4 Strings High Current White LED Driver with Boost Controller

DESCRIPTION

The EUP2588 is a high power and high efficiency boost controller with 4-channel current sinker which is ideal for large LCD backlighting applications.

EUP2588 uses current mode, fixed frequency architecture which can clamp the inductor peak current each cycle. The switching frequency is programmable by an external frequency setting resistor. It drives an external MOSFET to boost up the output voltage from a 4.5V to 28V input supply. The EUP2588 regulates the current in each LED string to the programmed value set by an external current setting resistor. The EUP2588 current matching can achieve ±1.5% and regulation accuracy can reach ±2%.

A 3μA shutdown current and 0.85V (ILED@180mA) feedback voltage and Maximum 65V output allows for up to 18 high-power LEDs in series will greatly improve efficiency and reduce power dissipation.

The device supports pulse width modulation (PWM) brightness dimming. During digital PWM dimming, the WLED current is turned on/off at the duty cycle and frequency determined by the PWM signal on the PWMI pin.

The EUP2588 integrated multiple protect functions, such as LED Open, LED Short, Output Over Voltage, Over thermal, Input Over Current, and Under Voltage Lockout (UVLO), these protection will prevent the LCD backlight from damage.

EUP2588 is available in 16pin SOP packages.

FEATURES

- 3μA shutdown current
- 4 strings in parallel and up to 18 LEDs per string
- External PWM Dimming Control
- Output voltage up to 65V
- Up to 180mA Drive Capability for Each String
- Wide Input voltage range 4.5V to 28V
- Better than 1.5% LED Current Regulation Accuracy Between Strings
- Boost Switching frequency can be programmed by external resistor
- Multiple Fault Protections
  -Current Limit protection
  -Output Short circuit detection
  -Over-temperature protection
  -Output Over-voltage protection
- LED current turn off in shutdown mode
- Integrated UVLO/ Over Thermal protection
- Minimal 0.5μs LED On-Time regulation
- Thermal Enhanced 16pin SOP-16 Package
- RoHS Compliant and 100% Lead (Pb)-Free Halogen-Free

APPLICATIONS

- LCD Monitor LED Backlighting
- LCD-TV LED Backlighting

Typical Application Circuit

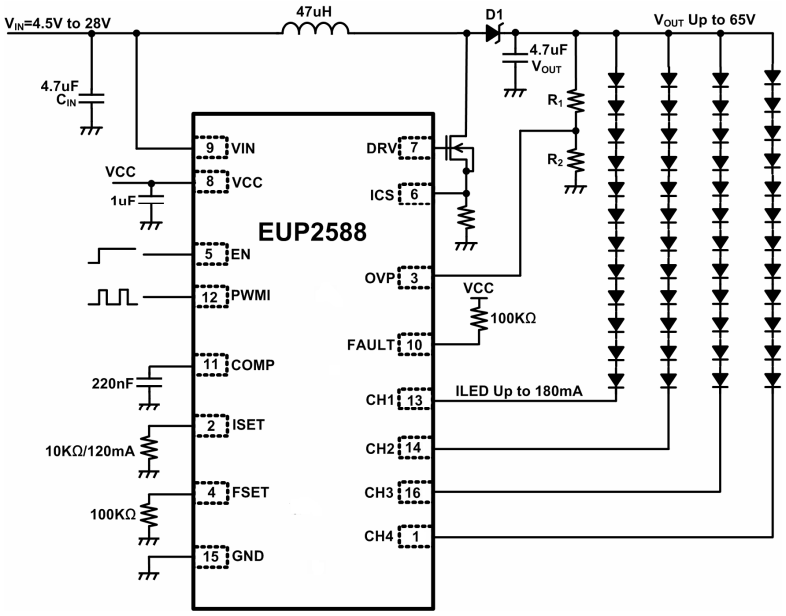
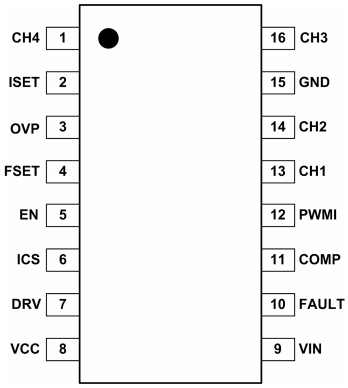


