

## PWM Step-Up DC/DC Converter for Panel Backlight (10 WLEDs Driver)

### General Description

The EMD2055 is a highly efficient, step-up DC/DC converter for driving white LEDs. The device can drive up to 10 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 EMD2055 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 EMD2055 includes various protection circuits such as under-voltage lockout, current limit, over voltage and thermal shutdown. EMD2055 are available in the tiny packages of SOT-23-6L and TDFN-8L (2x2mm).

### Applications

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

### Features

- Up to 10 WLEDs supports
- Low Quiescent Current: 120  $\mu$ A
- Over Voltage Protection: 36.5V
- Inherently Matched LED Current
- Shutdown Current < 1 $\mu$ A
- 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 and TDFN-8L Packages

### Typical Application (10S3P)

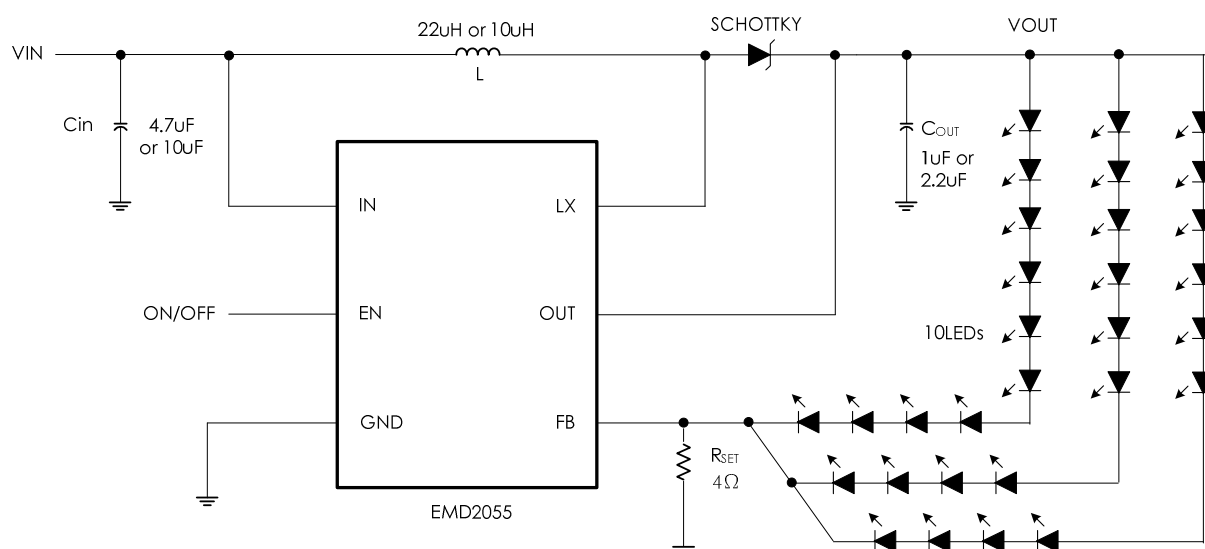
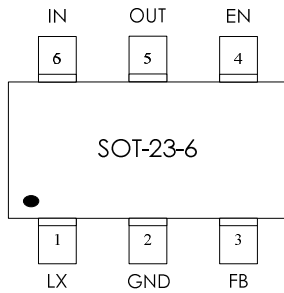


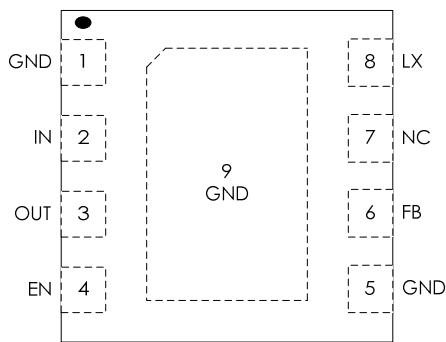
Fig. 1

### Connection Diagram



### Order Information

EMD2055-00VC06NRR  
 00 Output voltage  
 VC06 SOT-23-6L Package  
 NRR RoHS & Halogen free package  
 Rating: -40 to 85°C  
 Package in Tape & Reel



EMD2055-00FK08NRR  
 00 Output voltage  
 FK08 TDFN-8L 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	EMD2055-00VC06NRR	<p>2055 Tracking Code</p> <p>PIN1 DOT</p>	Tape & Reel 3Kpcs
TDFN-8L (2x2mm)	Adjustable	EMD2055-00FK08NRR	<p>2055 Tracking Code</p> <p>PIN1 DOT</p>	Tape & Reel 3Kpcs

