## 60V High Efficiency Four-String Boost LED Driver

General Description

SY7728F is a high efficiency peak current mode boost controller with four matching current sources to drive WLED arrays of LCD backlight.

The device has a wide input voltage range from 4.5V to 30V. The LED current is programmable through a resistor. It also integrates both PWM and Analog dimming function for accurate LED current control.

Ordering Information

SY7728 □(□ □)□

└ Temperature Code
── Package Code
── Optional Spec Code
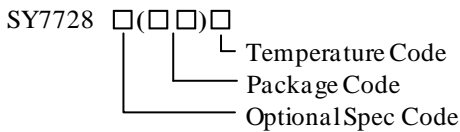
Ordering Number	Package Type	Note
SY7728FFEC	SOP16E	--------
SY7728FFFC	SOP16	--------

Features

- 4.5-30V Wide Input Voltage Range
- Programmable 5mA~240mA LED Current per String
- LED Current with +/-3% Accuracy at 100mA per String
- PWM and Analog Mode Dimming: Dimming Frequency: 100Hz~50 kHz
- +/-1% Current Matching Among Strings at 100mA per String
- Programmable Switching Frequency,100kHz-1MHz
- Internal Soft-start
- Open and Short LED Protection
- Programmable over-voltage Protection
- RoHS Compliant and Halogen Free
- Compact Package: SOP16E&SOP16

Applications

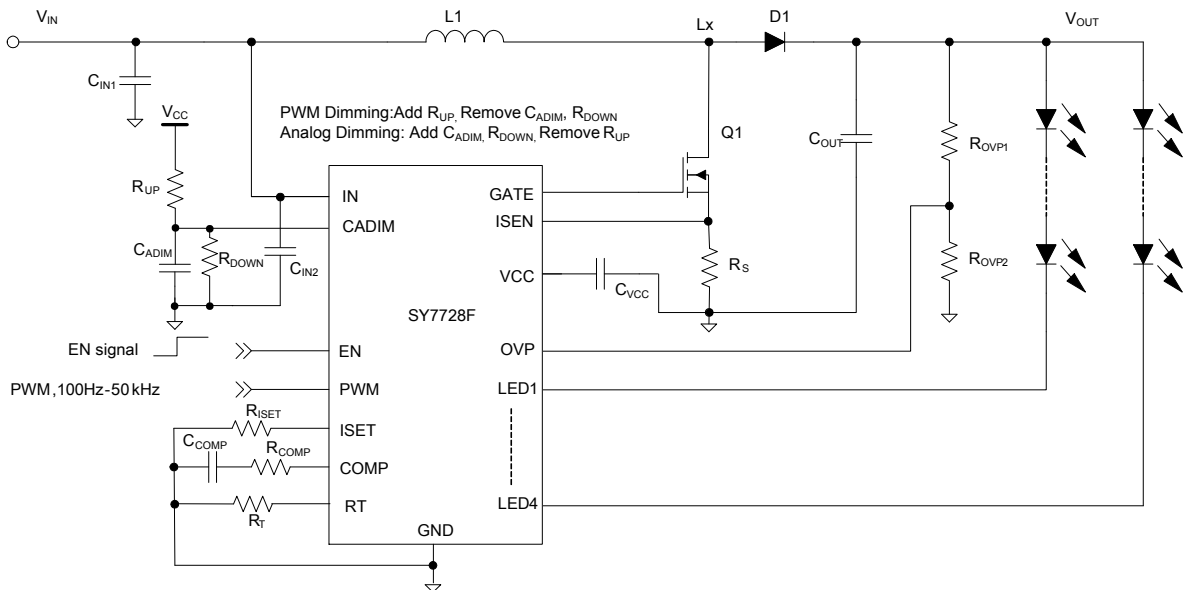- Monitor Panel Backlight
- TV Panel Backlight

