

### GENERAL DESCRIPTION

The SP7616 is a 30V 4-Channel linear low side LED driver. It is capable of powering up to four LED strings of nine LEDs @ 60mA per string for a total of 36 LEDs with 1.5% typical current matching between channels. The desired LED current can be adjusted with an external resistor, and the precision string-to-string current matching ensures consistent color temperature across the whole display. The device also features very low dropout voltage to maximize system efficiency and avoid difficult thermal design constraints. Dimming can be achieved by feeding a PWM signal to the PWM pin, or use an analog signal to control the ISET current, this allows brightness control without unwanted color shifts. Fast LED current turn-on/off time allows up to 5 kHz PWM dimming frequencies with as low as 10% duty cycle, completely eliminating flicker. The built-in thermal protection prevents damage to the device under fault conditions.

### APPLICATIONS

- CCFL replacement in TFT displays
- Panel backlighting
- Casino gaming light systems
- Advertising backlighting

### FEATURES

- Wide 4.5V to 30V operating range
- 60mA LED current per channel
- 1.5% channel to channel current matching
- Analog Dimming control
- PWM operation up to 5kHz with 10% Duty Cycle
- Low dropout: 150mV @ 20mA
- Built-in Over Temperature Protection
- Small 2X3mm DFN package
  - Lead Free, RoHS Compliant

### TYPICAL APPLICATION DIAGRAM

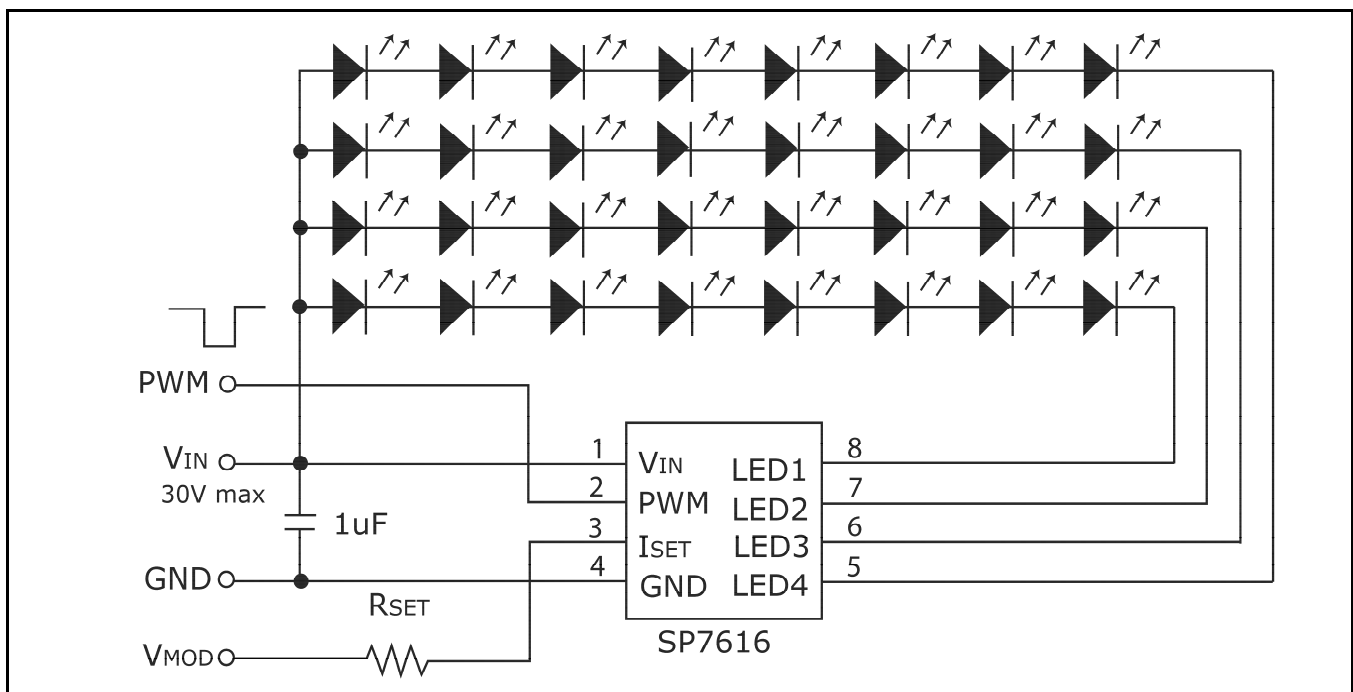


Fig. 1: SP7616 Application Diagram



# SP7616

## High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement

### ABSOLUTE MAXIMUM RATINGS

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

$V_{IN}$ ..... -0.3V to 32V  
 LED1, LED2, LED3, LED4 ..... -0.3V to 32V  
 $I_{SET}$ , PWM ..... -0.3V to 6.0V  
 Storage Temperature..... -65°C to 150°C  
 Power Dissipation ..... Internally Limited  
 Lead Temperature (Soldering, 10 sec) ..... 300°C

### OPERATING RATINGS

Input Voltage Range  $V_{IN}$ .....4.5V to 30V  
 Junction Temperature Range .....-40°C to 100°C  
 Thermal Resistance  $\theta_{JA}$  ..... 59°C/W  
 ESD Rating (HBM - Human Body Model) .....2kV  
 ESD Rating (MM - Machine Model)..... 500V  
 Operating Junction Temperature ..... -40°C to +125°C  
 Power Dissipation.....Internally Limited

### ELECTRICAL SPECIFICATIONS

Specifications with standard type are for an Operating Junction Temperature of  $T_J = 25^\circ\text{C}$  only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = 25^\circ\text{C}$ , and are provided for reference purposes only. Unless otherwise indicated,  $V_{IN} = 4.5\text{V}$  to  $30\text{V}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$ .