## Function Block

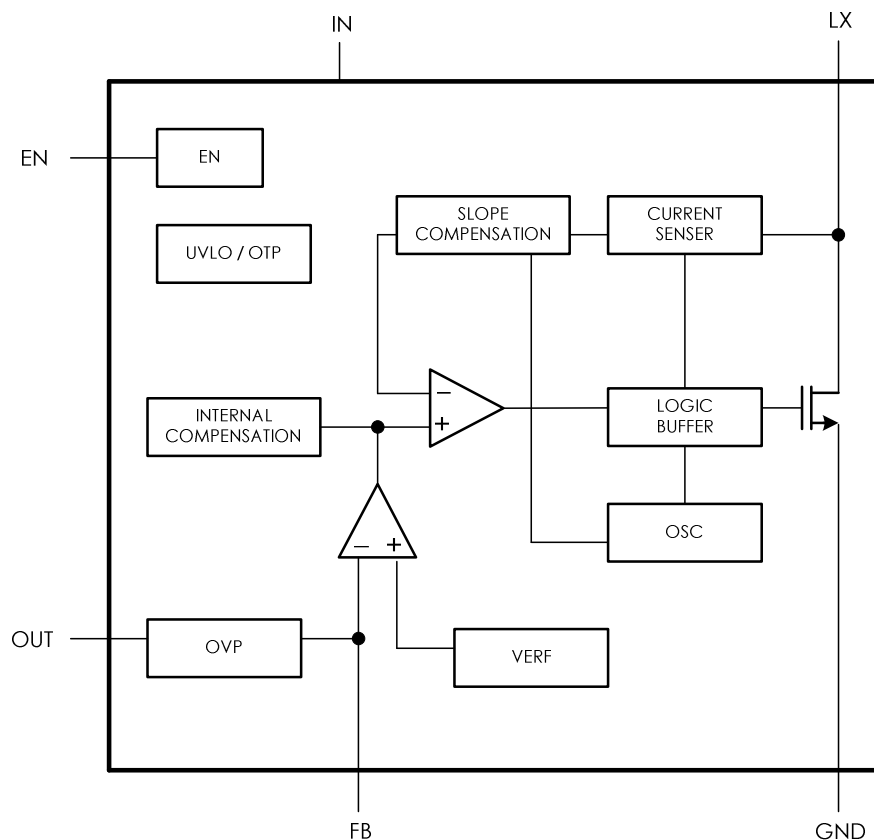


Fig. 2

## Pin Functions

Pin Name	SOT-23-6L Pin #	TDFN-8L Pin #	Function
LX	1	8	<b>Switch Pin.</b> Connect inductor/diode here.
GND	2	1, 5, 9	<b>Ground Pin.</b>
FB	3	6	<b>Feedback Pin.</b> Reference voltage is 0.245V, connect cathode of lowest LED and resistor here.
EN	4	4	<b>Chip Enable Pin and PWM Dimming Control Pin.</b> Connect to 1.2V or higher to enable device, 0.4V or less to disable device.
OUT	5	3	<b>Over Voltage Protection Pin.</b>
IN	6	2	<b>Input Voltage Pin.</b>
NC	N/A	7	<b>Not connected.</b>

## 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 MM 200V	Lead Temperature (Soldering, 10 sec)	260°C

## Thermal data

Package	Thermal resistance	Parameter	Value
SOT-23-5	$\theta_{JA}$ (Note 2)	Junction-ambient	250°C/W
	$\theta_{JC}$ (Note 3)	Junction-case	81°C/W
TDFN-8 (2x2 mm)	$\theta_{JA}$ (Note 2)	Junction-ambient	165°C/W
	$\theta_{JC}$ (Note 3)	Junction-case	24°C/W

**Note 1:**  $T_J$  is a function of the ambient temperature  $T_A$  and power dissipation  $P_D$  ( $T_J = T_A + (P_D) * (165^\circ\text{C/W})$ ).

**Note 2:**  $\theta_{JA}$  is measured in the natural convection at  $T_A=25^\circ\text{C}$  on a highly effective thermal conductivity test board (2 layers , 2S0P ) according to the JEDEC 51-7 thermal measurement standard.

**Note 3:**  $\theta_{JC}$  represents the heat resistance between the chip and the package top case.

## Electrical Characteristics

$V_{IN} = 3.7V$ ,  $C_{IN}=4.7\mu F$ ,  $C_{OUT}=1\mu F$ ,  $I_{OUT}=20mA$ ,  $L=22\mu H$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified.

