PWM Step-Up DC/DC Converter for Panel Backlight

General Description

The EMD2095 is a highly efficient, step-up DC/DC converter for driving white LEDs. The device can drive up to 8 serially connected white LEDs from a single Li-Ion battery, or to drive multiple serial and parallel combinations with a DC power supply from 2.5V to 5.5V. The EMD2095 uses current mode and pulse-width modulated (PWM) operation. Its high switching operation frequency of 1.2MHz allows the system to use small inductor, input and output capacitors. An internal compensation circuit can reduce the external component count.

To safeguard the system, the EMD2095 includes various protection circuits such as under-voltage lockout, current limit, over voltage and thermal shutdown. EMD2095 are available in the tiny packages of SOT-23-6L.

Applications

- Mobile Phone
- Digital Still Cameras
- Portable applications
- MP3 Players
- GPS Receivers

Features

- Up to 8 WLEDs supports
- Low Quiescent Current: 120 μA
- Over Voltage Protection: 31V
- Inherently Matched LED Current
- Shutdown Current < 1μA
- Reference Voltage 0.245V
- PWM Dimming Control (2KHz~200kHz)
- Internal Soft Start and Compensation
- 1.4A Internal power MOSFET Switch
- Low Profile SOT-23-6 Package
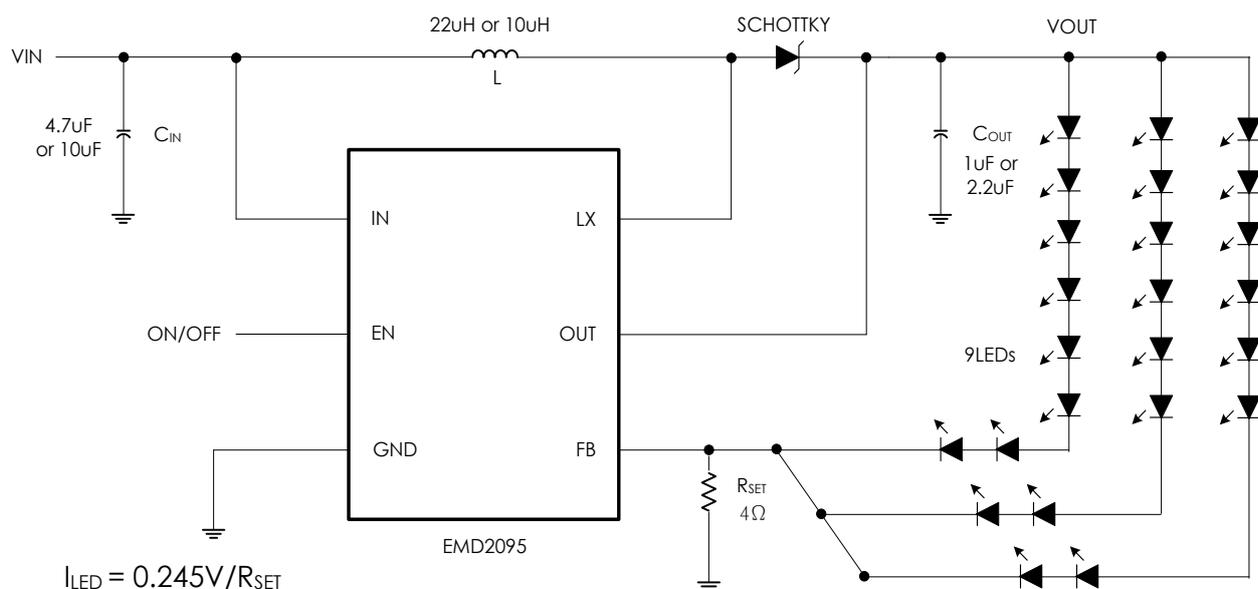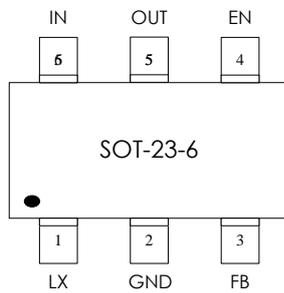
Typical Application (8S3P, I_{LED}=40mA)