Typical Applications

Figure 1. Typical Application Circuit

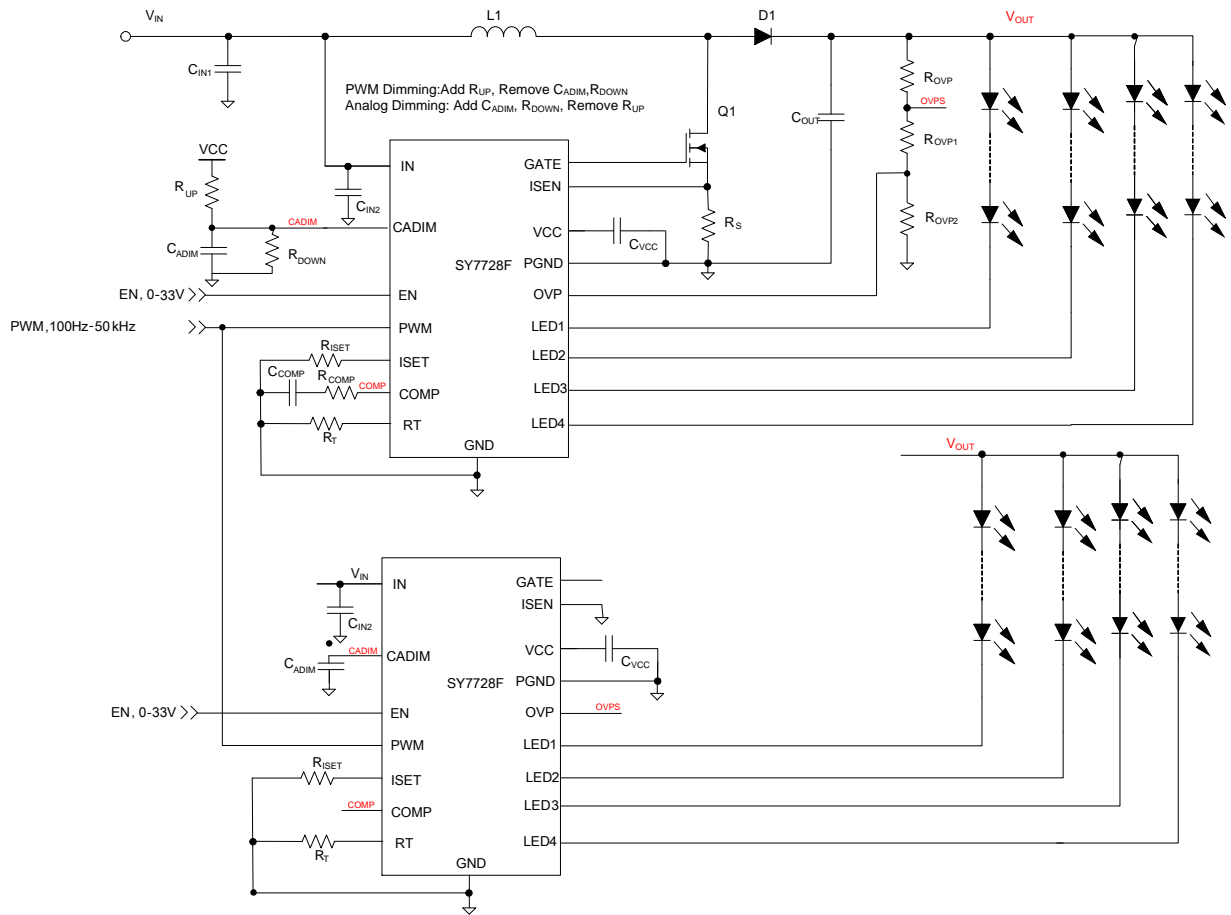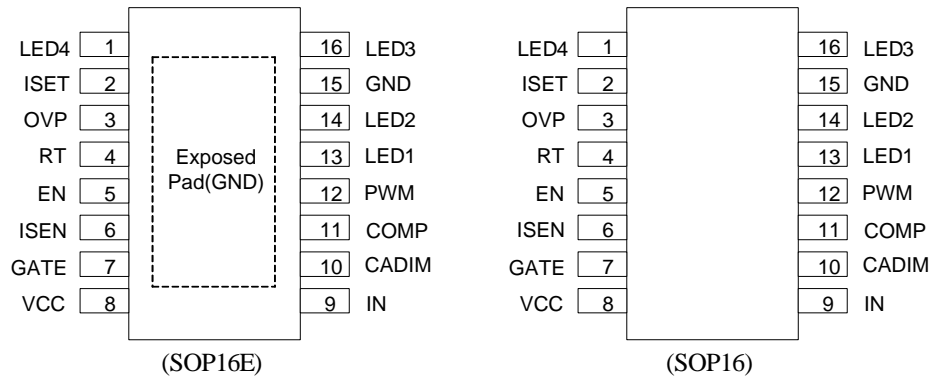## SY7728F REFERENCE APPLICATION CIRCUIT-PARALLEL OPERATION

Figure 2. Typical Application Circuit for 2 Controllers in Parallel Operation
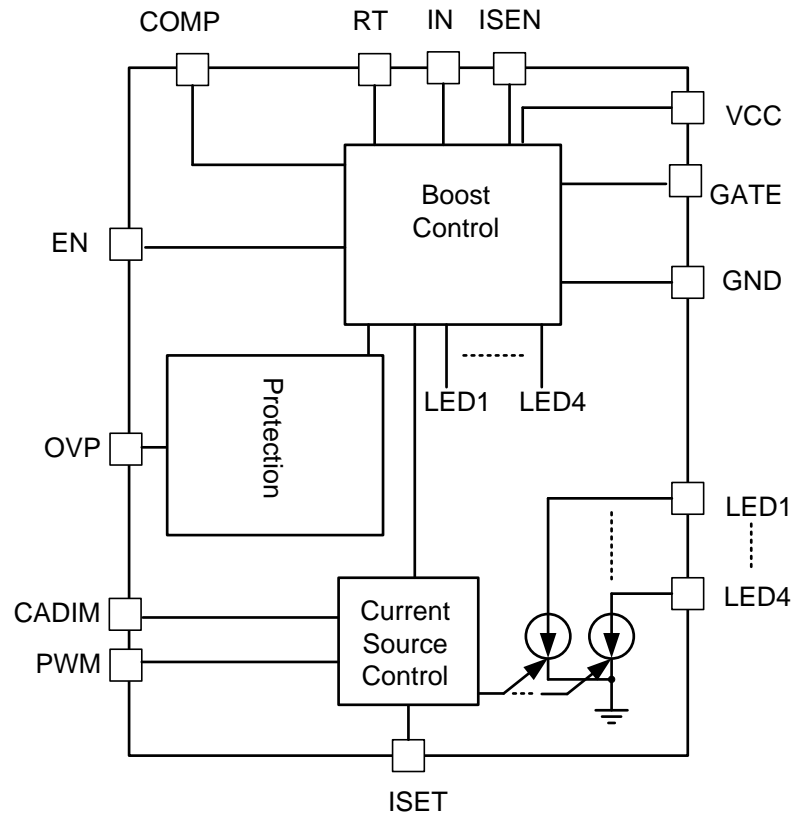
Pinout (top view)

```
        LED4  1 ┌──────────┐ 16  LED3        LED4  1 ┌──────────┐ 16  LED3
        ISET  2 │          │ 15  GND         ISET  2 │          │ 15  GND
        OVP   3 │          │ 14  LED2        OVP   3 │          │ 14  LED2
        RT    4 │ Exposed  │ 13  LED1        RT    4 │          │ 13  LED1
        EN    5 │ Pad(GND) │ 12  PWM         EN    5 │          │ 12  PWM
        ISEN  6 │          │ 11  COMP        ISEN  6 │          │ 11  COMP
        GATE  7 │          │ 10  CADIM       GATE  7 │          │ 10  CADIM
        VCC   8 └──────────┘ 9   IN          VCC   8 └──────────┘ 9   IN
                 (SOP16E)                              (SOP16)
```

