Description

The AP8800A is a step-down DC/DC converter designed to drive LEDs with a constant current. The device can drive up to 7 LEDs, depending on the forward voltage of the LEDs, in series from a voltage source of 8V to 28V. Series connection of the LEDs provides identical LED currents resulting in uniform brightness and eliminating the need for ballast resistors. The AP8800A switches at frequency up to 600kHz. This allows the use of small size external components, hence minimizing the PCB area needed.
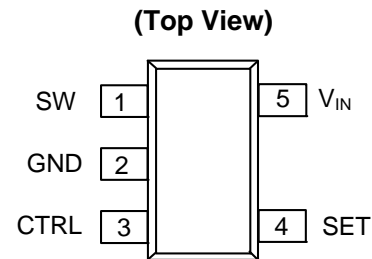
Maximum output current of AP8800A is set via an external resistor connected between the V_{IN} and SET input pins. Dimming is achieved by applying either a DC voltage or a PWM signal at the CTRL input pin. An input voltage of 0.2V or lower at CTRL switches off the output MOSFET simplifying PWM dimming.

Pin Assignments

(Top View)

SW	1	5	V_{IN}
GND	2		
CTRL	3	4	SET

Features

- LED driving current up to 370mA
- Better than 5% accuracy
- High efficiency up to 95%
- Operating input voltage from 8V to 28V
- Simple, versatile solution requiring only 4 components
- PWM/DC input for dimming control
- Built-in output open-circuit protection
- TSOT25: Available in "Green" Molding Compound (No Br, Sb) with lead Free Finish/ RoHS Compliant
  - **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
  - **Halogen and Antimony Free. "Green" Device (Note 3)**

Applications

- MR16 Lamps
- General Illumination Lamps

Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
          2. See http://www.diodes.com for more information about Diodes Incorporated's definitions of Halogen and Antimony free, "Green" and Lead-Free.
          3. Halogen and Antimony free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
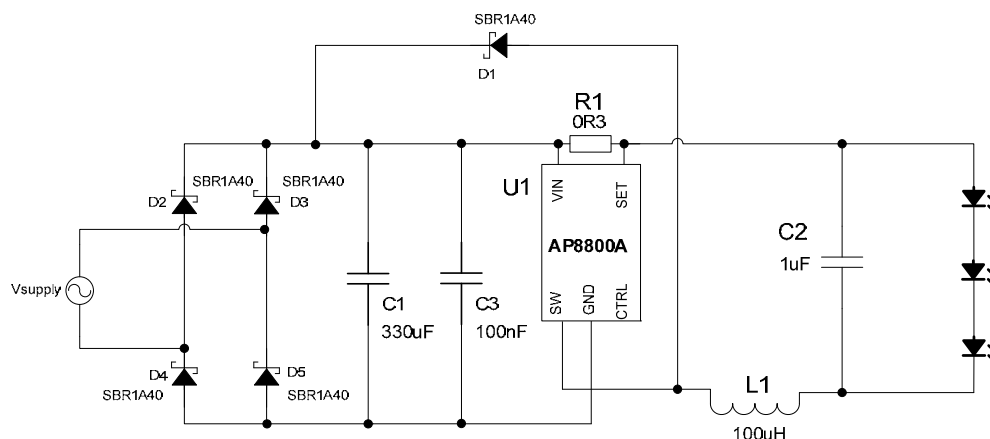
Typical Applications Circuit

AP8800A
Document number: DS35100 Rev. 3 - 2

1 of 13
www.diodes.com

August 2012
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Pin Descriptions

Pin Name	Pin Number	Function
SW	1	Switch Pin. Connect inductor/freewheeling diode here, minimizing track length at this pin to reduce EMI.
GND	2	GND Pin
CTRL	3	Dimming and On/Off Control Input. • Input voltage of 0.2V or lower forces the device into low current standby mode and shuts off the output. An open-drain/collector PWM signal allows the output current to be adjusted below the level set by the resistor connected to SET input pin. • The input impedance is about 50kΩ, and if the pin is left open $V_{CTRL} = V_{REF}$. • Drive with DC voltage (0.3V < V_{CTRL} < 2.5V) to adjust output current from 24% to 200% of I_{OUTnom}
SET	4	Set Nominal Output Current Pin. Configures the output current of the device.
V_{IN}	5	Input Supply Pin. Must be locally decoupled to GND with ≥ 2.2µF X7R ceramic capacitor – see applications section for more information.