Parameter	Min.	Typ.	Max.	Units	Conditions
Operating Input Voltage Range	4.5		30	V	•
Shutdown Supply Current		30	60	$\mu\text{A}$	Voltage at $I_{SET}$ is pulled to 3V $V_{IN}$ 30V
Quiescent Supply Current		350	500	$\mu\text{A}$	No LED connected, $V_{LED}$ pins are tied to GND. $R_{SET}=1\text{M}\Omega$
Quiescent Supply Current		1	1.5	mA	$I_{LED} = 30\text{mA}$
Quiescent Supply Current		1.5	3	mA	$I_{LED} = 60\text{mA}$
LED Current Matching	-3	0.5	3	%	• Relative to average of all 4 channels
LED Current Line Regulation		0.1	1	%/V	$V_{LED} = 0.5\text{V}$ to $25\text{V}$ , $V_{IN} = 28\text{V}$ , $R_{SET} = 50\text{k}\Omega$
Line Regulation		0.05	0.1	% / V	$V_{IN} = 4.5\text{V}$ to $25\text{V}$ , $V_{LED}=0.5\text{V}$ (Note 2)
Maximum LED Current per channel		60		mA	$R_{SET} = 17.4\text{k}\Omega$ ,
LED Leakage Current			2	$\mu\text{A}$	PWM pin LOW, $V_{LED} = 1\text{V}$ , $V_{IN}= 5\text{V}$
Dropout Voltage		0.30	0.45	V	(Note 3)
Output Current Multiplication Ratio $K = I_{LED} \cdot R_{SET}$	1032	1075	1118		$I_{LED} = 30\text{mA}$ , $R_{SET}=35.833\text{k}\Omega$ , • $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$
$I_{SET}$ Voltage		1		V	
Thermal Shutdown Die Temperature		150		$^\circ\text{C}$	$I_{LED} = 0\text{mA}$ . LED current will self recover when temperature drops below the trip point, minus thermal shut down hysteresis.
Thermal Shutdown Hysteresis		15	20	$^\circ\text{C}$	
PWM Pin Logic LOW			0.8	V	Driver is disabled
PWM Pin Logic HIGH	2.4		5.5	V	Driver is active
PWM pin Hysteresis		400		mV	
$I_{SET}$ Shutdown Threshold			3	V	• If $I_{SET}$ is pulled above this threshold the device goes into full shutdown
$I_{SET}$ Shutdown Threshold Hysteresis		0.3		V	
Typical PWM Maximum Dimming Frequency			5	kHz	Applied to PWM pin. See typical performance curves.
Typical PWM Dimming Duty Cycle Range	10		90	%	Applied to PWM pin @ 5kHz. See typical performance curves.



# SP7616

## High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement

Parameter	Min.	Typ.	Max.	Units	Conditions
Turn-on time from Shutdown		100	300	$\mu\text{s}$	$V_{\text{MOD}}$ from 5V to 0V, $R_{\text{SET}} = 50\text{k}\Omega$
Turn-off time into Shutdown			20	$\mu\text{s}$	$V_{\text{MOD}}$ from 0V to 5V, $R_{\text{SET}} = 50\text{k}\Omega$

Note 1:  $I_{\text{LED}}$  Variations from specified by  $R_{\text{SET}}$  value at  $V_{\text{LED}}$  changing from 0.5 to 25V

Note 2:  $I_{\text{LED}}$  Variations from specified by  $R_{\text{SET}}$  value at  $V_{\text{IN}}$  changing from 4.5 to 25V

Note 3:  $R_{\text{SET}} = 31.6\text{k}\Omega$ : Dropout voltage is measured as the  $V_{\text{LED}}$  voltage where LED current drops 5% from nominal value