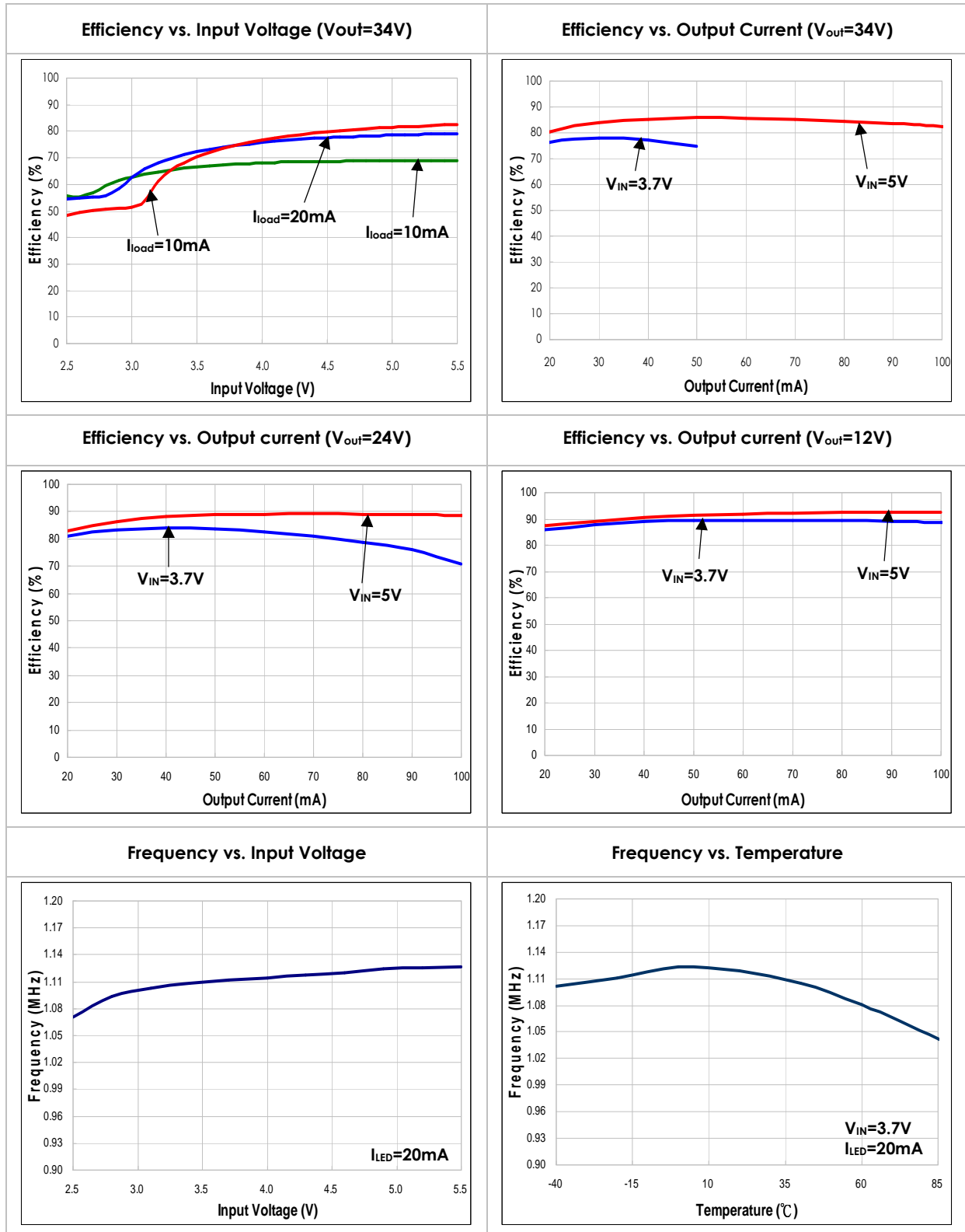
PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
Input Voltage		2.5		5.5	
Under Voltage Lock Out		1.8		2.4	V
UVLO Hysteresis			0.1		V
Supply Current	Continuously Switching			1	mA
Quiescent Current	No Switching		120		$\mu A$
Shutdown Current	$V_{EN} < 0.4V$			1	$\mu A$
Operation Frequency		0.9	1.2	1.5	MHz
Maximum Duty Cycle		93	95		%
Feedback Voltage		237.7	245	252.3	mV
Thermal Shutdown Protection			150		$^\circ\text{C}$
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$
$R_{on}$	$I_{sw} = 200mA$		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		$\mu A$
EN Minimum ON-time		80			$\mu S$

**Electrical Characteristics** **$V_{IN} = 3.7V$ ,  $C_{IN} = 4.7\mu F$ ,  $C_{OUT} = 1\mu F$ ,  $I_{OUT} = 20mA$ ,  $L = 22\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise specified.**

PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
Maximum Output Voltage			36		V
OVP		34	36.5	39	V
OVP Hysteresis			1	3	V