Functional Block Diagram
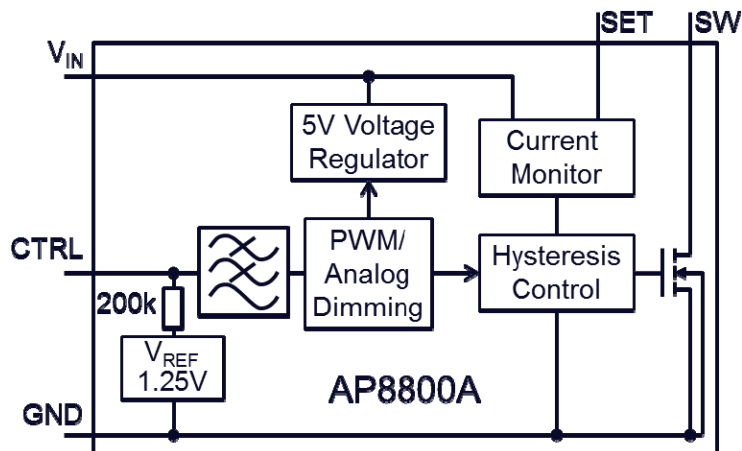
Absolute Maximum Ratings (@T_A = +25°C, unless otherwise specified.)

Symbol	Parameter	Ratings	Unit
V_{IN}	Continuous V_{IN} Pin Voltage Relative to GND	-0.3 to +30	V
V_{SET}	Set Voltage Relative to V_{IN}	V_{IN} -5 to V_{IN} +0.3	V
V_{SW}	SW Voltage Relative to GND	-0.3 to +30	V
V_{CTRL}	CTRL Pin Input Voltage	-0.3 to +5	V
I_{SW}	Switch Current	0.45	A
T_J	Junction Temperature	105	°C
T_{LEAD}	Lead Temperature Soldering	300	°C
T_{ST}	Storage Temperature Range	-55 to +150	°C

Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.

Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices.

