4 Strings High Current White LED Driver with Boost Controller

DESCRIPTION

The EUP2998 is a high power and high efficiency boost controller with 4-channel current sinker which is ideal for large LCD backlighting applications.

EUP2998 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 to maximum value of 90V from a 8V to 35V input supply. The EUP2998 regulates the current in each LED string to the programmed value set by an external current setting resistor. The EUP2998 current matching can achieve ±1.5%.

A 3μA shutdown current and 0.4V (ILED@100mA) feedback voltage will greatly improve efficiency and reduce power dissipation.

The device supports both direct pulse width modulation (PWM) brightness dimming and PWM to Analog dimming. When use PWM dimming signal to adjust the LEDs brightness, a direct PWM LED current and analog LED current will obtained set by the external circuits connected to LPF.

The EUP2998 integrated multiple protect functions, such as LED Open, LED Short, Inductor Short, Schottky Diode Short, CHx Short to Vout, Output Over Voltage, Over thermal, Input Over Current, and Under Voltage Lockout (UVLO), these protection will prevent the LCD backlight from damage.

EUP2998 is available in TSSOP16-EP and SOP-16 packages.

FEATURES

- 8.5V gate driver
- 4 strings in parallel and up to 25 LEDs per string
- Up to 240mA drive capability for each string
- Supports both Analog and Direct PWM Dimming
- Built in convert for converting external PWM signal to analog dimming signal
- Output voltage up to 90V
- Boost Switching frequency can be programmed by external resistor
- Wide Input voltage range 8V to 35V
- Better than 1.5% LED Current Regulation Accuracy Between Strings
- Multiple Fault Protections
  -Current Limit protection
  -Output Short circuit detection
  -Over-temperature protection
  -Output Over-voltage protection
- LED current turn off in shutdown mode
- Support multiple-IC parallel operation
- Thermal Enhanced TSSOP-16L and SOP-16 Packages
- RoHS Compliant and 100% Lead (Pb)-Free Halogen-Free

APPLICATIONS

- Desktop LCD Flat Panel Displays
- Flat Panel Video Displays
- LCD TVs and Monitors

Typical Application Circuit

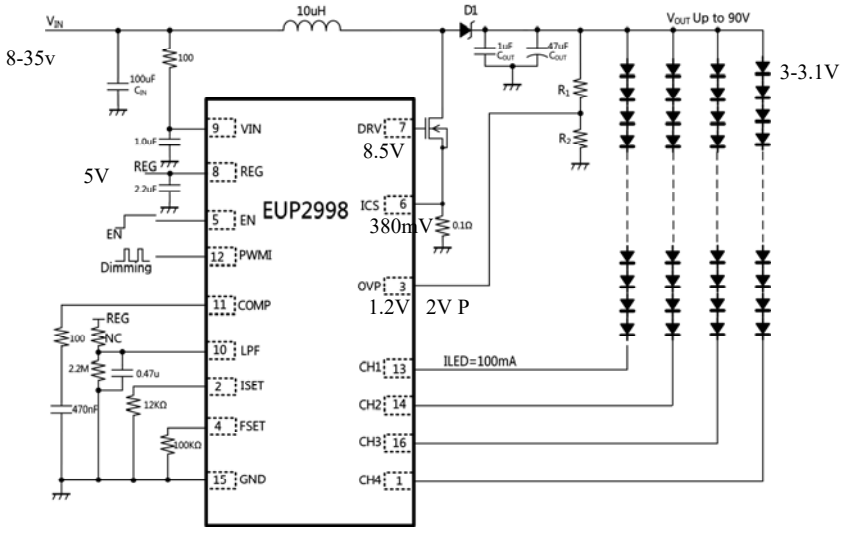
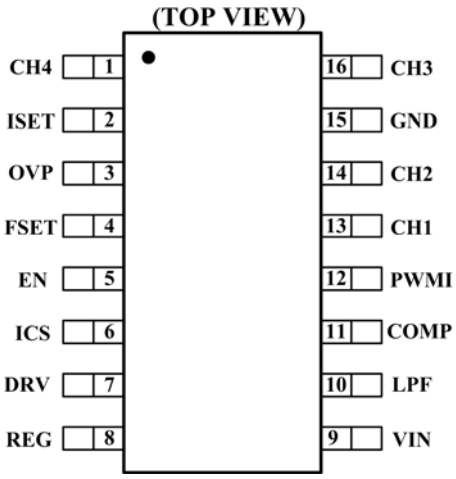
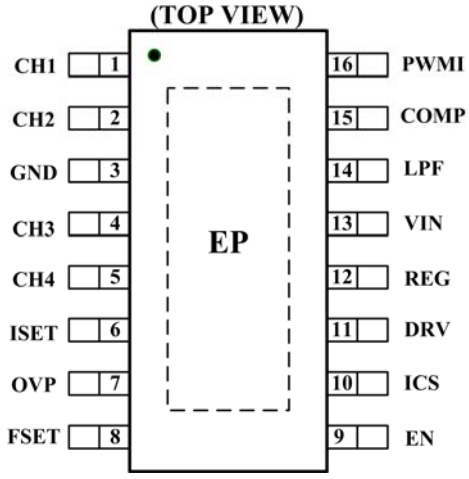


Figure 1. Typical Application Circuits

Pin Configurations

Package Type	Pin Configurations	Package Type	Pin Configurations
SOP-16		TSSOP16-EP	

Pin Description

PIN NAME	SOP-16	TSSOP16-EP	DESCRIPTION
CH4	1	5	Channel 4 LED current source. Leave it floating if not used.
ISET	2	6	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 1.5V, during full lighting, ICHx=1200/RISET Ohm. Set RISET=12KOhm, ICHx is set to 100mA.
OVP	3	7	Output over-voltage feedback input. Connect OVP to the tap point of the resistor divider between output and ground.
FSET	4	8	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.
EN	5	9	The device enable pin. A logic high signal turns on the internal LDO and enables the IC..
ICS	6	10	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.
DRV	7	11	External N-CH Power Device Gate Driver Output. This pin provides the boost converter power device gate drive signal.
REG	8	12	5V Linear Regulator Output to power internal circuitry. Bypass REG to GND with a ceramic capacitor of 1μF or greater.
VIN	9	13	Supply Voltage Input.
LPF	10	14	LED current dimming mode set. Connect LPF to REG, direct PWM dimming mode is set, LED current chopping according to the external dimming signal. Connect a RC to this pin, the external PWM dimming signal is converted into analog dimming to adjust the LED current.
COMP	11	15	Boost Converter Compensation Pin. Connect a RC compensation circuit from COMP to GND, the soft-start and compensation functions are implemented. When the EUP2998 shuts down, COMP is discharged to GND.
PWMI	12	16	Brightness Control Input. Apply a PWM signal on this pin for brightness control; in direct PWM dimming mode, the LED current chopped by the external dimming signal; in analog dimming mode, a dc LED current is controlled according to the dimming signal duty cycle.
CH1	13	1	Channel 1 LED current source. Leave it floating if not used.

CH2	14	2	Channel 2 LED current source. Leave it floating if not used.
GND	15	3	Ground.
CH3	16	4	Channel 3 LED current source. Leave it floating if not used.

