基于ZD831控制IC的无变压器AC-DC恒流LED驱动电路

[redacted]

摘要：ZD831型LED驱动器IC，无需变压器和桥式整流器，仅需外加几个元件，可以编程30mA的恒流输出，驱动多达50个相串联的LED，并提供数字PWM或模拟DC电压调光及过温度和过电压保护。

关键词：ZD831 无变压器 LED驱动 电流编程 热关闭 过压保护 PWM/模拟调光

引言

由110V/60Hz或220V/50Hz市电供电的恒流LED驱动电路，通常需使用变压器或桥式整流器及电感器。ZD831型AC-DC恒流LED驱动器IC，无需使用变压器，也不需要桥式整流器和降压电感器，仅需外加几个电阻和电容，就可以在85-120V_{AC}或200-240V_{AC}的交流电压下工作，驱动不超过30mA多达50颗LED串联连接的LED串。ZD831还提供数字PWM或模拟电压调光引脚及过温度保护和电压保护，并且不带电磁干扰(EMI)。高集成度的ZD831型AC-DC恒流LED驱动IC，为设计高性能、低成本和简单LED驱动电路提供了比较理想的一种解决方案。

一、ZD831引脚功能及其特性

1、ZD831引脚说明

为正确使用ZD831，必须了解其引脚功能。ZD831采用20引脚裸露并符合RoHS指令的绿色封装，引脚排列如图1所示。其中，未连接引脚有7个。

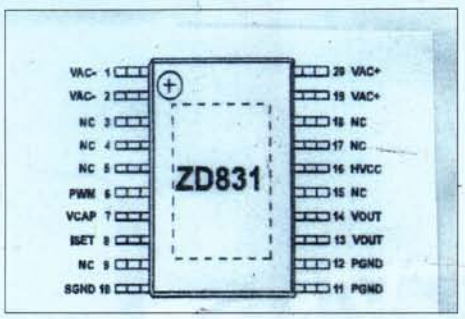


图1 ZD831引脚配置

引脚号	引脚名称	引脚说明
1，2	VAC-	85~120V 的高压AC 电压输入端
19，20	VAC+	85~120V 的高压AC 电压输入端
6	PWM	LED 控制端，脉宽调制或逻辑高/低电平输入
7	VCAP	内部稳压器输出端，该脚与SGND 之间连接一个1 的旁路电容
8	ISET	该端与PGND 之间连接一个电阻RSET设置LED电流
10	SGND	信号地
11，12	PGND	电源地
13，14	VOUT	LED 驱动器开路（MOSFET）漏极输出，LED 恒流灌入该端
16	HVCC	经整流的 DC 高压输出，该端连接一个不低于10 的旁路电容器
3，4，5，9 15，17，18	NC	不连接端，必须悬空

表一列示了ZD831各个引脚说明

2、ZD831性能特点

（1）ZD831引脚VAC+和VAC-之间的AC输入电压范围为85-120VAC，如果在输入端附加一个RC降压网络，AC输入电压范围可以扩展到85-240V_{AC}.

（2）在ZD831引脚HVCC上的高雅整流输出电压范围为85-170V_{DC}，可以驱动多达50个LED组成的LED串。

（3）LED电流由IC引脚ISET上的接地电阻RSET来编程，计算公式为：

ILED(mA)=2500/RSET（KΩ）

由于LED输出电流范围为3-30mA，因此RSET取值范围为：83 KΩ≤REST≤833 KΩ。（图2）示出了LED电流ILED与编程电阻RSET之间的关系曲线。

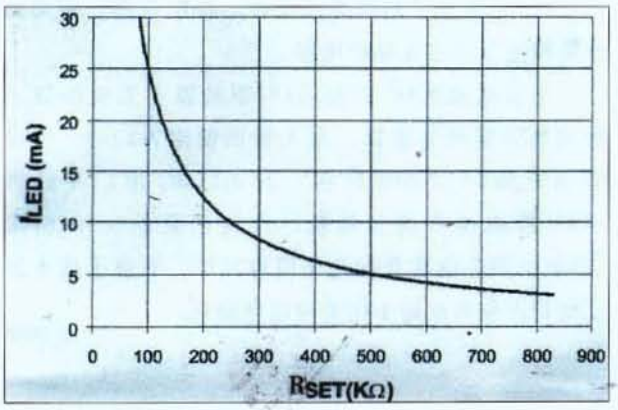


图2 LED电流与编程电阻之间的关系

(4)为保护IC内部功率晶体管，必须在LED串上加入一个电流限制电阻REXT，其电阻值为：

REXT=（V_{HVCC}-nvf-Vout）/I_{LED}

式中：V_{HVCC}= V_{AC}；n为LED串中LED数量；VF为单个LED的正向电压降；

Vout为IC引脚Vout上的电压，其典型值为5V，I_{LED}为LED电流，范围为3-30mA。

REXT的额定功率为：

PREXT=(ILED)2R_{EXT}

若 VF=3.2V， Vout=5V， Cout=10mF，I_{LED}=30mA，不同AC输入电压下R_{EXT}取值及LED串LED的最大数目如表2所示。

AC 输入电压	LED 串中LED 最大数目	REXT 值（Ω）	REXT 额定功率
85V_{AC}	35	66	0.25
100V_{AC}	41	126	0.25
120V_{AC}	50	100	0.25