### BLOCK DIAGRAM

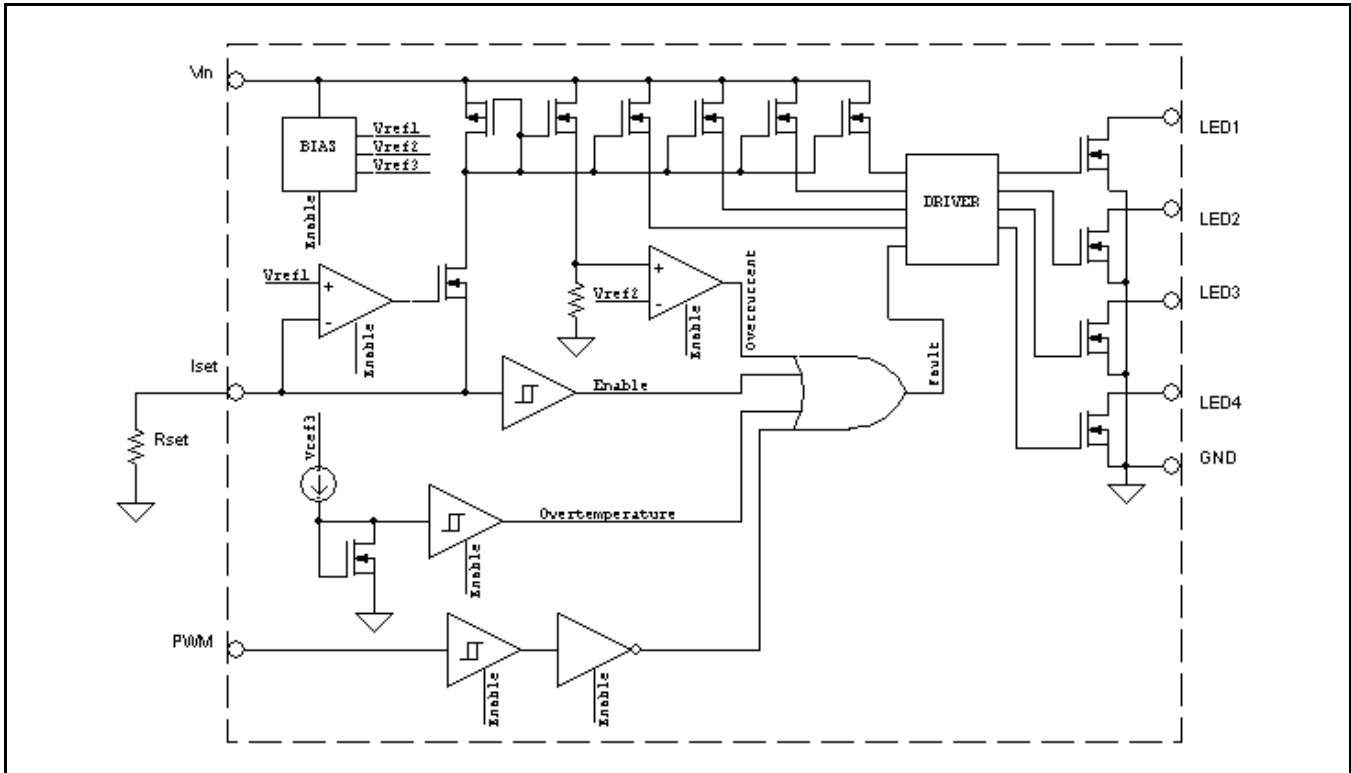


Fig. 2: SP7616 Block Diagram

### PIN ASSIGNMENT

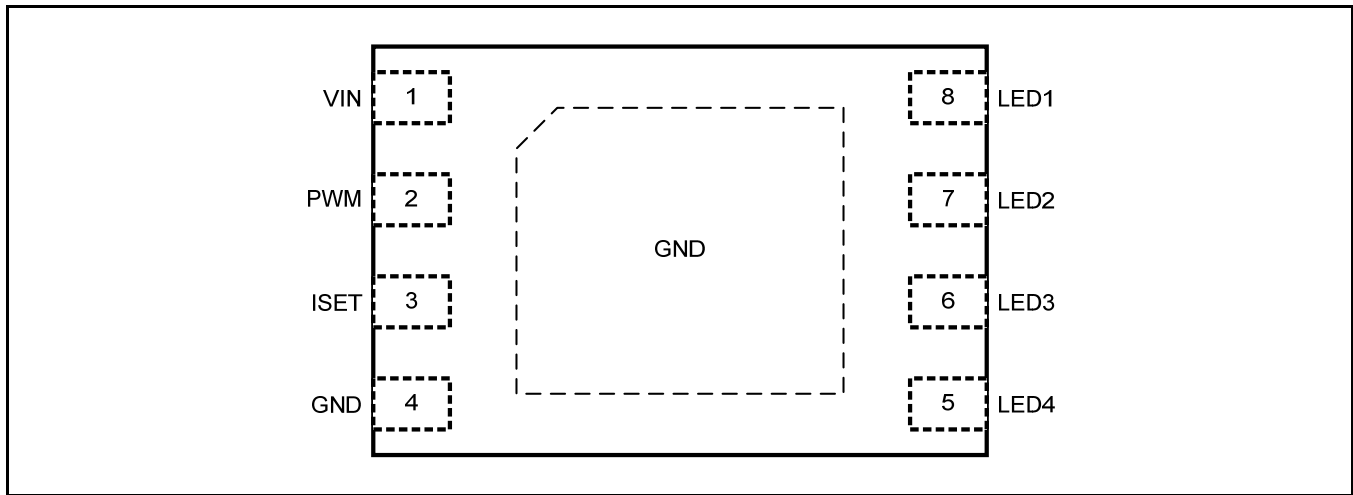


Fig. 3: SP7616 Pin Assignment

### PIN DESCRIPTION

Name	Pin Number	Description
VIN	1	Input voltage for the IC. Connect a 1uF decoupling capacitor between this pin and ground.
PWM	2	This pin must be held high to enable the output drivers. It can be used for PWM dimming up to 5 kHz.
ISET	3	Connect resistor RSET from this pin to ground to set output current. Pulling this pin above the shutdown threshold stated in the Electrical Specifications puts the IC into shutdown mode.
GND	4	Ground return for LED currents and circuitry of the SP7616.
LED1-4	5 - 8	Connect an LED between each pin and $V_{IN}$ . Current value is controlled by RSET. The current level through each pin is internally matched within 3%. Connect unused channel(s) to GND to save current consumption.