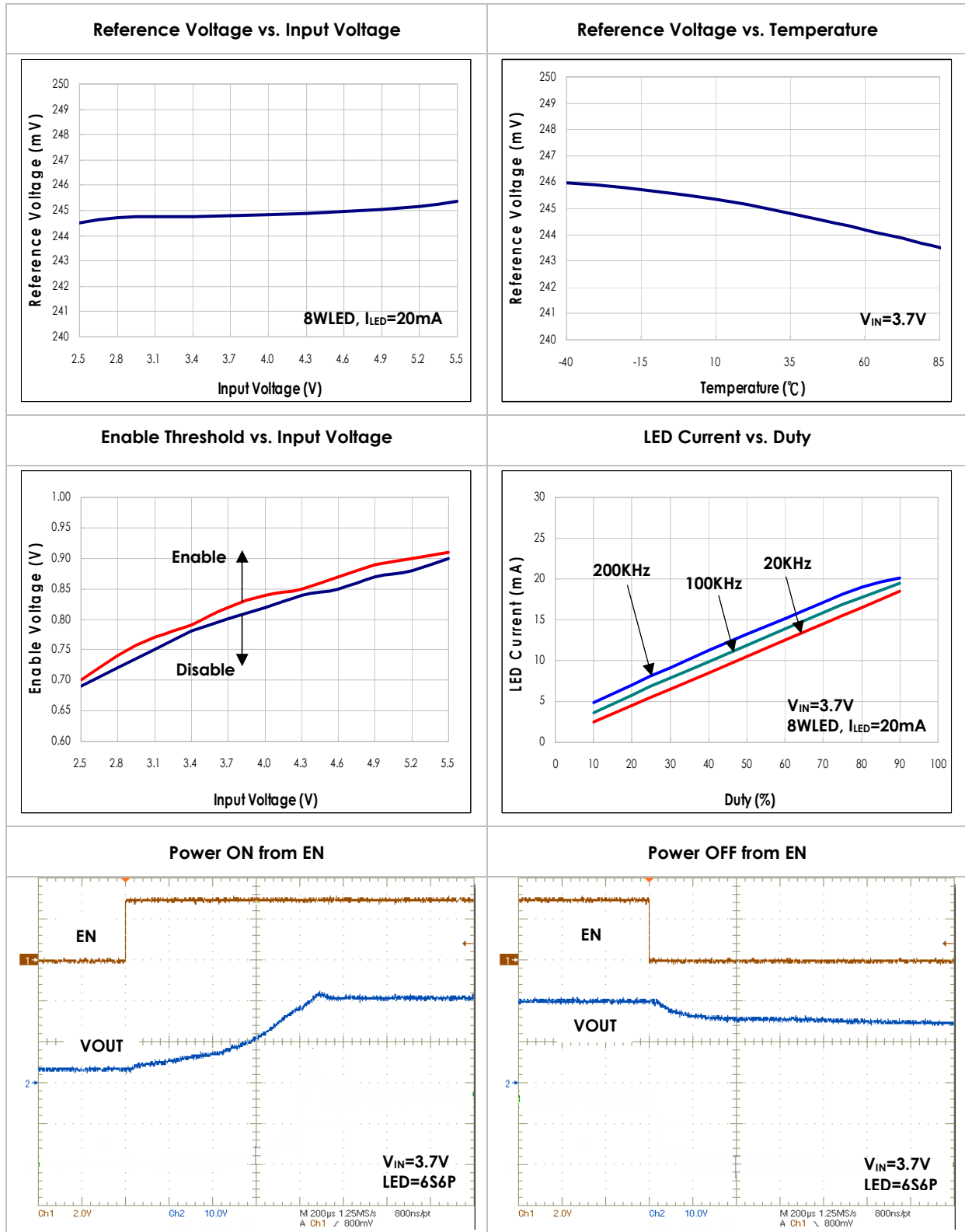
## Typical Performance Characteristics

$V_{IN} = 3.7V$ ,  $C_{IN} = 4.7\mu F$ ,  $C_{OUT} = 1\mu F$ ,  $I_{OUT} = 20mA$ ,  $L = 22\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise specified.



## Typical Performance Characteristics

$V_{IN} = 3.7V$ ,  $C_{IN} = 4.7\mu F$ ,  $C_{OUT} = 1\mu F$ ,  $I_{OUT} = 20mA$ ,  $L = 22\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise specified.



## Application Information

### Detailed Description

The EMD2055 is a constant frequency, current-mode boost DC-DC converter which can drive up to WLEDs 10S1P ~ 9S3P, depending on the input voltage range. The device can provide the well matched output current through each WLED serial chain to obtain uniform illumination. The fast operation frequency allows smaller inductor and input/output capacitors to be used.