表2 限制电阻REXT选择

(5) 提供PWM调光和模拟电压调光功能。

在ZD831引脚PWM上施加一个50Hz-5KHz的PWM信号，可以实现LED串的调光。调光正比于PWM5 因数，调光范围从10%-90%。当PWM信号为“0”时，IC关闭；当PWM信号为“1”时，IC则导通。

通过IC引脚I_{SET}上的LED电流设置电阻R_{SET}，施加一个0V-1.25V的DC电压，可以实现模拟电压调光，如（图3）所示。随输入模拟电压的增加，通过LED的电流减小，亮度变暗。

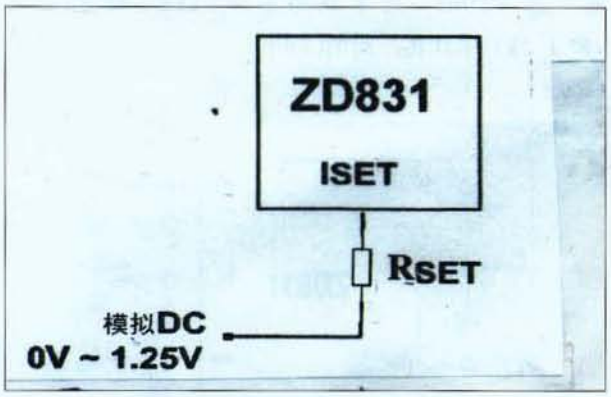


图3 利用DC电压实现模拟调光

二、基于ZD831的AC-DC恒流LED驱动电路

图4为基于ZD831交流输入为110V_{AC}（范围为85-120V_{AC}）驱动30个串联链接LED的电路。ZD831引脚Hvcc上的整流输出为156V_{DC}（110V×$\sqrt{2}$），R_{EXT}=220Ω，每个LED的正向压降VF=3.2V。由于R_{SET}=120KΩ，LED电流为I_{LED}=2500/120KΩ≈20mA。

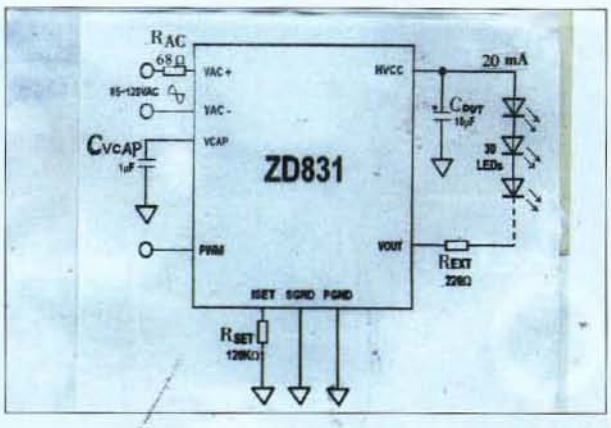


图4 ZD831在110VAC下操作驱动30个串联LED的电路

ZD831在220V_{AC}（范围为200-240V_{AC}）下操作驱动30个串联LED的电路如（图5）所示。

在IC引脚V_{AC}+输入端上串接的C_{AC}（0.47μf）为降压电容，R_{AC}为泄放电阻。220VAC的输入电压经RC电路后，在V_{AC}+和V_{AC}-输入端上的电压约100V_{AC}，

在Hvcc脚上的输出DC电压为142VDC（100V×$\sqrt{2}$），输出电流为20mA，用来驱动由30个LED（每个LED的VF=3.2V）串联在一起的LED串。

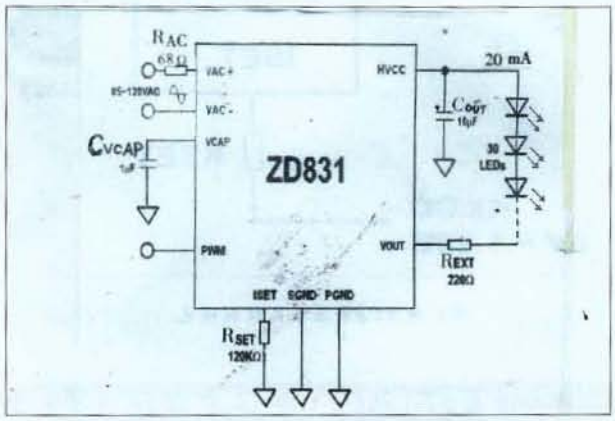


图5 ZD831在220VAC下操作驱动30个串联LED的电路

基于ZD831的AC-DC恒流LED驱动器有许多应用，其中之一是各种形式因数（form-factor）的LED灯泡，如图6所示。

结束语

ZD831集成了高压整流电路、控制电路、驱动晶体管和过热及过压保护电路。

由其组成的AC-DC恒流LED驱动器无需变压器、桥式整流器和电感器，最大输出恒流为30mA，可以驱动直到50个LED串联在一起的LED灯串，并提供PWM和模拟电压调光功能。这种创新的AC-DC恒流LED驱动器，仅需外加几个阻容元件，实现了成本最低化和占位面积最小化及应用便捷化。

参考文献：

【1】ZYWYN Corporation. World Class Transformer Free ™ AC-DC Constant Current LED Driver. WWW.zywyn.com.2007.