$$I_{LED} = 0.245V/R_{SET}$$

Fig. 1

Connection Diagram

IN	OUT	EN
6	5	4

SOT-23-6

1	2	3
LX	GND	FB

Order Information

EMD2095-00VC06NRR

00   Output voltage

VC06   SOT-23-6L Package

NRR   RoHS & Halogen free package

          Rating: -40 to 85°C

          Package in Tape & Reel

Order, Marking & Packing Information

Package	Vout	Product ID	Marking	Packing
SOT-23-6L	Adjustable	EMD2095-00VC06NRR	2095 Tracking Code PIN1 DOT	Tape & Reel 3Kpcs

Function Block
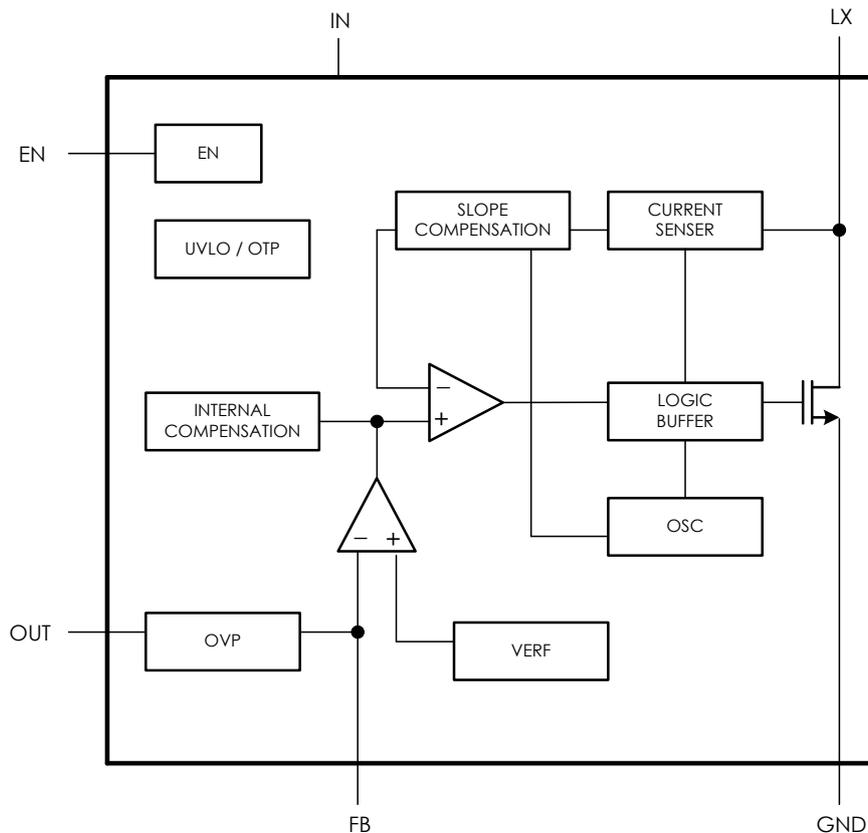
Fig. 2

Pin Functions

Pin Name	SOT-23-6L Pin #	Function
LX	1	**Switch Pin.** Connect inductor/diode here.
GND	2	**Ground Pin.**
FB	3	**Feedback Pin.** Reference voltage is 0.245V, connect cathode of lowest LED and resistor here.
EN	4	**Chip Enable Pin and PWM Dimming Control Pin.** Connect to 1.2V or higher to enable device, 0.4V or less to disable device.
OUT	5	**Over Voltage Protection Pin.**
IN	6	**Input Voltage Pin.**

Absolute Maximum Ratings

Devices are subjected to failure if they stay above absolute maximum ratings

Input Voltage	– 0.3V to 6V	Operating Temperature Range	–40°C to 85°C
EN, VFB Voltages	– 0.3V to VIN	Storage Temperature	–65°C to 150°C
LX ,OUT Voltage	– 0.3V to 40V	Junction Temperature	150°C
ESD Susceptibility	HBM 2kV	Lead Temperature (Soldering, 10 sec)	260°C
	MM 200V		

Thermal data

Package	Thermal resistance	Parameter	Value
SOT-23-5	θ_{JA} (Note 2)	Junction-ambient	250°C/W
	θ_{JC} (Note 3)	Junction-case	81°C/W

Note 1: T_J is a function of the ambient temperature T_A and power dissipation P_D ($T_J = T_A + (P_D) * (165°C/W)$).