Figure 1. Typical Application Circuits

Pin Configurations

Package Type	Pin Configurations
SOP-16	

Pin Description

PIN	SOP-16	DESCRIPTION
1	CH4	Channel 4 LED current source. Leave it floating if not used.
2	ISET	Full-Scale LED Current Adjustment Pin. The resistance from ISET to GND controls the full-scale current in each LED string. ISET voltage is around 1.0V, during full lighting, ICHx=1200/RISET Ohm. Set RISET=10KOhm, ICHx is set to 120mA.
3	OVP	Output over-voltage feedback input. Connect OVP to the tap point of the resistor divider between output and ground.
4	FSET	Boost Switching Frequency Program pin. Program the boost frequency by different external Resistance, and the boost converter frequency set by formula: FSW=50000/R_{FSET}(KΩ). If setting FSET=100K, boost frequency is 500KHz.
5	EN	The device enable pin. A logic high signal turns on the internal LDO and enables the IC. Connect EN to VCC and make EUP2588 always ON.
6	ICS	Current Sense Input. During normal operation, this pin senses the voltage across the external inductor current sensing resistor for peak current mode control and also to limit the inductor current during every switching cycle.
7	DRV	External N-CH Power Device Gate Driver Output. This pin provides the boost converter power device gate drive signal.
8	VCC	5V Linear Regulator Output to power internal circuitry. Bypass VCC to GND with a ceramic capacitor of 1μF or greater. If 4.5V<VIN < 5.5V, connect VCC directly to supply voltage of VIN.
9	VIN	Supply Voltage Input.
10	FAULT	EUP2588 Faults status output, it is an open drain output. If all the Channels open or Over Thermal/Over Current events happen, this pin will be pulled to low by internal open drain NMOS, otherwise, this pin will keep high by external resistor.
11	COMP	Boost Converter Compensation Pin. Connect a 220nF ceramic capacitor from COMP to GND. When the EUP2588 shuts down, COMP is discharged to GND.
12	PWMI	Brightness Control Input. To use external PWM dimming mode, apply a PWM signal on this pin for brightness control. The EUP2588 has positive dimming polarity on PWMI.
13	CH1	Channel 1 LED current source. Leave it floating if not used.
14	CH2	Channel 2 LED current source. Leave it floating if not used.
15	GND	Ground
16	CH3	Channel 4 LED current source. Leave it floating if not used.

Ordering Information

Order Number	Package Type	Marking	Operating Temperature Range
EUP2588DIR1	SOP-16	xxxxx P2588	-40 °C to +85°C

EUP2588 □ □ □ □

Lead Free Code
1: Lead Free, Halogen Free 0: Lead

Packing
R: Tape & Reel

Operating temperature range
I: Industry Standard

Package Type
D: SOP

Block Diagram

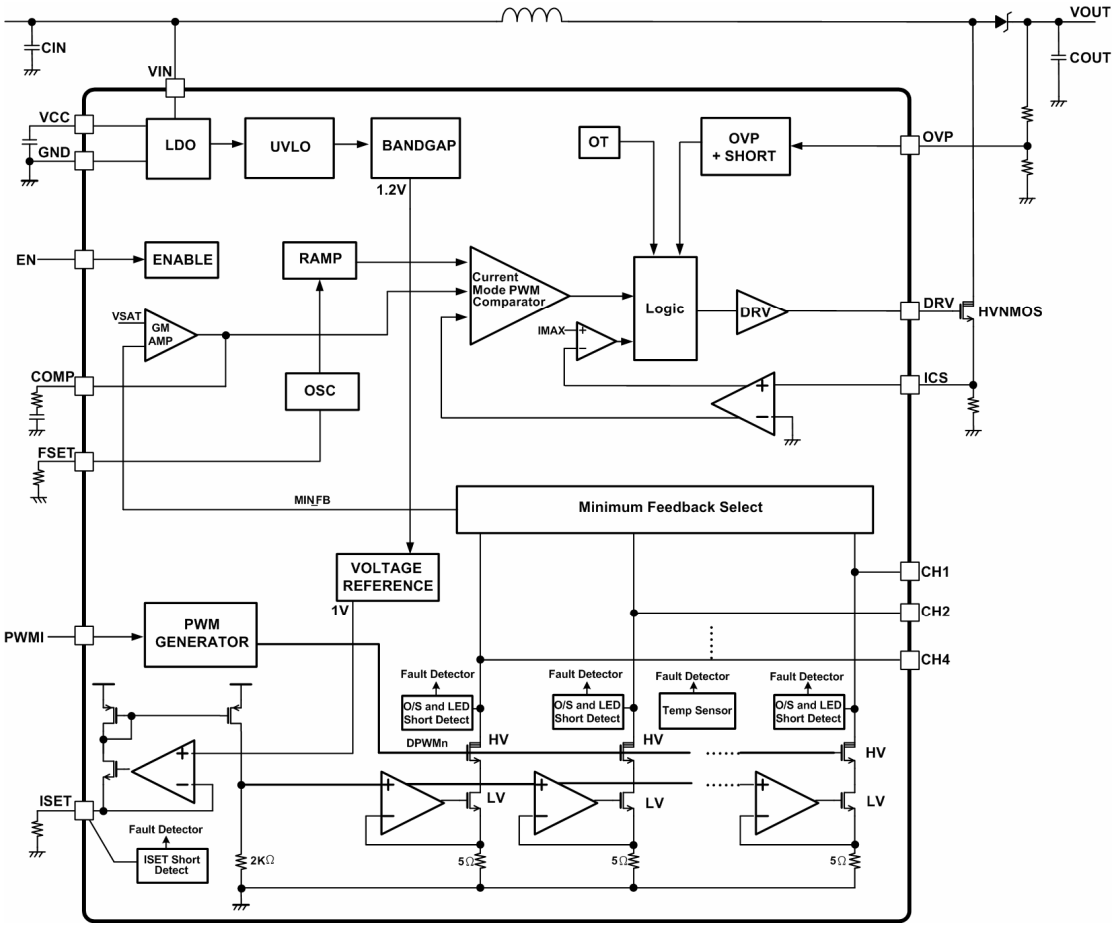


Figure 2. Block Diagram

Absolute Maximum Ratings (1)