AP8800A
Document number: DS35100 Rev. 3 - 2

2 of 13
www.diodes.com

August 2012
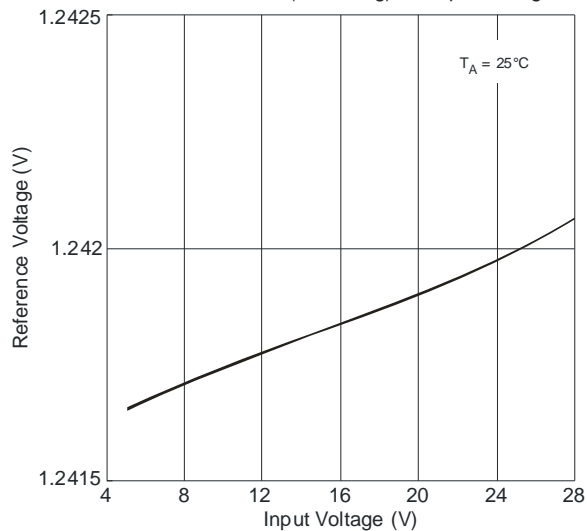© Diodes Incorporated

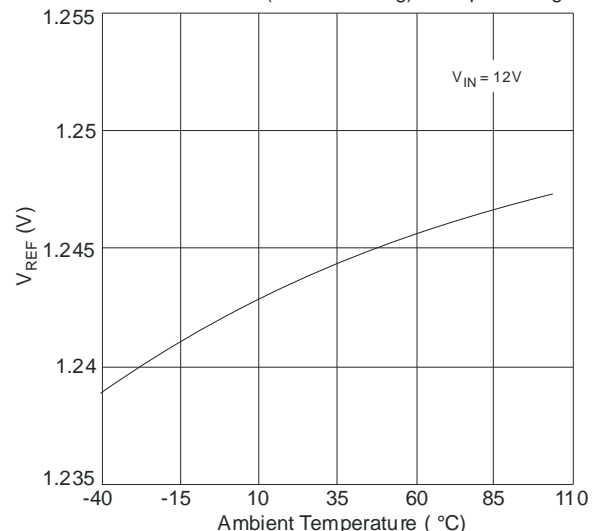## Typical Characteristics

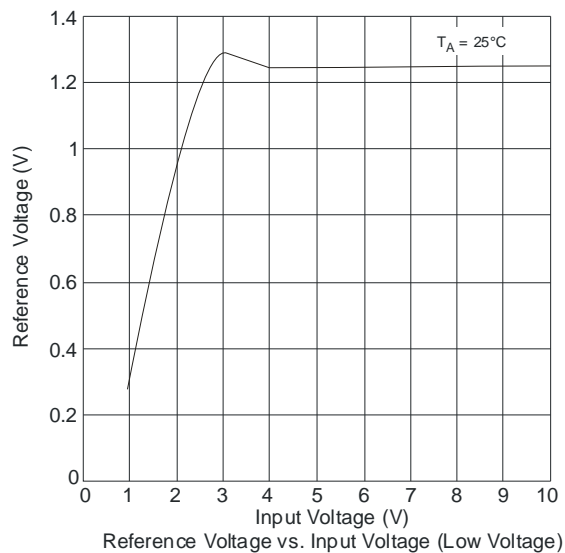Quiescent Current (Switching) vs. Input Voltage
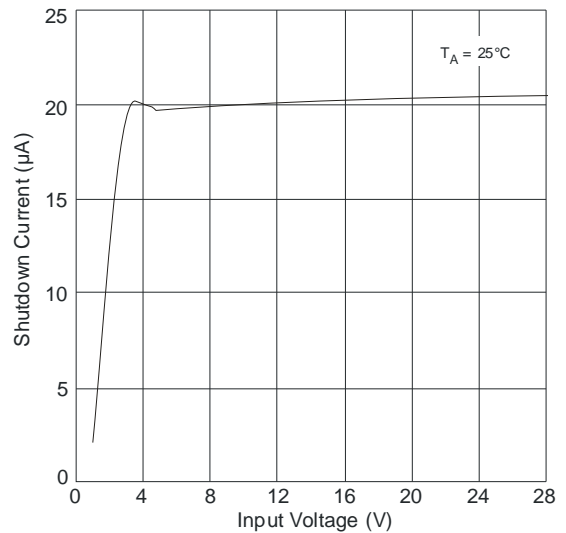
Shutdown Current (Non-Switching) vs. Input Voltage
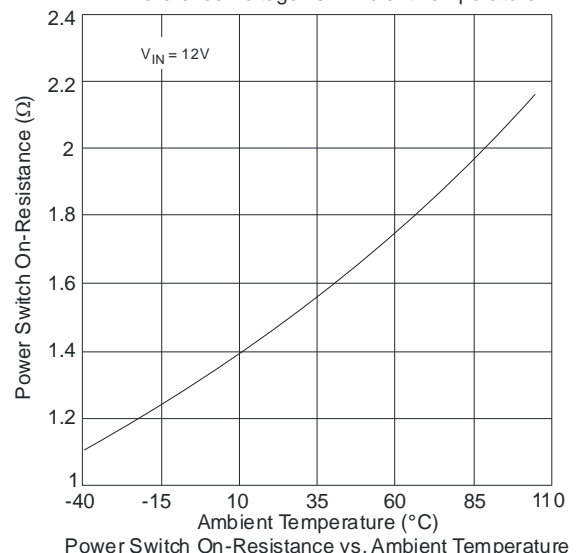

Reference Voltage vs. Input Voltage
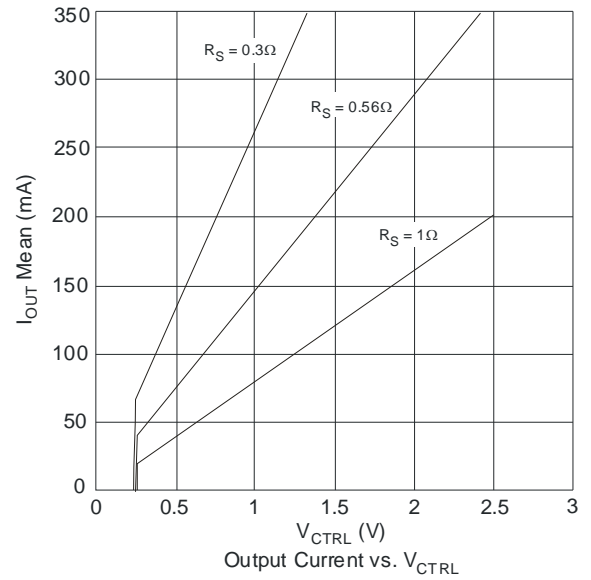

Reference Voltage vs. Ambient Temperature

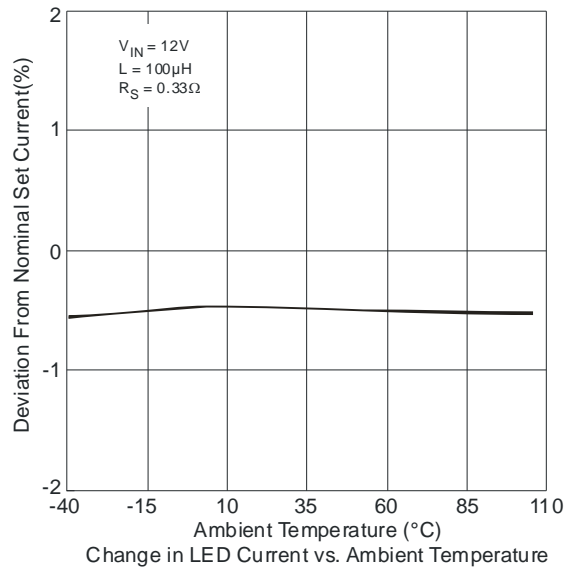Reference Voltage vs. Input Voltage (Low Voltage)

Power Switch On-Resistance vs. Ambient Temperature

AP8800A
Document number: DS35100 Rev. 3 - 2

4 of 13
www.diodes.com

August 2012
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Typical Characteristics (cont.)