Note 2: θ_{JA} is measured in the natural convection at T_A=25℃ on a highly effective thermal conductivity test board (2 layers , 2S0P) according to the JEDEC 51-7 thermal measurement standard.

Note 3: θ_{JC} represents the heat resistance between the chip and the package top case.

Electrical Characteristics

V_{IN} = 3.7V, C_{IN}=4.7uF, C_{OUT}=1uF, I_{OUT}=20mA, L=22uH, T_A = 25°C, unless otherwise specified.

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
Input Voltage		2.5		5.5	
Under Voltage Lock Out		1.8		2.4	V
UVLO Hysteresis			0.1		V
Supply Current	Continuously Switching			1	mA
Quiescent Current	No Switching		120		µA
Shutdown Current	VEN < 0.4V			1	uA
Operation Frequency		0.9	1.2	1.5	MHz
Maximum Duty Cycle		93	95		%
Feedback Voltage		232.7	245	257.3	mV
Thermal Shutdown Protection			150		℃
Thermal Shutdown Hysteresis			10		℃
Ron	Isw = 200mA		0.5	0.8	ohm
Current Limit			1.4		A
Shutdown Voltage Low		0.4			V
Enable Voltage High				1.2	V
EN Leakage Current			1.0		µA

Electrical Characteristics

V_{IN} = 3.7V, C_{IN}=4.7uF, C_{OUT}=1uF, I_{OUT}=20mA, L=22uH, T_A = 25°C, unless otherwise specified.

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
Maximum Output Voltage				30	V
OVP		31			V
OVP Hysteresis			1	3	V

Typical Performance Characteristics

V_{IN} = 3.7V, C_{IN}=4.7uF, C_{OUT}=1uF, I_{OUT}=20mA, L=22uH, T_A = 25°C, unless otherwise specified.

Efficiency vs. Input Voltage (Vout=30V)

I_{load}=30mA

I_{load}=20mA

I_{load}=10mA

Efficiency vs. Output Current (V_{out}=30V)

V_{IN}=3.7V

V_{IN}=5V

Efficiency vs. Output current (V_{out}=24V)

V_{IN}=3.7V

V_{IN}=5V

Efficiency vs. Output current (V_{out}=12V)

V_{IN}=3.7V

V_{IN}=5V

Frequency vs. Input Voltage

I_{LED}=20mA

Frequency vs. Temperature

V_{IN}=3.7V
I_{LED}=20mA

Typical Performance Characteristics

V_{IN} = 3.7V, C_{IN}=4.7uF, C_{OUT}=1uF, I_{OUT}=20mA, L=22uH, T_A = 25°C, unless otherwise specified.

Reference Voltage vs. Input Voltage

8WLED, I_{LED}=20mA

Reference Voltage vs. Temperature

V_{IN}=3.7V

Enable Threshold vs. Input Voltage

Enable

Disable

LED Current vs. Duty

200KHz 100KHz 20KHz

V_{IN}=3.7V
8WLED, I_{LED}=20mA

Power ON from EN

EN

VOUT

V_{IN}=3.7V
LED=6S6P

Power OFF from EN

EN

VOUT

V_{IN}=3.7V
LED=6S6P

Application Information

Detailed Description

The EMD2095 is a constant frequency current-mode boost converter, which can driver 8 series of WLED. The device provides the same output current through each WLED that get even illumination. The fast operation frequency allows for small inductor and input/output capacitors.

During normal operation, the internal oscillators send a pulse signal to set latch and turn on internal MOSFET each duty circle. A current sense voltage sums MOSFET current and slope signal connected to the negative terminal of the PWM comparator. When this signal voltage exceeds output voltage of error amplifier, the PWM comparator will send a signal to reset latch and turn off internal MOSFET. The output voltage of error amplifier is magnified from the difference between reference voltage and feedback voltage. If reference voltage is higher than feedback voltage, more current is delivered to the output, the other way, less current is delivered.