- ICS, CH (n) to GND ---------- -0.3V to 65V
- VIN to GND ---------- -0.3V to 30V
- OVP, EN, PWMI, FAULT, VCC to GND ---------- -0.3V to +6V
- COMP, DRV, ISET, FSET to GND---------- -0.3V to (VCC+0.3)V
- Continuous Power Dissipation (T_A = +70°C)
  16-Pin SOP [derate 12.5mW/°C (JEDEC high-k 2s2p) above +70°C] ---------- 1000mW
- Operating Temperature Range ---------- -40°C to +85°C
- Maximum Junction Temperature ---------- +150°C
- Storage Temperature Range ---------- -60°C to +150°C
- Lead Temperature (soldering, 10s) ---------- +300°C

Operating Conditions (2)

- Operating Temperature Range ---------- -40°C to +85°C
- Supply Voltage , VIN---------- 4.5V to 28V
- Maximum LED Current, ICHn ---------- 60mA to 180mA
- Maximum LED Pulse Current=1mS ----------200mA

Note (1): Stress beyond those listed under "Absolute Maximum Ratings" may damage the device.
Note (2): The device is not guaranteed to function outside the recommended operating conditions.

Electrical Characteristics

(Circuit of Figure 1, VIN=12V, GND=0V, R_{ISET}=10kΩ, R_{FSET}=100kΩ,V_{PWMI}= 5V, **T_A= 40°C to +85°C**, unless otherwise noted. Typical values are at T_A= +25°C.)

Symbol	Parameter	Conditions	EUP2588			Unit
			Min.	Typ.	Max.	
VIN	VIN Supply voltage		4.5		28	V
I_VIN	VIN Supply Current	PWMI=5V		1	2	mA
I_OFF	VIN Shutdown Current	PWMI=EN=0,VIN=12V			6	μA
I_STANDBY	VIN Standby Current	EN=5V, PWMI=0V, VIN=12V		750	1200	μA
VCC	VCC Output Voltage	VEN=5V, 6V<VIN<28V, 0<I_{VCC}<10mA	4.85	5	5.5	V
I_VCC	VCC Current Limit			50		mA
UVLO	UVLO Rising Threshold		3.7	4.1	4.4	V
UVLO_HYS	UVLO Hysteresis			0.15		V
VIH	EN High Level	VEN Rising	2.4			V
VIL	EN Low Level	VEN Falling			0.7	V
Boost Converter						
	DRV Sourcing Impendance	VIN=VCC=5V, IDRV=5mA		15		Ω
	DRV Sinking Impendance	VIN=VCC=5V, IDRV=5mA		4		Ω
FSW	Switching Frequency	R_{FSET}=100KΩ	475	500	525	KHz
TON_MIN	Minimum On Time			100		nS
ICS	Boost Current Limit	Boost ON Time>100nS (DRV=Hi Time>100nS)	450	500	550	mV
GM	COMP Transconductance	ΔICOMP=±10μA		60		μs
DMAX	Maximum Duty Cycle		90	93	96	%
LED Current Regulation						
RCH	CHn Sink Resistance	ILEDn=120mA		5		Ω
VISET	ISET Regulation Voltage			1		V

Electrical Characteristics (continued)

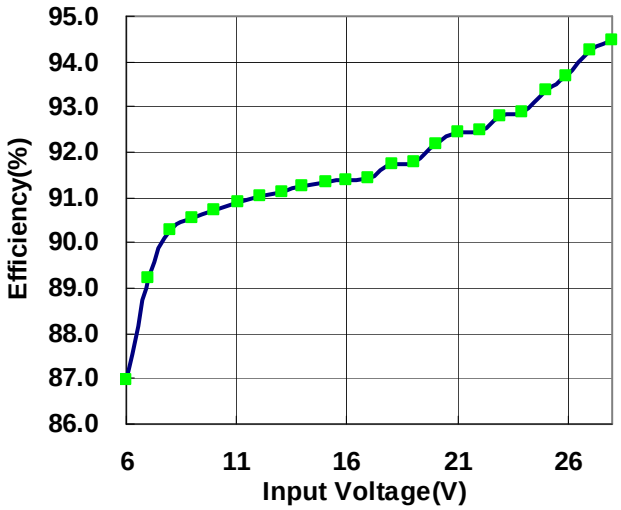
(Circuit of Figure 1, VIN=12V, GND=0V, R_{ISET}=10kΩ, R_{FSET}=100kΩ,V_{PWMI}= 5V, **T_A= 40°C to +85°C**, unless otherwise noted. Typical values are at T_A= +25°C.)

Symbol	Parameter	Conditions	EUP2588			Unit
			Min.	Typ.	Max.	
LED Current Regulation						
ILED	Output LED Current	RISET=10KΩ	115.2	120	124.8	mA
Imatch	CHn Current matching	ILED=120mA	-1.5		1.5	%
Dimming Controls						
TPWMImin	Minimum PWM Pulse	In External PWM Dimming Mode		0.5		μs
VPWMH	PWMI Input High Level		2.4		VCC	V
VPWML	PWMI Input Low Level		0		0.7	V
IPWMI	PWMI Pull Down Current	V_{PWMI}=5V	-1		+1	μA
Fault Detections						
Vovp	Over-voltage Threshold on OVP	Rising Edge	1.9	2.0	2.1	V
Vhys-ovp	OVP Hysteresis	Falling Edge		70		mV
VCHx_OV	CHx Over Voltage Threshold	V_{IN}>5.5V	6.5	7	7.5	V
R_{FAULT}	FAULT Sink Resistance			10		Ω
Tsd	Thermal Shutdown Threshold			150		ºC
Tsd_hys	Thermal Shutdown Hysteresis			30		ºC