During normal operation, the internal oscillator sends 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 the error amplifier, the PWM comparator sends a signal to reset the latch and turn off internal MOSFET. The output voltage of the error amplifier is magnified from the difference between reference voltage and feedback voltage. If the reference voltage is higher than feedback voltage, more current is delivered to the output; otherwise, less current is delivered.

### UVLO

The EMD2055 provides Under-Voltage-Lock-Out (UVLO) protection. When VIN is lowered below UVLO threshold, the UVLO circuit will send a signal to turn off the internal power MOSFET, which will stop supplying output current. The 100mV hysteresis circuit in the UVLO circuit can prevent supply transients from causing a false restart. Once the VIN exceeds UVLO threshold again, the device will unlock the latch and turn on the internal power MOSFET to continue the normal operation.

### Enable / Disable

The EMD2055 enters shutdown mode when EN pin voltage is less than 0.4V. During shutdown mode, all internal circuits of the EMD2055 are turned off and the quiescent current is reduced to less than 1uA. When the EN pin voltage is higher than 1.2V, the device will start operation.

The EN pin can also be used for dimming control by using a PWM modulated signal. The frequency of this PWM signal can range from 2kHz to 200kHz. The average LED driving current is directly proportional to the duty cycle of the PWM duty cycle, i.e., 0% duty cycle corresponding to zero WLEDs current and 100% duty cycle corresponding to full WLEDs current.

### OVP

When any of the serially connected WLEDs chain is open, the boost control loop behaves as an open loop operation, which may cause damage on the LX pin due to excessive voltage. In order to prevent this damage from happening, the EMD2055 provides an Over-Voltage-Protection (OVP) circuit, with the protection threshold set at 41V. When LX pin exceeds 41V, the internal operation will be shut off.



## OTP

The internal thermal sensor will turn off the internal power MOSFET when the junction temperature exceeds 165°C. This Over-Temperature-Protection (OVT) circuit has a built-in 20°C hysteresis.

## LED Current Setting

Referring to a typical application shown in Figure 1 the brightness of the WLED is controlled by adjusting the operating current. The EMD2055 regulates its operating current by adjusting the sense resistor ( $R_{SET}$ ), which 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 EMD2055 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 EMD2055 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.

$$V_{FB} = Duty \times 0.245V$$

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.

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

Where

VFB = 0.245 internal reference voltage

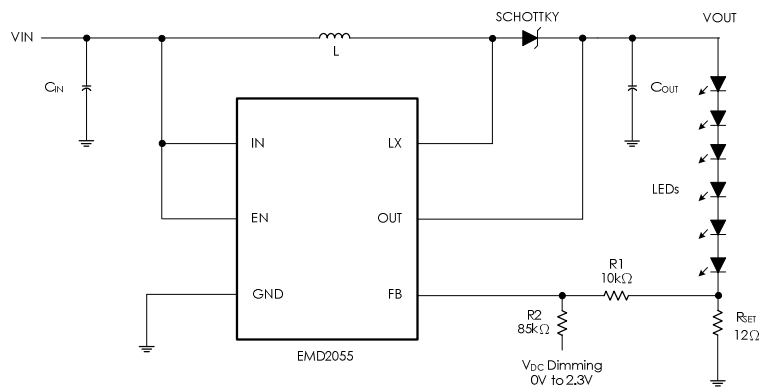


Fig. 3 Dimming control using a DC voltage

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.