Top Mark: CBP *xyz* for SY7728FFEC (Device code: CBP; *x=year code, y=week code, z= lot number code*)
CBG *xyz* for SY7728FFFC (Device code: CBG; *x=year code, y=week code, z= lot number code*)

Pin Name	Pin Number	Pin Description
LED1-4	1,13,14,16	The current source pin for the xth string of LEDs. Connect this pin to the cathode of the LED. If unused, ground this Pin.
ISET	2	LED current programming pin. Connect a resistor to ground to program the current in each LED string between 5mA and 240mA. The LED current equals to: PWM mode ILED=ISET(mA)=Dpwm*1200/RISET(KΩ); Analog mode ILED=ISET(mA)=Dpwm*1200*RDOWN/RISET/(RDOWN+50)(KΩ)
OVP	3	Output over voltage protection. Apply a resistor divider from V_{OUT} to Ground.
RT	4	Operation Frequency Resistor Setting Pin. F_{SW} [MHz] =52/R_T [KΩ]. The frequency can be programmed from 100KHz to 1MHz.
EN	5	Enable Pin. Pull high to enable the chip.
ISEN	6	Current sense input for peak current mode control in Boost switch.
GATE	7	Gate driver output pin.
VCC	8	LDO supply generated from V_{IN} and used to power the GATE driver.
IN	9	Input pin. Decouple this pin to GND pin with 1uF or more ceramic cap. It receives the input from 4.5V to 30V
CADIM	10	Bypass this pin to GND with enough capacitance (such as 1uF ceramic capacitor) to hold on internal voltage reference when used in Analog dimming mode. PWM dimming mode will be selected if this Pin is pulled up to V_{CC}.
COMP	11	Compensation pin.
PWM	12	Dimming signal input, 100Hz~50KHz dimming frequency.
GND	15	IC ground pin.
	Exposed Pad(GND)	Connect the exposed pad to GND plane for maximum power dissipation.

Function Block

COMP   RT   IN   ISEN

VCC

Boost Control

GATE

EN

GND

Protection

LED1   LED4

OVP

LED1

LED4

CADIM

PWM

Current Source Control

ISET

Absolute Maximum Ratings (Note 1)

LEDx --- -0.3 to 60V
IN, EN,CADIM -- -0.3 to 33V
Gate, VCC --- -0.3 to min (15V, VIN+0.3V)
All other pins --- -0.3 to 6V
Power Dissipation, PD @ TA = 25°C SOP16E/SOP16 --2.5W
Package Thermal Resistance (Note 2)

     SOP16E θ_{JA} --- 40°C/W
     SOP16E θ_{JC} -- 20°C/W
     SOP16 θ_{JA} --- 80°C/W
     SOP16 θ_{JC} --- 18°C/W
Junction Temperature Range --150°C
Lead Temperature (Soldering, 10 sec.) --- 260°C
Storage Temperature Range -- -65°C to 150°C

Recommended Operating Conditions (Note 3)

Supply Input Voltage --- 4.5V to 30V
Junction Temperature Range -- -40°C to 125°C
Ambient Temperature Range --- -40°C to 85°C

Electrical Characteristics

(V_{IN} = 12V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		4.5		30	V
Quiescent Current	I_Q	EN="1", PWM="0"		1.9		mA
Shutdown Current	ISHDN	EN="0"		1.4		µA
VCC Voltage	VCC	Vin=12V		10		V
Gate Sink Current				1		A
Gate Source Current				0.8		A
LED Current per Channel Note: Include Balance Rate	$I_{LED1-4(100\%)}$	R_{ISET}=12kΩ , Analog Dimming, Dpwm=100%,Cadim=1uF	97	100	103	mA
LED Current Balance Rate	$I_{LEDmatch(100\%)}$	$I_{LEDmatch}$=(I_{LEDmax}-I_{LEDmin})/($I_{LEDave*2}$)	-	±0.3	±1	%
LED Current per Channel Note: Include Balance Rate	$I_{LED1-4 (5\%)}$	R_{ISET}=12kΩ , Analog Dimming, Dpwm=5%,Cadim=1uF	4.6	5.7	6.8	m A
LED Current Balance Rate	$I_{LEDmatch(5\%)}$	$I_{LEDmatch}$=(I_{LEDmax}-I_{LEDmin})/($I_{LEDave*2}$)	-	±1	±2	%
LED Regulation Voltage	V_{REG}	R_{ISET}=12kΩ		590		mV
IN UVLO Rising Threshold	V_{IN_UVLO}				4.4	V
UVLO Hysteresis	V_{UVLO_HYS}			0.25		V
Thermal Shutdown Temperature	T_{SD}			150		℃
Thermal Recovery Temperature	$T_{recovery}$			130		℃
OVP Rising Threshold	V_{OVP_TH}		1.9	2	2.1	V
OVP Hystersis	V_{OVP_HYS}			103		mV
OSP Falling Threshold	V_{OSP_TH}			40	70	mV
Peak current limitation threshold	V_{ISEN}	Measure the peak voltage of ISEN pin		480		mV
EN Input Low Threshold					0.8	V
EN Input High threshold			2			V
PWM Input Low Threshold					0.8	V
PWM Input High Threshold			2			V
CADIM Output Resistance	R_{ADIM}	Note 4		50		kohm
PWM Mode Threshold	V_{CADIM}			2		V
LED Short Protection Threshold	V_{SCP_TH}		7.3	8	8.7	V
Switching Frequency	F_{SW}	R_T=100kΩ	468	520	572	kHz