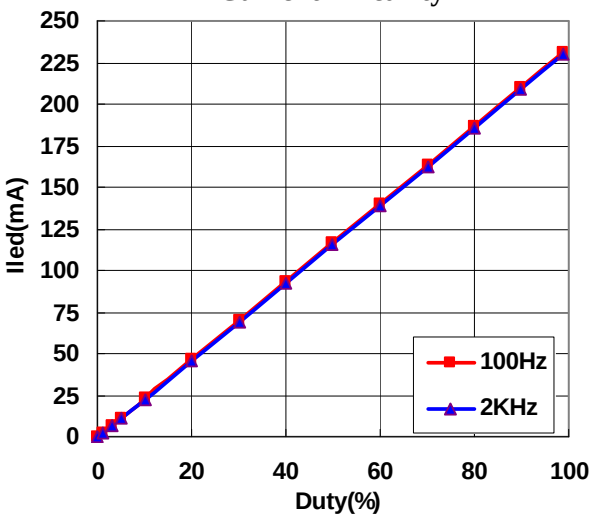
Typical Operating Characteristics

(V_{IN}=12V, I_{SET}=20K, FSET=330K, Status=100K, L=47µH, C_{COMP}=22nF, C_{OUT}=47µF)

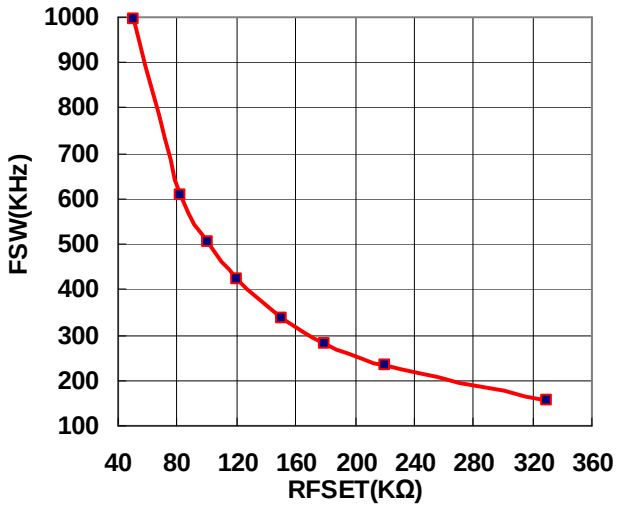
Efficiency vs. Input Voltage



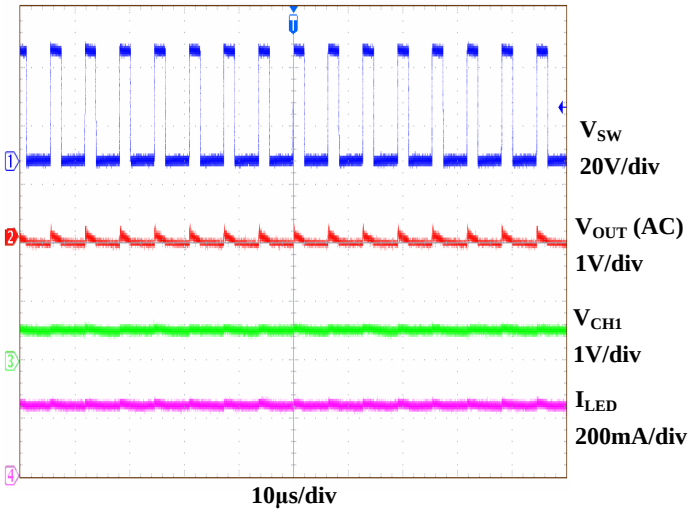
Current Linearity



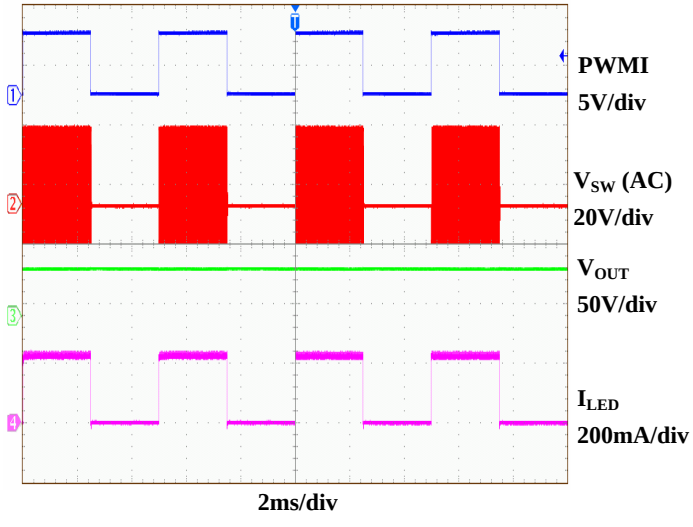
FSW vs. RFSET