UVLO

The EMD2095 provides under voltage lock out protection. When VIN is down close to UVLO threshold, the UVLO block will send a signal to turn off power MOSFET. The device stops to supply current to output. The 100mV hysteresis prevents supply transients from causing a restart. Once the VIN exceed UVLO threshold, the device unlocks latch and turn power MOSFET.

Enable / Disable

The EMD2095 enter shutdown mode when EN pin voltage is less 0.4V. When in shutdown mode, all internal circuits of the EMD2095 are turn off and quiescent current is reduced to 1uA. When driver EN pin voltage is higher than 1.2V, start-up begins.

EN pin can be used for dimming control, the PWM frequency range is from 2KHz to 200kHz. The average LED current is proportional to the PWM duty cycle, while 0% duty cycle triggers zero WLEDs current and 100% duty cycle triggers full WLEDs current.

OVP

When WLEDs are open, the boost control loop just like open loop operation, it may causes over voltage damage on LX pin. In order to prevent this damage, the EMD2095 provides OVP function to provide it. The protection threshold is set at 31V.

OTP

The internal thermal sensor turn off power MOSFET when junction temperature is exceeded 150℃, the OTP is designed with a 10℃ hysteresis.

LED Current Setting

Referring to Figure 1 of the typical application, adjusting the output current changes the brightness of WLEDs, the EMD2095 regulates output current by sense resistor (R_{SET}). The output current is given by:

LED current = 0.245V / R_{SET}

LED Dimming Control

a) Using a PWM signal to EN pin

With the PWM signal applied to the EN pin, the EMD2095 is correspondingly controlled ON or OFF by PWM signal. The LEDs alternate between zero and full programmed current. The average LED current increases proportionally with the duty cycle of the PWM signal. A 0% duty cycle PWM signal will turn off the EMD2095 and corresponds to zero LED current. A 100% duty cycle PWM signal turns on the LEDs continuously at full current. The minimum dimming frequency limit is due to error amplifier offset which will cause the larger LED current variation and the maximum dimming frequency limit is due to the boost converter startup time. In low PWM duty dimming signal, the filtered reference voltage is low and the error amplifier offset can cause bigger variation of the output current, that's not recommended to dimming it by the EN pin. The typical frequency range of the PWM signal is 2kHz to 200kHz.

V_{FB} = Duty x 0.245V

Where

Duty = duty cycle of the PWM dimming signal

0.245V = internal reference voltage

b) Using a DC voltage to FB pin

Using a variable DC voltage to adjust the brightness is a popular method in some application. The dimming control using a DC voltage circuit is shown in figure 3. As the DC voltage increases, the current flows through R1 increasingly and the voltage drop on R1 increase, it causes LED current decrease. The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{FB} - \dfrac{R1 \times (V_{DC} - V_{FB})}{R2}}{R_{SET}}$$

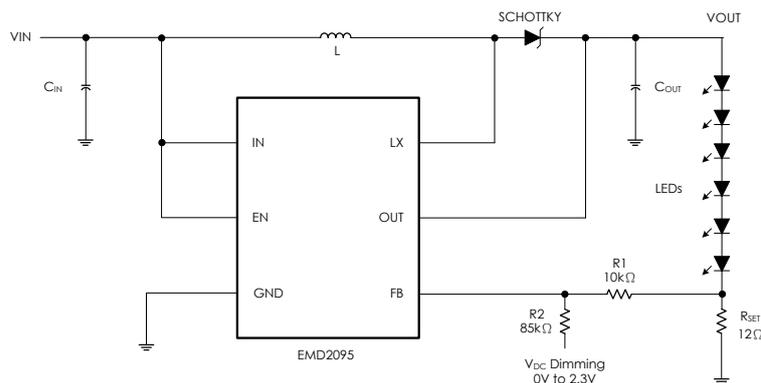Where

V_{FB} = 0.245 internal reference voltage

Fig. 3 Dimming control using a DC voltage

c) Using a filtered PWM signal to FB pin

Another common application is using a filtered PWM signal as an adjustable DC voltage for LED dimming control. A filtered PWM signal acts as the DC voltage to regulate the output current. The recommended application circuit is shown as figure 4. To fix the frequency of PWM signal and change the duty cycle of PWM signal can get different output current. This method can be used for higher frequency PWM dimming signals compared to method (a) using a PWM signal to EN pin. The lower limit of the PWM dimming frequency is controlled by the RC filter, PWM dimming frequency should be higher than the cutoff frequency of the RC filter (The recommended frequency of 2.8V PWM signal should be above 2kHz). The LED current can be calculated by the following equation.