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

Where

VFB = 0.245 internal reference voltage

Duty = duty cycle of the PWM dimming signal from FB pin

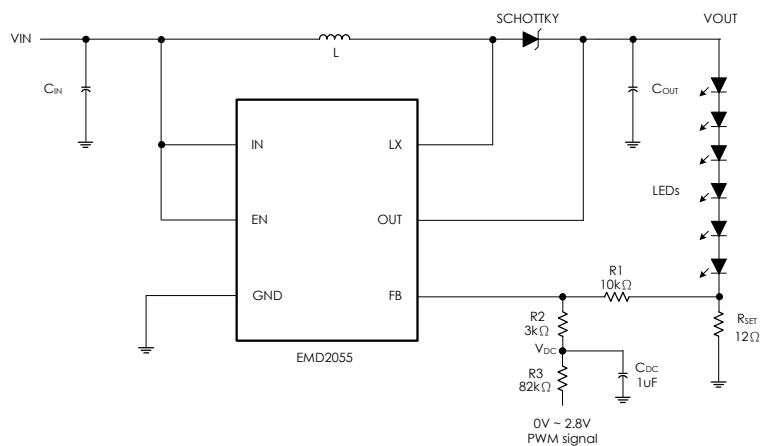
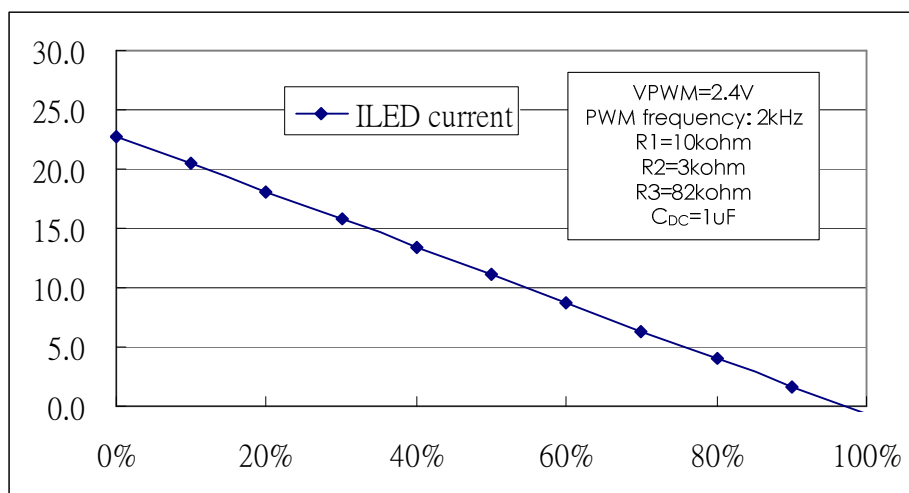


Fig. 4 Dimming control using a filtered PWM signal



## Cin and Cout 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 4.7 $\mu$ F is required for the EMD2055, the capacitor value may be increased without limit. The typical output capacitor value is 1 $\mu$ F, higher capacitance can be used to reduce voltage ripple.

## Inductor Selection

The inductor values range from 4.7 $\mu$ H to 22 $\mu$ H. The typical inductor value is 10 $\mu$ H. The low DCR inductor is preferred. In addition, the limit saturation current of inductor must exceed current limit of the EMD2055.

## Diode Selection

Referring to Figure 1 of the typical application, the EMD2055 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 10S1P