### ORDERING INFORMATION

Part Number	Temperature Range	Marking	Package	Packing Quantity	Note 1	Note 2
SP7616ER-L	$-40^{\circ}\text{C} \leq T_j \leq +125^{\circ}\text{C}$		8pin 2x3DFN	Bulk	Lead Free and/or Halogen Free	
SP7616ER-L/TR	$-40^{\circ}\text{C} \leq T_j \leq +125^{\circ}\text{C}$		8pin 2x3DFN	3K/Tape & Reel	Lead Free and/or Halogen Free	
SP7616EB	SP7616 Evaluation Board					

"YY" = Year - "WW" = Work Week - "X" = Lot Number

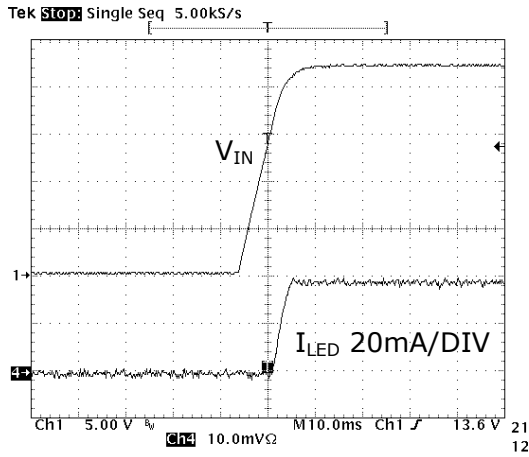


# SP7616

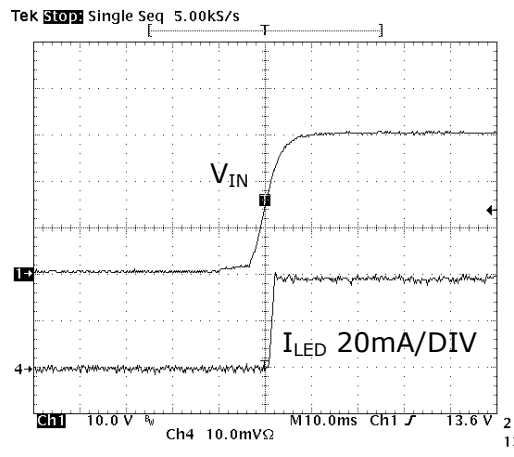
## High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement

### TYPICAL PERFORMANCE CHARACTERISTICS

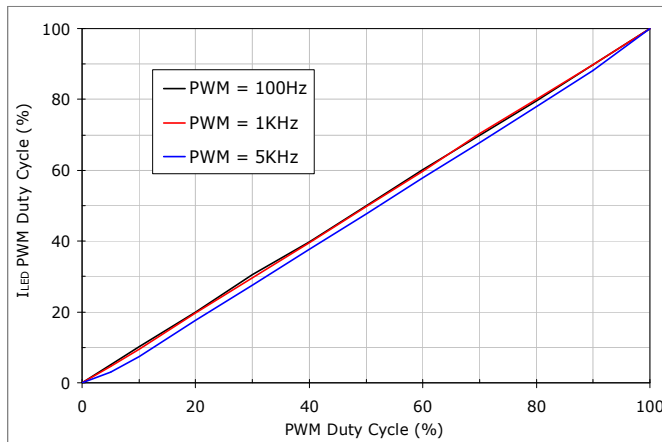
All data taken at  $V_{IN} = 8V$ ,  $T_J = T_A = 25^\circ C$ , unless otherwise specified.