Note 1: Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operatio nal sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
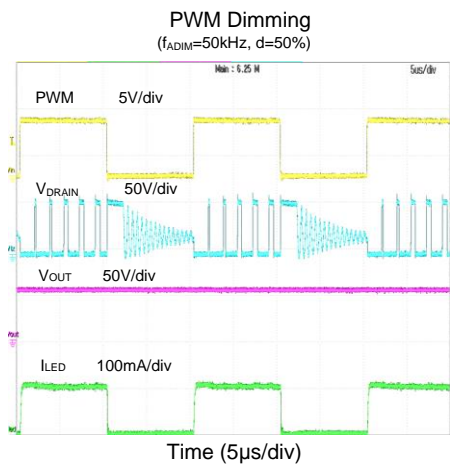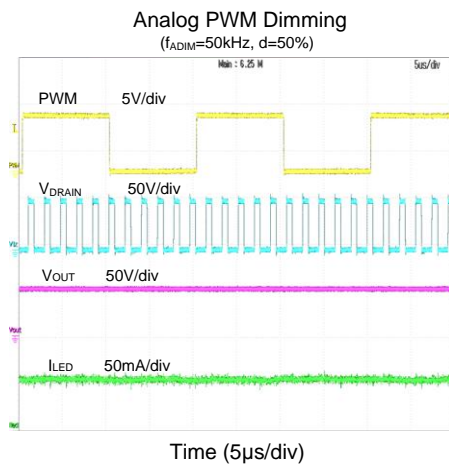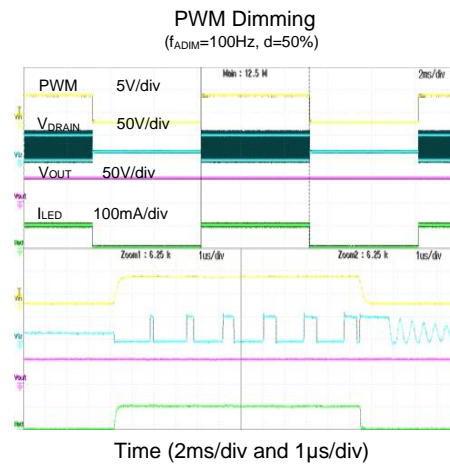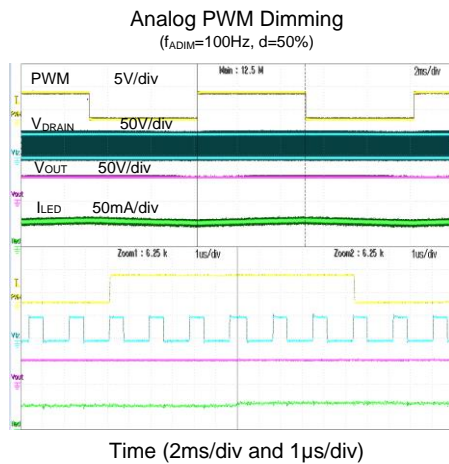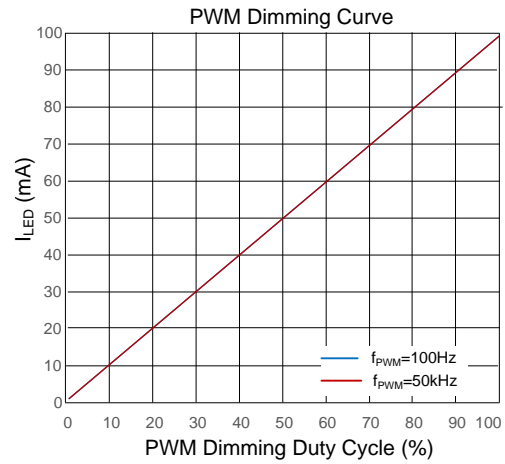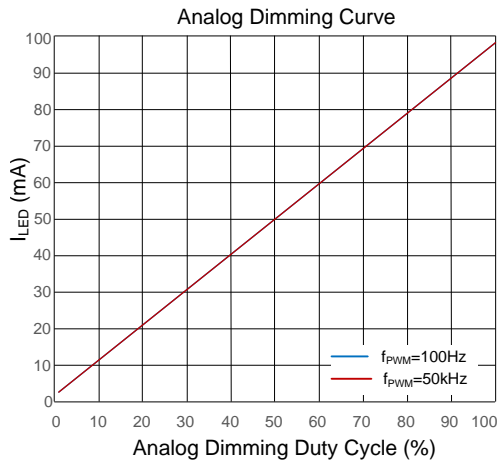
Note 2: θJA is measured according to JESD51-2, 51-7 while ambient temperature=25℃ , θJC is measured in accordance with JESD51-14.