$$I_{LED} = \frac{V_{FB} - \dfrac{R1 \times (V_{PWM} \times Duty - V_{FB})}{R2 + R3}}{R_{SET}}$$

Where

V_{FB} = 0.245 internal reference voltage

Duty = duty cycle of the PWM dimming signal from FB pin
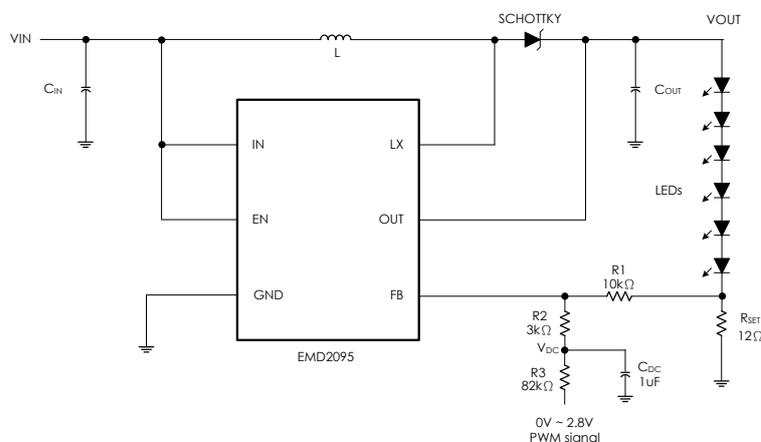
Fig. 4 Dimming control using a filtered PWM signal

Chart: ILED current vs. percentage (0% to 100%) with y-axis from 0.0 to 30.0. Parameters: VPWM=2.4V, PWM frequency: 2kHz, R1=10kohm, R2=3kohm, R3=82kohm, C_{DC}=1uF
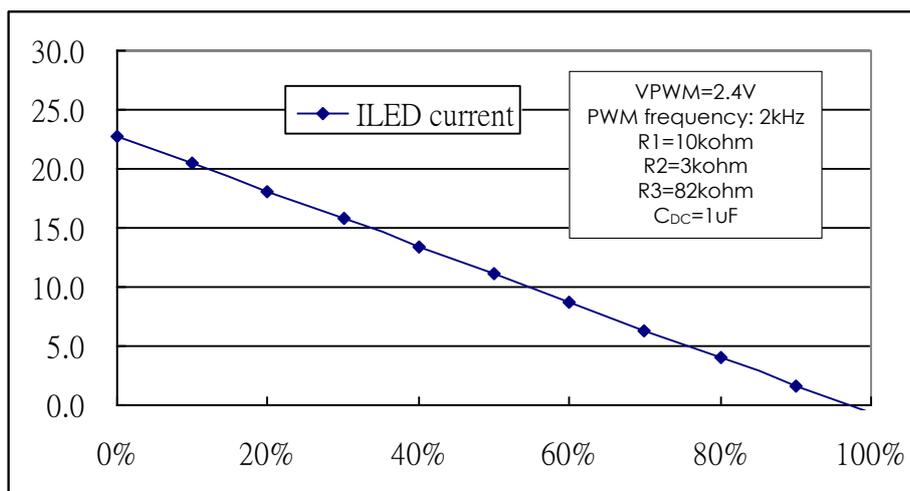
C_{in} and C_{out} Selection

It is recommended to use the X5R or X7R which have best temperature and voltage characteristics of all the ceramics for a give value and size. A minimum input capacitance of 1µF is required for the EMD2095, the capacitor value may be increased without limit, and higher capacitance can stable the switching voltage (LX) at low temperature. The typical output capacitor value is 1µF, higher capacitance can be used to reduce voltage ripple.