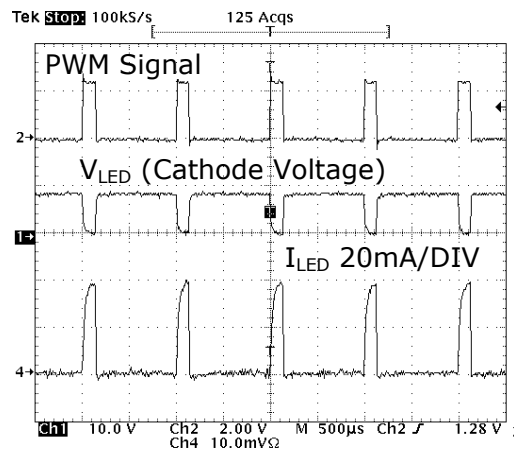
Typical Turn on Characteristics



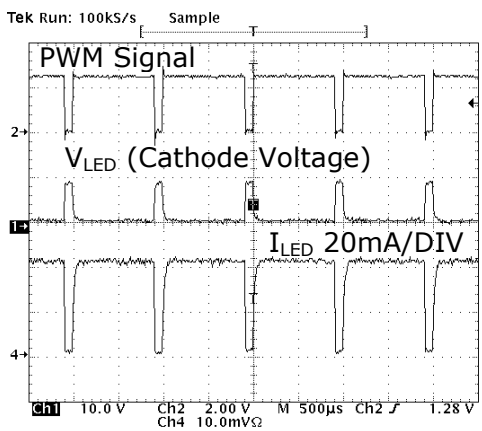
Typical Turn Maximum Input Voltage



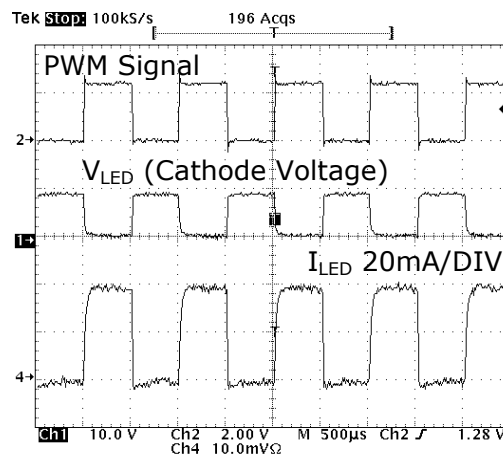
PWM Duty Cycle Linearity



PWM Response 1kHz 10% Duty Cycle



PWM Response 1kHz 90% Duty Cycle

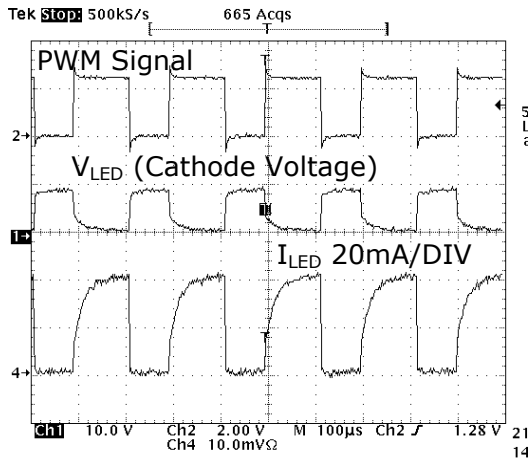


PWM Response 1kHz 50% Duty Cycle

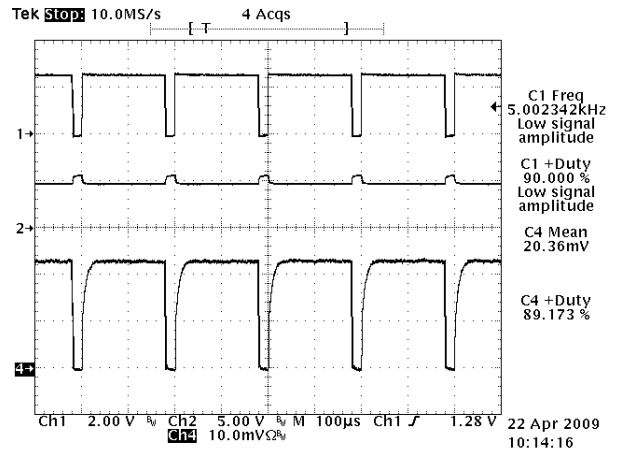


# SP7616

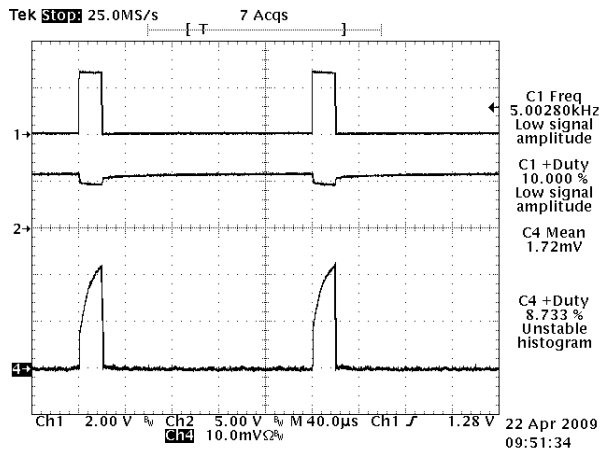
## High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement



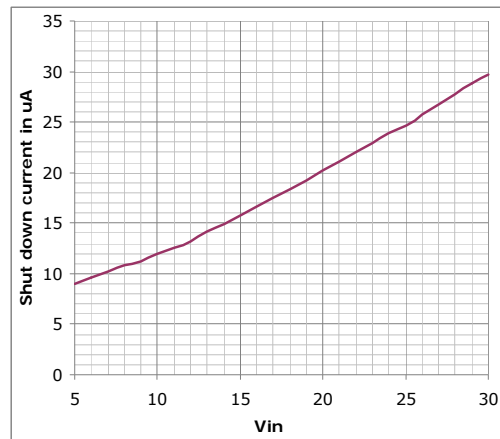
PWM Response 5kHz 50% Duty Cycle



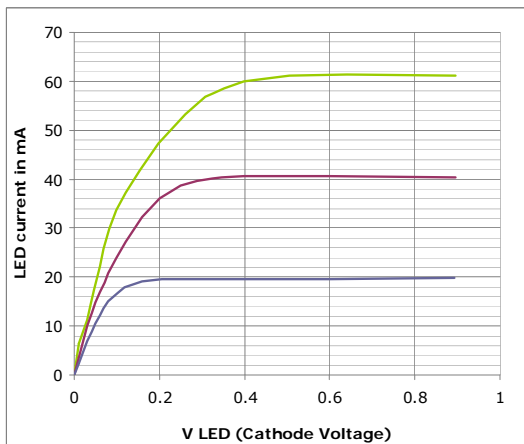
PWM Response 5kHz 90% Duty Cycle



PWM Response 5kHz 10% Duty Cycle



Typical Shutdown Current vs Input Voltage



Typical Dropout Performance

### THEORY OF OPERATION

#### INTRODUCTION

The SP7616 is a four-channel constant current source LED driver with programmable output current level. The design consists of a regulator reference voltage source, current amplifier, and output driver. The precision reference voltage ensures good performance over voltage and temperature. The four outputs are tightly coupled allowing for excellent LED current matching.

#### SETTING LED CURRENT

The current in the LED strings is set by adjusting the  $R_{SET}$  resistor connected between the  $I_{SET}$  pin and ground. The LED current is set using the following equation.

$$I_{LED} = \frac{K}{R_{SET}} mA$$

Where:

K = Output Current Multiplication Ratio

$I_{LED}$  is the desired LED current

#### PWM DIMMING

The LED dimming control is done through the PWM pin. The acceptable frequency range of this signal is 100Hz to 5kHz. The acceptable duty cycle range of the signal is 10% to 90% at 1KHz. When the PWM pin is driven low, only the LED current sources are disabled while the rest of the chip is still enabled.

#### ANALOG DIMMING CONTROL

Besides digital PWM control, the LED current can be controlled continuously (from high to low LED current) by raising the voltage at the bottom of  $R_{SET}$ ,  $V_{MOD}$ , from 0.0V to 1V maximum. This configuration is shown in figure 1 below.

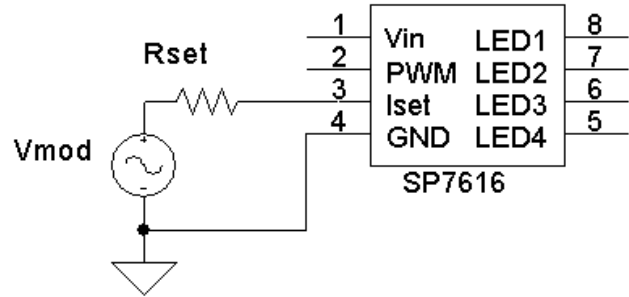


Figure 1

The  $R_{SET}$  value may be determined from the previous equation for  $V_{MOD} = 0V$ . The equation below shows the effect of using a  $V_{MOD}$  in the circuit on the LED current.

$$I_{LED} \approx (1V - V_{MOD}) \frac{K}{R_{SET}} mA$$

Where:

1V = Typical  $I_{SET}$  Voltage

K = Output Current Multiplication Ratio

$I_{LED}$  is the desired LED current

$V_{MOD}$  is the adjustment voltage

Note that this method of current control is not as precise as adjusting  $R_{SET}$ . The voltage at the  $I_{SET}$  pin is adjusted slightly during manufacturing to ensure that K, the output current multiplication ratio, is as accurate as possible. When the SP7616 was originally released at the end of 2006, the multiplication ratio and  $I_{SET}$  voltage were specified separately. However, market feedback for better accuracy when using  $R_{SET}$  alone prompted the change to the way the part is specified today.

#### SHUTDOWN USING $I_{SET}$ PIN

In normal operation, the voltage at  $I_{SET}$  pin is around 1V. To ensure fast turn on at low duty cycle and high PWM frequency, only the output drivers are switching in PWM mode. However, the whole chip can be shutdown by pulling the voltage at  $I_{SET}$  above 3V minimum.



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## High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement

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### **V<sub>IN</sub> CONSIDERATIONS (IMPORTANT)**

The V<sub>IN</sub> pin of the SP7616 (Pin 1) needs to be connected to the anode of the LED for proper operation. If these are not tied together, the part can get into a latch condition as a result of improper sequencing.

A second way the part can get into a latch condition is if the input voltage falls below 1.5V but does not fall below 0.5V before the power is re-applied.

In both cases, the latch condition can be "reset" by pulling the input voltage below 0.5V for >3 seconds. This latch is similar to what one might experience with a uC if a reset was not asserted after a brown out condition.

### **UNUSED CHANNELS AND LED 2 CHANNEL (PIN 7)**

LED 2 channel should never be grounded or left unconnected it should always be used during operation. Other unused channels can be tied to the ground to save on power consumption.

### **SHORTED LEDs**

If all LEDs on a string are shorted, the LED cathode voltage will be V<sub>IN</sub>. It is still a working condition for this device but it significantly increases the dissipated power.

At 20mA LED current and V<sub>IN</sub> = 30V additional power dissipated in the package is equal to 600mW that will increase die temperature to 59°C/W x 0.6W = 35.4C, where 59°C/W is the package thermal resistance. Assuming that all other channels are working at V<sub>LED</sub> = 1.5V the die temperature will be approximately 41°C above ambient temperature and that decreases operating temperature range. Also to protect the part if too many LEDs are shorted, and the V<sub>LED</sub> voltage becomes too high, making the part dissipates too much power, the over temperature protection will shut the part off when the die temperature reaches approximately 150°C.