【2】毛兴武等.新一代绿色光源LED及其应用技术【M】.北京：人民邮电出版社，2008

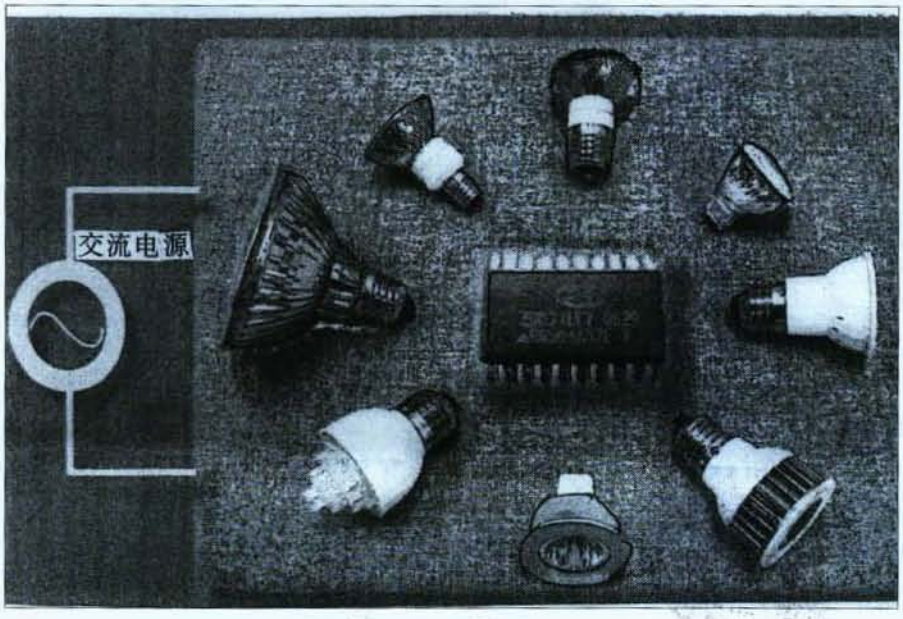
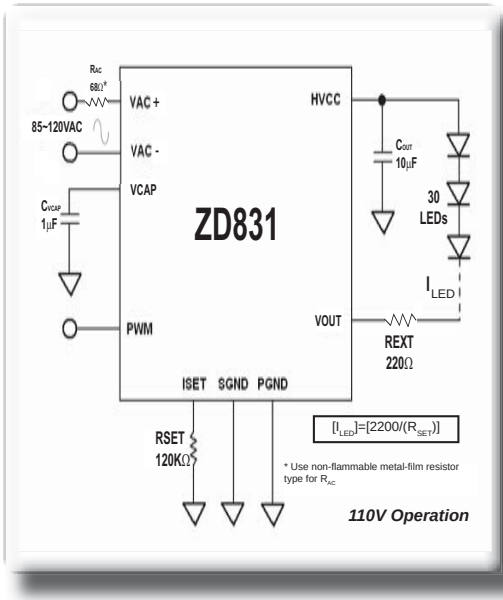


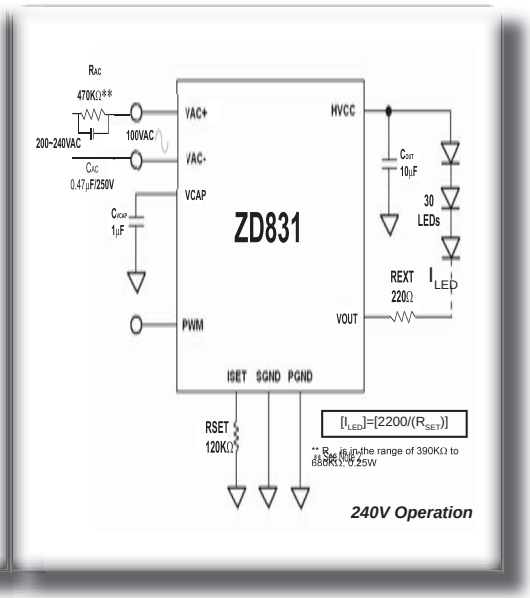
图6 基于ZD831的各种LED灯泡

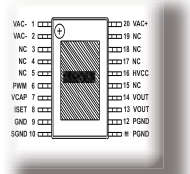
World Class TransformerFree™ AC-DC Constant Current LED Driver

....In The Smallest Footprint For All Form-Factored LED Lamps And Lighting Systems

Typical Applications







Ordering Information

Part Number	Temperature Range	Package Type
ZD831LEY	–40°C to +85°C	20-EP TSSOP
ZD831EVB	n/a	Evaluation Board

Pin Description

Pin Number	Pin Name	Pin Function
1, 2	VAC-	High Voltage AC Input, from 85~120VAC.
20	VAC+	High Voltage AC Input, from 85~120VAC.
6	PWM	LED Dimming Control Pin. PWM signal with duty cycle or logic high/low input.
7	VCAP	Internal Regulator Output. Decouple this pin with a 1µF capacitor.
8	ISET	Output Current Level Resistor Input. Connecting a resistor RSET from this pin to ground sets the output current of the LED driver.
9	GND	Substrate Ground. Must be connected to SGND (Pin# 10).
10	SGND	Signal Ground. Connects all small signal components to this ground.
11, 12	PGND	Power Ground. Connects high voltage decoupling capacitor to this ground.
13, 14	VOUT	LED Driver Open-Drain Output. Constant current sinking output rated for 120V.
16	HVCC	High Voltage Rectified DC Output. Connects a 10µF decoupling capacitor from this pin to PGND. The power rating (V_{DC}) of the capacitor depends on the input VAC voltage.
3, 4, 5, 15, 17, 18, 19	NC	No Connect Pins. Must be left open and unconnected.