Ordering Information

Order Number	Package Type	Marking	Quantity per Reel	Operating Temperature Range
EUP2998DIR1	SOP-16	xxxxx P2998	2500	-40 °C to +105°C
EUP2998XIR1	TSSOP-16 (EP)	xxxxx EUP2998	2500	-40 °C to +105°C

EUP2998 □ □ □ □

Lead Free Code
1: Lead Free, Halogen Free

Packing
R: Tape & Reel

Operating temperature range
I: Industry Standard

Package Type
D: SOP
X: TSSOP (EP)

Block Diagram

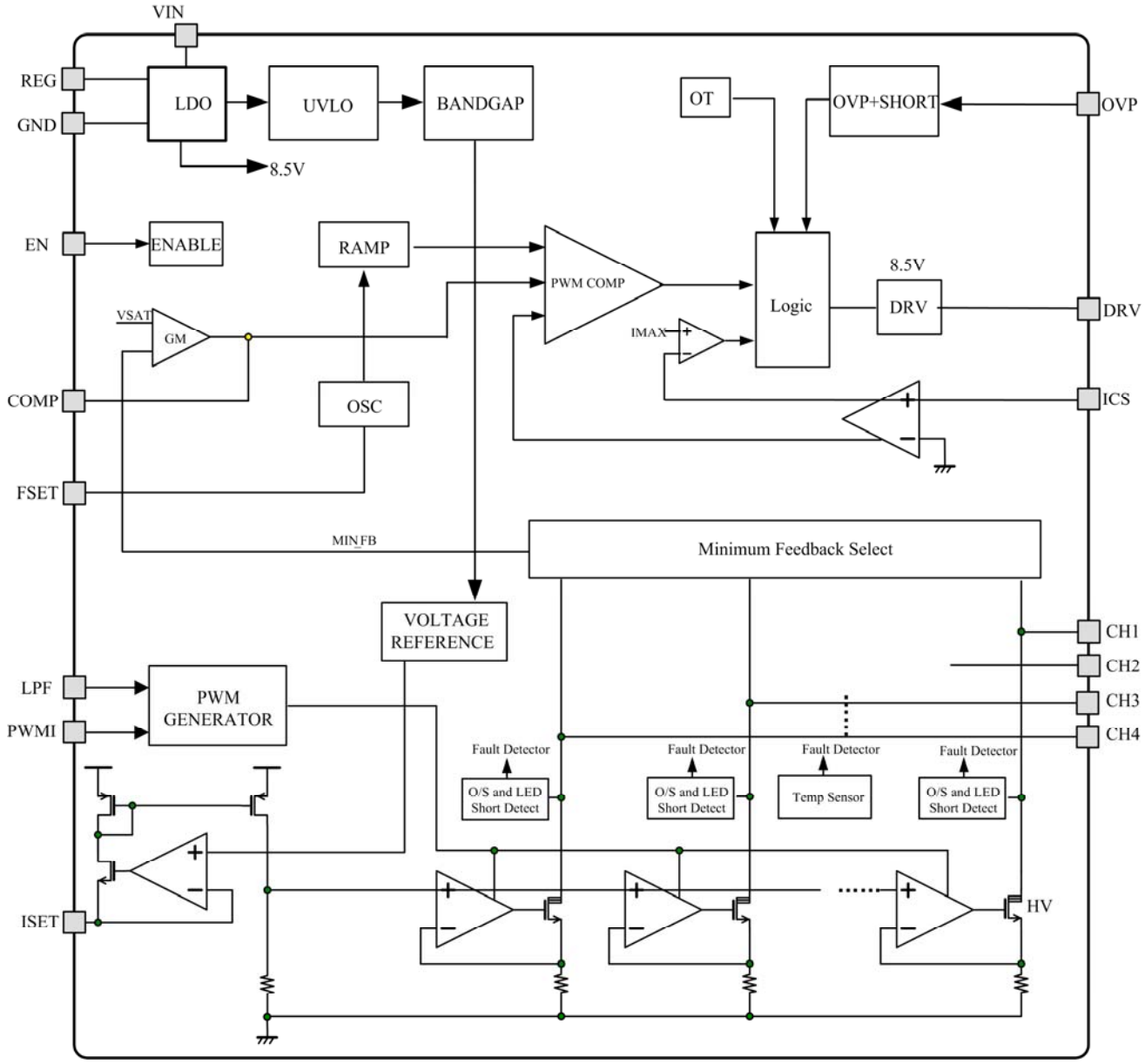


Figure 2. Block Diagram

Absolute Maximum Ratings (1)

- CH (n) to GND ---------- -0.3V to 90V
- VIN ,ICS,EN to GND ---------- -0.3V to 40V
- OVP, PWMI, FAULT, REG to GND ---------- -0.3V to +6V
- COMP, DRV, ISET, FSET to GND---------- -0.3V to (REG+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
  16-Pin TSSOP [derate 25mW/°C (JEDEC high-k 2s2p) above +70°C] ---------- 2000mW
- Operating Temperature Range ---------- -40°C to +105°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 +105°C
- Supply Voltage , VIN---------- 8V to 35V
- LED Current, ICHn ---------- 5mA to 240mA
- Maximum LED Pulse Current=1mS ----------240mA

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}=12kΩ, R_{FSET}=100kΩ,V_{PWMI}= 5V, T_A= 25°C, unless otherwise noted.)

Symbol	Parameter	Conditions	EUP2998			Unit
			Min.	Typ.	Max.	
VIN	VIN Supply voltage		8		35	V
I_VIN	VIN Supply Current	PWMI=5V		3.25		mA
I_OFF	VIN Shutdown Current	PWMI=EN=0,VIN=12V			6	μA
I_STANDBY	VIN Standby Current	EN=5V, PWMI=0V, VIN=12V		820		μA
REG	REG Output Voltage			5		V
I_REG(1)	REG Current Limit			30		mA
UVLO	UVLO Rising Threshold			4.05		V
UVLO_HYS	UVLO Hysteresis			0.15		V
V_{DRV}	DRV High Level			8.5		V
VIH	EN High Level	VEN Rising	2.4			V
VIL	EN Low Level	VEN Falling			0.7	V
Boost Converter						
I_{DRV_SRC}	DRV Sourcing Current		50			mA
I_{DRV_SINK}	DRV Sinking Current		50			mA
FSW	Switching Frequency	R_{FSET}=100KΩ		500		KHz
TON_MIN(1)	Minimum On Time			100		nS
ICS	Boost Current Limit	Boost ON Time>100nS (DRV=Hi Time>100nS)		500		mV
DMAX	Maximum Duty Cycle			93		%
V_{FSET}	FSET Voltage			2.5		V
LED Current Regulation						
RCH	CHn Sink Resistance	ILEDn=100mA		2.5		Ω

Electrical Characteristics (continued)

(Circuit of Figure 1, VIN=12V, GND=0V, R_{ISET}=12kΩ, R_{FSET}=100kΩ,V_{PWMI}= 5V, T_A= 25°C, unless otherwise noted.)