Inductor Selection

The inductor values range from 4.7µH to 22µH. The typical inductor value is 22µH. The low DCR inductor is preferred. In addition, the limit saturation current of inductor must exceed current limit of the EMD2095.

Diode Selection

Referring to Figure 1 of the typical application, the EMD2095 is high switching control devise which demands a high speed rectification diode for optimum efficiency. The schottky diode is preferred, for high efficiency, schottky diode provide fast recovery time and low forward voltage that reduce power loss. The recover breakdown voltage of schottky diode must exceed output voltage.

Application Circuit

- **Application circuit for 8S3P, I_{LED}=60mA**
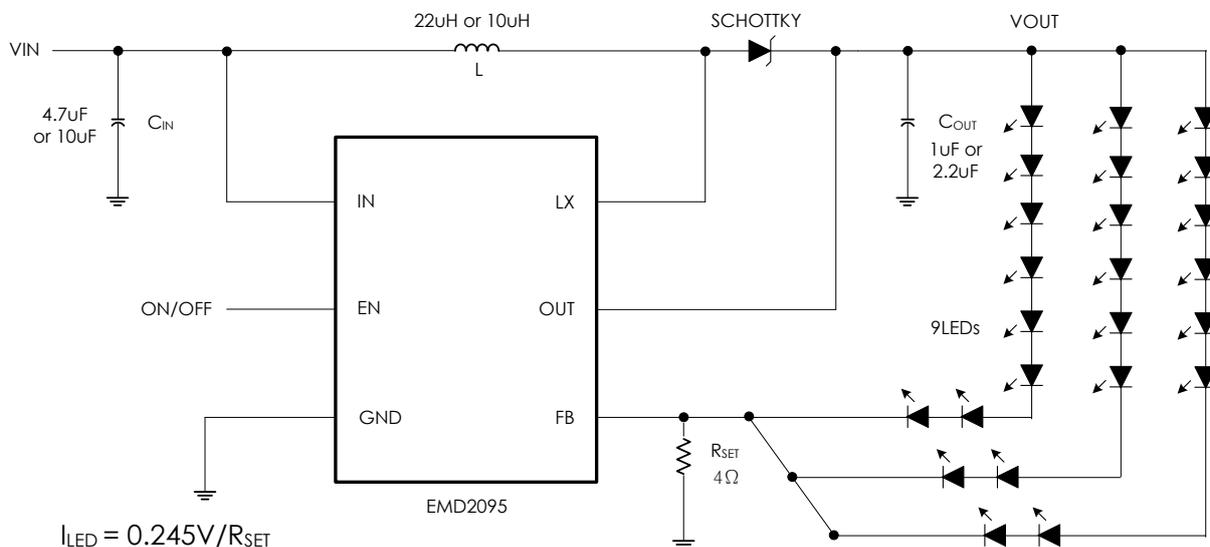
Fig. 5 8S3P application circuit
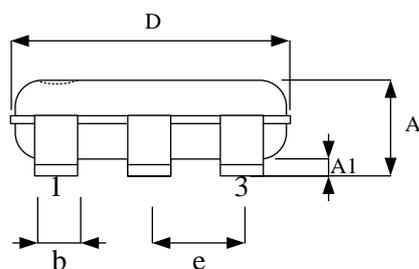
- **Application circuit for 8S1P, I_{LED}=20mA**
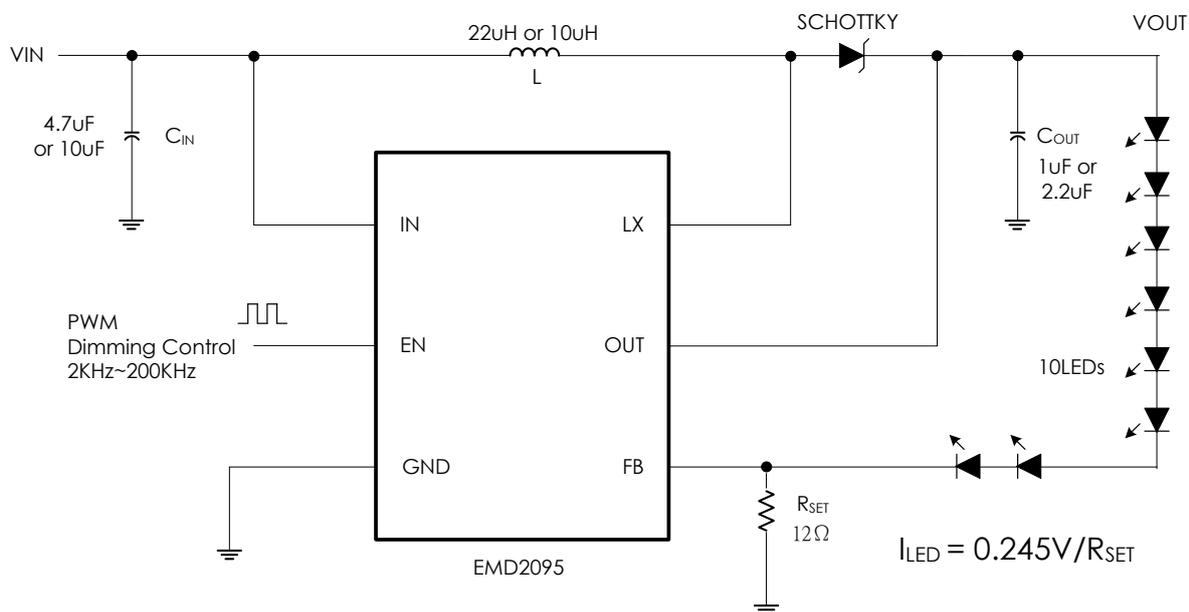
Fig. 6 8S1P application circuit with EN PWM dimming control