[#] Assuming Vf of LEDs is at 1.8V at constant current over the supply voltage range of 85VAC~120VAC.

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- No Transformer, No Bridge Rectifier
- 85VAC to 120VAC Input Voltage Range
- Programmable 30mA Constant Output Current
- Drives Up To 50 LEDs Per String[#]
- Digital PWM or Analog DC Voltage Dimming Control
- Over-Temperature/Voltage Protection
- Very Minimum External Components
- Complete Static Design With No EMI
- Thermally Enhanced 20-Pin Exposed TSSOP RoHS Green Package

ZD831 Display Driver

ZYWYN CORPORATION
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ZD831 Display Driver

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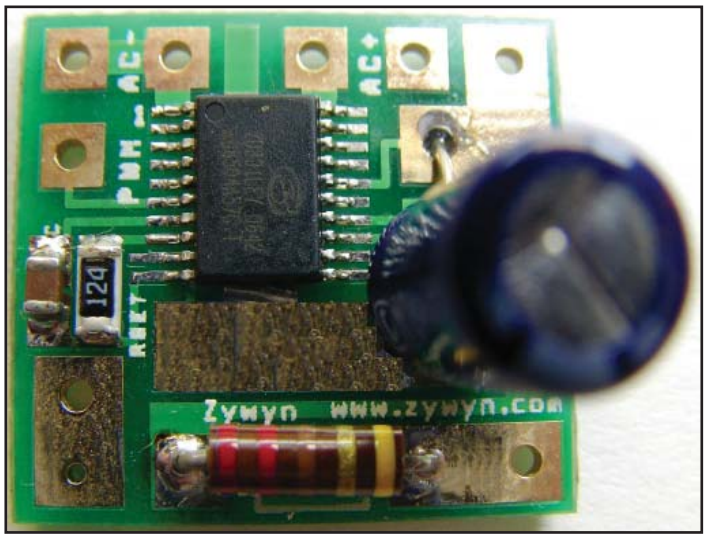
Application Note AN014

ZD831EVB Evaluation Board Manual

General Description

The ZD831 is a high voltage, transformerless AC-DC constant current driver for driving a string of white or RGB LEDs in series. It operates from an input voltage of 85VAC to 120VAC and generates a programmable constant output current. The high operating voltage of ZD831, along with its linear control architecture eliminates the need for an external inductor, transformer and rectifying diode bridge. The output current level is set by a single resistor and can be set as high as 30mA. Dimming control can be accomplished by using pulse-width modulation signal with varying duty cycle on the PWM pin or by applying an analog DC voltage on the ISET pin. Thermal and over-voltage circuitry protects the internal power transistors from excessive power dissipation. The ZD831EVB is configured for application using 110VAC or 240VAC (details in the Typical Applications section) operation by default settings from factory.

The ZD831 is available in a thermally enhanced 20-pin exposed TSSOP green package.



Typical Application

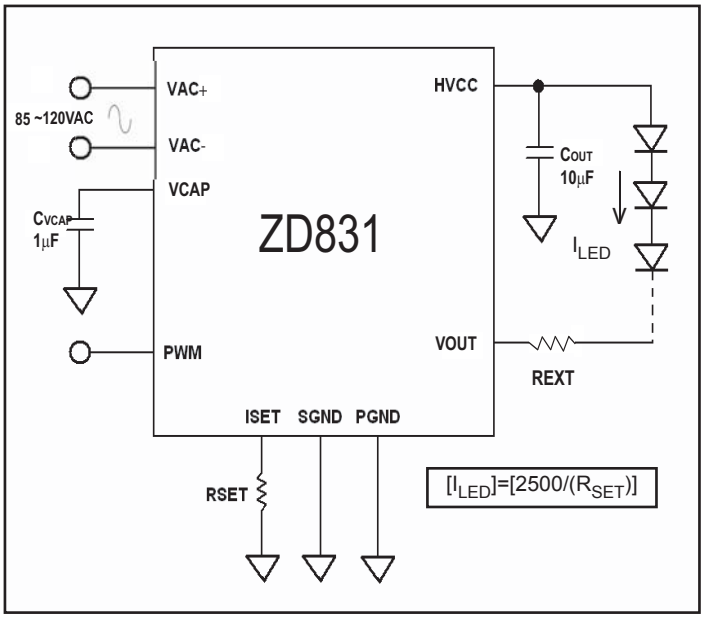
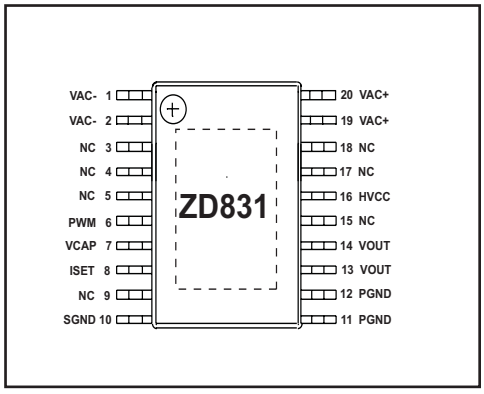


Figure 1. ZD831 driving a string of LEDs in series at a presetted constant current

Pin Configuration



20-Pin Exposed TSSOP

WARNING! This is a high voltage application circuit where Galvanic Isolation is not provided. Dangerous voltages are present when connected to the AC line. It is the responsibility of the engineer employing the ZD831EVB to ensure adequate safeguards are put in place to protect the end user from electrical hazardous shock. Do not connect the ZD831 circuit ground with earth grounded devices such as scopes and power supplies.