Symbol	Parameter	Conditions	EUP2998			Unit
			Min.	Typ.	Max.	
LED Current Regulation						
VISET	ISET Regulation Voltage			1.5		V
ILED100%	Output LED Current in Analog Dimming Mode	PWM Duty Cycle=100%, C_{LPF}=0.47μF	97	100	103	mA
Imatch100%	CHn Current matching in Analog Dimming Mode	PWM Duty Cycle=100%, C_{LPF}=0.47μF	-1.5		1.5	%
ILED5%	Output LED Current in Analog Dimming Mode	PWM Duty Cycle=5%, C_{LPF}=0.47μF	4	5.5	7	mA
Imatch5%	CHn Current matching in Analog Dimming Mode	PWM Duty Cycle=5%, C_{LPF}=0.47μF	-3		3	%
Dimming Controls						
VPWMH	PWMI Input High Level		2.4			V
VPWML	PWMI Input Low Level				0.7	V
IPWMI	PWMI Pull Down Current	V_{PWMI}=5V	-1		+1	μA
Fault Detections						
Vovp	Over-voltage Threshold on OVP	Rising Edge		2.0		V
Vhys-ovp	OVP Hysteresis			100		mV
Vovp_ab	Shutdown Under Abnormal Condition			3.2		V
VCHx_OV	CHx Over Voltage Threshold			8.7		V
VCHx_UV	CHx Under Voltage Threshold			100		mV
Tsd	Thermal Shutdown Threshold			150		ºC
Tsd_hys	Thermal Shutdown Hysteresis			30		ºC

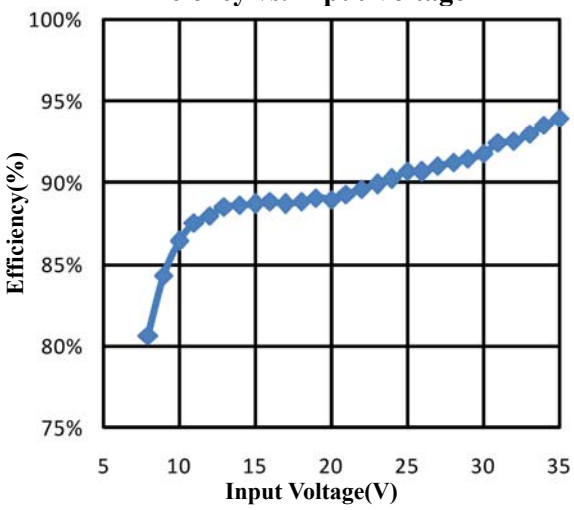
Note

(1)These are guaranteed by design and characterization.

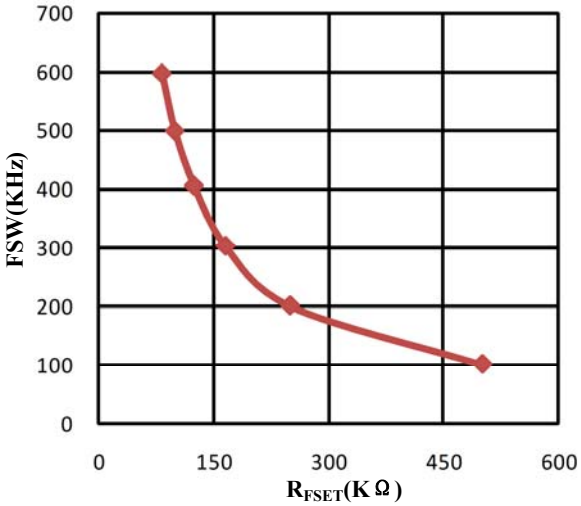
Typical Operating Characteristics

(V_{IN}=12V, R_{ISET}=12K, R_{FSET}=100K, L=10µH, C_{OUT}=47µF)

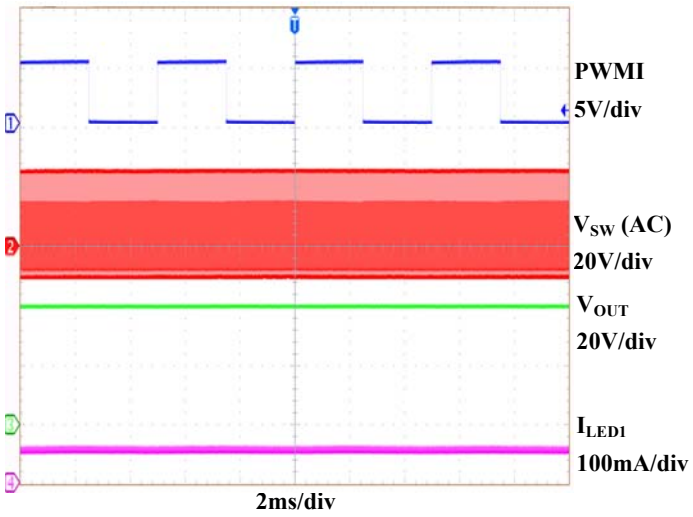
Efficiency vs. Input Voltage



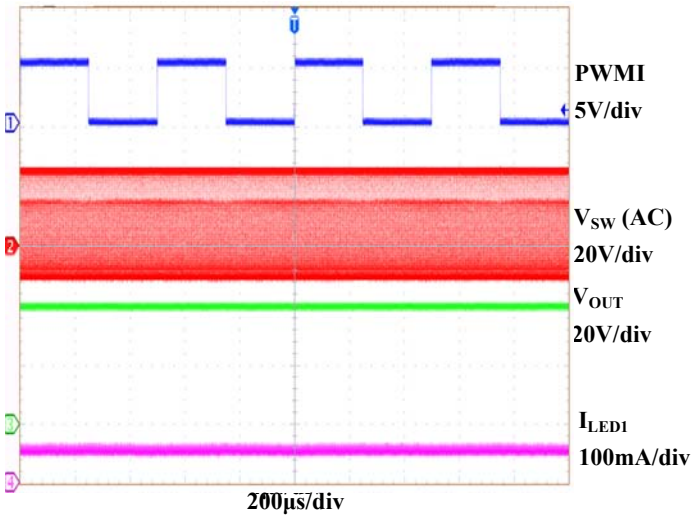
FSW vs. R_{FSET}



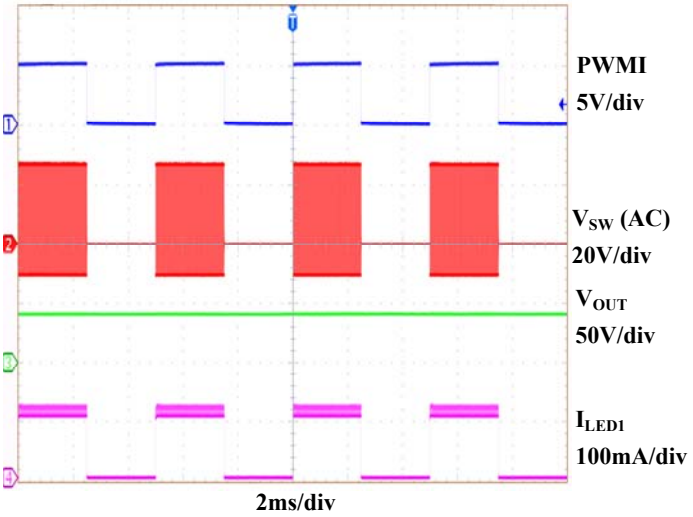
200Hz PWMI Dimming (Duty Cycle=50%)
PWM to Analog Mode



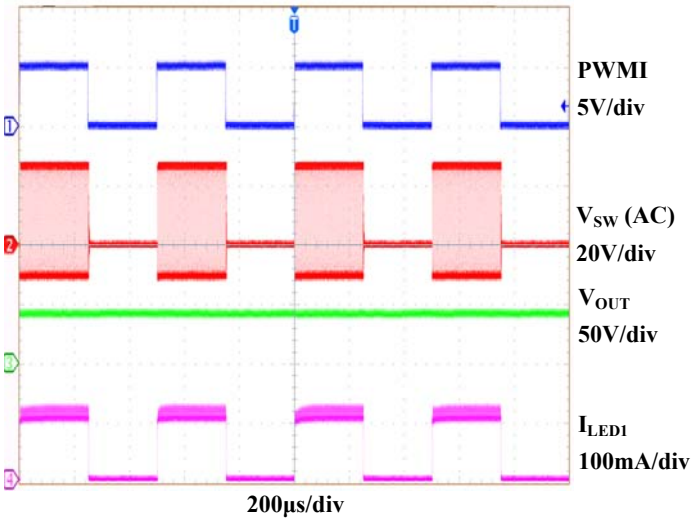
2KHz PWMI Dimming (Duty Cycle=50%)
PWM to Analog Mode