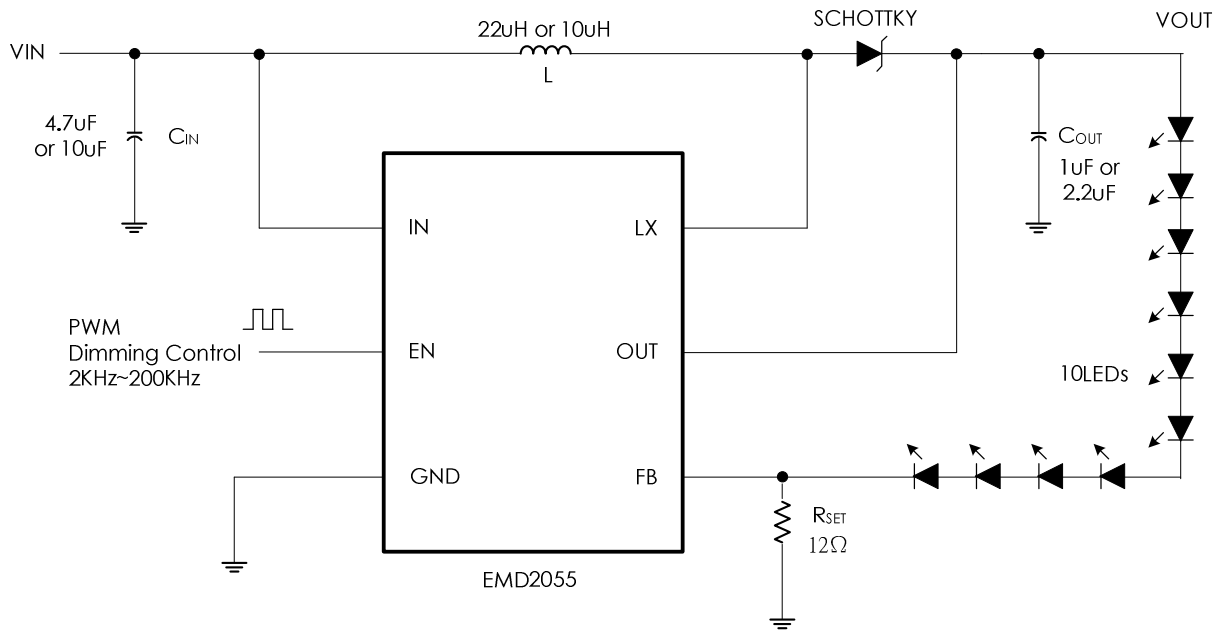


Fig. 5

- Application circuit for 9S3P

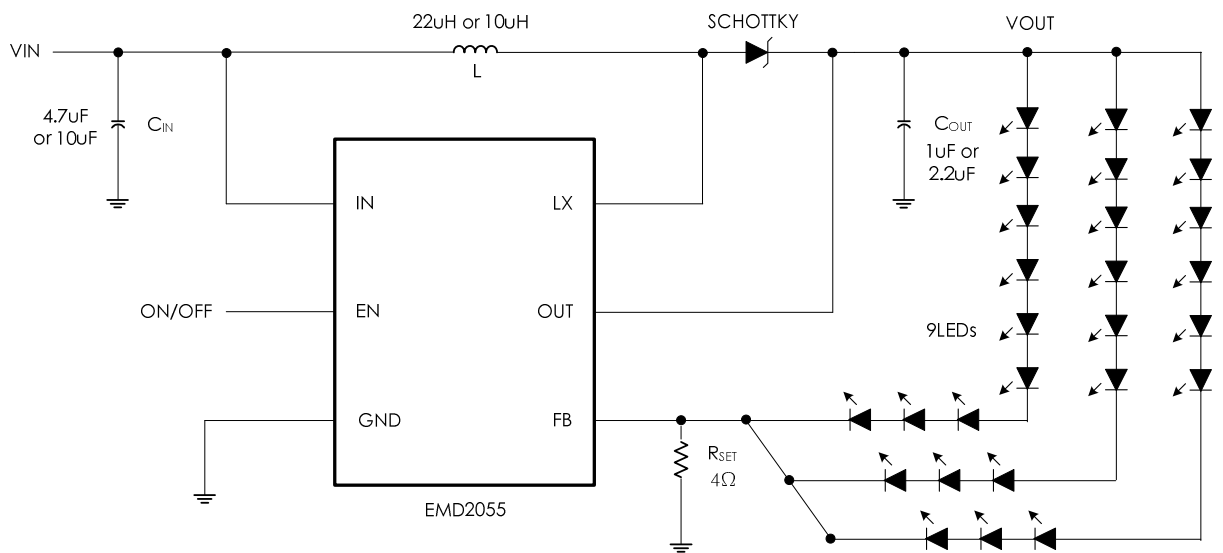
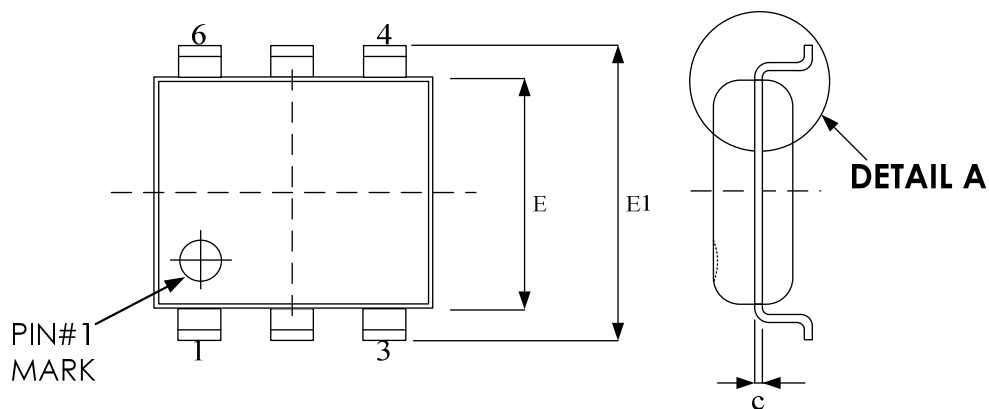
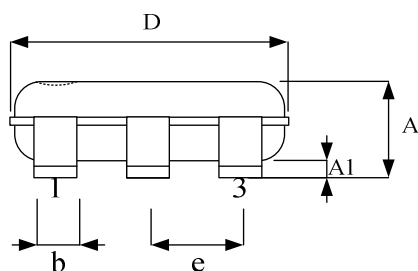