Ordering Information

Part Number	Temperature Range	Package Type
ZD831LEY	–40°C to +85°C	20-EP TSSOP
ZD831EVB	n/a	Evaluation Board

Please contact the factory for pricing and availability on Tape-on-Reel option.

Electrical Characteristics

T_A = +25°C, VAC+ & VAC- = 110VAC, SGND = PGND = 0V, C_{OUT} to PGND = 10µF (rated at 250V), C_{VCAP} to SGND = 1µF (rated at 10V), PWM = 5V; unless otherwise noted.

Parameter	Condition	Min	Typ	Max	Units
AC Input Voltage, VAC+ & VAC-		85	110	120	V_{AC}
High Voltage, HVCC DC Input applied to HVCC DC Output from HVCC	 un-connected VAC+ & VAC-, I_{LED}=5mA, VOUT=5V connected VAC+ & VAC-, I_{LED}=5mA, VOUT=5V	 120 120	 	 170 170	 V V
Supply Current, I_{VAC} Quiescent Current	R_{SET}=125kΩ, PWM=5V, un-connected VOUT		2	5	mA
LED Output Current Range, I_{LED}		3		30	mA
Output Current, I_{LED}	R_{SET}=125KΩ; $[I_{LED}]=[2500/(R_{SET})]$ VOUT=5V to 10V VOUT=3V to 30V	 18.6 17	 20 20	 21.4 23	 mA mA
Output Leakage Current, $I_{LED-Leakage}$	PWM=0V, VOUT=5V		20	100	µA
PWM Signal Pin Input Voltage High Input Voltage Low Input Leakage Current	 PWM=0V or 5V	 2.0 	 0.2 1	 10	 V V µA
ISET Pin Regulated ISET Voltage, V_{ISET}		 1.1	 1.25	 1.3	 V

Pin Description

Pin Number	Pin Name	Pin Function
1, 2	VAC-	High Voltage AC Input, from 85~120V_{AC}.
19, 20	VAC+	High Voltage AC Input, from 85~120V_{AC}.
6	PWM	LED Control Pin, Pulse-width Modulated or logic high/low Input.
7	VCAP	Internal Regulator Output. Bypass this pin with a 1µF capacitor to SGND.
8	ISET	LED Current Setting Pin. Connect RSET from ISET to PGND to set the LED current.
10	SGND	Signal Ground. Connects all small signal components to this ground.
11, 12	PGND	Power Ground. Connects high voltage decoupling capacitor to this ground.
13, 14	VOUT	LED Driver open-drain Output. Constant current sinking outputs rated for 100V.
16	HVCC	High Voltage Rectified DC Output from VAC+ & VAC-. Bypass HVCC with at least 10µF to PGND.
3, 4, 5, 9, 15, 17, 18	NC	No Connect Pins. Must be left open and unconnected.

Output Operation Description

High Voltage Rectified DC Output (HVCC)

A typical range of $85V_{DC}$ to $170V_{DC}$ can be sourced from the HVCC pin and is dependent on the AC input voltage at VAC+ and VAC-. A 10μF decoupling capacitor from the HVCC pin to PGND is used to reduce the rectified ripples at the output. The power rating (V_{DC}) of the capacitor depends on the input VAC voltage, but should typically be rated at 250V.

Input Operation Description

AC Input Voltage (VAC+, VAC-)

An AC voltage power source, with a typical range of $85V_{AC}$ to $120V_{AC}$, can be applied directly to the VAC+ and VAC- pins of the ZD831 to drive a string of LEDs. An input voltage range of $85V_{AC}$ to $240V_{AC}$. can also be applied with additional external RC components to assist the ZD831 to operate under this condition. The input voltage power source should be able to provide a 1.5A load current. The ZD831EVB demo board is capable of providing a constant current for the string of LEDs over this input voltage ranges of $85V_{AC}$ to $120V_{AC}$. (Refer to Figure 4) and $85V_{AC}$ to $240V_{AC}$ (Refer to Figure 6).

Note: The ZD831EVB evaluation board is not protected from output open/short circuit conditions. Potential damage to the Demo Board may occur if the output load is not properly connected.

High Voltage DC Input (HVCC)

A typical range of $85V_{DC}$ to $170V_{DC}$ can be applied to the HVCC pin to drive the LED string directly without connecting the VAC+ and VAC-. A small 1μF decoupling capacitor from the HVCC pin to PGND is used to reduce possible ripples. The power rating (V_{DC}) of the capacitor depends on the input voltage at HVCC, but should typically be rated at 250V.