Package Outline Drawing
SOT-23-6
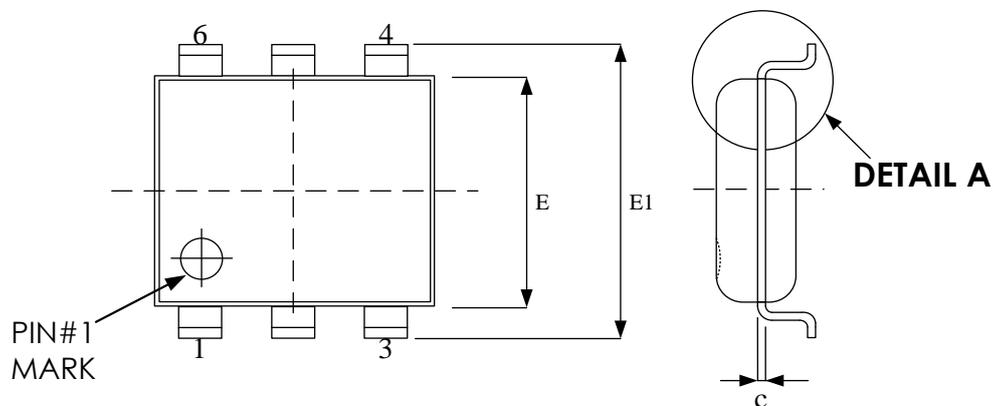
TOP VIEW

SIDE VIEW
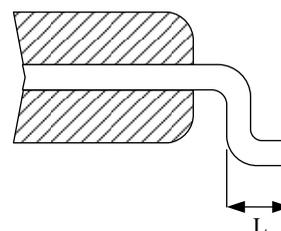
DETAIL A

Symbol	Dimension in mm	
	Min.	Max.
A	0.90	1.45
A1	0.00	0.15
b	0.30	0.50
c	0.08	0.25
D	2.70	3.10
E	1.40	1.80
E1	2.60	3.00
e	0.95 BSC	
L	0.30	0.60

Revision History

Revision	Date	Description
0.1	2013.10.09	Initial version.
0.2	2013.11.20	Revise VFB spec to 5% from 3%.
0.3	2014.04.07	Updated EN dimming control information into.
1.0	2015.04.01	Updated reversion to 1.0
1.1	2015.05.27	Updated LX ,OUT Voltage Maximum Ratings Updated 8 serial LEDs application