Change in LED Current vs. Ambient Temperature

V_{IN} = 12V
L = 100µH
R_S = 0.33Ω

R_S = 0.3Ω

R_S = 0.56Ω

R_S = 1Ω

Output Current vs. V_{CTRL}

AP8800A
Document number: DS35100 Rev. 3 - 2

5 of 13
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Application Information (@T_A = +25°C, V_{IN} = 12V, unless otherwise specified.)

AP8800A Operation

The AP8800A is a hysteretic LED current switching regulator sometimes known as an equal ripple switching regulator. In normal operation, when voltage is applied at +V_{IN} (See Figure 1), the AP8800A internal switch is turned on. Current starts to flow through sense resistor R_1, inductor L1, and the LEDs. The current ramps up linearly, and the ramp rate is determined by the input voltage +V_{IN}, and the inductor L1 (See Figure 2).
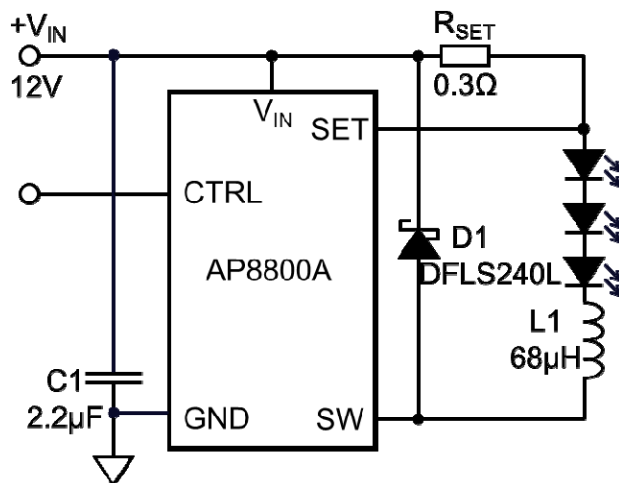

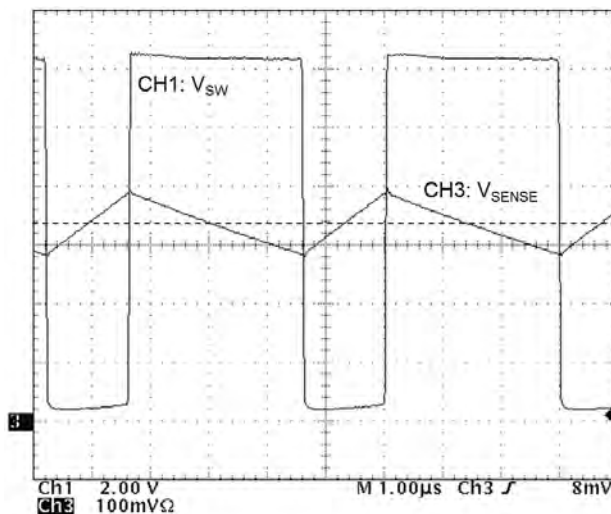**Figure 1 Typical Configuration**

Figure 2 Typical Switching Waveform

This rising current produces a voltage ramp across R_{SET}. The internal circuit of the AP8800A senses the voltage across R_{SET} and applies a proportional voltage to the input of the internal comparator.

When this voltage reaches an internally set upper threshold, the internal switch is turned off. The inductor current continues to flow through R_{SET}, L1, the LEDs and the schottky diode D1, and back to the supply rail, but it decays, with the rate of decay determined by the forward voltage drop of the LEDs and the schottky diode.

This decaying current produces a falling voltage at R_{SET}, which is sensed by the AP8800A. A voltage proportional to the sense voltage across R_{SET} is applied at the input of the internal comparator. When this voltage falls to the internally set lower threshold, the internal switch is turned on again. This switch-on-and-off cycle continues to provide the average LED current set by the sense resistor R_{SET}, with a switching current determined by the input voltage and LED chain voltage.