LED Dimming

PWM Dimming

The output string of series LEDs can be dimmed by applying an input pulse-width modulated signal (50Hz to 5kHz) to the PWM pin. This allows for a wide range of dimming gradient. The dimming is proportional to the PWM duty cycle, which can range from 10% to 90%. The device is in shutdown mode when PWM is at LOGIC LOW "0" state, and is fully-on when PWM is at a LOGIC HIGH "1" state.

Analog Voltage Dimming

To allow for LED current amplitude adjustment as well as linear dimming, ISET can be connected to an analog voltage through a resistor, RSET, where RSET is in the range of 833KΩ ≥ RSET ≥ 83KΩ. The ISET pin is typically regulated at 1.25V.

As shown in figure 2, when the DC voltage is set at 0V for example, the I_{LED} current is positioned at its default value which is calculated from the equation,

$$[I_{LED}]=[2500/(RSET)]$$

Increasing the DC voltage from 0V to 1.25V will dim the LEDs in linear proportion with decreased in the I_{LED} current. Setting the DC voltage at midpoint upon device power-up can control the dimming up and down function.

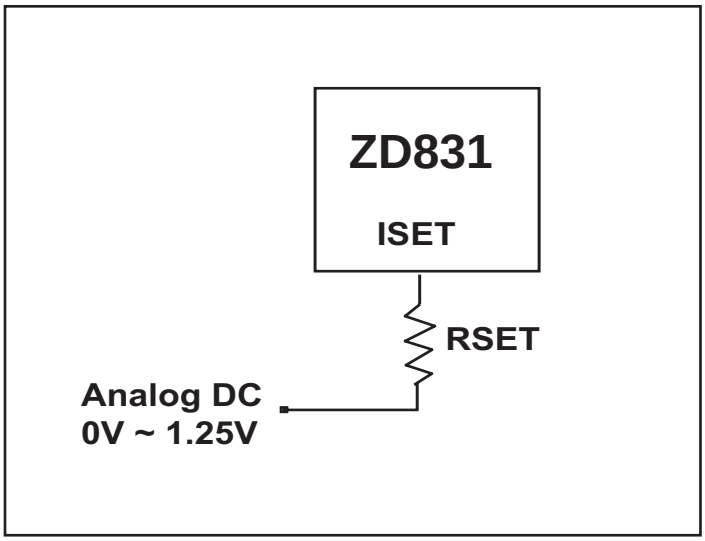


Figure 2. Analog dimming using analog DC voltage.

Note: The ZD831EVB circuit is not isolated from AC mains. Connecting external devices or equipments to the ZD831 input pins without the use of proper isolations, such as opto-isolators, can be hazardous and may cause equipment damages. Do not connect the ZD831 circuit ground with earth grounded devices such as scopes and power supplies.

Circuit Description

The Limiting Resistor R_{EXT}

To protect excessive power dissipation on the internal power transistor, an external resistor R_{EXT} may be required to maintain the V_{OUT} within the range of 3V and 30V. The formula for the limiting resistor R_{EXT} should be used to calculate the resistor value in series with the LEDs as follows,

$$R_{EXT} = (HVCC - n \cdot V_{FORWARD\text{-}LED} - V_{OUT})/I_{LED}$$

where,

HVCC = High Voltage Rectified DC, typically $\sqrt{2} \cdot V_{AC}$
n = Number of LEDs connected in series.
$V_{FORWARD\text{-}LED}$ = Forward bias voltage of a single LED.
V_{OUT} = Voltage at VOUT pin, typically 5V
I_{LED} = Regulated LED current, ranges from 3mA to 30mA.

Use the following formula to make sure R_{EXT} has adequate power rating tolerance:
$P_{REXT} = (I_{LED})^2 \cdot R_{EXT}$

where
P_{REXT} = Power dissipated by R_{EXT}
I_{LED} = Regulated LED current, ranges from 3mA to 30mA.

The maximum number of driven LEDs per string is shown in table below for reference, assuming the forward bias voltage of LED is 3.2V, V_{OUT} = 5V, C_{OUT} = 10μF, and I_{LED} = 30mA:

VAC Input Voltage	Max. Number of LEDs	R_{EXT} (Ω)	Power Rating (W)
85 VAC	35	66	0.25
100 VAC	41	126	0.25
120 VAC	50	100	0.25
240VAC	100*	366	0.25

* Available only for ZD832 application.

Selecting External Component RSET to Set I_{LED} Current

The ZD831 uses an external resistor, RSET, to set the constant LED current, I_{LED}. I_{LED} is determined by the formula:

$$[I_{LED}]=[2500/(RSET)]$$

with a minimum value of RSET ≥ 83KΩ, which sets the I_{LED} to 30mA, and a maximum value of RSET ≤ 833KΩ, which sets the minimum I_{LED} to 3mA (Refer to Figure 3). The maximum allowable capacitance at the ISET pin is 50pF.