### **OVER-TEMPERATURE PROTECTION**

The SP7616 has over-temperature protection to prevent permanent damage to the device. When the die temperature rises above 150°C the output drivers are shut off. The output current will self recover when the temperature drops below the trip point with the preset hysteresis of 15°C. Thus a part that shut off at 150°C will not try to restart unless the die temperature is below 135°C



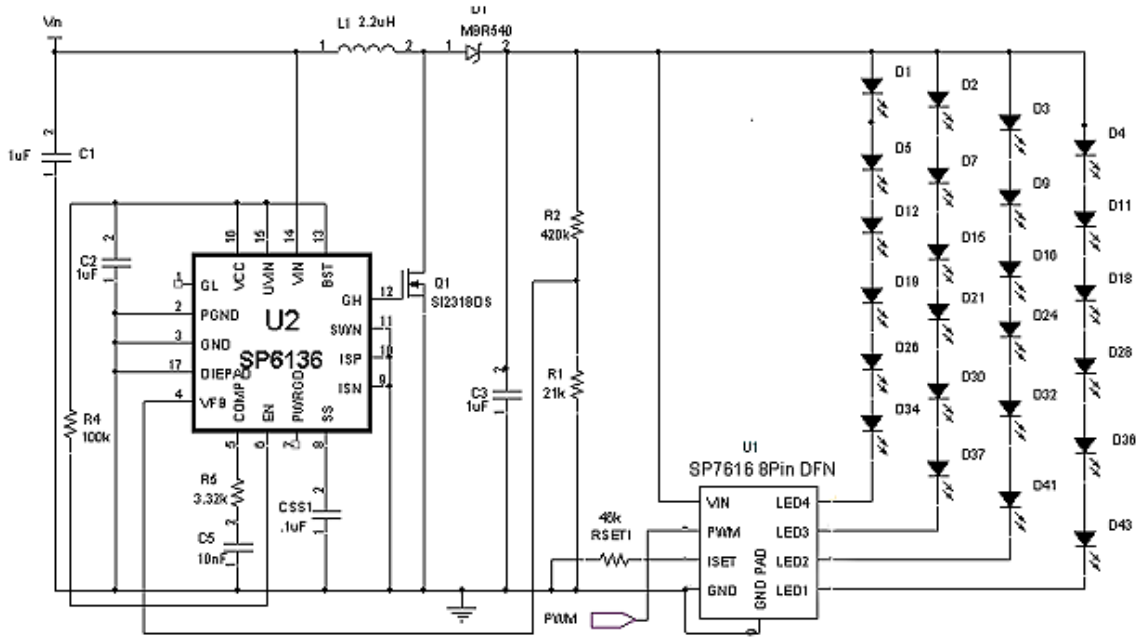


Figure 2  
Typical Application: CCFL Replacement powered from 3 Li-ion batteries.