In normal operation the off time is relatively constant (determined mainly by the LED chain voltage) with only the on-time varying as the input voltage changes. At duty cycles up to around 80% the ramp of the LED/switch current is very linear; however, as the duty cycle approaches 95% the LED current ramp starts to become more exponential. This has two effects:

1. The overall on time starts to increase lowering the overall switching frequency.
2. The average LED current starts to increase – which may impact accuracy.

LED Current Control

With the CTRL pin left floating and the external current sense resistor, R_{SET} (greater than 0.3 Ω) is connected between V_{IN} and SET, the nominal average output current in the LEDs is:

$$I_{LED} = \frac{V_{TH}}{R_{SET}} \qquad \text{where } V_{TH} \text{ is nominally 100mV}$$

AP8800A
Document number: DS35100 Rev. 3 - 2

6 of 13
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Application Information (cont.) (@T$_A$ = +25°C, V$_{IN}$ = 12V, unless otherwise specified.)

LED Current Dimming

The LED current can be dimmed in two ways;

1. Analog Dimming: Where a dc voltage is applied to the CTRL pin

   or

2. PWM Dimming: Where a Pulse Width Modulated (PWM) signal is applied to the CTRL pin.

Analog Dimming

If the CTRL pin is driven by an external voltage (lower than 2.5V), the average LED current in this case is:

$$I_{LED} = \frac{V_{CTRL}}{V_{REF}} \times \frac{V_{TH}}{R_{SET}}$$

A DC signal from 0.3V to 2.5V applied to the CTRL pin will vary the LED current from 24% to 200% of nominal LED current. This gives an approximate 8:1 dimming range; care, should be exercised when overdriving the CTRL pin to 200% of nominal LED current not to exceed the power dissipation of the package.

The graph in figure 4 shows values of nominal average output current for 3 values of current setting resistor (R$_{SET}$) in the typical application circuit shown on Figure 1, for different voltages applied on the CTRL pin.
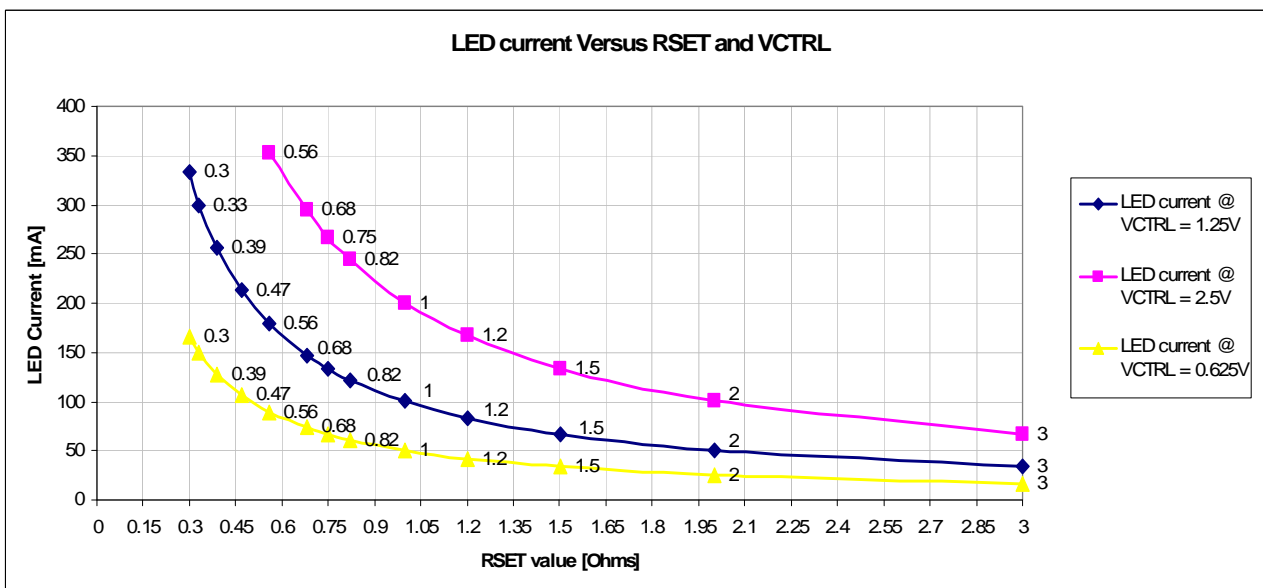

Figure 4 LED Current Setting vs. R$_{SET}$ and V$_{CTRL}$

AP8800A
Document number: DS35100 Rev. 3 - 2

8 of 13
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Application Information (cont.) (@T$_A$ = +25°C, V$_{IN}$ = 12V, unless otherwise specified.)