200Hz PWMI Dimming (Duty Cycle=50%)
Direct PWM Mode



2KHz PWMI Dimming (Duty Cycle=50%)
Direct PWM Mode

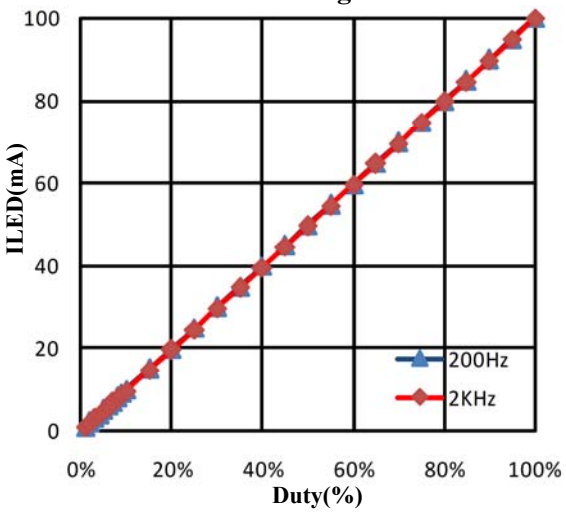


Typical Operating Characteristics (continued)

(V_{IN}=12V, R_{ISET}=12K, R_{FSET}=100K, L=10µH, C_{OUT}=47µF)