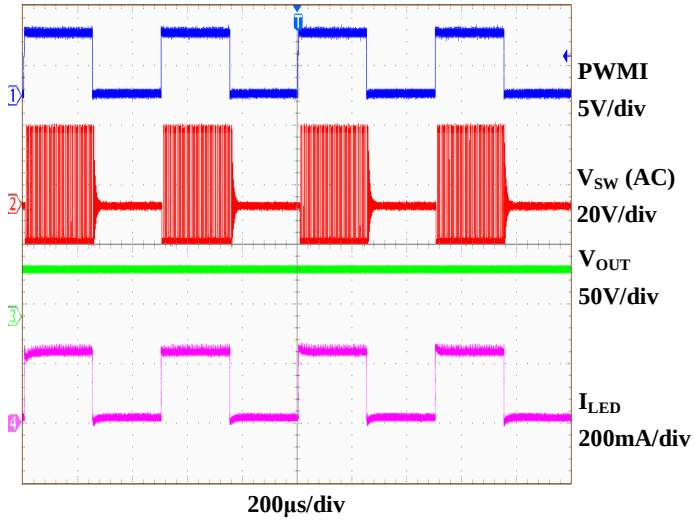
Steady State



200Hz PWMI Dimming (Duty Cycle=50%)



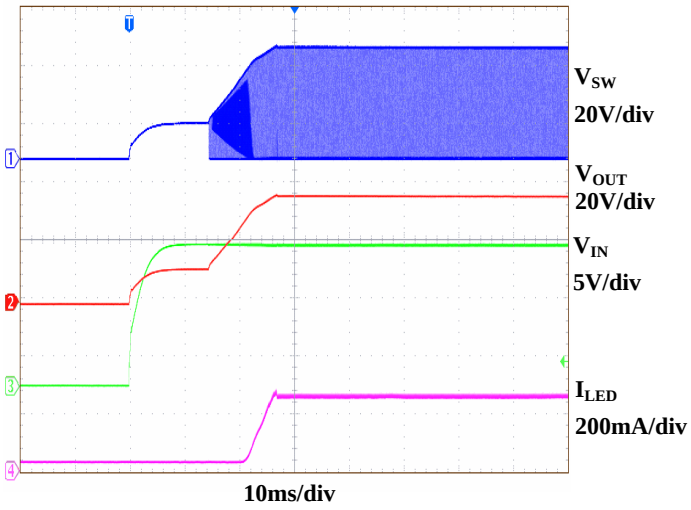
2KHz PWMI Dimming (Duty Cycle=50%)



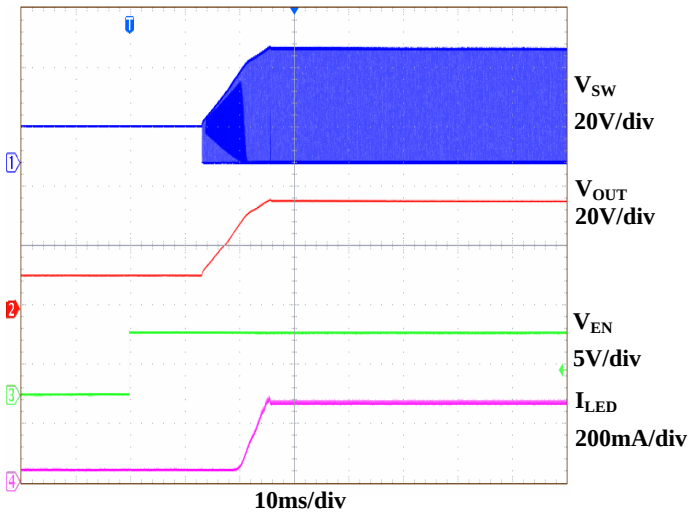
Typical Operating Characteristics (continued)

(V_{IN}=12V, I_{SET}=20K, FSET=330K, Status=100K, L=47µH, C_{COMP}=22nF, C_{OUT}=47µF)