PWM Dimming

A PWM signal with a max resolution of 8bit can be applied to CTRL regulate the output current to a value below the nominal average value set by resistor R$_{SET}$. PWM dimming gives a wider average LED current variation and is more accurate at lower average LED currents than by applying dc voltage to the CTRL pin to achieve average LED current dimming.

Figure 5 shows the typical PWM response of the AP8800A. An internal filter produces a rump.
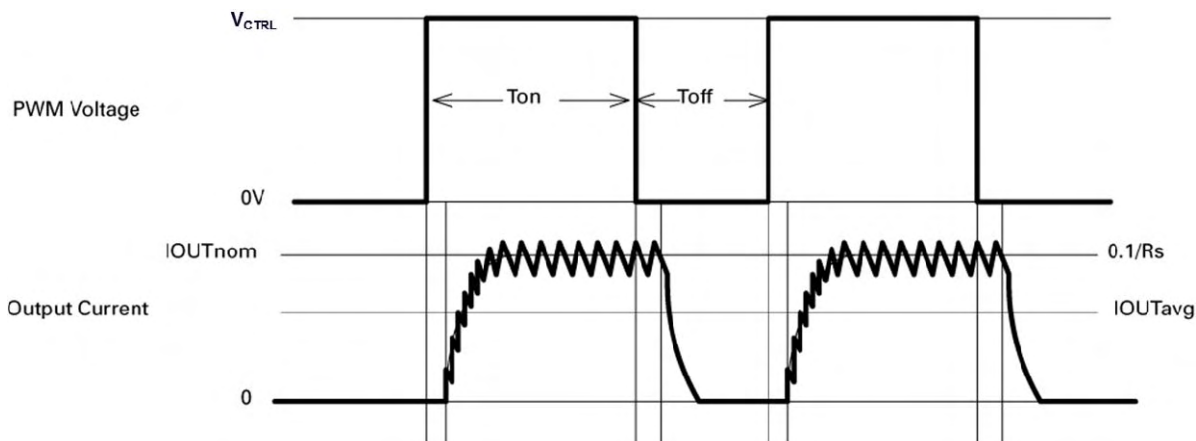

Figure 5 Typical PWM Dimming Waveform

The recommended method of driving the CTRL pin and controlling the amplitude of the PWM waveform is to use a small NPN switching transistor as shown below:
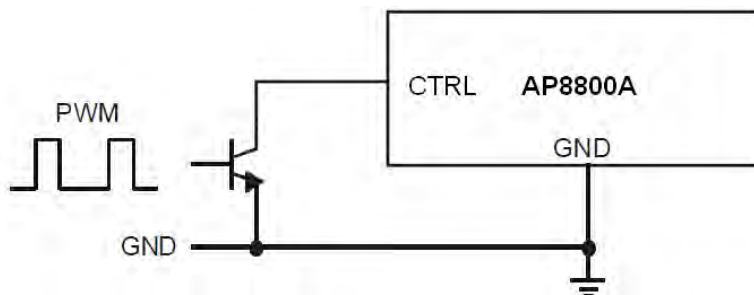

Figure 6 Open Collector PWM Dimming Circuit

This scheme uses the 200k resistor between the ADJ pin and the internal voltage reference as a pull-up resistor for the external transistor eg MMBT3904.

Soft-Start

An external capacitor from the CTRL pin to ground will provide soft-start delay, by increasing the time taken for the voltage on this pin to rise to the turn-on threshold and by slowing down the rate of rise of the control voltage at the input of the comparator.

The soft-start time is 0.5ms/nF.

AP8800A
Document number: DS35100 Rev. 3 - 2

9 of 13
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Application Information (cont.) (@T_A = +25°C, V_{IN} = 12V, unless otherwise specified.)

Fault Conditions

The AP8800A is inherently protected against open-LED conditions. If one LED becomes open circuit the device automatically stops switching and will only retart if the open-LED fault is removed.

If one or more LEDs should become shorted together then the switching frequency and duty cycle will change. If one or more LEDs get shorted together, the ramp-up time of LED current will become shorter due to there being a larger voltage across the inductor. However, the ramp-down time of the LED current will increase due to the voltage across the inductor becoming smaller.