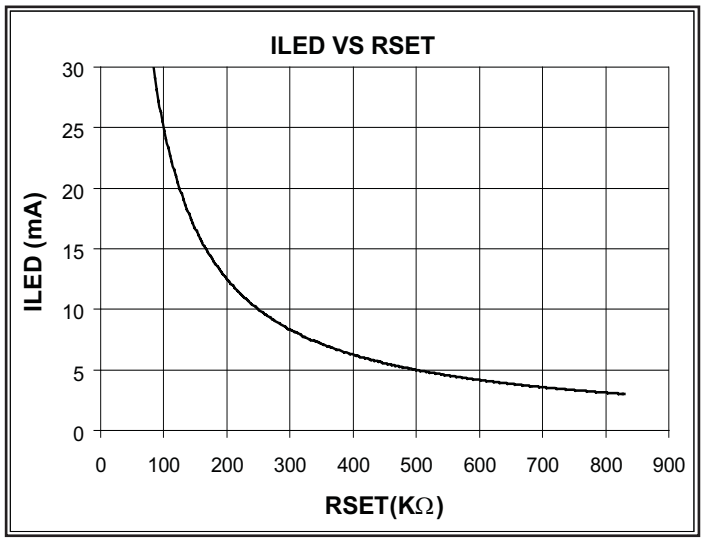


Figure 3 ILED vs RSET

Typical Application Circuit

The ZD831EVB Evaluation Board is populated for operations with a 110VAC input or with a 240VAC input. Both circuit boards are wired for driving 30 LEDs at a constant output current of about 20mA using a RSET of 120kΩ.as the default value configuration at factory.

Application circuit using 110VAC

An input voltage of $110V_{AC}$ can be applied to the VAC+ and VAC- pin of the ZD831EVB. The output at HVCC is rectified at $156V_{DC}$ (110V •√2) and the limiting REXT is set be 220Ω, assuming 30 LEDs in series with V_f of 3.2V are being used. Figure 4 shows the typical circuit schematics and figure 5 shows the actual ZD831EVB demo board.

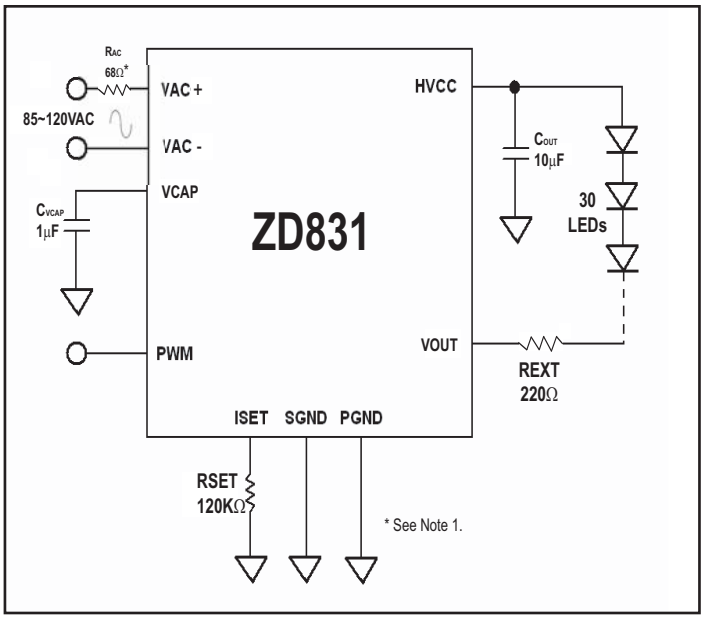


Figure 4. ZD831 driving a string of LEDs in series at 110VAC operation with constant current of 20mA.

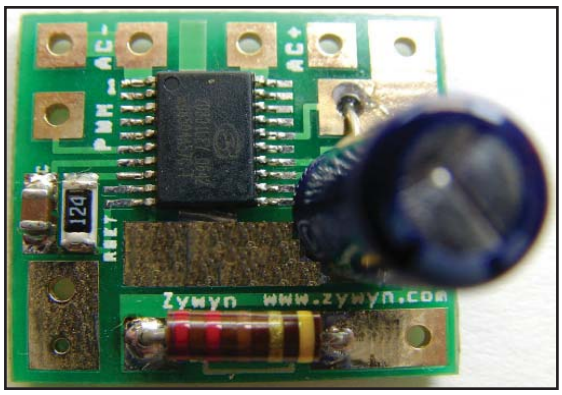


Figure 5. ZD831EVB evaluation board configured for 110V operation.

Application circuit using 240VAC

An input voltage of $240V_{AC}$ can be stepped down by using an external RC circuit to about $100V_{AC}$ across the VAC+ and VAC- pin. The output at HVCC will be at $142V_{DC}$ (100V •√2) and the limiting REXT is set at 220Ω, assuming 30 LEDs in series with V_f of 3.2V are being used. Figure 6 shows the typical circuit schematics and figure 7 shows the actual ZD831EVB demo board.