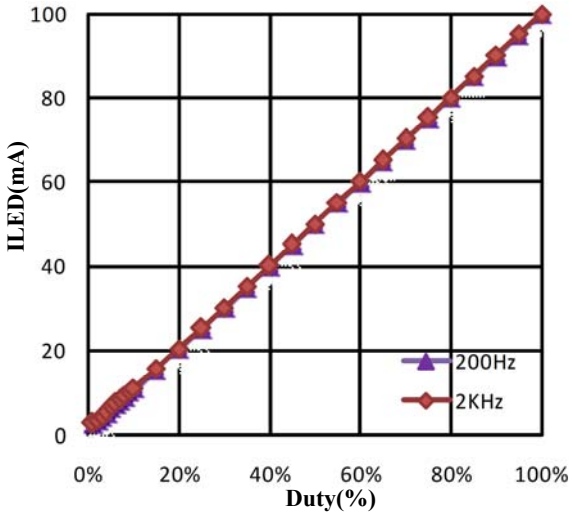
Current Linearity

PWM to Analog Mode

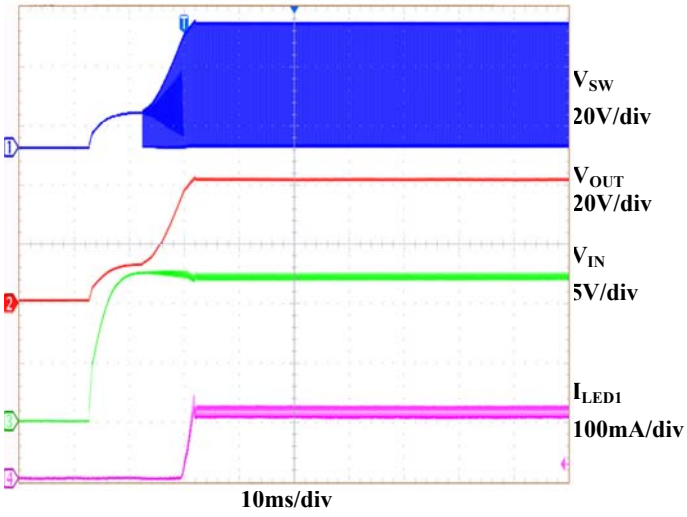


Current Linearity

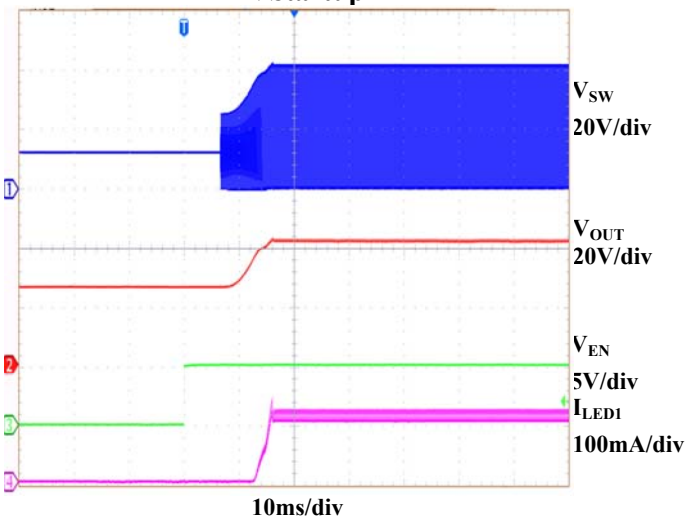
Direct PWM Mode



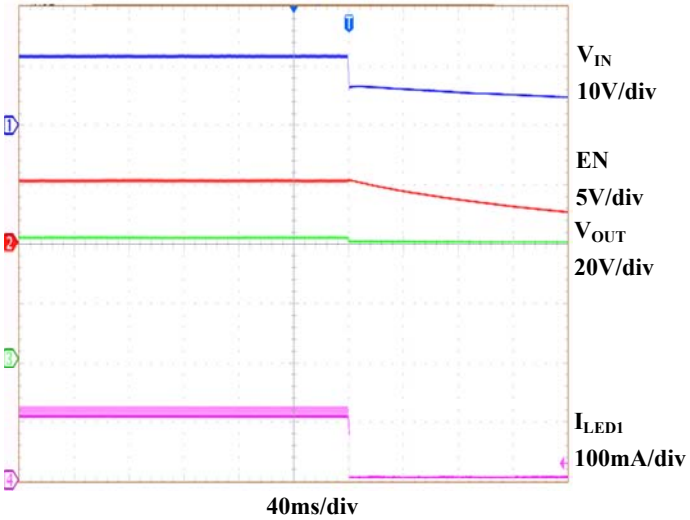
V_{IN} Startup



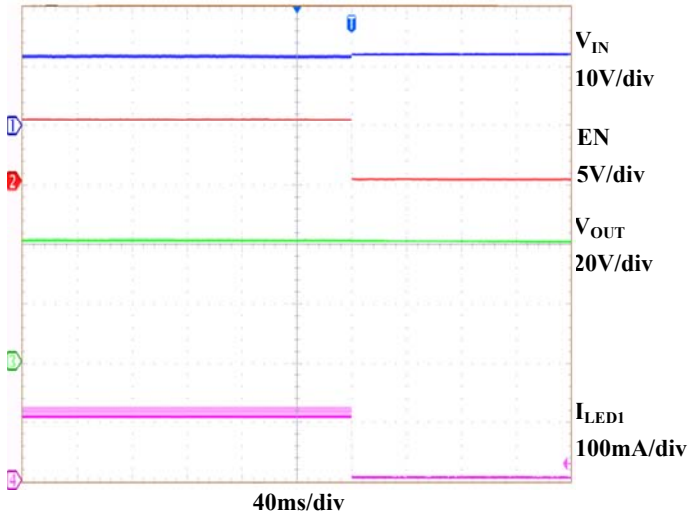
EN Startup



VIN from On to Off



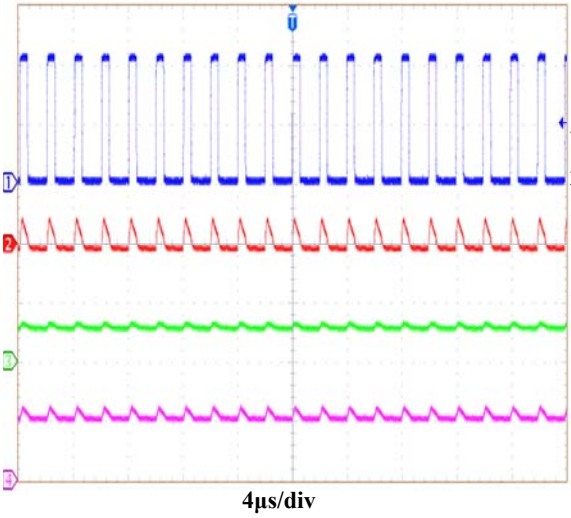
EN from On to Off



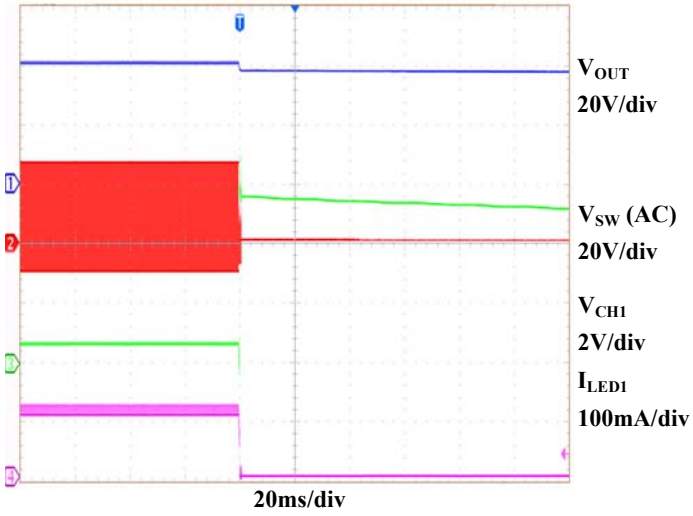
Typical Operating Characteristics (continued)

(V_{IN}=12V, R_{ISET}=12K, R_{FSET}=100K, L=10µH, C_{OUT}=47µF)

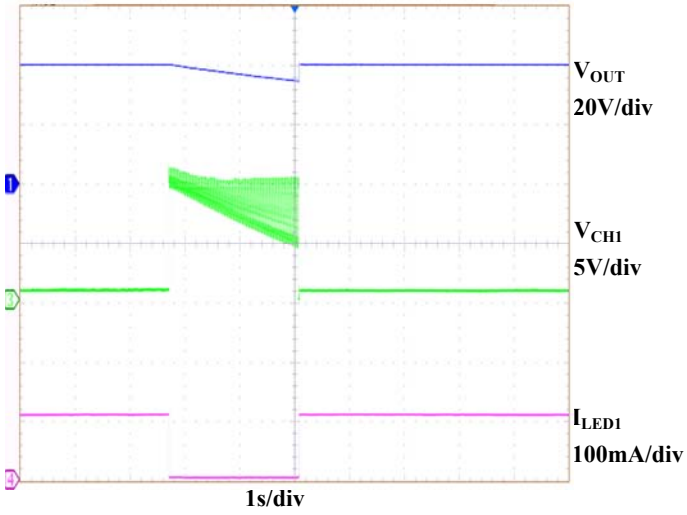
Steady State



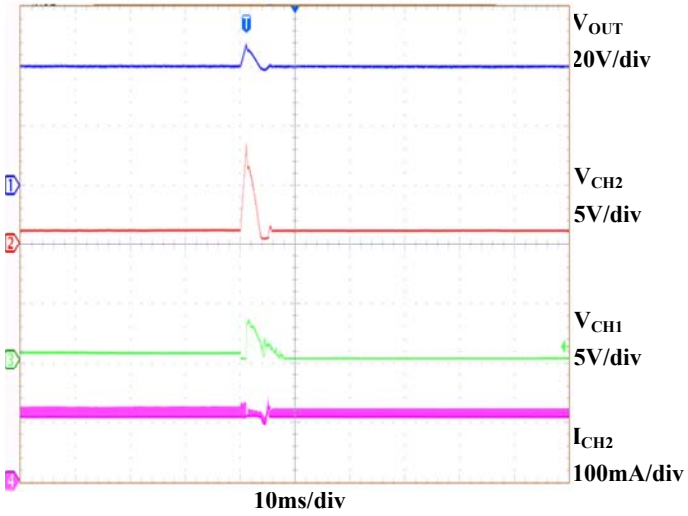
Protection of Inductor Short



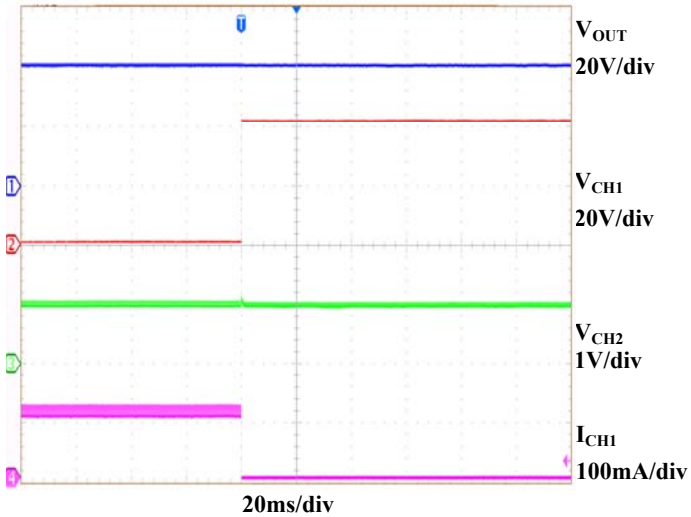
Protection of Over Thermal



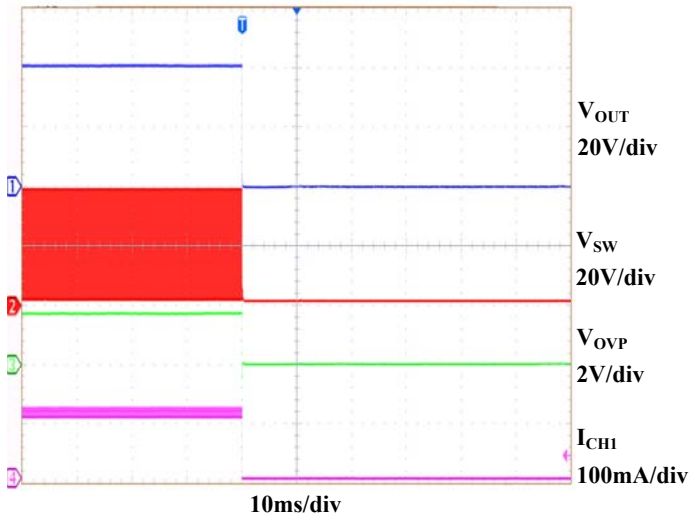
Protection of Channel Open (Channel 1 Open)



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



Protection of VOUT Short to GND



Detailed Descriptions

The EUP2998 is a high-efficiency driver for arrays of white LEDs. It contains a fixed-frequency, current mode, PWM step-up controller, a 5V linear regulator and a 8.5V linear regulator for external power device gate driver, dimming control circuit, and 4 regulated current sources. 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 EUP2998 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 EUP2998 supports both analog and digital control of the LED current through a PWM input signal. The EUP2998 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 both a 5V linear regulator that provides the internal circuitry power supply, and a 8.5V LDO for gate drive for the step-up controller. An internal crude LDO keeps alive to provide power supply for internal logic and controller even EN is low, which only dissipate 3μA quiescent current.