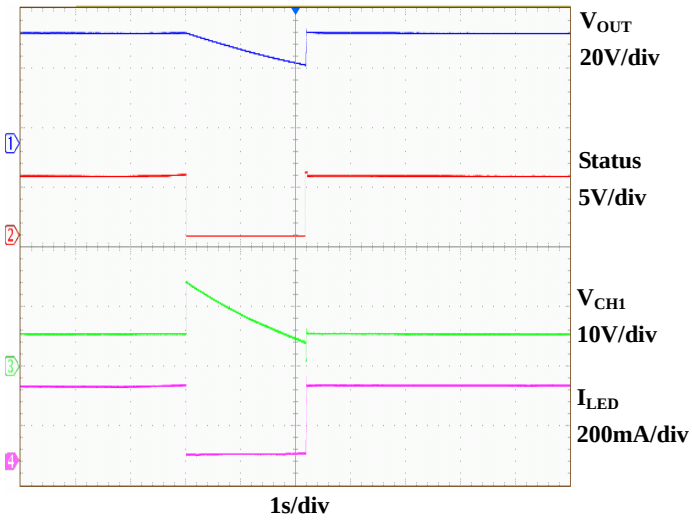
V_{IN} Startup



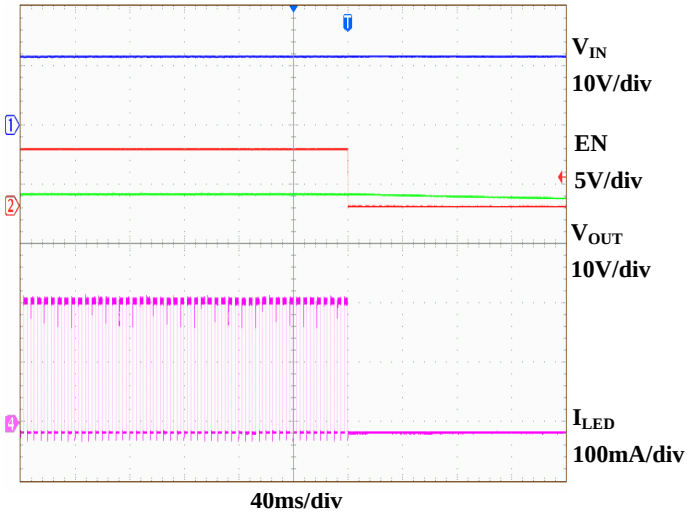
EN Startup



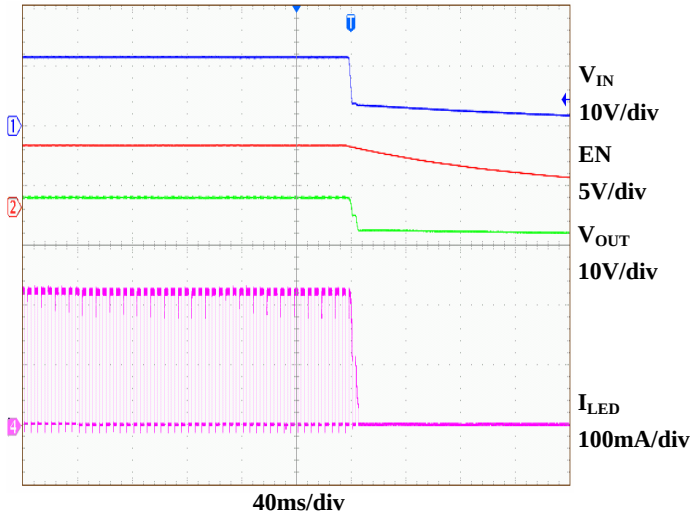
Protection of Over Thermal



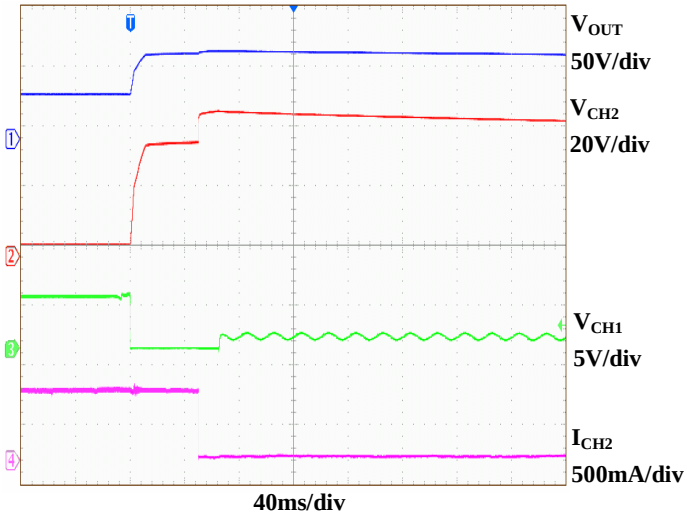
EN from On to Off



VIN from On to Off



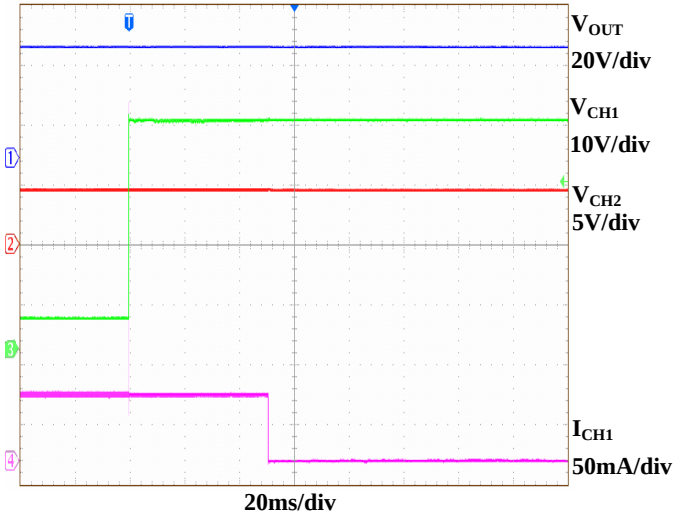
Protection of Channel Open (Channel 1 Open)



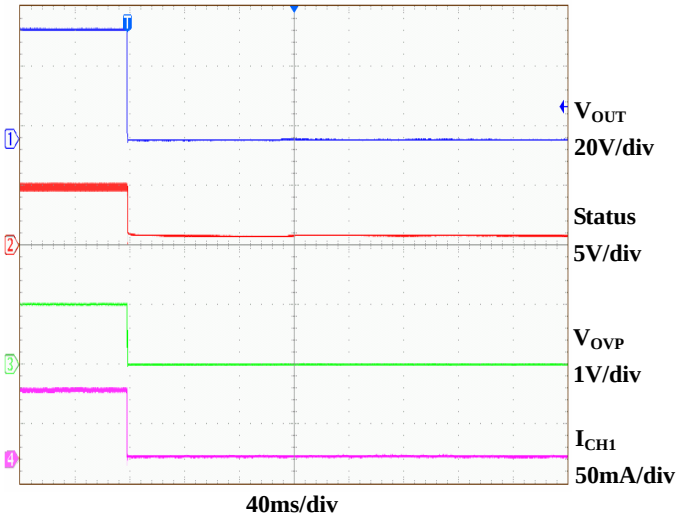
Typical Operating Characteristics (continued)