Figure 7 below shows the AP8800A driving 3 LEDs when all 3 LEDs become shorted together. Due to the large voltage change across the inductor during both LED current ramp-up and ramp-down we see a large difference in switching frequency.
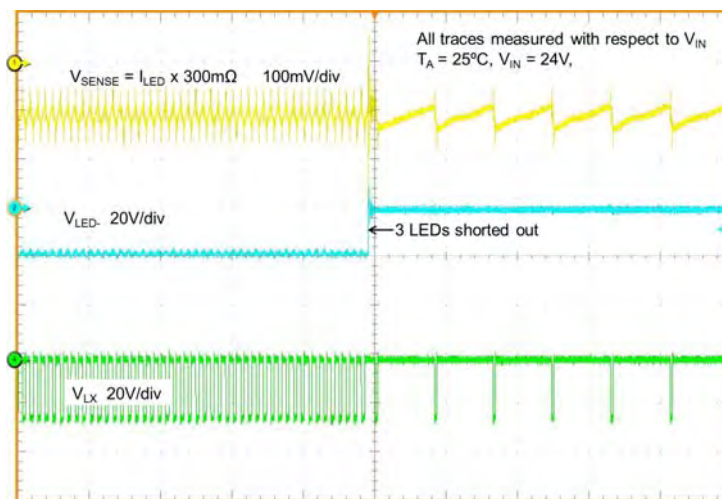
Figure 7   LED Short Fault Condition

Thermal Considerations

The graph below in Figure 8, gives details for the power derating of the AP8800AWT. This assumes the device to be mounted on a 25 x 25mm PCB with 1oz copper standing in still air.
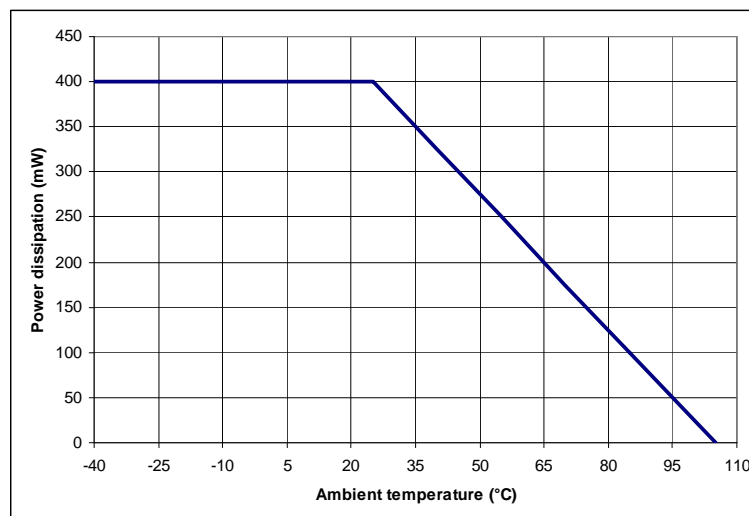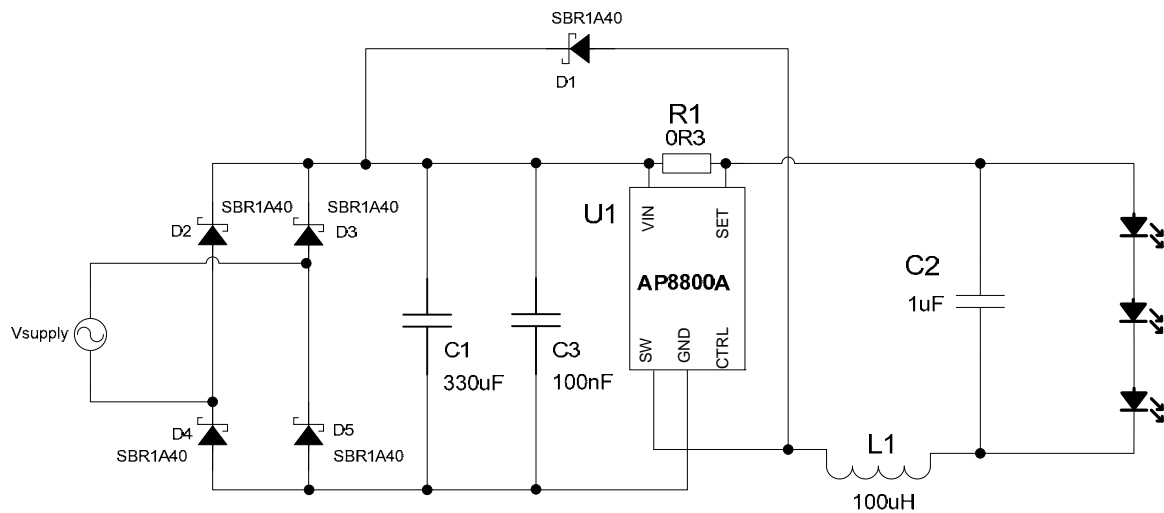

Figure 8 Derating Curve

AP8800A
Document number: DS35100 Rev. 3 - 2

10 of 13
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Application Information (cont.) (@T$_A$ = +25°C, V$_{IN}$ = 12V, unless otherwise specified.)
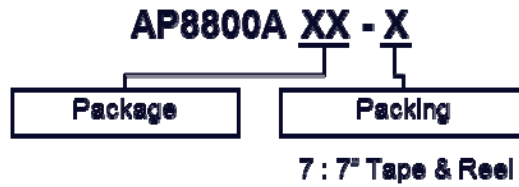
Application Example

The typical application for the AP8800A is the MR16 application driving 1W rated LEDs from a 12V ac supply.

