EN	Voltage Low	OFF	-	-	0.4	V
I_{EN}	EN Pin Pull Low Current		-	4	6	μA
OVP	OVP Threshold		26	30	34	V
θ_{JA}	Thermal Resistance Junction-to-Ambient	SOT26 (Note 3)		162		°C/W
		DFN2020C-6 (Note 3)		200		°C/W
θ_{JC}	Thermal Resistance Junction-to-Case	SOT26 (Note 3)		36		°C/W
		DFN2020C-6 (Note 3)		30		°C/W

Notes: 3. Test condition for SOT26 and DFN2020C-6: Devices mounted on FR-4 substrate PC board, 2oz copper, with minimum recommended pad layout.

Schematic

Test Circuit



Bill of Materials

Component Location	Quantity	Specification	Mark	Maker Part No.	Size
C1,C2	2	22uF/25V (Ceramic Capacitor)	TAIYO YUDEN	TMK212 B7105MG-T	C0805
L1	1	22uH/0.88A	Wurth Electronics	744042220	4.8 X 4.8 X 1.6
		22uH/0.56A	GOTREND	GLP3810PH220N	3.8 X 3.8 X 1.05
R1	1	5Ω(1%)	YAGEO		R0805
D1	1	40V/0.5A	ZETEX	ZLLS400	SOD323
		40V/0.5A	DIODES	B0540WS	SOD323
		40V/0.25A	DIODES	SDM20U40	SOD523
U1	1	AP5724_SOT26	Diodes		SOT26

PCB Layout

Top Layer	Bottom Layer