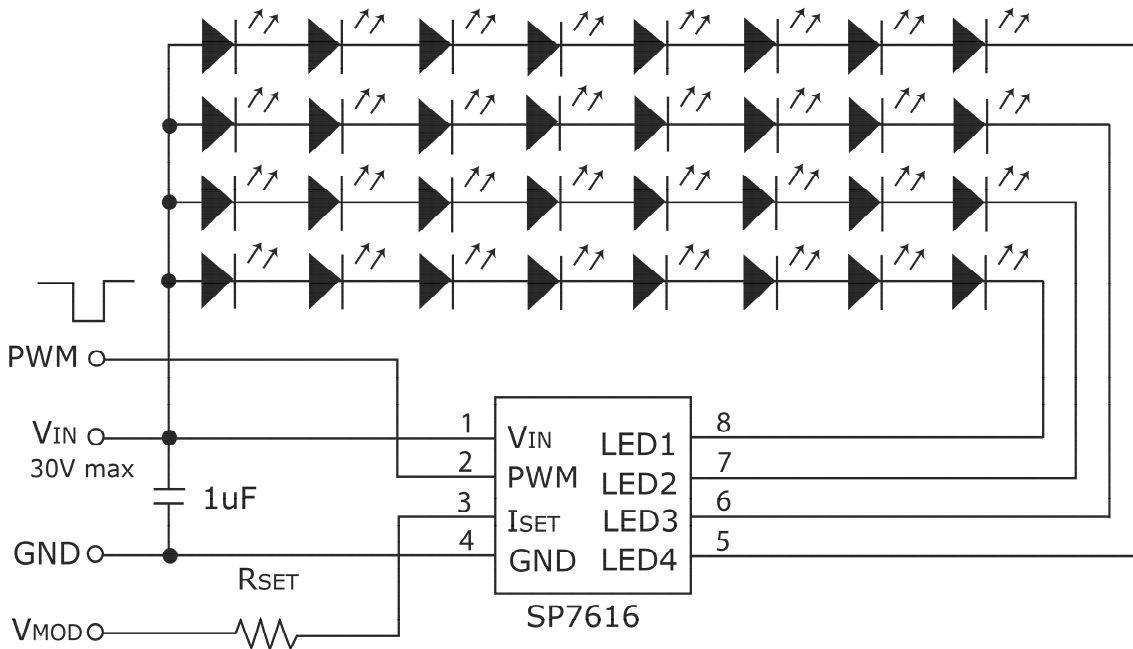


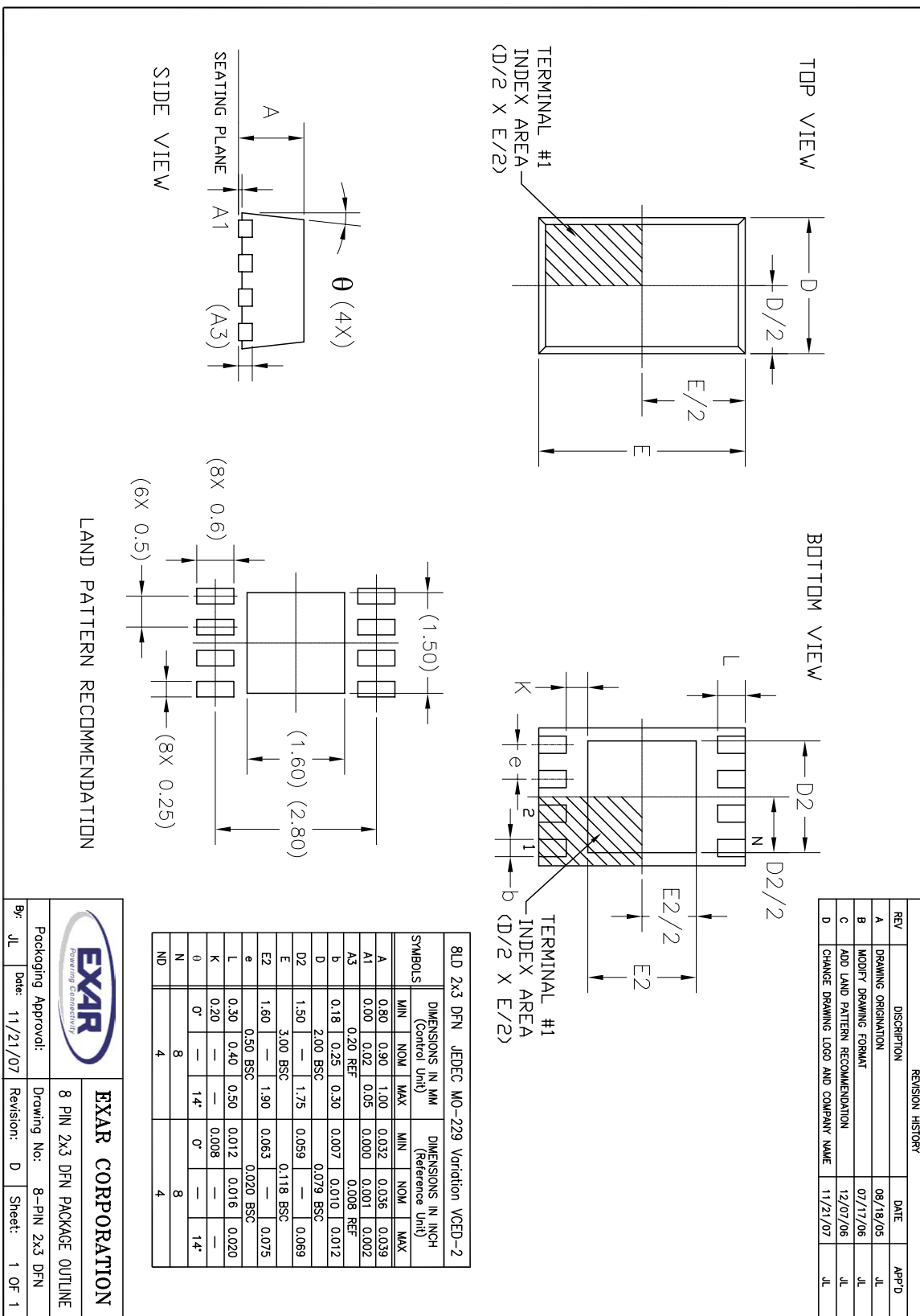
Figure 3  
Using the SP7616 from a fixed source



# SP7616 High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement

## PACKAGE SPECIFICATION

## 8PIN 2X3mm DFN





# SP7616

## High Accuracy 4-Channel Low Side LED Driver for CCFL Replacement

### REVISION HISTORY

Revision	Date	Description
2.0.4	May 22, 2009	Reformat. Increased shutdown current to 60uA. Changed specification methodology for setting LED current. Multiplier value changed to 1075 typical. Changed room and over temp limits. Dropout voltage changed to 300mV typical, 450mV maximum. Added additional information in applications "V <sub>IN</sub> Considerations" section. Updated resistor values for Maximum LED current per channel specification and current multiplication ratio. Changed PWM frequency and PWM duty cycle to typicals and referred to new curves in the typical performance graph section.

### FOR FURTHER ASSISTANCE

Email: [customersupport@exar.com](mailto:customersupport@exar.com)  
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### EXAR CORPORATION

#### HEADQUARTERS AND SALES OFFICES

48720 Kato Road  
Fremont, CA 94538 – USA  
Tel.: +1 (510) 668-7000  
Fax: +1 (510) 668-7030  
[www.exar.com](http://www.exar.com)

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