Fig. 6

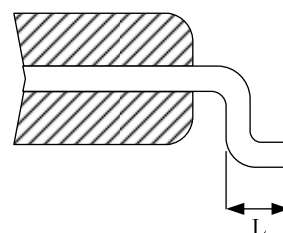
## Package Outline Drawing SOT-23-6



### TOP VIEW



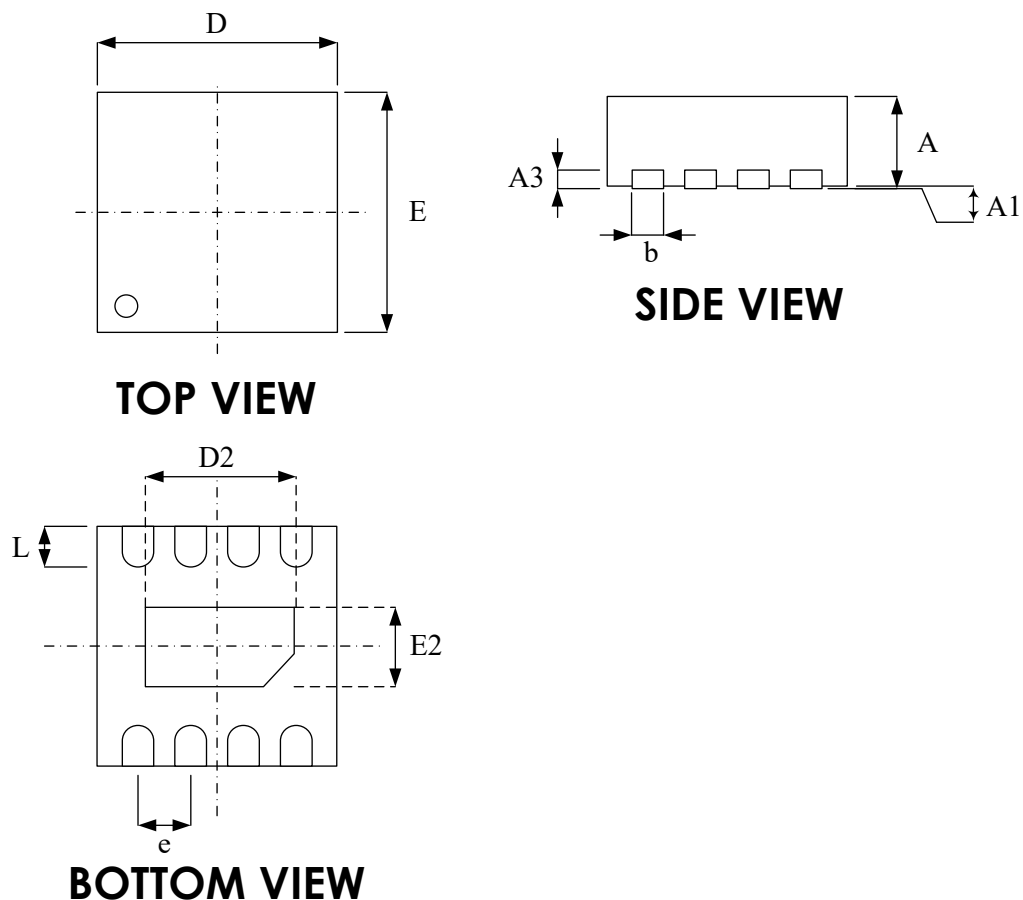
### SIDE VIEW



### 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

## Package Outline Drawing TDFN-8L (2x2 mm)



Symbol	Dimension in mm	
	Min	Max
A	0.70	0.80
A1	0.00	0.05
A3	0.18	0.25
b	0.18	0.30
D	1.90	2.10
E	1.90	2.10
e	0.50 BSC	
L	0.20	0.45

### Exposed pad

	Dimension in mm	
	Min	Max
D2	1.15	1.65
E2	0.65	0.95

## Revision History

<b>Revision</b>	<b>Date</b>	<b>Description</b>
0.1	2013.10.09	Initial version.
0.2	2014.04.07	Updated dimming control information into.
1.0	2015.03.10	Modify version to 1.0
1.1	2015.05.18	1) Updated LX ,OUT Voltage Maximum Ratings. 2) Updated Features ; 10 WLEDs supports.
1.2	2017.01.09	Modified TDFN-8L Exposed Pad information.
1.3	2018.01.26	Modified Electrical Characteristics.
1.4	2019.06.12	Update TDFN 8LDS 2x2x0.75 mm outline
1.5	2019.08.05	Modified Electrical Characteristics.

Important Notice

All rights reserved.

No part of this document may be reproduced or duplicated in any form or by any means without the prior permission of ESMT.

The contents contained in this document are believed to be accurate at the time of publication. ESMT assumes no responsibility for any error in this document, and reserves the right to change the products or specification in this document without notice.

The information contained herein is presented only as a guide or examples for the application of our products. No responsibility is assumed by ESMT for any infringement of patents, copyrights, or other intellectual property rights of third parties which may result from its use. No license, either express, implied or otherwise, is granted under any patents, copyrights or other intellectual property rights of ESMT or others.

Any semiconductor devices may have inherently a certain rate of failure. To minimize risks associated with customer's application, adequate design and operating safeguards against injury, damage, or loss from such failure, should be provided by the customer when making application designs.

ESMT's products are not authorized for use in critical applications such as, but not limited to, life support devices or system, where failure or abnormal operation may directly affect human lives or cause physical injury or property damage. If products described here are to be used for such kinds of application, purchaser must do its own quality assurance testing appropriate to such applications.