5V Supply REG and UVLO

The EUP2998 has built in 5V linear regulator REG supply for internal control voltage. The EUP2998 includes the power on reset (POR) and under-voltage lockout (UVLO) features. POR resets the fault latches. POR occurs when REG rises above 2.8V (typ). The controller is disabled until REG exceeds the UVLO threshold of 4.05V (typ). Hysteresis on UVLO is approximately 150mV. The REG should be bypassed to GND with a 2.2μF or greater ceramic capacitor.

8.5V Gate Driver

The EUP2998 integrated a 8.5V linear regulator only for external power MOS gate driver. For most of 100V NMOS, the RDSON is reducing quickly along with the gate voltage increasing before the VGS reaches to 8.5V, so the 8.5V gate driver is a good choice for the boost converter efficiency improvement.

Step-up Converter

The converter operation frequency is programmable (from 100KHz to 600KHz) 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:

$$F_{SW}(KHz) = 50000/R_{FSET}$$

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

The EUP2998's fixed-frequency, current-mode, step-up controller automatically chooses the lowest active CHx voltage to regulate the output voltage. When ILED=100mA, a 0.4v 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 EUP2998 provides two PWM dimming modes: Direct PWM Dimming mode and Analog Dimming mode. Within Direct PWM Dimming mode, the LED current for all 4 channels are chopped directly by the PWM dimming signal; within Analog Dimming mode, the dimming signal is filtered to a DC value according to the dimming signal duty cycle, the LED current for all 4 channels is set by the DC value. Because of the offset voltage in the LED current regulators, the dimming duty cycle less than 5% is not recommended in the analog dimming mode.

1. Direct PWM Dimming

An external PWM dimming signal is employed to achieve PWM dimming control. Connect PIN LPF to REG, the direct PWM dimming mode is setting. Within this mode, the LED current sinkers are turned on and off following the external PWM dimming signal, the LED current are set to the maximum LED current amplitude with a logic High at PWMI, otherwise, the LED current are set to Zero. A minimum 2.3uS pulse width is limited on the direct PWM dimming signal, so a dimming ratio up to 1000:1 allows with a properly PWM dimming frequency selection.

2. PWM to Analog Dimming

To apply a capacitor from LPF to GND, the PWM to Analog dimming mode is achieved. The capacitor and the external resistor consists of a LPF(Low Pass Filter), so the external PWM dimming signal will be integrated as a DC voltage to regulate the amplitude of the LED current. The LPF circuit is shown as Figure3, an internal resistor RIN=50kΩ, the external RC connected as Figure3.

It is recommended that the product of should be greater than 10 times the period (1/Frequency) of external PWM signal. The LPF output DC voltage is proportional to the input PWM duty, accords to the ILED setting equation; the LED current is proportional to the PWM dimming

signal duty.

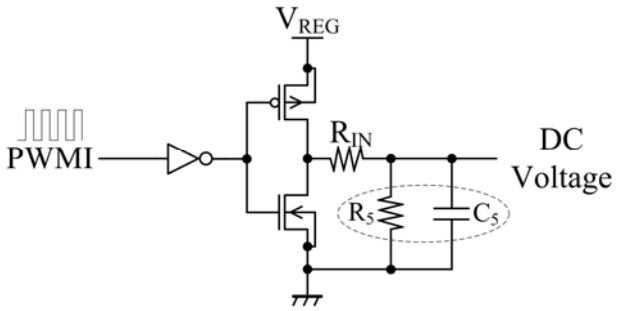


Figure3. PWM to Analog Dimming LPF

Varying the PWM duty cycle from 100% to 5%, the LED current amplitude adjusts from maximum to minimum of about 20:1 ratio. The LED current amplitude can be set as:

$$I_{LED}(mA) = D \times \frac{1200}{R_{ISET}\left[k\Omega\right]} \times \frac{R_5}{R_5\left[k\Omega\right] + R_{IN}\left[k\Omega\right]}$$

Where:

D is the duty cycle of the PWM signal

R5 is an optional resistor to keep LPF pin voltage low under IC disabled condition.

To ensure proper operation in LED current balance function, the minimum regulation current per channel is recommended to be not less than 5mA.

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 or ICS reach current limit threshold. Then the part will mark-off the open strings whose CHx pin voltage is less than 100mV. 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 EUP2998 always tries to light at least one string and if all strings in use are open, the EUP2998 shuts down the step-up converter. The part will maintain mark-off information until the part re-toggled.

Short String Protection

The EUP2998 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. For proper protection the part from damage, EUP2998 sets 2 CHx over-voltage thresholds.

A: If the CHx pin voltage is higher than 8.7V, the short string condition is detected on the respective string. When the short string fault (CHx over-voltage fault) continues for greater than 10000*1/FSW, 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 EUP2998 will shut down the step-up converter.

B: If the CHx pin voltage is higher than 16.2V, this condition is detected on the respective string; the part will mark off the string immediately until EUP2998 restart;

Setting the Over Voltage Protection

The open string protection is achieved through the over voltage protection (OVP) or boost current limits. 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.

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

Fault Protection

The EUP2998 has multiple features to protect the device from damage 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 EUP2998 also features short LED detection. Table 1 lists all the EUP2998 fault protections control.

Table 1. EUP2998 Fault Protection

Faults	Trigger Conditions	Boost DC-DC	WLED Current
CHx Short to GND	CHx<100mV & OVP>2V	Only 4CHx All OFF, Controller will Shutdown. Otherwise, Keep Normal	Mark OFF the shorted CHx, Others keep Normal
CHx Over Voltage	CHx>8.7V and Time>10000*1/FSW	Only 4CHx All OFF, Controller will Shutdown. Otherwise, Keep Normal	Mark OFF the LED Open CHx, Others keep Normal
	CHx>16.2V		
OVP shorted to GND or Boost Schottky Diode Malfunction	V_{OVP}<0.1V	When VOVP Lower than 0.1V, the Boost OFF OVP>0.1V, Boost ON	When VOVP Lower than 0.1V, the Current OFF OVP>0.1V, the Current ON
DC-DC Boost Output Exceeds OVP Threshold	V_{OVP}>2.0V	When VOVP is greater than 2.0V, the boost controller will be turned off until VOVP drops to 1.9V.	ON
DC-DC Boost Output Exceeds OVP Threshold	V_{OVP}>3.2V	When VOVP is greater than 3.2V, the boost controller will be turned off until toggle EN	When VOVP is greater than 3.2V, the Current will be turned off until toggle EN
Thermal Fault (TJ>+150ºC)	TJ>150ºC,	Off first, Then Return to soft-start after TJ falls below 120ºC	Off first, Then Return to soft-start after TJ falls below 120ºC
Current Limit	V_{ICS}>0.5V	When VICS>0.5V, the boost controller will be turned off immediately, and re-work next cycle	ON
Inductor Short	V_{ICS}>1.5V	When V_{ICS}>1.5V, the boost controller will be turned off until toggle EN	When V_{ICS}>1.5V, the Current will be turned off until toggle EN