AP8800A Component List

Quantity	PCB Ident	Value	Description	Suggested Source
1	U1	AP8800A	LED Driver IC	Diodes Inc.
1	D1, D2, D3, D4, D5	SBR1A40	Input bridge & freewheeling diode	Diodes Inc.
1	R1	0R15	Resistor, 0805, +/-1% <+/-300ppm KOA SR732ATTDR150F	Kemet
1	C1	330µF 20V	Electrolytic capacitor	Kemet
1	C2	1µF > = 25V	X7R 1206 Generic Kemet C1206105K5RAC7800 (50v) NIC NMC1206X7R105K50F (50v)	Kemet NIC Components
1	C3	100nF > = 25V	X7R 0805 Generic Kemet C0805C104K5RAC (50v) NIC NMC0805X7R104K50TRPF (50v)	Kemet NIC Components
1	L1	100µH	LPS6235 - series	Coilcraft

AP8800A
Document number: DS35100 Rev. 3 - 2

11 of 13
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August 2012
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Ordering Information

AP8800A XX - X

Package | Packing

7 : 7" Tape & Reel

Part Number	Package Code	Packaging	7" Tape and Reel	
			Quantity	Part Number Suffix
AP8800AWT-7	WT	TSOT25	3000/Tape & Reel	-7

Marking Information

(1) TSOT25

(Top View)

5		4
	XX Y W X	
1	2	3
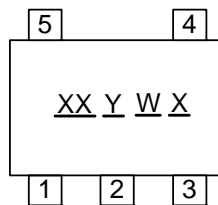
XX : Identification code
Y : Year 0~9
W : Week : A~Z : 1~26 week;
    a~z : 27~52 week; z represents
    52 and 53 week
X : A~Z : Internal code

Part Number	Package	Identification Code
AP8800AWT-7	TSOT25	AZ

Package Outline Dimensions (All dimensions in mm.)

Please see AP02002 at http://www.diodes.com/datasheets/ap02002.pdf for latest version.
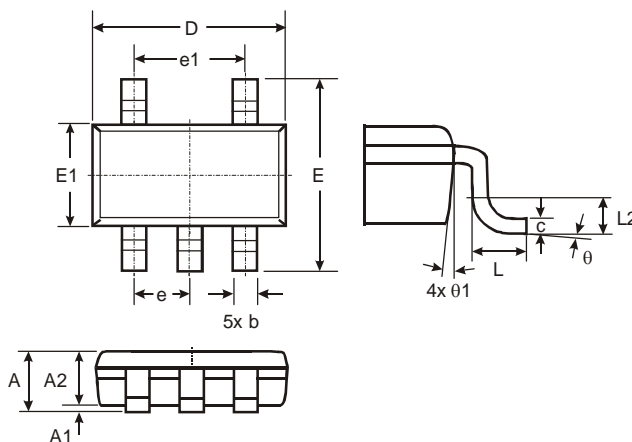
Dim	TSOT25		
	Min	Max	Typ
A	–	1.00	–
A1	0.01	0.10	–
A2	0.84	0.90	–
D	–	–	2.90
E	–	–	2.80
E1	–	–	1.60
b	0.30	0.45	–
c	0.12	0.20	–
e	–	–	0.95
e1	–	–	1.90
L	0.30	0.50	
L2	–	–	0.25
θ	0°	8°	4°
θ1	4°	12°	–
All Dimensions in mm			

AP8800A
Document number: DS35100 Rev. 3 - 2

12 of 13
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Suggested Pad Layout

Please see AP02001 at http://www.diodes.com/datasheets/ap02001.pdf for the latest version.
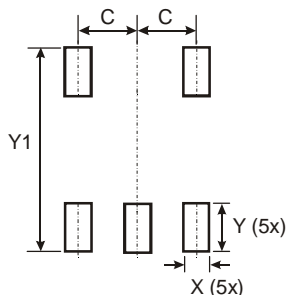
Dimensions	Value (in mm)
C	0.950
X	0.700
Y	1.000
Y1	3.199

AP8800A
Document number: DS35100 Rev. 3 - 2

13 of 13
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August 2012
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