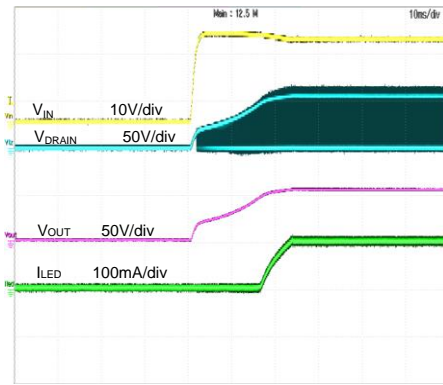**Note 3:** The device is not guaranteed to function outside its operating conditions.

Note 4: This parameter is guaranteed by design.

Note 5: The recommended minimum PWM on time is 1µs.

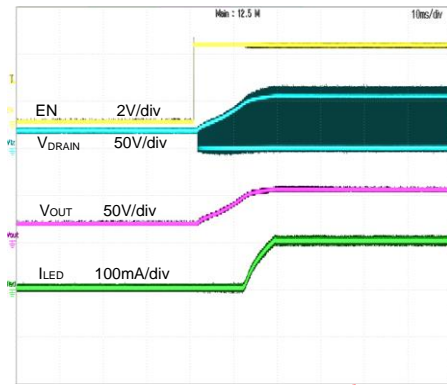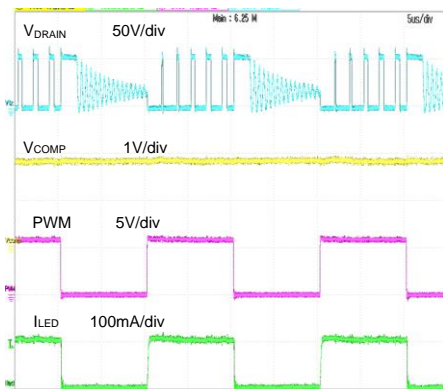## Typical Performance Characteristics (V_{IN}=12V, I_{LED}=100mA, 54V per string, 4 strings)

Analog Dimming Curve

PWM Dimming Curve

Analog PWM Dimming
(f_{ADIM}=100Hz, d=50%)

Time (2ms/div and 1μs/div)

PWM Dimming
(f_{ADIM}=100Hz, d=50%)

Time (2ms/div and 1μs/div)

Analog PWM Dimming
(f_{ADIM}=50kHz, d=50%)

Time (5μs/div)

PWM Dimming
(f_{ADIM}=50kHz, d=50%)

Time (5μs/div)

Startup from V$_{IN}$

Time (10ms/div)

Startup from EN

Time (10ms/div)

Steady State

Time (5µs/div)

Open LED Protection (Open LED2)
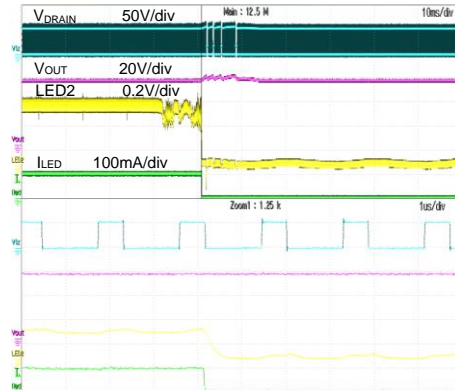
Time (10ms/div and 1µs/div)

Applications Information

The SY7728F contains a peak current mode boost controller and 4-channel matching current sources to drive WLED arrays of LCD backlight. The device works under programmable switching frequency. The internal soft-start function avoids the inrush current during startup. Refer to the block diagram to better understand the operation of the IC.

LED Current Setting:
LED1~LED4 are the 4-channel LED driver outputs. The sinking current of each channel can be programmed with a resistor R_{ISET} connecting from ISET pin to ground:

$$I_{LED}=I_{SET}(mA)= \frac{1200 \times D_{pwm}}{R_{ISET}(Kohm)} \ (PWM)$$

$$I_{LED}=I_{SET}(mA)= \frac{1200 \times D_{pwm} \times R_{DOWN}}{R_{ISET} \times (R_{DOWN}+50)(Kohm)} \ (Ana\ log)$$

For PWM mode R_{ISET}=10KΩ (ohm), the LED current is set to 120mA. The maximum sinking current of each channel is 240mA. For higher current application, different channels can be paralleled. The LED current evenly flow through the paralleled channels because of good current matching.

Input Capacitor CIN:
The ripple current through input capacitor is calculated as:

$$I_{CIN\_RMS} = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{2\sqrt{3} \times L \times F_{SW} \times V_{OUT}}$$

X5R or X7R ceramic capacitors with greater than 4.7uF capacitance are recommended to handle this ripple current. To minimize the potential noise problem, place this ceramic capacitor really close to the IN and GND pins. Care should be taken to minimize the loop area formed by C_{IN}, and IN/GND pins.

Output Capacitor C$_{OUT}$:
The output capacitor is selected to handle the output ripple noise requirements. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). For the best performance, it is recommended to use X5R or better grade low ESR ceramic capacitor. The voltage rating of the output capacitor should be higher than the maximum output voltage. The minimum required capacitance can be calculated as:

$$C_{OUT} = \frac{n \times I_{LED} \times (V_{OUT} - V_{IN})}{F_{SW} \times V_{OUT} \times V_{RIPPLE}}$$

V_{RIPPLE} is the peak to peak output ripple, n is the number of LED string.
For LED applications, the output capacitance should be large enough to attenuate the V_{LEDX} ripple voltage. For most applications, a 4.7μF ceramic capacitor in parallel with a 47uF electrolytic capacitor will be sufficient.