Reference Application Circuit

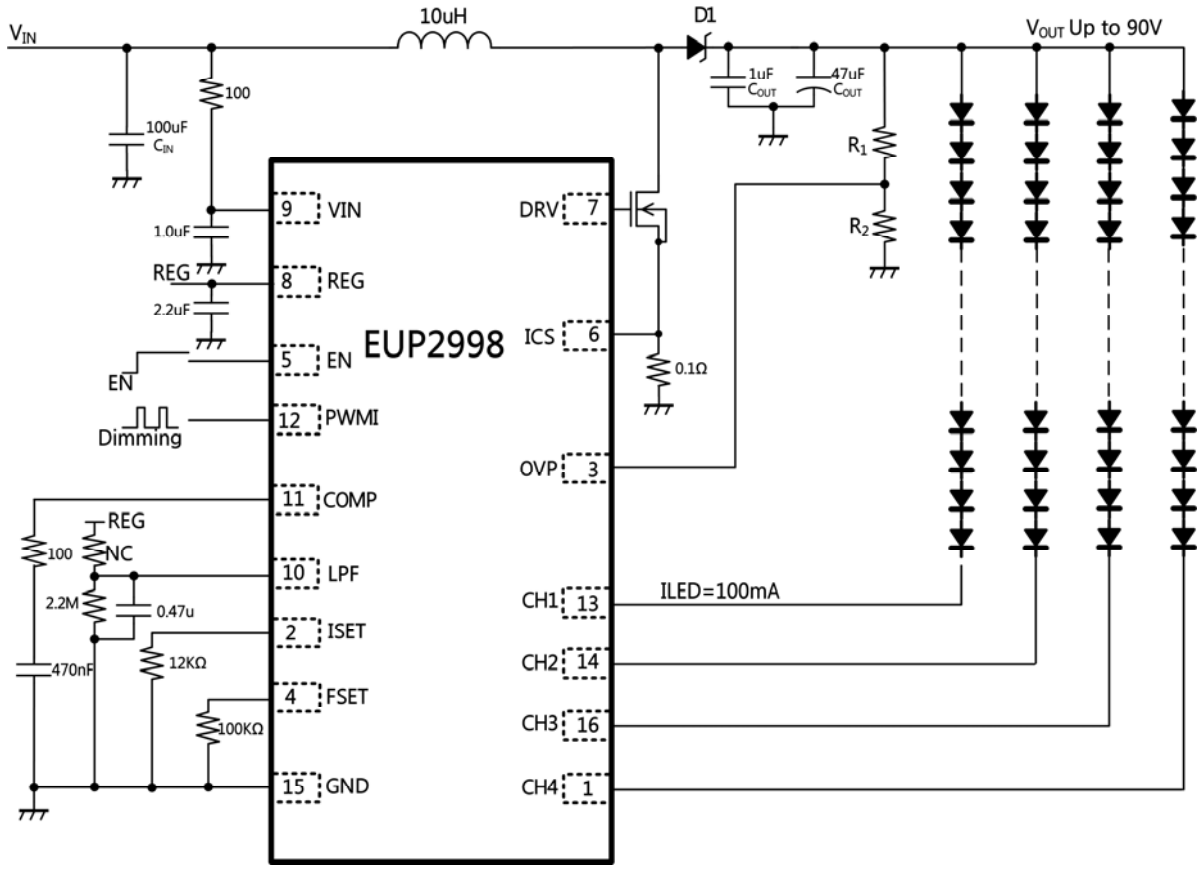


Figure4. EUP2998 4Strings PWM to Analog Dimming Application

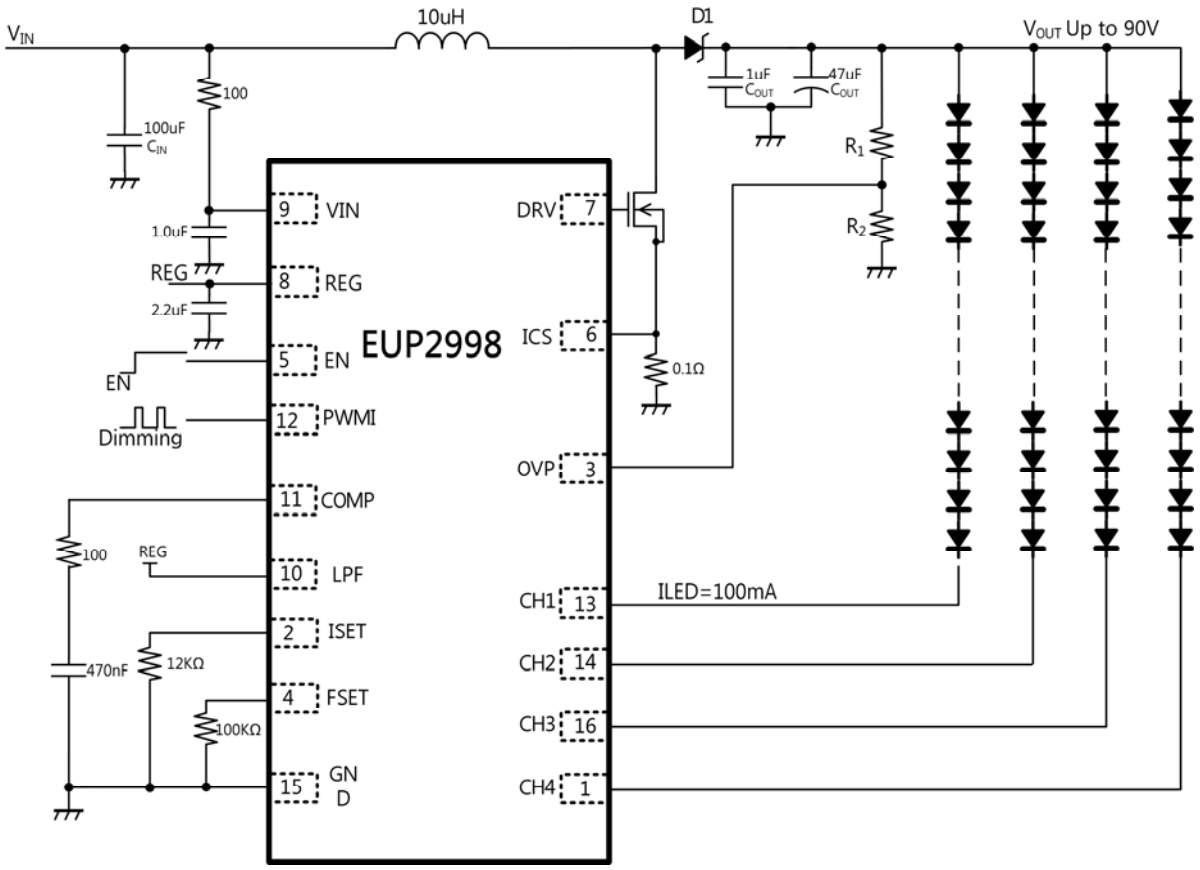


Figure5. EUP2998 4Strings Direct PWM Dimming Application

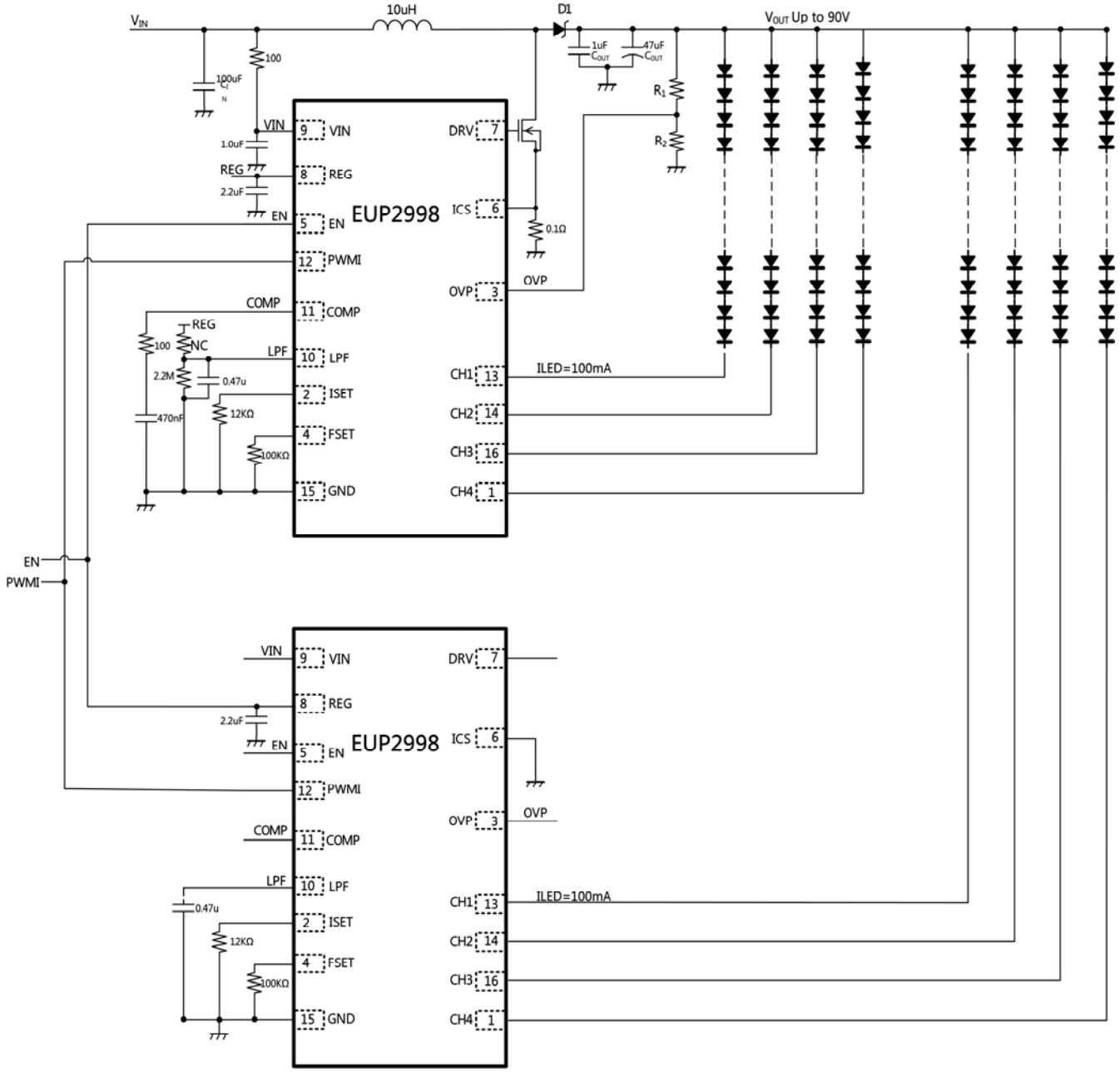
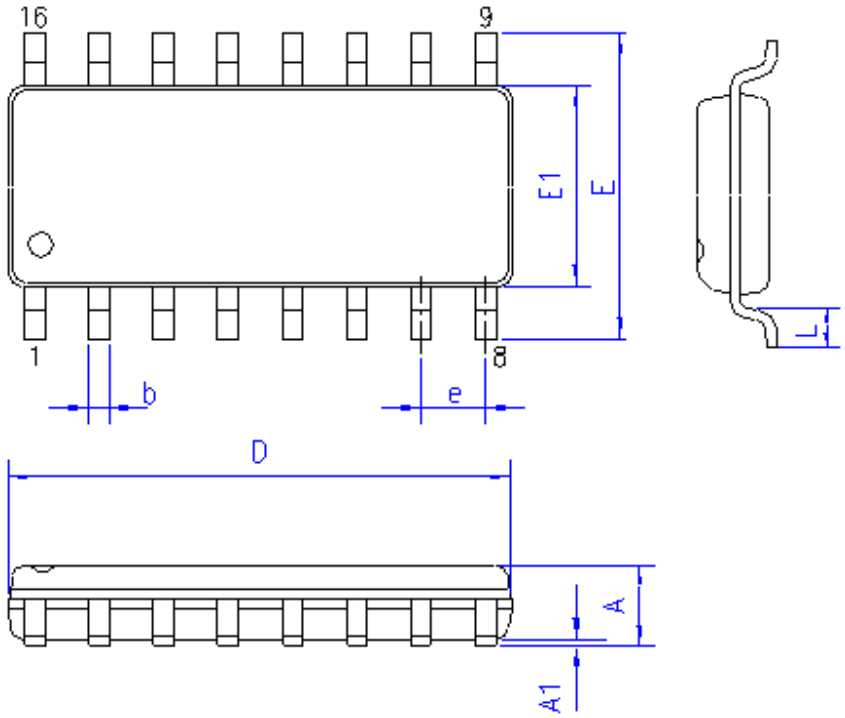


Figure6. 2 Controllers in Parallel Operation Application

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