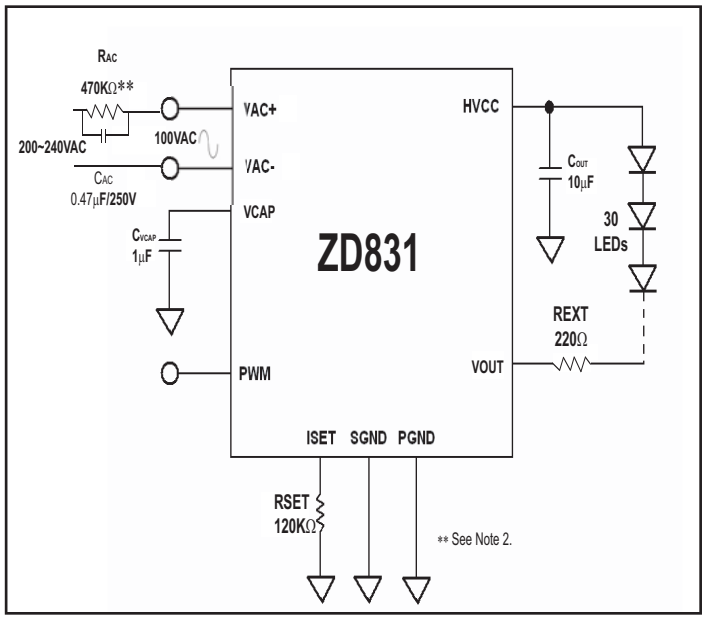


Figure 6. ZD831 driving a string of LEDs in series in 240VAC operation with constant current of 20mA.

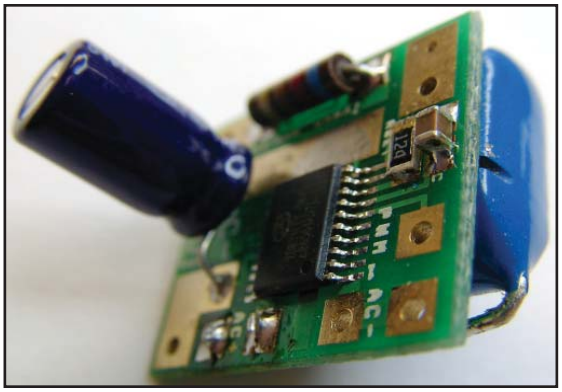


Figure 7. ZD831EVB evaluation board configured for 240V operation.

Note: The ZD831EVB evaluation board is not protected from output open/short circuit conditions. Potential damage to the Demo Board may occur if the output load is not properly connected. The ZD831EVB circuit is not isolated from AC mains. Connecting external devices or equipments to the ZD831 input pins without the use of proper isolations, such as opto-isolators, can be hazardous and may cause equipment damages. Do not connect the ZD831 circuit ground with earth grounded devices such as scopes and power supplies.

Components Selection

Capacitor Selection

The small size of ceramic capacitors makes them ideal- for ZD831 applications. X5R and X7R types retain their capacitance over wider voltage and temperature ranges and are recommended over Y5V or Z5U types. A 10μF filtering output capacitor and a 1μF input capacitor are sufficient for the most ZD831 applications.

AVX	www.avxcorp.com
Kemet	www.kemet.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com

Table 1. Recommended Ceramic Capacitor Manufacturers

ZD831EVB Bill of Material (BOM) Listing

For VAC from 85V to 120V Operation

Item	Quantity	Location	Part
1	1	VCAP	1μF/16VDC
2	1	HVCC	10μF/250VDC
3	1	RSET	Variable
4	1	R_{EXT}	Variable
5	1	U1	ZD831LEY
6	30 ~ 50	HVCC	LEDs
7	1	VAC	68Ω*/0.25W

For VAC from 85V to 240V Operation

Item	Quantity	Location	Part
1	1	VCAP	1μF/16VDC
2	1	HVCC	10μF/250VDC
3	1	RSET	Variable
4	1	R_{EXT}	Variable
5	1	U1	ZD831LEY
6	30 ~ 50	HVCC	LEDs
7	1	VAC	0.47μF/250VDC
8	1	VAC	470kΩ**/0.25W

* Note 1. A non-flammable metal-film resistor, R_{AC}, should be used to limit inrush current spikes during start-up and transient voltage induced in the AC-power line by incidental lightning strike. In normal operations, the AC current does not exceed $30mA_{RMS}$, and a 47Ω-82Ω, 0.25W reistor provides sufficient current limiting.

** Note 2. R_{AC} should be in the range of 390KΩ~680KΩ, 0.25W when used in the external RC circuit.

Evaluation Board Information

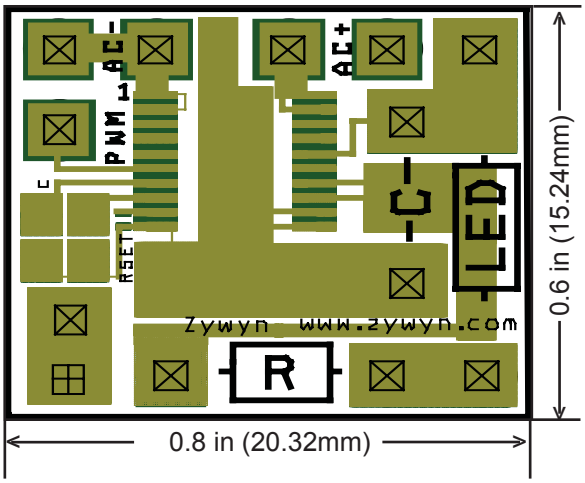


Figure 8. ZD831EVB Single-Layer Evaluation Board
Component Side Layout

Zywyn Corporation
Headquarters and Sales Office
1270 Oakmead Parkway, Suite 201 • Sunnyvale, CA 94085 • Tel: (408) 733-3225 • Fax: (408) 733-3206
Email: sales@zywyn.com • www.zywyn.com