Inductor L:
There are several considerations in choosing this inductor.
1) Choose the inductance to provide the desired ripple current. The inductance is calculated as:

$$L = \left(\frac{V_{in}}{V_{out}}\right)^2 \times \frac{(V_{out} - V_{in}) \times \eta}{n \times I_{led} \times F_{sw} \times \frac{\Delta I_L}{I_L}} (for\ CCM)$$

$$Select\ \frac{\Delta I_L}{I_L} = 0.4{\sim}2 (for\ CCM)$$

Where F_{SW} is the switching frequency, n is the number of LED string , I_{LED} is the current of each LED string, Vin is input voltage, Vout is output voltage , ΔI_L is total inductor current ripple, I_L is inductor average current.

2) The saturation current rating of the inductor must be selected to be greater than the peak inductor current under full load conditions.

$$I_{sat\_min} > \frac{V_{out} \times n \times I_{led}}{V_{in} \times \eta} + \frac{V_{in} \times (V_{out}-V_{in})}{V_{out} \times L \times F_{sw} \times 2} \quad (for\ CCM)$$

Where η is total efficiency.
3) The DCR of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement.

Main MOSFET Selection:
The choice of the main MOSFET depends on the current through MOSFET, the maximum V_{DS} voltage, the switching frequency, the capability of the MOSFET to dissipate heat.
The maximum RMS current through MOSFET is given by:

$$I_{mos\_rms} = \frac{V_{out} \times n \times I_{led}}{V_{in} \times \eta} \sqrt{\frac{(V_{out} - V_{in})}{V_{out}}} \sqrt{1 + \frac{1}{3}(\frac{\Delta I_L}{2 \times I_L})^2} \quad (for\ CCM)$$

The maximum drain to source voltage equals the output voltage.

Rectifier Diode Selection:
Because of high switching speed of SY7728F, a Schottky diode with low forward voltage drop and fast switching speed is desirable for the application. The voltage rating of the diode must be higher than maximum output voltage. The diode's average and peak current rating should exceed the average output current and peak inductor current.

Internal 10V LDO:
VCC is the output of internal LDO. Connect a 1uF capacitor from VCC pin to ground. This LDO provides 10V power supply for the external MOSFET gate driver. The typical dropout voltage of the LDO is 200mV. VCC drops to 0 when the IC shuts down.

Open LED Protection:
When any LED string is open, the respective LEDx pin will be pulled to ground. SY7728F continues charging the output voltage until over voltage protection is triggered. Then the part stops switching and checks the condition of all the LEDx pins. The part will mark off and disable the one which voltage is below 100mV. Then the output of boost slowly drops because of the load current. The IC resumes switching once the V_{OUT} goes back to the regulation value. When all LED strings are open, over voltage protection is triggered, the IC will turn off the boost converter.

Short LED Protection:
When any diode on the LED string becomes shorted, the LEDx voltage on that string may exceed V_{SCP_TH} (typical 8V), and short LED fault is detected. If short LED fault lasts for more than 15mS (typical value), the IC will mark off and disable that string. When all strings are marked off, the IC will also latch off the boost converter. Recycling input power or enable signal to turn on the disabled string after fault condition is removed.

No Rectifier Diode Protection:
When the chip is enabled, SY7728F will check the connection of the rectifier diode by sensing the voltage on OVP pin. If the voltage on OVP pin is lower than V_{OSP_TH} (typical 40mV), the IC will shut down.

Peak Current Limitation:
The device employs cycle by cycle current limitation to protect the main FET of Boost circuit. When the peak current sensing voltage (V_{ISEN}) exceeds 480mV (typical value), the device will turn off the main FET. The FET will turn on again until next clock signal arrives.

Diode/Inductor Short-Circuit Protection:
When Diode/Inductor Short is happened, the current flow through Boost MOSFET will increase significantly. If the voltage on ISEN pin exceeds approximately 0.58V during the ON period of the boost MOSFET. If the short last for about 15ms during PWM on time, The IC will shut off and stay latched after timer expires. Timer will be reset if ISEN pin voltage drops below 0.58V for eight (8) consecutive clock cycles.

Over Temperature Protection:
To prevent the IC from over temperature, the device will shutdown when the junction temperature exceeds 150℃. When the junction temperature decrease to 130 ℃,IC will resume to switching.

Abnormal Working when VIN>VLED:
If VIN>LED Forward Voltage at EN on, which may cause VLEDX>LED regulation voltage last for about

15ms then the boost converter will be latched off. Need to avoid such application condition.

High Output Voltage Application:
In applications when the LED string voltage is higher than the maximum voltage rating of LEDx pins, a high voltage rating external MOSFET can be used as shown below to prevent the IC from damage.
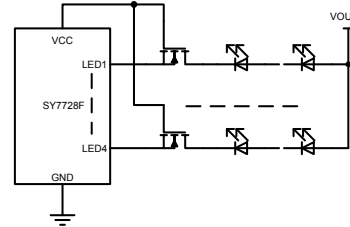
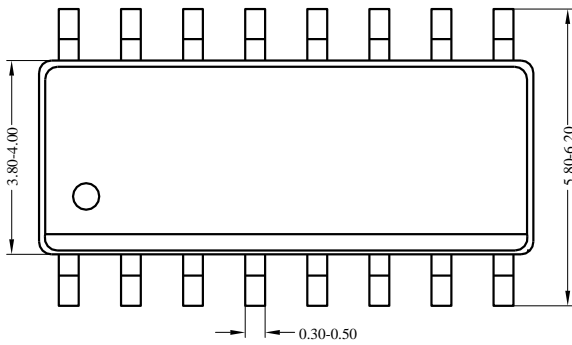**Multiple Controllers in Parallel Operation：**
For applications having more than 4 LED strings, designer can use multiple controllers for parallel operation. A reference circuit is illustrated in Figure 2.Both controllers share the common Boost converter power train for 8 strings of LED operation.
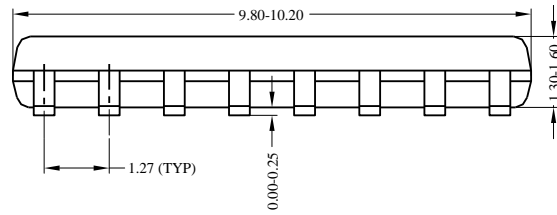
Layout Design:
Proper PCB layout and components placement are critical to the performance of the IC and to prevent noise and electromagnetic interference problems. Following are some rules for the PCB layout:

1) The loop of main FET, rectifier diode, and output capacitor must be as short as possible
2) It is desirable to maximize the PCB copper area connecting to GND pin to achieve the best thermal and noise performance. If the board space allowed, a ground plane is highly desirable.
3) C_{IN} must be close to Pins IN and GND. The loop area formed by C_{IN} and GND must be minimized.
4) The PCB copper area associated with main FET drain must be minimized to avoid the potential noise problem.
5) The small signal components must be placed close to IC and must NOT be adjacent to the main FET drain net on the PCB layout to avoid the noise problem.
6) The GND of ceramic capacitor of C_{ADIM} must be placed as closed as GND pin (pin 15) to avoid noise interference in analog dimming application.
7) Boost rectifier diode/inductor short protection is achieved by detecting the voltage between ISEN pin (pin 6) and GND pin (pin 15).The current is very high when short fault occurs, the trace between the source pole of boost main FET and current sense resistor, the trace between the drain pole of boost main FET and anode of boost rectifier diode/inductor must be as short and wide as possible.
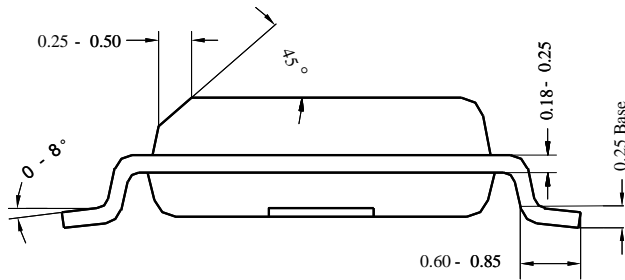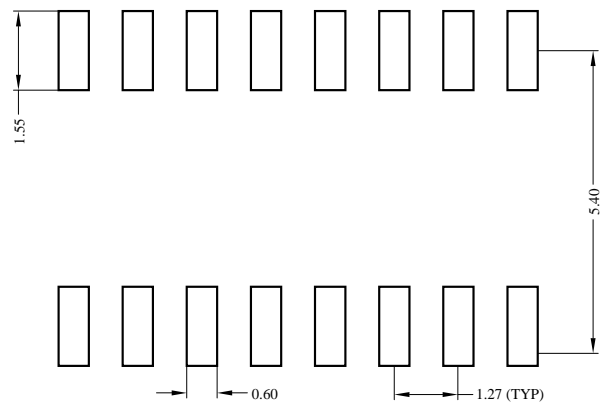
SOP16 Package Outline & PCB Layout

Top view

3.80-4.00

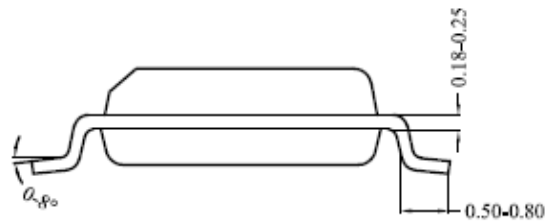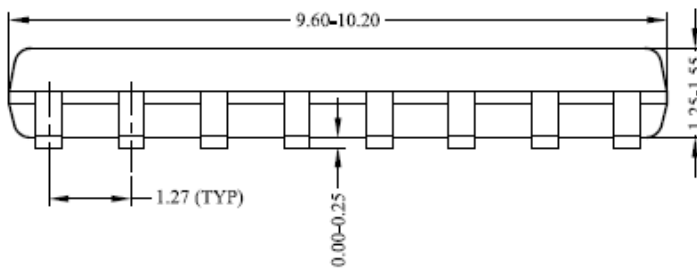5.80-6.20

0.30-0.50

Front view

9.80-10.20

1.30-1.60

1.27 (TYP)

0.00-0.25

Side view

0.25 - 0.50

45°

0.18 - 0.25

0.25 Base

0 - 8°

0.60 - 0.85

Recommended PCB layout

1.55

5.40

0.60

1.27 (TYP)

Notes: **All dimension in millimeter and exclude mold flash & metal burr**
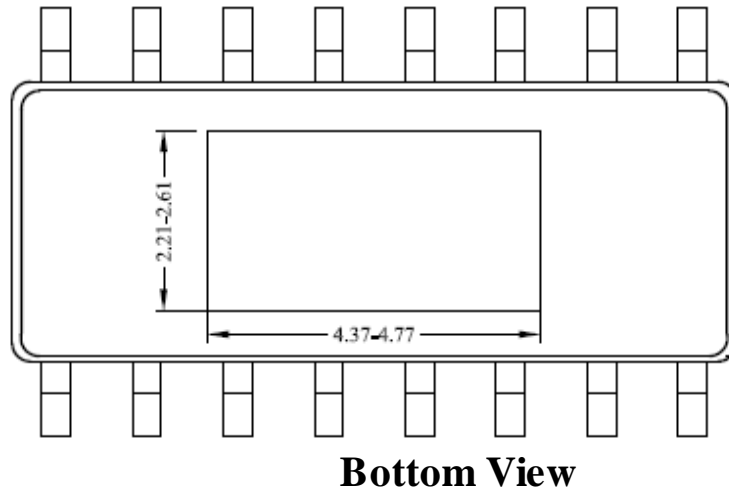
SOP16E Package Outline & PCB Layout