(V_{IN}=12V, ISET=20K, FSET=330K, Status=100K, L=47µH, C_{COMP}=22nF, C_{OUT}=47µF)

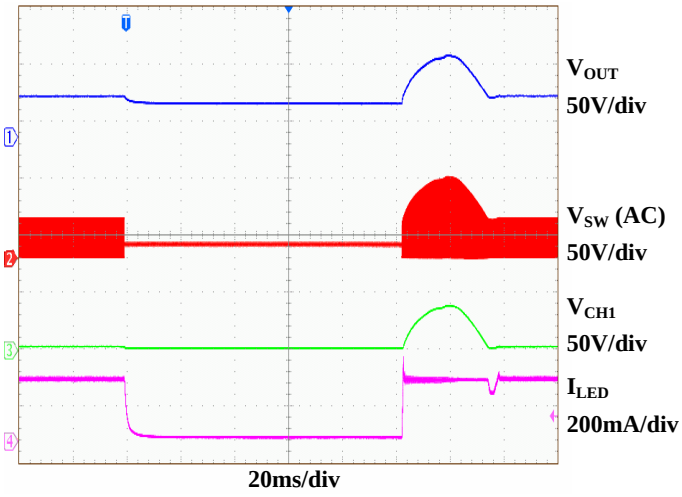
Protection of Channel Short to VOUT (Channel 1 Short to VOUT)



Protection of VOUT Short to GND



Protection of Inductor Short



Detailed Descriptions

The EUP2588 is a high-efficiency driver for arrays of white LEDs. It contains a fixed-frequency, current mode, PWM step-up controller, 5V linear regulator, dimming control circuit, and 4 regulated current sources (see Figure 2). When enabled, the step-up controller boosts the output voltage to provide sufficient headroom for the current sources to regulate their respective string currents. The EUP2588 features programmable switching frequency, which allows trade-offs between external component size and operating efficiency. The control architecture automatically skips pulses at light loads to improve efficiency and prevents overcharging the output capacitor. The EUP2588 supports external digital control of the LED current through a PWM logic input signal on PWMI. The EUP2588 has multiple features to protect the controller from fault conditions. Separate feedback loops limit the output voltage if one or more LEDs fail open or short. The controller features cycle-by-cycle current limit to provide consistent operation and soft-start capability. A thermal-shutdown circuit provides another level of protection. This part includes a 5V linear regulator that provides the internal bias and gate drive for the step-up controller. When an external 5V is available, the internal LDO can be overdriven to decrease power dissipation. Otherwise, connect the VIN pin to an input greater than 5.5V. An internal crude LDO keeps alive to provide power supply for internal logic and controller even EN is low, which only dissipate 3uA quiescent current.

5V Supply VCC and UVLO

The EUP2588 has built in 5V linear regulator VCC supply for internal control voltage. The EUP2588 includes the power on reset (POR) and under-voltage lockout (UVLO) features. POR resets the fault latchs. POR occurs when VCC rises above 2.8V (typ). The controller is disabled until VCC exceeds the UVLO threshold of 4.05V (typ). Hysteresis on UVLO is approximately 150mV. The VCC should be bypassed to GND with a 0.47μF or greater ceramic capacitor.

System Startup

When the EUP2588 is enabled, the chip checks the topology connection first. And after 8mS delay, the chip monitors the OVP pin to see if the Schottky diode is not connected or the boost output is short to GND. If the OVP voltage is lower than 70mV, the chip will be disabled. It is recommended on the start up sequence that the enable signal comes after input voltage and PWM dimming signal established.

Step-up Converter

The converter operation frequency is programmable (from 150kHz to 1.5MHz) with a external set resistor on FSET pin, which is helpful for optimizing the external components sizes and improving the efficiency. An oscillator resistor on FSET pin sets the internal oscillator frequency for the step-up converter according to the equation:

$$F_{SW} = 50000/R_{FSET}$$

For R_{FSET}=100kΩ, the switching frequency is set to 500kHz.

The EUP2588's fixed-frequency, current-mode, step-up controller automatically chooses the lowest active CHx voltage to regulate the output voltage. When ILED=180mA, a 0.85V is setting as the minimum CHx feedback reference. The error signal is compared to the external switch current plus slope compensation to determine the switch on-time. As the load changes, the error amplifier sources or sinks current to the COMP output to deliver the required peak-inductor current. The slope-compensation signal is added to the current-sense signal to improve stability at high duty cycles.

At light-load or Vout near to Vin operation, the converter runs into the pulse-skipping mode, the FET is turned on for a minimum on-time of approximately 100ns, and then the converter discharges the power to the output in the remain period. The external MOSFET will keep off until the output voltage needs to be boosted again.

Dimming Control

The EUP2588 provides external PWM dimming for all 4 channels LED current adjustment. This PWM signal results in PWM chopping of the current in the LEDs for all 4 channels to provide LED control. EUP2588 accepts 100Hz to 20KHz external PWM signal, and this signal with low level less than 0.7V and high level above 2.4V.

Open String Protection

The open string protection is achieved through the over voltage protection. If one or more strings are open, the respective CHx pins are pulled to ground and the IC keeps charging the output voltage until it reach OVP threshold. Then the part will mark-off the open strings whose CHx pin voltage is less than 210mV. Once the mark off operation completes, the remaining LED strings will force the output voltage back into tight regulation. The string with the highest voltage drop is the ruling string during output regulation.