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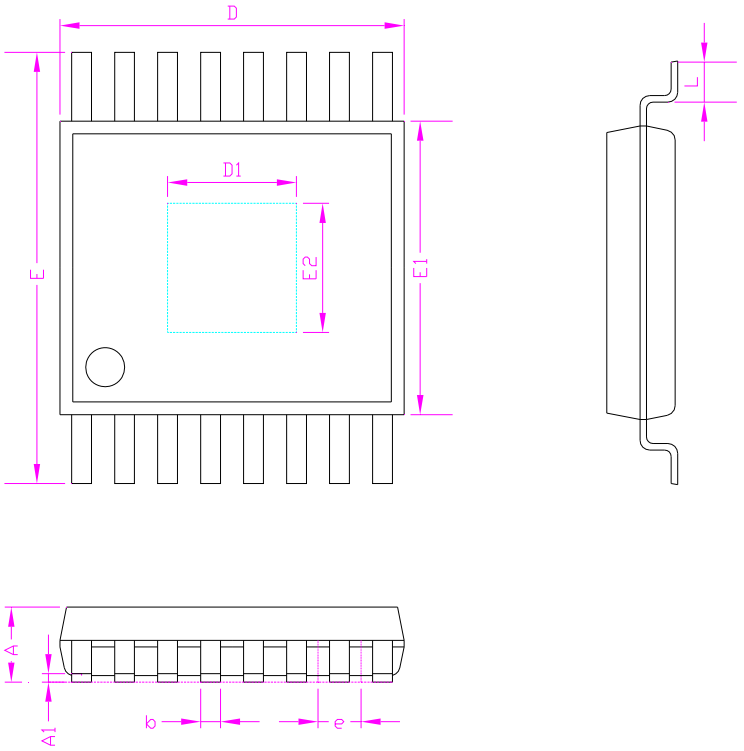

Note: Exposed pad outline drawing is for reference only.

SYMBOLS	MILLIMETERS			INCHES		
	MIN.	Normal	MAX.	MIN.	Normal	MAX.
A	-	-	1.20	-	-	0.047
A1	0.00	-	0.15	0.000	-	0.006
b	0.18	-	0.30	0.007	-	0.012
E1	4.25	4.40	4.55	0.167	0.173	0.179
D	4.85	5.00	5.15	0.191	0.197	0.203
D1	1.98	-	3.15	0.078	-	0.124
E	6.20	6.40	6.60	0.244	0.252	0.260
E2	1.98	-	3.15	0.078	-	0.124
e	0.65 REF			0.026 REF		
L	0.40	-	0.80	0.016	-	0.031