Top View

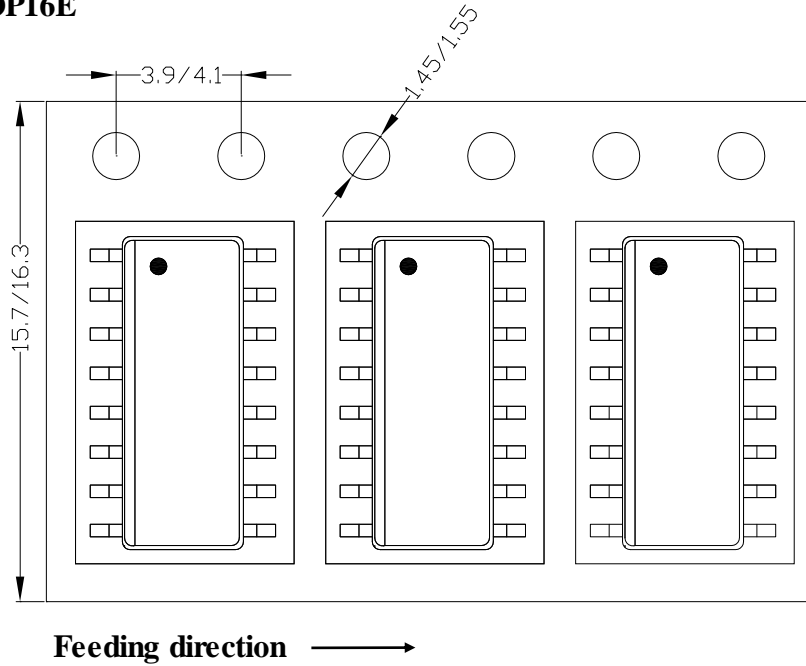**Bottom View**

Side View A   **Side View B**
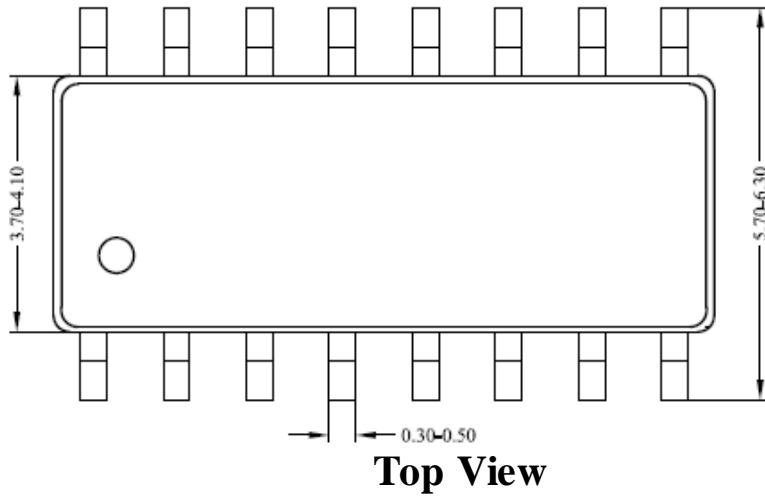
Notes: All dimension in millimeter and exclude mold flash & metal burr

Taping & Reel Specification

1. Taping orientation

SOP16&SOP16E

3.9/4.1

1.45/1.55

15.7/16.3

Feeding direction ⟶

2. Carrier Tape & Reel specification for packages

Reel Width
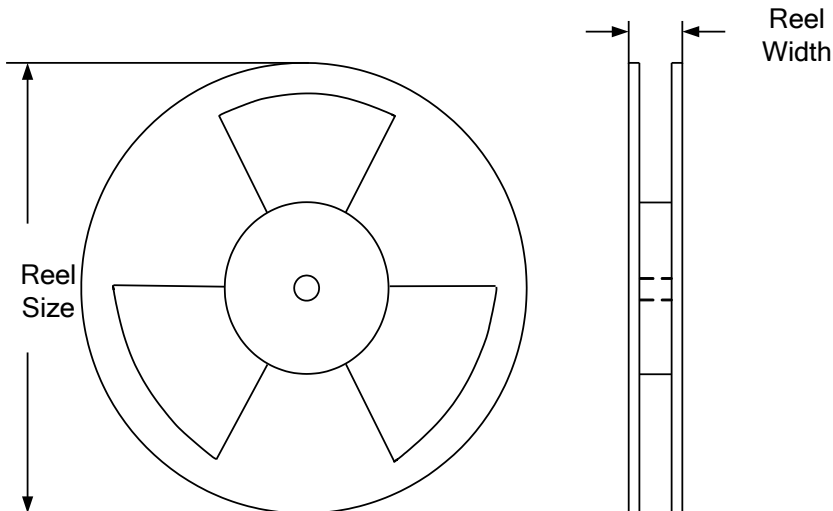
Reel Size

Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Reel width(mm)	Trailer length(mm)	Leader length (mm)	Qty per reel
SOP16 & SOP16E	16	8	13"	12.4	400	400	2500

3. Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
March 16, 2021	Revision 0.9B	Add Abnormal Working when VIN>VLED
January 7,2020	Revision 0.9A	Update the formula in application information
April 17,2019	Revision 0.9	Initial Release