The EUP2588 always tries to light at least one string and if all strings in use are open, the EUP2588 shuts down the step-up converter. The part will maintain mark-off information until the part shuts down.

Setting the Over Voltage Protection

The open string protection is achieved through the over voltage protection (OVP). In some cases, an LED string failure results in the feedback voltage always zero. The part then keeps boosting the output voltage higher and higher. If the output voltage reaches the programmed OVP threshold, the protection function will be triggered.

To make sure the chip functions properly, the OVP setting resistor divider must be set with a proper value. The recommended OVP point is about 1.2 times higher than the output voltage for normal operation.

$$V_{OVP} = 2.0 \times \left(\frac{R_1 + R_2}{R_2} \right)$$

Short String Protection

The EUP2588 monitors the CHx pin voltage to judge if the short string occurs. If one or more strings are shorted, the respective CHx pins will be pulled up to the boost output and tolerate high voltage stress. If the CHx pin voltage is higher than 7V, the short string condition is detected on the respective string. When the short string fault (CHx over-voltage fault) continues for greater than 2ms, the string is marked off and disabled. Once a string is marked off, its current regulation is forced to disconnect from the output voltage loop regulation. The marked-off LED strings will be shut off totally until the part restarts. If all strings in used are short, the EUP2588 will shut down the step-up converter.

Fault Protection

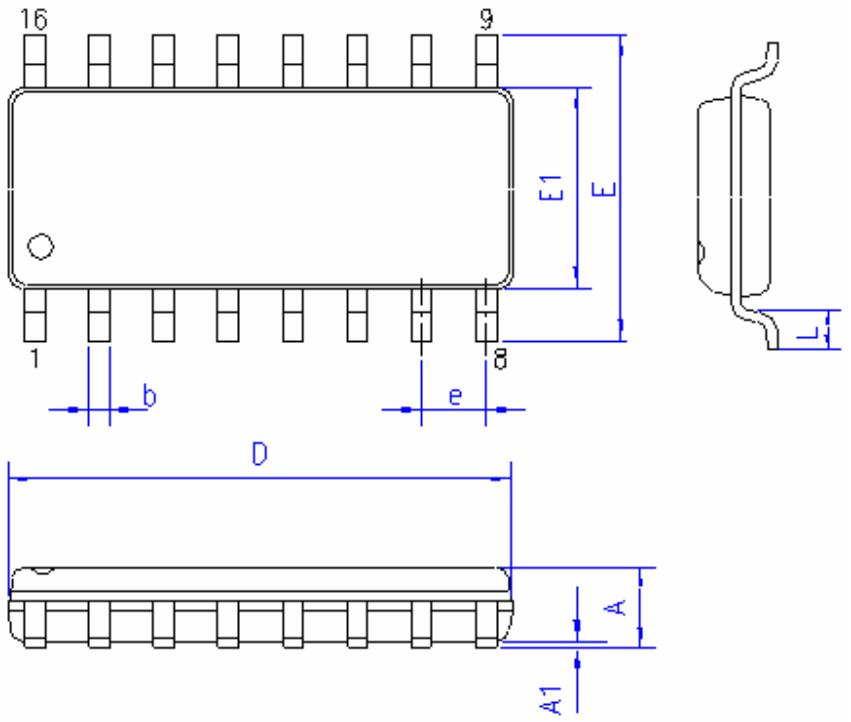
The EUP2588 has multiple features to protect the device from fault conditions. Separate feedback loops limit the output voltage under any circumstance, ensuring safe operation. Once an open string is detected, the string is disabled while other strings operate normally. The EUP2588 also features short LED detection. Table 1 lists all the EUP2588 fault protections control.

Table 1. EUP2588 Fault Protection

Faults	FAULT State	Boost DC-DC	WLED Current
CHx Short to GND	High, Only 4CHx OFF FAULT=Lo	Only 4CHx All OFF, Controller will Shutdown. Otherwise, Keep Normal	Mark OFF the shorted CHx, Others keep Normal
CHx Over Voltage	High, Only 4CHx OFF FAULT =Lo	Only 4CHx All OFF, Controller will Shutdown. Otherwise, Keep Normal	Mark OFF the LED Open CHx, Others keep Normal
OVP shorted to GND or Boost Schottky Diode Malfunction (VOVP<0.07V)	FAULT =Lo	Off	Off
DC-DC Boost Output Exceeds OVP Threshold (VOVP=2.0V)	VOVP>2.0V, FAULT =Lo VOVP<1.95V, FAULT =Hi	When VOVP is greater than 2.0V, the boost controller will be turned off until VOVP drops to 1.95V.	On
Thermal Fault (TJ>+150ºC)	TJ>150ºC, FAULT =Lo TJ<120ºC, FAULT =Hi	Off first, Then Return to soft-start after TJ falls below 120ºC	Off first, Then Return to soft-start after TJ falls below 120ºC
EN Low	FAULT =Hi	Off	Off

Packaging Information

SOP-16



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
b	0.31	0.51	0.012	0.020
D	9.90		0.389	
E1	3.90		0.153	
E	5.79	6.20	0.228	0.244
e	1.27		0.050	
L	0.38	1.27	0.015	0.050